Review of Surveys Contributing to Groundfish Assessments with Recommendations for an Ecosystem Survey Program in the Maritimes Region

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ABSTRACT

The Maritimes Region Science Branch supports two research vessel surveys on the Scotian Shelf (March RV Survey (4VsW) and Summer RV Survey (4VWX5Yb)) and three collaborative surveys with the fishing industry (4Vn Sentinel Longline Survey, 4VsW Sentinel Longline Survey and the Individual Transferable Quota (ITQ) Fixed Station Mobile Gear Survey). These surveys were designed to provide abundance indices for groundfish stock assessments, primarily gadoids and in particular Cod and Haddock. Since the start of these surveys there has been increasing interest in the multi-species aspects of these surveys to collect data for stock assessment of other finfish and invertebrates, as well as species-at-risk recovery potential assessments (RPA), and to provide information related to ecosystem attributes in support of the DFO ecosystem approach to management (EAM). These new demands create a different set of expectations from those that existed when these surveys were initially designed. These demands create the need to evaluate whether the surveys as conducted are providing the best use of resources or if consideration for reallocating resources to other scientific questions is warranted.

This review evaluates the biological data obtained in the aforementioned surveys and the ability to provide data of sufficient quality to develop indices of change for parameters such as distribution, abundance, and length. These parameters form the basis for advising on the consequences of management decisions through stock assessments, analytical population models and RPAs and are integral to the EAM. A key consideration in this evaluation is that a robust index comes from a survey that covers a consistent proportion of the stock area and that changes observed in the survey data are proportional to changes in the overall population.

The review has demonstrated that the Summer RV Survey is the most valuable survey for drawing conclusions about distribution, abundance, and length trends in the stocks examined for stock assessment.

There are no gaps in information for single species analytical stock assessments in the Summer RV Survey series that are filled by the other surveys. Biological information not available from other sources on age at maturity, fecundity, condition factor and diet in winter is provided by the March 4VsW RV survey.

However, additional distribution information is provided by these surveys as follows:

1. For Lobster (LFAs 34 and 35), Haddock (4X), and Winter Flounder (4X) by the ITQ Survey
2. For Capelin, Sea Cucumber, shrimp, and Spiny Dogfish by the March 4VsW RV Survey
3. For Northern Wolffish, Spotted Wolffish, and Winter Flounder by the 4Vn Sentinel Survey

Additional information on abundance trends is provided by these surveys as follows:

1. For Cod (4Vn) by the 4Vn Sentinel Survey
2. For American Plaice (4X), Atlantic Halibut, Cod (4X), Silver Hake, and Winter Flounder (4X) by the ITQ Survey
3. No additional abundance information is provided by the 4VsW Sentinel Survey

Additional information on useful length indices are provided by the March 4VsW RV Survey, the ITQ Survey, and Sentinel surveys in order of importance.

Our review started with a focus on individual surveys and has concluded with a recommendation to look at a survey program for assessment and ecosystem consideration. This program must continue to provide the information required for single species stock assessments to provide fishery and species-at-risk advice. This requires the maintenance of long-term indices and biological sampling programs that will detect changes in life-history characteristics related to fishery or environmental pressures. In addition, the survey program must provide improvements in ecosystem sampling that relate directly to the National and Regional Ecosystem Management Frameworks (EMF) being developed. These frameworks consider a range of decisions that go beyond applying an EAM and include how the cumulative effect of human activities alter specific ecosystem attributes.

This review concludes that there is scientific benefit in exploring reallocation of resources currently put towards the March 4VsW RV, ITQ, 4Vn Sentinel, and 4VsW Sentinel surveys. To explore these benefits DFO Maritimes Region Science, Fisheries Management, and Ecosystem Management Branches will need to work with clients and with biological sampling programs in The United States, Newfoundland and the Southern Gulf with whom we share responsibility for monitoring in large Ocean Management Areas, to examine alternative questions that could be addressed using these resources. Some options to consider include developing a comprehensive ecosystem survey program or addressing a series of short-term research questions to develop a better understanding of underlying ecosystem processes.

A broad range of considerations will be important for these evaluations and an emphasis on combining surveys which will involve different platforms and designs will need to be included to provide the most robust evaluation for future survey programs. We have provided nine recommendations for consideration as we continue to move from a survey program focussed on provision of indices for single-species stock assessments to an ecosystem survey program. These will provide guidance on how to ensure we can make progress on providing information for EMF while continuing to meet the existing monitoring requirements.

LIST OF RECOMMENDATIONS

<u>Recommendation (1)</u>

We recommend that summer RV ship time be used to conduct comparative surveys using the Western IIa bottom trawl and the National Marine Fisheries

Service Ecosystem Survey Trawl (NEST) to collect data to evaluate calibration and catchability estimates across a broad size range for key species. When these experiments are completed an evaluation on the consequences of changing to a NEST trawl can be completed.

Recommendation (2)

Using information from current longline surveys, including the stock specific Halibut Survey, conduct a simulation study to determine the cost and benefits of designing a consolidated longline survey to provide consistent catchability for species where depth and habitat prevent a trawl survey from providing robust indices.

Recommendation (3)

A summary of the analysis of acoustic data collected during the RV survey in 2011 and 2012 is needed. In addition, a review of specific cases where acoustics and other gears have been used to provide robust indices for pelagic and semi-pelagic species is needed. The objective of this review would be to identify whether creating a synoptic survey to provide robust indices is possible for these species.

Recommendation (4)

Work with the US National Marine Fisheries Service (NMFS) to design a synoptic survey that extends broadly across the Scotian Shelf and Gulf of Maine. This design would be consistent with the general objectives of an ecosystem survey program. Options to explore include the US commencing a July survey or Canada expanding the winter survey of Georges Bank and 4VsW to include a broader geographic area. Surveys and analyses investigating the consequences of these changes on long-term indices would need to be completed.

Recommendation (5)

Include sampling of the 4V portion of the Laurentian Channel in the Summer RV Survey. Work with Newfoundland Region to determine if the expansion of the Summer RV Survey and development of weighting factors for the two gear/vessel combinations would be sufficient to combine indices of abundance across the Laurentian Channel. Surveys and analyses to develop conversion factors and investigation of the utility of these indices would need to be completed.

Recommendation (6)

Establish a working group to develop the protocols and design for an inshore survey that would provide robust indices to be used in combination with offshore survey indices for assessments and ecosystem studies.

Recommendation (7)

Stratified random designs are the default design unless there is a strong reason based on simulation experiments to adopt another design for resource surveys.

Recommendation (8)

Develop estimates of catchability (q) for some species and recommendations on probable bounds on q for use in single species and ecosystem assessments.

Recommendation (9)

The sampling intensity (number and frequency) for hydrographic, benthic, and trophic level interactions for an ecosystem survey program should be determined through simulation studies.

RÉSUMÉ

La Direction des sciences de la région des Maritimes soutient deux relevés par navire de recherche (NR) menés sur le plateau néo-écossais, soit le relevé de mars par NR (4VsW) et le relevé d'été par NR (4VWX5Yb), de même que trois relevés effectués en collaboration avec l'industrie de la pêche, à savoir les relevés de pêche sentinelle à la palangre dans les divisions 4Vn et 4VsW et le relevé des quotas individuels transférables (QIT) par engin mobile et engin fixe. Ces relevés ont été conçus pour fournir des indices d'abondance pour les évaluations du stock de poisson de fond, en grande partie les gadidés, soit, en particulier, la morue et l'aiglefin. Depuis qu'on a commencé à réaliser ces relevés, on s'intéresse de plus en plus à leurs aspects plurispécifiques pour recueillir des données en vue de l'évaluation du stock d'autres poissons et invertébrés, ainsi que de l'évaluation du potentiel de rétablissement (EPR) d'espèces en péril, et pour fournir des renseignements sur les attributs de l'écosystème à l'appui de l'approche écosystémique de gestion de Pêches et Océans Canada (MPO). Ces nouvelles demandes créent un différent ensemble d'attentes par rapport à celles que l'on avait au moment de la conception initiale de ces relevés. Par conséquent, on a besoin d'évaluer si les relevés, tel qu'ils sont réalisés, assurent la meilleure utilisation des ressources ou s'il faut envisager de réaffecter les ressources à d'autres questions scientifiques.

Au cours du présent examen, on évalue les données biologiques obtenues grâce aux relevés susmentionnés et la capacité à fournir des données de qualité suffisante pour élaborer des indices de variation quant à des paramètres tels que la répartition, l'abondance et la longueur. Ces paramètres, qui font partie intégrante de l'approche écosystémique de gestion, constituent le fondement pour fournir des avis sur les conséquences des décisions de gestion prises par suite d'évaluations du stock, de modèles analytiques des populations et d'EPR. Le fait que les relevés couvrant une proportion uniforme de la zone de stock produisent des indices solides et que les changements observés dans les données du relevé sont proportionnels aux changements dans l'ensemble de la population est un facteur clé de cette évaluation.

L'examen a révélé que le relevé d'été par NR est le plus important pour tirer des conclusions sur la répartition, l'abondance et les tendances relatives à la longueur des stocks évalués.

Il ne manque aucune information pour l'évaluation du stock d'espèces uniques dans la série de relevés d'été par NR, car les lacunes sont comblées au moyen des autres relevés. Les données biologiques qu'on ne peut pas trouver à partir d'autres sources sur l'âge à la maturité, la fécondité, le coefficient de condition et le régime alimentaire en hiver sont fournies par le relevé de mars par NR dans la division 4VsW.

Toutefois, des renseignements supplémentaires sur la répartition sont fournis grâce aux relevés suivants :

1. Relevé de QIT sur le homard (zones de pêche du homard 34 et 35), l'aiglefin (4X) et la plie rouge (4X)
2. Relevé de mars par NR dans la division 4VsW sur le capelan, l'holothurie, la crevette et l'aiguillat commun
3. Relevé de pêche sentinelle dans la division 4Vn sur le loup à tête large, le loup tacheté et la plie rouge

Des renseignements supplémentaires sur les tendances relatives à l'abondance sont d'ailleurs fournis grâce aux relevés suivants :

1. Relevé de pêche sentinelle dans la division 4Vn sur la morue
2. Relevé de QIT sur la plie canadienne (4X), le flétan de l'Atlantique, la morue (4X), le merlu argenté et la plie rouge (4X)
3. Aucune information supplémentaire n'a été fournie grâce au relevé de pêche sentinelle dans la division 4VsW

Des renseignements supplémentaires sur des indices de longueur pratiques sont fournis grâce au relevé de mars par NR dans la division 4VsW, au relevé de QIT et aux relevés de pêche sentinelle (en ordre d'importance).

Au début, l'examen mettait l'accent sur les relevés individuels. Il en a découlé une recommandation d'envisager un programme de relevé pour l'évaluation et les considérations écosystémiques. Ce programme doit continuer à fournir les renseignements dont on a besoin pour évaluer le stock d'espèces uniques, et ce, en vue d'offrir des conseils sur la pêche et les espèces en péril. Pour y parvenir, il faut maintenir des indices à long terme et des programmes d'échantillonnage biologique qui permettront de repérer les changements en matière de caractéristiques du cycle biologique causés par la pêche ou les pressions environnementales. En outre, le programme de relevé doit contribuer à des améliorations de l'échantillonnage de l'écosystème qui sont directement liées aux cadres de gestion des écosystèmes nationaux et régionaux en cours d'élaboration. Ces cadres, qui tiennent compte d'un éventail de décisions dépassant le contexte d'application d'une approche écosystémique de gestion, traitent également de la façon dont l'effet cumulatif des activités humaines nuit à des attributs précis de l'écosystème.

Par suite de l'examen, on a constaté qu'il serait avantageux sur le plan scientifique d'étudier la réaffectation des ressources qui sont actuellement consacrées aux relevés de mars par NR (4VsW), de QIT et de pêche sentinelle (4Vn et 4VsW). Pour étudier ces avantages, la Direction des sciences, la Direction de la gestion des pêches et la Direction de la gestion des écosystèmes du MPO dans la région des Maritimes auront besoin de travailler avec des clients, ainsi que des programmes d'échantillonnage biologique des États-Unis, de Terre-Neuve-et-Labrador et du sud du Golfe, avec lesquels le Ministère partage la responsabilité d'assurer la surveillance dans les zones étendues de gestion des océans (ZEGO) et d'examiner de nouvelles questions que l'on pourrait aborder en utilisant ces ressources. Parmi les options à envisager, on compte l'élaboration d'un programme de relevé exhaustif des écosystèmes ou la résolution d'une série de questions sur les activités de recherche à court terme afin de mieux comprendre les processus écosystémiques sous-jacents.

Une vaste gamme de facteurs à considérer seront importants pour ces évaluations et il faudra mettre l'accent sur la combinaison de relevés qui comprendront différentes plateformes et conceptions afin de fournir l'évaluation la plus rigoureuse au cours des prochains programmes de relevé. Nous avons formulé neuf recommandations à prendre en compte pendant que nous continuons de passer d'un programme de relevé axé sur la fourniture d'indices aux fins d'évaluations du stock d'espèces uniques à un programme de relevé des écosystèmes. Les recommandations fourniront une orientation sur la façon de veiller à ce que nous puissions réaliser des progrès quant à la fourniture de renseignements pour le cadre de gestion des écosystèmes, tout en continuant à respecter les exigences actuelles en matière de surveillance.

LISTE DE RECOMMANDATIONS

Recommandation 1

Nous recommandons d'utiliser le temps-navire pour les NR en été afin de réaliser des relevés comparatifs sur le chalut Western IIA et le chalut de relevé des écosystèmes du National Marine Fisheries Service en vue de recueillir des données pour évaluer les estimations d'étalonnage et de capturabilité pour une vaste gamme de tailles d'espèces clés. Une fois les expériences terminées, il sera possible d'effectuer une évaluation des conséquences du passage au relevé des écosystèmes au chalut.

Recommandation 2

Il faudrait utiliser les renseignements provenant des relevés à la palangre actuels, y compris le relevé propre au stock de flétan, pour mener une étude de simulation en vue de déterminer les coûts et les avantages de la conception d'un relevé à la palangre global qui permettra de fournir des données uniformes sur la capturabilité d'espèces dont la profondeur de l'habitat empêche de fournir des indices solides au moyen d'un relevé au chalut.

Recommandation 3

Il faudrait un résumé de l'analyse des données acoustiques recueillies au cours des relevés par NR réalisés en 2011 et en 2012. De plus, il faudrait examiner les cas précis où l'on s'est servi d'appareils acoustiques et d'autres engins afin de fournir des indices solides pour les espèces pélagiques et semi-pélagiques. Cet examen aurait pour objet de déterminer s'il est possible de créer un relevé synoptique pour fournir des indices solides pour ces espèces.

Recommandation 4

Il faudrait collaborer avec le National Marine Fisheries Service des États-Unis afin de concevoir un relevé synoptique qui couvre une grande partie du plateau néo-écossais et du golfe du Maine. La conception serait conforme aux objectifs généraux d'un programme de relevé des écosystèmes. Pour ce qui est des options à explorer, les États-Unis pourraient entamer un relevé en juillet ou le Canada pourrait agrandir l'étendue du relevé d'hiver sur le banc Georges et 4 VsW pour inclure une zone géographique plus vaste. Il faudrait effectuer les relevés et les analyses traitant des conséquences des changements sur les indices à long terme.

Recommandation 5

Il faudrait intégrer la division 4V du chenal Laurentien au relevé d'été par NR. Il faudrait travailler avec la région de Terre-Neuve-et-Labrador pour déterminer si l'expansion de la couverture du relevé d'été par NR et l'élaboration des facteurs de pondération des combinaisons de deux engins/navires sont suffisantes pour combiner les indices d'abondance dans l'ensemble du chenal Laurentien. Il faudrait d'ailleurs effectuer des relevés et des analyses pour élaborer des facteurs de conversion et une enquête sur l'utilité de ces indices.

Recommandation 6

Il faudrait établir un groupe de travail chargé d'élaborer les protocoles et la conception d'un relevé côtier qui fournirait des indices solides dont on pourrait se servir avec les indices découlant de relevés effectués au large des côtes aux fins d'évaluations et d'étude des écosystèmes.

Recommandation 7

Le plan aléatoire stratifié constitue le plan par défaut, à moins d'avoir une bonne raison, fondée sur les expériences de simulation, d'employer un autre plan pour le relevé des ressources.

Recommandation 8

Il faudrait élaborer des estimations de capturabilité (q) pour certaines espèces et formuler des recommandations sur les limites probables en matière de capturabilité aux fins d'utilisation dans les évaluations d'espèces uniques et des écosystèmes.

Recommandation 9

Il faudrait déterminer, au moyen d'études de simulation, l'intensité de l'échantillonnage (nombre et fréquence) pour les interactions hydrographiques, benthiques et trophiques dans le cadre d'un programme de relevé des écosystèmes.

INTRODUCTION

The breadth of information expected from research surveys has expanded from data to support stock assessments for a few species to provision of biological advice for the management of aquatic ecosystems. Requests for science advice to provide information on status, threats, and recovery potential for species at risk are increasing. In addition, requests are also being made for the provision of advice in support of an ecosystem approach to management that focuses on decision making with respect to achieving productivity, biodiversity, and habitat objectives, with the goal of assessing the cumulative impact of human activities on marine biota.

The preferred sampling design for a fisheries independent survey is a stratified random design (ICES 2004, 2005). The entire geographic range of the stocks of interest should be covered, and strata should be defined in some way which captures key variables influencing differences in species abundance. Generally, depth, bottom type and hydrography are used to define strata although geographic regions can be used as well. Several alternatives exist including systematic designs or hybrids with systematic sampling following a random selection of the initial starting point. These methods allow for the possibility of sampling in any location within the range surveyed and have robust statistical designs which permit estimates of variance. Fixed station sampling can be used, but because this excludes the possibility of sampling in any but the initially selected locations, it does not provide an unbiased sample and meaningful variance estimates cannot be calculated (ICES, 2004).

Trawl surveys can provide data on a broad range of commercial and non-commercial species, which provide data that is independent of fishery practices and regulations. This independence is important for completing robust analyses on stock status (Cotter et al, 2009).

Surveys have been carried out in the Northwest Atlantic since the 1940's. These surveys were conducted to obtain basic biological information and were not conducted in a manner that provided the necessary information on changes in stock structure and abundance essential for fisheries management (Halliday and Kohler, 1971). Canadian research surveys relevant to offshore groundfish fisheries increased steadily after 1945. Initially a combination of commercial fishing vessels and a 65-foot side-trawler research vessel, the *J.J Cowie,* were used as survey vessels. In the late 1950's, the addition of two side draggers, the 85-foot *Harengus* and the 170-foot *A.T. Cameron*, followed by the *E.E. Prince*, a 130-foot stern dragger in 1966, greatly increased Canada's offshore research surveys to investigate fish distribution and describe the life history characteristics of the major commercial species.

By the late 1960s, survey research objectives also included investigating changes in stock and community structure and fish abundance. Two examples of surveys initiated with these objectives were the winter-March 4VsW surveys that focused on Haddock spawning in Div. 4VW and the summer survey that focused on juvenile Haddock in Div. 4W (Halliday and Kohler, 1971).

Different sampling designs were employed for groundfish surveys during the 1960s, including sampling along transects, fixed station patterns in areas of commercial fishing. In 1969, a stratified random design was adopted for the Summer RV Survey, following the approach used for US surveys in the Gulf of Maine and on the Scotian Shelf. The US Fall RV survey, which began in 1963, used this design with the goal of producing unbiased abundance indices as well as broadening of the geographic coverage to detect changes in fish distribution (Grosslein, 1969). The stratification serves to reduce variance in indices of abundance, while the random allocation of sets ensures all locations can be sampled, so the indices should be directly proportional to abundance, and also allows for the calculation of valid variance estimates, so the precision of the indices can be determined (Halliday and Kohler 1971).

A stratification scheme, based on fish distribution, for the Gulf of St. Lawrence, Scotian Shelf and Bay of Fundy was created using the research of Canadian, USA and USSR scientists. Depth was the predominate factor used with boundaries placed at the 50, 100 and 200 fathom isobaths. This stratification scheme was instituted for a summer survey of the entire Scotian Shelf/Bay of Fundy (Halliday and Kohler 1971), which has remained essentially unchanged since 1970 (Chadwick et al, 2007). The survey was intended to provide information on distribution and abundance of all groundfish and selected commercial invertebrate species (Halliday and Kohler 1971).

From 1978 – 1984, spring and fall surveys were conducted covering the same geographic area as the Summer RV Survey. This coverage provided information on spawning distribution, age at maturity, and post-spawning condition for most gadoids and some flatfish which was not possible to obtain from summer surveys. It also provided information on some species, such as Spiny Dogfish, Gaspereau and Shad which are offshore and available to surveys in winter, but in summer are in coastal areas or in fresh water and are not adequately sampled by the RV survey. The fall survey was discontinued after 1984, but a February - March survey was continued, with sampling primarily on Georges Bank and in parts of 4VsW which were important habitat for Cod.

In 1993, the Cod fishery on the eastern Scotian Shelf was closed. The fishing industry in Cape Breton argued that DFO Science had seriously underestimated the stock abundance and obtained DFO funding to conduct additional data collection (O’Boyle et al., 1995). A test fishery was established and this became the basis for the present-day 4Vn Sentinel Survey. With the establishment of the Emerging Fishery Policy in 1994 requiring industry to undertake survey activity and the growing awareness by industry of their importance, seven joint DFO Science/Industry surveys were implemented by 1995, some of which were relatively short-lived. These surveys used a variety of gears and survey designs at different times of the year, each with a species-specific focus. The ITQ Survey, an otter trawl survey jointly managed by DFO and the Individual Transferable Quota fleet (4X), and the 4VsW Fixed Gear Sentinel Survey have also continued through to the present. These surveys, and the DFO research surveys, are described in greater detail in Appendix 1.

The Emerging Fishery Policy led to the development of a number of non-traditional fisheries, such as Northern Shrimp, skates and crabs. While collection of data for Snow Crab (*Chionoecetes opilio*) and Northern Shrimp (*Pandulus borealis*) had been included in the original protocols for the Summer RV Survey (Halliday and Kohler 1971), this had been discontinued in the 1970's. New surveys, funded by industry and restricted to the areas exploited by the commercial fisheries, were developed for these species with much higher sampling intensity than the Summer RV Survey to provide more precision in estimates of stock abundance.

The *Oceans Act*, passed in 1996, states 'WHEREAS Canada holds that conservation, based on an ecosystem approach, is of fundamental importance to maintaining biological diversity and productivity in the marine environment' and that Canada should 'conduct marine scientific surveys relating to fisheries resources and their supporting habitat and ecosystems'.

In recognition of the ecosystem approach provisions in the *Oceans Act* the number of invertebrate species sampled during the regional DFO RV surveys was increased in 1999. Sampling of invertebrates was further expanded in 2005, with over 100 taxa recorded in the most recent survey (Emberley and Clark, 2012). A second initiative, which commenced in 1998, was a major project to sample stomach contents of finfish. This was initiated to better understand trophic connections and overlap between species and also to provide additional information on the abundance of small and underrepresented species normally not available in the survey (Cook and Bundy 2012).

The Maritimes Region Science Branch supports two research vessel surveys, a Summer RV survey of the Scotian Shelf and a Winter RV survey of Georges Bank and 4VsW, in February and March, which provide abundance indices for groundfish assessments, along with biological and hydrographic sampling. The Georges Bank portion of this survey is not included in this review, therefore from here forward the portion of this survey included in the review will be referred to as the March 4VsW RV Survey. The Region also supports collaborative surveys with the fishing industry, some of which were initially designed to provide indices of abundance for groundfish assessments. These are the 4Vn Sentinel Survey, the 4VsW Sentinel Survey, and the ITQ Survey in 4X. There are additional surveys which are supported by Science focused on Scallops, Shrimp, Snow Crab and Halibut. While the RV survey catches invertebrates, there was no consistent recording of invertebrates other than Lobster and Shortfin Squid prior to 1999. The Halibut longline survey covers a geographic area larger than the Maritimes Region and was initiated to provide indices of abundance for adult halibut which were not provided by the Summer RV Survey.

While the scallop, Snow Crab, shrimp and Halibut surveys have objectives that differ from the RV survey, the geographic coverage and objectives of the RV surveys, ITQ survey and sentinel surveys overlap broadly. In this review we examine the role that these five surveys which take place on the Scotian Shelf (July Summer RV, March 4VsW RV, 4Vn Sentinel Survey, the 4VsW Sentinel Survey, and the ITQ Survey in 4X) have in providing information for the requests for science advice on: 1) species/stock assessment for fishery management and species-at-risk management; and 2) ecosystem assessment. This review will help determine whether current surveys are adequately addressing our mandate or if they are leaving gaps which need to be resolved. It will also evaluate whether these surveys are complementary, or if there is duplication of effort which is not providing incremental benefits to our understanding of the ecosystem and resources.

The review first looks at the role that these surveys have in providing advice for individual species, with a primary focus on the effect of the fishery. Second, we examine what the surveys can provide for advice on species-at-risk, which requires an examination of a broad range of human activities and ecosystem effects, but still for a single species. Finally, we consider the inputs that these surveys provide toward an ecosystem approach, which looks at a broad range of human activities and focuses on ecosystem attributes accumulated across a broad range of species rather than a single species approach.

The Summer RV Survey provides the primary source of data for many groundfish assessments. The March 4VsW RV Survey and the industry surveys were initiated to address concerns about possible gaps in Cod and Haddock assessment data that the Summer RV Survey could not fill (See Appendix for details on these surveys). An overview of the various sentinel/Industry surveys was presented in 1995 (O'Boyle et al. 1995). However, although all these surveys have been ongoing for well over ten years, the value added by these surveys has not been reviewed.

The specific objectives of this review are:

- Groundfish and species at risk assessments:
  a) Determine the advice that would be provided in assessments using each survey on its own.
  b) Determine the value that is added in assessments by using a stepwise approach to adding each survey.
- Ecosystem interactions:
  a) Identify input from these surveys that have contributed to the Region's ecosystem approach to management.
  b) Assess the potential of these surveys to contribute to the Region's ecosystem approach to management.

While we concentrate on surveys that are focused on groundfish, we have included a broad range of fish and invertebrate stocks of economic or ecological importance in the review. This allows us to evaluate the above assessment, species-at-risk, and ecological objectives for this set of surveys across a broad range of stocks, species, areas, and seasons and determine where there is potential value in these surveys.

EVALUATION FRAMEWORK

A review and evaluation of the relative role that each of these surveys contributes toward stock assessments, species at risk assessments, and the contribution toward the Region's EAM, is necessary at this time. We focus the discussion on the strengths and weaknesses of the surveys with respect to providing robust indices of change for decision making in fishery management, species-at-risk recovery potential assessments, and ecosystem approaches to management as they currently exist. We recommend next steps in answering the key questions related to gaps and future direction for the DFO related to fishery and ecosystem management decisions and the research required to better understand the ecosystem and support these decisions.

Groundfish Assessments

The provision of biological advice for marine groundfish stock assessments requires estimates of current abundance, the size of incoming recruitment or growth, and exploitation rate (fishing mortality) (Doubleday, 1981). Some of this information can be obtained from commercial fisheries, but these data have shortcomings that can only be met by the use of fishery independent research vessel surveys (Doubleday, 1981). Robust indices of population trends for providing advice for management decisions must, at a minimum, have the following two characteristics:

- The survey covers a consistent proportion of the population.
- Proportional to abundance (requires an analytical model to test).

Ideally a population or statistical model is used to test for consistency among the data. If the survey is not consistent with the principles of a good abundance index then the data produced by it can only be considered a sample of a biological characteristic and not an index for evaluating a population's response to management actions. Surveys are most likely to satisfy these conditions when they cover the whole geographic range of a stock.

Species at Risk Assessments

The first step of the DFO species at risk assessment (SARA) process is an examination of all data sources available for the species of concern. These data are made available to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) at a Pre-COSEWIC meeting. The purpose of this meeting is to compile and review DFO's data holdings and to provide context for the COSEWIC status report author. Information on life history and ecology is also compiled. DFO usually holds most, if not all, of the data available on the marine fish and invertebrate species. The data come from special projects, commercial fishing, and from surveys. Not all data provided are necessarily included in determining the status of the species. After the COSEWIC status report is completed, COSEWIC determines the status of the stock based on indicators of current trends in abundance and distribution. A Recovery Potential Assessment (RPA) is conducted by the DFO for species that are assessed by COSEWIC as Threatened, Endangered, or Extirpated. In addition to examining past and projected trends in population abundance and distribution during the RPA, habitat characteristics, threats, and allowable harm are identified. The DFO SARA process and COSEWIC status assessment rely primarily on survey data to provide the long term trends, life history data, and environmental data necessary to evaluate most Terms of Reference for these assessments. Surveys are the only source of information for many species that are not of commercial importance.

Of the 51 fish stocks that were included in this survey review, 17 (4Vn Cod, 4VsW Cod, 4X Cod, Atlantic Halibut, Unit II redfish, Unit III redfish, Atlantic Wolffish, Spiny Dogfish, Spotted Wolffish, Northern Wolffish, Smooth Skate, Thorny Skate, Winter Skate, Barndoor Skate, Cusk, 4X American Plaice, 4VW American Plaice) have been assessed by COSEWIC, one stock is scheduled to be assessed (4VWX White Hake), and four stocks (4TVW Haddock, 4X Haddock, 4Xopqrs5 Pollock, 4VWXmn Pollock) are mid-priority on the COSEWIC Species Specialist Subcommittees' Candidate list (a list of species that have not yet been assessed by COSEWIC, but are suspected of being at some risk of extinction or extirpation). These stocks do not represent a cohesive taxonomic or ecological group and thus it is not possible to make generalizations on these species that are of concern to the Species at Risk Management Division (SARMD). The commonality amongst stocks and species is in the data use and analyses in the DFO SARA process and COSEWIC assessments.

The criteria for robust indices of population trends identified above for fishery assessments apply equally to assessments of these species.

Ecosystem Objectives or Context

In Canada as well as across the globe, regulatory bodies are moving towards ecosystem based approaches to fisheries and ocean management (EAM; Garcia et al 2003; Marasco et al 2007; Ruckelshaus et al. 2008, ICES, 2010, Curran et al. 2012), which requires the integration of information on the broader ecosystem and human dimensions. National and international agreements indicate that both sustainable use and conservation objectives be clearly defined in an ecosystem based approach (Shelton and Sinclair 2008). Sustainable use requires fisheries and ocean management plans that prevent long term decline in stocks, species or habitat. Conservation is required at the genetic, species and ecosystem levels such that diversity is studied and understood not only for commercial or target species but also for those species impacted by fisheries either as incidental captures (by-catch) or as those negatively impacted by fishing activities (habitat disturbance, prey removal).

Monitoring ecosystem status requires a broad suite of data collected in a coordinated manner and preferably includes data collection at more than one time of year (ICES, 2010). For an ecosystem survey, it is recommended that data be collected on fish and invertebrates, both near bottom and in the pelagic zone, as well as on zooplankton, phytoplankton, abiotic conditions and on diets, which provide information on food webs within the ecosystem. Collection of data on this scale requires a large platform which can deploy a range of sampling gear and carry enough science staff to undertake the sampling.

One approach for providing ecosystem advice for management is the development of models which account for the various intra- and inter-specific interactions, as well as the environmental and anthropogenic drivers of the system. Some examples include ATLANTIS and ECOPATH, and have been reviewed by Plaganyi (2007). These types of models allow for simulation and predictive testing of different management regimes and various ecosystem considerations.

There are, of course, numerous steps that can be taken prior to exploring sophisticated modeling approaches which will improve our understanding of the ecosystem and help in the move toward EAM. One often used indicator is species richness which provides a description of the number of species present in the ecosystem, and has been related to ecosystem resilience (Downing et al 2010). Studying the species linkages through stomach contents analysis provides information on the ecosystem functions and energy flows (Arajuo and Bundy 2012).

More complex ecosystem indicators or suites of indicators have been developed to describe the current status of the ecosystem relative to historic patterns in order to assess ecosystem health and productivity. For most of this work, the baseline information on macrofauna, at least from large marine ecosystems, is obtained from bottom trawl and longline surveys. These surveys often provide the most synoptic areal and temporal coverage. In addition, the added value of using the gut contents of macrofauna collected during bottom trawl surveys to describe the distribution and abundance of small or underrepresented species has been shown by Cook and Bundy (2012).

Most long-running surveys were originally intended to provide indices of abundance for assessments of commercial fish stocks. The focus now is on monitoring the ecosystem. This broader focus requires additional gear deployment to include a suite of hydrographic sampling and plankton sampling, and requires enumeration of all aspects of the trawl catch, not just the fish species. The objective is to provide advice against reference points or objectives of ecosystem status and evaluate success of management actions in meeting those objectives. As a result, the principles of robust indices for stock assessment apply to the enumeration aspects for non-commercial species and hydrographic sampling. If these principles are not met, then the surveys are not likely to be useful for ecosystem modelling.

METHODS

A standard evaluation method was required to compare and assess the usefulness of the five surveys for the development of advice for stock assessments and species-at-risk assessments and for the contribution of the surveys to an ecosystem approach to management. The geographic range covered by 4VsW Sentinel Survey has been reduced over time; therefore the role of this survey was evaluated for both the broad and restricted geographic scales.

The surveys evaluated in this review were:

- DFO Summer RV Survey
- DFO March 4VsW RV Survey
- 4Vn Sentinel Survey
- 4VsW Sentinel Survey
    - Broad Geographic Scale (1995-2003; 252 sets)
    - Restricted Geographic Scale (2004-present; 53 sets)
- ITQ Survey

A working group first identified the types of data that were required to address the objectives of this review. Next, a list of the indices and types of analyses used to develop the advice was compiled and separated into analytical and non-analytical categories. Three standard forms were developed to enable an objective and consistent approach for the comparison of the surveys with respect to the information collected and whether the data were useful in addressing the objectives. Form 1 provided details of the type of data collected from individual surveys (Table 1). Form 2 (Table 2) provided an evaluation of whether or not the data collected from the individual surveys was useful for non-analytical analyses. Form 3 (Table 3) considered whether the data collected from the surveys was useful for quantitative population modeling to provide an analytical assessment of resource status. A fourth form (Table 4) was completed to identify which types of environmental data were collected in each of the surveys.

A broad list of species/stocks (n=51) were chosen to be used for the evaluation of the surveys (Table 5). The species selected included:

- Commercial species for which advice is requested from DFO Science by DFO Fishery Management
- Species which are of interest to Species-at-Risk Management Division (SARMD)
- Invertebrates which sustain fisheries
- Fish and invertebrates which we are not asked to report on in the Annual RV Survey Trends report (i.e. DFO 2012) but are important either because they sustain fisheries or are an appreciable portion of the survey catch/ecosystem biomass

The list does not include:

- Zooplankton and phytoplankton
- Species which are found in water deeper than 400m but which are not common at shallower depths (e.g. Roundnose Grenadier, Portuguese Shark, Bairds and Agassiz Smoothheads, Longnose Chimaera)
- Species found in the littoral zone (e.g. Atlantic silversides)
- Specific species of starfish
- Small bodied fishes which are not fished commercially
- Large pelagic fishes, sea turtles, marine mammals, birds

The three standard forms (Tables 1-3) were distributed to species experts for completion. Of the 51 species/stocks included in this review, analytical assessments are done for 4TVW Haddock, 4Vn Cod, 4VsW Cod, 4VW Plaice, 4X Cod, 4X5Y Haddock, 4VWX Silver Hake, western component Pollock, and White Hake. For species without analytical assessments the third form was not completed.

In order to consistently compare the species information collected across surveys, a standardized rating system was devised (see Tables 1-3 for rating systems). The rating system used in forms 2 and 3 evaluated the relative utility of the data collected and also allowed the identification of potential data sources that have not been explored for a given species. The ratings are categorical and thus an average of rating values is not meaningful. Information sessions were held at the Bedford Institute of Oceanography (BIO) (December 2011) and the St. Andrews Biological Station (SABS) (January 2012) to provide species experts with the objectives and instructions in order to increase consistency of ranking methods and results.

A single workbook was created with two main worksheets (”collected data” and “data used”) to collate the survey summary data for all species. “Collected data” contained the information from form 1 (Table 1) and “data used” contained the information from forms 2 and 3 (Tables 2, 3). Each cell contained the ratings provided by the species expert. If required, changes to some of the ratings provided by species experts were made after consensus among the working group.

For the 51 species\stocks from each of the surveys, the “collected data” worksheet summarized whether or not samples were collected for fecundity and ageing studies and whether data were collected on total number, total weight, species ID, individual length, individual weight, sex determination and maturity stage, age material, fecundity sampling, and spawning area identification.

In the “data used” worksheet, the attributes considered by the working group to be the most important for analysis included:

- The importance of the survey for providing distributional information (Table 6)

- The importance of the survey for providing trends in abundance (especially important for stocks that are not modeled, i.e. for defining LRP's) (Table 7)
- The importance of the survey for providing trends in length composition (Table 8)

One summary table was produced on the importance of including a specific survey index for population modeling (Table 9). Other information produced for consideration in the report included:

- A summary of the number of species by survey for which data is collected and is informative (Figure 1)
- A summary of the number of species by survey for which data is not collected but could be (Figure 2)
- A summary of the number of species by survey for which data collected is not useful (Figure 3)

SURVEY CONTRIBUTION TO EAM

For the ecosystem component of this survey review several objectives were addressed. First, a literature review was conducted to determine the frequency and the focus of the studies using data from the five surveys in the primary and secondary literature. Second, the species richness estimated from each survey was compared using species accumulation curves. A comparison of the frequency of occurrence of different size classes of finfish within the different surveys was also performed. Finally, a brief summary of the gut content analysis data from the Summer RV, March 4VsW RV, and 4VsW Sentinel Surveys (no stomach content data has been collected for the ITQ Survey; stomach content data collected from the 4Vn Sentinel Survey is not currently in a useable form) was described and used to depict the trophic connections and overlap between species.

Literature Review

An extensive search of the primary and secondary or "grey" literature was conducted and a database of the references using each of the surveys reviewed in this document was compiled. Internet searches were performed though ASFA, Web of Science, DFO Waves, Google Scholar, and the CSAS website. Additionally, all bound issues of the Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC) were examined for content related to these surveys. Summary statistics of the number of primary and secondary papers published per year of survey were calculated. The most common journal or series where documents were published was also determined. To compare how the survey information was being used in the literature a bar plot of the most common key words from titles of documents was generated. An arbitrary cut-off at a frequency of occurrence of 2% was used for the plot.

Species Accumulation Curves

For each survey, region, and species group (all species, finfish only, and invertebrates only), species accumulation curves were generated. Survey data was limited to the years 1995-2011, consistent with the start of several of the surveys. Species accumulation curves depict the rate at which new species are captured as a plot of the cumulative number of species recorded as a function of sampling effort. In this instance the sampling effort was a single set. The species accumulation curves were generated using a resampling procedure which randomly adds new sets to the cumulative curve and is repeated through 10,000 iterations. This procedure produces a smooth curve which includes the confidence bounds on the estimate. A plateau in the species accumulation curve suggests a low probability of discovering new species with increasing effort under the assumption that sampling occurs in a closed system. All species codes recorded in the data were used for these accumulation curves. In some cases, coding errors may have caused an overestimation of species richness as there were some duplicated codes and unidentified species included. This method assumes that all species used in the analysis were consistently and correctly identified.

Finfish Length Based Frequency of Occurrence

The frequency of occurrence of finfish length classes were compared between regional surveys using a two proportion t-test. Similar to the above species accumulation curves, all survey data was limited to the years 1995-2011 to remove any potential biases from population abundance or size class changes over time. For each survey, the frequency of occurrence of each individual finfish species and length class was estimated and compared between each pair of surveys covering the same geographic region (4Vn, 4VsW and 4X) for the shared species and length groups.

Food Habits Information

A summary of the diet information collected during surveys was compiled from the Food Habits Database described in Cook and Bundy (2010). Trophic horrendograms were produced using the diet information from respective surveys.

RESULTS

Evaluation of the information provided by species experts demonstrated that the Summer RV Survey provides useful information for the development of advice in stock assessments and species at risk assessments for more species than any of the other surveys (Figure 1). Tables 6-9 highlight the value of each survey for the provision of information on species distribution, abundance trends, length composition trends, and the contribution by the surveys toward analytical assessments of select species. Summaries of other biological parameters that are available from the surveys and their usefulness to stock and species at risk assessments are also provided in Appendix A.

FISHERY AND SPECIES AT RISK ASSESSMENTS

Species Distribution

The usefulness of each survey type for providing information related to the distribution of the 51 selected species/stocks is summarized in Table 6. Ratings indicate the impact that dropping the survey would have on the information available to provide advice based on species distribution ranging from no impact on ability to understand distribution (score 0) to essential - not possible to understand distribution (score 3). The Summer RV Survey provides essential information on geographic distribution for 34 of the 51 stocks examined. The ITQ Survey provides essential information on geographic distribution that is not provided by any of the other surveys for 1 of the 51 stocks (LFA 34 Lobster). The remaining surveys did not provide any essential information on geographic distribution for the 51 stocks examined however some good information on distribution of some species/stocks is provided by the other surveys (see Table 6 for summary of ranks for the surveys reviewed).

With respect to species at risk assessments, the Summer RV Survey provides essential information on geographic distribution for 16 of the 22 species at risk stocks examined (Table 6). The remaining surveys do not provide essential information on geographic distribution for the 22 species at risk stocks examined.

Species Abundance

Evaluation of the input by the species experts on trends in abundance information provided by the surveys determined that the Summer RV Survey is a good source of abundance data for 32 of the 51 stocks examined, 14 of which are species at risk stocks. Good information on abundance trends is also provided by the ITQ Survey for 4 of the 51 species/stocks examined, 3 of which are species at risk stocks. The March 4VsW RV Survey is a good source of information on abundance trends for 3 of the 51 stocks examined. The 4Vn Sentinel Survey provides good information on abundance trends for 4Vn cod, also a species at risk stock, while the 4VsW Sentinel Survey did not provide any essential information on abundance trends (Table 7).

There are seven marine finfish stocks for which none of the surveys provide good annual indices of abundance – Herring, Cusk, Northern Wolffish, Spotted Wolffish, redfish (Unit 2), Pollock (Eastern component), Pollock (Western component) (Table 7). With the exception of Herring, all of these species are also species at risk stocks.

Species Length Composition

The Summer RV survey is a good source of information (Score 1) on length trends for 31 of the 51 stocks examined, 16 of which are species at risk stocks. The March 4VsW RV survey is a good source of length composition information for 9 of the 51 stocks examined. Good length composition information is also obtained from the ITQ Survey for 4 (3 species at risk stocks) of the 51 stocks examined and from the 4Vn Sentinel Survey for 1 stock which is also a species at risk stock. The 4VsW Sentinel Survey is not considered to be a good source of information on length trends for any of the stocks examined (Table 8).

There are many species, including species at risk stocks, for which some useful information on length indices with limitations can be provided by the surveys in this review. Table 8 provides a full summary of the ratings given to all species for trends in length composition provided by the five surveys reviewed.

Analytical Assessment Contribution (as a tuning index)

Table 9 provides a summary of the ranks for the biomass/abundance drop test by survey type for nine stocks on the Scotian Shelf which have analytical assessments. For all of these stock assessments, the Summer RV survey abundance indices contributed most to the assessment model (rank = 1), and without this survey series the model results would have been compromised. Seven of the stock assessments considered in Table 9 are for species at risk stocks. The March 4VsW RV Survey indices were the least influential on model results but it was concluded that this survey provides useful biological data collected on this stock (i.e. condition, weight-at-age, size at age 1, distribution of spawning females). The ITQ survey is considered to be a useful tuning index for 4X Cod and 4X5Y Haddock assessments, but when they are removed from the population analysis the assessment results do not change. The 4Vn Sentinel Survey and the 4VsW Sentinel Survey were considered to provide useful abundance data for the 4Vn Cod and 4VsW Cod assessments, respectively, but these surveys are not applicable to most of the Scotian Shelf groundfish stock assessments considered here.

CONTRIBUTION OF SURVEY INFORMATION TO EAM

Environmental Data Collected: All Surveys

All surveys provide information (available in databases) on the date/time and position (latitude and longitude) of each set, as well as bottom depth and fishing depth (Table 4). None of the surveys currently provide information on bottom type or other benthic habitat features. The RV surveys provide detailed hydrographic data, including temperature/salinity depth profiles, nutrient and chlorophyll concentrations and light attenuation with depth, as well as information on zooplankton species composition and abundance with depth. This sampling is undertaken as part of the standard survey protocol and contributes to the Atlantic Zonal Monitoring Program. While the ITQ, 4Vn Sentinel, and 4VsW Sentinel surveys collect data on bottom temperature, this information is currently not provided in any databases. The 4VsW Sentinel Survey also collects temperature/salinity profiles of the water column (CTD casts) but this information is not available electronically. The Summer RV Survey provides the only complete spatial coverage for the Scotian Shelf and is the best representation of baseline data. The March 4VsW RV Survey takes place during the most interesting biological period for plankton, new energy production and lower trophic levels. The AZMP data is used for many purposes including climate modelling, ground truthing satellite images, habitat mapping, and MPA and sensitive benthic area planning.

Oceans Management

The identification of areas of interest (AOI) and networks of protected areas are current strategies being employed for the management of our oceans. A quantitative tool called Marxan is being used by managers for spatial marine planning. It identifies areas based on specific data inputs and weightings to meet conservation objectives. The data, presented in GIS layers, largely comes from the Summer RV Survey. For example, during the identification of St. Anns Bank as an AOI, Summer RV Survey data was used to produce fish distribution layers for the area. The 4Vn Sentinel Survey data was also useful to provide information on fish distribution for coastal areas.

Literature Citations

The Summer and March 4VsW RV Surveys are the only surveys that have been used in the primary scientific literature. The Summer RV Survey is the most widely cited in the primary and secondary literature with about 14 citations per year. Across all surveys most citations are recorded in the secondary literature with CSAS Research Documents and CAFSAC documents being most frequent.

The survey data was used frequently in a number of primary citations in the fisheries journals including Canadian Journal of Fisheries and Aquatic Sciences (CJFAS), ICES Journal of Marine Science and the North American Journal of Fisheries Management. Additionally, it has been used in more widely read ecological journals including Marine Ecology Progress Series, Ecological Applications, Science and Nature.

Over the time series of citations collected there has been a larger emphasis toward using the survey data for individual fish stock assessments on some of the more economically important groundfish species (Cod, Haddock, and Pollock). However, focus on using the data for ecosystem, oceanographic and environmental studies has also been important.

Species Accumulation Curves

The Summer and March 4VsW RV Surveys have identified >250 species. Species accumulation curves indicate new species are still being identified (Figure 4). There are no species identified in the industry surveys or March 4VsW RV Survey that are not identified in the Summer RV Survey.

The 4Vn and 4VsW sentinel surveys identify fewer species than the Summer and March 4VsW RV Surveys. This is a result of the sentinel surveys using longline gear versus the small mesh trawl gear in the Summer and March 4VsW RV Surveys.

Not surprisingly, the sentinel surveys in 4Vn and 4VsW identify more finfish than invertebrates, however they do record about 2-3 invertebrate species on a regular basis. The 4Vn Sentinel Survey has recorded a higher number of finfish species than the 4VsW Sentinel Survey with numbers at 66 and 51 respectively.

Frequency of Size Classes

The sentinel surveys sample a higher frequency of finfish over 76 cm in length than the RV surveys (see Figure 5). Larger fish make up a higher proportion of the length distribution in samples collected from the sentinel surveys compared to the RV surveys. These proportional differences are usually <1% (Figure 5).

Food Habits Data

The diet data collected during these surveys was fully described in Cook and Bundy (2010). Stomachs were collected and contents analyzed from the Summer RV Survey, 4Vn Sentinel Survey, March 4VsW RV Survey, and the 4VsW Sentinel Survey. The 4Vn Sentinel Survey data is not currently in a usable form, but would provide an excellent source of additional data. Across all surveys, diet data were collected on >30 finfish species with a large number of prey items identified (Table 10). The trophic horrendograms were shown in Figure 6, for surveys where data was available. The Summer RV Survey data shows the most linkages for competition and predation than the data from the other two surveys, however, the March 4VsW RV Survey provides information on diet at a second period in the year, which is useful in indicating seasonal variability in diet. This abundance of linkages was largely due to the broader temporal and spatial coverage in the Summer RV Survey as well as the increased number of samples analyzed. The 4VsW Sentinel Survey has provided diet information on relatively few species, i.e. Cod, Haddock, Pollock and White Hake, which reduced the complexity of this horrendogram. The circular pattern at the base of each plot occurred because all invertebrates were allocated to the same trophic level since we do not describe their diet.

DISCUSSION

ASSESSMENT OBJECTIVES

Loss of the Summer RV Survey would cripple many stock assessments for groundfish species as it serves as the primary indicator for distribution, abundance, and length for most commercial species. The loss of industry surveys and the March 4VsW RV Survey for stock assessment would primarily result in the loss of additional seasonal and areal coverage.

The Summer RV Survey is also the most valuable survey for drawing conclusions about distribution, abundance, and length of the species-at-risk stocks examined. With the exception of Cusk length, there are no species that received a low distribution, abundance, or length index rating in the Summer RV Survey that obtained a high impact index from another survey.

The Summer RV Survey is essential to the analytical assessments of 4VN Cod, 4VsW Cod, 4X Cod, 4TVW Haddock, 4X Haddock, Western Component Pollock and 4VW American Plaice. While other surveys have been used as an index of abundance for some of these stocks, or could potentially be used, these other indices are viewed as supporting information and are not essential to the assessment. The 4VsW Sentinel Survey when broadly distributed could be used as an index for Cod or Haddock, but the index of abundance from the restricted distribution survey is not informative to either assessment. Vessel size is a limiting factor in collecting data useful for ecosystem monitoring. Small vessels can often carry only one person dedicated to collecting data. It will be very difficult to collect useful data for more than a very limited number of species during a survey unless the vessel can take at least 3 or 4 science staff.

The *Alfred Needler* can carry a Science staff of 11. With this number of staff, it is possible to work around the clock and to collect hydrographic data along with detailed biological data from most species in the catch. This number of staff is not sufficient to include detailed acoustic data collection or collection of surface sightings of marine species, such as sea birds, cetaceans and sea turtles, on a regular basis without scaling back effort in other areas. Northern Gulf DFO RV surveys are able to take dedicated staff to count cetaceans and birds on the *Teleost*, which can carry 14 science staff. Adding additional data collection streams to the summer RV survey while maintaining the existing objectives will not be possible until the survey moves to a larger vessel or some current activities are dropped.

GAPS IN SINGLE FISHERY AND SPECIES AT RISK ASSESSMENTS

Principles of assessment indices

Only the Summer RV survey meets the criteria for providing sufficient data for analytical assessments. Most of the surveys examined are not meeting the criteria for providing robust indices for management decisions. Satisfying the requirements for an analytical assessment is the most rigorous test and does not necessarily mean that the information on abundance, distribution, and length trends is not useful for providing management advice but does indicate there are appreciable gaps which must be filled for the DFO to improve its ability to fulfill mandates associated with fishery assessments, species-at-risk assessments, and ecosystem based management. This lack of robustness likely occurs because of high variation among samples resulting from a mismatch between the species life-history, gear, survey area and season, or statistical design.

We first examine where and why some of the gaps occur and then propose recommendations for addressing these gaps to improve the ability of DFO to meet its mandate.

Groundfish

Distribution and abundance data is generally well-resolved for most commercially exploited groundfish species in Maritimes Region with the exceptions of Northern Wolffish, Spotted Wolffish, Cusk, and Unit II redfish. The two species of wolffish are generally rare in Maritimes Region and restricted to deep waters that are not well represented in RV surveys. Commercial longline fisheries are the principle source of bycatch for these wolffish species. Cusk is a species found primarily on rough bottom which is difficult to survey with an otter trawl. Habitat type covered by trawl surveys is the prime contributor to this gap.

Unit II redfish includes both 3P and 4VWfgj. There is no single survey which covers the redfish stock area which is shared between Newfoundland Region and Maritimes Region. This is an area which supports commercial fishing, but is not regularly sampled in a DFO survey. Depth covered by the Maritimes Region Summer RV survey in the Laurentian channel is the prime contributor to this gap. Filling this gap would provide complete geographic coverage for Unit II redfish, but some way of scaling the results from the Newfoundland and Maritimes Region surveys would still be required.

Many deep water-species, such as Spiny Dogfish, Witch Flounder, Silver Hake, White Hake and Monkfish are distributed throughout the Gulf of Maine. This is a transboundary area and neither Canada nor the US has a survey which covers the whole area. Addressing this shortcoming would require collaborating with the US on a coordinated international survey.

For commercial size Halibut, more precise information on abundance trends are available from a species specific survey, so the low ranking for commercial size Halibut in relation to abundance trends in these surveys is not essential to address.

Invertebrates

For commercial species of invertebrates such as Snow Crab, Northern Shrimp and Atlantic Scallops, more precise information on abundance trends are available from species specific surveys, so the low ranking of these surveys in relation to abundance trends is not essential to address.

Although the Summer RV Survey is the only survey which covers the entire 4VWX area it ranks poorly for monitoring the distribution of most invertebrates. Since no other survey covers this broad range, this survey is the only one which can monitor distribution changes at this scale. Review of the trends for these species in the survey to determine if they reflect trends in abundance as documented in the stock assessments is required. Adjusting sampling intensity by area will improve precision in invertebrate monitoring. Until this analysis is undertaken, it will remain unclear whether the survey is reflecting abundance and distribution patterns for these species.

Pelagic (large i.e. sharks, tuna, swordfish and small i.e. herring, diadromous), and Semi pelagic (i.e. Pollock) stocks

Monitoring the abundance of pelagic and semi-pelagic species constitutes a gap in Maritimes Region surveys and is reflected in the ratings for Herring and Mackerel in Tables 6-8. A mis-match of gear and life-history is the prime contributor to this gap. Acoustic survey indices are available for Herring in the Bay of Fundy from industry surveys but not on the Scotian Shelf. While the Summer RV Survey covers this area, the catch of pelagic species like Herring and Mackerel does not reflect trends in abundance.

Pollock are a semi-pelagic schooling species which are difficult to survey using only bottom trawling. Pollock distribution and abundance information is considered to be adequate at present although strong year effects can occur owing to their semi-pelagic schooling behaviour and changes in availability arising from differing distributions in the water column at the time of the surveys. Acoustic profiling coupled with bottom trawl catch information will increase our understanding of changes in depth distribution of Pollock at the time of the survey. Pollock life history involves an offshore spawning and larval phase, recruitment to coastal areas for 1-2 years, followed by an offshore migration. Appropriately timed nearshore surveys in these areas during summer will provide data on pre-recruit (ages 1-2) abundance trends. For Western Component Pollock, the Summer RV Survey in most years has not covered the full stock area which includes eastern Georges Bank. Expanding coverage to include the full stock area would improve the reliability of this survey. In 2011 and 2012, the Summer RV survey has included some coverage of eastern Georges Bank in an effort to address this gap.

Diadromous species have been successfully sampled using specialized mid-water trawls (Lacroix and Knox 2005). Among the primary species caught in this gear, somewhat surprisingly, were adult Lumpfish, along with juveniles of many species. Catches of Shad and Gaspereau are also much higher in winter surveys, so the potential for using indices from a winter survey could be investigated using data from 1978 - 1984 when seasonal surveys were conducted.

Surface Species (Marine mammals, seabirds, large bycatch species)

Surface species enumeration requires dedicated personnel with specific training to identify and count them in a manner that is consistent with the criteria for robust indices. Thus, a mis-match of gear and life-history is the prime contributor to this gap. On an *ad hoc* basis, Environment Canada has provided staff for seabird enumeration on RV surveys. The limited space for science staff on the *CCGS Alfred Needler* in excess of those dedicated to fish and hydrographic studies has restricted our ability to take additional staff to count birds or mammals, so this has been done only when we used the *CCGS Teleost* or when the Chief Scientist has conducted hydrographic sampling allowing us to sail with one hydrographer rather than two.

SOLUTIONS TO GAPS

This review highlights difficulties in achieving stable catchability for a diverse set of species given variable factors such as depth, area, season, and life-history of the species for which the surveys are directed. Our recommendations focus on temporal, spatial and gear aspects of survey design that will help to address the gaps that we have identified by increasing the likelihood of stable catchability. We argue that it is possible to stabilise catchability and thus improve statistical analysis of survey data when surveys are conducted during the optimal season, cover as much of the ecosystem as possible and use gear that provides consistent catchability among a set of species. We recommend that new survey designs allow for the combination of data from complimentary surveys and that they be tested using simulated data before new or modified surveys are undertaken.

Gear

Trawl

The Summer RV Survey has used the same Western IIa net since 1982. This practice has ensured consistency in sampling and is an important aspect in providing consistent catchability among species across years. However, this net is poor at sampling close to the substrate. While this is acceptable for providing indices for many species, catchability (q) differs widely amongst species and size classes and compromises ecosystem analyses. If changes in catchability are related to size rather than age, this also leads to problems in assessing stocks which experience changes in growth rate. The net dimensions also change with depth complicating comparisons among depth zones. For many ecosystem studies it is assumed that catchability is constant across species and sizes. This assumption is not met with our current trawl net.

The NEST trawl used for surveys conducted by the US National Marine Fishery Service (NMFS) in the Gulf of Maine and Georges Bank area was designed to conform to these principles of robust indices and to minimize variability in catchability. It is designed to have consistent dimensions at all depths, so that the area and volume sampled is constant. This will eliminate differences in catchability among species or life-history stages of fish which result from changes in gear parameters with depth. It has a higher opening than the Western IIa, and uses rockhopper footgear. These characteristics reduce escape under and over the net and result in less variability of catchability with size and age of fish. Comparative fishing studies conducted by NMFS demonstrate that differences in catch between the NEST trawl and the Yankee trawl (similar to the Western IIa trawl) are consistent with what would be expected from a reduced variability in catchability with age and size (Brooks et al, 2010; Miller et al, 2010). Catches with the NEST trawl are similar to those with a Yankee trawl for large commercial gadoids, but it catches much larger quantities of small gadoids and flounders which evade the Yankee trawl by swimming between the rollers in the footgear and going under the net.

Recommendation (1)

We recommend that summer RV ship time be used to conduct comparative surveys using the Western IIa and NEST to collect data to evaluate calibration and catchability estimates across a broad size range for key species. When these experiments are completed an evaluation on the consequences of changing to a NEST trawl can be completed.

Longline

There are several species, including Cusk, Northern Wolffish and Spotted Wolffish for which an otter trawl is unlikely to provide robust indices of abundance. Longlines can be used in areas with very rough bottom, which is preferred habitat for these species, and has the advantage of much higher catchability for some species (e.g., large Cod, Cusk, Halibut, large skates, and wolffishes).

A deep water survey is conducted off Portugal using longline. The use of longline as fishing gear in this area is strictly related to the bottom topography of the region which is too rough to tow a bottom trawl (ICES 2010). Longlining is generally a less preferred method of sampling for ecosystem indices because the diversity of species and the length range captured is restricted. As well, the area from which a sample is drawn depends on the range within which they are attracted by the bait. Nevertheless, longline represent an important option for obtaining reliable indices of abundance for some species.

Recommendation (2)

Using information from current longline surveys, including the stock specific halibut survey, conduct a simulation study to determine the cost and benefits of designing a consolidated longline survey to provide consistent catchability for species where depth and habitat prevent a trawl survey from providing robust indices.

Acoustics

Pelagic and semi-pelagic species have been surveyed using acoustic techniques. For herring, these techniques are common and have been shown to be useful (ICES, 2010). For semi-pelagic species the results have been more uncertain and in some cases, acoustics and trawl have been combined (ICES 2010). Acoustic data are now being collected from the Summer RV Survey; however, the data have yet to be analyzed so it is unclear what contribution these data will make to the survey program. These data will provide additional information on total pelagic biomass; however, without additional biological sampling and modifications to the survey track, the ability to determine biomass of individual pelagic species is unlikely.

Recommendation (3)

A summary of the analysis of acoustic data collected during the RV survey in 2011 to 2013 is needed. Further investigation of the potential for integrating acoustics into the trawl survey will be dependent on the results of this analysis.

Area and season

All of the surveys reviewed, other than the March 4VsW RV Survey, are conducted at times between July and early October. Filling area and season gaps requires expanding geographic coverage or developing surveys where none now exist. The Summer RV Survey does not include sampling in coastal areas, particularly in the area off SW Nova Scotia. The 4V portion of the Laurentian Channel has been sampled only during the March 4VsW RV Survey and has not been included in the Summer RV Survey sampling. Also, our surveys are not coordinated with surveys in adjacent areas, so they fail to provide synoptic coverage for transboundary stocks in the Gulf of Maine and the Laurentian Channel.

The March 4VsW RV Survey was originally based on cod distribution in the early 1980's. The limited spatial coverage means it does not cover the stock area for many species and therefore, catchability of many species is subject to variation depending on migration and life-history.

Recommendation (4)

Work with NMFS to design a synoptic survey that extends broadly across the Scotian Shelf and Gulf of Maine. This design would be consistent with the general objectives of an ecosystem survey program. Options to explore include the US commencing a July survey or Canada modifying the Winter survey of Georges Bank and 4VsW coverage to include a broader geographic area. Surveys and analyses investigating the consequences of these changes on long-term indices need to be completed.

Recommendation (5)

Include sampling of the 4V portion of the Laurentian Channel in the Summer RV Survey. Work with Newfoundland Region to determine if the expansion of the Summer RV Survey and development of weighting factors for the two gear/vessel combinations would be sufficient to provide indices of abundance across the Laurentian Channel. Surveys and analyses to develop conversion factors and investigation of the utility of these indices would need to be completed.

Recommendation (6)

Establish a working group to develop the protocols and design for an inshore survey that would provide robust indices to be used in combination with offshore survey indices for assessments and ecosystem studies

The Summer RV, March 4VsW RV and 4Vn Sentinel surveys use a stratified random sampling design which is the preferred sampling design for producing robust indices for advice. Strata should be defined in some way which captures geographic differences in species composition and abundance. Generally, depth, bottom type, and hydrography are used to define strata although geographic regions can also be used. Alternatively, a systematic design can be used, or a hybrid with systematic sampling following a random selection of the initial starting point. These methods allow for the possibility of sampling in any location within the range surveyed, and have robust statistical designs which permit estimates of variance. Fixed station sampling excludes the possibility of sampling in any but the initially selected locations. It does not provide an unbiased sample and no meaningful estimate of variance can be calculated.

Recommendation (7)

Stratified random designs are the default design unless there is a strong reason based on simulation experiments to adopt another design for resource surveys.

GAPS IN SURVEYS FOR THE ECOSYSTEM APPROACH

An ecosystem survey program has at its core a program for providing robust indices on population trends which can be used to assess stock status. The lack of robust estimates of survey catchability is a constraint on our ability to assess population abundance. The lack of an estimate of the probability of capture by the survey gear, independent of the analytical assessment, has hindered the review of assessments for species such as Silver Hake (Stone et al, 2013), Haddock (Showell et al, 2013), redfish (Duplisea et al, 2012), and 5Z Cod (Wang and O'Brien , 2012). In addition, ecosystem analyses assume that q for species which have no analytical assessment is the same as it is for a similar assessed species.

Recommendation (8)

Develop species specific q estimates or recommendations on probable bounds on q for use in single species and ecosystem assessments.

Ecosystem studies are hampered by having only a single glimpse at species distribution and diet composition. Having robust indices for abundance, distribution, and length at one season is the first step. Advice on ecosystem consequences to decisions will also require information on the pressures that might influence abundance, distribution, and length including environmental factors, cumulative effects from human activities, and trends in prey, predators, and competitors (i.e. diet sampling) in more than one season. Hydrographic sampling, benthic substrate and structure mapping, and enumeration of all trophic levels are ideal as part of an ecosystem survey program.

Recommendation (9)

The sampling intensity (number and frequency) for hydrographic, benthic, and trophic level interactions for an ecosystem survey program should be determined through simulation studies.

An ecosystem survey program must provide more than robust indices for stock assessments. An ecosystem survey program must include additional sampling requirements that are catalogued in the ICES WKCATDAT Report (ICES 2010). We have provided a series of recommendations for acquiring the necessary data.

FUTURE DIRECTIONS

Our review started with a focus on individual surveys and has concluded with a recommendation to look at a survey program for assessment and ecosystem consideration. This program must continue to provide the information required for single species stock assessments to inform fishery and species–at-risk analyses. These objectives require the maintenance of long-term indices and biological sampling programs that will detect changes in life-history characteristics related to fishery or environmental pressures. In addition, the survey program must provide improvements in ecosystem sampling that relate directly to the National and Regional EMF being developed. These frameworks consider a range of decisions that go beyond applying an EAM and include how the cumulative effect of human activities alter specific ecosystem attributes. In the Maritimes Region, the EAM includes investigation of attributes related to biological diversity, productivity, and habitat (Curran et al. 2012). Consideration of these new demands have generally added to procedures already in place by increasing the variety of species sampled, enhancing sampling for hydrographic and plankton characteristics, and monitoring for stomach contents, rather than making changes to statistical designs and long-term sampling methods. This approach is consistent with the recommendations from WKCATDAT for moving towards ecosystem surveys for ICES members (ICES, 2010).

This review concludes that there is scientific benefit in exploring reallocation of resources currently put towards the March 4VsW RV, ITQ, 4Vn Sentinel, and 4VsW Sentinel surveys. To examine alternative questions that could be addressed using these resources the DFO Maritimes Region Science, Fisheries Management, and Ecosystem Management Branches will need to work with clients and with biological sampling programs in the United States, Newfoundland and the Southern Gulf with whom we share responsibility for monitoring Large Ocean Management Areas. Some options to consider include developing a comprehensive ecosystem survey program or addressing a series of short-term research questions to develop a better understanding of underlying ecosystem processes.

As the requirements for ecosystem monitoring and management are refined, new sampling will be needed. Ensuring we meet the objectives in a coordinated fashion will require evaluation of a series of parameters:

- Survey design options (most appropriate design for each attribute, for example fixed vs. random)
- Biological sampling (choice of attributes or indicator, and sampling method, design, and intensity)
- Environmental sampling (choice of attributes or indicator, and sampling method, design, and intensity)
- Consequences to the provision of single species stock assessment advice (how any sampling changes would influence advice and subsequent decisions)

A broad range of considerations will be important for these evaluations and an emphasis on combining surveys which will involve different platforms and designs will need to be included to provide the most robust evaluation for future survey programs. We have provided nine recommendations for consideration as we continue to move from a survey program focussed on provision of indices for single-species stock assessments to an ecosystem survey program. These will provide guidance on how to ensure we can make progress on providing information for EMF while continuing to meet the existing monitoring requirements.

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TABLES

Table 1. Form 1 (completed for each of the 51 selected species/stocks): summary of data currently collected from each of the five surveys.

Rating guide:

- na – survey does not cover the stock area or gear does not fish the species
- 0 – not collected
- 1 – yes, data are currently collected
- 2 – samples saved for onshore collection

Biological Parameters	Summer RV	March 4VsW RV	4Vn Sentinel	4VsW Sentinel	ITQ	Comments
Identification Level						
Set Weight						
Number						
Length						
Individual Weight						
Sex						
Maturity						
Age Material						
Fecundity						
Diet						
Permits ID of Primary Spawning Grounds						
Comments						

Table 2. Form 2 (completed for each of the 51 selected species/stocks): evaluation of whether the data collected are useful for monitoring stocks.

Rating guide:

1 – good source of stock information

2 – useful information with some limitations

3 – some information with many caveats

4 – data not collected but could be collected

5 – data not useful or not estimated

6 – data not possible to collect

0 – not applicable

Rating guide for last row – impact of dropping survey on distribution

0 – no impact

1 some impact; survey covers part of distribution not covered by other surveys

2 – high impact; survey covers large part of distribution not covered by other surveys

3 – essential, not possible to understand distribution without survey

BIOLOGICAL PARAMETERS	SUMMER RV	MARCH 4VSW RV	4VN SENTINEL	4VSW SENTINEL BROAD DISTRIBUTION	4VSW SENTINEL RESTRICTED DISTRIBUTION	ITQ
Length of Survey Series (yrs)						
Trends in Abundance						
Trends in Length Composition						
Describes Immature Size Distribution						
Describes Mature Size Distribution						
Age						
Sex Ratio						
Maturity Ogive						
Fecundity						
ANALYSES						
Range for catchability (see new scale)						
Growth model						
Recruitment events						
Changes in weight at age						
Changes in size at maturity						
Catchability related to temperature						
Ability of survey to estimate absolute abundance (catchability)						
Habitat preference						
Provides distributional information						
Use as sole source for distribution data (stand alone)						
Impact of dropping survey on conclusions about distribution						

Table 3. Form 3 (completed for each of the 51 selected species/stocks): evaluation of whether the data are useful for analytical assessments (VPA or modelling).

Rating guide:

1 – good source of stock information
2 – useful information with some limitations
3 – some information with many caveats
4 – data not collected but could be collected
5 – data not useful or not estimated
6 – data not possible to collect
0 – not applicable

ANALYSES	SUMMER RV	MARCH 4VSW RV	4VN SENTINEL	4VSW SENTINEL BROAD DISTRIBUTION	4VSW SENTINEL RESTRICTED DISTRIBUTION	ITQ
Tracking cohorts (age) [1]						
Annual Variation (year effect) [2]						
How well does the survey fit the model						
Use only 1 survey (biomass/abundance)[3]						
Biomass/abundance drop test [4]						
Comments						

[1] Can the survey track cohorts (strong vs weak) – aged stocks only.

[2] Over and above what is expected from natural or biological expectations.

[3] If you only use one survey how does the assessment result compare with the accepted estimates.

[4] If you leave out one survey does this impact on your estimates of biomass/abundance.

Table 4. Summary of environmental data collected from DFO RV surveys (Summer and March 4VsW) and Industry/Science Surveys (4Vn Sentinel, 4VsW Sentinel, and ITQ). (Y: data collected and available electronically in databases; N: Data not collected; P: Data collected but not available electronically in databases).

	Survey				
Data collected	Summer RV	March RV (4VsW cod)	4Vn Sentinel	4VsW Sentinel	ITQ
Date/Time	Y	Y	Y	Y	Y
Latitude and Longtitude	Y	Y	Y	Y	Y
Water Temperature bottom	Y	Y	N	P	P
Salinity	Y	Y	N	N	N
Bottom Depth	Y	Y	Y	Y	Y
Fishing Depth	Y	Y	Y	Y	Y
Bottom Type	N	N	N	N	N
Other Habitat Features	N	N	N	N	N
Water temperature profile	Y	Y	N	P	N
Sea surface temperature	Y	Y	N	N	N
Atlantic Zonal Monitoring Program	Y	Y	N	N	N

Table 5. List of selected species/stocks included in the survey review analyses. Inclusion was based on several criteria including: interest to managers, interest to SARMD, role forage species and ecosystem considerations (* species of concern to SARMD).

Information is requested by Fisheries Management for these stocks either to assist in setting quotas/triggering an assessment or to assist in monitoring trends for species identified as bycatch in MSC reviews.	4TVW Haddock *
	4X5Y Haddock *
	4Vn Cod *
	4VsW Cod *
	4X Cod *
	4Xopqrs5 Pollock *
	4VWXmn Pollock *
	4VWX White Hake *
	4VWX Silver Hake
	Atlantic Halibut *
	Unit II Redfish *
	Unit III Redfish *
	Monkfish
	Spiny Dogfish *
	Atlantic Wolffish *
	Spotted Wolffish *
	Northern Wolffish *
	Smooth Skate *
	Thorny Skate *
	Winter Skate *
	Little Skate *
	Barndoor Skate *
	Longhorn Sculpin
	Cusk *
	4X Yellowtail Flounder
	4VW Yellowtail Flounder
	4X Witch Flounder
	4VW Witch Flounder
	4X American Plaice *
	4VW American Plaice *
	4X Winter Flounder

Table 5. Continued.

Invertebrates which are subject to directed fisheries	Lobster LFA 40-41
	Lobster LFA 22-33
	Lobster LFA 34
	Lobster LFA 35-38
	Arctic Surfclam
	4WVX Invertebrates
	Sea Cucumber
	Shrimp (Pandalus sp.)
	4VWX5 Sea Scallop
	Snow Crab
Important "forage" fish	Herring
	Capelin
	N. Sand Lance
Other fish	Cunner
	Sea Raven
	Black-bellied Rosefish
	Greenland Halibut
Other invert	Whelk
	4VWX Invertebrates
	Shortfin squid

Table 6. Summary of the ranks for the distribution drop test by stock/species for each of the five surveys. Dark Grey highlighted information indicates surveys which provide essential information on the distribution of a particular species. Light grey highlighted information indicates surveys which have no impact on determining species distribution. Rank codes: 0 = no impact; 1= some impact (survey covers part of the distribution not covered by other surveys); 2 = high impact (survey covers large part of distribution not covered by other surveys); 3 = not possible to understand distribution without this survey.

Species	Survey Type					
	4Vn Sentinel	4VsW Sentinel		ITQ	March 4VsW RV	Summer RV
		(Broadly Distributed)	(Restricted Distribution)			
American Plaice (4VW) *	0	1	1	0	1	3
American Plaice (4X) *	0	0	0	1	0	3
Arctic Surfclam	0	0	0	0	0	0
Atlantic Halibut *	1	1	1	1	1	2
Atlantic Herring	0	0	0	1	1	3
Atlantic Wolffish *	0	1	1	1	1	3
Barndoor Skate *	1	2	2	1	1	3
Black Belly Rosefish	0	0	0	1	0	3
Capelin	0	0	0	0	3	3
Cod (4Vn) *	1	0	0	0	0	3
Cod (4VsW) *	0	2	2	0	2	3
Cod (4X) *	0	0	0	1	0	3
Cunner	0	0	0	1	1	3
Cusk *	0	1	1	0	0	1
Greenland Halibut	0	0	0	0	1	3
Haddock (4TVW) *	0	1	1	0	2	3
Haddock (4X5Y) *	0	0	0	2	0	3
Invertebrates (4VWX)	0	0	0	0	1	2
Little Skate	0	0	1	1	1	3
Lobster (LFA 27)	0	0	0	0	0	0
Lobster (LFA 34)	0	0	0	3	0	1
Lobster (LFA 35)	0	0	0	2	0	3
Lobster (LFA 41)	0	0	0	2	0	2
Longhorn Sculpin	0	1	1	1	0	3
Monkfish	0	1	1	1	1	3
Northern Sand Lance	0	0	0	0	1	3
Northern Wolffish *	2	1	1	0	1	2
Pollock (Eastern Component) *	0	0	0	0	1	3
Pollock (Western Component) *	0	0	0	0	0	3

Table 6. Continued

Redfish (Unit 2) *	0	0	0	0	0	0
Redfish (Unit 3) *	0	0	0	0	1	2
Sea Cucumber	0	0	0	1	2	3
Sea Raven	0	0	0	1	1	3
Sea Scallop (4VWX5)	0	0	0	0	1	2
Shortfin Squid	0	0	0	1	1	2
Shrimp (Pandalus)	0	0	0	0	2	2
Silver Hake (4VWX)	0	0	0	1	1	3
Smooth Skate *	0	0	0	1	1	3
Snow Crab	0	0	0	0	1	1
Spiny Dogfish *	0	1	0	1	2	3
Spotted Wolffish *	2	1	1	0	1	2
Thorny Skate *	0	0	0	1	1	3
Whelk	0	0	0	0	1	3
White Hake (4VWX) *	2	1	1	1	1	3
Winter Flounder (4X)	0	0	0	2	0	2
Winter Skate *	0	0	0	1	1	3
Witch Flounder (4VW)	0	0	0	0	1	3
Witch Flounder (4X)	0	0	0	0	0	3
Yellowtail Flounder (4VW)	0	0	0	0	1	3
Yellowtail Flounder (4X)	0	0	0	1	0	3

* species of concern to SARMD

Table 7. Summary of the ratings for “trends in abundance” data by stock/species for each of the five surveys. Dark grey highlighted cells indicate surveys that provide “good” information on trends in abundance. Light grey highlighted cells indicate surveys which have “non-useful” information trends in abundance.

Rating guide:

1 – good source of stock information
2 – useful information with some limitations
3 – some information with many caveats
4 – data not collected but could be collected
5 – data not useful or not estimated
6 – data not possible to collect
0 – not applicable

Species	Survey Type					
	4Vn Sentinel	4VsW Sentinel (Broadly Distributed)	4VsW Sentinel (Restricted Distribution)	ITQ	March 4VsW RV	Summer RV
American Plaice (4VW) *	3	3	0	0	3	1
American Plaice (4X) *	0	0	0	1	0	1
Arctic Surfclam	0	0	0	0	0	0
Atlantic Halibut *	1	1	1	1	0	2
Atlantic Herring	0	0	0	3	3	3
Atlantic Wolffish *	2	3	3	3	2	1
Barndoor Skate *	5	2	2	2	2	1
Black Belly Rosefish	0	0	0	2	3	1
Capelin	0	0	0	0	1	1
Cod (4Vn) *	1	0	0	0	0	1
Cod (4VsW) *	0	2	2	0	2	1
Cod (4X) *	0	0	0	1	0	1
Cunner	3	3	3	3	3	1
Cusk *	5	2	3	5	5	3
Greenland Halibut	3	3	3	0	3	1
Haddock (4TVW) *	3	2	2	0	2	1
Haddock (4X5Y) *	0	0	0	1	0	1
Invertebrates (4VWX)	0	0	0	0	3	3
Little Skate	5	3	3	3	2	1
Lobster (LFA 27)	0	0	0	3	0	3
Lobster (LFA 34)	0	0	0	1	0	1
Lobster (LFA 35)	0	0	0	1	0	1
Lobster (LFA 41)	0	0	0	2	3	2
Longhorn Sculpin	4	3	3	2	2	1
Monkfish	5	2	2	2	2	1
Northern Sand Lance	0	0	0	2	3	1
Northern Wolffish *	3	5	5	5	5	5
Pollock (Eastern Component) *	0	5	5	0	5	2

Table 7. Continued.

Pollock (Western Component) *	0	0	0	3	0	2
Redfish (Unit 2) *	5	3	3	0	3	3
Redfish (Unit 3) *	0	3	3	2	3	1
Sea Cucumber	0	0	0	3	2	2
Sea Raven	3	3	3	2	3	1
Sea Scallop (4VWX5)	0	0	0	0	3	3
Shortfin Squid	0	0	0	0	3	3
Shrimp (Pandalus)	0	0	0	5	2	2
Silver Hake (4VWX)	0	0	0	1	2	1
Smooth Skate *	0	5	5	4	2	1
Snow Crab	0	0	0	0	3	3
Spiny Dogfish *	3	3	5	2	2	1
Spotted Wolffish *	3	5	5	5	5	5
Thorny Skate *	3	3	3	3	2	1
Whelk	0	0	0	4	3	1
White Hake (4VWX) *	3	3	3	2	2	1
Winter Flounder (4X)	0	0	0	1	0	2
Winter Skate *	5	3	3	2	2	1
Witch Flounder (4VW)	0	0	0	0	1	1
Witch Flounder (4X)	0	0	0	2	0	1
Yellowtail Flounder (4VW)	0	0	0	0	1	1
Yellowtail Flounder (4X)	0	0	0	2	0	1

* species of concern to SARMD

Table 8. Summary of the ratings for “trends in length composition” data by stock/species for each of the five surveys. Dark Grey highlighted cells indicate surveys that provide “good” information on the length composition. Light grey highlighted cells indicate surveys which have “non-useful” information on length composition.

Rating guide:
1 – good source of stock information
2 – useful information with some limitations
3 – some information with many caveats
4 – data not collected but could be collected
5 – data not useful or not estimated
6 – data not possible to collect
0 – not applicable

Species	Survey Type					
	4Vn Sentinel	4VsW Sentinel		ITQ	March 4VsW RV	Summer RV
		(Broadly Distributed)	(Restricted Distribution)			
American Plaice (4VW) *	0	0	0	0	3	1
American Plaice (4X) *	0	0	0	3	0	1
Arctic Surfclam	0	0	0	0	0	0
Atlantic Halibut *	1	1	1	1	0	2
Atlantic Herring	0	0	0	0	2	1
Atlantic Wolffish *	2	3	3	4	2	1
Barndoor Skate *	5	2	2	4	2	1
Black Belly Rosefish	0	0	0	4	1	1
Capelin	0	0	0	4	1	1
Cod (4Vn) *	1	0	0	0	0	1
Cod (4VsW) *	0	0	0	0	2	1
Cod (4X) *	0	0	0	1	0	1
Cunner	0	0	0	4	2	1
Cusk *	5	2	3	5	5	3
Greenland Halibut	3	0	0	0	1	1
Haddock (4TVW) *	5	2	2	0	2	1
Haddock (4X5Y) *	0	0	0	1	0	1
Invertebrates (4VWX)	0	0	0	0	0	0
Little Skate	5	4	4	4	2	1
Lobster (LFA 27)	0	0	0	0	0	0
Lobster (LFA 34)	0	0	0	2	0	2
Lobster (LFA 35)	0	0	0	2	0	2
Lobster (LFA 41)	0	0	0	2	3	2
Longhorn Sculpin	0	0	0	4	1	1
Monkfish	4	2	2	4	2	1
Northern Sand Lance	0	0	0	4	1	1
Northern Wolffish *	3	5	5	5	5	5
Pollock (Eastern Component) *	0	0	0	0	3	1

Table 8. Continued.

Pollock (Western Component) *	0	0	0	1	0	1
Redfish (Unit 2) *	0	0	0	0	2	2
Redfish (Unit 3) *	0	0	0	2	2	2
Sea Cucumber	0	0	0	0	0	0
Sea Raven	0	0	0	4	1	1
Sea Scallop (4VWX5)	0	0	0	0	3	3
Shortfin Squid	0	0	0	0	3	3
Shrimp (Pandalus)	0	0	0	5	5	5
Silver Hake (4VWX)	0	0	0	4	1	1
Smooth Skate *	0	5	5	4	2	1
Snow Crab	0	0	0	0	3	3
Spiny Dogfish *	5	5	5	4	2	2
Spotted Wolffish *	3	5	5	5	5	5
Thorny Skate *	3	5	3	3	2	1
Whelk	0	0	0	4	4	4
White Hake (4VWX) *	3	3	3	3	2	1
Winter Flounder (4X)	0	0	0	1	0	1
Winter Skate *	5	3	3	4	2	1
Witch Flounder (4VW)	0	0	0	0	1	1
Witch Flounder (4X)	0	0	0	3	0	1
Yellowtail Flounder (4VW)	0	0	0	0	1	1
Yellowtail Flounder (4X)	0	0	0	3	0	1

* species of concern to SARMD

Table 9. Summary of the ranks for the Biomass/abundance drop test by survey type for stocks which have analytical assessments (4X/5Y Cod, 4Vn cod, 4VsW cod, 4X/5Y Haddock, 4TVW Haddock, Silver hake, Western Pollock, White Hake, 4VW Plaice). Dark grey highlighted cells show the surveys by species that provide a good source for indices of abundance.

Rating guide: 0 = no impact; 1= some impact; 2 = high impact; 3 = not possible to understand without this survey.

Species	Survey Type					
	4Vn Sentinel	4VsW Sentinel (Broad Distribution)	4VsW Sentinel (Restricted Distribution)	ITQ	March 4VsW RV	Summer RV
American Plaice (4VW)	0	0	0	0	0	3
Cod (4Vn)	2	0	0	0	0	3
Cod (4VsW)	0	2	0	0	1	3
Cod (4X)	0	0	0	2	0	3
Haddock (4TVW)	0	1	1	0	2	3
Haddock (4X5Y)	0	0	0	2	0	3
Pollock (Western Component)	0	0	0	0	0	3
Silver Hake (4VWX)	0	0	0	0	0	3
White Hake (4VWX)	0	0	0	0	0	3

Table 10: Summary of stomach data collected during surveys

	Summer RV	March 4VsW RV	ITQ	4VsW Sentinel	4Vn Sentinel
Stomach Samples	yes	yes	no	yes	yes
# Years	14	12		8	19
Number Species	32	27		3	1
Number Prey Items	281	235		101	not available
Number Stomachs	41,842	23,226		3,510	30,622

FIGURES

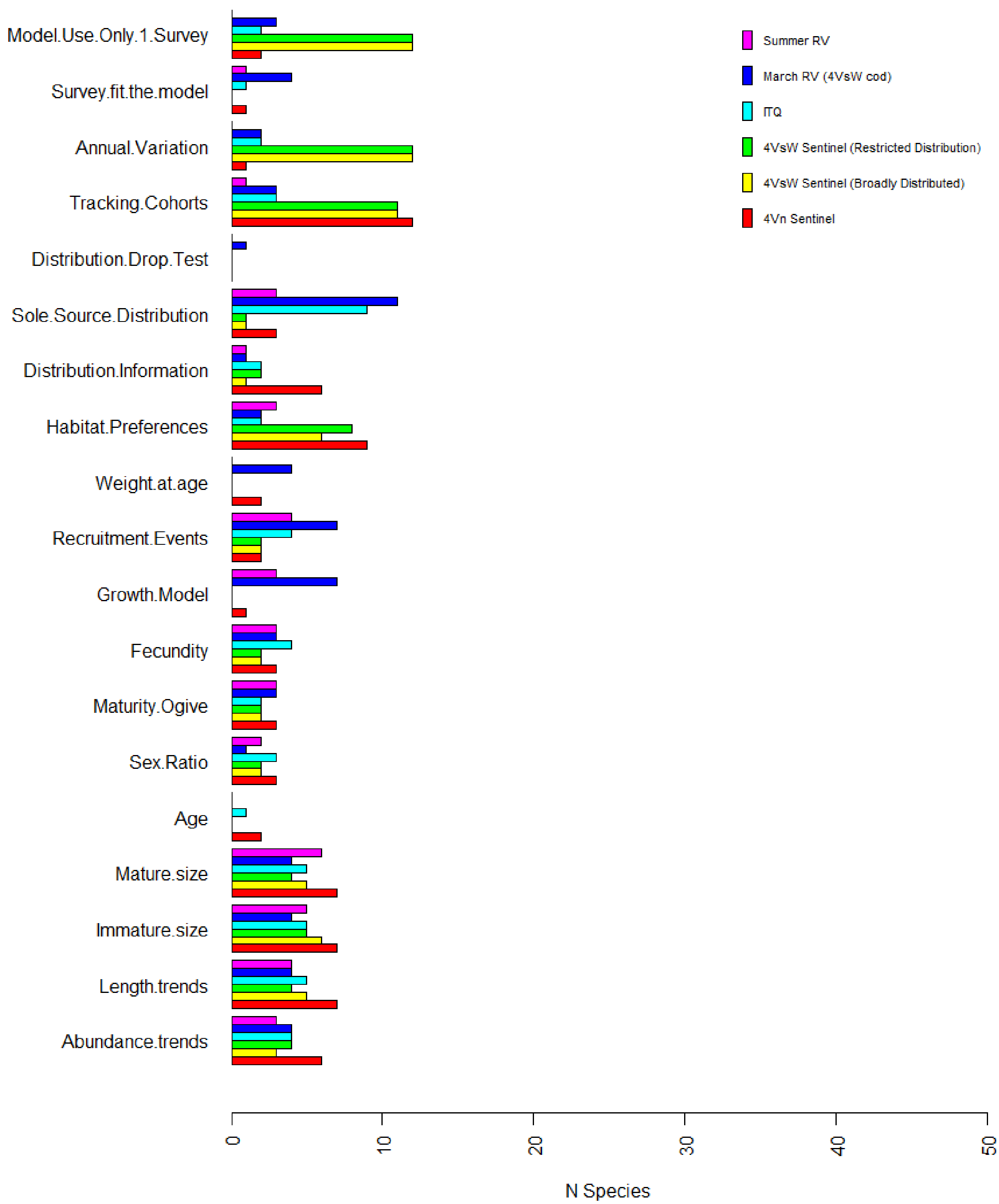

Figure 1. Total number of species whose information is collected by specific surveys and is informative.

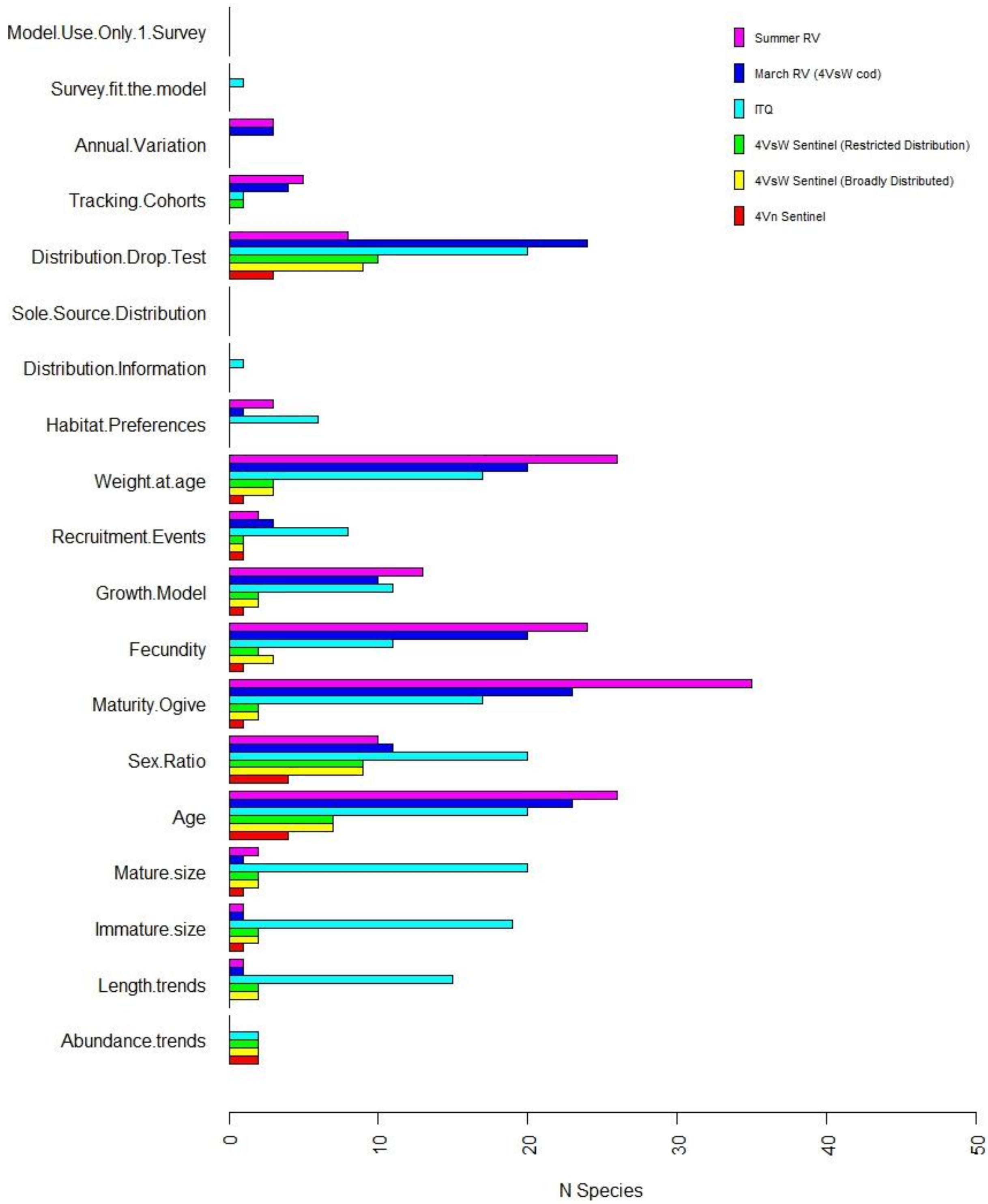

Figure 2. Total number of species whose information is not collected by specific surveys but could be.

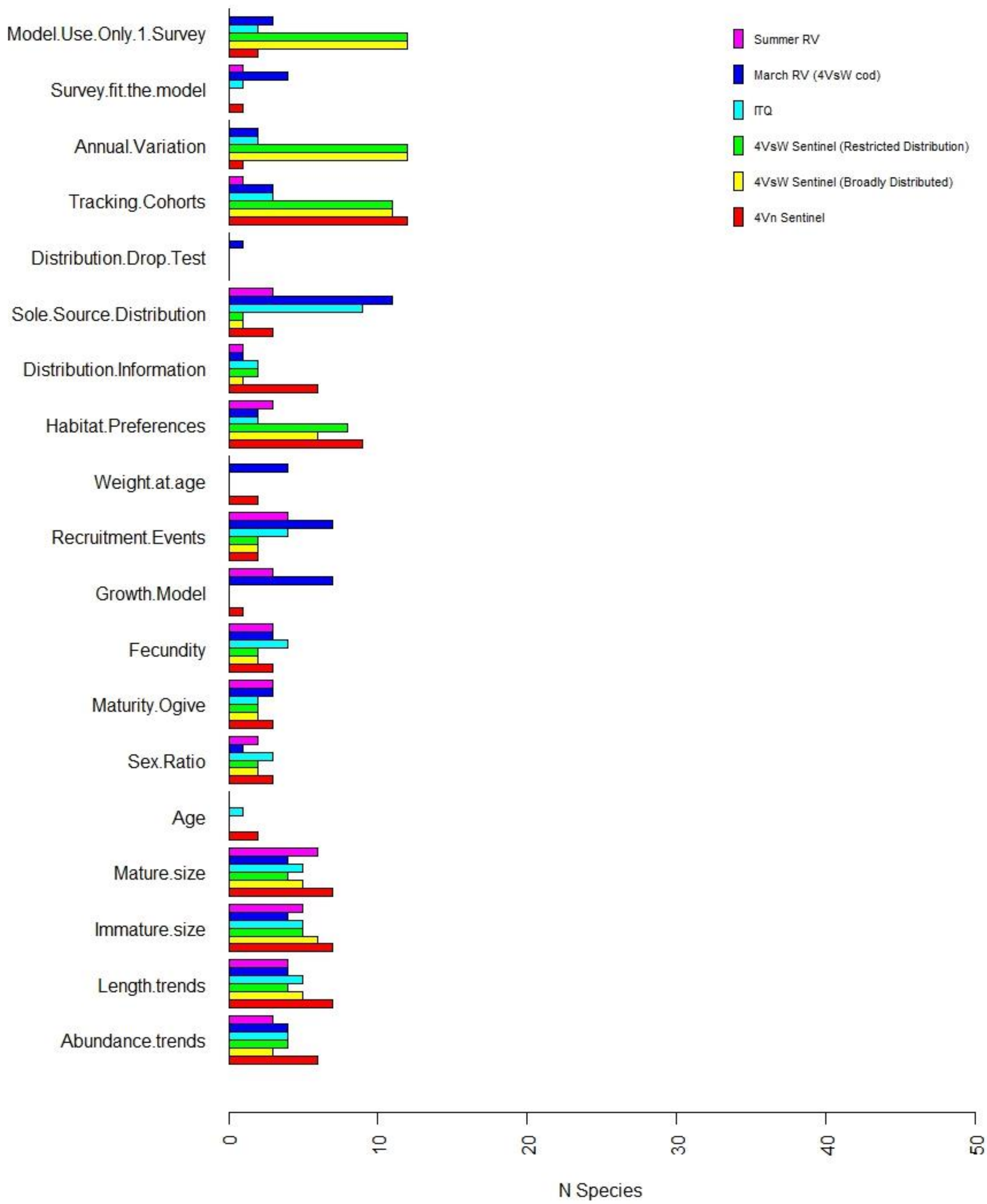

Figure 3. Total number of species whose information is collected by specific surveys but is not useful.

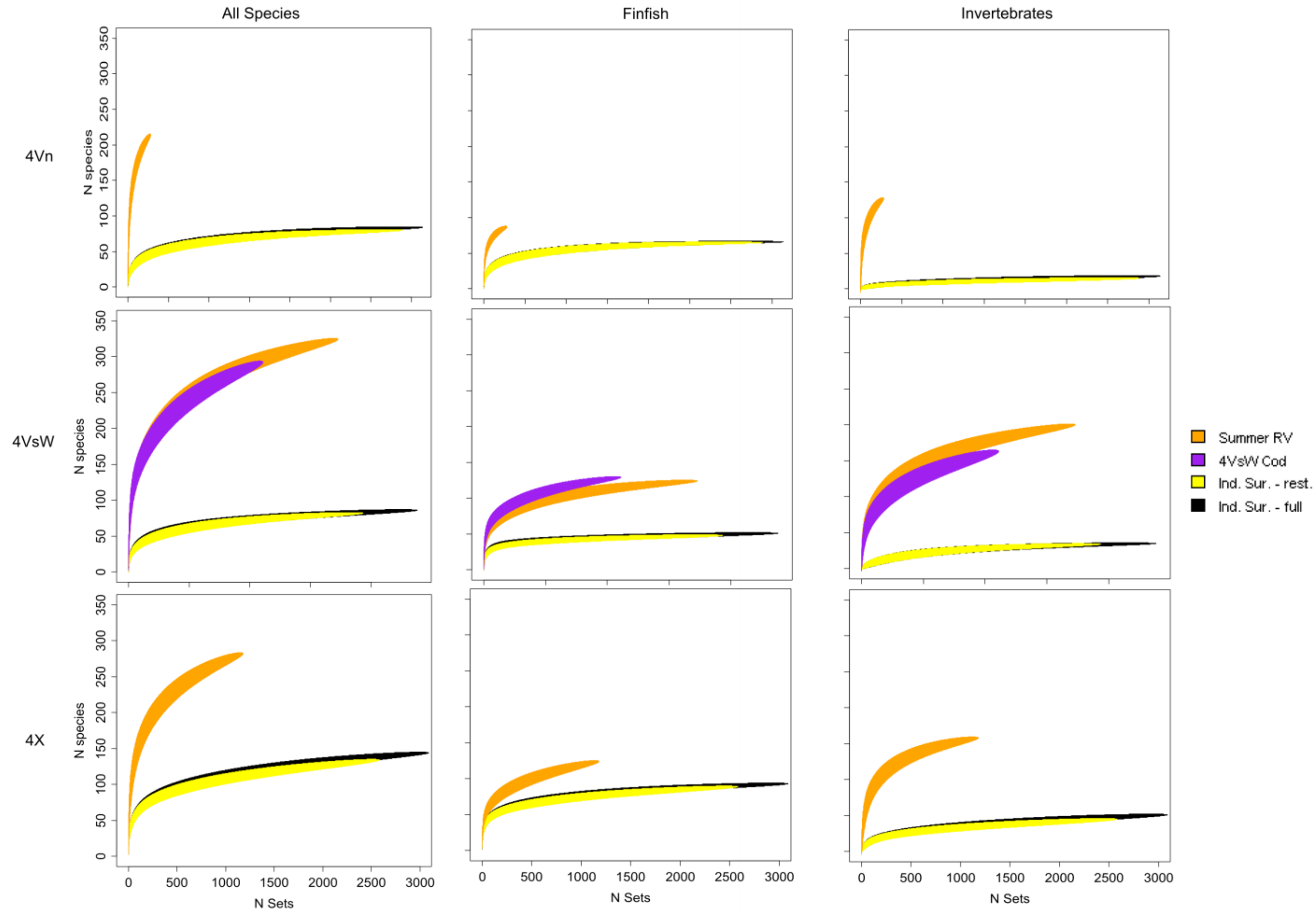

Figure 4. Species accumulative curves by region, species group and survey. Throughout all panels the orange and purple polygons represent the Summer RV and March 4VsW RV survey respectively. The yellow and black polygons represent the area specific industry surveys with black representing the full geographic area of the survey and the yellow being the overlapping area for the Summer RV and industry surveys. Data was limited to that from 1996 to the end of the time series or 2012, whichever came first.

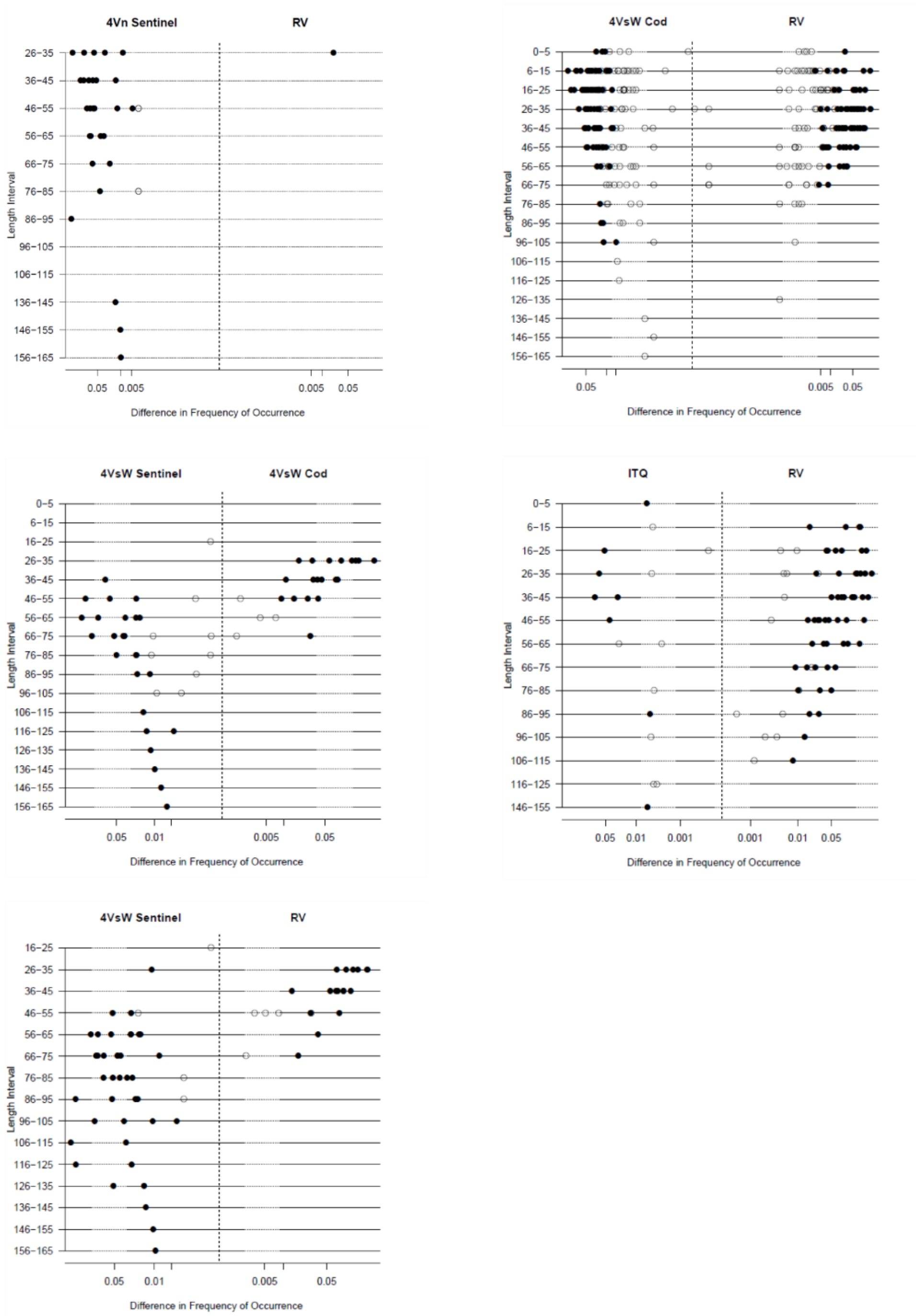

Figure 5. Difference in frequency of occurrence between regional surveys for individual finfish species broken down by length intervals (cm). Only species and length groups captured by both surveys were compared. Points represent the difference in frequency of occurrence with those the left or right of the dashed vertical line represent length intervals of species which occur in greater frequency in the above labelled survey. Filled circles represent statistically significant differences ($p < 0.05$, t-test).

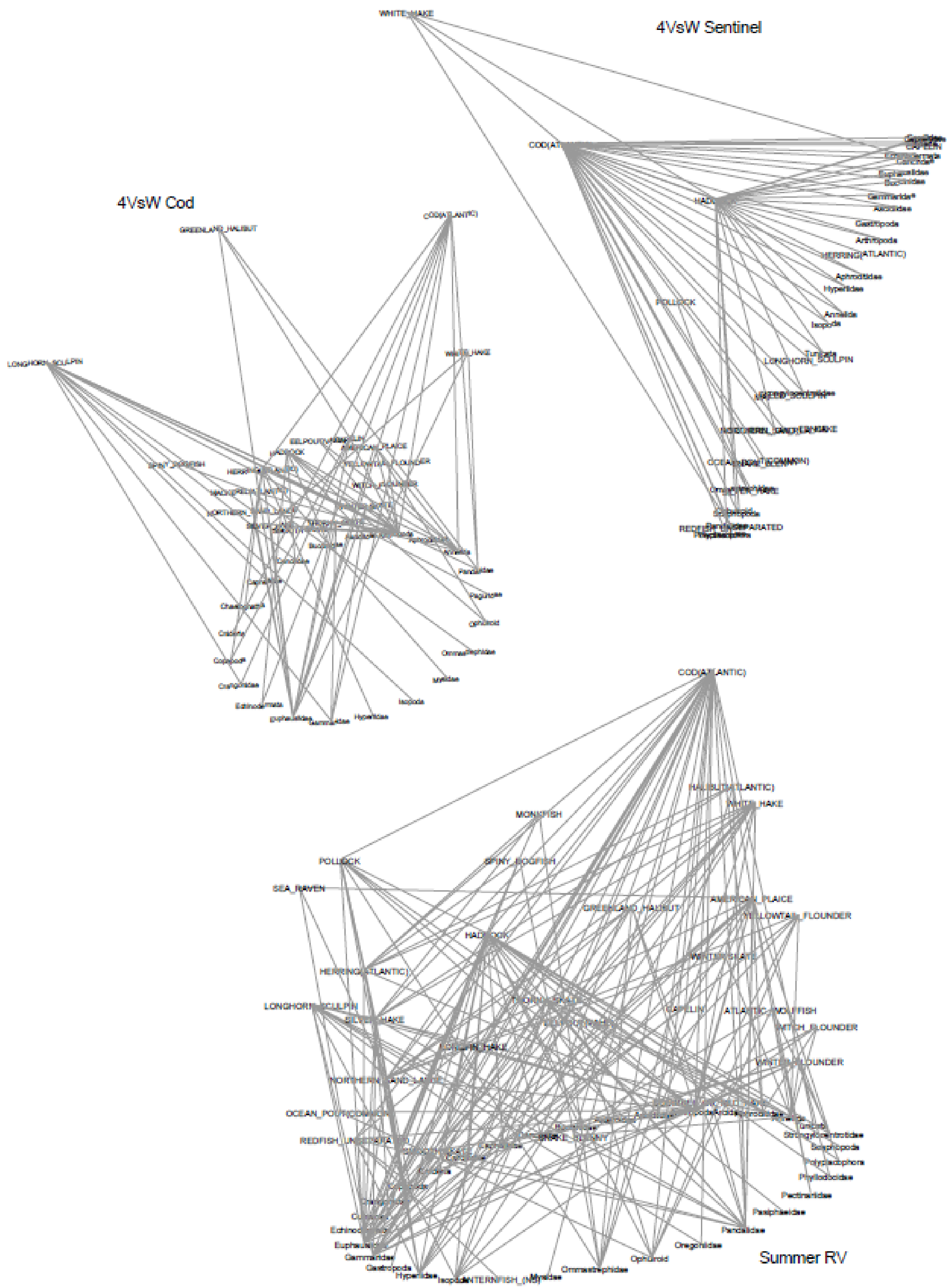

Figure 6. Trophic horrendograms - connections between species as obtained from gut contents analysis of finfish collected during the Summer RV, the March 4VsW RV and the 4VsW Sentinel Survey.

APPENDIX

OVERVIEW OF CURRENT PROTOCOLS FOR MARITIMES REGION RESEARCH VESSEL AND INDUSTRY/SCIENCE SURVEYS

DFO Summer RV Survey

The DFO Summer RV Survey has been conducted annually on the Scotian Shelf (4VWX5Yb) since 1970 using a stratified random design based on depth and geographic area (Figure A1). The survey originally covered depths down to 366 m, as shallow as 27 m in the Bay of Fundy and off Cape Breton, and to a depth of 92 m along the rest of the Nova Scotia coast. In 1995, coverage was expanded into three deepwater strata (365-732 m) on the edge of the continental shelf. From 1970 to 1981, the survey was conducted by the *A.T. Cameron* using a Yankee 36 trawl. In 1982, the *A.T. Cameron* was replaced for one year by the *Lady Hammond* using the Western IIA as the new standard trawl. Since 1983, the Alfred Needler has conducted the survey using the Western IIA trawl, except in 2004, 2007 and 2008. In 2004, the *Alfred Needler* was replaced by the *Teleost* due to a fire on the *Alfred Needler*. The 2005 survey was conducted by both the *Teleost* and the Alfred *Needler* to investigate differences in catchability between the two vessels. In 2007, the survey was again conducted on the *Teleost* while the *Needler* was in refit and in 2008, the sister ship of the *Alfred Needler*, the *Wilfred Templeman*, conducted the survey.

The 42 survey strata are grouped into three major depth categories < 92 m, 92-181 m and > 181 m. Deep-water strata, between 365-732 m, were added south of the shelf break from Brown's Bank to Banquereau Bank in 1995. The shallowest strata (<92 m) are found on the outer banks as well as in the inner Bay of Fundy, off St. Mary's Bay and east of Cape Breton Island. These near shore strata range in depth as shallow as 27 m, while elsewhere on the Nova Scotian coast, the survey only fishes as shallow as 92 m.

Fish Sampling

All fish caught are identified to the species level when possible. If this is not possible at sea, they are preserved and returned to the Biological Station for positive identification.

Total numbers and weight caught and length frequencies (by sex if required) for all fish species are collected from all successful sets according to instructions in the Groundfish Bottom Trawl Surveys Manual (2007). Whenever possible, the total catch is processed. Large catches are sub-sampled when necessary, following established protocols.

Length stratified samples are taken for all fish species from each set with 1 per 1 cm stratification for most species. Detailed observations taken from stratified samples include:

- Total length, sex, weight and otoliths for Cod, Haddock, Pollock, Cusk, Halibut, White Hake and Silver Hake
- Maturities for Silver Hake
- Observations by sex (one per one cm per sex) for Silver Hake, redfish, all flatfish, all skates and Spiny Dogfish
- Fork length for Herring and Mackerel with weight recorded for two fish per one cm length group

- Stomach sampling from a subset of individuals from selected fish species captured during each survey set stratified by body length

Invertebrate Sampling

All invertebrates caught are identified to as specific a taxonomic level as possible and are sampled (for length, weight and sex) according to the Groundfish Bottom Trawl Surveys Manual (2007). Large catches of shrimp (greater than 2 kg) are subsampled to ascertain species composition and total numbers and weights.

Hydrographic Sampling

At selected stations profiles of temperature, salinity, oxygen, fluorescence and irradiance (PAR extinction) are obtained with a SBE-25 CTD on a rosette. Niskin bottles attached to the CTD-Rosette collect water samples from the bottom, intermediate depths, and from near surface. VEMCO depth/temperature MINILOGGERS are attached to the trawl during each set to monitor the temperature of the water strained by the nets.

In addition to the sampling described above, one vertical zooplankton net tow from bottom to surface (200 microns with flow meter if possible) is conducted for the Atlantic Zonal Monitoring Program (AZMP) at various stations across the Scotian Shelf, in close proximity to standard hydrographic transect lines. These samples are preserved for analysis at a later date.

To illustrate the extent of sampling from the summer survey program, there were 107 fish taxa and 132 invertebrate taxa recorded during the 2011 summer survey (from a total of 245 sets), with total catch in numbers and weight recorded for each (Table A1). As well, individual lengths and weights were recorded for all fish species and 11 of the invertebrate species captured.   A broader sampling strategy implemented in 2007 has increased the requirement of survey personnel to identify all of invertebrate species.

DFO March 4VsW RV Survey

The March 4VsW RV Survey has been conducted since 1986 on the eastern half of the Scotian Shelf (Figure A2). This survey does not include all of 4VW and uses a stratification scheme different from the summer survey that was meant to optimize the abundance estimates for 4VsW Cod. No surveys were conducted in 1998 or 2004 or 2011 and the 2009 survey was incomplete. The *Alfred Needler* has conducted the survey using the Western IIA trawl in all years except 2007 and 2008. The *Wilfred Templeman,* using the same gear, conducted the 2007 survey and in 2008, the *Teleost* was the survey vessel. Deep-water strata 397-400 (365-549 m) in the Laurentian Channel were added to this survey in 1993. Although these strata have not been used in the analytical assessments in 4VW, they have been used in a number of developing fisheries and COSEWIC assessments. Coverage of eastern strata was restricted in some years due to ice cover. Protocols for sampling fish, invertebrates and for hydrographic sampling are essentially identical to the DFO summer RV survey.

The most recent March 4VsW RV Survey was completed in 2010 (n = 82 sets). There were 70 individual fish taxa and 86 invertebrate taxa recorded during this survey with total catch in numbers and weight recorded for each (Tables A2). Individual lengths and weights were recorded for all fish species and 11 of the invertebrate species captured.

MARITIMES REGION INDUSTRY/SCIENCE SURVEYS

The Maritimes Region Industry/Science surveys are conducted on small vessels (< 20 m in length) with restricted capacity for carrying staff dedicated to data collection. When they began, the primary objective of these surveys was to collect data on commercial species which were of concern to the fishing industry and to provide indices of abundance which could be used in stock assessment (O'Boyle *et al.* 1995). While collections of additional specimens have taken place as requested on an *ad hoc* basis, the number of species for which detailed data are regularly collected has been limited.

4Vn Sentinel Survey

Fixed gear fishermen operating in NAFO Div. 4Vn felt that the DFO research vessel surveys did not reflect their observations on the status of the groundfish resources in this region. The 1993 moratoria on fishing activity in 4Vn meant a loss of catch data from the commercial fishery, so the 4Vn Sentinel Survey was initiated as a means of collecting data using commercial fixed gear longline for comparison with the DFO surveys. The 4Vn Sentinel Survey is a stratified random longline survey that samples an area bounded by the summer RV strata 440-442 as well as the coastal area inshore of these strata (Figure A3). The survey covers an area approximately 13,750 km^2 composing all of Div. 4Vn within the 100 fathom contour with the omission of about 650 sq. miles in the southeast corner of the subdivision (O'Boyle et al. 1995). The survey has been conducted in September and October since September 1994 with approximately 56 sets completed annually. Since 1994 there have also been a number of other more restricted surveys in the area conducted by the same participants using a variety of survey designs. The 4Vn survey is managed and conducted by the 4Vn Sentinel Fishery Association (4Vn SFA) using four fully equipped longline vessels with crews experienced in commercial groundfish fishing in 4Vn. The 4Vn SFA provides space for an onboard observer on each vessel and supplies technicians to conduct detailed sampling of cod onshore. All landings are tracked by dockside monitors.

The at-sea observer records all information on the sets with the assistance of the boat captain. Boat crews are required to assist the observer with sampling when possible. At each station, the total number and weight of each species captured is recorded and a sample of 200 cod is retained for individual length and weight measurements. In addition, a subsample of 50 cod (the first 50 fish over the rail) is set aside for detailed sampling. Sea surface temperatures are recorded at each station and a temperature recorder is attached to one string of gear before setting and retrieving at the end of the set.

Standardized gear and effort specifications are as follows:

- One set is 5 tubs of gear (450-500 #12 circle hooks)
- Gangions are 18 inches long and are made of 150-200 lb. test braided nylon set 6 ft. apart along the groundline
- Bait used is Mackerel
- Soak time is 3-6 hours

Detailed sampling onshore includes measurements of length and weight, sex and maturity determination, liver, stomach and gonad weights and extraction of otoliths for ageing. Stomach fullness is recorded and stomach contents identified as often as is practical. The most recent 4Vn Sentinel Survey was completed in 2011 (n = 56 sets). There were 23 individual fish codes and 2 invertebrate codes recorded during the 2011 4Vn Sentinel survey, with total catch in numbers and weight recorded for each (Table A3). Individual lengths and weights were recorded for only two groundfish species: Atlantic Cod and Greenland Cod.

4VsW Sentinel Survey

Fixed gear fishermen operating in NAFO Div. 4VW felt that the DFO research vessel surveys did not reflect their observations on the status of the groundfish resources in this region. The 1993 moratoria on fishing activity in 4VW meant a loss of catch data from the commercial fishery, so the 4VW Sentinel Program was initiated as a means of collecting data using the commercial fixed gear longline fleet for comparison with the DFO surveys. The 4VsW Sentinel Survey was developed as a stratified random longline survey conducted by industry participants. The series began in the fall 1995 and included all areas surveyed by the Summer RV survey in Div. 4VsW as well as three additional inshore strata.

The protocols for the 4VsW Sentinel Program were established by DFO in partnership with the Fishermen and Scientists Research Society (FSRS), and were intended to provide unbiased estimators of fish abundance and catch rates. The objective of the 4VsW Sentinel program was to establish a long-term series of catch rate and abundance indices, which would reflect the overall abundance of groundfish resources in the area and could therefore be useful in assessments and management of the resource. Additional objectives were to collect and process biological samples from fish populations in 4VsW for the purposes of examining fish stock structure, fish diet, growth, health and reproductive activity, as well as improve the relationship and understanding between scientists and fishermen.

The FSRS is responsible for the management of the program, while the scientific authority remains with DFO. The 4VsW Sentinel Program initially consisted of two phases, a Sentinel Survey phase using a stratified random design to select station locations and a Commercial Index phase. The Sentinel survey phase consisted of 252 sets that were selected by DFO using the summer RV strata (443-466) in Div. 4VsW, as well as three new inshore strata (467-469) from Halifax to Cape Breton (Figure A4). In 2004, the survey was reduced in area to the three offshore strata that were encompassed by the Haddock Closed area in Div. 4W (463, 464, 465), strata 462 that was landward of this area and the two inshore strata (468, 469) from Halifax to Canso. The total number of sets sampled annually since 2004 has been reduced to 53.

The commercial index phase began in 1996 with 246 sets occupied throughout the survey area. In 1997 and 1998, the number of sets occupied declined to 201 and 61 respectively and has numbered fewer than 30 from 1999-2003. The commercial index was suspended in 2004.

Survey Protocols

- The FSRS contracts up to three commercial longliners; the survey begins in September
- Fishing occurs at pre-selected stratified random stations fished with 1500 #12 circle hooks baited with frozen mackerel and set within a specified six hour period. The gear consists of 7/32 to 1/4 easyhaul or nylon mainline (non-leaded gear) with 18 to 20 inch snoods spaced at 6 ft. intervals
- The gear is required to soak for a minimum of 2 hours
- Vessels are supplied with VEMCO minilog temperature recorders that are placed on the first anchor of each set of gear
- Two CTD (Conductivity, Temperature, and Depth) profilers are deployed from participating vessels according to a protocol established by DFO and the FSRS

- Vessels must hail out and hail in prior to landing to the hail service designated by the FSRS, and provide information on landing time and location, amount and species caught, and stations completed
- All vessels fish under a Sentinel Program Condition of License issued by DFO. Once a vessel begins the Sentinel Survey Phase, it will be required to complete this phase before resuming activity under any other condition of license
- All vessels are accompanied by an observer/FSRS Technician for the first trip and on additional trips if required
- All vessels must follow the regulations regarding the restrictions on the 3 species of Wolffish (catfish) as well as not keeping Atlantic Halibut catches

Sampling Requirements At-sea

At each station, all fish species are counted individually and total weights are recorded. Length frequencies are conducted on 3 species per station with the first priority species being Cod, Haddock, Pollock, Monkfish and Halibut. Second priority species are White Hake and Cusk, while the third priority species are Spiny Dogfish, Thorny and Winter Skate and American Plaice. Other species, such as Barndoor Skate, are measured as part of a special sampling request.

Each set requires detailed sampling of one fish species according to predetermined requirements. These requirements include individual weights, sex determination, maturity staging, otolith and stomach removal. All Halibut are weighed individually and released. Barndoor Skates that are alive are released; if dead, they are measured and discarded. A technician at dockside downloads temperature data from the VEMCO minilog temperature recorders and the CTD profilers.

The most recent 4VsW Sentinel Survey was completed in 2011(n = 53 sets). There were 22 individual fish taxa and 3 invertebrate taxa recorded during this survey, with total catch in numbers and weight recorded for each (Table A4). Individual lengths and weights were recorded for Atlantic Cod, Haddock, White Hake and Atlantic Halibut.

Individual Transferable Quota (ITQ) Fixed Station Industry Survey

The ITQ Fixed Station Industry Survey in Div. 4X began in the summer of 1995 as a collaborative effort between fishing industry participants from southwest Nova Scotia and DFO Science staff from BIO. The primary objectives of the survey were to:

- Provide annual indices of abundance (pre-recruit and adult) and information on the distribution of cod, haddock and winter flounder in Div. 4X
- Collect of basic biological information on these species

The survey takes place during the first two weeks of July and therefore overlaps with the first leg of the DFO Summer RV Survey. It is conducted by three otter trawlers (< 20 m in length) which use a balloon trawl with rock hopper footgear. The rock hopper is a small diameter footgear which, unlike the gear used in the RV survey, does not leave space under the net for fish to escape. This gear design gives a higher catchability for species which are closely associated with the bottom. The area sampled is similar to the RV survey in 4X, however, this survey includes some additional area (blocks) inshore of the 92 m line and excludes some deep areas and parts of the inner Bay of Fundy (Figure A5). In the Bay of Fundy, all blocks extend to the shore, whereas in the DFO Summer RV Survey the minimum depth is 36 m. Although these blocks extend to the shore throughout Div. 4X, the positions where industry generally chose the fixed stations within each block is uneven. In the Bay of Fundy, all stations are clustered in the central portion of the Bay, with no stations further up the bay than Isle Haute. In the remainder of Div. 4X, they are either centred in the block or more towards the 92 m line. Between Shelburne and the LaHave Islands, five of the blocks have never been fished. Inshore coverage is excellent from Cape Sable Island to St. Mary's Bay.

The selection of the three vessels and captains to conduct the survey is done by the ITQ Committee and is based on factors such as general fishery knowledge, ability to conduct the survey, and willingness to cooperate in the project for the long-term. Survey vessels are selected to be as similar in fishing power as possible and each carries one trained sampler (former certified observer) and a crewmember to assist in processing the catch and recording data.

The survey uses a fixed-station design with the station locations selected by the vessel captain. This approach allows the skipper to place sets in spots that can be fished in the midst of an area where the bottom is generally too rough too fish. Captains are encouraged to select the set location before sailing and are discouraged from searching for fish prior to setting. Where possible, vessels are to use the same tow locations each year. If a vessel cannot complete the assigned tows due to gear conflict, they can move the set location up to 2 nm from the assigned location.

The survey area was initially divided into 260 grid blocks of similar size, 174 of which have been fished consistently since 1998 (Figure A5). Several stations were added in 1998, and a few have been dropped over time. Generally, only one station is fished in each block, although there are 5 blocks which have more than one station. Fishing is done only during daylight hours with the net towed for one nautical mile. The protocol is to complete the tow in 20 minutes, towing at 3 knots, but tows can take more than twice this long when against the tide. Two of the vessels have been replaced during the time series but it is assumed this has had no impact on catch.

The standard gear includes:

- A 280 Balloon trawl rigged with 14 inch "cookie" footgear, and no ground warps
- 120 foot bridles
- A codend liner similar in size to that used in the Western IIA trawl

At sea sampling

The total number and total weight of each species caught is recorded at each station. Initially, length frequencies were collected for only the primary species: Cod, Haddock, Pollock and Winter Flounder. In later years, redfish and Halibut were added as target species. Detailed sampling was not required as this data is available from the summer bottom trawl survey. Bottom temperature data is recorded during the tow. Scanmar sensor measurements of trawl headline height and wing spread are also obtained for each vessel.

For the most recent ITQ survey completed in 2011(n = 181 sets), there were 44 individual fish taxa and 17 invertebrate taxa recorded during this survey, with total catch in numbers and weight recorded for each (Table A5). Individual lengths and weights were recorded for 7 fish species (Atlantic Cod, Haddock, Silver Hake, Pollock, redfish (Sebastes sp.), Atlantic Halibut and Winter Flounder) and one invertebrate species (American Lobster). The ITQ survey captures and samples a broader range of fish and invertebrates compared to the two sentinel surveys, but still considerably less than the two DFO RV surveys.

REFERENCES

O'Boyle, R., Beanlands, D., Fanning, P., Hunt, J., Hurley, P., Lambert, T., Simon, J., and Zwanenburg, K. 1995. An overview of joint science/industry surveys on the Scotian Shelf, Bay of Fundy and Georges Bank. CSAS Res. Doc. 95/133. 34p.

FIGURES

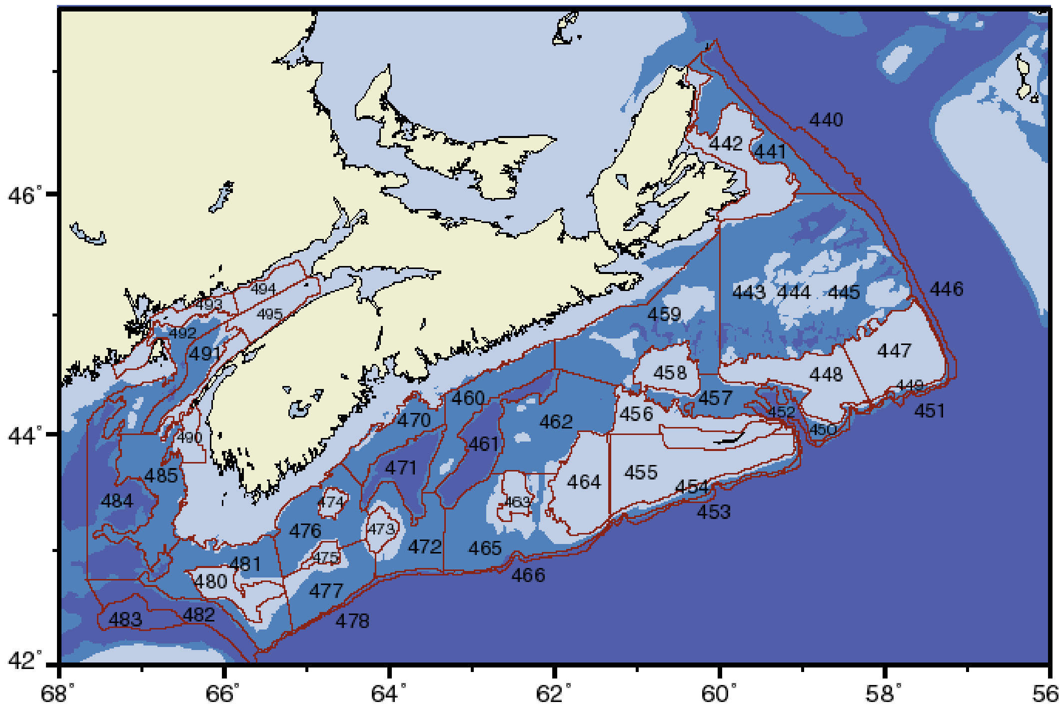

Figure A1. DFO Scotian Shelf/Bay of Fundy (4VWX5Yb) Summer RV survey strata and area of coverage.

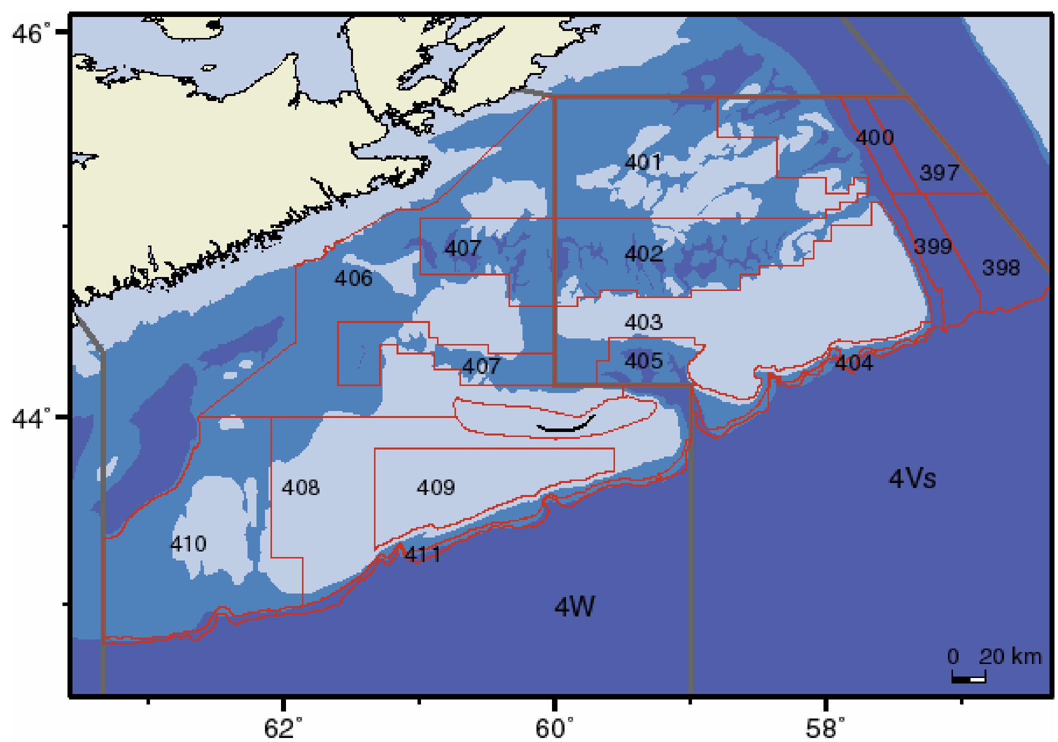

Figure A2. DFO Eastern Scotian Shelf (4VsW) March 4VsW RV survey strata and area of coverage.

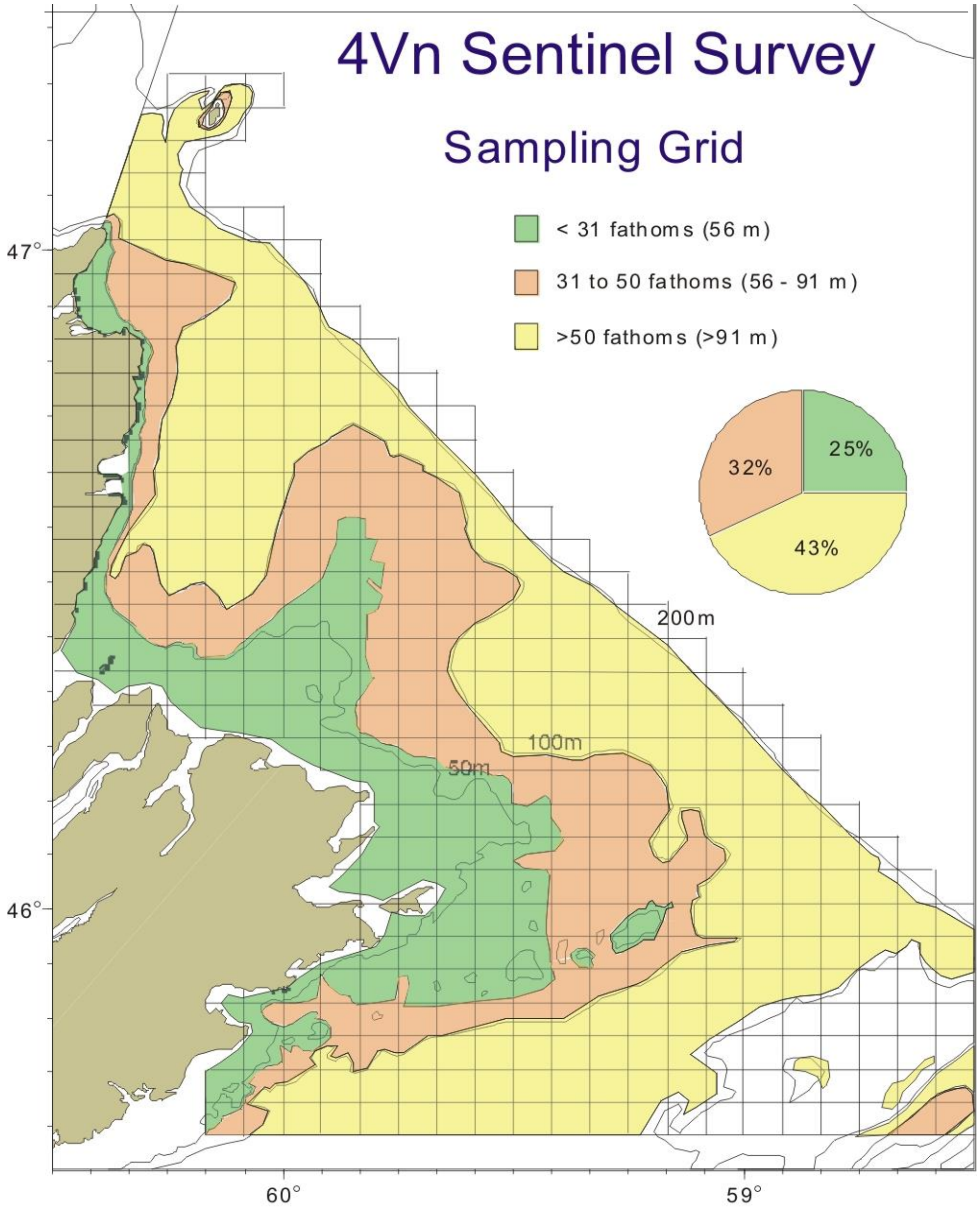

Figure A3. 4Vn Sentinel Industry Survey strata located off eastern Nova Scotia (Sydney Bight area).

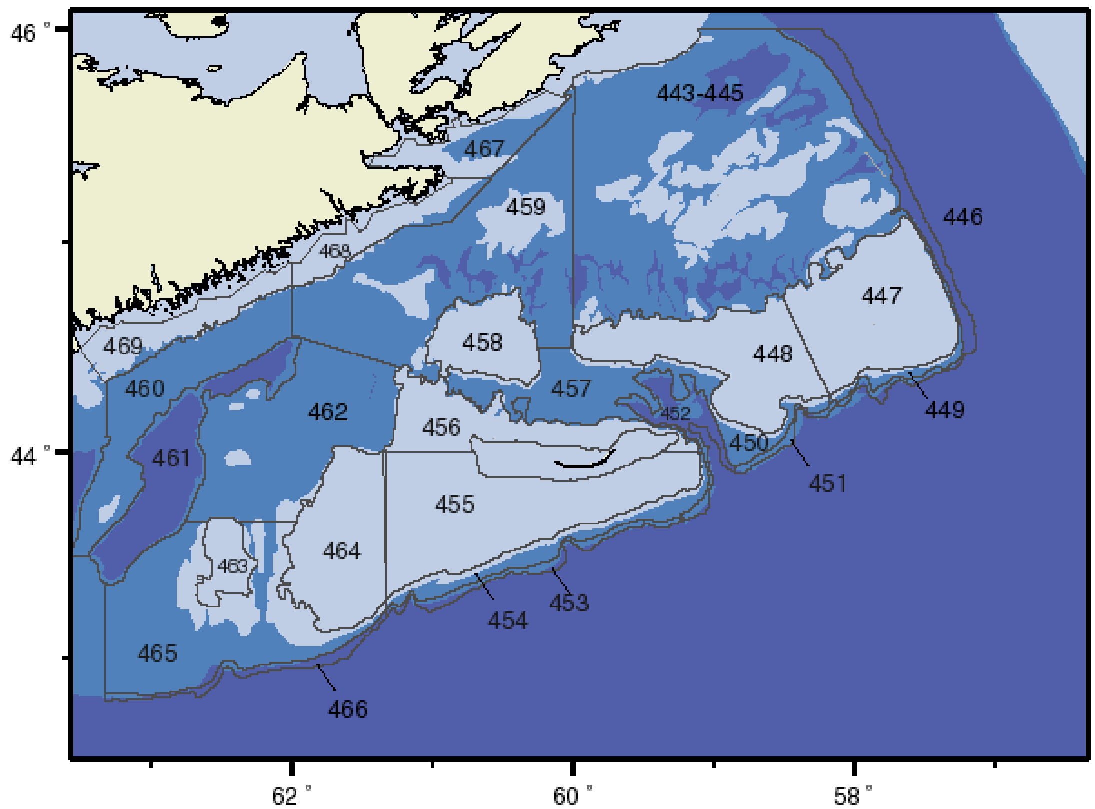

Figure A4. 4VsW Sentinel Industry Survey strata located on the eastern Scotian Shelf. Note the 3 inshore strata (467-469). The survey was reduced in area in 2005 to 4 offshore strata (462-465) and 2 inshore strata (468,469).

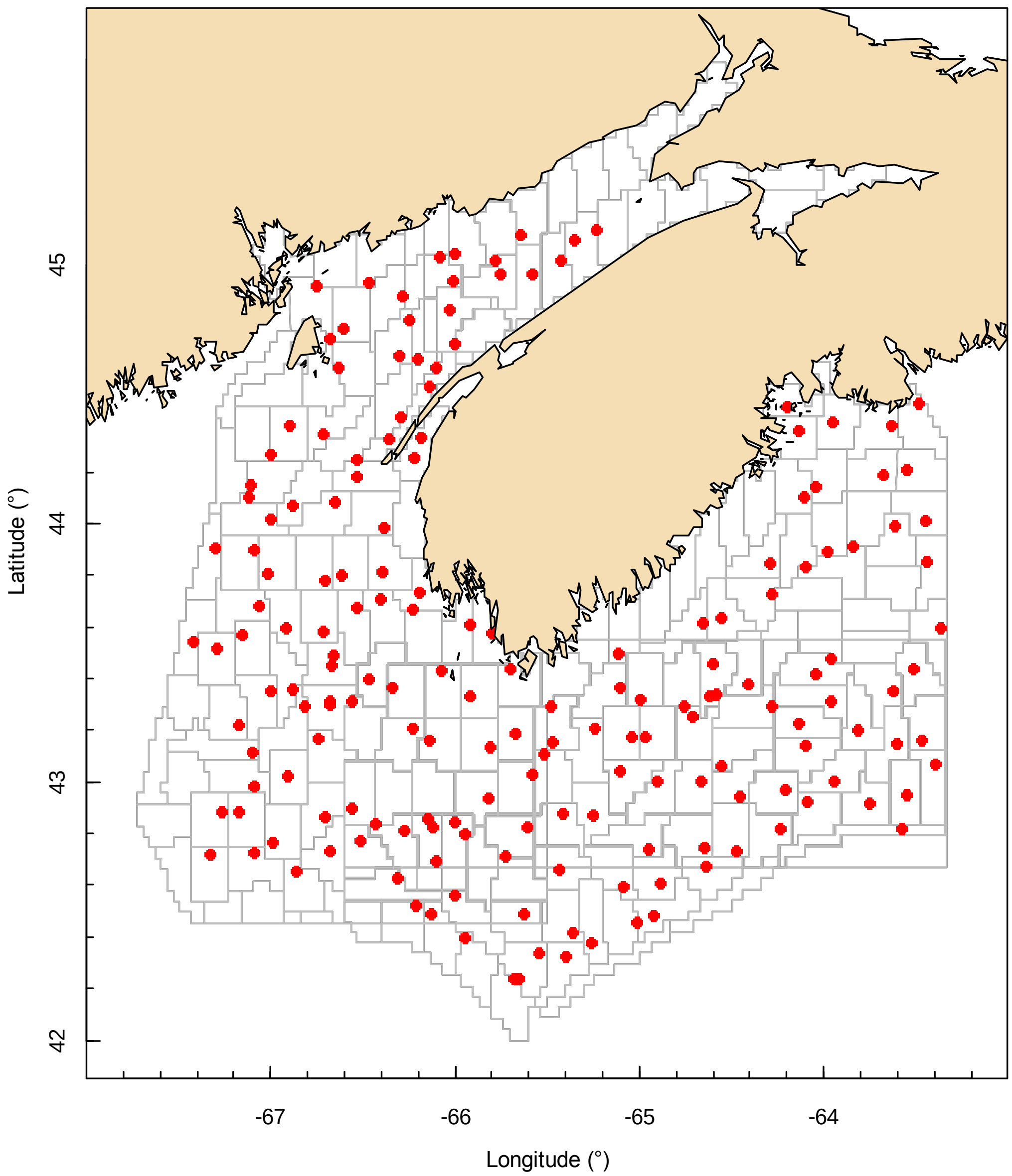

Figure A5. Location of grid blocks used for the 4X ITQ Fixed Station Industry Survey as well as the set locations that have been consistently sampled every year within blocks.

TABLES

Table A1. Summary of fish and invertebrate catches (total weight (kg) and total number) and sampling (individual lengths and individual weights) by species from the 2011 Scotian Shelf Summer RV survey. In 2011 a total of 245 sets were completed.

Species Code	Common Name	Scientific Name	Total Number	Total Weight (kg)	Numbers per Species Sampled	
					Individual lengths	Individual weights
10	Atlantic Cod	*Gadus morhua*	3,200	2,110	1,534	672
11	Haddock	*Melanogrammus aeglefinus*	12,457	4,708	9,358	1,902
12	White Hake	*Urophycis tenuis*	892	638	892	596
13	Red Hake	*Urophycis chuss*	575	84	575	360
14	Silver Hake	*Merluccius bilinearis*	26,657	2,814	11,594	2,144
15	Cusk	*Brosme brosme*	6	10	6	6
16	Pollock	*Pollachius virens*	4,681	6,220	1,547	408
17	Atlantic Tomcod	*Microgadus tomcod*	130	4	130	33
19	Off-Shore Hake	*Merluccius albidus*	4	7	4	4
23	Redfish Unseparated	*Sebastes sp.*	59,406	13,127	12,617	2,085
25	Tile Fish	*Lopholatilus chamaeleonticeps*	1	13	1	1
30	Atlantic Halibut	*Hippoglossus hippoglossus*	237	501	237	224
31	Turbot	*Reinhardtius hippoglossoides*	523	298	523	323
40	American Plaice	*Hippoglossoides platessoides*	3,600	639	3,600	1,593
41	Witch Flounder	*Glyptocephalus cynoglossus*	1,923	350	1,775	814
42	Yellowtail Flounder	*Limanda ferruginea*	6,231	842	4,492	1,217
43	Winter Flounder	*Pseudopleuronectes americanus*	1,284	348	1,284	559
44	Gulf Stream Flounder	*Citharichthys arctifrons*	10	0	10	8
50	Striped Atlantic Wolffish	*Anarhichas lupus*	123	68	123	97
60	Atlantic Herring	*Clupea harengus*	24,636	2,934	7,286	1,504
61	Shad American	*Alosa sapidissima*	58	28	58	49
62	Alewife	*Alosa pseudoharengus*	459	47	459	143

Table A1 (continued).

Species Code	Common Name	Scientific Name	Total Number	Total Weight (kg)	Numbers per Species Sampled Individual lengths	Individual weights
63	Rainbow Smelt	*Osmerus mordax*	1	0	1	1
64	Capelin	*Mallotus villosus*	1,136	18	477	37
65	Atlantic Salmon	*Salmo salar*	1	2	1	1
70	Atlantic Mackerel	*Scomber scombrus*	901	74	380	58
112	Longfin Hake	*Urophycis chesteri*	335	27	335	150
114	Fourbeard Rockling	*Enchelyopus cimbrius*	144	4	144	94
115	Threebeard Rockling	*Gaidropsarus ensis*	2	0	2	2
122	Cunner	*Tautogolabrus adspersus*	15	6	15	7
123	Black Belly Rosefish	*Helicolenus dactylopterus*	381	41	381	140
141	Summer Flounder	*Paralichthys dentatus*	15	7	15	11
142	Fourspot Flounder	*Hippoglossina oblonga*	15	9	15	11
143	Brill/Windowpane	*Scophthalmus aquosus*	9	2	9	8
149	Longnose Greeneye	*Parasudis truculenta*	3	0	3	2
150	Lanternfish (Ns)	*Myctophidae*	1,050	1	219	27
156	Short-Nose Greeneye	*Chlorophthalmus agassizi*	22	0	22	7
157	Glacier Lanternfish	*Benthosema glaciale*	180	0	-	-
158	Muller's Pearlsides	*Maurolicus muelleri*	29	0	29	8
159	Boa Dragonfish	*Stomias boa*	49	1	49	29
160	Atlantic Argentine	*Argentina silus*	100	36	100	44
169	Viperfish	*Chauliodus sloani*	1	0	1	1
193	Hake (Ns)	*Urophycis sp.*	1	0	1	1
200	Barndoor Skate	*Dipturus laevis*	14	62	14	14

Table A1 (continued).

Species Code	Common Name	Scientific Name	Total Number	Total Weight (kg)	Numbers per Species Sampled: Individual lengths	Numbers per Species Sampled: Individual weights
201	Thorny Skate	*Amblyraja radiate*	537	352	537	359
202	Smooth Skate	*Malacoraja senta*	99	30	99	84
203	Little Skate	*Leucoraja erinacea*	140	69	140	121
204	Winter Skate	*Leucoraja ocellata*	278	96	278	224
207	Round Skate	*Rajella fyllae*	1	0	1	1
220	Spiny Dogfish	*Squalus acanthias*	658	1,056	565	184
221	Black Dogfish	*Centroscyllium fabricii*	88	30	88	27
240	Sea Lamprey	*Petromyzon marinus*	1	1	1	1
241	Northern Hagfish	*Myxine glutinosa*	86	5	86	79
272	Sturgeon	*Acipenseridae f.*	5	2	5	0
300	Longhorn Sculpin	*Myoxocephalus octodecemspinosus*	1,899	294	1,460	512
301	Shorthorn Sculpin	*Myoxocephalus scorpius*	8	1	8	7
302	Arctic Staghorn Sculpin	*Gymnocanthus tricuspis*	3	0	3	3
303	Grubby or Little Sculpin	*Myoxocephalus aenaeus*	79	0	79	16
304	Mailed Sculpin	*Triglops murrayi*	258	3	258	110
314	Spatulate Sculpin	*Icelus spatula*	1	0	1	1
320	Sea Raven	*Hemitripterus americanus*	535	308	535	410
323	Hookear Sculpin (Ns)	*Artediellus sp.*	15	0	15	3
340	Alligatorfish	*Aspidophoroides monopterygius*	302	1	283	129
350	Atlantic Sea Poacher	*Leptagonus decagonus*	22	0	22	19
376	Polyipnus Sp.	*Polyipnus sp.*	1	0	1	1
400	Monkfish, Goosefish, Angler	*Lophius americanus*	67	94	67	65

Table A1 (continued).

Species Code	Common Name	Scientific Name	Total Number	Total Weight (kg)	Numbers per Species Sampled	
					Individual lengths	Individual weights
410	Marlin-Spike Grenadier	*Nezumia bairdii*	58	2	58	49
411	Roughhead Grenadier	*Macrourus berglax*	3	3	3	3
414	Roundnose Grenadier	*Coryphaenoides rupestris*	2	1	2	2
455	Cutthroat Eel (Ns)	*Synaphobranchidae f.*	26	1	26	16
501	Lumpfish	*Cyclopterus lumpus*	6	2	6	6
502	Atlantic Spiny Lumpsucker	*Eumicrotremus spinosus*	25	0	25	13
503	Atlantic Seasnail	*Liparis atlanticus*	2	0	2	2
505	Gelatinous Seasnail	*Liparis fabricii*	1	0	1	1
512	Dusky Seasnail	*Liparis gibbus*	2	0	2	2
595	Red Dory	*Cyttopsis rosea*	1	0	1	1
602	Gray's Cutthroat Eel	*Synaphobranchus kaupi*	3	0	3	3
603	Wolf Eelpout	*Lycenchelys verrili*	3	0	3	3
604	Snipe Eel	*Nemichthys scolopaceus*	12	0	12	12
610	Northern Sand Lance	*Ammodytes dubius*	18,304	298	2,261	338
611	Sand Lance (Ns)	*Ammodytes sp.*	1	0	1	1
616	Fish Doctor	*Gymnelis viridis*	1	0	1	1
620	Laval's Eelpout	*Lycodes lavalaei*	11	2	11	10
621	Rock Gunnel Eel	*Pholis gunnellus*	4	0	4	3
622	Snake Blenny	*Lumpenus lumpretaeformis*	227	5	227	128
623	Daubed Shanny	*Lumpenus maculatus*	551	3	551	78
625	Radiated Shanny	*Ulvaria subbifurcata*	29	1	29	27
630	Wrymouth	*Cryptacanthodes maculatus*	12	4	12	12

Table A1 (continued).

Species Code	Common Name	Scientific Name	Total Number	Total Weight (kg)	Numbers per Species Sampled Individual lengths	Individual weights
637	Spotfin Dragonet	*Foetorepus agassizi*	1	0	1	1
640	Common Ocean Pout	*Macrozoarces americanus*	177	43	177	155
646	Atlantic Soft Pout	*Melanostigma atlanticum*	2	0	2	2
647	Vahl Shorttailed Eelpout	*Lycodes vahlii*	434	26	434	122
694	Batfish Sp.	*Ogcocephalidae f.*	1	0	1	1
700	Atlantic Silver Hatchfish	*Argyropelecus aculeatus*	2	0	2	1
701	Butterfish	*Peprilus triacanthus*	69	5	69	47
704	American John Dory	*Zenopsis ocellata*	2	0	2	2
712	White Barracudina	*Notolepis rissoi*	53	1	53	39
714	Simonyi's Frostfish	*Benthodesmus simonyi*	2	0	2	2
720	Atlantic Saury, Needlefish	*Scomberesox saurus*	2	0	2	2
741	Hatchetfish	*Sternoptychidae f.*	1	0	1	1
805	Tonguefish	*Symphurus sp.*	5	0	5	5
816	Tongue Fish	*Symphurus diomedeanus*	5	0	5	4
880	Atlantic Hookear Sculpin	*Artediellus atlanticus*	101	0	101	46
1054	Duckbill Barracudina	*Paralepis atlantica kroyer*	2	0	2	2
1100	Eggs Unidentified	*Unidentified eggs*	1	0	1	1
1224	Skate Unidentified Eggs	*Raja eggs*	104	1	-	-
1279	Tremaster mirabilis	*Tremaster mirabilis*	1	0	-	-
1510	Whelk Eggs (Ns)	*Buccinidae eggs*	18	4	-	-
1810	Tunicata S.P.	*Tunicata sp.*	75	77	-	-
1823	Sea Potatoe	*Boltenia sp.*	130	6	-	-

Table A1 (continued).

Species Code	Common Name	Scientific Name	Total Number	Total Weight (kg)	Numbers per Species Sampled: Individual lengths	Individual weights
1900	Bryozoans P.	*Bryozoans p.*	0	112	-	-
1901	Lemonweed	*Flustra foliacea*	0	224	-	-
1930	Lampshells	*Bryozoans brachiopoda p.*	3	1	-	-
2211	Pandalus Borealis	*Pandalus borealis*	178,238	1,141	-	-
2212	Pandalus Montagui	*Pandalus montagui*	189,573	638	-	-
2213	Was Pandalus Propinquus	*Atlantopandalus propinquus*	11	0	-	-
2221	Pasiphaea Multidentata	*Pasiphaea multidentata*	4,014	12	-	-
2223	Sergestes Arcticus	*Sergestes arcticus*	8,403	6	-	-
2310	Spirontocaris	*Spirontocaris sp.*	71	0	-	-
2312	Lebbeus Polaris	*Lebbeus polaris*	654	1	-	-
2313	Spirontocaris Liljeborgii	*Spirontocaris liljeborgii*	32	0	-	-
2316	Spirontocaris Spinus	*Spirontocaris spinus*	1,681	2	-	-
2319	Lebbeus Groenlandicus	*Lebbeus groenlandicus*	7	0	-	-
2331	Eualus Macilentus	*Eualus macilentus*	1,614	3	-	-
2333	Eualus Gaimardii	*Eualus gaimardii*	1,414	1	-	-
2411	Argis Dentata	*Argis dentate*	5,967	20	-	-
2414	Sclerocrangon Boreas	*Sclerocrangon boreas*	333	1	-	-
2415	Pontophilus Norvegicus	*Pontophilus norvegicus*	54	0	-	-
2416	Crangon Sp.	*Crangon sp.*	37	1	-	-
2417	Crangon Septemspinosa	*Crangon septemspinosa*	258	0	-	-
2419	Sabinea Sarsi	*Sabinea sarsi*	78	0	-	-

Table A1 (continued).

Species Code	Common Name	Scientific Name	Total Number	Total Weight (kg)	Numbers per Species Sampled Individual lengths	Individual weights
2507	Crab	*Crab*	1	0	-	-
2511	Jonah Crab	*Cancer borealis*	129	23	129	2
2513	Atlantic Rock Crab	*Cancer irroratus*	646	61	644	-
2521	Hyas Coarctatus	*Hyas coarctatus*	101	3	79	1
2523	Northern Stone Crab	*Lithodes maja*	69	20	69	1
2526	Queen Snow Crab	*Chionoecetes opilio*	2,951	465	2,951	-
2527	Toad Crab	*Hyas araneus*	1,364	20	540	1
2532	Red Deepsea Crab	*Chaceon quinquedens*	57	13	57	-
2541	Axius Serratus	*Axius serratus*	2	0	-	-
2550	American Lobster	*Homarus americanus*	1,032	933	1,032	2
2556	Munida Valida	*Munida valida*	4	0	-	-
2559	Hermit Crab	*Paguridae f.*	249	6	-	-
2560	Paguroidea S.F.	*Paguroidea s.f.*	56	2	-	-
2600	Krill Shrimp	*Euphausiacea o.*	32,399	9	-	-
2611	Meganyctiphanes Norvegica	*Meganyctiphanes norvegica*	303	0	-	-
2800	Amphipoda O.	*Amphipoda o.*	4	0	-	-
2811	Gammaridae F.	*Gammaridae f.*	49	0	-	-
2864	Amphipod	*Ampelisca macrocephala*	1	0	-	-
2930	Oithona Spinirostris	*Oithona spinirostris*	12	0	-	-
2980	Red Isopod	*Isopoda o.*	16	0	-	-
2990	Barnacles	*Cirripedia s.c.*	66	17	-	-
2999	Isopod	*Calathura branchiata*	1	0	-	-

Table A1 (continued).

Species Code	Common Name	Scientific Name	Total Number	Total Weight (kg)	Numbers per Species Sampled: Individual lengths	Individual weights
3000	Segmented Worms	*Annelida p.*	2	0	-	-
3100	Bristle Worms	*Polychaeta c.*	511	1	-	-
3101	Large Polychaete, 3 mm Dia.	*Polychaeta c., Large*	16	0	-	-
3130	Nereis Sp.	*Nereis sp.*	1	0	-	-
3200	Sea Mouse	*Aphrodita hastate*	41	2	-	-
3212	Aphrodita Sp.	*Aphrodita sp.*	26	2	-	-
3221	Chone Sp.	*Chone sp.*	1	0	-	-
3501	Lepidonotus squamatus	*Lepidonotus squamatus*	6	0	-	-
4200	Snails and Slugs	*Gastropoda o.*	4	0	-	-
4210	Whelks	*Buccinum sp.*	357	26	-	-
4211	Common Edible Wave Whelk	*Buccinum undatum*	44	2	-	-
4212	Silky Buccinum	*Buccinum scalariforme*	1	0	-	-
4221	Northern Moonsnail	*Euspira heros*	16	1	-	-
4227	New England Neptune	*Neptunea decemcostata*	37	2	-	-
4228	Spindle Shell	*Colus sp.*	17	1	-	-
4300	Bivalvia C.	*Bivalvia c.*	2	0	-	-
4304	Ocean Quahaug	*Arctica islandica*	12	0	-	-
4310	Clams (Ns)	*Protobranchia, Heterodonta*	3	0	-	-
4311	Quahaug	*Venus mercenaria (Obsolete)*	4	0	-	-
4312	Bank Clam	*Cyrtodaria siliqua*	7	0	-	-
4318	Soft Shell Clam	*Mya arenaria*	3	0	-	-
4321	Sea Scallop	*Placopecten magellanicus*	660	52	660	0

Table A1 (continued).

Species Code	Common Name	Scientific Name	Total Number	Total Weight (kg)	Numbers per Species Sampled: Individual lengths	Individual weights
4322	Iceland Scallop	*Chlamys islandica*	146	8	141	-
4330	Mussels (Ns)	*Mytilidae f.*	23	19	-	-
4331	Common Mussel	*Mytilus edulis*	7	0	-	-
4332	Horse Mussel	*Modiolus modiolus*	4	1	-	-
4334	Musculus Niger	*Musculus niger*	2	0	-	-
4340	Cockles	*Cardiidae f.*	1	0	-	-
4355	Stimpson's Arctic Surf Clam	*Mactromeris polynyma*	1	0	-	-
4380	Anomia Simplex	*Anomia simplex*	5	0	-	-
4400	Sea Slugs	*Nudibranchia o.*	5	0	-	-
4511	Short-Fin Squid	*Illex illecebrosus*	5,302	446	2,646	592
4521	Octopus	*Octopoda o.*	220	4	-	-
4536	Bobtail Squid	*Sepiolodae f.*	120	1	-	-
4569	Gonatus Sp.	*Gonatus sp.*	1	0	-	-
5100	Sea Spider	*Pycnogonida s.p.*	45	0	-	-
6100	Asteroidea S.C.	*Asteroidea s.c.*	48	0	-	-
6101	Ceremaster Granularis	*Ceremaster granularis*	81	1	-	-
6102	Porania Pulvilis	*Porania pulvilis*	88	4	-	-
6109	Asterias Forbesi	*Asterias forbesi*	103	1	-	-
6110	Asterias Sp.	*Asterias sp.*	51	0	-	-
6111	Asterias rubens	*Asterias rubens*	1,382	115	-	-
6114	Leptasterias Sp.	*Leptasterias sp.*	201	20	-	-
6115	Mud Star	*Ctenodiscus crispatus*	882	5	-	-

Table A1 (continued).

Species Code	Common Name	Scientific Name	Total Number	Total Weight (kg)	Numbers per Species Sampled Individual lengths	Individual weights
6116	Pseudarchaster Sp.	*Pseudarchaster sp.*	2,167	15	-	-
6117	Hippasteria Phrygiana	*Hippasteria phrygiana*	340	31	-	-
6119	Blood Star	*Henricia sanguinolenta*	29	0	-	-
6120	Henrica Sp.	*Henrica sp.*	1,110	3	-	-
6121	Purple Sunstar	*Solaster endeca*	145	16	-	-
6123	Spiny Sunstar	*Crossaster papposus*	595	20	-	-
6125	Pteraster Militaris	*Pteraster militaris*	125	1	-	-
6129	Poraniomorpha Hispida	*Poraniomorpha hispida*	35	0	-	-
6131	Diplopteraster Multipes	*Diplopteraster multipes*	1	0	-	-
6134	Slender Armed Sea Star	*Leptasterias tenera*	7	1	-	-
6200	Brittle Star	*Ophiuroidea s.c.*	8,325	41	-	-
6211	Daisy	*Ophiopholis aculeate*	31	0	-	-
6213	Ophiura Sarsi	*Ophiura sarsi*	31	1	-	-
6300	Basket Star	*Gorgonocephalidae, Asteronychidae*	153	98	-	-
6400	Sea Urchin	*Strongylocentrotus sp.*	78	48	-	-
6411	Green Sea Urchin	*Strongylocentrotus droebachiensis*	3,941	223	-	-
6413	Heart Urchin	*Brisaster fragilis*	741	4	-	-
6500	Sand Dollar	*Clypeasteroida o.*	890	16	-	-
6511	Echinarachnius Parma	*Echinarachnius parma*	207	8	-	-
6600	Sea Cucumber Unidentified	*Holothuroidea c.*	72	14	-	-
6611	Common Sea Cucumber	*Cucumaria frondosa*	18,745	4,330	-	-
7500	Turbellaria C.	*Turbellaria c.*	6	0	-	-

Table A1 (continued).

Species Code	Common Name	Scientific Name	Total Number	Total Weight (kg)	Numbers per Species Sampled: Individual lengths	Individual weights
8100	Comb Jellies	*Ctenophora p.*	51	0	-	-
8300	Sea Anemone	*Anthozoa c.*	1,519	44	-	-
8318	Sea Pen	*Pennatulacea*	4,882	8	-	-
8322	Sea Corn	*Primnoa resedaeformis*	1	0	-	-
8324	Strawberry Sea Cauliflower	*Eunephthya rubiformis*	14	0	-	-
8326	Acanthogorgia Armata	*Acanthogorgia armata*	1	0	-	-
8327	Soft Coral Unidentified	*Soft Coral Unidentified*	26	0	-	-
8328	Anthomastus Grandiflorus	*Anthomastus grandiflorus*	2	0	-	-
8335	Cup Coral	*Flabellum sp.*	2	0	-	-
8338	Chrysogorgia Agassizii	*Chrysogorgia agassizii*	3	0	-	-
8347	Psilaster Andromeda	*Psilaster andromeda*	1,266	6	-	-
8354	Sergia Sp.	*Sergia sp.*	1	0	-	-
8500	Jellyfish	*Scyphozoa c.*	62	102	-	-
8600	Sponge	*Porifera p.*	406	95	-	-
8601	Russian Hats	*Vazella pourtalesi*	5	108	-	-

Table A2. Summary of fish and invertebrate catches (total weight (kg) and total number) and sampling (individual lengths and individual weights) by species from the 2010 March 4VsW RV Survey. In 2010, the last year this survey was conducted, a total of 82 sets were completed

					Numbers per Species Sampled	
Species Code	Common Name	Scientific Name	Total Number	Total Weight (kg)	Individual lengths	Individual weights
10	Atlantic Cod	*Gadus morhua*	561	286	561	241
11	Haddock	*Melanogrammus aeglefinus*	7,665	3,307	3,093	441
12	White Hake	*Urophycis tenuis*	177	69	177	130
13	Red Hake	*Urophycis chuss*	117	19	117	65
14	Silver Hake	*Merluccius bilinearis*	14,604	669	4,008	518
15	Cusk	*Brosme brosme*	1	2	1	1
16	Pollock	*Pollachius virens*	159	109	159	53
19	Off-Shore Hake	*Merluccius albidus*	3	6	3	3
23	Redfish Unseparated	*Sebastes sp.*	17,085	2,695	3,633	539
30	Atlantic Halibut	*Hippoglossus hippoglossus*	46	292	46	46
31	Turbot	*Reinhardtius hippoglossoides*	430	296	430	241
40	American Plaice	*Hippoglossoides platessoides*	1,590	320	1,429	774
41	Witch Flounder	*Glyptocephalus cynoglossus*	1,225	133	1,225	478
42	Yellowtail Flounder	*Limanda ferruginea*	2,571	313	1,705	365
43	Winter Flounder	*Pseudopleuronectes americanus*	41	8	41	27
44	Gulf Stream Flounder	*Citharichthys arctifrons*	1	0	1	1
50	Striped Atlantic Wolffish	*Anarhichas lupus*	8	1	8	8
60	Atlantic Herring	Clupea harengus	3,179	304	1,589	314
61	Shad American	*Alosa sapidissima*	4	3	4	4
62	Alewife	*Alosa pseudoharengus*	748	77	700	96
64	Capelin	*Mallotus villosus*	5,157	30	561	49
70	Atlantic Mackerel	*Scomber scombrus*	968	311	274	68

Table A2 (continued).

Species Code	Common Name	Scientific Name	Total Number	Total Weight (kg)	Numbers per Species Sampled: Individual lengths	Individual weights
112	Longfin Hake	*Urophycis chesteri*	92	9	92	64
114	Fourbeard Rockling	*Enchelyopus cimbrius*	29	1	29	25
122	Cunner	*Tautogolabrus adspersus*	2	0	2	2
123	Black Belly Rosefish	*Helicolenus dactylopterus*	39	0	39	19
142	Fourspot Flounder	*Hippoglossina oblonga*	6	2	6	6
149	Longnose Greeneye	*Parasudis truculenta*	4	0	4	3
150	Lanternfish (Ns)	*Myctophidae*	1	0	1	1
156	Short-Nose Greeneye	*Chlorophthalmus agassizi*	1	0	1	1
158	Muller's Pearlsides	*Maurolicus muelleri*	2	0	2	2
160	Atlantic Argentine	*Argentina silus*	78	39	78	31
201	Thorny Skate	*Amblyraja radiata*	333	172	333	221
202	Smooth Skate	*Malacoraja senta*	38	13	38	37
203	Little Skate	*Leucoraja erinacea*	10	5	10	10
204	Winter Skate	*Leucoraja ocellata*	56	31	56	38
207	Round Skate	*Rajella fyllae*	1	0	1	1
216	Atlantic Torpedo	*Torpedo nobiliana*	1	13	1	1
220	Spiny Dogfish	*Squalus acanthias*	1	2	1	1
221	Black Dogfish	*Centroscyllium fabricii*	425	130	425	157
241	Northern Hagfish	*Myxine glutinosa*	6	0	6	6
300	Longhorn Sculpin	*Myoxocephalus octodecemspinosus*	405	59	405	153
301	Shorthorn Sculpin	*Myoxocephalus scorpius*	4	1	4	4
304	Mailed Sculpin	*Triglops murrayi*	95	1	95	42

Table A2 (continued).

Species Code	Common Name	Scientific Name	Total Number	Total Weight (kg)	Numbers per Species Sampled: Individual lengths	Individual weights
314	Spatulate Sculpin	*Icelus spatula*	2	0	2	2
320	Sea Raven	*Hemitripterus americanus*	57	33	57	47
340	Alligatorfish	*Aspidophoroides monopterygius*	22	0	22	17
350	Atlantic Sea Poacher	*Leptagonus decagonus*	39	1	39	26
400	Monkfish, Goosefish, Angler	*Lophius americanus*	12	11	12	12
410	Marlin-Spike Grenadier	*Nezumia bairdii*	92	5	92	63
414	Roundnose Grenadier	*Coryphaenoides rupestris*	1	0	1	1
501	Lumpfish	*Cyclopterus lumpus*	2	5	2	2
502	Atlantic Spiny Lumpsucker	*Eumicrotremus spinosus*	57	1	57	19
503	Atlantic Seasnail	*Liparis atlanticus*	11	0	11	8
505	Gelatinous Seasnail	*Liparis fabricii*	6	0	6	6
602	Gray's Cutthroat Eel	*Synaphobranchus kaupi*	2	0	2	2
604	Snipe Eel	*Nemichthys scolopaceus*	1	0	1	1
610	Northern Sand Lance	*Ammodytes dubius*	3,363	62	574	127
622	Snake Blenny	*Lumpenus lumpretaeformis*	37	1	37	30
623	Daubed Shanny	*Lumpenus maculatus*	80	0	80	38
625	Radiated Shanny	*Ulvaria subbifurcata*	3	0	3	3
630	Wrymouth	*Cryptacanthodes maculatus*	1	0	1	1
640	Common Ocean Pout	*Macrozoarces americanus*	3	0	3	3
646	Atlantic Soft Pout	*Melanostigma atlanticum*	5	0	5	4
647	Vahl Shorttailed Eelpout	*Lycodes vahlii*	187	9	187	104
701	Butterfish	*Peprilus triacanthus*	187	10	187	32

Table A2 (continued).

Species Code	Common Name	Scientific Name	Total Number	Total Weight (kg)	Numbers per Species Sampled: Individual lengths	Individual weights
712	White Barracudina	*Notolepis rissoi*	3	0	3	2
742	Atlantic Batfish	*Dibranchus atlanticus*	1	0	1	1
819	Loosejaws (Ns)	*Malacosteidae f.*	1	0	1	1
880	Atlantic Hookear Sculpin	*Artediellus atlanticus*	47	0	47	20
1203	Purse Little Skate	*Purse Leucoraja erinacea*	2	0	-	-
1204	Purse Winter Skate	*Purse Leucoraja ocellata*	4	0	-	-
1224	Skate Eggs Unidentified	*Raja eggs*	106	2	-	-
1228	Sculpin Eggs Unidentified	*Myoxocephalus eggs*	5	0	-	-
1510	Whelk Eggs (Ns)	*Buccinidae eggs*	8	1	-	-
1810	Tunicata sp.	*Tunicata sp.*	37	34	-	-
1823	Sea Potatoe	*Boltenia sp.*	69	4	-	-
1930	Lampshells	*Bryozoans brachiopoda p.*	4	0	-	-
2000	Crustacea C.	*Crustacea c.*	18	0	-	-
2211	Pandalus Borealis	*Pandalus borealis*	147,818	1,010	-	-
2212	Pandalus Montagui	*Pandalus montagui*	20,193	57	-	-
2213	Was Pandalus Propinquus	*Atlantopandalus propinquus*	46	0	-	-
2221	Pasiphaea Multidentata	*Pasiphaea mulidentata*	613	1	-	-
2312	Lebbeus Polaris	*Lebbeus polaris*	190	0	-	-
2319	Lebbeus Groenlandicus	*Lebbeus groenlandicus*	432	0	-	-
2332	Eualus Fabricii	*Eualus fabricii*	339	0	-	-
2333	Eualus Gaimardii	*Eualus gaimardii*	596	1	-	-
2411	Argis Dentata	*Argis dentata*	1,733	5	-	-

Table A2 (continued).

Species Code	Common Name	Scientific Name	Total Number	Total Weight (kg)	Numbers per Species Sampled Individual lengths	Individual weights
2415	Pontophilus Norvegicus	*Pontophilus norvegicus*	247	1	-	-
2416	Crangon Sp.	*Crangon sp.*	249	1	-	-
2417	Crangon Septemspinosa	*Crangon septemspinosa*	1,169	2	-	-
2511	Jonah Crab	*Cancer borealis*	20	5	20	19
2513	Atlantic Rock Crab	*Cancer irroratus*	39	6	39	37
2521	Hyas Coarctatus	*Hyas coarctatus*	221	5	221	185
2523	Northern Stone Crab	*Lithodes maja*	29	7	29	26
2526	Queen Snow Crab	*Chionoecetes opilio*	1,483	210	1,482	917
2527	Toad Crab	*Hyas araneus*	29	1	29	29
2550	American Lobster	*Homarus americanus*	19	50	19	18
2555	Munida Iris	*Munida iris*	2	0	-	-
2556	Munida Valida	*Munida valida*	24	0	-	-
2559	Hermit Crabs	*Paguridae f.*	4	0	-	-
2560	Paguroidea S.F.	*Paguroidea s.f.*	63	3	-	-
2611	Meganyctiphanes Norvegica	*Meganyctiphanes norvegica*	985	1	-	-
2800	Amphipoda O.	*Amphipoda o.*	36	0	-	-
2980	Red Isopod	*Isopoda o.*	4	0	-	-
3000	Segmented Worms	*Annelida p.*	20	0	-	-
3212	Aphrodita Sp.	*Aphrodita sp.*	134	14	-	-
4000	Mollusca P.	*Mollusca p.*	4	0	-	-
4210	Whelks	*Buccinum sp.*	98	5	-	-
4211	Common edible Wave Whelk	*Buccinum undatum*	28	1	-	-

Table A2 (continued).

Species Code	Common Name	Scientific Name	Total Number	Total Weight (kg)	Numbers per Species Sampled: Individual lengths	Individual weights
4221	Northern Moonsnail	*Euspira heros*	11	1	-	-
4227	New England Neptune	*Neptunea decemcostata*	5	1	-	-
4228	Spindle Shell	*Colus sp.*	6	0	-	-
4230	Duck or Pelican Foot	*Aporrhais sp.*	2	0	-	-
4250	Periwinkles	*Littorinidae f.*	1	0	-	-
4304	Ocean Quahaug	*Arctica islandica*	13	1	-	-
4312	Bank Clam	*Cyrtodaria siliqua*	7	1	-	-
4321	Sea Scallop	*Placopecten magellanicus*	153	21	153	115
4322	Iceland Scallop	*Chlamys islandica*	29	1	29	23
4511	Short-Fin Squid	*Illex illecebrosus*	22	2	22	18
4512	Longfin Squid	*Loligo pealeii*	4	0	4	4
4521	Octopus	*Octopoda o.*	19	1	-	-
4536	Bobtail Squid	*Sepiolodae f.*	9	0	-	-
5100	Sea Spider	*Pycnogonida sp.*	2	0	-	-
6100	Asteroidea S.C.	*Asteroidea s.c.*	13	0	-	-
6110	Asterias Sp.	*Asterias sp.*	41	7	-	-
6111	Asterias Rubens	*Asterias rubens*	6	0	-	-
6113	Leptasterias Polaris	*Leptasterias polaris*	140	122	-	-
6115	Mud Star	*Ctenodiscus crispatus*	280	9	-	-
6117	Hippasteria Phrygiana	*Hippasteria phrygiana*	47	9	-	-
6119	Blood Star	*Henricia sanguinolenta*	32	0	-	-
6120	Henrica Sp.	*Henrica sp.*	3	0	-	-

Table A2 (continued).

Species Code	Common Name	Scientific Name	Total Number	Total Weight (kg)	Numbers per Species Sampled	
					Individual lengths	Individual weights
6121	Purple Sunstar	*Solaster endeca*	44	6	-	-
6123	Spiny Sunstar	*Crossaster papposus*	161	13	-	-
6125	Pteraster Militaris	*Pteraster militaris*	2	0	-	-
6130	Poraniomorpha Borealis	*Poraniomorpha borealis*	5	0	-	-
6131	Diplopteraster Multipes	*Diplopteraster multipes*	43	2	-	-
6200	Brittle Star	*Ophiuroidea s.c.*	1	1	-	-
6300	Basket Star	*Gorgonocephalidae, Asteronychidae f.*	142	52	-	-
6411	Green Sea Urchin	*Strongylocentrotus droebachiensis*	659	205	-	-
6413	Heart Urchin	*Brisaster fragilis*	26	1	-	-
6511	Echinarachnius Parma	*Echinarachnius parma*	1,026	52	-	-
6600	Sea Cucumber Unidentified	*Holothuroidea c.*	230	142	-	-
6611	Common Sea Cucumber	*Cucumaria frondosa*	75	170	-	-
6715	Psolus Phantapus	*Psolus phantapus*	1	0	-	-
8300	Sea Anemone	*Anthozoa c.*	71	35	-	-
8323	Bubble Gym Coral	*Paragorgia arborea*	12	0	-	-
8324	Strawberry Sea Cauliflower	*Eunephthya rubiformis*	1	0	-	-
8327	Soft Coral Unidentified	*Soft Coral Unidentified*	8	0	-	-
8335	Cup Coral	*Flabellum sp.*	8	0	-	-
8346	Pseudarchaster Parelii	*Pseudarchaster parelii*	4	0	-	-
8347	Psilaster Andromeda	*Psilaster andromeda*	137	6	-	-
8349	Lophaster Furcifer	*Lophaster furcifer*	2	0	-	-
8364	Geodia Sp.	*Geodia sp.*	5	3	-	-
8500	Jellyfish	*Scyphozoa c.*	1	1	-	-
8600	Sponge	*Porifera p.*	49	26	-	-

Table A3. Summary of fish and invertebrate catches (total number, total weight (kg) and total number) and sampling (individual lengths and individual weights) by species from the 2011 4Vn Sentinel Survey. A total of 56 sets were completed in 2011.

					Numbers per Species Sampled	
Survey	Common Name	Scientific Name	Total Number	Total Weight (kg)	Individual lengths	Individual weights
4Vn Sentinel	Atlantic Cod	*Gadus morhua*	3878	5594	1420	1420
	Haddock	*Melanogrammus aeglefinus*	2	5	-	-
	White Hake	*Urophycis tenuis*	760	909	-	-
	Pollock	*Pollachius virens*	14	8	-	-
	Redfish unseparated	*Sebastes sp.*	5	8		
	Atlantic Halibut	*Hippoglossus hippoglossus*	93	755	-	-
	Turbot	*Reinhardtius hippoglossoides*	45	59	-	-
	American Plaice	*Hippoglossoides platessoides*	104	61	-	-
	Winter Flounder	*Pseudopleuronectes americanus*	1	1	-	-
	Striped Atlantic Wolffish	*Anarhichas lupus*	132	121	-	-
	Spotted Wolffish	*Anarhichas minor*	4	4	-	-
	Wolffish Unidentified	*Anarhichadidae f.*	43	30	-	-
	Atlantic Mackerel	*Scomber scombrus*	5	3	-	-
	Greenland Cod	*Gadus ogac*	357	394	282	282
	Cunner	*Tautogolabrus adspersus*	1	1	-	-
	Barndoor Skate	*Dipturus laevis*	9	12	-	-
	Skates (Ns)	*Rajidae f.*	316	391	-	-
	Blue Shark	*Prionace glauca*	1	11	-	-
	Longhorn Sculpin	*Myoxocephalus octodecemspinosus*	145	79	-	-
	Sculpins	*Cottidae f.*	447	228	-	-
	Eelpouts (Ns)	*Zoarcidae f.*	12	6	-	-
	American Eel	*Anguilla rostrata*	8	5	-	-
	Common Ocean Pout	*Macrozoarces americanus*	3	4	-	-
	Atlantic Rock Crab	*Cancer irroratus*	5	5	-	-
	Queen Snow Crab	*Chionoecetes opilio*	25	32	-	-

Table A4. Summary of fish and invertebrate catches (total number, total weight (kg) and total number) and sampling (individual lengths and individual weights) by species from the 2011 4VsW Sentinel Survey. A total of 53 sets were completed in 2011.

Survey	Common Name	Scientific Name	Total Number	Total Weight (kg)	Numbers per Species Sampled: Individual lengths	Individual weights
4VsW Sentinel	Atlantic Cod	*Gadus morhua*	350	348	-	-
	Haddock	*Melanogrammus aeglefinus*	454	386	24	24
	Red Hake	*Urophycis chuss*	185	42	-	-
	Silver Hake	*Merluccius bilinearis*	58	26	-	-
	Cusk	*Brosme brosme*	78	119	-	-
	Pollock	*Pollachius virens*	9	21	-	-
	Redfish Unseparated	*Sebastes sp.*	1	1	-	-
	Atlantic Halibut	*Hippoglossus hippoglossus*	20	261	-	-
	Wolffish Unidentified	*Anarhichadidae f.*	9	7	-	-
	Hake (Ns)	*Urophycis sp.*	340	413	57	54
	Skates (Ns)	*Rajidae f.*	24	28	-	-
	Spiny Dogfish	*Squalus acanthias*	399	442	-	-
	Monkfish,Goosefish,Angler	*Lophius americanus*	2	10	-	-
	Brachiuran Crabs	*Brachyura s.*	1	1	-	-

Table A5. Summary of fish and invertebrate catches (total number, total weight (kg) and total number) and sampling (individual lengths and individual weights) by species from the 2011 4X ITQ Survey. The number of individual lengths and weights recorded is also indicated. A total of 181 sets were completed in 2011.

Survey	Common Name	Scientific Name	Total Number	Total Weight (kg)	Numbers per Species Sampled: Individual lengths	Numbers per Species Sampled: Individual weights
ITQ	Atlantic Cod	*Gadus morhua*	1183	1278	750	750
	Haddock	*Melanogrammus aeglefinus*	17866	6897	2381	2381
	White Hake	*Urophycis tenuis*	895	658	-	-
	Red Hake	*Urophycis chuss*	1	1	-	-
	Silver Hake	*Merluccius bilinearis*	8605	1196	-	-
	Cusk	*Brosme brosme*	11	18	9	9
	Pollock	*Pollachius virens*	768	690	318	318
	Redfish Unseparated	*Sebastes sp.*	54530	13408	1114	1114
	Atlantic Halibut	*Hippoglossus hippoglossus*	149	256	87	87
	Turbot	*Reinhardtius hippoglossoides*	3	3	-	-
	American Plaice	*Hippoglossoides platessoides*	717	170	-	-
	Witch Flounder	*Glyptocephalus cynoglossus*	471	187	-	-
	Yellowtail Flounder	*Limanda ferruginea*	340	88	-	-
	Winter Flounder	*Pseudopleuronectes americanus*	3912	1219	1112	1112
	Atlantic Herring	*Clupea harengus*	44997	5477	-	-
	Shad American	*Alosa sapidissima*	19	14	-	-
	Alewife	*Alosa pseudoharengus*	295	83	-	-
	Rainbow Smelt	*Osmerus mordax*	5	2	-	-
	Atlantic Mackerel	*Scomber scombrus*	199	38	-	-
	Cunner	*Tautogolabrus adspersus*	6	5	-	-
	Black Belly Rosefish	*Helicolenus dactylopterus*	229	17	-	-
	Fourspot Flounder	*Hippoglossina oblonga*	2	1	-	-

Table A5 (continued).

Survey	Common Name	Scientific Name	Total Number	Total Weight (kg)	Numbers per Species Sampled: Individual lengths	Numbers per Species Sampled: Individual weights
ITQ (continued)	Atlantic Argentine	*Argentina silus*	11	6	-	-
	Barndoor Skate	*Dipturus laevis*	19	108	-	-
	Thorny Skate	*Amblyraja radiata*	19	32	-	-
	Smooth Skate	*Malacoraja senta*	33	32	-	-
	Little Skate	*Leucoraja erinacea*	1	1	-	-
	Winter Skate	*Leucoraja ocellata*	39	63	-	-
	Atlantic Torpedo	*Torpedo nobiliana*	1	35	-	-
	Spiny Dogfish	*Squalus acanthias*	1012	1914	-	-
	Porbeagle/Mackerel Shark	*Lamna nasus*	1	1	-	-
	Sea Lamprey	*Petromyzon marinus*	16	8	-	-
	Argentines (Ns)	*Argentinidae f.*	322	108	-	-
	Longhorn Sculpin	*Myoxocephalus octodecemspinosus*	1715	710	-	-
	Sculpins	*Cottidae f.*	1546	222	-	-
	Sea Raven	*Hemitripterus americanus*	659	560	-	-
	Monkfish,Goosefish,Angler	*Lophius americanus*	55	103	-	-
	Roughhead Grenadier	*Macrourus berglax*	1	1	-	-
	Lumpfish	*Cyclopterus lumpus*	6	6	-	-
	Eelpouts (Ns)	*Zoarcidae f.*	1	1	-	-
	American Eel	*Anguilla rostrata*	28	24	-	-
	Common Ocean Pout	*Macrozoarces americanus*	3	2	-	-
	Butterfish	*Peprilus triacanthus*	71	24	-	-
	American John Dory	*Zenopsis ocellata*	7	5	-	-

Table A5 (continued).

Survey	Common Name	Scientific Name	Total Number	Total Weight (kg)	Numbers per Species Sampled: Individual lengths	Individual weights
ITQ (continued)	Molgulidae F.	*Molgulidae f.*	40	1	-	-
	Pandalus Montagui	*Pandalus montagui*	423	8	-	-
	Was Pandalus Propinquus	*Atlantopandalus propinqvus*	515	7	-	-
	Jonah Crab	*Cancer borealis*	1	1	-	-
	Northern Stone Crab	*Lithodes maja*	2	2	-	-
	Queen Snow Crab	*Chionoecetes opilio*	1	1	-	-
	American Lobster	*Homarus americanus*	4526	2755	4138	-
	Sea Scallop	*Placopecten magellanicus*	8	1	-	-
	Short-Fin Squid	*Illex illecebrosus*	2080	202	-	-
	Squid (Ns)	*Loliginidae, Ommastrephidae f.*	140	35	-	-
	Octopus	*Octopoda o.*	1	1	-	-
	Asteroidea s.c.	*Asteroidea s.c.*	2	1	-	-
	Basket Stars	*Gorgonocephalidae, Asteronychidae f.*	1	1	-	-
	Sea Urchins	*Strongylocentrotus sp.*	57	21	-	-
	Sea Cucumber (Unidentified)	*Holothuroidea c.*	9	5	-	-
	Jellyfishes	*Scyphozoa c.*	8	2	-	-
	Sponges	*Porifera p.*	1	5	-	-
	Stones and Rocks	*Stones and rocks*	5	25	-	-