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Maritimes Region

Information on the Potential for Recovery of Cusk (*Brosme brosme*) in Canadian Waters

L.E. Harris, M. Greenlaw, Q. McCurdy, and D. MacDonald

Fisheries and Oceans Canada
St. Andrews Biological Station
531 Brandy Cover Road
St. Andrews, New Brunswick E5B 2L9

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research documents are produced in the official language in which they are provided to the Secretariat.

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ABSTRACT

Cusk (*Brosme brosme*) was reassessed as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in November 2012 for reasons that include long-term declines beginning in the 1970s. Commercial catch rates for Cusk have declined since the 1980s. The extent of the decline in abundance cannot be reliably estimated. The Halibut Industry Survey, which began after the decline in commercial catch per unit effort (CPUE) of Cusk was observed, has fluctuated without trend since 1999. This suggests that the population abundance has stabilized. The 3-year geometric mean (2011-2013) of the Cusk CPUE in the Halibut Industry Survey is 17.9kg/1000 hooks, which suggests that the stock is in the cautious zone when utilizing the DFO Precautionary Framework. The Limit Reference Point is 13.3kg/1000 hooks in the Halibut Industry. The Upper Stock Reference Point of 26.6kg Cusk/1000 hooks in the Halibut Industry Survey is the proposed population recovery target.

Fishing is the only known major source of human-induced mortality of Cusk in Atlantic Canada. Groundfish longline and lobster pots are considered the greatest threats based on landings records and discard estimates, respectively. The Cusk reported landings for the 2012 fishing year in Maritimes Region were 462.2mt. The 2012 Cusk landings for the Gulf Region and Newfoundland and Labrador Region were 0.043mt and 1.88mt, respectively. The Cusk bycatch for 2012 in Lobster Fishing Area (LFA) 41 was estimated at 8.6mt. The 2006/2007 estimate of bycatch in LFA 34 was 344mt. Cusk catches in other LFAs have not been estimated. Cusk CPUE in the Halibut Industry Survey has fluctuated without trend for the past 14 years suggesting that the population can sustain recent levels of fishing mortality without jeopardizing survival of the species. A reduction in fishing mortality may be required for the species to achieve the proposed recovery target for abundance.

There is no evidence of a reduction in the range of Cusk. Habitat does not appear to be, nor is likely to become, a limiting factor to Cusk survival and recovery. There are no known anthropogenic threats that have reduced Cusk habitat quantity or quality. The proposed distribution target for recovery is to maintain current distribution. Preliminary analyses suggest the six most influential environmental variables on Cusk habitat suitability, ranked using the Random Forest Model, were salinity variability, winter total suspended matter (2006-2010), fall benthic temperature, depth, root mean square (RMS) current stress, and winter benthic temperature. These variables are expected to have both indirect and direct relationships on Cusk distribution patterns.

Renseignements sur le potentiel de rétablissement du brosme (*Brosme brosme*) dans les eaux canadiennes

RÉSUMÉ

En novembre 2012, le brosme (*Brosme brosme*) a été réévalué et désigné comme étant en voie de disparition par le Comité sur la situation des espèces en péril au Canada (COSEPAC) pour plusieurs raisons, notamment un déclin à long terme amorcé durant les années 1970. Les taux de prises de la pêche commerciale pour le brosme ont baissé depuis les années 1980. On ne peut estimer avec confiance l'ampleur du déclin de l'abondance. Le relevé de l'industrie sur le flétan, commencé à la suite du déclin observé des prises de brosme par unité d'effort (CPUE) de la pêche commerciale, fluctue depuis 1999 sans afficher de tendance, ce qui laisse croire que l'abondance de la population s'est stabilisée. La moyenne géométrique de prises de brosme par unité d'effort sur trois ans (2011 à 2013) dans le relevé de l'industrie sur le flétan était de 17,9 kg/1 000 hameçons, ce qui donne à penser que le stock se trouve dans la zone de prudence selon le cadre préventif de Pêches et Océans Canada. Le point de référence limite est 13,3kg/1 000 hameçons dans l'industrie du flétan. L'objectif de rétablissement de la population proposé est le point de référence supérieur du stock figurant dans le relevé de l'industrie sur le flétan, soit 26,6 kg de brosme/1 000 hameçons.

La pêche est la seule grande source connue de mortalité d'origine anthropique chez le brosme au Canada atlantique. Les palangres à poisson de fond et les casiers à homard sont considérés comme les principales menaces, à la lumière des rapports sur les débarquements et des estimations des rejets, respectivement. Durant l'année de pêche 2012, les débarquements déclarés de brosme dans la région des Maritimes totalisaient 462,2 tm. Au cours de la même année, les débarquements de brosme dans les régions du Golfe et de Terre-Neuve-et-Labrador (T.-N-.L.) ont atteint respectivement 0,043 tm et 1,88 tm. Toujours en 2012, les prises accessoires de brosme dans la zone de pêche du homard (ZPH) 41 étaient estimées à 8,6 tm. En 2006-2007, les prises accessoires dans la ZPH 34 étaient estimées à 344 tm. Les prises de brosme n'ont pas été estimées dans les autres ZPH. Les prises par unité d'effort de brosme dans le relevé de l'industrie sur le flétan fluctuent sans afficher de tendance depuis 14 ans, ce qui laisse entendre que la population peut supporter les récents taux de mortalité par pêche sans que la survie de l'espèce soit compromise. Une réduction de la mortalité par pêche pourrait être nécessaire afin que l'espèce atteigne l'objectif d'abondance proposé pour le rétablissement.

Rien n'indique que l'aire de répartition de l'espèce a diminué. L'habitat ne semble ni être ni risquer de devenir un facteur limitatif à la survie et au rétablissement du brosme. Il n'y a pas de menaces anthropiques connues ayant occasionné une baisse de la quantité ou de la qualité de l'habitat. L'objectif de répartition proposé pour le rétablissement est de maintenir la répartition actuelle. Les analyses préliminaires semblent indiquer que les six variables environnementales qui influent le plus sur la qualité de l'habitat du brosme, classées à l'aide du modèle de forêts aléatoires, sont la variabilité de la salinité, le total des particules en suspension en hiver (2006-2010), la température benthique en automne, la profondeur, la tension efficace liée au courant et la température benthique en hiver. On s'attend à ce que ces variables soient liées de manière directe et indirecte aux profils de répartition du brosme.

INTRODUCTION

Cusk (*Brosme brosme*) are currently under consideration for addition to Schedule 1 of the *Species at Risk Act* (SARA). The recovery potential assessment (RPA) informs the listing decision, socio-economic analyses, and consultations with the public. This document provides an update to the Cusk RPA conducted in 2007 (DFO 2008a). Should this species be added to the List set out in Schedule 1 to SARA, the advice from this RPA update will also inform the recovery strategy.

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated Cusk as Threatened in May 2003 based on a status report at that time. Following COSEWIC's assessment, Fisheries and Oceans Canada (DFO) prepared an allowable harm assessment (DFO 2004a), which was reviewed during a National Advisory Process meeting convened in October 2004. In April 2006, following consultations with the Provinces, Aboriginal peoples, stakeholders and the public, the Governor in Council (GiC) referred COSEWIC's assessment back to that committee for further information and consideration since all available information was not used. The explanation provided was that significant emphasis was placed on trawl survey data, which may have exaggerated the decline of Cusk. Cusk are a bottom-dwelling species best measured by tools that can reach Cusk at greater depths, such as the available bottom longline surveys and commercial catch data; these tools suggest Cusk may be more abundant than indicated in the previous assessment. In December 2006, COSEWIC reaffirmed the original assessment without reassessing the species, citing an absence of new information that would lead to a change in the status of this species. An RPA was conducted in 2007 (DFO 2008a, DFO 2008b, Davies and Jonsen 2008, Harris and Hanke 2010). In a process separate from the DFO SARA-process, proposed reference points for Cusk and other Maritimes Region stocks were reviewed at a DFO Regional Peer Review meeting in February 2012 (DFO 2012, Harris et al. 2012). In March 2013, The Minister of the Environment recommended, on the advice of the Minister of Fisheries and Oceans Canada, that Cusk not be added to the List set out in Schedule 1 of the SARA in light of the new management measures implemented, those to be implemented, the lack of scientific certainty regarding the decline of the species, the socio-economic impacts, and the concerns of stakeholders.

Meanwhile, the 10-year reassessment of Cusk status was completed during the November 2012 COSEWIC meeting. Cusk was designated Endangered. The rationale provided for this designation was:

> "This species is a large, slow-growing, bottom-living fish that resides in the Gulf of Maine, and Scotian Shelf, and which has been declining continuously since 1970. The mature portion of the population has declined by approximately 85% over three generations. There is also strong evidence that its area of occupancy has declined considerably. Average fish size has also declined, consistent with a decline in abundance. Limited management efforts have not been effective in halting the decline." (COSEWIC 2012, p. iii)

Thus, the species is once again being considered for listing on Schedule 1 of the SARA. As a result, DFO Science has been asked to update the RPA, based on the National Frameworks (DFO 2007a and b). The advice generated via this process will update and/or consolidate previous advice regarding Cusk and support a new listing recommendation for Cusk by the Minister of Fisheries and Oceans Canada. The advice in the update may be used to inform both scientific and socio-economic elements of the listing decision, as well as development of a recovery strategy and action plan, and to support decision-making with regards to the issuance of permits, agreements, and related conditions, as per sections 73, 74, 75, 77, and 78 of SARA.

SARA is intended to protect species at risk of extinction in Canada and promote their recovery. SARA includes prohibitions on killing, harming, harassing, capturing or taking individuals of species listed as Threatened or Endangered on Schedule 1. SARA prohibits sale or trade of individuals of such species (or their parts), damage or destruction of their residences or destruction of their critical habitat. SARA also specifies that a recovery strategy must be prepared for species that are listed as Threatened or Endangered. The provisions of these recovery strategies will have to address all potential sources of harm, including harvesting activities, in a way that will not jeopardize the survival and recovery of the populations concerned.

Section 73 (2) of the SARA provides the competent ministers with the authority to permit normally prohibited activities affecting a listed species, its critical habitat, or its residence, even though they are not part of a previously approved recovery plan. Such activities can only be approved if:

1. they are scientific research relating to the conservation of the species and conducted by qualified persons;
2. they will benefit the species or are required to enhance its chance of survival in the wild; or
3. affecting the species is incidental to carrying them out.

The decision to permit allowable harm and the development of a recovery strategy must consider the species' current situation and its recovery potential, the impacts of human activities on the species, and its ability to recover, as well as alternatives and measures to reduce these impacts to a level which will not jeopardize the survival and recovery of the species. Therefore, a species recovery potential assessment process was established by DFO Science Branch in order to provide the information and scientific advice required to meet the various requirements of the SARA, such as the authorization to carry out activities that would otherwise violate the SARA, as well as the development of recovery strategies. In the case of a species that has not yet been added to Schedule 1, as with Cusk, the scientific information also contributes to the decision on whether or not to add the species to the list. Consequently, the information is used when analyzing the socio-economic impacts of adding the species to the list as well as during subsequent consultations, where applicable.

SPECIES BIOLOGY

CUSK DISTRIBUTION

Cusk is a solitary, sedentary, slow swimming species (Colette and Klein-MacPhee 2002) found across the northern North Atlantic from the United States, north to Greenland, across to Iceland, Svalbard, along the Murmansk Coast, and south in the Northeast Atlantic to Ireland. It has also been found along the mid-Atlantic Ridge (Figure 1). In Canadian waters, Cusk is most common in the Gulf of Maine, Western Scotian Shelf, and along the edge of the Scotian Shelf to Banquereau Bank (Figure 2, see Figure 3 for locations of oceanographic features) although it has been caught from Cape Cod, in the United States, to Labrador. It is rare in the Gulf of St. Lawrence and the inner Bay of Fundy.

Cusk exhibit a preference for hard rocky bottom or pebbles (Svetovidov 1948, Bigelow and Schroeder 1953, Andriyashev 1964, Oldham 1966, Colette and Klein-MacPhee 2002) and have been observed hiding in crevices (Hovland and Judd 1988, Freiwald et al. 2002, Jones et al. 2009). They are occasionally found on mud but rarely on sand (Bigelow and Schroeder 1953, Colette and Klein-MacPhee 2002). A study off southwestern Norway comparing abundance of selected fish species in coral (*Lophelia pertusa*) reefs and non-coral habitats found no significant difference in Cusk bottom longline catches (Husebø et al. 2002). A more recent Norwegian study identified a positive correlation between Cusk catches and the density of cold-water coral (*Lophelia pertusa*) in one of two field seasons. The authors concluded that their study did not provide evidence that the cold-water-coral mounds are important habitat for Cusk (Kutti et al. 2014). No correlation was found between Cusk catches and sponge or boulder distributions (Kutti et al. 2014).

Cusk is considered a deep-water species although it has been observed, albeit less commonly, in shallow waters as well. Globally, their depth range is reported to be from about 20m to 1100m (Svetovidov 1948, Andriyashev 1964, Oldham 1966, Hareide and Garnes 2001, Colette and Klein-MacPhee 2002). Bergstad (1991) found that Cusk were caught up to depths of 600m in the Norwegian Deep. In their bottom longline surveys, Hareide and Garnes (2001) found that Cusk were caught to depths of 1100m at 2 locations: on the Reykjanes Ridge and on the Hecate Seamount. At these sampling stations, catches were highest at 700m, 1000m, and 600m, respectively. The highest average catch (684.1kg/1000 hooks) for the 3 Rekjanes ridge and Hecate seamount areas combined was at a depth 1000m. In the mid-Atlantic, Cusk were caught at temperatures ranging from 3.8-4.9°C. Reykjanes ridge catches peaked at 700m and 4.2°C. The Cusk were not caught at the Faraday Seamounts nor the sampling area north of the Azores. These two areas were only sampled by bottom trawl. Because Cusk are seldom caught by bottom trawl, the authors were unable to confirm if the absence of Cusk indicated the southern limit of their range in the mid-Atlantic or if it was due to the sampling gear used.

In the Halibut Industry Survey off Nova Scotia and Newfoundland (Figure 4), the largest set of Cusk (907kg) was caught at around 560m. The sets with the highest Catch Per Unit Effort (CPUE), grouped by 50m bins, peaked between 400-600m (Harris and Hanke 2010), with Cusk caught at depths as great as 1185m. There were only 4 sets deeper than this.

CUSK GENETICS

Cusk genetics in the North Atlantic have not been well studied and, as a result, there is little information on Cusk population structures. Cusk occupy a wide geographic range along the continental shelf of the Northwest Atlantic and throughout the Northeast Atlantic around Iceland and the Faroe Islands and extending northward along the European shelf from Ireland to the North and Barents seas (Knutsen et al. 2009). Cusk habitat is limited to depths less than about 1000m for larval and adult stages. Deep-water ocean troughs and basins, as well as oceanic currents, likely present barriers to Cusk distribution (Knutsen et al. 2009). Barriers to distribution may also limit gene flow from one region to another. A study of Cusk mitochondrial DNA from samples collected in Canada, Greenland, Norway, and the Mid-Atlantic Ridge revealed no obvious geographic patterns in the distribution of mitochondrial diversity and weak or no genetic structure was detected. Haplotypes were shared among regions and the most common haplotypes for the 3 loci studied were found in Canada, Norway, and Greenland (Clifford 2007). A mismatch distribution analysis by the same author suggested that the population structure within Cusk populations is large and stable with widespread gene flow. While the previous study found no geographic subdivision among samples from across the North Atlantic, Knutsen et al. (2009) found weak but statistically significant genetic subdivision among Cusk samples taken from the Rockall region and the mid-Atlantic Ridge of the Northeast Atlantic. Using microsatellite DNA analysis it was determined that these populations were significantly differentiated from relatively homogeneous sites across the Nordic seas. Both the Rockall and mid-Atlantic Ridge areas are separated from adjacent Cusk habitat by deep water (> approximately 1000m) and a deep ocean basin. Cusk differentiation was found to be positively affected by habitat structure that reflects bathymetric features rather than geographic distance between and among sites. Oceanic areas deeper than approximately 1000m likely limit Cusk migration and distribution, and ocean currents may also create retention zones in some areas and resultantly prevent larval drift to other regions. The Canadian distribution of Cusk is along the continental shelf from George's Bank to the Grand Banks of Newfoundland and across to East Greenland. There are no basins or deep water areas (> approximately 1000 m) that separate Cusk habitat areas in Canadian waters (Michelle Greenlaw, pers. comm.) and, as such, there is no reason to believe that Cusk in Canadian habitat areas are genetically differentiated.

GROWTH AND REPRODUCTION

In the Northeast Atlantic, Cusk reach at least 15kg and 110cm (Wienerroither et al. 2013). They are found to be slow growing and reach maturity at 8 to 10 years of age, or 40-50cm (Magnusson et al. 1997, Wienerroither et al. 2013). The otoliths of larger fish are very difficult to read. The oldest fish aged was estimated to be approximately 20 years old (Bergstad and Hareide 1996, Magnusson et al. 1997) but they are believed to live longer (Wienerroither et al. 2013). No significant difference in growth rate has been observed between the sexes (Magnusson et al. 1997).

From the Scotian Shelf, Oldham (1972) reported lengths at which 50% of the specimens were mature as 43.5cm for males and 50.7cm for females. He found that males do not grow faster than females although they mature more rapidly. Recently, radiocarbon bomb dating methods have been used to estimate the age of Cusk from Canadian waters. This ageing effort has returned older age estimates, including an 82cm fish aged at 39 years (the longest reported Cusk from Canadian waters is 118cm). These new ageing data also suggest that Cusk may reach maturity at 10 years in contrast to previous estimates of 5-6 years. These results are more consistent with ageing results from the Northeast Atlantic. These efforts to age Cusk are continuing. Ageing Cusk from sectioned otoliths has proven difficult. Current efforts are yielding results consistent with the bomb radiocarbon dated otoliths. However, there is still further ageing and testing to be conducted before there is enough confidence in the ageing method to develop a growth curve that can be used.

The largest Cusk recorded in Canadian waters were caught in the Halibut Industry bottom longline survey (118cm). Fish less than 40cm were recorded infrequently by at-sea observers on industry surveys and commercial trips; there are only 48 specimens less than 40cm of 3253 specimens in the database. Juveniles, 15cm and less, have been caught in annual DFO bottom trawl surveys. Five specimens less than 10cm in this data series were all recorded in the same set in a 1982 survey. The identification of the species is questioned but cannot be verified. If nursery areas exist for juvenile Cusk, they have not yet been observed.

Magnusson et al. (1997) reported that Cusk spawn from April to July off the south and southwest coasts of Iceland, from March to April in Ireland, the Hebrides and Rockall areas, from April to June in the Faeroes, and from April to May along the Norwegian Shelf. Ichthyoplankton data (Harris et al. 2002) and maturity studies (Oldham 1972, Collette and Klein-MacPhee 2002) indicate that spawning on the Scotian Shelf occurs from May to August, and peaks in June. Port samplers examining catches from the Western Scotian Shelf and Gulf of Maine have observed Cusk in spawning condition as early as March (G. Donaldson, DFO port sampler, pers. comm.). No spawning aggregations were evident. This may be due to a cessation of feeding during spawning, making them not vulnerable to bottom longline gear.

Cusk are among the most fecund fish (Bigelow and Schroeder 1953). Oldham (1966) reported a range in fecundity of 100,000 eggs in a 56cm fish to 3,927,000 eggs in a 90cm fish. The buoyant eggs are 1.3-1.5mm in diameter with a pinkish oil globule. Hatched pelagic larvae are about 4mm long and migrate to the bottom when they have grown to approximately 50mm in length.

DIET

In the Northwest Atlantic, the diet of Cusk is not well known as their stomachs generally evert when they are brought to the surface (Scott and Scott 1988, Bergstad 1991). An examination of 22 stomachs of Cusk from the Georges Bank, Gulf of Maine, and Scotian Shelf regions of the North Atlantic revealed that crustaceans (approximately 51%), including isopods, amphipods, euphausids, decapods, echinoderms (approximately 15%), and various bony fishes (approximately 15.5%) made up the predominant diet items (Bowman et al. 2000). Maurer and Bowman (1975) examined Cusk stomachs from the shelf waters of Cape Hatteras to Nova Scotia and found that fish were the main diet item (71.9%), while crustaceans (20.4%), and echinoids (6.5%) were also of importance. Langton and Bowman (1980) found that diet items of Cusk collected from various regions in the North Atlantic varied among regions: in Western Nova Scotia, fish comprised 98.2% of the diet; the Georges Bank samples contained Brittle Stars (80%), and the Toad Crab, *Hyas coarctatus* (20%); and the largest sample of Cusk came from the Gulf of Maine where the primary prey were crustaceans (90.6%), mainly several shrimp species, with the remainder of the diet consisting of fish (4.2%), and other smaller groups such as brachiopods, and animal remains. Data from various DFO surveys in North Atlantic Fisheries Organisation (NAFO) divisions 4VWX5 between 1999 and 2008 (n=158) indicate that crustaceans (44.6%), primarily decapods comprised of various crab species and krill species; various fish species (44.7%), Silver Hake comprising 9.5%; and molluscs (10.11%), primarily Short-Fin Squid (9.7%), are the main components of Cusk diet in these regions. Polychaetes, echinoderms, and cnidarians made up less than 0.7% of the remainder of the diet in this area (A. Cook, unpublished data). Similarly, surveys of Cusk diet in the Aktivneset and Sørmannsneset located at the continental break off Southwestern Norway indicated that crustaceans, fish, and poylchaetes were the three primary diet items (Husebø et al. 2002). Bait studies have revealed that in pots, Cusk have preferred squid over fish bait when Mackerel (Bjordal 1983) or Herring (Furevik and Lokkeborg 1994) were used.

PREDATORS

There is no evidence to suggest that Cusk are a major prey item for any Northwest Atlantic species. Cusk have, on occasion, been found in the diets of Cod (*Gadus morhua*), Atlantic Halibut (*Hippoglossus hippoglossus*), Greenland Halibut (*Reinhardtius hippoglossoides*), Blue Shark (*Prionace glauca*) (A. Cook, unpublished data), Grey Seals (*Halichoerus grypus*) (Bowen et al. 1993) and Windowpane Flounder (*Scophthalmus aquosus*) (Bowman et al. 2000).

BAROTRAUMA

There is a high frequency of barotrauma (injury of a body part or organ as a result of changes in barometric pressure) in Cusk. Symptoms include everted stomach, blistering, and protruding eyes, and, internally, damage to the organs including the liver. It has been assumed that this will result in high mortality even when fish caught by fishing gear are returned to the water alive. Based on a visual assessment of fish condition during a special sampling project, around half of the Cusk bycatch in LFA 34 (49%) and 86% of the Cusk bycatch in LFA 41 were considered dead or moribund. This estimate included fish that were alive with their stomach everted. A map of LFA boundaries is found in Figure 5.

Research on barotrauma of Pacific species has revealed that the factors affecting stomach eversion rates in fish include: the original gas volume at depth, swim bladder thickness (which affects permeability, elasticity, and rate of healing), temperature change, and depth at capture. Fish that show high degrees of stomach eversion, as do Cusk, generally do not exhibit swim bladder tears or ruptures and can often recover if re-pressurized quickly (Tallack 2012). Further study is required to determine mortality rates of discarded Cusk in order to get more accurate fishing mortality. It is also recommended that the effectiveness of recompression tools and techniques for Cusk be investigated.

MONITORING

There are no surveys dedicated to sampling Cusk. The annual DFO bottom-trawl research vessel survey data are not considered a reliable index of abundance because the survey does not adequately sample Cusk's preferred habitat and depths, and uses inappropriate gear to sample Cusk (DFO 2004a, DFO 2008a). The Halibut Industry Survey, a bottom longline survey that samples 4VWX and parts of 3OPs has been accepted as an abundance index for Cusk (DFO 2004a, DFO2008b, Harris and Hanke 2010, Harris et al. 2012). Bottom longline gear is effective for sampling Cusk due to the species' preference for rocky bottom and its habit of hiding in crevices (Oldham 1972). This is demonstrated by the commercial fishery; over 90% of landings were made by the bottom longline fleet (Table 1). The survey generally runs annually from May 22nd to June 22nd. It includes a fixed station and a commercial index component. Unfortunately, not all fixed stations were sampled in all years, which reduced the number of stations to be used in the indices. Catch weights rather than numbers are available because most species caught, though weighed, are not routinely counted. The survey began with a pilot year in 1998, and has run every year from 1999 to present. It does not provide any information from the period of higher Cusk abundance in the 1980s.

Consisting of approximately 300 fixed stations with a stratification scheme based on landings information, the survey runs annually from May to July. On average, 200 are completed each year. Fishermen follow fishing protocols, including rules on minimum distance from a station (3 nautical miles), hook-size (14 circle hook), number of hooks (1000), and preferred soak time (10 hours). During the same time as the survey, a Commercial Index Survey, which serves as a proxy for commercial fishing, is conducted. For the Commercial Index, fishermen fish with similar protocols as fixed stations but at locations of their choice.

THREATS

COMMERICAL FISHERY

Fishing is the only known major source of human-induced mortality on Cusk in Atlantic Canada. Overfishing is identified as the most important threat to Cusk in the 2012 COSEWIC status report, specifically the Atlantic Cod, Haddock, Pollock, and Atlantic Halibut fisheries (primarily bottom longline). Between 2002 and 2012, annual Cusk landings from Maritimes, Newfoundland and Gulf regions have ranged from minimum landings of 317.3, 1.1, and 0.0mt to maximum landings of 817.5, 7.6, and 0.5mt, respectively (Table 1). Most landings are from the groundfish longline fleet, accounting for over 95% In the Maritimes Region and over 90% in Newfoundland and Labrador. On average, 73% of reported landings are from 4X and 19% from NAFO Subarea 5 for the 2002-2013 period.

Cusk caught in groundfish fisheries can be legally landed and sold. Since 2002, DFO management measures for Cusk include limits on bycatch in several NAFO divisions for both fixed and mobile fishing gear (Table 2). Fixed gear trip limits have been established since 2003 and state that for fixed gear in NAFO divisions 4VWX, Cusk catch is not to exceed 25% of the round weight of the directed species and the trips' landings shall not exceed 4,000lbs round weight at any time. For fixed gear In NAFO Division 5Z, Cusk shall not exceed the lesser of 15% of the amount of Cod, Haddock, and Pollock combined onboard the vessel or 3000 pounds round weight. In an effort to keep landings from further surpassing the bycatch cap, Cusk closures were implemented in some years. Area closures were issued in 2003, 2007, and 2008 when the bycatch cap for a given area has been reached by the licensed vessel classes in that area (Table 3). For years in which Cusk closures were implemented, unreported fishing mortality of Cusk due to discarding is considered to be very likely (DFO 2008a). Cusk discards have been estimated based on at-sea observer data. No closures were issued from 2004 to 2006 and since 2008 to present.

In the Maritimes Region, most landings are from the groundfish bottom longline fleet, accounting for 95%, on average, of the total reported landings from 2002 to present (Table 1 and Figure 6). Catches by trawlers are low (Table 1) due to Cusk's behaviour of hiding in crevices and their preferred rocky habitat (Oldham 1972). Gillnet catches are also low, possibly due in part to the fish's sedentary nature. The majority of reported Cusk landings were from NAFO Division 4X (72%), followed by 5Y (20%). Landings from other areas were small, representing less than 8% of the total (Figure 2). The reported Cusk landings for the 2012 fishing year from the MARFIS database was 462mt (Table 1).

Discards have been estimated using observer data. The discard rates were extrapolated to represent total discards in a given fishery (Clark et al. 2015 and Gavaris et al. 2010). Combined discards for 4X5Y groundfish bottom longline, bottom trawl, and redfish bottom trawl was estimated to be 5.81mt in 2011 (Table 4, Clark et al. 2015). The three years that Cusk closures were implemented to keep landings from further surpassing the bycatch cap were, as one might expect, the years of highest observed discarding (Table 4). Since 2009, the bycatch cap for fixed gear has not been met (Tables 1 and 2) and the estimated discards (Table 4) were much lower. The number of trips with very large landings of Cusk is also less than in the past (Figures 7a-b and 8a-b). The mode in both 4VWX (Figure 7a-b) and 5Z (Figure 8a-b) Cusk landings has been decreasing from 2003 to 2012, as well as fewer trips with landings greater than 1000kg.These changes may indicate that the fishing fleet is avoiding Cusk areas in order to keep catches low. Discarding may also contribute to the reduction in landings. The extent of this practice is not known.

Since 1999, Cusk caught in other fisheries, such as lobster and crab pot and trap fisheries, cannot be legally kept and must be discarded. The Cusk bycatch for 2009 in LFA 41 was estimated at 5.3mt (Pezzack et al. 2014). The 2006/2007 estimate of bycatch in LFA 34 was 344mt (Harris and Hanke 2010). Discards in other additional invertebrate fisheries such as Shrimp and Scallop can be found in Tables 4 and 5 (Clark et al. 2015 and Gavaris et al. 2010). Particular estimates should not be construed as definitive or accepted uncritically (Clark et al. 2015). There is some mortality of Cusk that are not landed due to the barotrauma they suffer when brought to the surface and also to the practice, by some, of using them as bait rather than returning them to the water.

Cusk are also caught in small amounts in other parts of Atlantic Canada. The 2012 landings for Cusk in Newfoundland and Labrador were 1.88mt, of which 93% was caught by bottom longline and the remainder by bottom trawl and gill net. The majority of these landings are from 3Ps.

On occasion Cusk are caught in the Gulf of St. Lawrence, but abundance in this area is considered very low as they are rare in fishing and survey data. The highest annual reported landings in that area was in 2010 when 41kg for all trips combined, longline and bottom trawl. The 2012 Cusk reported landings were 25kg, caught by bottom longline gear.

Threats were prioritized in a threats table prepared for the single population of Cusk, following the requirements laid out by Fisheries and Oceans (DFO 2014a) (Table 2). The impact that commercial fisheries may have on the Cusk population is related to whether the fish are found in the area where the fishery occurs, the likelihood that the gear will capture Cusk, and the level of effort. In areas where there are little or no Cusk, the fishery will have no impact on the Cusk population.

Based on landings records and discard estimates, respectively, groundfish longline and lobster pots are considered the greatest threats.

FOOD, SOCIAL, AND CEREMONIAL FISHING

Currently, there is only one Food, Social, Ceremonial (FSC) licence that has a Cusk allocation for 2013/2014. No Cusk were harvested in 201/2012 or 2012/2013 under this license. There were no reports of Cusk bycatch under any other FSC licenses. This may reflect a lack of reporting rather than an absence of any catch.

INFORMATION TO UPDATE THE POTENTIAL FOR RECOVERY

ASSESS CURRENT/RECENT SPECIES/STATUS

1. Update Present Status for Abundance and Range and Number of Populations

This section has been combined with directly below (2. Update recent species trajectory for abundance).

2. Update Recent Species Trajectory for Abundance (i.e., Numbers and Biomass Focusing on Mature Individuals) and Range and Number of Populations

Abundance

There is no reliable abundance estimate for Cusk.

Commercial catch rates for Cusk have declined since the 1980s. Management measures (e.g., trip limits, overall caps, and bycatch percentages) may have contributed to this reduction in catch rates (and landings); however, it is thought the decline in CPUE is also due to a decline in Cusk abundance (Harris and Hanke 2010). The extent of the decline in abundance is not known. The Halibut Industry Survey, which began after the decline in commercial CPUE was observed, has fluctuated without trend since 1999. This suggests that any decline has stabilized.

The Reference Points for Cusk under the Precautionary Framework were set at Upper Stock Reference (USR)=26.6kg/1000 hooks and Limit Reference Point (LRP)=13.3kg/1000 hooks in the Halibut Industry (Figure 9, Harris et al. 2012). The 3-year geometric mean was accepted as the metric for monitoring Cusk status relative to the USR and LRP (Harris et al. 2012). The mean Cusk CPUE from the Halibut Industry Survey has been at or above LRP for the last 7 years. The 3-year geometric mean (2011-2013) of the Cusk CPUE is 17.9kg/1000 hooks, which suggests that the stock is in the Cautious Zone. A high level of uncertainty is indicated by the wide confidence interval (Figure 9, DFO 2014b).

Range

There is no evidence of a reduction in the range of Cusk. Anecdotal information suggests that localized depletions have occurred when ‘Cusk holes’ have been fished out. These areas are recolonized after several years with no fishing effort. Despite these localized depletions, Cusk are still caught in commercial fisheries and in the Halibut Industry Survey throughout their range from the Gulf of Maine, on the Scotian Shelf and Slope, to the Grand Banks of Newfoundland (Figures 2 and 4).

Number of Populations

There is no evidence of spatially separated populations of Cusk; rather, they seem to form one continuous distribution from the Gulf of Maine to the Grand Banks. Little is known of their life history, and no studies have been undertaken to compare Cusk caught in different areas. The larval data from the Scotian Shelf Ichthyoplankton Program indicate one continuous spawning period from May to July or August and, thus, do not suggest recruitment pulses of multiple spawning components. Genetic studies of Cusk in the North Atlantic have not found population differentiation of Cusk in Canadian waters. In addition, Cusk habitat areas in Canadian waters are not disrupted by deep water basins or troughs (> approximately 1000m) thus allowing for genetic mixing and homologous population structure. Cusk are assessed as a single unit in this report. There is no evidence of a change in number of populations of Cusk.

3. Estimate, to the Extent that Information Allows, the Current or Recent life-History Parameters (Total Mortality, Natural Mortality, Fecundity, Maturity, Recruitment, etc.) or Reasonable Surrogates, and Associated Uncertainties for all Parameters

Fecundity

Cusk are considered to be quite fecund, with reports of 100,000 to 3,927,000 eggs from a 56- and 90cm fish, respectively (Oldham 1972). Eggs are buoyant, the pelagic larvae are about 4mm in length when hatched, and larvae migrate to the bottom when they reach approximately 50mm in length.

Growth

Radiocarbon bomb dating methods have been used to estimate the age of Cusk from Canadian waters (Harris and Hanke 2010). This ageing effort has returned older age estimates, including an 82cm fish aged at 39 years (the longest reported Cusk from Canadian waters is 118cm). These new ageing data also suggest that Cusk may reach maturity at 10 years in contrast to previous estimates of 5-6 years. These results are more consistent with ageing results from the Northeast Atlantic.

Oldham (1972) found that males do not grow faster than females although they mature more rapidly. He reported lengths at which 50% of the specimens were mature as 43.5cm for males and 50.7cm for females.

These efforts to age Cusk are continuing. Ageing Cusk from sectioned otoliths has proven to be difficult. Current efforts are yielding results consistent with the bomb radiocarbon dated otoliths. However, there is still further ageing and testing to be conducted before there is enough confidence in the ageing method to develop a growth curve that can be used.

Generation Time

Assuming natural mortality of 0.2, 10yr + 1/0.2 = 15 years.

4. Estimate Expected Population and Distribution Targets for Recovery, According to DFO Guidelines (DFO 2005 and 2011a)

Population Targets for Recovery

The Upper Stock Reference Point of 26.6kg/1000 hooks in the Halibut Industry Survey is the proposed population recovery target. This USR was calculated as 80% of the proxy for Maximum Sustainable Yield, the average of the commercial CPUE from the period of higher catch rates (1986-1992) in the commercial fishery.

Distribution Targets for Recovery

There is no evidence for a reduction in the area occupied by Cusk. A reasonable recovery target would be to maintain current distribution.

ASSESS THE HABITAT USE

5. Provide Functional Descriptions (as Defined in DFO 2007b) of the Required Properties of the Aquatic Habitat for Successful Completion of all Life-history Stages

Background

A Species Distribution Model (SDM) of Cusk has been used to help understand Cusk's habitat preferences and to provide a prediction suitable habitat. SDMs use species occurrence data and environmental variables to create a spatially explicit prediction of species distribution or habitat suitability. Unless biological variables are also included, SDMs assume that environmental variables are the most important predictors of species distribution patterns. A limitation of SDMs (which is a similar limitation of mapping in general) is that mapping is often based on insufficient data, and involves interpolation and extrapolation. Input data and methods used should be scrutinized to ensure reliable output maps (Kostylev 2002).

This application was part of a test case for a DFO National Species at Risk project, to assess species distribution modeling as a tool to identify important habitat for Species at Risk (SAR). Results will be compiled with those of Dutil et al. (2013) who assembled a variety of tools that could be used to identify important habitat of SAR.

There have been previous attempts to model Cusk distribution in the region to understand the probability of loss or gain of habitat with climate change (Shackell et al. 2014). Shackell et al. (2014) used depth and temperature as predictors of suitable Cusk habitat. However, their analysis used data from the DFO Ecosystem Survey; a survey which is known to avoid Cusk's preferential habitat. Cusk are expected to prefer some of the most rugged bottom terrain, where benthic trawls irregularly sample due to the risk of gear damage.

Hare et al. (2012) also provided a SDM of Cusk over the Gulf of Maine using bottom temperature and bottom ruggedness as predictors of Cusk habitat. Depth was available but excluded from their model as it was expected to be an indirect predictor of Cusk habitat. A model used by Hare et al. (2012) was applied at a coarse scale and used the Northeast Fisheries Science Centre (NEFSC) survey data, which, similar to the DFO Ecosystem Survey data, does not sample Cusk's preferential habitat.

Methods

Three SDM methods were chosen to analyze Cusk distribution, including a General Additive Model (GAM), maximum entropy model (Maxent), and random forest (RF) model. Models were run with both presence/absence and catch data. However, only one RF presence/absence model will be discussed at length within this document. A comparison of the three model types is in preparation for publication.

Models results were used to:

- help understand the habitat preferences of Cusk summarized in the text and;
- develop a spatially explicit prediction of suitable Cusk habitat, and determine important long-term habitat areas, discussed in coordination with mitigation closure scenarios.

Statistical Methods

Several studies have shown that RF models often reach top predictive performance compared to other methods (e.g., Cutler et al. 2007). The RF method (Breiman 2001) is an ensemble learning technique based on a combination of a large set of decision trees. Each tree is trained by selecting a random set of variables and a random sample from the training dataset (i.e., the calibration data set). Three training parameters need to be defined in the RF algorithm: *ntree*, the number of bootstrap samples for the original data (the default is 500); *mtry*, the number of different predictors tested at each node (which in this case can be 19 at most); and *nodesize*, the minimal size of the terminal nodes of the trees, below which leaves are not further subdivided. RF was implemented using the random forest package in R with the default values of *ntree*=500, *mtry*=6, and *nodesize*=5. To cross-validate, training and testing data were created by random sampling (without replacement) using k-fold data partitioning from the *dismo* library in R.

Response Variable

Fishery dependent and independent data were combined (Figure 10) to form the Cusk response variable. This variable was created using Cusk groundfish longline data (kg/1000 hooks; Figure 11a), Halibut Industry Survey data (kg/1000 hooks; Figure 11b) and zero catches from the Ecosystem Survey data (abundance/tow; Figure 11c). The random forest algorithm in R was limited in the amount of data it could analyze; therefore, data were resampled and the algorithm was run multiple times (Figure 12).

Groundfish longline data included the years 2002 to 2013 (28,386 records). These data varied in month landed from January to December, with the most frequent month being August. Data expected to be erroneously recorded were removed from the analysis before aggregation; specifically, effort amounts less than 500 hooks (11,328 of 39,854 samples = 28%) and catches per unit effort greater than 2500 (140 of 28,525 = 0.4%).

The Halibut Industry Survey data included the years 1998 to 2013 (3565 records). These data varied in month sampled from May to October, with the most frequent months being June and July.

Data from the DFO Ecosystem Survey, from the years 1970 to 2013 (15,573 records), were also included. This survey is not generally expected to sample preferential Cusk habitat, as the survey avoids complex rocky habitat. Cusk do show up in the survey occasionally, in a general pattern of what is expected to be their actual distribution; however, the survey does not sample German Bank and the Western Portion of the Northeast Channel, which are expected to be the most preferred Cusk habitat in the region. The survey does, however, provide a good distribution of absence values that can be used to effectively model the absence portion of the distribution of Cusk. Therefore, records with a catch of zero were extracted and combined with the other data (8,481 records).

Sampling effort is expected to vary between the Ecosystem Survey, groundfish longline, and Halibut Industry Survey data. If only fishery-dependent groundfish longline data were used in the RF model, the model may over-predict presences on the eastern shelf due to a few erroneously recorded latitude and longitude records, as there is little to no fishing in most areas on the eastern shelf. Fishery-dependent groundfish longline data are also biased in their spatial distribution. Cusk are caught as bycatch and, therefore, fisherman have targeted fishing grounds with higher landings of commercial species such as Pollock, Haddock, Halibut, and White Hake. Using the Ecosystem Survey data alone in the model could over predict absences. Absences are not expected to be over predicted using the combined datasets unless there are areas of high Cusk catch not fished by the groundfish longline industry or sampled in the Halibut

Industry Survey data. This is not expected, due to the pattern of Cusk found in the Ecosystem Survey data, which is expected to be a good general representation of Cusk's actual distribution. However, as mentioned above, it excludes the areas of highest abundance of Cusk catch including German Bank and the Western Northeast Channel. Similarly, the Halibut Industry Survey data does not sample Cusk's most preferential habitat (German Bank and the Western Northeast Channel).

Predictor Variables

Oceanographic and physical variables for the Scotian Shelf were assembled over the Scotian Shelf). Environmental variables included in the analysis were cropped to the extent -68, -54, 41.0, 46 degrees and aggregated or resampled to 1.0km resolution. The original spatial resolution and time period of input environmental variables varied (Table 6). Of the assembled layers, only those that best corresponded to the timeframe of the majority of the response variable (approximately 2000 - 2013), and those that were expected to provide the most reliable data were selected.

Occasionally overlapping time periods could not be obtained and historical data had to be used, which was the case for many of the benthic modeled oceanographic variables (temperature and salinity). Optimally estimated oceanographic variables for current time periods were included in a previous analysis to determine whether current interpolated (optimal estimation) oceanographic variables had more predictive power than historical modeled variables (including data from 1912 to 1991). Historical modeled variables showed more predictive power (M. Greenlaw, unpublished data[1]), likely due to the limited temporal and spatial sampling of temperature and salinity data across the shelf. Therefore, the assumption was made that historically modeled temperature and salinity should be used over interpolations of oceanographic conditions during the time period of the biological response variable.

Salinity was removed from the assembled variables. This variable was removed due to a correlation > 0.7 with other variables included in the analysis. To choose between variables, a ranking procedure was used. The correlated variable was removed if it had a probability of selection < 0.8 in the presence/absence RF analysis (using the AUCRF variables selection routine in R); if it was pelagic vs. benthic; or if it was seasonal vs. annual. When applying a GAM model to Cusk presence/absence data, Hare et al. (2012) also found that annual average salinity was a weak or non-significant predictor. Environmental variables were imported into R as rasters and processed in WGS84 UTM Zone 20. Biological samples were only included in the analysis if they intersected with all of the environmental variables.

Results and Discussion

The RF presence/absence model explained 45% of the deviance in Cusk distribution, with an area under the receiver operating characteristic (AUC:ROC) of 0.88. The AUC describes the relationship between the proportion of observed presences correctly predicted (sensitivity) and the proportion of observed absences incorrectly predicted (1-specificity). Therefore, a model that predicts perfectly will generate an AUC of 1, while model with predictions that are no better than random will generate and AUC of 0.5.

[1] Greenlaw, M.E., C. Fuentes-Yaco, Q.M. McCurdy, and G.N. White III. 2013. A Geodatabase of Oceanographic Datasets for Habitat Mapping and Species Distribution Modeling on the Scotian Shelf. (unpublished data)

Most of the error was associated with the prediction of Cusk was at locations where they were not observed (e.g., over-prediction; Table 7; Figure 10). This result is expected for a species that is depleted in abundance and for a model that only partially defines the niche space (Hare et al. 2012).

The maximum probability of presence was predicted in the outer German Bank area, the western Northeast Channel, Roseway Bank, and the northern area above La Have Basin (Figure 10). Roseway Bank and upper La Have Basin do not currently have high landings values comparable to other areas with high presence probabilities, and could represent a portion of the species niche that has been depleted. However, the RF model only includes presence/absence data and appears to simply predict this area as a high probability of encountering Cusk (few absences), whereas landings may not be as abundant. To determine if this portion of the niche has been depleted over time, a time series of groundfish longline landings or Ecosystem Survey abundance data could be used to analyze the variance in catch over time in these regions.

Cusk occurrences were confined to regions with specific oceanographic conditions. These variables are expected to have both indirect and direct relationships on Cusk distribution patterns. Indirect predictors are related to resources or regulators and, therefore, correlate with species distributions, but they may be easier to measure than direct predictors. Examples are latitude, longitude, depth, slope angle, and exposure. Ideally, variables describing direct and resource gradients would always be used in species distribution models. However, when only variables describing indirect gradients are available, it is important not to extrapolate the model results beyond the range of conditions used to develop the model.

The six most prominent environmental variables influencing Cusk habitat suitability, ranked over the random forest model (Figure 13), were, Root Mean Square (RMS) current stress, average annual chlorophyll ’03-12’, winter total suspended matter ’06-’10, fall benthic temperature, average annual total suspended matter ’06-10’, and annual salinity variability. Partial plots representing the marginal effect of the six most important variables on predicted habitat suitability of Cusk are shown in Figure 14. Partial plots depict the log of the fraction of votes on the y-axis, which can be thought of as the log of the presence probability.

Cusk were more prevalent in areas with medium RMS current stresses (Figures 14 and 15a). This is a classic response predicted by the intermediate disturbance hypothesis, where species are more tolerant of physical disturbance within the mid-range along the gradient of a variable. However, areas of high current stress may also generally be areas with high turbidity. This could help explain the relationship to total suspended matter, if it is not a physiological response. The total suspended matter variable may be more spatially resolved than the modeled RMS current stress variable as it is derived from remote sensing data. Cusk were also negatively correlated to areas of very low current stress, which are areas that could be more stratified, and could have fewer nutrients on the bottom.

Cusk were less prevalent in coastal areas with higher suspended matter (Figure 15c and e), which corresponds to areas in the Bay of Fundy, and nearshore areas with higher tidal range. It is unknown whether this is a direct physiological relationship to high turbidity, or if there is a changing community composition that influences the availability of food sources for Cusk in areas with higher turbidity and decreasing light. This result may explain why Cusk are rarely found in the Bay of Fundy, despite otherwise favourable conditions.

Overall temperature characteristics indicate that Cusk are averse to temperatures below 3°C, and above 10°C. Of the temperature variables, fall temperature had the most significant relationship to Cusk distribution with a preference between 6 and 10.5 degrees (Figures 14 and 15d). The range of fall temperatures analyzed was between 0 and 13°C. Annual average temperature was the tenth most important variable. Cusk were more prevalent in areas with annual average temperatures between 3.5 and 8.5°C and had a higher preference for annual temperatures between 5 and 6°C, and 7 and 8.5°C. The range of annual average temperature analyzed was between 0 and 10°C. These responses confirm previous findings that Cusk are restricted to waters greater than 4°C (Oldham 1972, Hare et al. 2012). At the other end of their range, Cusk have shown an aversion to temperatures higher than 12°C (Hare et al. 2012). Hare et al. (2012) noted that the November to December period was when “preferred” temperature was the most spatially limited in the North Atlantic, indicating that Cusk may not be capable of capitalizing on the seasonal expansion of habitat into shallower and more southern portions of the region in colder months. Hare et al. (2012) also noted that this is consistent with information suggesting that Cusk have small home ranges, and limited movement capabilities.

Cusk were also more prevalent in areas with a low or high annual range in benthic salinity; a bimodal response curve (Figure 14). Higher salinity ranges corresponded to the banks on the western Scotian Shelf (Figure 15). It is unlikely that the response to annual range in benthic salinity is a physiological relationship, since the species is averse to areas within the mid-range along the gradient of salinity variability; and biologically, a bimodal relationship is unlikely. It is more likely that this variable is an indicator of certain oceanographic conditions found within water masses associated with the Gulf of St. Lawrence outflow, and areas of tidal mixing and upwelling. These conditions could be highly related to a variable that physiologically influences Cusk, or influences the distribution of their food sources (although analyses indicate that Cusk are generalists (A. Cook, unpublished data)). Cusk are absent in the Bay of Fundy, which has high salinity variability, but also high total suspended matter, which Cusk were also negatively correlated with.

Cusk generally have been considered a deep water species (DFO 2008a) although, based on our analyses, Cusk seem more likely to be a depth generalist, i.e. they have a large depth suitability range, even though depth is considered an indirect predictor of habitat. Cusk habitat was within depths from 0 to 1500m. Cusk were prevalent in depths from 50 to 375m, and more prevalent in depths between 200 to 375m. The highest CPUEs were found between 50 and 375m (Figure 16). There were landings records that would be considered very deep: 92 records from the groundfish longline landings data were above a depth of 1000m, 33 above a depth of 1200m, and 11 above 1400m. However, it is likely that some of these landings records are erroneous due to poor positioning data, as there were also values recorded on land and at depths above 1500m. In previous analyses of Cusk depth preferences, Hare et al. (2012) found that Cusk were likely to occur at depths ranging from 74 to 719m. Bergstad (1991) found that Cusk were caught up to depths of 600m in the Norwegian Deep. In their longline surveys, Hareide and Garnes (2001) found that Cusk were caught to depths of 1100m at 2 locations, on the Reykjanes Ridge and on the Hecate Seamount. At these sampling stations, catches were highest at 700m, 1000m, and 600m, respectively. The highest average catch (684.1kg/1000 hooks) for the three Rekjanes Ridge and Hecate Seamount areas combined was at a depth 1000m in the mid-Atlantic. Cusk were among the most numerous of species caught in the 3 locations sampled. In the Halibut Industry Survey off Nova Scotia and Newfoundland, the largest set of Cusk (907kg) was caught at approximately 560m.

Benthic complexity was expected to be one of the most important predictors of Cusk habitat. Cusk have shown a preference for hard, rocky bottom or gravel (Svetovidov 1948, Bigelow and Schroeder 1953, Oldham 1972, Scott and Scott 1988, Colette and Klein-MacPhee 2002) and have been observed hiding in crevices (Hovland and Judd 1988, Freiwald et al. 2002, Jones et al. 2009). It was expected that high benthic complexity would be a predictor of complex rocky habitat. Benthic complexity ended up sixteenth in importance. However, evidence from locations where the Scotian Shelf Ecosystem Survey net has torn, indicates that Cusk are landed in some of the most rugged bottom terrain, where the groundfish survey irregularly samples (Figure 17). This confirms that even though bottom complexity was not one of the most significant variables, the complexity variable in the model is likely not adequate to determine complexity of the bottom. It is expected that areas near the northeast channel and Roseway Bank are highly complex, which do not show up as complex areas in the benthic complexity variable. This might have been expected, given the sparse Canadian Hydrographic Service (CHS) depth data in many locations where Cusk are present. In the future, the accuracy of this variable is expected to increase through the help of the CHS. In fact, currently there are attempts to incorporate a variety of other multibeam data into the depth and benthic complexity models. Another variable that would reflect rocky habitat is an offshore substrate interpretation, similar to the one being developed for the coastal zone (M. Greenlaw et al. unpublished[2]).

In previous years of the Species at Risk National Project, Dutil et al. (2013) proposed a standardized methodology to describe important habitat of species at risk. Available date was used from the annual research surveys overlaid onto classified benthic habitats using a principal component analysis (megahabitats). Also investigated was the kernel density contours, Hot Spot, and Cold Spot analysis, area of occupancy, and statistics on the proportion of each of these products within the megahabitat clusters. Finally, multiple forward linear regression was used to understand the importance of explanatory environmental variables. Species Distribution Model alleviates the needs for the disparate methods used by Dutil et al. (2013), as it produces a spatial prediction of the important habitat while also providing an understanding of the importance of the different explanatory variables. Species distribution models, such as random forest, are also non-parametric and can account for non-linear relationships with variables in comparison to multiple linear regression. Species distribution models also assume that the environment is a better predictor of the species of interest in contrast to the distance form observed values. For some species, environment will not be a good predictor of species distribution. Including latitude and longitude in these models will account for this, by predicting based on distance to the other observed values; however, in this case, kernel density estimates would also be an appropriate tool for mapping expected distribution.

6. Identify the Activities Most Likely to Threaten the Habitat Properties that Give the Sites Their Value, and Provide Information on the Extent and Consequences of These Activities

Habitat does not appear to be, nor is likely to become, a limiting factor to Cusk survival and recovery. There are no known threats that have reduced Cusk habitat quantity or quality.

In the habitat preference analyses, the variables that were the best predictors of Cusk distribution were total suspended matter, depth, current stress, salinity variability, and bottom temperature. From the literature, substrate, and benthic complexity are thought to be important features of Cusk habitat. Future climate change and large-scale activities that would alter the seabed are the only potential threats to the functional properties of Cusk habitat. The effects of these potential threats are unknown and difficult to predict.

Cusk have a fairly generalized diet. It is not known how the development of a large-scale fishery directing for or capturing any of these species as bycatch may compromise Cusk's ability to

[2] Greenlaw, M.E., C. Fuentes-Yaco, Q.M. McCurdy, and G.N. White III. 2013. A Geodatabase of Oceanographic Datasets for Habitat Mapping and Species Distribution Modeling on the Scotian Shelf. (unpublished data)

feed. Given the variety of prey items, Cusk are likely less vulnerable than species with a more specialized diet.

SCOPE FOR MANAGEMENT TO FACILITATE RECOVERY

7. Assess the Probability that the Recovery Targets can be Achieved Under Current Rates of Parameters for Population Dynamics, and How that Probability Would Vary with Different Mortality (Especially Lower) and Productivity (Especially Higher) Parameters

Cusk recovery to abundance levels in the 1980s should be achievable, assuming there has been no major decrease in productivity. Elevated natural mortality is believed to have decreased productivity of other gadiforme populations in Atlantic Canada such as Atlantic Cod (Swain and Chouinard 2008, DFO 2011b) and White Hake (Swain et al. 2012). Past or present natural mortality of Cusk is not known. A dramatic increase in natural mortality would negatively influence Cusk's ability to reach a recovery target.

Despite recent reductions in the bycatch cap (since 2008 the bycatch cap has been at about half of what is was in 2002), the Halibut Industry Survey index shows no increase in Cusk abundance (Figure 10). This is not surprising since the elapsed time represents approximately half of a generation for Cusk.

Cusk are slow-growing and do not reach maturity until about 10 years of age, which will likely influence time to recovery. Other long-lived, late-maturing species have not demonstrated recovery after one or more generation times. Sadovy (2001) reported that an analysis of 90 stocks of gadids, flatfishes, sparids, and scombrids revealed that after a cessation of fishing for 15 years following reductions of 45-99%, the reproductive biomass' recovery was slower than predicted by theory. Hutchings and Reynolds (2004) looked at Scorpaenidae populations 5 and 15 years after a decrease in fishing mortality and found that after 5 years there was still greater than a 70% decline and that after 15 years it had dropped to just over 60%. Species such as redfish that are slow-growing, long-lived, and late maturing may not show changes in population recovery for one to several generations (Devine and Haedrich 2011). Since the reductions in catch in response to more stringent management measures have only been seen since 2008 or 2009 (Tables 1 and 4) and Cusk generation time is approximately 15 years, it is unlikely that any increases in Cusk abundance would be in evident in the Halibut Industry Survey abundance index at this time.

8. Quantify to the Extent Possible the Magnitude of Each Major Potential Source of Mortality Identified in the Pre-COSEWIC Assessment, the COSEWIC Status Report, Information from DFO Sectors, and Other Sources

Commercial Fishing

The most recent landings estimate for a full fishing year is 2012. The fishing year begins April 1st and runs until March 31st the following year. For example, the 2012 fishing year would run from April 1, 2012, to March 31, 2013. The Cusk reported landings for the 2012 fishing year in Maritimes region was 462.2mt (Table 1). The 2012 Cusk landings for the Gulf Region and Newfoundland and Labrador region are to be 0.043mt and 1.88mt, respectively.

Cusk caught in other fisheries, such as Lobster, crab pot and trap fisheries, are discarded. The Cusk bycatch for 2009 in LFA 41 was estimated at 5.3 mt (Pezzack et al. 2014). Combined discards for 4X5Y groundfish bottom longline, bottom trawl, and redfish bottom trawl was estimated to be 5.81mt in 2011 (Table 4, Clark et al. 2015). Discards in other invertebrate fisheries such as shrimp and scallop can be found in Tables 4 and 5 (Clark et al. 2015 and Gavaris et al. 2010). Particular estimates should not be construed as definitive or accepted uncritically (Clark et al. 2015).

Food Social and Ceremonial Fishing

No Cusk landings or discards were reported in 201/2012 or 2012/2013 under a Food, Social, Ceremonial (FSC) license.

Threats Assessment

The mortality rate of discarded Cusk is thought to be high due to the high rate of barotrauma they suffer when brought to the surface. Whether Cusk can survive barotrauma has not been studied. The practice of using Cusk as bait rather than returning them to the water will also contribute to mortality.

For species assessed as Extirpated, Endangered or Threatened by COSEWIC, assessment and prioritization of threats to survival and recovery of the species needs to be provided in the RPA. A threats table was prepared for the single population of Cusk, following the requirements laid out by Fisheries and Oceans (DFO 2014a and Appendix A). The threats table can be found in Table 6. Threats were ranked based on landings and discard data. The bottom longline fishery had the highest number of Cusk landings. Although there are many unknowns associated with the lobster fishery, the discard rate of Cusk is still high compared to other fisheries.

SCENARIOS FOR MITIGATION AND ALTERNATIVE TO ACTIVITIES

9. Using Input from all DFO Sectors and Other Sources as Appropriate, Develop an Inventory of all Feasible Measures to Minimize/Mitigate the Impacts of Activities that are Threats to the Species and its Habitat (Steps 18 and 20)

- Elimination of the retention of Cusk in commercial fisheries; however, given the expected high post-release mortality associated with catching Cusk, the impact of this measure on Cusk abundance is unknown.

This is not considered to be an exhaustive list of possible mitigation measures. A tabular depiction of the mitigation inventory for Cusk can be found in Appendix B. No alternatives to activities have been considered.

10. Using Input From all DFO Sectors and Other Sources as Appropriate, Develop an Inventory of all Reasonable Alternatives to the Activities that are Threats to the Species and its Habitat (Steps 18 and 20)

- Elimination of the retention of Cusk in recreational or FSC fisheries; however, catches are thought to be low and the impact is unlikely to be significant.

This is not considered to be an exhaustive list of possible mitigation measures. A tabular depiction of the mitigation inventory for Cusk can be found in Appendix B. No alternatives to activities have been considered.

11. Using Input from all DFO Sectors and Other Sources as Appropriate, Develop an Inventory of Activities that Could Increase the Productivity or Survivorship Parameters (Steps 3 and 17)

- Closing areas of high Cusk abundance or areas where Cusk is the main species caught to groundfish longline fishing and/or lobster fishing. Figures 18 and 19 shows the areas associated with the 80th and 90th percentile of Cusk commercial longline landings. The amount of Cusk, Atlantic Cod, Haddock, and Atlantic Halibut caught in the 2012/2013 fishing year are in Tables 9 and 10, as is the ratio of Cusk to the other species.
- The development and implementation of Cusk handling and release protocols to maximize post-release survival.
- Increased at-sea observer coverage in the groundfish longline fishery in NAFO divisions 4X5Y.
- Routine at-sea observer coverage in the lobster fishery.
- One hundred percent dockside monitoring for the groundfish fixed gear fleet authorized to use vessels less than 45' in NAFO Division 4VsW and 4X5Y.

This is not considered to be an exhaustive list of possible mitigation measures. A tabular depiction of the mitigation inventory for Cusk can be found in Appendix B. No alternatives to activities have been considered.

12. Estimate, to the Extent Possible, the Reduction in Mortality Rate Expected by Each of the Mitigation Measures in Step 21 or Alternatives in Step 22 and the Increase in Productivity or Survivorship Associated With Each Measure in Step

- Implementation of an avoidance/move-away protocol as a condition of license in fisheries that catch Cusk (e.g., after catching some amount of Cusk/trip, must pull up gear and move a specified distance away).

This is not considered to be an exhaustive list of possible mitigation measures. A tabular depiction of the mitigation inventory for Cusk can be found in Appendix B. No alternatives to activities have been considered.

ALLOWABLE HARM ASSESSMENT

13. Evaluate Maximum Human-induced Mortality Which the Species can Sustain and not Jeopardize Survival or Recovery of the Species

No major potential sources of non-lethal harm have been identified at this time and are not thought to be a concern. The only known major source of human-induced mortality is fishing mortality.

There are inadequate data to quantify the maximum human-induced mortality that Cusk can sustain and not jeopardize survival or recovery. It is believed that the stock can recover from human-induced mortality as it has been withstanding fishing pressure with no appreciable trend in recent years. The Halibut industry Survey indicates that Cusk population status is in the cautious zone (Figure 4) and has been for 7 years. Because Cusk are slow-growing and late to mature, this current period reflects responses to past management measures. It would stand to reason that if the Cusk population is stable in response to the exploitation from past years, it should be able to sustain the current reduced levels of mortality without jeopardizing survival or recovery.

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TABLES

Table 1. Cusk landings (mt) by fishing year, NAFO Division, and gear type from 2002 to 2013. Data are from MARFIS (Maritimes) and Commercial Data Division (NL). Landings from the Gulf region were not included in this table, as the total did not exceed 1.0mt. Zero landings were reported under the 'Misc" gear type in Newfoundland Region, so a column was not included in the table.

Fishing Year	Gillnet					Longline					Otter Trawl					MISC**				Grand Total
	NFLD	Maritimes			Gillnet Total	NFLD	Maritimes			Longline Total	NFLD	Maritimes			Otter Trawl Total	Maritimes			Misc Total	
	3NOP	4VW	4X	5YZE		3NOP	4VW	4X	5YZE		3NOP	4VW	4X	5YZE		4VW	4X	5YZE		
2002	0.1	0.5	12.0	0.6	13.2	3.2	94.8	820.8	309.5	1228.4	0.1	0.7	35.6	1.6	38.0	0.0	3.1	0.0	3.2	1282.7
2003	0.2	0.2	11.8	0.6	12.9	3.8	68.0	646.6	304.5	1023.0	0.1	0.6	26.4	0.8	27.9	0.0	3.4	0.1	3.5	1067.2
2004	0.2	0.1	5.7	0.4	6.4	2.3	68.3	454.7	256.1	781.2	0.1	1.8	30.1	0.2	32.2	0.0	0.6	0.0	0.6	820.5
2005	0.1	0.2	5.4	0.3	6.0	0.8	50.2	602.7	119.9	773.7	0.2	0	22.7	1.0	23.9	0.0	1.1	0.0	1.1	804.7
2006	0.3	0.3	4.2	0.1	4.9	7.2	32.2	575.5	152.9	767.8	0.1	0.7	18.5	2.3	21.7	0.0	3.3	0.0	3.3	797.6
2007	0.0	0.7	5.0	0.5	6.2	4.5	52.1	746.2	131.8	934.7	0.0	0.2	15.4	0.8	16.4	0.0	0.5	0.0	0.5	957.7
2008	0.0	0.3	4.0	0.9	5.1	2.9	46.8	441.8	49.5	541.0	0.0	0.1	16.5	0.2	16.7	0.0	0.3	0.1	0.3	563.1
2009	0.0	0.2	4.0	1.5	5.8	2.5	36.6	400.1	75.1	514.4	0.1	0.7	24.7	0.6	26.1	0.0	0.1	0.0	0.1	546.3
2010	0.3	0.1	5.5	9.2	15.1	3.1	28.8	319.5	58.4	409.8	0.0	0.1	16.7	0.9	17.7	0.0	0.2	0.0	0.2	442.9
2011	0.0	0.1	7.1	2.6	9.9	3.3	33.1	291.7	88.7	416.8	0.0	0.0	18.4	1.9	20.3	0.0	0.1	0.0	0.1	447.0
2012	0.0	0.0	4.9	4.9	9.8	5.1	37.1	314.5	78.9	435.6	0.1	1.0	13.6	2.0	16.8	0.0	0.1	0.0	0.1	462.2
2013*	0.0	0.0	5.0	4.1	9.2	2.4	33.1	136.9	32.8	205.3	0.1	0.6	7.4	0.2	8.3	0.0	0.0	0.0	0.0	222.8
Grand Total	1.2	2.8	74.8	25.7	104.5	41.1	581.2	5751.0	1658.1	8031.4	1.0	6.6	246.0	12.3	265.9	0.0	12.7	0.2	12.9	8414.6

* Denotes incomplete data for that Fishing Year.

**Gear types qualified as "Misc" include midwater trawls, Scottish seine, and handline method.

Table 2. Cusk bycatch cap (mt) by fleet in NAFO Divisions 4X5, 4VW, and 4VWX5 for 2002 to 2013 inclusive. Fleet categories are: Fixed Gear less than 45 feet (FG<45), Fixed Gear from 45 to 65 feet (FG 45-65), and Mobile Gear less than 65 feet (MG <65).

	FG < 45	**FG < 45**	**FG 45-65**	**FG 45-66**	**MG < 65**
YEAR	**4X5**	**4VW**	**4X5**	**4VW**	**4VWX5**
2002	1000	125	100	20	25
2003	750	100	100	20	25
2004	750	100	100	20	25
2005	750	150	100	20	25
2006	550	70	65	13	20
2007	550	70	65	13	20
2008	500	70	35	13	20
2009	500	70	35	13	20
2010	500	70	35	13	20
2011	500	70	35	13	20
2012	500	70	35	13	20
2013	500	70	35	13	20

Table 3. Licensed quota cap closures for Cusk in years and NAFO Divisions where closures occurred. The fishing gear is broken into the following categories: Fixed Gear less than 45 feet (FG<45), Fixed Gear from 45 to 65 feet (FG 45-65), and Mobile Gear (MG).

Year	Start Date	End Date	NAFO Divisions	Gear
2003/2004	1-Dec-03	31-Mar-04	4VWX5	FG<45, FG 45-65 MG (individual)
2003/2004	12-Dec-03	31-Mar-04	4X 5	FG<45
2005	n/a	n/a	n/a	No closure
2006	n/a	n/a	n/a	No closure
2007/2008	26-Sep-07	31-Mar-08	4VWX5	FG<45
2008/2009	27-Sep-08	31-Mar-09	4VWX5	FG<45
2010	n/a	n/a	n/a	No closure
2011	n/a	n/a	n/a	No closure
2012	n/a	n/a	n/a	No closure
2013	n/a	n/a	n/a	No closure

Table 4. Cusk discards (kg) in 4X5Yb by fishery and year. Estimates were extrapolated from observer data to represent the entire fishery. A dash (-) represents no data. Estimates should not be construed as definitive or accepted uncritically. (From Clark et al. 2015)

Area	Fishery	2007	2008	2009	2010	2011
4X5Yb	Groundfish bottom longline	26,299	113,532	287	49	1,811
4X5Yb	Groundfish bottom trawl	252	-	-	2,141	25
4X5Yb	Groundfish bottom trawl offshore	-	34	-	-	20
4X5Yb	Redfish bottom trawl	-	-	53	591	3,952
4X5Yb	Redfish bottom trawl offshore	-	-	-	112	-

Table 5. Cusk discards (kg) for area, fishery and year. Estimates were extrapolated from observer data to represent the entire fishery. n/a represents no data. Particular estimates should not be construed as definitive or accepted uncritically. (From Gavaris et al., 2010)

Area	**Fishery**	**2002**	**2003**	**2004**	**2005**	**2006**
4VW	Jonah Crab trap	2,197	n/a	n/a	n/a	n/a
4VW	Groundfish bottom longline	n/a	131	n/a	4,311	n/a
4VW	Silver Hake bottom trawl	n/a	35	n/a	n/a	27
4VW	Shrimp bottom trawl	n/a	n/a	13	n/a	n/a
4X5Y	Groundfish bottom longline	n/a	565	n/a	n/a	n/a
4X5Y	Groundfish bottom trawl	n/a	n/a	3,040	141	n/a
4X5Y	Groundfish bottom trawl offshore	29	n/a	n/a	n/a	n/a
4X5Y	Lobster/Jonah trap offshore	13,130	11,758	20,133	16,445	9,057
4X5Y	Scallop dredge	n/a	89	n/a	n/a	n/a
4X5Y	Scallop dredge offshore	n/a	n/a	136	n/a	n/a
5Z	Groundfish bottom longline	n/a	13,209	8,050	n/a	27
5Z	Groundfish bottom trawl	13	254	n/a	n/a	21
5Z	Groundfish bottom trawl offshore	n/a	8	n/a	n/a	9
5Z	Lobster/Jonah trap offshore	5,835	8,084	n/a	33,744	13,255

Table 6. The compiled physical environmental variables (Stratification = temperature difference between 0m and 30m depth, MODIS = Moderate Resolution Imaging Spectroradiometer, MERIS = Medium Resolution Imaging Spectrometer, NOAA = National Oceanographic and Atmospheric Administration, SeaWiFS = Sea-viewing Wide Field-of-view Sensor).

Variable	Variable Name	Units	Resolution (m)	Data Source
Depth	depth	meters	50	Greenlaw et al. unpublished*
Complexity	compl	degree	50	Greenlaw et al. unpublished*
Benthic Current Stress	RMS	N/m^2	1127	Smith, 2005
Benthic Current Velocity	botcurr	cm/s	6800	Brickman Model
Stratification	strat	degree C	1000	Smith , 2005
Benthic Salinity Average	sal	psu	1000	Naimie et al., 1994
Benthic Salinity Variability	salvar	psu	1000	Naimie et al., 1994
Benthic Temperature Average	t	degree C	1000	Naimie et al., 1994
Benthic Temperature Variability	tvar	degree C	1000	Naimie et al., 1994
Benthic Temperature Summer	tsum	degree C	500	Naimie et al., 1994
Benthic Temperature Fall	tfall	degree C	500	Naimie et al., 1994
Benthic Temperature Winter	twin	degree C	500	Naimie et al., 1994
Benthic Temperature Spring	tspr	degree C	500	Naimie et al., 1994
CHL Case I 10 year annual average	chlmo03_12	mg/m^3	2000	MODIS
Sea Surface Temperature 10 year annual average	sst01_10	degree C	2000	NOAA
Primary Production 1 year annual average	pp2010	mgC/m^2/d	10000	SeaWiFS
Primary Production 5 year annual average	pp06_10	mgC/m^2/d	10000	SeaWiFS
Total Suspended Matter 5 year annual average	tsm06_10	log(g/m^3)	2000	MERIS
Total Suspended Matter 5 year seasonal average	wintsm-6_10	log(g/m^3)	2000	MERIS

- Greenlaw, M.E., C. Fuentes-Yaco, Q.M. McCurdy, and G.N. White III. 2013. A Geodatabase of Oceanographic Datasets for Habitat Mapping and Species Distribution Modeling on the Scotian Shelf. (unpublished data)

Table 7. Confusion matrix results from the Random Forest analysis.

	Cusk Absence Predicted	Cusk Presence Predicted	Class Error
Cusk Absence Actual	6537	1541	0.1907
Cusk Presence Actual	1321	5601	0.1908
Out of Bag Error 19%			

Table 8. Threats Table based on Cusk bycatch between 2002 and 2011. Where column names represent: Likelihood (L), Severity (S), Causality certainty (CC), Population threat risk (PTR), Population-level threat occurrence (PTO), Population-level threat frequency.

Fishery	L	S	CC	PTR	PTO	PTF	PTE
Bottom Longline	Known	Medium	Low	Medium	Current	Recurrent	Extensive
Lobster	Known	Low/ Medium	Low/ Medium	Low/ Medium	Current	Recurrent	Broad
Gillnet	Known	Low	Low	Low	Current	Recurrent	Restricted
Handline	Known	Low	Low	Low	Current	Recurrent	Restricted
Bottom Trawl	Known	Low	Low	Low	Current	Recurrent	Narrow
Scallop	Likely	Low	Low	Low	Current	Recurrent	Restricted
Shrimp	Likely	Low	Low	Low	Current	Recurrent	Restricted

Table 9. A summary of Cusk, Atlantic Halibut, Atlantic Cod, and Haddock landings (kg) from 2012/2013 within 7 boxes of Cusk habitat within the 80th percentile of catch weight and larger than 20km in length/width. The ratios of Cusk landings to landings of each fishery (Atlantic Halibut, Atlantic Cod, and Haddock) are also given. Ratios of the Cusk caught to the impact on each fishery can be used as a method as a method of prioritizing the boxes. A higher ratio equals more Cusk saved and less impact to fishery. The two highest ratios for each fishery are identified in bold.

Box	Cusk	Halibut	Cod	Haddock	Cusk/Halibut	Cusk/Cod	Cusk/Haddock
1	**90,489**	**10,729**	**84,892**	**39,659**	**8.43**	**1.07**	**2.28**
2	10,887	4,476	24,007	230,492	2.43	0.45	0.05
3	**34,878**	**5,553**	**24,149**	**268,192**	**6.28**	**1.44**	**0.13**
4	10,980	24,833	27,208	107,423	0.44	0.40	0.10
5	21,923	48,722	59,072	25,050	0.44	0.37	0.88
6	10,901	55,730	42,618	59,142	0.20	0.26	0.18
7	9,716	4,296	112,688	349,028	2.26	0.09	0.03

Table 10. A summary of Cusk, Atlantic Halibut, Atlantic Cod, and Haddock landings (kg) from 2012/2013 within 7 boxes of Cusk within the 90th percentiles of catch weight and larger than 20km in length/width. The ratios of Cusk landings to landings of each fishery (Halibut, Cod and Haddock) are also given. Ratios of the Cusk saved to the impact on each fishery can be used as a method as a method of prioritizing the boxes. A higher ratio equals more Cusk saved and less impact to fishery. The two highest ratios for each fishery are identified in bold.

Box	Cusk	Halibut	Cod	Haddock	Cusk/Halibut	Cusk/Cod	Cusk/Haddock
1	87,184	12,496	79,595	37,772	**6.98**	**1.10**	**2.31**
2	7,889	2,993	17,483	51,074	2.64	0.45	0.15
3	35,247	5,908	25,780	217,590	**5.97**	**1.37**	0.16
4a	1,788	4,287	3,518	8,716	0.42	0.51	0.21
4b	1,486	5,205	3,978	14,506	0.29	0.37	0.10
5	9,306	22,266	20,537	5,687	0.42	0.45	**1.64**
6	6,177	19,777	17,674	9,593	0.31	0.35	0.64
7	11,515	4,437	120,185	255,542	2.59	0.10	0.05

FIGURES

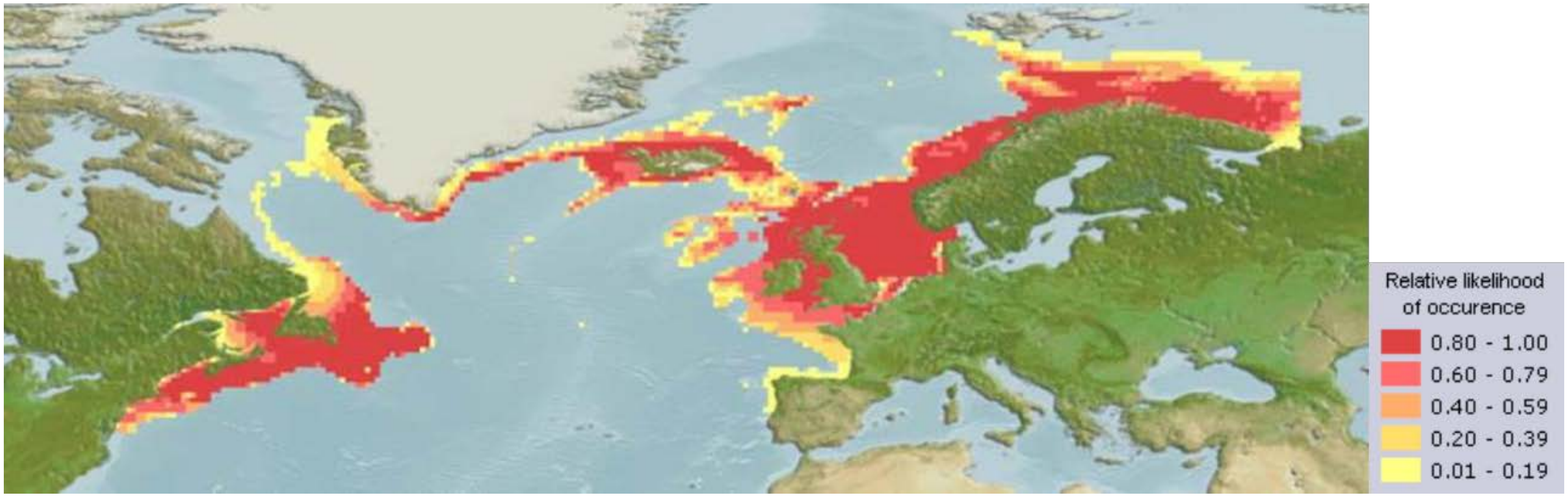


*Figure 1. Global distribution of Cusk (from [FishBase\)](). *

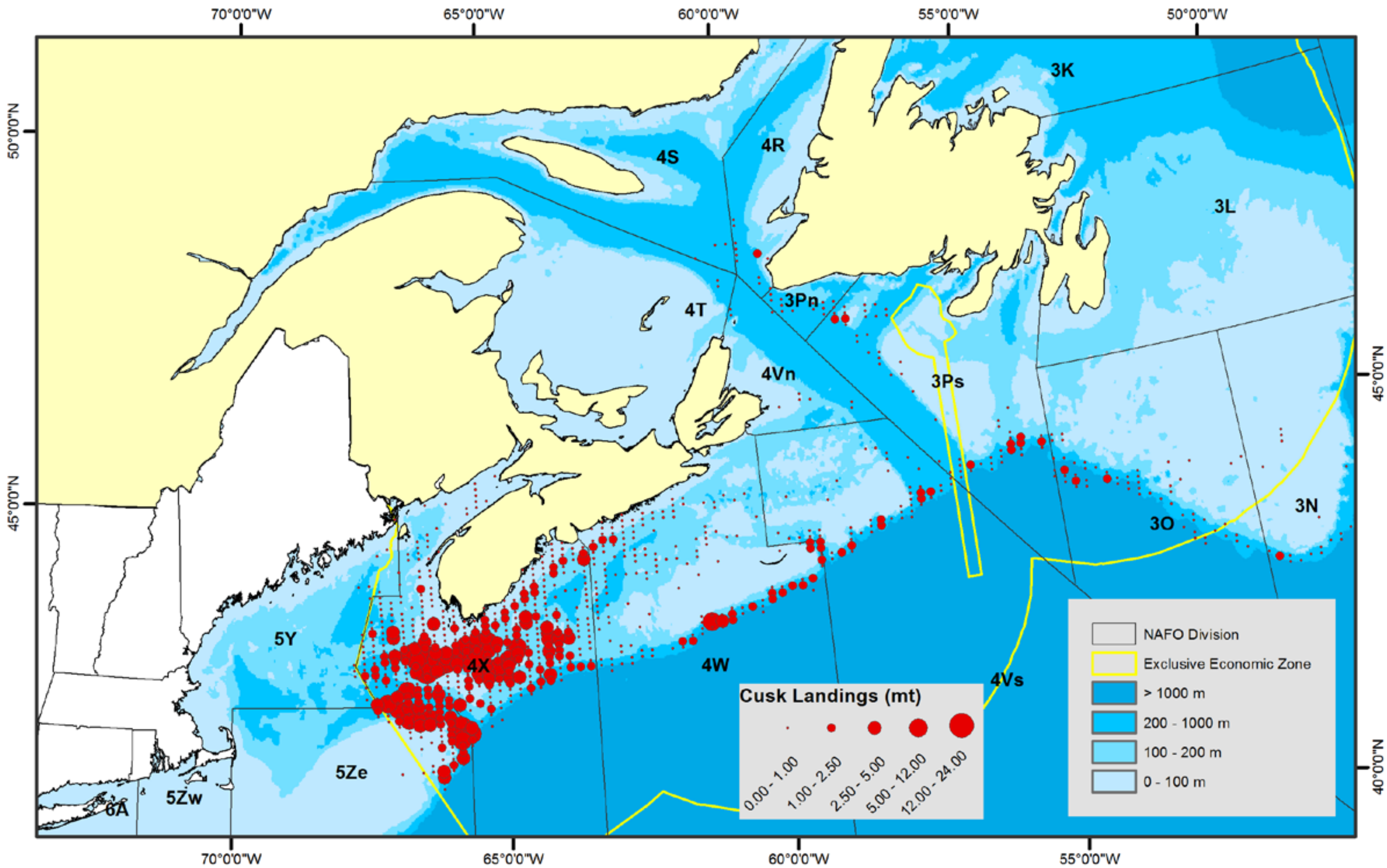


Figure 2. Cusk Landings between 2002 and 2013 on the Scotian Shelf and Grand Bank, overlaid on NAFO and Exclusive Economic Zone boundaries. Landings data were summed to 12km grid cells. Landings without lat/long information are not represented here, as well as landings that were reported to be on land or at a depth greater than 1100m. A total of 39.0mt (0.004%) are not represented in this figure.

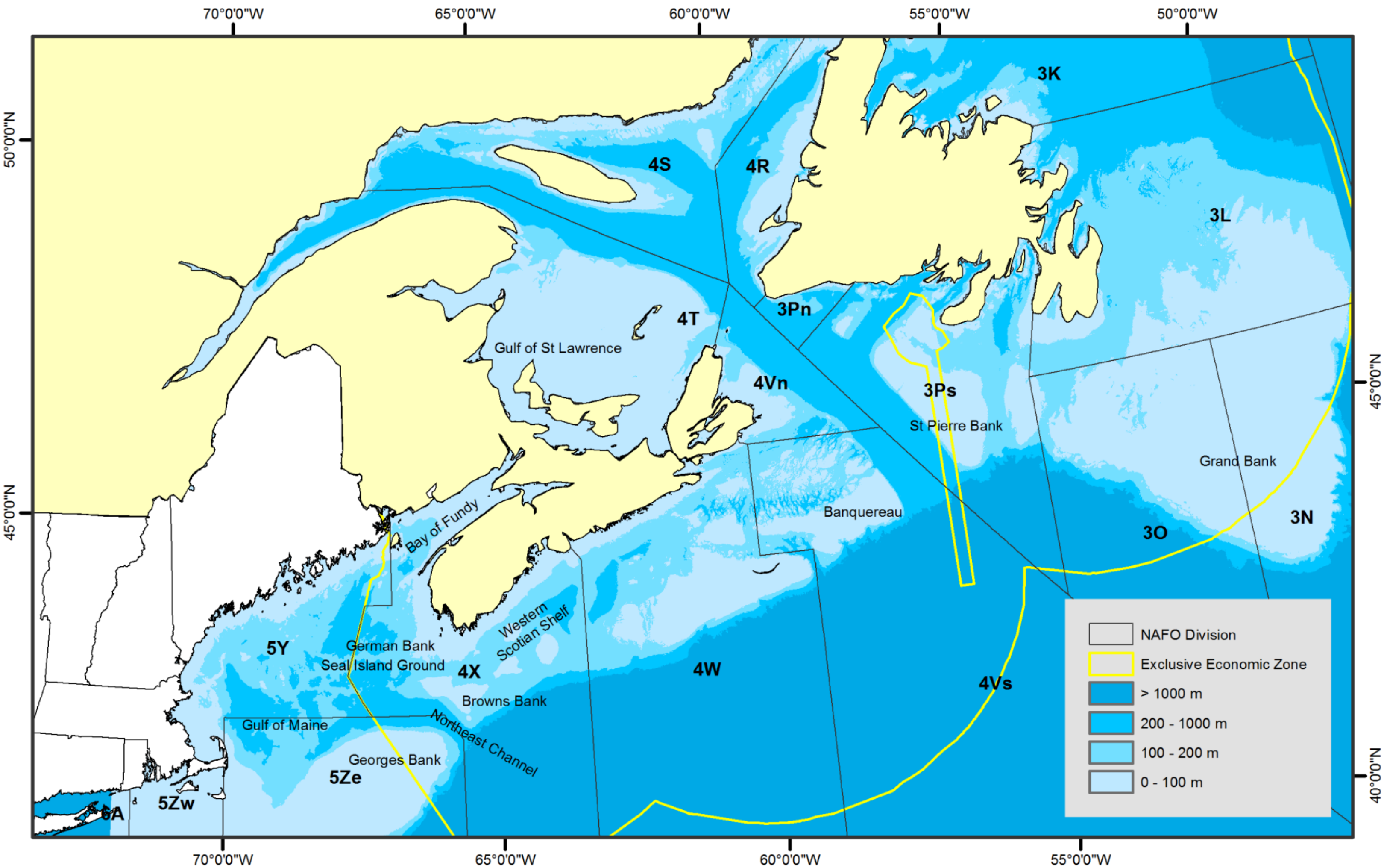


Figure 3. NAFO Divisions, Exclusive Economic Zone boundary, and oceanographic features on the Scotian Shelf and Grand Bank.

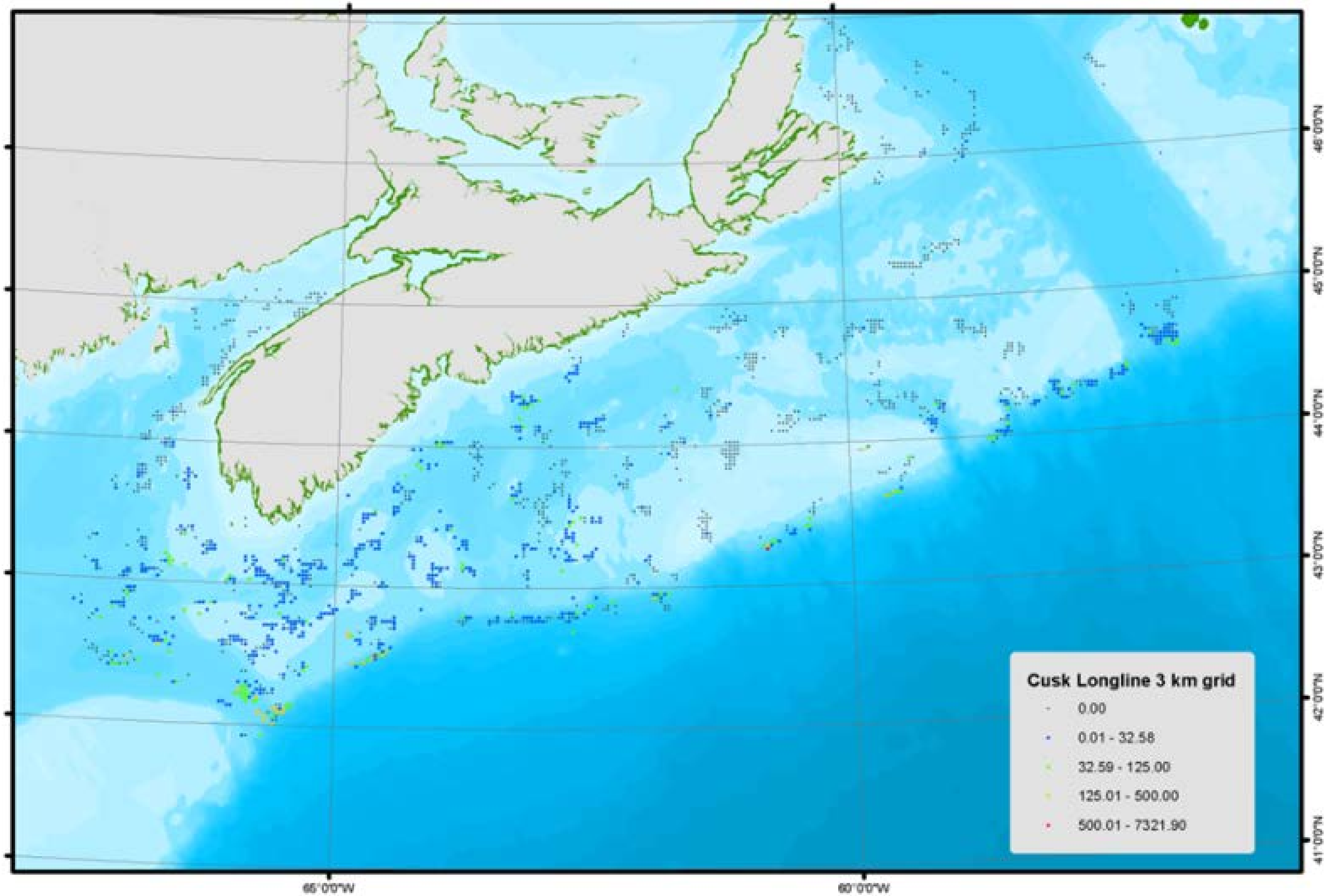


Figure 4. Cusk catches (mt) from Halibut survey from 2003 to 2012.

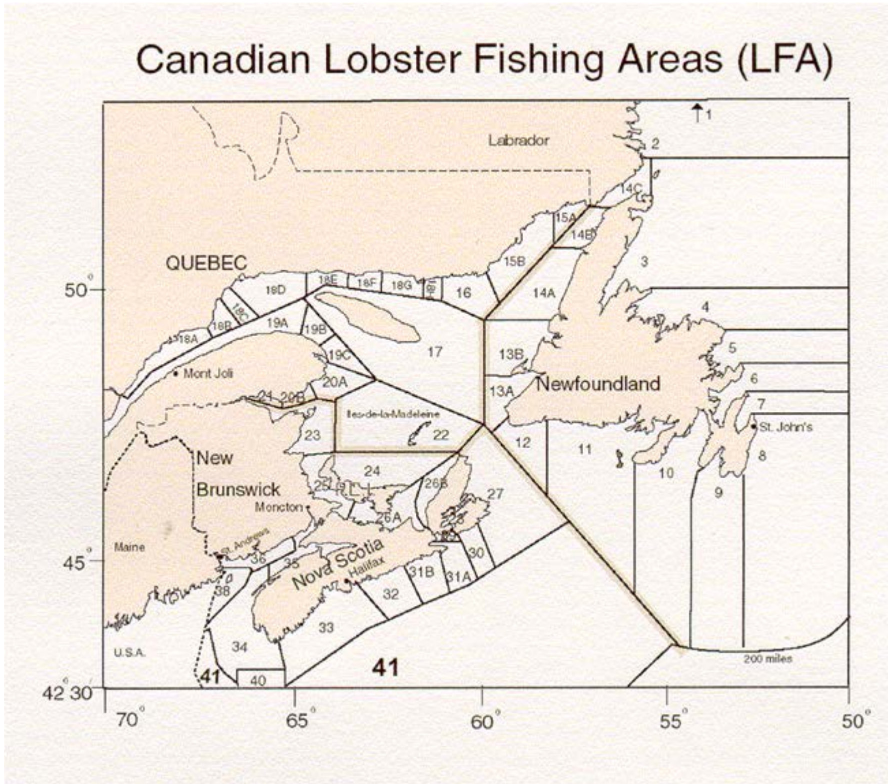


Figure 5. Lobster Fishing Areas (LFAs) in the Maritimes Region ([Offshore Lobster (LFA 41) Integrated Fishery Management Plan, Maritimes Region, 1999-2000](#)).

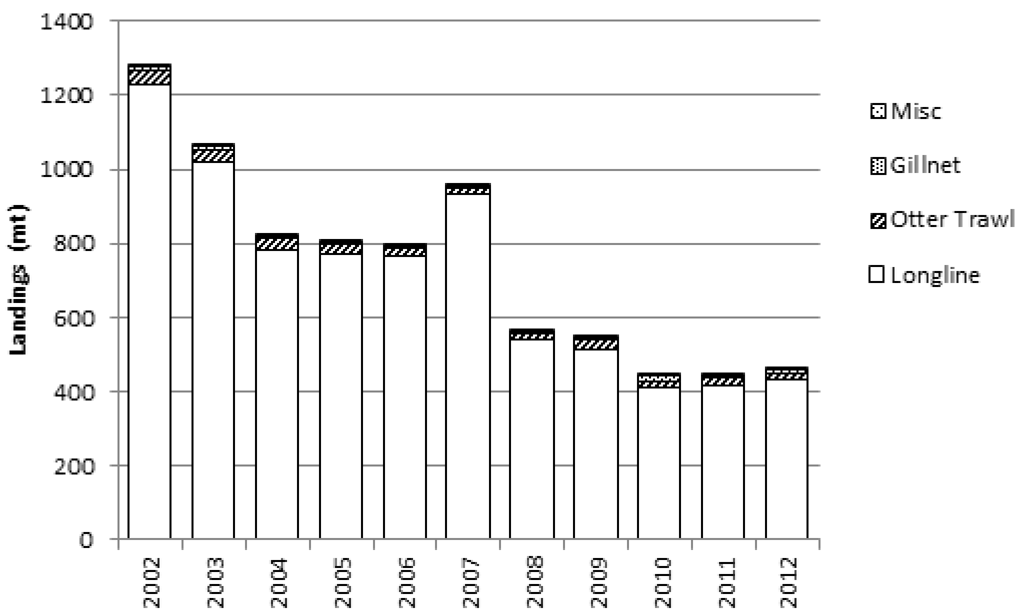


Figure 6. Cusk reported landings (mt) in 4VWX+5 by fishery. Data from MARFIS.

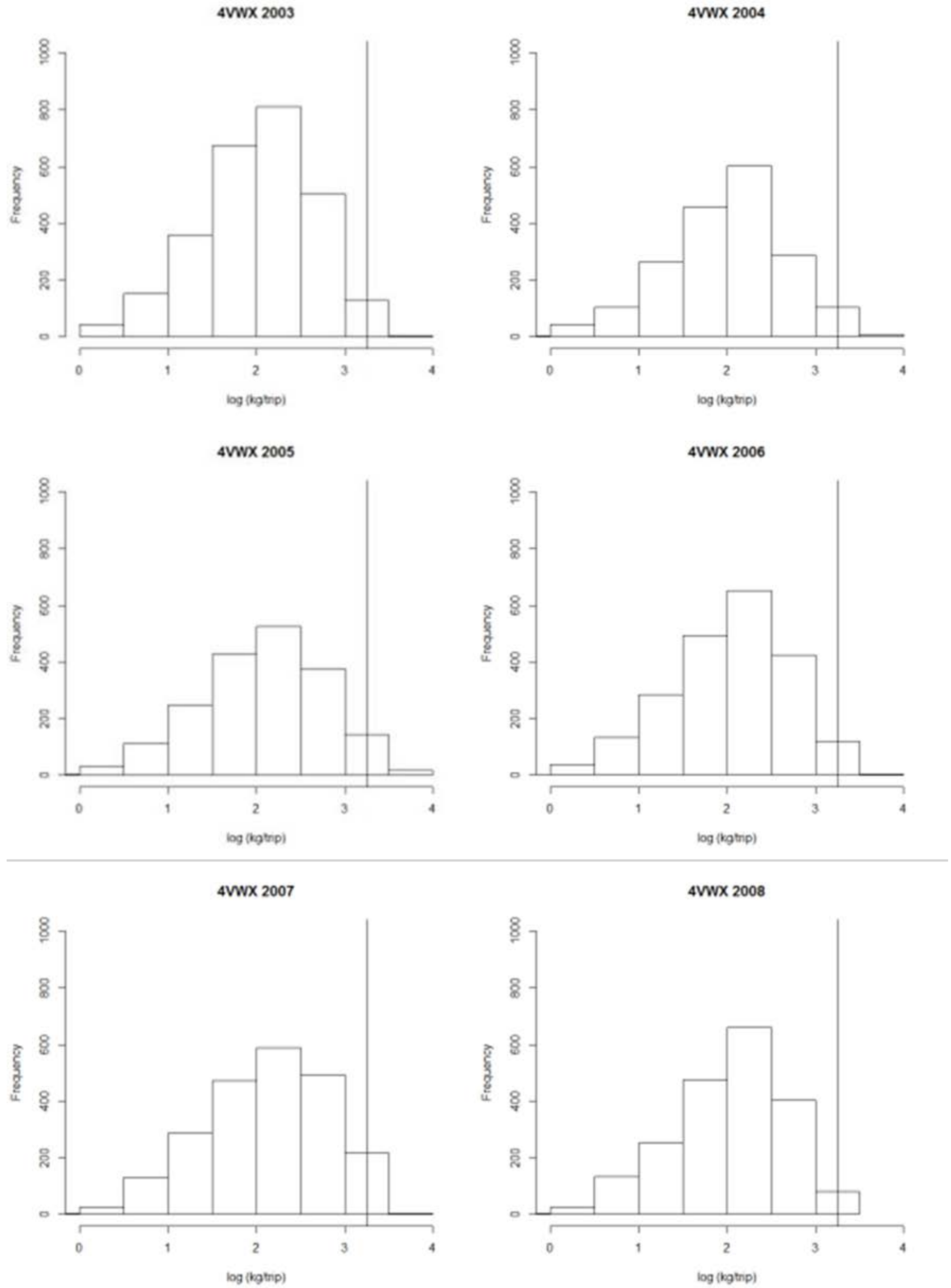


Figure 7a. Cusk caught per trip for NAFO divisions 4VWX using bottom longline gear from 2003 – 2008. Vertical line shows the 4VWX 4000 pound trip limit (1814kg).

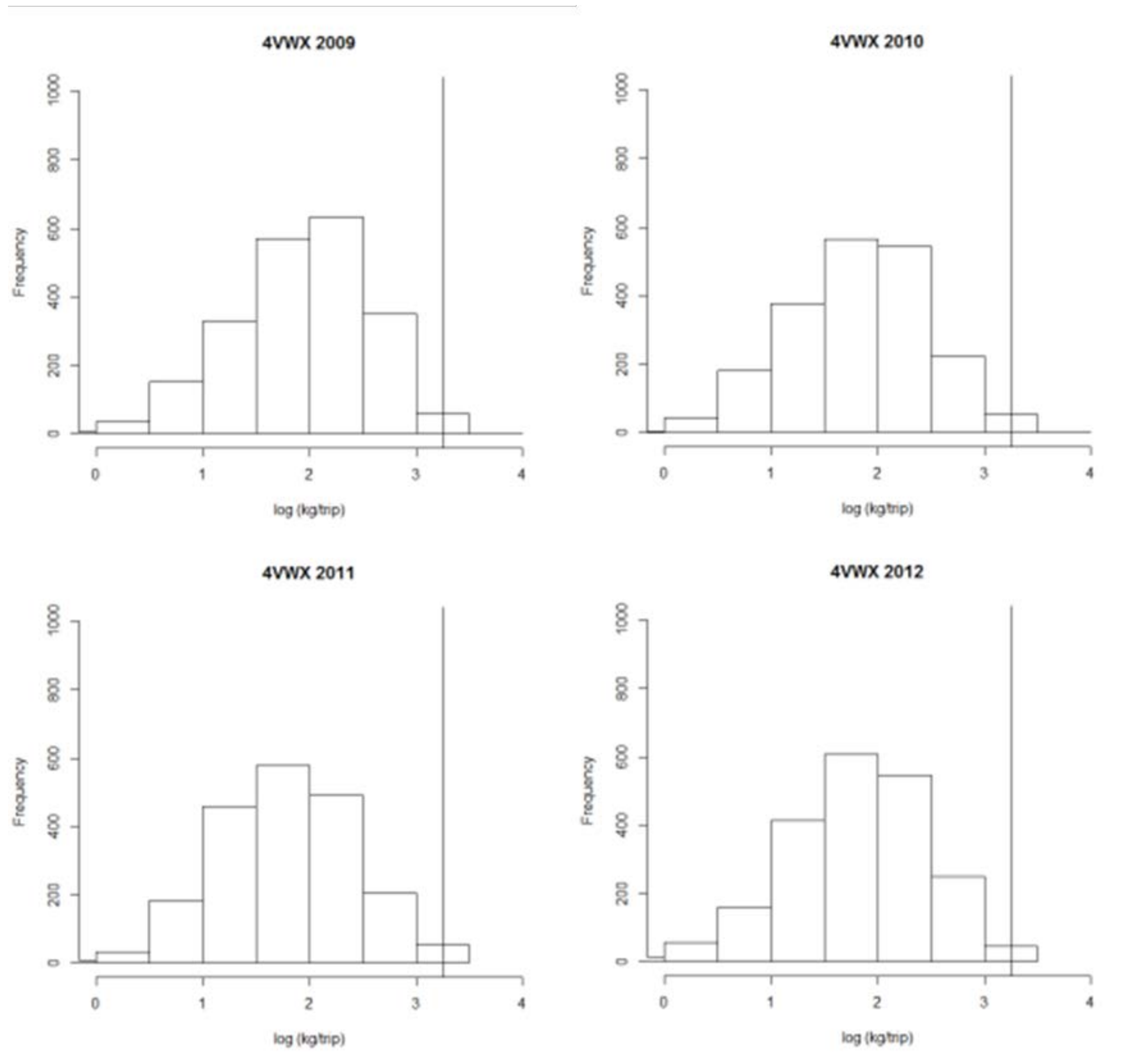


Figure 7b. Cusk caught per trip for NAFO Divisions 4VWX using bottom longline gear from 2009 – 2012. Vertical line shows the 4VWX 4000 pound trip limit (1814kg).

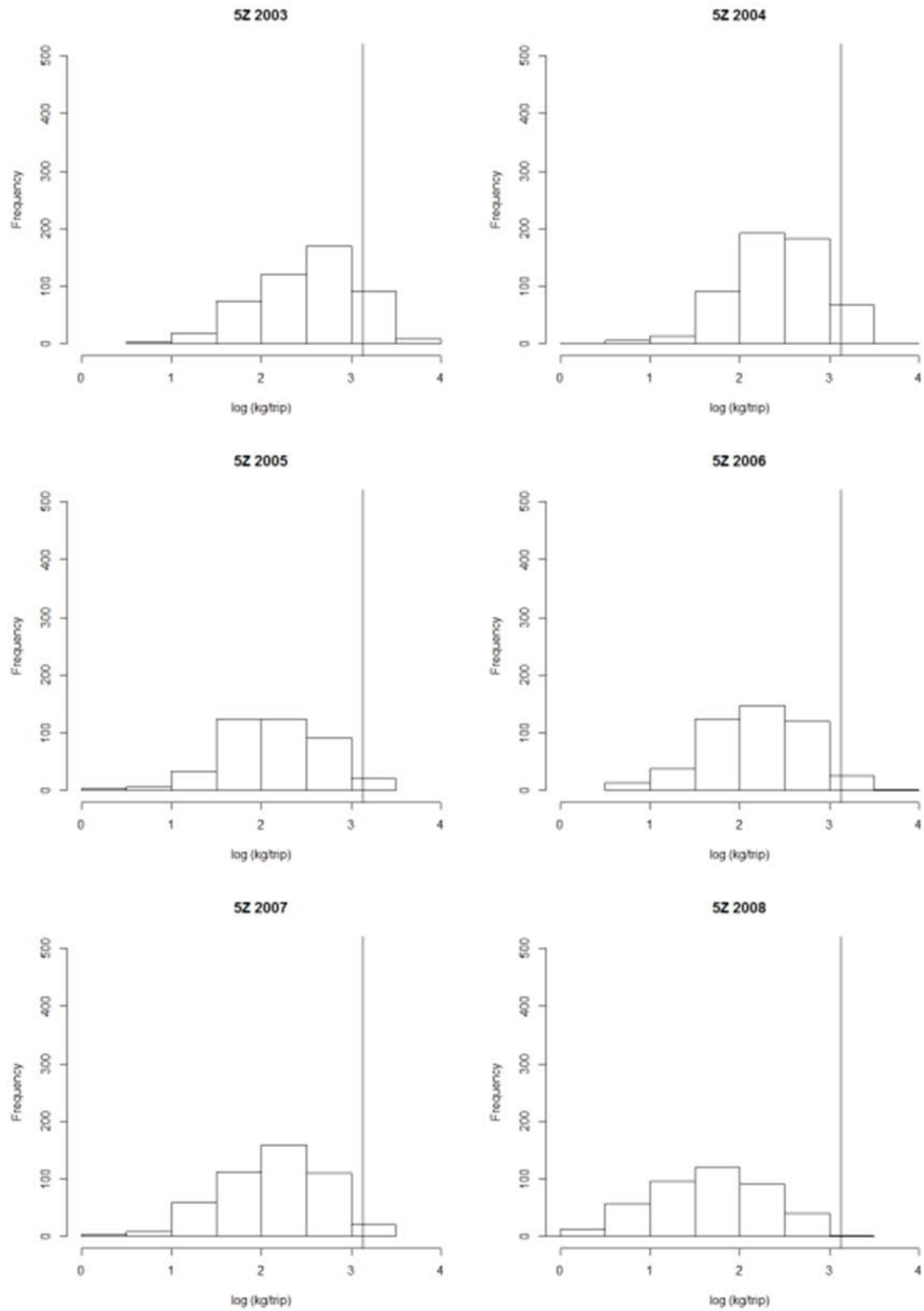


Figure 8a. Cusk caught per trip for NAFO Divsion 5Z using bottom longline gear from 2003 – 2008. Vertical line shows the 5Z 3000 pound trip limit (1360kg).

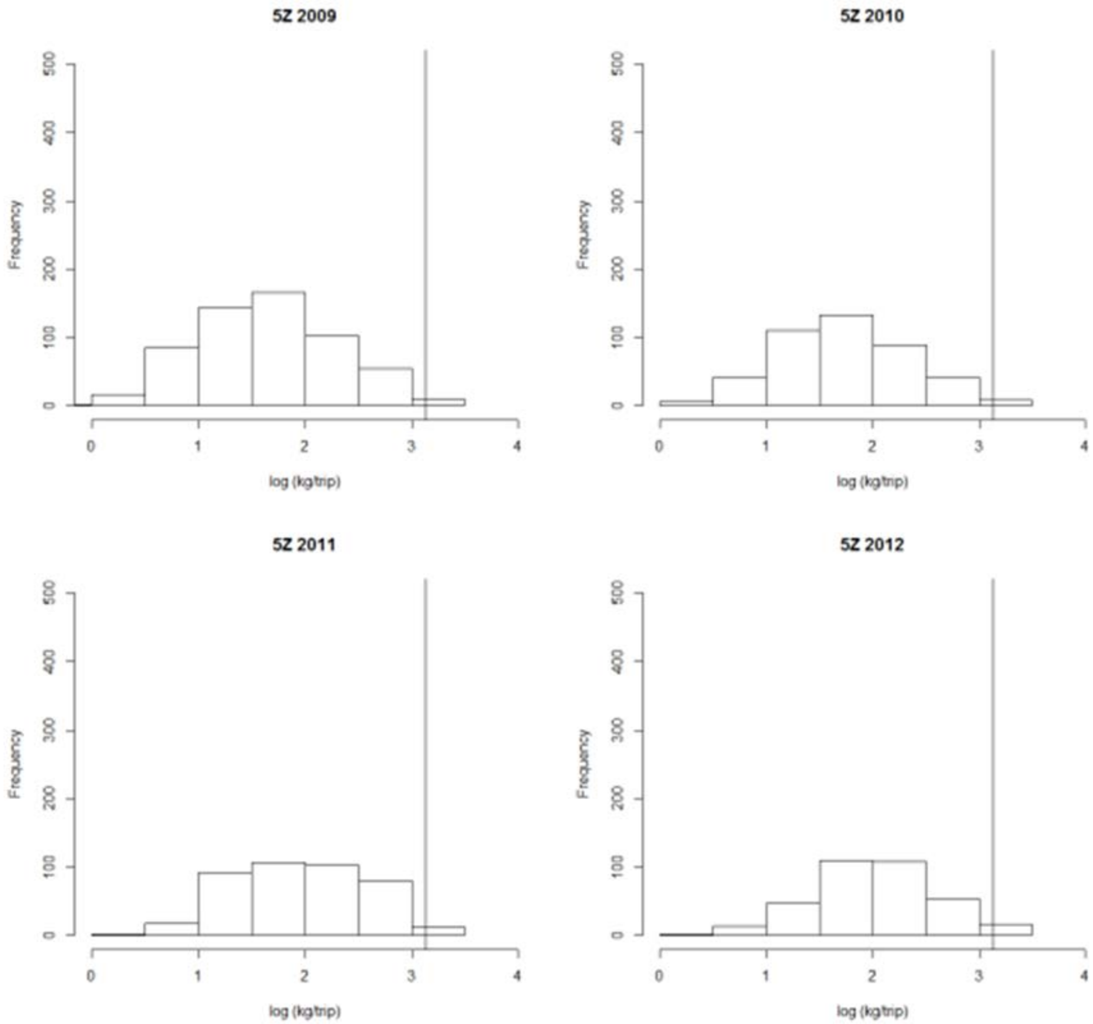


Figure 8b. Cusk caught per trip for NAFO Divison 5Z using bottom longline gear from 2009 – 2012. Vertical line shows the 5Z 3000 pound trip limit (1360kg).

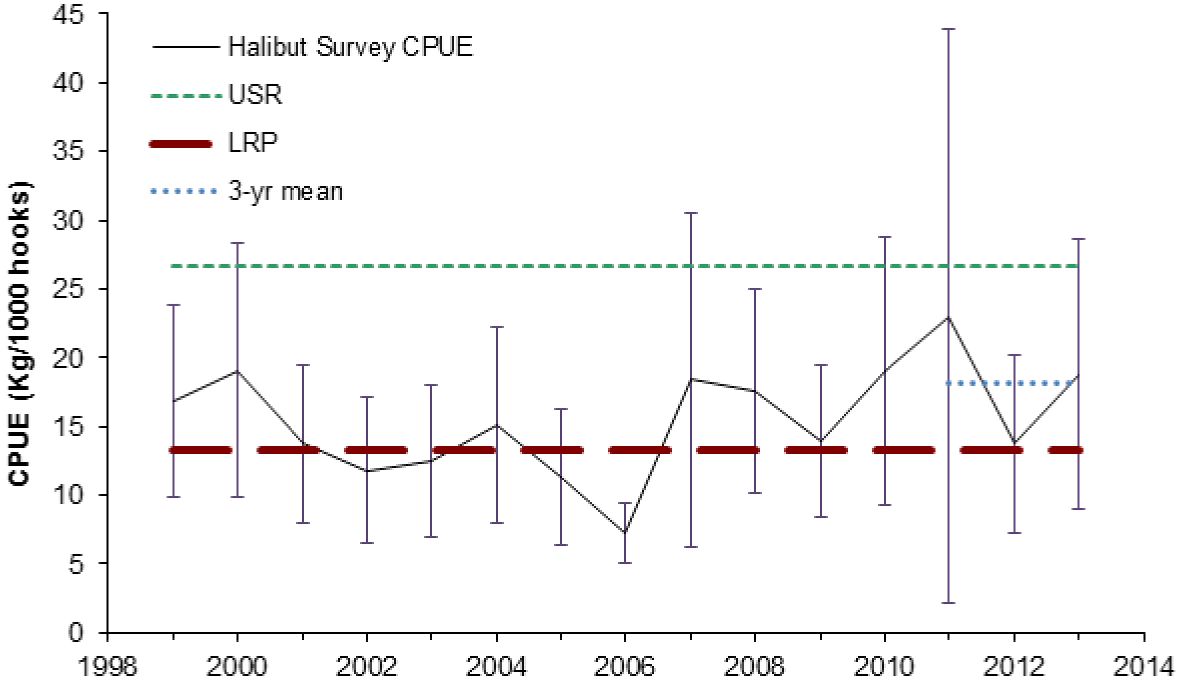
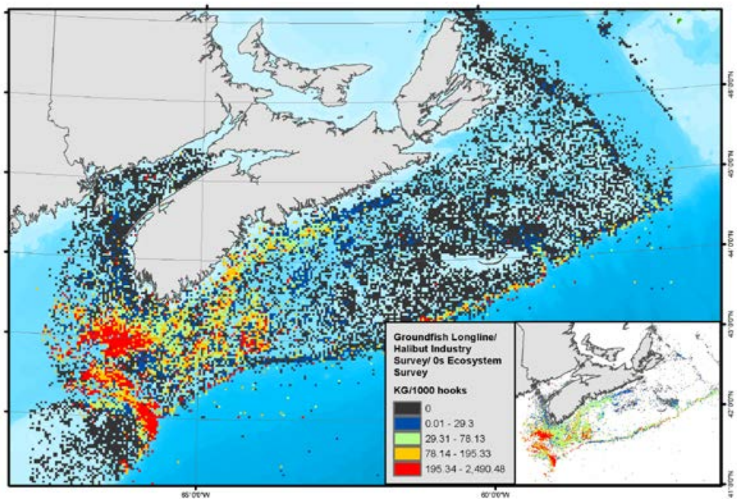


Figure 9. The green dashed reference line represents the upper stock reference point (80% of MSY proxy), the red dashed reference line represents the limit reference point (40% of MSY proxy), the solid black line represents the Halibut Industry Survey CPUE (kg/1000 hooks) for stations sampled in all years (n=50) including the 95% confidence interval and the dotted blue line represents the geometric mean of the CPUE for 2011-2013.



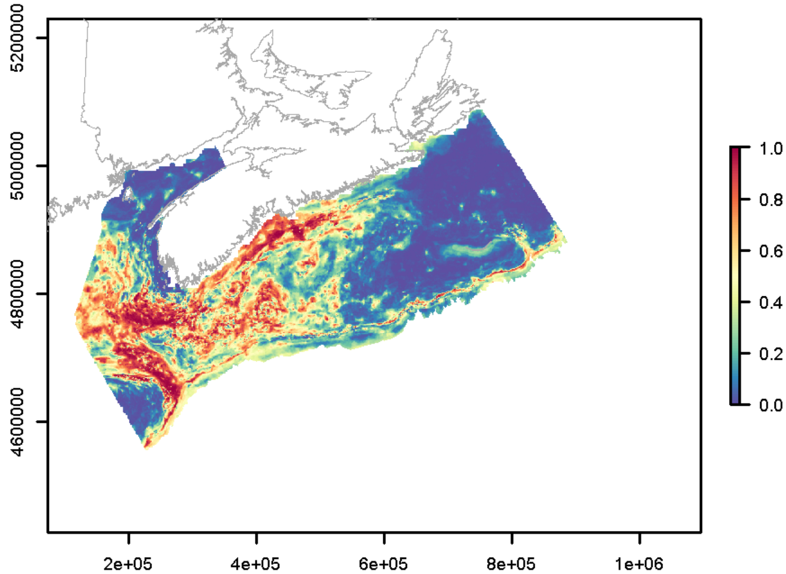


Figure 10. a - (upper panel): Response variable used in the species distribution model, including the: groundfish bottom longline landings data (2002-2013; kg/1000 hooks), Halibut Industry Survey data (1998-2013; kg/ 1000 hooks) and Cusk absences in the Ecosystem Survey data (1970-2013; per tow), aggregated over a 3km grid. b - (lower panel): A map showing the predicted presence of Cusk over the Maritimes Region obtained by the application of the Random Forest model with colours scaled from a probability of 0% to 100%.

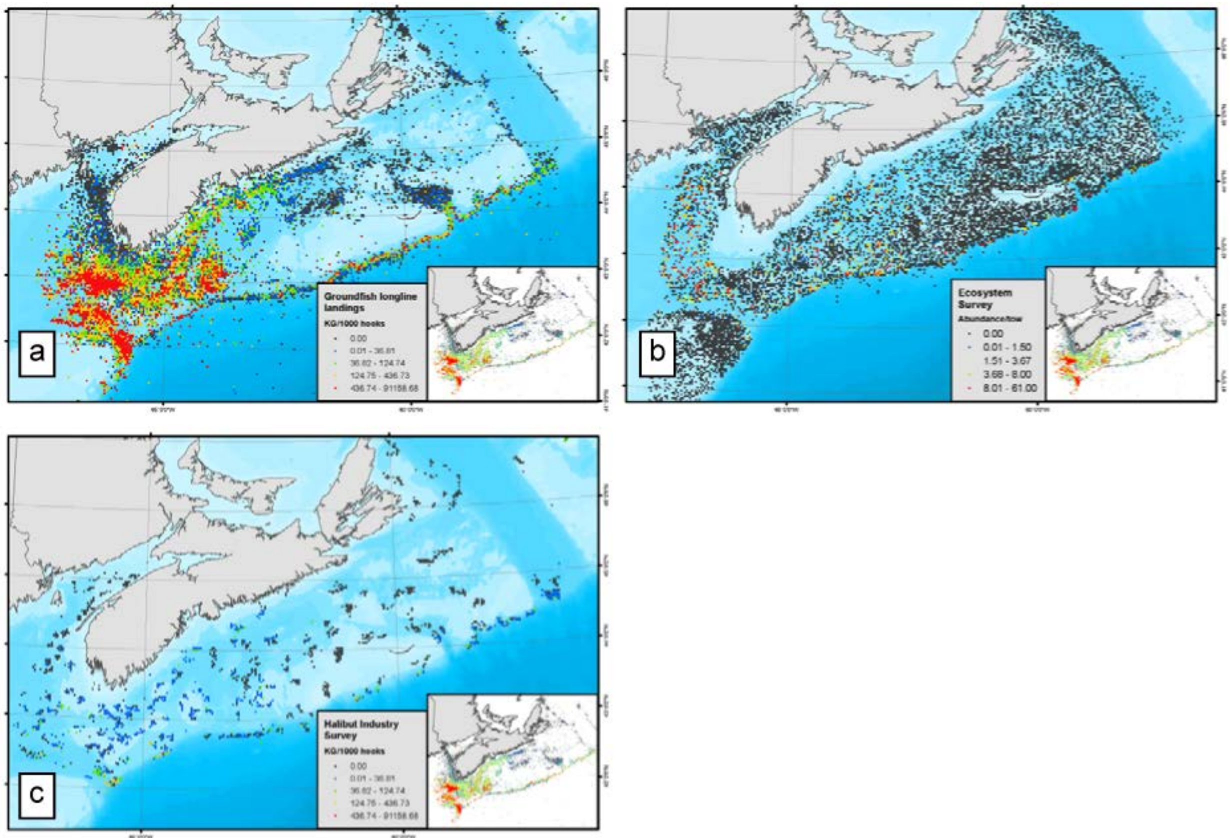


Figure 11. a) Groundfish bottom longline landings (kg/1000 hooks) from 2002 to 2013, b) Ecosystem Survey sampling locations (abundance/tow), from 1970 to 2013. Although this figure shows all of the data, only samples with 0 abundance were used in the species distribution models, as it was difficult to standardize trawl and groundfish bottom longline sampling methods and the Ecosystem Survey provided a good distribution of absence values, and c) the Halibut Industry Survey data (kg/1000 hooks) from 1998-2013.

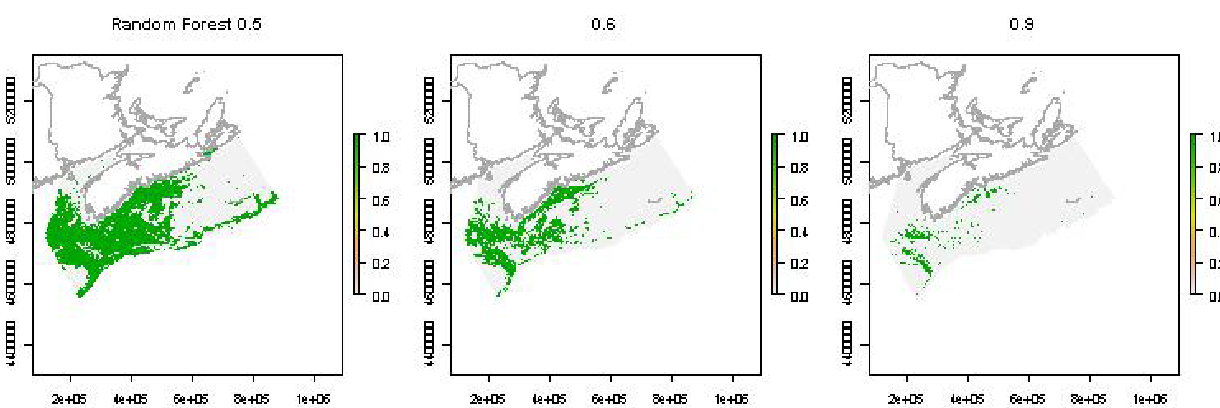


Figure 12. A map showing the predicted presence of Cusk over the Maritimes Region obtained by the application of the Random Forest model a) with a threshold at 50% chance of presence and b) with a threshold at 60% chance of presence and c. with a threshold at 90% chance of presence.

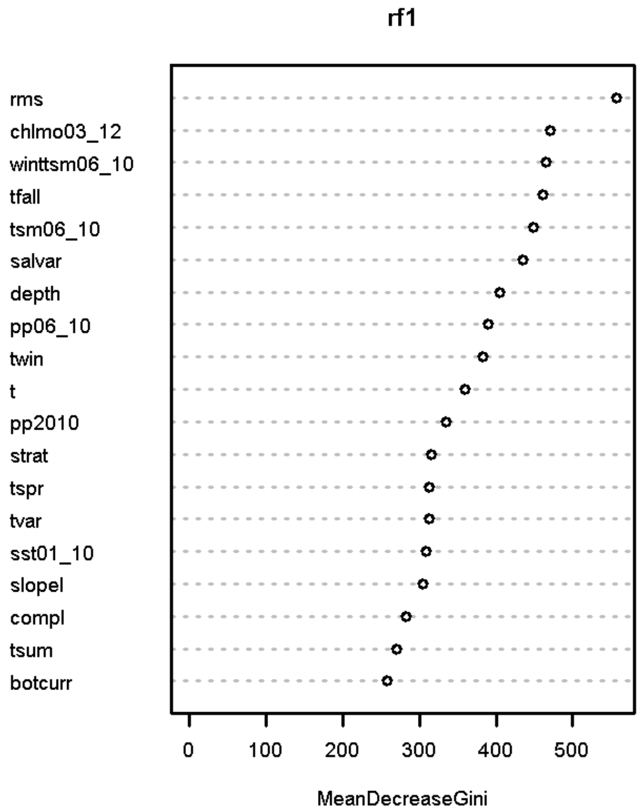


Figure 13. A variable importance plot generated by the random forest algorithm included in the randomForest package for R software. The plot shows the variable importance measured as the total decrease in node impurities from splitting on the variable, averaged over all trees (500).

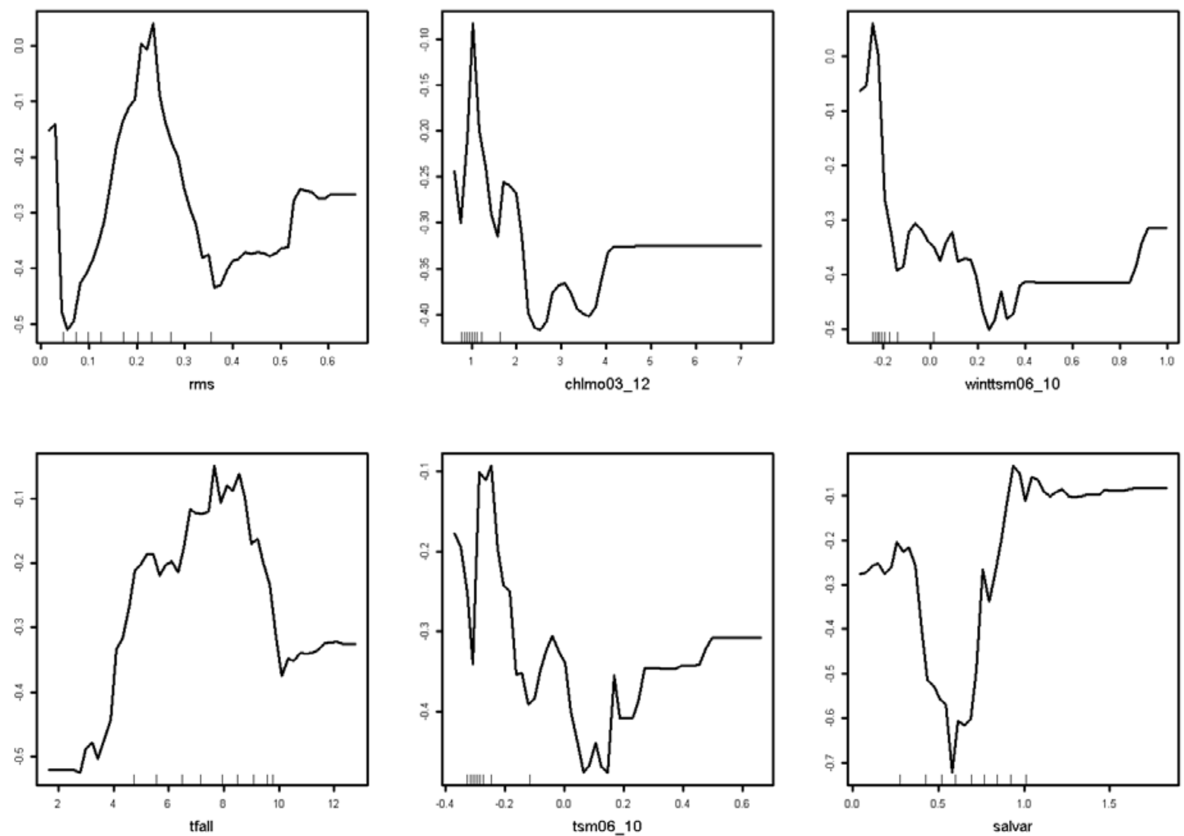


Figure 14. Partial plots representing the marginal effect of the six most important variables included in the RF model, on estimates of presence of Cusk, while averaging the effect of all other variables. In a partial plot, marginal effects on the range of the values (and not the absolute values) can be compared between plots of different variables. The y-axis depicts the log of the fraction of votes, which can be thought of as the log of the presence probability.

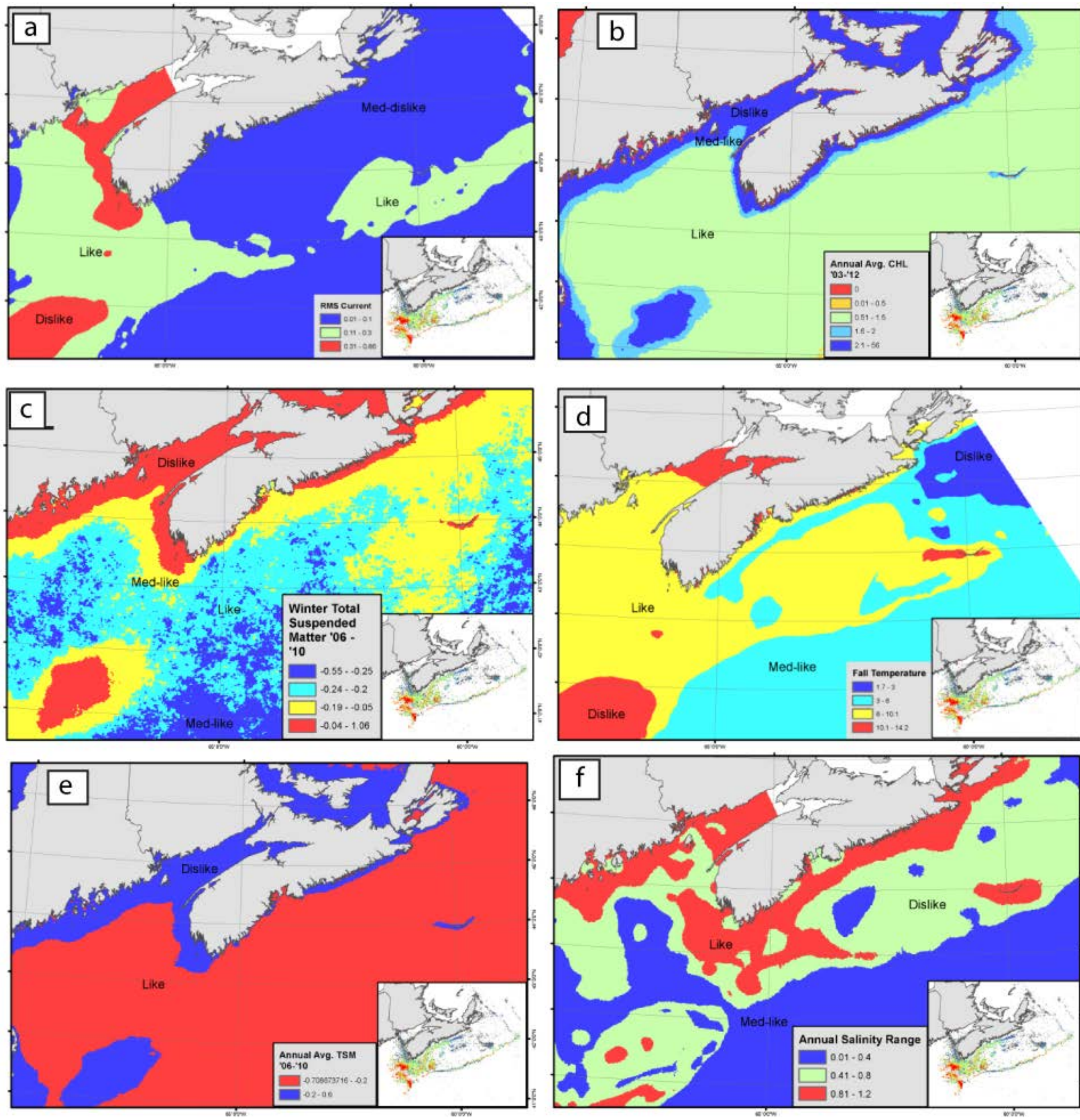


Figure 15. Approximate regions along the physical gradient of the six most important physical variables identified as preferred Cusk habitat: a) RMS Current Stress; b) average annual chlorophyll '03-'12; c) winter total suspended matter; d) fall temperature; e) average annual total suspended matter '06-'10; and f) salinity variability (seasonal max- seasonal min).

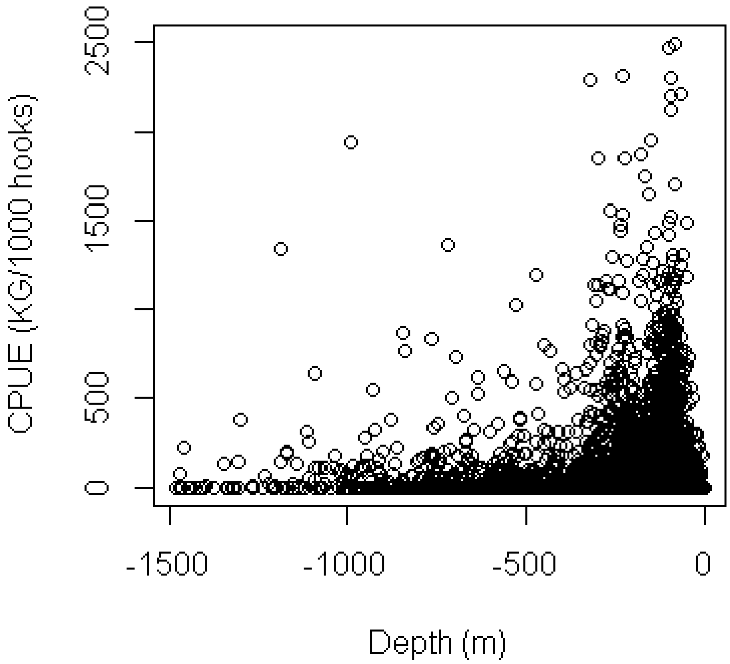


Figure 16. A plot of Cusk CPUE (kg/1000 hooks) vs depth (m).

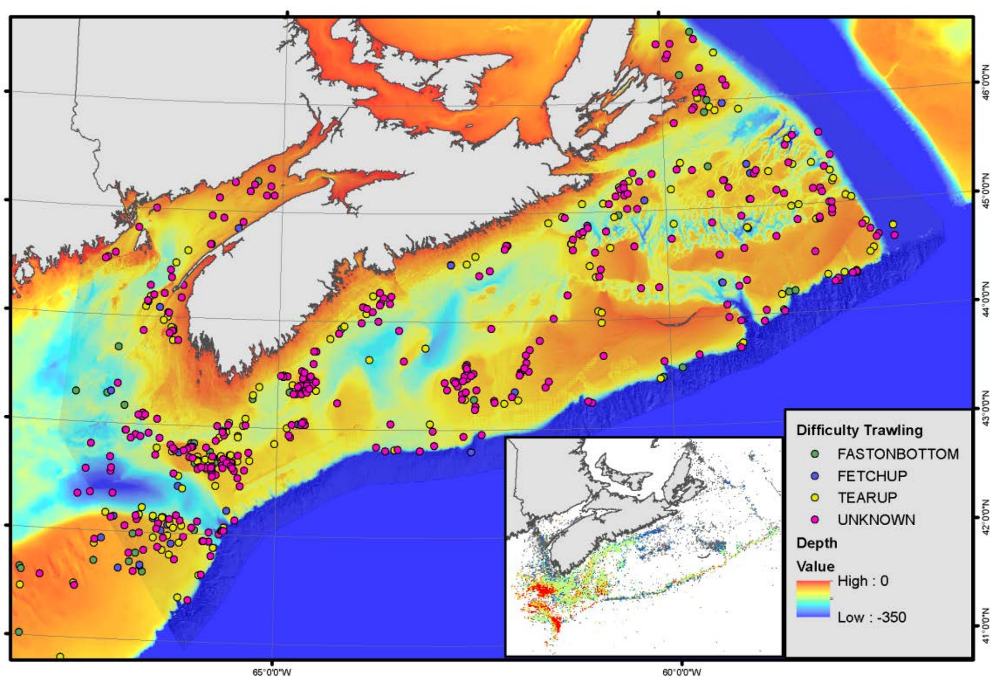


Figure 17. A map of the locations where the Ecosystem Survey trawl net has been torn, fetched up, fast on bottom (areas where due to the sounding information they expected to tear did not do a proper tow), or locations before they identified coding for the tear-up data. These data are overlaid on a depth raster for the Scotian Shelf and Gulf of Maine.

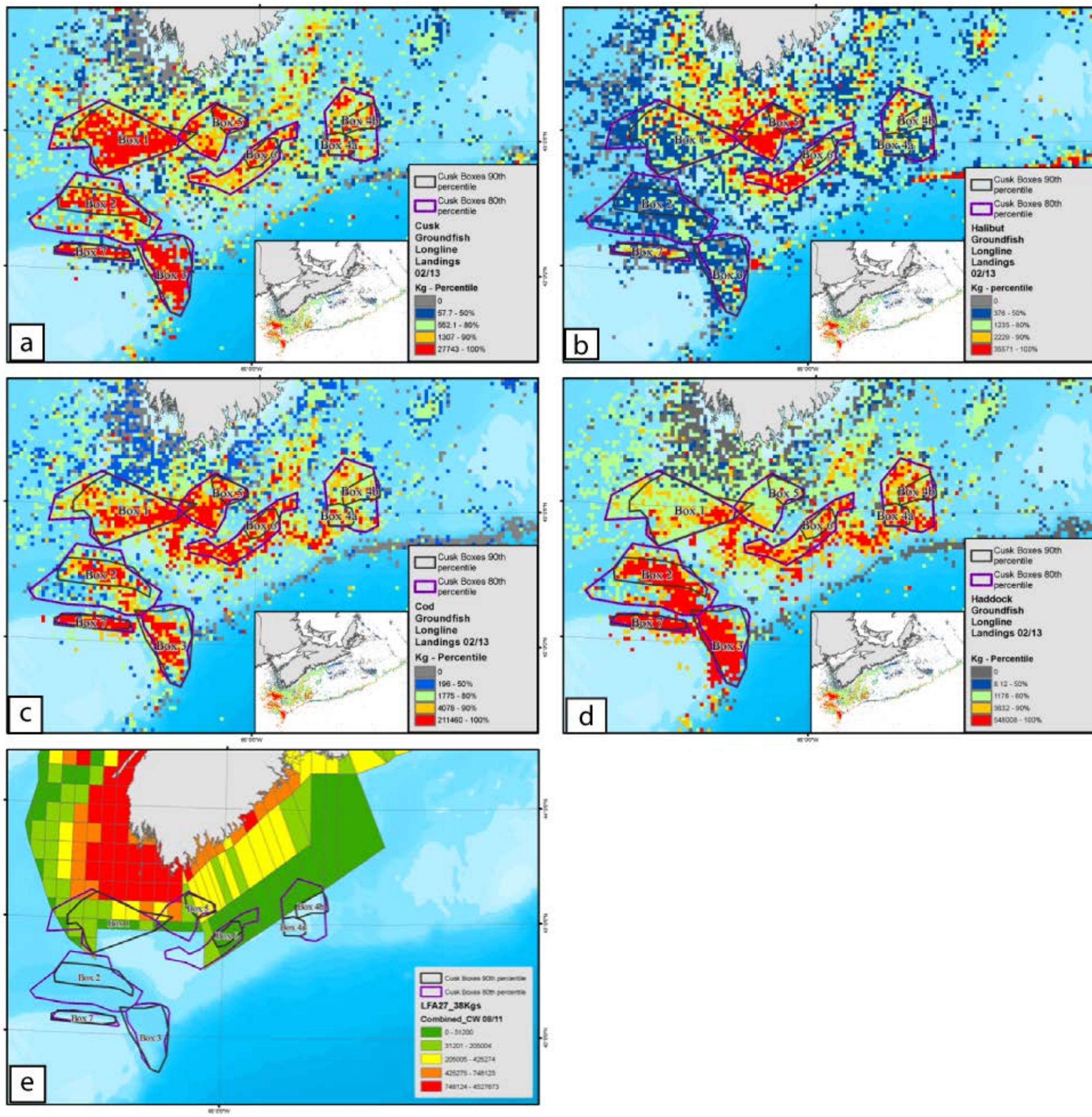


Figure 18. Boxes within the 80th and 90th percentiles of Cusk catch weight from 2002-2013, and larger than 20km in length/width, overlayed on the sum of catch weight (kg), from 2002 – 2013 on a 3km grid a) Cusk b), Halibut, c) Cod, d) Haddock, and e) inshore lobster composite catch weight from 2008–2011 in LFAs 27-38, over the statistical grids (mapped by Coffen-Smout et al. 2013). (not used in text)

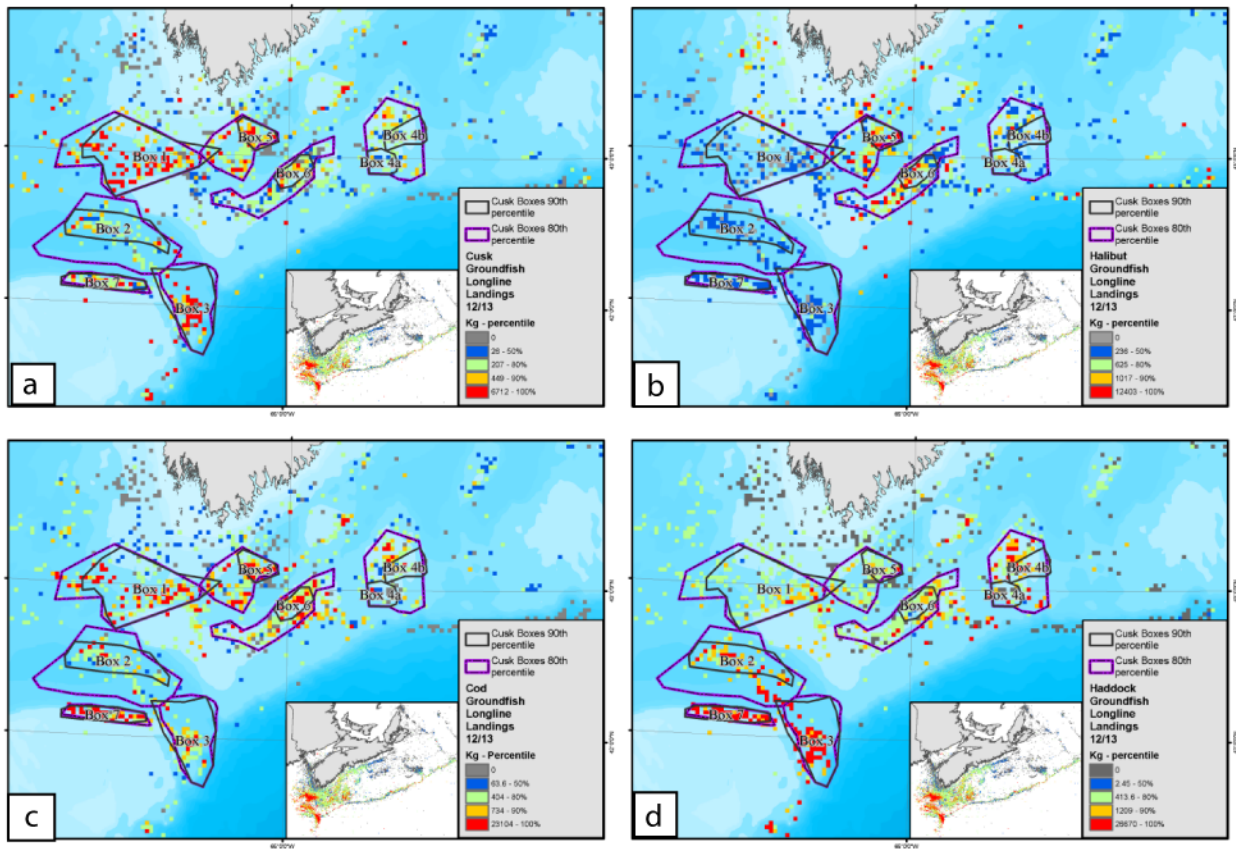


Figure 19. Boxes within the 80th and 90th percentiles of Cusk catch weight from 2002-2013, and larger than 20km in length/width, overlayed on the sum of catch weight (kg), from 2012 – 2013 on a 3km grid a) Cusk, b) Halibut, c) Cod, and d) Haddock. (not used in text)

APPENDICES

APPENDIX A: EXCERPT FROM “GUIDANCE ON ASSESSING THREATS, ECOLOGICAL RISK AND ECOLOGICAL IMPACTS FOR SPECIES AT RISK (DFO 2014a)”

Standardized Terminology for Threat Assessment

An assessment of threats should include the use of common terminology to:

- link recovery efforts to anthropogenic factors affecting species;
- facilitate completion of zonal or national RPAs;
- facilitate the creation of multi-species recovery strategies; and
- allow for comparisons between species;

Definitions

Jeopardize: to place a wildlife species or population in a situation where its survival or recovery are at risk.

Recovery: a return to a state in which the population and distribution characteristics and the risk of extinction are all within the normal range of variability for the wildlife species.

Survival: the achievement of a stable or increasing state where a wildlife species exists in the wild in Canada and is not facing imminent extirpation or extinction as a result of human activity.

Threat: any human activity or process that has caused, is causing, or may cause harm, death, or behavioural changes to a wildlife species at risk, or the destruction, degradation, and/or impairment of its habitat, to the extent that population-level effects occur. A human activity may exacerbate a natural process.

Limiting Factor: a non-anthropogenic factor that, within a range of natural variation, limits the abundance and distribution of a wildlife species or a population (e.g., age at first reproduction, fecundity, age at senescence, prey abundance, mortality rate).

Harm: The adverse result of an activity where a single or multiple events reduce the fitness (e.g., survival, reproduction, growth, movement) of individuals.

Stress: a wildlife species at risk is stressed when a key ecological or demographic attribute of a population, or behavioural attributes of individuals, are impaired or reduced resulting in a reduction of the species viability (Salafsky et al. 2003).

Allowable Harm: harm to the wildlife species that will not jeopardize its recovery or survival.

Pathway of Effects: description of the mechanisms through which potential environmental effects of a threat may cause a stress on a wildlife species.

A Two-step Standardized Approach to Threat Assessment

Many different tools have been developed to assess, categorize and prioritize threats (e.g., International Union for Conservation of Nature threat calculator, BC Freshwater Fish Threats Assessment Tool, etc.). These tools contain different lists of threats, and although no preference is highlighted here, threat assessors must make sure that each threat meets the accepted definition of threat above. Other factors (e.g., climate change) or limiting factors can be treated in the narrative, but should not be classified by the following approach.

The following approach outlines a step-by-step process to characterize and prioritize threats to the survival and/or recovery of a species. The two-step approach first characterizes threats at the population level and then at the wildlife species level. Since threats vary across a species range and populations, assessing threats at the population level informs management of activities at a local scale. Assessing threats at a wildlife species level aids in determining a national perspective and enables a better allocation of resources.

General Overview

Step 1 – Evaluate threats at the population level. This includes evaluating:

- Likelihood (L);
- Severity (S);
- Causal Certainty (CC),
- Population Threat Risk (PTR; product of Likelihood and Severity);
- Population-level threat Occurrence (PO);
- Population-level threat Frequency (PF); and
- Population-level threat Extent (PE).

Step 2 – Evaluate threats at the species level. This includes evaluating:

- Species Threat Risk [STR – Roll-up of Population Threat Risk (PTR)];
- Species-level threat Occurrence (SO);
- Species-level threat Frequency (SF); and
- Species-level threat Extent (SE) – Roll-up of Population-level threat Extent (PE).

Step 1 - Evaluating Threats at the Population Level

Evaluate threats at the population level. This includes evaluating likelihood, severity and causal certainty of the threat.

Likelihood refers here to the probability of a specific threat occurring for a given population over 10 years or 3 generations, whichever is shorter (Table A1).

Table A1: Categories of likelihood (L) for threat occurrence.

Likelihood Categories	Definition	Symbol
Known or very likely to occur	This threat has been recorded to occur 91-100%	**K**
Likely to occur	There is 51-90% chance that this threat is or will be occurring.	**L**
Unlikely	There is 11-50% chance that this threat is or will be occurring	**UL**
Remote	There is 1-10% or less chance that this threat is or will be occurring.	**R**
Unknown	There are no data or prior knowledge of this threat occurring now or in the future.	**U**

Severity refers to the impact caused by a given threat, and the level to which it affects the survival or recovery of the population (Table A2).

Table A2: Categories of severity of impact (S) linked to a threat.

Severity of Impact	Definition	Symbol
Extreme	Severe population decline (e.g., 71-100%) with the potential for extirpation.	**E**
High	Substantial loss of population (31-70%) or Threat would jeopardize the survival or recovery of the population.	**H**
Medium	Moderate loss of population (11-30%) or Threat is likely to jeopardize the survival or recovery of the population.	**M**
Low	Little change in population (1-10%) or Threat is unlikely to jeopardize the survival or recovery of the population.	**L**
Unknown	No prior knowledge, literature or data to guide the assessment of threat severity on population.	**U**

Causal certainty reflects the strength of evidence linking the threat to the survival and recovery of the population. Evidence can be scientific, traditional ecological knowledge or local knowledge (Table A3).

Table A3. Categories of Causal Certainty linked to a threat.

Causal Certainty	Definition	Rank
Very high	Very strong evidence that threat is occurring and the magnitude of the impact to the populations can be quantified.	**1**
High	Substantial evidence of a causal link between threat and declines in population or jeopardy to survival or recovery	**2**
Medium	There is some evidence linking the threat to declines in population or jeopardy to survival or recovery	**3**
Low	There is a theoretical link with limited evidence that threat is leading to a decline in population or jeopardy to survival or recovery	**4**
Very low	There is a plausible link with no evidence that the threat is leading to a decline in population or jeopardy to survival or recovery	**5**

Threat Risk Matrix

Determine population threat risks using rankings for severity and likelihood and plotting them in the Threat Risk Matrix below (Table A4). Incorporate causal certainty by placing level of certainty in brackets after the classification. This gives the population-level threat risk (Table A5).

		Threat Severity				
		Low	Medium	High	Extreme	Unknown
Threat Likelihood	Known	Low	Medium	High	High	Unknown
	Likely	Low	Medium	High	High	Unknown
	Unlikely	Low	Medium	Medium	Medium	Unknown
	Remote	Low	Low	Low	Low	Unknown
	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown

Figure A1: Threat Risk Matrix.

Table A4: Population level threat risk.

	Population 1			
	L	S	CC	PTR
Threat 1	L	E	4	High (4)
Threat 2	K	L	1	Low (1)
…				

Then evaluate the population-level threat occurrence (PTO), population-level threat frequency (PTF) and population- level threat extent (PTE) for each threat. Complete the population level input table (Table A5).

Table A5: Population Level threat assessment.

L – Likelihood
S – Severity
CC – Causal certainty
*PTR – Population-level threat risk [PTR = Likelihood*Severity (Causal Certainty)]*
PTO – Population-level threat occurrence
PTF – Population-level threat frequency
PTE – Population-level threat extent

	Population 1							**Population 2**						
	L	**S**	**CC**	**PTR**	**PTO**	**PTF**	**PTE**	**L**	**S**	**CC**	**PTR**	**PTO**	**PTF**	**PTE**
Threat 1														
Threat 2														
…														

PTO refers to the timing of the occurrence of the threat and describes whether a threat is historical, current and/or anticipatory for a given population (Table A6). Any combination of PO categories is possible.

Table A6: Categories of Population-level threat occurrence (PTO).

Population Level Threat Occurrence	Definition	Symbol
Historical	A threat that is known to have occurred in the past and negatively impacted the population.	**H**
Current	A threat that is ongoing, and is currently negatively impacting the population.	**C**
Anticipatory	A treat that is anticipated to occur in the future, and will negatively impact the population.	**A**

PTF refers to the temporal extent of a given threat over the next 10 years or 3 generations, whichever is shorter (Table A7). Select only one of the 3 possible categories.

Table A7: Population-level threat frequency (PTF).

Population Level Threat Frequency	Definition	Symbol
Single	The threat occurs once.	**S**
Recurrent	The threat occurs periodically, or repeatedly.	**R**
Continuous	The threat occurs without interruption.	**C**

PTE refers to the proportion of the population affected by a given threat (Table A8).

Table A8: Population-level threat extent (PTE).

Population Level Threat Extent	Definition	Symbol
Extensive	71-100% of the population is affected by the threat.	**E**
Broad	31-70% of the population is affected by the threat.	**B**
Narrow	11-30% of the population is affected by the threat.	**NA**
Restricted	1-10% of the population is affected by the threat.	**R**

Step 2 – Roll-Up Population-Level Threat Risk to Species-Level Threat Risk (Table A9)

Population-level threat risk (PTR) to Species-level threat risk (STR)

The highest level of risk for a given population must be retained when rolling-up at the species level (Precautionary Approach). Describe population-level differences in threat risk when applicable. Incorporate causal certainty by carrying the associated level of certainty forward.

Population-level threat occurrence (PTO) to Species-level threat occurrence (STO)

Include all categories that have been identified in population-level assessment (e.g., threat could be classified as 'H, C, A', or any combination thereof).

Population-level threat frequency (PTF) to Species-level threat frequency (STF)

Include all categories that have been identified in population-level assessment (e.g., threat could be classified as 'S, R, C', or any combination thereof).

Population-level threat extent (PTE) to Species-level threat extent (STE)

Provide context to the extent of the threat to the species by considering the proportion of each population and the proportion of the overall population affected by the threat. For the later, options are to use the mode (value that appears most often), median (mid value), mean or proportion of area of occupancy.

Table A9: Species Level threat assessment.

*STR – Species-level threat risk [STR = Likelihood*Severity (Causal Certainty)]*
STO – Species-level threat occurrence
STF – Species-level threat frequency
STE – Species-level threat extent

	Species			
	STR	**STO**	**STF**	**STE**
Threat 1				
Threat 2				
…				

APPENDIX B: MITIGATION INVENTORY – CUSK

Table B1a: Current Management (Resource Management Template) Directed Fisheries for Cusk.

Type of Fishery	Fishing Method	Number of Gear Units Total/ Number of Licenses	Fishing Season Dates	NAFO/ Manage-ment Units	Units of Effort/ Location	Quota (caps)	Other Control Methods	Mortality Rates	Other Comments
Maritimes Region – ***the bulk of the population is located in the Gulf of Maine and southern Scotian Shelf***									
FSC (non-specific groundfish and/or directed Cusk)	Hand line, long line	General FSC groundfish licences issued to several Aboriginal groups. Directing for Cusk listed in one licence	None	BoF, 4X, 4W, tidal waters of CB Broader coastal waters of NS	N/A	As req'd for FSC purposes		Unknown	
Recreational groundfish fishery	Hand line or angling	N/A	Varies by area	All	N/A	N/A	Although there is no reporting from recreational groundfish licenses, catch of Cusk is anticipated to be extremely low.	Unknown	
Newfoundland and Labrador Region – ***Cusk occurs off N.L, but is rare.***									

Table B1b: Current Management (Resource Management Template) Bycatch Fisheries (incidental catch of Cusk).

Type of Fishery	Fishing Method	Fleets	NAFO/ Manage-ment Units	Gear restrictions	Number of gear units total/ number of licences	Cusk quota (caps)	Other Control Methods	Mortality Rates	Other?
Maritimes Region – ***the bulk of the population is located in the Gulf of Maine and southern Scotian Shelf***									
Groundfish Commercial Fishery	Hand-line, Long line, gillnet, bottom trawl	Offshore >100' Fixed and Mobile Gear Fixed gear 65-100' Inshore (45-65') Fixed Gear Inshore <45' Fixed Gear Mobile gear 65-100 Aboriginal communal Commercial Mobile gear <65'	4VWX+5	Minimum hook size is 12mm. Minimum mesh size is 130mm for mobile gear. Minimum mesh size for gillnet is 140mm, except in 5Z where it is 152mm.	2,682 for all fleets	By-catch cap of 638t plus trip limits for midshore and offshore fleets. Non-groundfish fleets are not permitted to retain Cusk.	Catch of Cusk is limited by the following trip limit and annual quota cap for each fleet sector: -FG <45' and FG 45'-65' – catches of Cusk are not to exceed 25% of the groundfish on board to a limit of 4000lbs in 4X5Y or 15% and 3000lbs in 5Z. -Catches are capped at 500 t in 4X5 and 70t in 4VW for FG <45'. Catches are capped at 35t in 4X5 and 13t in 4VW for FG 45'-65'. -MG<65' and Aboriginal Communal Commercial – catches of Cusk are not to exceed 10% of the groundfish on board. Catches are capped at 20t in	-Landings of up to 638t by inshore groundfish fisheries. -Discard rate is not known for any fishery. -Discarding is associated with up to 100% post-release mortality.	Cusk is caught predominantly by baited hook and line fisheries.

Type of Fishery	Fishing Method	Fleets	NAFO/ Manage-ment Units	Gear restrictions	Number of gear units total/ number of licences	Cusk quota (caps)	Other Control Methods	Mortality Rates	Other?
							4VWX+5. -FG 65'-100' – catches of Cusk are not to exceed 5% of the groundfish on board. -MG 65'-100' and offshore >100' – catches of Cusk are not to exceed 10% of the groundfish on board. All Cusk incidentally caught on a groundfish trip must be retained. Once a fleet quota cap is reached and notice to stop fishing has been given, all Cusk caught by that fleet must be returned to the water. -Fixed gear logbooks include column for reporting discards of Cusk. -Fishers may not re-bait hooks using Cusk; all Cusk must be landed as per license conditions before it can be		

Type of Fishery	Fishing Method	Fleets	NAFO/ Manage-ment Units	Gear restrictions	Number of gear units total/ number of licences	Cusk quota (caps)	Other Control Methods	Mortality Rates	Other?
							used as bait. Mandatory DM for all fleets except for the FG<45. Monitoring requirements in this fleet vary depending on area fished and amount of fish caught.		
Lobster Commercial Fishery	Trap	Inshore LFA 33/34 Offshore LFA 41	4X inshore 4X5ZY (CDN portion)	Inshore trap size limits, limited number of traps, escape panels, and ghost panels. Offshore , no trap limit ~ 5000. Limit on size of trap. Escape panels and ghost panels	LFA 33 (700 licences X 250 traps = 175,000 LFA 34 (985 licences X 375/400 = 394,000 traps Offshore no trap limit ~ 5000 utilized	No lobster fishery may retain Cusk (must be discarded)	No retention of Cusk. Studies have been conducted through use of observer to estimate levels of Cusk bycatch from both the inshore and offshore lobster fisheries.	Cusk mortality rates anticipated at close to 100%. Mortality levels associated with this fishery are unknown but anticipated to be high especially in deep water.	
FSC fisheries with Cusk by-catch (e.g,	Hand line, long line	N/A	BoF, 4W, 4X, tidal waters of CB	Based on license conditions for individual	N/A	None. Cusk by-catch can only be	No retention of Cusk, unless license is for unspecified groundfish.	Mortality levels associated with this fishery are	

Type of Fishery	Fishing Method	Fleets	NAFO/ Management Units	Gear restrictions	Number of gear units total/ number of licences	Cusk quota (caps)	Other Control Methods	Mortality Rates	Other?
flounder, halibut, cod, pollock, mackerel)			Broader coastal waters of NS	group.		retained by groups with a general groundfish FSC license.		unknown.	
FSC trap fisheries with Cusk by-catch– (e.g., lobster, eel, crab fisheries)	Trap	N/A	BoF (eel) LFA 25-32	Based on license conditions for individual group.	N/A		No retention of Cusk.	Mortality levels associated with this fishery are unknown.	
Newfoundland and Labrador Region – *Cusk occurs off N.L., but is rare.*									
Groundfish Commercial Fixed Gear/hook and line Fishery	Hand-line, Long line		3LMNO 2GHJ						

Table B2: Mitigation and Alternatives.

Threat Description	Potential Mitigation Measures and Alternatives	Expected Outcome of Measure	Feasibility of Measure
Maritimes Region – *the bulk of the population is located in the Gulf of Maine and southern Scotian Shelf*			
Directed fishery – recreational groundfish fishery	Vary the Cusk retention limit to zero.	Very little to no impact anticipated.	May be completed through a variation order, similar to that used to vary wolfish retention to zero.
Directed Fisheries – FSC groundfish	Eliminate retention of Cusk in FSC fisheries (directed and “unspecified groundfish”)	Actual numbers of Cusk caught and/or retained in FSC fisheries is not known.	
By-catch Mortality – Groundfish Commercial Fixed Gear/hook and line Fishery (Maritimes Region)	**No known measures that would increase post-catch survival**	**N/A**	**N/A**
	Video monitoring	Improved information on discard rates	Not likely to be considered as a single-species measure but if it was being implemented for broader MCS, it may be useful.
	Increase at-sea observer coverage to 25% in 4X5Y	Improved information on discard rates	Measure already implemented in 5Z
	Decrease by-catch cap + mandatory closure of fishery when cap reached.	Decreased mortality	Would require increased observer coverage
	Closed areas in 4X5Y	Targeted closure in 4X5Y to achieve a 25% decrease in landings (closure to be based on GIS data).	*Note: use GIS data to propose potential closed areas that would have the least impact on other GF landings, while still allowing a 25% reduction in Cusk caught.*
	100% dockside monitoring for FG<45’	Possible improvements to landings information for Cusk	In place for 4Vn and 5Z already, with high levels of coverage in 4VsW, 4X5Y. Based on 2012/13 preliminary information, this would equate to an additional 615 trips.
	Avoidance/Move-Away Protocol as a condition of license	Decreased fishing pressure in Cusk	Difficult to monitor compliance with

Threat Description	Potential Mitigation Measures and Alternatives	Expected Outcome of Measure	Feasibility of Measure
	(e.g., after catching X Cusk/trip, must pull up gear and move X Kms)	"hot-spots"	protocol.
By-catch mortality – Groundfish Commercial Mobile Gear Fishery (Maritimes)	No know measures that would increase post-catch survival	n/a	n/a
By-Catch Mortality – Lobster trap fisheries	There are no known gear modifications or bait modifications to reduce Cusk by-catch.	N/A	NA
	Closed areas in 4X5Y	Fishermen will move to adjacent nearby areas. May reduce Cusk by catch if the area is a true year-round Cusk reserve area.	
	Avoidance/Move-Away Protocol as a condition of license (e.g., after catching X Cusk/trip, must pull up gear and move X Kms)	Decreased fishing pressure in Cusk "hot-spots" that may be unknown at this time.	Measure could be implemented in license conditions. It would be difficult to determine if the measure was working well.
By-catch mortality – FSC handline/longline (e.g, flounder, halibut, cod, pollock, mackerel)	*See By-catch Mortality –Groundfish Commercial Fixed Gear/hook and line Fishery*		
By-catch mortality – FSC lobster	*See By-catch Mortality – Lobster Trap Fisheries*		
Newfoundland and Labrador Region – *Cusk occurs off N.L., but is rare.*			
By-catch Mortality – Groundfish Commercial Fixed Gear/hook and line Fishery (N.L. Region)			