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Recovery Potential Assessment of Common Lumpfish (*Cyclopterus lumpus*) in the Atlantic and Arctic Oceans

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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.

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ABSTRACT

Common Lumpfish (*Cyclopterus lumpus*) in Atlantic Canada was designated as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 2017, due to severe declines in both research survey abundance and biomass indices and commercial landings. In support of listing recommendations by the Minister, Fisheries and Oceans Canada has been asked to undertake a Recovery Potential Assessment (RPA) for Common Lumpfish, based on the national RPA Guidance. A review of available data indicates that survey indices remain low in areas historically associated with higher Common Lumpfish abundance and biomass (i.e., Subdivision [Subdiv.] 3Ps; Division [Div.] 3KL). In addition, commercial landings remain low. Attempts to model Common Lumpfish in this Designatable Unit (DU) using survey and fishery data were unsuccessful. Therefore, precautionary management is advised based on survey-based proxy reference points. Since commercial fishing is the only quantified source of anthropogenic mortality, and the directed fishery targets the eggs of mature females, a reduction in fishing mortality may be required to achieve recovery targets.

1. INTRODUCTION

Common Lumpfish (*Cyclopterus lumpus*) in Atlantic Canada was designated as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in November 2017, due to a severe decline in abundance and biomass indices in bottom trawl surveys over approximately two decades, combined with sharp declines in commercial landings (COSEWIC 2017). This species met the criteria for Endangered, but was not designated as such because it was not considered at risk of imminent extirpation (COSEWIC 2017). A pre-COSEWIC meeting, which reviewed all the available information on this species, was held November 17–18, 2015 (Simpson et al. 2016). More recently, an assessment of Common Lumpfish in the Quebec Region was conducted (DFO 2016).

In support of listing recommendations for Common Lumpfish by the Minister, Fisheries and Oceans Canada (DFO) was asked to undertake a Recovery Potential Assessment (RPA), based on the national RPA Guidance. Advice in the RPA may be used to inform both scientific and socio-economic aspects of the listing decision, development of a recovery strategy and action plan, and to support decision-making regarding issuance of permits or agreements, and formulation of exemptions and related conditions, as per sections (s.) 73, 74, 75, 77, 78, and 83(4) of the *Species at Risk Act* (SARA). Advice may also be used to prepare for the reporting requirements of SARA s.46 and s.55. The advice generated through this process will update and consolidate any existing advice regarding the Common Lumpfish Designatable Unit (DU).

2. BIOLOGY, ABUNDANCE, DISTRIBUTION, AND LIFE HISTORY PARAMETERS

2.1. GENERAL BIOLOGY AND ECOLOGY

Common Lumpfish are distinguishable from other northwest Atlantic fishes by their stout, thick body, a partly cartilaginous and partly gelatinous bump on their back that engulfs the dorsal fin in adults, modified pelvic fins forming a sucking disk, and tubercle-covered skin (Figure 1a, b). Their colour is variable, except in breeding males when it is red (Figure 1a). The biology and ecology of the Common Lumpfish was previously reviewed by Simpson et al. (2016) and is summarized below.

The species is widely distributed in temperate waters on both sides of the north Atlantic Ocean as well as the Arctic Ocean. In the western Atlantic, its distribution ranges from southwestern Greenland, off southeast Baffin Island, along the coasts and the shelf of Newfoundland and Labrador, on the Flemish Cap, in the Gulf of St. Lawrence, off the coast of New Brunswick and Nova Scotia, and as far south as Chesapeake Bay (Figure 2). This species has also been reported in southern areas of the Arctic Ocean: Hudson and James Bays, Hudson Strait, and Ungava Bay (Coad and Reist 2018). Common Lumpfish occur from shallow coastal waters (<20 m) to depths of over 300 m (Collins 1978, Able and Irion 1985, Collette and Klein-MacPhee 2002). Davenport (1985) indicated that adult Common Lumpfish are semi-pelagic. This was confirmed by catches of adults in the pelagic surveys of the Barents Sea (Wienerroither et al. 2011, 2013, Eriksen et al. 2014) and the Labrador Sea (Sheehan et al. 2012), and in a salmon survey in the Bay of Fundy and Gulf of Maine (Lacroix and Knox 2005). Data from the Iceland Groundfish Survey analyzed by Kennedy et al. (2016), indicated that 99% of Common Lumpfish were caught at depths shallower than 296 m, and the number caught benthically was lower at night and increased during daylight hours. Both data sources indicated that the species exhibits daily vertical diel migrations within the water column and spends time associated with both surface waters and the benthic environment. The study found that

Common Lumpfish spend more time within 10 m of the surface as they move closer to the coast, but also spend time at depth, especially offshore (Kennedy et al. 2016).

Collins (1976) suggested that an inshore spawning migration of Common Lumpfish occurs annually in Newfoundland during spring, with spawning normally taking place in May-June in shallow waters, though it is uncertain whether all reproduction occurs in nearshore areas, as adults continue to be caught in offshore waters during the spring DFO Newfoundland and Labrador Region survey. After spawning in intertidal and/or subtidal areas, inshore migrating Common Lumpfish return to deeper waters offshore in late summer and early fall. Males have been observed migrating to inshore spawning areas first to establish territories, building nests at locations of high structural complexity (Davenport 1985, Goulet 1985, Goulet et al. 1986). The subsequent arrival of females is asynchronous, such that males are able to court multiple mates (Goulet et al. 1986, Goulet and Green 1988). Females are determinate batch spawners, depositing two batches of adhesive eggs at intervals of 8–14 days (Shears 1980, Davenport 1985, Kennedy et al. 2018), typically in crevices or between boulders on rocky bottoms often associated with macroalgae (Cox and Anderson 1922, Mochek 1973, Shears 1980, Davenport 1985, Goulet 1985, Goulet et al. 1986, Fahay 2007). After external fertilization and departure of the female, the male remains and provides parental care, consisting of cleaning and aerating the eggs and discouraging predation by invertebrates such as sea urchins and periwinkles (*Littorina* sp.), and fish such as Cunners (*Tautogolabrus adspersus*) and Ocean Pouts (*Macrozoarces americanus*) (Shears 1980, Davenport 1985, Goulet et al. 1986).

In Newfoundland waters, newly-hatched Common Lumpfish are 5–6 mm in length (Collins 1976, Brown et al. 1992), pelagic, and immediately use their ventral disc to attach to macroalgae, eelgrass (*Zostera marina*), and hard substrates (Davenport 1985, Brown 1986, Moring 1989, Moring and Moring 1991). Eelgrass beds appear to be particularly important for early developmental stages and, upon reaching 20–25 mm in length, Common Lumpfish associate more with macroalgae species such as *Laminaria* spp. and *Ascophyllum nodosum* (Moring 1989, Moring and Moring 1991). During late summer/early fall pelagic sampling, young of the year (YOY) Common Lumpfish have been caught on the northeast Newfoundland and Labrador shelf, Gulf of St. Lawrence, Scotian Shelf, and Bay of Fundy in less than 10 m of water (Sheehan et al. 2012, Ocean Biodiversity Information System [OBIS] 2015, COSEWIC 2017).

Goulet et al. (1986) reported that Common Lumpfish egg masses are consumed by Ocean Pouts, Cunners, Green Sea Urchins (*Stronglyocentrus droebachiensis*), and periwinkles. Grey Seals (*Halichoerus grypus*), Greenland Sharks (*Somniousus microcephalus*), and Sperm Whales (*Physeter macrocephalus*) are known predators of adult Common Lumpfish (Roe 1969, Thorsteinsson 1983, Benoît and Bowen 1990a,1990b). Common Lumpfish have also been found occasionally in stomachs of wolffishes (*Anarhichas* spp.), Atlantic cod (*Gadus morhua*), Greenland Halibut (*Reinhardtius hippoglossoides*), Atlantic Halibut (*Hippoglossus hippoglossus*), and Spiny Dogfish (*Squalus acanthias*) (Chumakov and Podrazhanskya 1986, Rountree 1999, Simpson et al. 2013).

2.2. ABUNDANCE AND DISTRIBUTION METHODS

The primary sources of data regarding abundance, biomass, and distribution of Common Lumpfish are the DFO research surveys conducted in the Regions of interest–Newfoundland and Labrador (NL), Quebec (QC), Gulf, Maritimes (MAR), and Central and Arctic (C&A). These research surveys employed a stratified random design based on depth intervals and location (latitude, longitude), and were designed to provide information on abundance, distribution, and area occupied by numerous demersal and benthic fish, as well as several invertebrate species.

Survey abundance and biomass indices for Common Lumpfish were expressed as mean number per standard tow and mean weight (in kg) per standard tow, respectively. The timing and type of trawl gear used varied between Regions, and across time, making it difficult to infer spatial and temporal trends in some instances.

Spatial distribution of Common Lumpfish was investigated using point plots of the geographic distribution of standardized catch rates (number of fish per tow) for each DFO Regional survey series. It should be noted that tows are not directly comparable across surveys. Plots were generated for 2014 through 2017/2018 where data were available. Point maps of standardized catch rates from the Regional surveys for years prior to 2014 are available in Simpson et al. (2016). Very few Common Lumpfish have been caught in C&A Region surveys; therefore, presence and absence of Common Lumpfish catch (unstandardized) were plotted for all survey years combined. Inshore Common Lumpfish abundance was also investigated using long-term monitoring data from Newman Sound, NL.

2.2.1. Newfoundland and Labrador (NL) Region Research Vessel Surveys

Data were obtained during DFO-NL multi-species bottom trawl surveys conducted over the continental shelves of NL, in Div. 3LNOP in winter/spring (1971–2018; Table 1) and in Div. 2GHJ3KLNO in fall (1977–2017; Table 2), including areas beyond the Canadian Exclusive Economic Zone (EEZ; Figure 3). Survey details, including changes in gear type and spatial coverage over time, are discussed in Doubleday (1981), Bishop (1994), McCallum and Walsh (1996), Walsh and McCallum (1997), Brodie and Stansbury (2007), Healey and Brodie (2009), and Simpson and Miri (2013). It should be noted that different trawls have been deployed during the spring (Yankee 41.5 in 1971–83; Engel 145 in 1984–95; and Campelen 1800 in 1996–2018) and fall (Engel 145 in 1977–94; Campelen 1800 in 1995–2017) surveys, and there are no conversion factors to account for differences in Common Lumpfish catchability due to these gear changes. Therefore, the resultant survey time series are not directly comparable. In addition, fall surveys reach deeper maximum depths (~1,400 m) than those in winter/spring (~750 m), and thus cover a greater portion of the species' potential range. Therefore, fall survey data are not directly comparable to winter/spring survey data. It should be noted that the spring survey was incomplete in 2006 due to partial sampling of Div. 3NO and almost no coverage of Subdiv. 3Ps. In addition, the fall survey was incomplete in 2014 due to partial coverage of Div. 3L and no sampling of Div. 3NO. Subdiv. 3Pn was not surveyed in spring 2008 and 2014–18.

2.2.2. Maritimes (MAR) Region Research Vessel Surveys

The DFO-MAR summer research survey has been conducted annually on the Scotian Shelf (Div. 4VWX5Yb; Figure 4) since 1970 (Figure 5). There were 42 survey strata grouped into three categories based on depth: <92 m, 92–181 m, and >181 m. In 1995, coverage was expanded to include three deepwater strata (i.e., 365–732 m) on the shelf edge. Various vessels, with potentially different catchabilities, and trawl types (primarily Western IIA) were used over the span of this survey (see Claytor et al. 2014 for details). There are no conversion factors to account for differences in catchability of Common Lumpfish among the various gears used. The eastern Scotian Shelf (Div. 4VW) was not surveyed in 2018.

The Div. 4VsW research survey was conducted in March on the eastern half of the Scotian Shelf from 1986–2010, using a Western IIA trawl (see Claytor et al. 2014). This survey did not include all of Div. 4VW and used a stratification scheme differing from that of the summer survey. No surveys were conducted in 1998 and 2004, and the 2009 survey was incomplete. The Canadian Coast Guard Ship (CCGS) *Alfred Needler* was used in most years (except for 2007 and 2008). The CCGS *Wilfred Templeman* was used in 2007, and the CCGS *Teleost* in

2008. In 1993, deepwater strata (i.e., 365–549 m) in the Laurentian Channel were added to this survey. Coverage of eastern strata was restricted in some years due to ice coverage.

The February/March research survey on Georges Bank (Div. 5Z) has occurred annually since 1987, using a Western IIA trawl and a stratified random design (Figure 6). This survey is concentrated on the Canadian side of the bank with some additional sets in American waters just outside, and adjacent to Canada's EEZ boundary (Div. 5Z 1–4); in recent years (2012, 2014, 2016), sampling has extended north into the Bay of Fundy (Div. 4X), following the sampling strata of the summer research survey.

2.2.3. Gulf Region Research Vessel Surveys

The DFO-Gulf bottom trawl survey of the southern Gulf of St. Lawrence (sGSL), in Div. 4T, has been conducted annually in September since 1971 (see Hurlbut and Clay 1990, and Chadwick et al. 2007 for details). The standard research tow in all years was 30 minutes in duration, conducted at a speed of 3.5 knots, and all catches were adjusted to 1.75 nautical miles.

The sGSL survey has been conducted by different research vessels (RVs) and trawls (see Benoît 2014 for details): the *E.E. Prince* (1971–85) used a Yankee 36 trawl; the *Lady Hammond* (1985–91), CCGS *Alfred Needler* (1992–2002, 2004–05), CCGS *Wilfred Templeman* (2003), and CCGS *Teleost* (2004-present); all employed a Western IIA trawl. Prior to the gear change and for all but one of the vessel changes (CCGS *Wilfred Templeman*), paired comparative tows involving both vessels and trawls were conducted at common sites to estimate their relative catchabilities (Benoît and Swain 2003, Benoît 2006). In every case, Common Lumpfish were seldom caught in paired tows, thereby precluding any estimation of a catchability conversion factor. Consequently, each vessel/gear combination is assumed to capture this species with the same efficiency.

A common group of strata (i.e., 415–439), covering most of the survey area (70,061 km^2), were sampled annually at the same time of year since 1971 (Figure 7). The number of valid fishing sets completed annually in these strata varied from approximately 70 (in the early-1980s) to >160 (during the 1990s and 2000s). Three nearshore strata (401–403) were added to this survey in 1984, but data from these were not included here in order to maintain a standardized series for 1971–2017, and also because Common Lumpfish were rarely captured in these strata. In a few instances, some strata were not sampled in particular years: strata 424 and 428 were not surveyed in 1978, and stratum 421 was not surveyed in 1983 and 1988. In order to maintain a consistent survey area for the years when these strata were not surveyed, their catch weights were added to those of neighbouring strata (i.e., at the same depths) for calculations of stratified mean catch rates and distribution indices. In 2003, deeper water strata 438 and 439 were not surveyed. Furthermore, Common Lumpfish were not caught in these strata over three years preceding or following 2003, so it was assumed that they would not be found in these strata during 2003.

The sGSL survey was restricted to daylight (0700–1900 hrs) in 1971–84, but has since been conducted 24 hours per day. Common Lumpfish were found to be significantly more catchable during daylight by the CCGS *Alfred Needler* (2.1 times), but not by the *Lady Hammond* (Benoît and Swain 2003). Using the same methods as the previous study, no statistically significant diel effect was detected for CCGS *Teleost* tows in 2004–14 (p=0.842; H. Benoît unpublished). Therefore, nighttime catches by CCGS *Alfred Needler* were adjusted to daytime equivalents for this analysis. Surveys from 2014 to present were treated in the same manner.

2.2.4. Quebec (QC) Region Surveys

2.2.4.1. DFO Research Vessel Surveys

Common Lumpfish data were obtained from two annual DFO-QC bottom trawl groundfish surveys in the northern Gulf of St. Lawrence (nGSL; Table 3): a winter survey conducted in January 1978–94, and a summer survey in August 1990–2018 (Figure 8a; see Bourdages et al. 2018 for details). The survey area included the Laurentian Channel and north, from the lower Estuary in the west to the Strait of Belle Isle and Cabot Strait in the east (i.e., Div. 4RS, depth strata >183 m in the northern part of Div. 4T; Figure 8a, b). Subdiv. 3Pn was covered in the winter survey. Data from these two series are not comparable due in part to differences in seasonality, trawl, and vessel. Details of the January (i.e., winter) survey were presented in Simpson et al. 2016.

From 1990–2003, the summer survey used a URI (University of Rhode Island) 81'/114' shrimp trawl on the CCGS *Alfred Needler*. Since 2004, this survey used a Campelen shrimp trawl on the CCGS *Teleost.* In the summer of 2004 and 2005, comparative fishing experiments were done between these two vessel/trawl combinations to estimate the catchability difference between them (Bourdages et al. 2007). The conclusion for Common Lumpfish was that vessel/trawl combinations had no effect on catchability; no correction was required to combine data from the two summer survey series and produce a 1990–2018 series.

A multiplicative model was used to account for the fact that over the years, some strata were not sampled by a minimum of two successful tows. This model provides a predicted value for strata with less than two tows by averaging the data of the current year (if available) and the previous three years. Thus, indicators presented for the series are representative of a standard total survey area of 116,115 km^2, the sum of the area of all strata over the 1990–2018 time period.

2.2.4.2. Sentinel Program – July Mobile Survey

Data from a nGSL Sentinel program that conducted a mobile gear survey annually in July since 1995, were also examined (Table 3). This survey used a depth-stratified random design and sampling methodology similar to DFO-QC nGSL summer surveys and consisted of 300 stations randomly selected and sampled by commercial trawlers from NL and QC. However, Estuary strata (i.e., 411, 412, 413; Figure 8a) were not surveyed, while Subdiv. 3Pn was. A multiplicative model was also used in this series to present data for a common survey area of 117,449 km^2 over the 1995–2018 time period.

2.2.5. Central and Arctic (C&A) Region Research Vessel Surveys

In DFO-C&A, random depth-stratified bottom trawl surveys have been conducted using the Greenland Institute of Natural Resources RV *Pâmiut* and two gear types, the Alfredo III (400 m to 1,500 m) and the Cosmos 2000 (100 m to 800 m) (Table 4, Figure 9). Surveys in southern Div. 0A (to 72.5^{o} N) using Alfredo trawl gear took place in fall 1999 and 2001, in every second year from 2004–14, and each year from 2015–17 (Treble 2018). Northern Div. 0A (72.5^{o} to 75.5^{o} N) surveys using Alfredo trawl gear took place in 2004, 2010 and 2012 (Treble 2013). Div. 0B surveys using Alfredo trawl gear took place in 2000, 2001, 2011, and annually from 2013–16 (Treble 2017). The Cosmos 2000 shrimp trawl surveys took place in Div. 0A (100 m to 800 m and including Shrimp Fishing Area [SFA] 1) in 2006 and 2008; in SFA 1 only in 2010 and 2012; in Div. 0B and SFA 3 in 2007, 2009, 2011 and 2013, in Western Hudson Strait (WHS) and Ungava Bay (UB) in 2009; and in Resolution Island Shrimp Area (RISA) in 2007 and 2009.

Surveys of shrimp (*Pandalus borealis* and *P. montagui*) in SFA 2EX, RISA, and SFA 3 have been conducted by the Northern Shrimp Research Foundation (NSRF), with a survey plan developed by DFO Science in the C&A Region (Table 4, Figure 9). These surveys used a standard Campelen 1800 shrimp trawl from 2005 to 2007. However, high incidences of tear-ups were reported and in 2008 modifications were made to the trawl including increasing the size of the footgear and adding floatation to the fishing line and lower belly seams (Siferd and Legge 2014).

The SFA 2Ex and RISA were surveyed with the commercial fishing vessels *Cape Ballard* from 2005 to 2011, and *Aqviq* in 2012 and 2013. In 2014, the NSRF took over the survey of SFA 3. SFA 2Ex, RISA, and SFA 3 were all surveyed by the commercial fishing vessel *Kinguk* in 2014. In 2015, the commercial fishing vessel *Katsheshuk II* was used, while in the last three years (2016–18) the surveys were completed again with the *Aqviq*.

2.2.6. Inshore Coastal Fjord Surveys from Newman Sound, NL

Inshore Common Lumpfish data from a DFO long-term monitoring program in Newman Sound in Terra Nova National Park, NL, provided a snapshot of species abundance (predominantly YOY and juveniles) in Newfoundland coastal fjords. Newman Sound long-term fish and habitat monitoring has occurred annually since 1995. The program sampled 12 sites bi-weekly (typically July to November), with an average of 12 trips per year. A May trip has occurred annually since 2002 to assess over-winter juvenile fish survival. Sites were sampled during a four hour low-tide window with a 25 m demersal seine net deployed ~55 m from shore by boat. Seine hauls covered 880 m^2 per site. All fish species were counted and/or measured. Common Lumpfish were measured to the nearest half centimeter, and occurrence/frequency of males with breeding colouration was recorded. Data from an expansion of the Newman Sound long-term monitoring program were also used to verify Newfoundland coastal fjord Common Lumpfish abundance trends. The expansion program used the same methodology to sample eight seine sites at four locations (Sunnyside, Trinity, Fortune Harbour, and Woodford’s Arm) across the east coast of Newfoundland. Sampling occurred monthly from August to October in 2017 and 2018. These data provided information on juvenile Common Lumpfish annual abundance, seasonal abundance, seasonal length trends, and male size-at-maturity.

2.3. ABUNDANCE AND DISTRIBUTION RESULTS

It is important to note that Common Lumpfish are semi-pelagic during part of their annual migration, so their catchability in bottom trawls remains unknown, and may be low. Also, the inshore spawning migration in spring-summer means that adults may move outside the survey area and thus be less available to a RV survey conducted during the spring and summer at depths >92 m than one conducted in fall or winter. Estimates of absolute abundance and biomass are therefore difficult to obtain, but relative changes in the indices should be indicative of stock status, assuming the timing of each survey is kept reasonably consistent and there have not been shifts in timing of seasonal behaviours that would affect susceptibility to capture in the bottom trawl surveys.

2.3.1. Newfoundland and Labrador (NL) Region Research Vessel Surveys

DFO-NL survey abundance and biomass indices for Common Lumpfish were calculated for spring (Div. 3LNOP) and fall (Div. 2J3KLNO) surveys. Total abundance was also estimated by areal expansion of the stratified mean catch per tow using data from both spring and fall surveys (Smith and Somerton 1981).

In 1971–82 (Yankee trawl), catches of Common Lumpfish were sporadic and generally low in Subdiv. 3Ps, although winter/spring survey numbers per tow and mean weight per tow indices peaked in 1973 at approximately 25 fish/tow and 84 kg/tow, respectively (Figure 10). Both indices then declined to negligible levels, and increased dramatically in 1979, to approximately

23 fish/tow and 84 kg/tow, followed by a precipitous decline. Over 1984–95 (Engel trawl), catches were generally higher, averaging 22 fish/tow and 53 kg/tow. It is worth noting that the highest indices in Subdiv. 3Ps occurred primarily when the survey was conducted earlier in the year. Three dimensional plots expose a shift in abundance indices for those surveys conducted in January-March versus those conducted in April-June (Figure 11, Figure 12). For the Yankee series (1972–83), the highest abundance indices coincided with surveys conducted in February and March. The timing of the survey may have had even more of an effect on the Engel (1983–95) series as each of the winter period values were higher than any spring period value. Whether this is indicative of changes in abundance due to behaviour, migration, or some change in catchability during these months is unknown.

Compared to the Yankee and Engel series, the spring Campelen series in Subdiv. 3Ps was characterized by markedly lower abundance and biomass, especially in the past 10 years (Figure 10). Abundance and biomass indices for the period 1996–2008 (excluding 2006) averaged 1.32 fish/tow and 2.65 kg/tow, respectively; for 2009–18, they averaged 0.10 fish/tow and 0.15 kg/tow, respectively.

Spring abundance and biomass indices for Div. 3LNO (which was characterized by relatively few catches of Common Lumpfish) varied without trend from 1996–2009, averaging 0.025 fish/tow and 0.056 kg/tow (Figure 13). Both indices declined after 2009 and have since remained near zero. Average abundance from 2010–18 was 0.001 fish/tow; average biomass for the same period was 0.002 kg/tow.

Total abundance of Common Lumpfish from the spring survey is presented in Figure 14; Figure 15 provides a finer scale for recent abundance estimates from the Campelen series only.

Fall abundance and biomass indices for Common Lumpfish in Div. 2J3KLNO (1977–94; Engel trawl) varied considerably over time (Figure 16), due in part to expansion of survey coverage (Div. 3L was added in 1983 and Div. 3NO in 1990; 3L was sampled with the Yankee trawl in 1981–82, but has been excluded). Abundance and biomass indices remained low (<0.5 fish/tow and 1.0 kg/tow, respectively), with a slight increase over 1986–94 due to increases in Div. 2J3K. From 1995 (with the introduction of the Campelen trawl) to 2007, abundance and biomass indices in 2J3KLNO averaged 0.45 fish/tow and 0.86 kg/tow, respectively, but have since declined; from 2008–17, they averaged 0.13 fish/tow and 0.26 kg/tow, respectively. Estimates of total abundance of Common Lumpfish from the fall surveys for 1977–2017 are presented in Figure 17.

2.3.2. Maritimes (MAR) Region Surveys

DFO-MAR survey total biomass and total abundance indices were estimated for the winter (Div. 4VsW and Div. 5Z) and summer (Div. 4VWX) surveys.

Given that only 3% of survey tows in 1970–2018 captured Common Lumpfish (882 fish in total), analysis of such sporadic catches was not robust. Of these 882 fish, 273 were from summer surveys, 580 from winter surveys, and 29 from fall surveys in the early-1980s. Biomass indices were estimated only for divisions with the longest survey time-series: highest estimates were found for Div. 4VsW in winter (Figure 18), and for Div. 4X in summer (Figure 19). Total abundance across all areas and seasons is represented in Figure 20.

2.3.3. Gulf Region Surveys

DFO-Gulf survey abundance and biomass indices were expressed as mean fish number per standard tow and mean weight (in kg) per standard tow, respectively, for sGSL (Div. 4T). Irrespective of trawl used, both indices that include fish of all sizes varied without trend and were generally low (Figure 21). The abundance index averaged 0.06 fish/tow over 1971–85 (Yankee trawl), and 0.068 fish/tow in 1986–2017 (Western IIA trawl). The biomass index averaged 0.09 kg/tow in 1971–85, and 0.062 kg/tow over 1986–2017. Over time, the catch rates of Common Lumpfish greater than or equal to 34 cm (size-at-maturity in other locations) have decreased with very few specimens being caught in recent surveys (Figure 22). Since 2000, specimens measuring 34 cm or larger were caught in the RV survey in only four years: 2002, 2007, 2009, and 2012.

2.3.4. Quebec (QC) Region Surveys

In the summer nGSL survey, catches of Common Lumpfish occurred regularly but were not abundant, averaging 30 fish over 20 standard tows out of a total of 180 fishing sets annually. From 1990–2004, abundance and biomass indices were fairly stable, but below the series average. From 2005–18, the variation in these indices was greater, coinciding with the change of vessel/gear combination for this survey. Both indices increased from 2012–16, but have since decreased, though they remain above their respective long term averages. In 2018, the abundance was 0.37 fish/tow, for a series average of 0.22; the biomass index was 0.22 kg/tow, for a series average of 0.12 (Figure 23). Very few mature Common Lumpfish (i.e., ≥34 cm) are caught in the nGSL survey, and variation in the indices is therefore driven by fish <34 cm. Estimates of total abundance and biomass for two population components (i.e., mature and immature) in Div. 4RST from 1990–2018 are presented in Figure 24.

Detailed results of the January trawl survey of Subdiv. 3Pn and 4R are presented in Simpson et al. (2016). To summarize, the Subdiv. 3Pn abundance and biomass indices averaged 3.2 fish/tow and 7.8 kg/tow, respectively; the Div. 4R abundance and biomass indices averaged 3.3 fish/tow and 4.5 kg/tow, respectively. These indices varied without trend.

Between 1990 and 1994, the summer and winter bottom trawl surveys were both conducted in the nGSL. A comparison of catch distributions for these two surveys showed a marked difference in seasonal catchability, with Common Lumpfish being caught in 46% of tows in winter versus 8% in summer. The fact that catches were higher in winter might indicate an aggregation of Common Lumpfish on the bottom, making them more available to the trawl during that period of the year. Increased availability of this species to bottom trawls in winter has been documented in other surveys (Wienerroither et al. 2011 Wienerroither et al. 2013). It is important to note that in addition to seasonality, which varied in both surveys, selectivity was also different due to the use of different vessels and trawls.

Common Lumpfish abundance and biomass indices from nGSL July Sentinel surveys (1995–2018) are presented in Figure 25. They were caught in only 5% of the tows conducted for this survey. Over the time series, abundance and biomass indices varied slightly around the series averages of 0.08 fish/tow and 0.09 kg/tow, respectively. No trends were evident in either index. Highest values were observed in 2017, but were associated with wide confidence intervals (CIs), and both indices decreased in 2018.

2.3.5. Central and Arctic (C&A) Region Surveys

Abundance was not estimated for any of the surveyed areas within the C&A Region (Div. 0A and 0B, RISA, SFA 2Ex, SFA 3, and WHS) due to very small annual catches. Also, given the variability in gear and vessels used throughout the years and areas surveyed it was not feasible to examine trends in these data. Over all surveys (i.e., DFO and NSRF) and years, a total of 73 Common Lumpfish have been caught (Figure 26).

2.3.6. Spatial Distribution and Habitat Association

2.3.6.1. Newfoundland and Labrador (NL) Region

Point maps of DFO-NL standardized catch rates from spring 2014–18 (Figure 27) and fall 2014–17 (Figure 28) research surveys indicated that Common Lumpfish distribution varied inter-annually. This variability may represent seasonal changes related to inshore spawning migrations in spring. Point maps for previous survey years can be found in Simpson et al. (2016).

2.3.6.2. Maritimes (MAR) Region

Historically, Common Lumpfish have been caught infrequently in DFO-MAR research surveys. Catch distributions of this species from the summer and winter surveys since 2014 are presented in Figures 29 and 30, respectively. Catches have been low in both surveys in recent years.

In the summer research survey, they are found predominantly in Div. 4X, often near Grand Manan at the mouth of the Bay of Fundy (Figure 29), and near Cape Breton in 4Vn. In the March 4VsW research survey (discontinued in 2010), catches occurred mainly on Banquereau Bank in Subdiv. 4Vs. During the Georges Bank winter research survey, Common Lumpfish were seldom captured in Div. 5Z (45 instances in 32 years) but were captured in the Bay of Fundy when that survey was extended into Div. 4X (Figure 30).

2.3.6.3. Gulf Region

Common Lumpfish were found infrequently in Div. 4T, with inter-annual variability in catch location and magnitude: largest catches occurred close to the Div. 4S border in some years, and around Prince Edward Island in others. Most catches occurred near the northern boundary of the surveyed areas (i.e., off of Gaspe Peninsula and in the Baie des Chaleurs). Point maps of DFO-sGSL survey standardized catch rates for 2014 through 2017 are presented in Figure 31. Point maps for previous survey years can be found in Simpson et al. (2016).

2.3.6.4. Quebec (QC) Region

Annual point maps of DFO-QC standardized catch rates from the nGSL summer survey series for 2014–18 are presented in Figure 32.

Catches of Common Lumpfish in the August survey (1990–2018) were small, and occurred mainly in the Bay of Sept-Îles, northwest and northeast of Anticosti Island, at the head of Esquiman Channel, and in the approaches of the Strait of Belle Isle (Figure 33). In 2015–18, Common Lumpfish were also found close to the coast on the north side of the Estuary.

The Sentinel July mobile gear survey indicated the same Common Lumpfish distribution as the DFO-QC August survey (Figure 34). This survey also found Common Lumpfish in Subdiv. 3Pn, though only up to 2015, with none having been caught in this subdivision since.

2.3.6.5. Central and Arctic (C&A) Region

Common Lumpfish have been caught occasionally in areas surveyed within the C&A Region (Div. 0A and 0B, RISA, SFA 2Ex, SFA 3, and WHS). A plot of presence and absence using data from the surveys described above indicates their general distribution (Figure 35).

2.3.7. Inshore Coastal Fjord – Newman Sound, NL

Common Lumpfish are routinely caught in low numbers (Mean 58 fish/year, SD ± 67.2) in Newman Sound seining surveys. Annual abundance from July to November increased marginally from 2002 onward, though there was considerable annual variability (Figure 36).

Annual May survey trips began in 2002 and showed variability in catches of this species, with no discernible pattern across years (Figure 37).

During the sampling period, Common Lumpfish catches in Newman Sound were highest in May, October, and November (Figure 38). Catches of larger specimens (185–260 mm total length [TL]) were highest in May, consistent with a seasonal inshore breeding migration (Figure 39; Figure 40). However, the majority of the May catch was composed of smaller specimens (10–35 m TL).

Larger Common Lumpfish were rarely retained in seines, likely due to the shallow sampling depth. However, seven breeding males (displaying red courtship colouration) were identified in Newman Sound since 1995. Breeding male size ranged from 190–240 mm TL. All breeding males were retained in May at the same survey site located at the bottom of Newman Sound. Additionally, the five highest catch sites were located in the more sheltered inner sound, suggesting that breeding Common Lumpfish preferentially select sheltered nest sites, or that nests are more successful in more sheltered areas. More research on nest site selection is required.

Common Lumpfish catches were lowest at the Newman Sound survey site with the least amount of eelgrass coverage. This supports previous studies (e.g., Moring 1989, Moring and Moring 1991) which suggest that eelgrass is an important nursery habitat for juveniles.

Common Lumpfish abundance, length, and seasonal trends were consistent across the two-year east coast expansion study, suggesting that Newman Sound is representative of coastal fjord systems across the east coast of Newfoundland.

2.4. LIFE HISTORY PARAMETERS

Preliminary aging studies, using otoliths of Common Lumpfish captured in the NL Region, indicate that the mean age at first attainment of sexual maturity in females is 5.6 years, with a range of 4–7 years; this corresponds to a length of approximately 35 cm (Grant 2001). More recent data suggests that male Common Lumpfish attain maturity at much smaller sizes. Preliminary data from the nGSL estimated length at 50% maturity (L_{50}) at 22.5 cm for males, and 33 cm for females, and seining data from Newman Sound, NL suggest that some males may reach sexual maturity at 19 cm TL.

The average number of eggs produced by each female per spawning season is roughly 100,000, and depends on body size: the largest females produce up to 350,000 to 400,000 eggs (Davenport 1985, Muus and Nielsen 1999). A recent study of fecundity in Div. 4RS and Subdiv. 3Pn reported an average of 122,000 eggs/female (Gauthier et al. 2017).

Examination of various estimates from empirical relationships, using growth/size and maturity data from several studies of Common Lumpfish, yielded a natural mortality rate (M) of 0.3, and a generation time (G) of 7 years (COSEWIC 2017).

The maximum age for this species has been estimated as 13–14 years (Thorsteinsson 1981). Depending on location, maximum size appears to be 60–70 cm (Cox and Anderson 1922, Scott and Scott 1988), and maximum recorded weight is 9.6 kg (Collins 1976).

3. HABITAT AND RESIDENCE REQUIREMENTS

3.1. HABITAT

Common Lumpfish occur from shallow coastal waters (<20 m) to depths of over 1,000 m; maximum recorded depth is 1,272 m (Collins 1978, Able and Irion 1985, Collette and Klein-MacPhee 2002, Coad and Reist 2018).

Davenport (1985) indicated that Common Lumpfish are semi-pelagic/benthopelagic They are caught in both demersal and pelagic surveys (Casey and Myers 1998, Wienerroither et al. 2011, Sheehan et al. 2012, Wienerroither et al. 2013, Eriksen et al. 2014, Kennedy et al. 2016, Simpson et al. 2016). Kennedy et al. (2016) used data storage tags on Common Lumpfish to demonstrate that they display a mix of pelagic/demersal behavior, and exhibit diel patterns in vertical movement. When demersal, they may occur over a variety of bottom types (COSEWIC 2017). Common Lumpfish, especially young individuals, are commonly associated with a variety of macroalgae, including *Laminaria* spp. and *Ascophyllum nodosum*, as well as eelgrass (Moring 1989, Moring and Moring 1991, Collette and Klein-MacPhee 2002, Nellis et al. 2012).

Common Lumpfish is considered a cold-water species, though it can tolerate temperatures in excess of 20°C for short periods (i.e., less than 24 hours; Ern et al. 2016). In a more recent study, the upper limit of thermal tolerance was estimated at 18°C, due to relatively high mortality at that temperature over a three week period, as well as cataract formation and abnormal swimming behaviour (Hvas et al. 2018). Based on recent research survey data, they appear to prefer temperatures less than 5°C in Canadian waters, and have been captured in waters as cold as -1°C (Simpson et al. 2016). They are able to tolerate reduced salinity (McKenzie 1959, Able and Irion 1985, Davenport 1985), perhaps even as low as 13 parts per thousand (ppt) (O'Connell et al. 1984), though correct egg development requires salinities of at least 20 ppt (Kjørsvik et al. 1984).

3.2. RESIDENCE

SARA defines "residence" as:

"a dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating" (SARA s.2[1]).

The 2015 policy document entitled, "DFO's Guidelines for the Identification of Residence and Preparation of a Residence Statement for an Aquatic Species at Risk" (unpublished report) states that the following four conditions should be used to determine whether the concept of residence applies to an aquatic species:

1. There is a discrete dwelling-place that has structural form and function similar to a den or nest or other similar area;
2. An individual of the species has made an investment in creating and/or modifying the dwelling-place;
3. The dwelling-place has the functional capacity to support the successful performance of an essential life-cycle process such as spawning, breeding, nursing and rearing; and
4. The dwelling-place is occupied by one or more individuals at one or more parts of their life cycle.

Based on these criteria, Common Lumpfish mating/nesting sites would constitute residences, since adult males construct dens for the eggs; they also modify and protect the area once the eggs are deposited. These dens support reproduction (an essential life-cycle process) and are occupied by both adults and larvae (Goulet et al. 1986).

As mentioned previously, tagging studies (Schopka 1974, Fréchet et al. 2011) strongly suggest homing to inshore spawning grounds in spring, so these sites should be considered as breeding residences. Directed fisheries targeting adults, as well as removals due to bycatch in other fisheries, that occur near or at these breeding sites in spring/summer could negatively impact reproduction and recruitment.

4. THREATS AND LIMITING FACTORS TO SURVIVAL AND RECOVERY OF COMMON LUMPFISH

Knowledge pertaining to the level of risk posed by the following identified threats is summarized in Appendix 1.

4.1. COMMERCIAL FISHERY (DIRECTED AND BYCATCH)

The only quantified anthropogenic threat to recovery of Common Lumpfish is ongoing fishing related mortality resulting from directed commercial fisheries for this species and, to a lesser extent, bycatch (retained/landed and/or discarded) in commercial fisheries directing for other species.

In Atlantic Canadian waters, the directed fishery for this species targets females exclusively, which are harvested to collect unfertilized eggs (i.e., roe) that are marketed as caviar. The Canadian roe fishery in Div. 3KL, Subdiv. 3Ps, and Div. 4R developed in the early-1970s. In Subdiv. 3Pn, a directed fishery began in 1980. For Div. 4S, the first reported landings are from 1986, but fishing for this species for local markets may have begun earlier (Bérubé 1990). The fishery occurs in shallow coastal waters for a few weeks between April and July, and is conducted primarily by small vessels (i.e., <35 feet in length) using gillnets with 10½ inch mesh. This roe fishery is highly dependent on market conditions. No directed commercial fishery for this species exists in the MAR Region (Div. 4VWX5YZ), Gulf Region (Div. 4T), or C&A Region (Div. 0AB and Hudson Strait), though they may be taken as bycatch. The roe is the landed product, while the carcass has little commercial value and is generally discarded at sea (Kennedy et al. 2018). With respect to Canadian reported roe landings in the Zonal Interchange File Format (ZIFF) database, no conversion factor exists to convert these landings to whole (round) weight of females. However, a factor of 4 is currently used to derive a round weight equivalent (Stevenson and Baird 1988) and DFO-QC reports roe and round equivalent weights (Gauthier et al. 2017). Information on Common Lumpfish roe landings in Atlantic Canada has been published in Stevenson and Baird (1988), Chouinard el. at. (1992), Stansbury et al. (1995), DFO (2002), Fréchet et al. (2011), COSEWIC (2017), Gauthier et al. (2017), and Kennedy et al. (2018). The following includes an update from the pre-COSEWIC Common Lumpfish assessment (Simpson et al. 2016).

4.1.1. Methods

Commercial fisheries removals of Common Lumpfish in Div. 3KLNOP and Div. 4RS were examined for 1970–2017, using commercial data in three databases: the Northwest Atlantic Fisheries Organization (NAFO) STATLANT 21A landings (1970–2017), as reported by NAFO member countries; DFO ZIFF landings (1985–2017) and Maritimes Fisheries Information System (MARFIS) landings (2002–17), as reported by Canadian fishers (recorded in their logbooks and on fish plants' purchase slips); and Canadian At-Sea Fisheries Observers' (ASO) catch and discard data (1983–2017), collected on a set-by-set basis in a standardized format on board commercial fishing vessels at sea. Canadian ASOs constitute the only source of data on bycatch discarded at sea in fisheries where this program operates. The ASO coverage varies greatly among different directed fisheries, but the requirements are often 5%, though actual coverage levels may be as low as 0–1%. For the STATLANT 21A database, Canada records the weight of the landed roe product and multiplies this weight by 4 to obtain a round weight equivalent (Stevenson and Baird 1988). Other NAFO-member countries do not convert to round, so all reported values are assumed to be round weights.

In the MAR Region, commercial fisheries removals through bycatch were calculated using the ZIFF (1988–2009) and MARFIS (2002–17) databases. Very little Common Lumpfish was landed, so the MAR Region ASO database was used as an indicator of potential interaction between this species and commercial fishing gear (1978–2018). Observed catches in all Regions were not scaled to landings of the targeted species, and are biased by the frequency and level of observer coverage allotted to a fishery.

4.1.2. Results

Common Lumpfish roe landings were initially low in Div. 3P4RS, then significantly increased from 1976 to a peak in 1987 (Gauthier et al. 2017, Fréchet et al. 2011; Figure 41). Over 1987–2000, roe landings were variable, but averaged 1,281 t annually. Roe landings were significantly lower in 2001–03 (305 t average), then increased in 2004, but have since declined to a 29 t annual average over 2009–17. Overall, Div. 4S was a minor contributor, while Subdiv. 3Ps dominated roe landings from 1978–2007 (Figure 42). In recent years, roe landings were predominantly from Div. 4R with a smaller percentage of landings from Subdiv. 3Ps. There were few reported landings of whole Common Lumpfish in NAFO Div. 4RS and Subdiv. 3Pn from 2000–17. For the same period, annual bycatch reported as roe in other directed fisheries was low.

In Div. 2J3KL, Common Lumpfish roe landings increased over 1970–79, declined to low levels in 1980–84, and then increased dramatically to a peak in 1987 (Stansbury et al. 1995; Figure 43). Roe landings remained relatively high until 1993, and have since declined to very low levels. Roe landings were variable in Div. 3KL and only occasionally reported from Div. 2J. From 2004–12 the proportion of roe landings from Div. 3K increased, and in the past 5 years the percentages of landings from 3K and 3L have been variable (Figure 44).

In Div. 3KLOP, the Common Lumpfish-directed gillnet fishery landed the majority of reported roe in 1995–2003, while gillnet fisheries targeting Atlantic cod and skates (combined) averaged 2% annually (Figure 45). Since 2004, the directed fishery reported almost all roe landings (312 t annual average). Table 5 details the number of fishers directing for Common Lumpfish roe between 1998 and 2018 per NAFO Division in 3KLP4RS. Activity was much higher prior to 2013, with an average of 960 fishers per year from 1998–2012. From 2013–18, the average fell to 29 active fishers per year.

From 1998 (i.e., when ‘month’ was recorded in NL fishers’ logbooks) to 2007, roe landings from Div. 3KL occurred predominantly in June; since then, 40%, on average were reported annually in July (Figure 46). Small amounts continued to be landed annually in May. In Subdiv. 3Ps and 3Pn, the majority of Common Lumpfish roe (70% and 84%, respectively) from 1998–2006 were landed in May, and from 2007–12, landings occurred mainly in June (75% and 82%, respectively). Negligible amounts were sporadically reported in July. Over the 1994–2014 period, the Div. 4R fishery occurred in May and June, with 50% of the reported landings in each of those two months; since 2015 most of landings are reported in June. In Div. 4S, 70% of the reported landings occurred in June.

DFO-NL ZIFF data also indicated that whole Common Lumpfish were occasionally landed in Subarea 3. Over 1977–82, landings averaged 121 t annually. In 2010–17, average annual landings were <0.5 t. The DFO-MARFIS database contained only 61 records of Common Lumpfish landings for 2002–17 and indicated that bycatch of this species occurred in groundfish fisheries using otter trawls, gillnets, and longlines in Div. 4X and, to a lesser extent, Div. 5Y.

Although dependent on the percentage of ASO coverage of each fishery in each year, NL ASO data from 1983–2017 indicated that most catches of Common Lumpfish occurred in Subdiv. 3Ps (Figure 47). However, in the NL Region there has been no observer coverage of the directed-fishery for Common Lumpfish since 2010, so there is no way to quantify discards of male and immature fish. In 1983–93, bottom otter trawls targeting American Plaice (*Hippoglossoides platessoides*) and Atlantic cod took the majority of observed Common Lumpfish bycatch: annually averaging 18 t (peak of 63 t in 1990) and 9 t, respectively (Figure 48; Figure 49). Over 1994–2006, the Common Lumpfish-directed fishery was observed to annually catch 30 t on average (peak of 73 t in 1999) with fixed gillnets, while the redfish (*Sebastes* spp.) gillnet fishery averaged 5 t in 1994–2003. Observed catches of Common Lumpfish in directed and bycatch fisheries became negligible by 2008. Changes in these observed catches may be due to annual variation in ASO coverage of fisheries in Subdiv. 3Ps.

No Common Lumpfish roe has been reported landed in the MAR Region since 1997. Only 176 kg of Common Lumpfish were reported landed between 2002 and 2017, mainly from bycatch in gillnet and otter trawl gears in Div. 4X.

Prior to the moratorium placed on Div. 4VW in 1993, Common Lumpfish were most often observed in fisheries directing for groundfish such as Atlantic cod, Pollock (*Pollachius virens*), and Haddock (*Melanogrammus aeglefinus*), with a total observed weight of 90 t over the years 1978–93 (Table 6). Since 1993, Common Lumpfish have been observed mainly in fisheries directing for redfish, followed by gadoids, flatfish, and Longhorn Sculpin (*Myoxocephalus octodecemspinosus*). Observations of Common Lumpfish in fisheries directing for shrimp declined with the introduction of the Nordmore grate (a groundfish excluder) in 1993 (Bourdages and Marquis 2019).

Coarse estimates of total Common Lumpfish catches have been calculated by scaling observed catches to total landings for some years in Div. 4VWX. Gavaris et al. (2010) estimated total catches of 1.3 to 2.0 t by groundfish bottom trawling in Div. 4VW, and 0.7 to 7.7 t in Div. 4X5Y for 2002–06. A total catch of 2.4 t was estimated for the one year in which Common Lumpfish were observed in gillnets deployed in Div. 4X5Y. Total catches in offshore scallop dredges were 0–0.5 t in Div. 4X5Y and from 0–10 t in Div. 5Z (Gavaris et al. 2010). Estimated total catches of Common Lumpfish in lobster gear (mostly discarded) in 2009–10 were 3.6 t in Div. 4VW and 0.5 t in Div. 4X5Y (Pezzack et al. 2014). Estimates of Common Lumpfish discards from the inshore scallop fishery in Div. 4X by Sameoto and Glass (2012) range from 0–19.1 t for 2002–09.

In Div. 4RS, bycatch of Common Lumpfish was looked at using the ASO database. From 2000 to 2017, this database reported 39,826 fishing activities observed in Div. 4RS. Bycatch of Common Lumpfish was reported in 372 (0.9%) of those observed fishing activities, and 99% was discarded at sea (Table 7). When observed, Common Lumpfish catches were mostly of less than 1 kg per activity. The species was caught in fisheries targeting for Winter Flounder (*Pseudopleuronectes americanus*), American Plaice, redfish, Northern Shrimp, Witch Flounder (*Glyptocephalus cynoglossus*), Greenland Halibut, Atlantic cod, and Iceland Scallop (*Chlamys islandica*). In total, the ASO database reported 495 kg of Common Lumpfish bycatch in Div. 4RS from 2000-17. Catches occurred in gillnets, otter trawl, shrimp trawl, seine, and dredge. Except for the shrimp fishery, Common Lumpfish bycatch was not scaled to the total effort or total landings of the fisheries. When scaled to the total effort of the shrimp fishery, Common Lumpfish bycatch in Div. 4RST remains low and is estimated to an average of 50 kg for the period 2000–17. Bycatch of this species consists essentially of juveniles due to use of the Nordmore grate.

In Div. 4T, ASO data reported Common Lumpfish (by decreasing weight) in cod otter trawls, plaice scottish seines, cod gillnets, Winter Flounder gillnets, redfish trawls, plaice gillnets, pandalus shrimp trawls, cod scottish seines, Winter Flounder trawls, and Greenland Halibut gillnets (Figure 50). Since 2009, bycatch of this species was observed in the Div. 4T pandalus fishery most frequently, as well as in redfish trawl, Greenland Halibut gillnet, Atlantic cod otter trawl, and Winter Flounder gillnet fisheries. It is important to note that availability of data was dependent on the percentage of Canadian ASO coverage of each fishery. ZIFF records for Div. 4T suggest few Common Lumpfish were reported in landed bycatch since 2005, with the largest catch being 20 kgs bycaught in the Winter Flounder gillnet fishery in 2017.

Commercial length frequencies taken in Subdiv. 3Ps over 1995–97 by Canadian ASOs indicated that gillnets caught 30–52 cm Common Lumpfish, consisting of 478 females (31–52 cm; 40 cm mode) and 35 males (27–38 cm; 32 cm mode); data from the DFO-NL spring and fall surveys in Div. 2J3KLNOPs 1979–2014 show a shorter length frequency (COSEWIC 2017). In Subdiv. 3Pn and Div. 4RS over 2004–12, Common Lumpfish-directed gillnets caught 28–52 cm females (40 cm mode; n=3,782), while males were rare and not measured for length (Figure 51, top panel). In 2017 and 2018, commercial length frequencies were measured in the Div. 4R Common Lumpfish-directed fishery; females ranged from 26 cm to 53 cm (mode=40 cm, n=9,388) and males ranged from 22 cm to 37 cm (mode=28 cm, n=346). Males represented 4% of the total catch due to their smaller size (Figure 51, bottom panel).

Relative fishing mortality (Rel. F=[ZIFF-reported commercial Common Lumpfish roe landings]*4/Canadian research survey biomass of female fish >34 cm) was variable and high in Div. 3L over 1996–2006, while remaining low in Div. 3P, and negligible in Div. 3K (Figure 52). Rel. F in Div. 3LP decreased to its lowest levels since 2007. For nGSL, catches of mature females in the Common Lumpfish-directed fishery largely exceeded the available population estimates, which are based on the DFO RV survey.

4.2. INTERSPECIFIC INTERACTIONS

4.2.1. Parasitic, Viral, and Bacterial Infections

As discussed in Simpson et al. 2016, Common Lumpfish are hosts to parasitic copepods (*Lernaeocera branchialis*; *Caligus elongates*) and protozoans (*Cryptobia dahli*; *Trichodina domerguei*). Several helminth species are known to infect Common Lumpfish, including the nematode *Anisakis simplex* (McLelland et al. 1990, Rolbiecki and Rokicki 2008), which also infects humans. They are hosts for the parasitic microsporidian, *Nucleospora cyclopteri*, which attacks the kidneys and was first identified in a wild population of Common Lumpfish off Iceland (Freeman et al. 2013, Karlsbakk et al. 2014). Recently, they were confirmed as hosts to another microsporidian, *Tetramicra brevifium*, which affects all internal organs, liquefies skeletal muscle, and causes cysts on skin and fins (Scholz et al. 2017).

Common Lumpfish are also subject to bacterial and viral infections. Bacterial infections may be caused by atypical *Aeromonas salmonicida*; *Vibrio* spp.; *Pseudomonas anguilliseptica*; *Pasteurella* spp.; and *Tenacibaculum* spp. (Marcos-López et al. 2013, Gulla et al. 2015, Alarcón et al. 2016, Bornø et al. 2016). The causative agent of winter ulcer disease, *Moritella viscosa*, infects a number of fish species, including Common Lumpfish (Gudmundsdóttir and Björnsdóttir 2007, Einarsdottir et al. 2018). Recently, *Tenacibaculum maritimum*, which causes another form of ulcerative disease in a variety of fish species, was first isolated from cultured juvenile Common Lumpfish (Småge et al. 2016). In 2015, a putative new virus of the family Flaviviridae, which primarily attacks the liver and kidneys, was isolated from tissues of Common Lumpfish kept in culture, and was named "*Cyclopterus lumpus* virus" (CLuV; Skoge et al. 2018). In addition, a novel genotype of Viral Haemorrhagic Septicaemia Virus (VHSV) was recently identified in a group of wild juvenile Common Lumpfish from Iceland, which were transported to a land-based farm as broodstock (Guðmundsdóttir et al. 2019).

The impacts of these infections have not been quantified for Common Lumpfish populations in Canada. Many of the aforementioned infectious agents were identified in Common Lumpfish populations from the northeast Atlantic. However, it seems reasonable to conclude that both wild and farmed populations of Common Lumpfish in Canadian waters could be impacted, particularly if aquaculture enterprises in the northwest Atlantic rely heavily on imported broodstock as cleaner fish.

4.2.2. Invasive Species

Several aquatic invasive species may have deleterious effects on Common Lumpfish and/or their habitat, though it is not possible to quantify any effects at present.

In Atlantic Canada, European Green Crabs (*Carcinus maenas*) now range from the Bay of Fundy to northeastern New Brunswick and southern Newfoundland (Therriault et al. 2008). Declines in eelgrass presence and percent coverage correlate strongly with the presence of green crabs (Matheson et al. 2016). Eelgrass is known to be particularly important for early developmental stages of a number of fish, including Common Lumpfish. Adult Green Crabs are known to be omnivorous (Therriault et al. 2008) and inhabit shallow water on a variety of bottom types including hard substrates of the outer coast and hard and soft substrates in protected embayments (Klassen and Locke 2007). It is possible that Green Crabs could predate juvenile Common Lumpfish and egg clusters, while causing destruction of vegetation important to nesting sites.

Golden Star (*Botryllus schlosseri*), Pancake Batter (*Didemnum vexillum*), Vase (*Ciona intestinalis*), and Violet (*Botrylloides violaceus*) Tunicates, along with the Compound Sea Squirt (*Diplosoma listerianum*), could all reduce available habitat for egg denning and juvenile Common Lumpfish rearing, by outcompeting other bottom dwelling species for space. The Vase Tunicate attaches to eelgrass in Newfoundland (Sargent et al. 2013). The behavior of Common Lumpfish in response to the presence of this invasive species has not been described. However, it is known that scallop larvae will avoid settling on the Pancake Batter Tunicate (Carman et al. 2016). These tunicates can make it more difficult for other animals to attach to surfaces, leaving them more vulnerable to removal by currents. Additionally, these tunicates most commonly colonize hard or firm substrates such as rocky seabed (Carman et al. 2016), which often constitutes a preferred nesting site for Common Lumpfish.

4.3. OIL AND GAS, SEISMIC EXPOSURE

Seismic surveys are widely used to detect potential drilling locations for oil and gas reserves, and involve sending sound waves down to the sea floor and recording echoes that return from various sedimentary layers. Impacts on life stages of Common Lumpfish and/or their prey may occur, but it is impossible to verify this at present.

There are significant drilling license areas in NL waters. Hibernia, Terra Nova, White Rose, Hebron, and North Amethyst oil fields are currently in operation in the Jeanne d'Arc Basin. In addition, there is current interest in the development of the Bay du Nord oil field. Any significant oil pollution could be transported by the Labrador Current and thus potentially impact Common Lumpfish (especially eggs and larvae), and their habitat. There are no data currently available on the impact of oil and gas drilling, or of oil pollution, on Common Lumpfish life stages or habitat, but they have been identified as a species which is vulnerable to potential oil spill in the Gulf of St Lawrence (Desjardins et al. 2018).

4.4. AQUACULTURE AND OTHER INSHORE ANTHROPOGENIC DISTURBANCES

The potential for anthropogenic disturbance and negative impacts on marine species is often highest in inshore and coastal areas, as they are more proximal to human population centers and associated activity (Ban and Adler 2008).

Aquaculture enterprises in Newfoundland utilize Common Lumpfish as cleaner fish, to control sea lice (*Lepeophtheirus salmonis*) infestations in farmed Atlantic salmon (*Salmo salar*). Any reliance on wild broodstock to achieve this may not be sustainable, given recent indications that stocks in Canada and Iceland may already be overexploited (Pampoulie et al. 2014). The increasing demand for cleaner fish as a consequence of aquaculture expansion and declining efficacy of antiparasitic chemicals may necessitate the sourcing of eggs from Iceland, or other countries, so that the fish can be raised entirely in captivity prior to their use. Common Lumpfish from Iceland, along with those from Norway, form a genetically distinct group separate from those in Canada (Pampoulie et al. 2014). The potential for intermixing of these two distinct groups exists should a specimen sourced from Iceland escape captivity, and the implications for wild Canadian stocks of Common Lumpfish are unknown.

Apart from the aforementioned potential impacts of aquaculture, which takes place in coastal areas, there is the possibility of negative effects from terrestrial activities. For example, run-off in the form of chemicals/fertilizers from agriculture and other industries and domestic use of detergents are known to result in eutrophication in nearshore waters. Pollution in nearshore environments as a consequence of both industrial and domestic activities may cause mortality of Common Lumpfish, or their prey, when these animals come in contact with toxic substances. Hydroelectric power generation results in the release of freshwater in bays and other nearshore environments, which may impact survival of early life stages of Common Lumpfish and other fish species.

4.5. CLIMATE CHANGE

Although Common Lumpfish are tolerant of a wide range of temperatures, they prefer waters less than 5°C. Warmer waters, particularly those in excess of 15°C, are associated with increased mortality, as well as the formation of cataracts and the development of abnormal swimming behaviour (Hvas et al. 2018). Ocean warming as a consequence of climate change may reduce the survival of Common Lumpfish, either directly, or as a consequence of a reduction in prey availability, as a number of other species may be negatively impacted by increasing water temperatures.

5. RECOVERY TARGETS

5.1. MODELLING

There are no currently accepted recovery or fishing reference points for this species in Atlantic and Arctic Canadian waters. With the aim of establishing a biomass target in the form of B_{lim} (i.e., the limit reference point [LRP] for spawning stock biomass), attempts were made to model the stocks in Subdiv. 3Ps and Div. 3KL, Div. 4RS, and Div. 4T (using a length-based stage-structured model; Swain and Benoit 2017). No attempts to model stocks in other Regions were made, due to insufficient data.

5.1.1. Newfoundland and Labrador (NL) Region

A Bayesian state-space implementation of the Schaefer Surplus-Production (SP; Schaefer 1954) model was used for stocks in Div. 3KL and Subdiv. 3Ps, using DFO-NL research survey data and available landings data. SP models were chosen due to a lack of age-disaggregated data for this population and limited length data with which to develop length-based models.

Note that Common Lumpfish roe landings were converted to Common Lumpfish round weight using a multiplier of 4 (Stevenson and Baird 1988).

Non-informative priors were used for catchability (q), and for observation and process errors. These priors were given non-informative, gamma distributions.

Vague priors were also used for carrying capacity (K), and the intrinsic rate of population increase (r). The starting value of r was 0.58, consistent with the estimate used by Fréchet (2005). Typically, K is set to stock biomass in the year prior to onset of fishing (P0; Meyer and Millar 1999). However, in models used here, stock biomass in 1970 was not assumed to be virgin biomass, B_0; therefore, P0 was allowed to vary between 0.1 and 1 (i.e., initial biomass was allowed to vary between K*0.1 and K).

Modeling attempts were evaluated with regard to the overall deviance information criteria (DIC), model process error range and variability, model residual fits, and diagnostics plots (e.g., Kernel density estimates of posteriors, Gelman and Rubin shrink factors, convergence of chains using sampler running means, time series trace).

In all cases, there were issues in the model diagnostics which could not be resolved. In Subdiv. 3Ps, there was a pattern in the residuals which could not be resolved. In addition, the model fit and convergence were poor and the process error was high. Similarly, the Bayesian model developed for Div. 3KL had a very high process error, but overall, it was concluded that the data, and other information available, were insufficient to model the population dynamics of Common Lumpfish in these areas with a surplus production model. Possible reasons for the lack of model fit include poor quality catch data, lack of information on discard survival of males, and lack of conversion factors between survey gears.

5.1.2. Maritimes (MAR) Region

No modelling was attempted due to insufficient data.

5.1.3. Gulf Region

In the sGSL, Div. 4T, where catch biomass is not available, a length-based stage-structured model was attempted (Swain and Benoit 2017). RV abundance indices for Common Lumpfish were modelled using two stages: juveniles (<34 cm) and adults (≥34 cm). Catchability for the adult stage was fixed at 1 in the model, whereas catchability for the juvenile stage was a model parameter. Total mortality (Z) was estimated separately for juvenile and adult stages over six time periods. As well, recruitment was estimated as the log average plus an annual lognormal deviate.

Overall, the modeling was unsuccessful. Estimates of Z were at the parameter bounds for both juvenile and adults and all attempts to solve the problem failed. Warnings occurred that either the Hessian or the estimated covariance matrix might not be positive. As well, the Markov chain Monte Carlo medians and the means were often inconsistent with the maximum likelihood estimates of juvenile total mortality. Overall, it was concluded that the data, and other information available, were insufficient to model population dynamics of Common Lumpfish in Div. 4T.

5.1.4. Quebec (QC) Region

In the QC Region, a Surplus Production in Continuous Time (SPiCT) model (Pedersen and Berg 2017) was used to model Common Lumpfish in Div. 4RS. Data from the DFO RV summer survey, winter survey, and Sentinel surveys, along with commercial fishery catch (converted to round weight), were used to populate the original model. Overall, the various models which were attempted were found to violate the assumption of normality in the catch index, had issues with convergence, and had a high level of uncertainty. Furthermore, a retrospective analysis indicated issues with the model. Various attempts to fix the models were unsuccessful. Therefore, it was concluded that the data, and other information available, were insufficient to model population dynamics of Common Lumpfish in Div. 4RS.

5.1.5. Central and Arctic (C&A) Region

No modelling was attempted due to insufficient data.

5.2. ABUNDANCE AND DISTRIBUTION TARGETS

In the absence of models for this species in Canadian waters, an interim recovery target was proposed based on combined NL survey biomass indices for Subdiv. 3Ps and Div. 3KL. Surveys in these management units target the areas where most of the Common Lumpfish biomass in Canadian waters is concentrated, the combined biomass index for these areas showed contrast, and data from these areas is the main source of information on which COSEWIC based the status of the species. These recovery targets were developed according to the DFO Precautionary Approach (DFO 2006). A proxy of the biomass at maximum sustainable yield (B_{msy}) is estimated at 19,788 t based on the average biomass of a productive period between 1996–2006. The proposed interim recovery target is set to be above the LRP which is estimated at 7,915 t (40% of B_{msy}). The recovery target is set at the upper stock reference point (USR) 15,831 t (80% of B_{msy}). Current survey biomass is estimated to be 50% of the LRP.

It should be noted that these proxy reference points are proposals which are consistent with the intent of recovery, but are not permanent and may be refined over time as new methods, data, or approaches become available.

Due to the lack of a quantitative model, the population trajectories could not be projected.

The candidate distribution recovery target for this DU is to increase the distribution to historic levels in NAFO Subdiv. 3Ps and Div. 3KL, and to maintain the current distribution throughout the other areas (Div. 2J; Div. 3NO; Subdiv. 3Pn; Div. 4RST; Div. 4VWX5YZ; and SA 0). Sufficient suitable habitat is thought to be available to meet the demands of the species both at present and when it reaches the recovery target.

6. SCENARIOS FOR MITIGATION OF THREATS AND ALTERNATIVES TO ACTIVITIES

Fishing is the only quantified source of anthropogenic mortality for Common Lumpfish in the Atlantic DU. There is a directed fishery and additional mortality occurs as a consequence of bycatch in fisheries directing for a variety of species. Current levels of fishing mortality are not thought to jeopardize survival. However, a decrease in fishing mortality may be required to achieve the abundance and distribution recovery targets. Reduction of fishing mortality and mitigation of impacts to nesting and nursery habitat can be achieved through a variety of fisheries management and habitat protection measures.

Potential measures to decrease fishing mortality of Common Lumpfish include:

- Reduction of fishing pressure through a license buy-back program.
- Reduction of fishing pressure through alternate resource management methods (closures/limits, etc.)
- Prohibition of the directed fishery for Common Lumpfish roe.
- Prohibition of retention of Common Lumpfish in other fisheries in which this species is captured as bycatch.
- Implementation of a license condition giving priority to the sorting and rapid discard of bycaught Common Lumpfish with the least possible harm.
- Development of gear modifications which would reduce the bycatch of Common Lumpfish.
- Reduction in bycatch potential by implementing temporal and spatial closures for commercial fisheries in which there is Common Lumpfish bycatch.

Other measures include improved monitoring of Common Lumpfish catch and discards by increasing Canadian ASO coverage. This would provide information on species, catch rates, locations, and seasonality of bycatch and discarding in these fisheries. Such data would prove crucial to informing management decisions on effective measures to reduce anthropogenic activities that pose threats to this species. Given that discards are not reported by Canadian and foreign fishers (i.e., only landings are recorded), Canadian ASOs constitute the sole source of bycatch data by species, including retained catch and discards at sea. It should be noted that annual observer coverage of relevant fisheries remains low to non-existent (≤7%).

In addition, given the role of eelgrass and macroalgae in the survival of juveniles, any activities which increase the availability of eelgrass/macroalgae habitats may benefit Common Lumpfish populations.

7. ALLOWABLE HARM

Allowable harm is “harm to the wildlife species that will not jeopardize its recovery or survival” (DFO 2004). Under SARA, activities can be permitted if the total harm (i.e., from all potential sources) which could occur would not jeopardize survival or recovery of the species, and the following criteria are met:

1. “The current population is neither so small that random factors threaten population viability nor so concentrated in space that it is vulnerable to elimination by a catastrophic event”.
2. “The recent trajectory of the stock is stable or likely to be increasing, so that survival or recovery is not in jeopardy in the period when the permit is in place”.
3. “The known sources of human-induced mortality are unlikely to increase during the permitting period. This means that there is high confidence that the causes of human-induced mortality are under management control, monitored, and can be enforced effectively”.
4. “There is a relatively high likelihood that recovery goals will be achieved in biologically reasonable time frames with the activity present”.

For Common Lumpfish in Canada, the population is neither small nor concentrated in space, given its widespread geographic distribution throughout Atlantic Canada and into the Arctic. As well, the movement patterns and spatial distribution in the northwest Atlantic should make Common Lumpfish relatively invulnerable to localized catastrophic events. However, the current trends in biomass are variable in different Regions of the DU. In NAFO Div. 4RS, biomass is currently above the long term average; in Subdiv. 3Ps, the biomass appears to continue to be in decline.

Fishing is the only quantified threat to Common Lumpfish in the Atlantic and Arctic Oceans, through both incidental bycatch in other fisheries and by directed fishing. Incidental bycatch of Common Lumpfish is known to occur at low levels and these current low levels of bycatch could have an impact on the potential survival or recovery of Common Lumpfish. As well, while directed fishing mortality of this species is under management control, is monitored, and can be enforced effectively, it is unclear if it can sustain a directed fishery in some areas (e.g., Subdiv. 3Ps), particularly when the fishery targets mature spawning females. It should be noted that Subdiv. 3Ps has been undergoing structural changes as observed in ecosystem signals in recent years, which indicate that overall ecosystem productivity may be low. The full impacts of these changes on Common Lumpfish are not fully known, but could potentially result in impaired productivity.

Therefore, it is probable that recovery of Common Lumpfish can occur in a biologically reasonable time frame, if directed fishing mortality is reduced or eliminated.

8. SUMMARY

Common Lumpfish in Atlantic Canada was designated as Threatened by COSEWIC in 2017, due to severe declines in both research survey abundance/biomass indices and commercial landings. A review of available data indicates that survey indices remain low in some areas historically associated with higher abundance and biomass estimates (e.g., Subdiv. 3Ps; Div. 2J3KL). Commercial landings remain low throughout all areas. Attempts to model Common Lumpfish in this DU using survey and fishery data were unsuccessful. However, proxy abundance targets and reference points for some stocks were proposed. Therefore, precautionary management is advised. Since commercial fishing is the only quantified source of anthropogenic mortality, and the directed fishery targets the eggs of mature females, a reduction in fishing mortality may be required to achieve the abundance and distribution recovery targets.

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11. TABLES

Table 1. DFO winter/spring research surveys conducted in NL waters (Div. 3LNO and Subdiv. 3Ps) using: Yankee 41.5 otter trawl (Y) in 1971–83; Engel 145 otter trawl (E) in 1984–95; and Campelen 1800 shrimp trawl (C) in 1996–2018. Empty cell (-): no survey was conducted. The survey in 2006 was incomplete (INC); those data were not included in the analyses.

YEAR	Div. 3L	Div. 3N	Div. 3O	Subdiv. 3Ps	YEAR	Div. 3L	Div. 3N	Div. 3O	Subdiv. 3Ps
1971	Y	Y	Y	-	1996	C	C	C	C
1972	Y	Y	-	Y	1997	C	C	C	C
1973	Y	Y	Y	Y	1998	C	C	C	C
1974	Y	Y	-	Y	1999	C	C	C	C
1975	Y	Y	Y	Y	2000	C	C	C	C
1976	Y	Y	Y	Y	2001	C	C	C	C
1977	Y	Y	Y	Y	2002	C	C	C	C
1978	Y	Y	Y	Y	2003	C	C	C	C
1979	Y	Y	Y	Y	2004	C	C	C	C
1980	Y	Y	Y	Y	2005	C	C	C	C
1981	Y	Y	Y	Y	2006	INC	INC	INC	-
1982	Y	Y	Y	Y	2007	C	C	C	C
1983	-	-	-	E	2008	C	C	C	C
1984	E	E	E	E	2009	C	C	C	C
1985	E	E	E	E	2010	C	C	C	C
1986	E	E	E	E	2011	C	C	C	C
1987	E	E	E	E	2012	C	C	C	C
1988	E	E	E	E	2013	C	C	C	C
1989	E	E	E	E	2014	C	C	C	C
1990	E	E	E	E	2015	INC	C	C	C
1991	E	E	E	E	2016	C	C	C	C
1992	E	E	E	E	2017	INC	C	C	C
1993	E	E	E	E	2018	C	C	C	C
1994	E	E	E	E					
1995	E	E	E	E					

Table 2. DFO fall research surveys conducted in NL waters (Div. 2GHJ3KLMNO) using: Engel 145 otter trawl (E) in 1977–94; and Campelen 1800 shrimp trawl (C) in 1995–2017. Empty cell (-): no survey was conducted.

YEAR	Div. 2G	Div. 2H	Div. 2J	Div. 3K	Div. 3L	Div. 3M	Div. 3N	Div. 3O
1977	-	-	E	E	-	Y	-	-
1978	E	E	E	E	-	E	-	-
1979	E	E	E	E	-	E	-	-
1980	-	-	E	E	-	E	-	-
1981	E	E	E	E	E	E	-	-
1982	-	-	E	E	E	E	-	-
1983	-	-	E	E	E	E	-	-
1984	-	-	E	E	E	E	-	-
1985	-	-	E	E	E	E	-	-
1986	-	-	E	E	E	-	-	-
1987	E	E	E	E	E	-	-	-
1988	E	E	E	E	E	-	-	-
1989	-	-	E	E	E	-	-	-
1990	-	-	E	E	E	-	E	E
1991	E	E	E	E	E	-	E	E
1992	-	-	E	E	E	-	E	E
1993	-	-	E	E	E	-	E	E
1994	-	-	E	E	E	-	E	E

YEAR	Div. 2G	Div. 2H	Div. 2J	Div. 3K	Div. 3L	Div. 3M	Div. 3N	Div. 3O
1995	-	-	C	C	C	-	C	C
1996	C	C	C	C	C	C	C	C
1997	C	C	C	C	C	C	C	C
1998	C	C	C	C	C	C	C	C
1999	C	C	C	C	C	C	C	C
2000	-	-	C	C	C	C	C	C
2001	-	C	C	C	C	C	C	C
2002	-	-	C	C	C	C	C	C
2003	-	-	C	C	C	C	C	C
2004	-	C	C	C	C	-	C	C
2005	-	-	C	C	C	-	C	C
2006	-	C	C	C	C	C	C	C
2007	-	-	C	C	C	C	C	C
2008	-	C	C	C	C	-	C	C
2009	-	-	C	C	C	-	C	C
2010	-	C	C	C	C	-	C	C
2011	-	C	C	C	C	-	C	C
2012	-	C	C	C	C	-	C	C
2013	-	C	C	C	C	-	C	C
2014	-	C	C	C	C	-	INC	-
2015	-	C	C	C	C	-	C	C
2016	-	C	C	C	C	-	C	C
2017	-	C	C	C	C	-	C	C

Table 3. DFO-QC research surveys conducted in the nGSL, 1978–2017.

Surveys	Vessel	Vessel Size (m)	Year	Month	Gear	NAFO	Coverage	Tow duration (min)	Tow speed (knots)	Wing spread (ft)
DFO-Winter	Gadus Atlantica	73.8	1978–94 No survey in 1982	January	Engels 145 Hi-Lift Codend liner mesh size:30 mm	3Pn, 4RST	Strata >50 fathoms Estuary not covered Average area: 31,700–100,400 km^2 3Pn and 4R well covered	30	3.5	45
DFO-Summer	Alfred Needler	50.3	1990–2005 No survey in 2004	August	URI shrimp trawl 81'/114' Codend liner mesh size:19 mm	4RST	Addition of shallow strata: 20–50 fathoms Survey Area 116,115 km^2	24	3	44
DFO-Summer	Teleost	63	2004–18	August	Campelen 1800 Rock Hopper foot gear Codend liner mesh size: 12.7 mm	4RST	Survey Area 116,115 km^2	15	3	55.6
Industry	Sentinel commercial boats from QC and NL Regions	13.72–19.81	1995–2018	July	Star Balloon 300 Rock Hopper foot gear Codend liner mesh size: 40 mm Restrictor cable	3Pn, 4RST	Estuary not covered Survey area: 117,449 km^2	30	2.5	54

Table 4. DFO-C&A and NSRF research surveys conducted in DFO-C&A waters (Div. 0AB ; SFA 1, 2Ex, and 3; RISA, WHS and UB) using an Alfredo III otter trawl (A), a Cosmos 2000 shrimp trawl (Co), a standard Campelen 1800 shrimp trawl (Ca) and a modified Campelen 1800 shrimp trawl (Ca-m). Where no survey has been conducted, the cell is empty.

Year	0A-South	0A-North	0B	SFA 1	SFA 3	RISA	SFA2 Ex	WHS & UB
1999	A	-	-	-	-	-	-	-
2000	-	-	A	-	-	-	-	-
2001	A	-	A	-	-	-	-	-
2002	-	-	-	-	-	-	-	-
2003	-	-	-	-	-	-	-	-
2004	A	A	-	-	-	-	-	-
2005	-	-	-	-	-	Ca	Ca	-
2006	A & Co	-	-	Co	-	Ca	Ca	-
2007	-	-	-	-	Co	Co & Ca	Ca	-
2008	A & Co	-	-	Co	-	Co & Ca-m	Ca	-
2009	-	-	Co	-	Co	Ca-m	Ca-m	Co
2010	A	A	-	Co	-	Ca-m	Ca-m	-
2011	-	-	A	-	Co	Ca-m	Ca-m	-
2012	A	A	-	Co	-	Ca-m	Ca-m	-
2013	-	-	A	-	Co	Ca-m	Ca-m	-
2014	A	-	A	-	Ca-m	Ca-m	Ca-m	-
2015	A	-	A	-	Ca-m	Ca-m	Ca-m	-
2016	A	-	A	-	Ca-m	Ca-m	Ca-m	-
2017	A	-	-	-	Ca-m	Ca-m	Ca-m	-

Table 5. Number of active fishers directing for Common Lumpfish roe between 1998 and 2018 per NAFO Division.

NAFO Division	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
3K	314	289	354	395	300	215	241	270	251	138	176
3L	285	377	339	378	239	198	354	410	304	129	93
3PN	153	138	129	75	29	83	72	73	46	30	5
3PS	475	482	386	384	148	344	432	412	333	268	132
4R	337	357	238	179	64	125	120	143	129	97	101
4S	42	74	26	53	29	59	59	53	51	22	38
TOTAL	**1,606**	**1,717**	**1,472**	**1,464**	**809**	**1,024**	**1,278**	**1,361**	**1,114**	**684**	**545**

Table 5 Continued.

NAFO Division	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
3K	143	169	138	119	1	8	8	6	4	7
3L	105	82	36	36	1	-	3	4	-	1
3PN	-	11	1	-	-	-	-	-	-	-
3PS	38	26	12	8	-	-	-	1	5	1
4R	78	103	87	67	17	34	30	15	10	18
4S	22	19	8	14	-	-	-	-	-	-
TOTAL	**386**	**410**	**282**	**244**	**19**	**42**	**41**	**26**	**19**	**27**

Table 6. Observed number of sets and total catches (kg) of Common Lumpfish grouped by fishing trip type in the MAR Region (Div. 4VWX5Y) commercial fisheries from 1978–2018 (data from DFO-MAR ASO database). Where no observations were recorded, the cell contains a "-".

Trip Type (Target Species)	1978–1993		1994–2018	
	No. of sets	Total catch (kg)	No. of sets	Total catch (kg)
Groundfish[1]	3,757	89,985	382	2,348
Flatfish[2]	114	2,448	85	449
Herring	5	58	3	7
Redfish	376	5,124	601	4,426
Shrimp	9	79	-	-
Lobster	-	-	13	15
Sea Scallop	-	-	13	15
Sea Urchin	-	-	2	2
Sculpin	-	-	30	202
Silver Hake	107	455	107	272
Skate	6	80	10	59
Snow Crab	-	-	3	3
Squid	3	13	-	-

1. Atlantic cod, Pollock, Haddock
2. American Plaice, Yellowtail, Witch Flounder

Table 7. Information on bycatch of Common Lumpfish in Div. 4RS based on the 2000–17 ASO database.

Fishery	Number of activities observed	Number of activities observed with bycatch of lumpfish	Observed activities with bycatch of lumpfish (%)	Weight of lumpfish (kg)		
				Kept	Discarded at sea	Total
Winter Flounder	38	8	21.1	-	28	28
American Plaice	149	9	6.0	-	32	32
Redfish	581	16	2.8	-	43	43
Shrimp	17,453	269	1.5	1	285	286
Witch Flounder	298	3	1.0	-	4	4
Greenland Halibut	5,583	42	0.8	3	57	60
Atlantic Cod	3,399	24	0.7	1	40	41
Iceland Scallop	8,378	1	0	-	1	1
White Hake	2	0	0	-	-	0

Fishery	Number of activities observed	Number of activities observed with bycatch of lumpfish	Observed activities with bycatch of lumpfish (%)	Weight of lumpfish (kg)		
				Kept	Discarded at sea	Total
Atlantic Halibut	1,716	0	0	-	-	-
Atlantic Herring	135	0	0	-	-	-
Capelin	119	0	0	-	-	-
Atlantic Mackerel	17	0	0	-	-	-
Thorny Skate	2	0	0	-	-	-
Spiny Dogfish	1	0	0	-	-	-
Atlantic Hagfish	1	0	0	-	-	-
Toad Crabs	109	0	0	-	-	-
Snow Crab	1,826	0	0	-	-	-
American Lobster	16	0	0	-	-	-
Sea Scallop	3	0	0	-	-	-
TOTAL	39,826	372	0.9	5	490	495

12. FIGURES

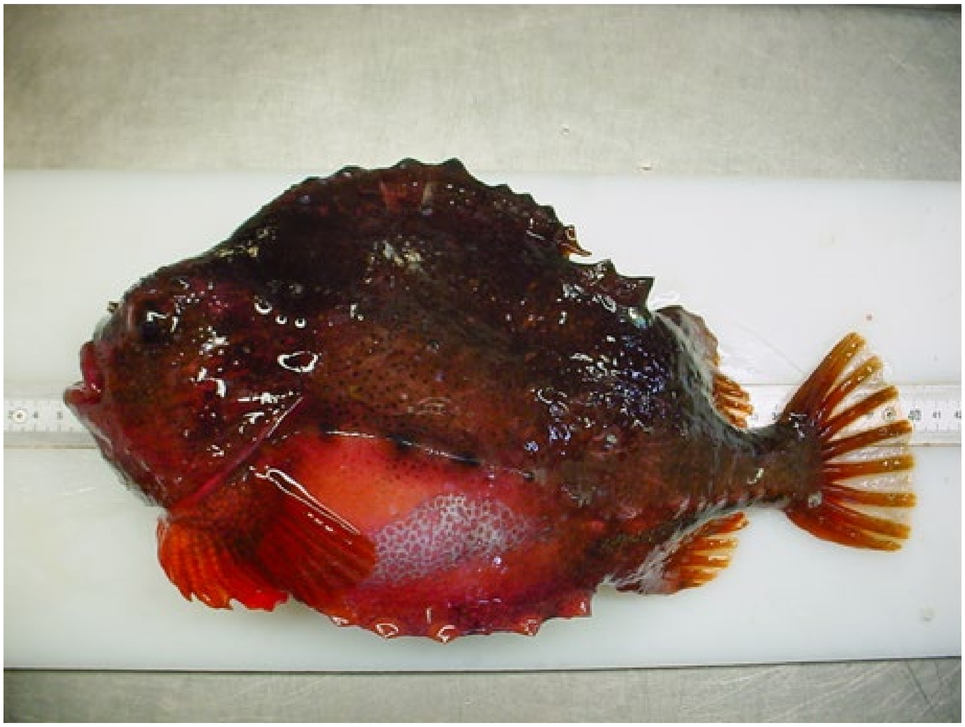

Figure 1a. Common Lumpfish adult male, displaying courtship colouration. Photo provided by C. Nozères (QC Region).

Figure 1b. Common Lumpfish adult female. Photo provided by C. Nozères (QC Region).

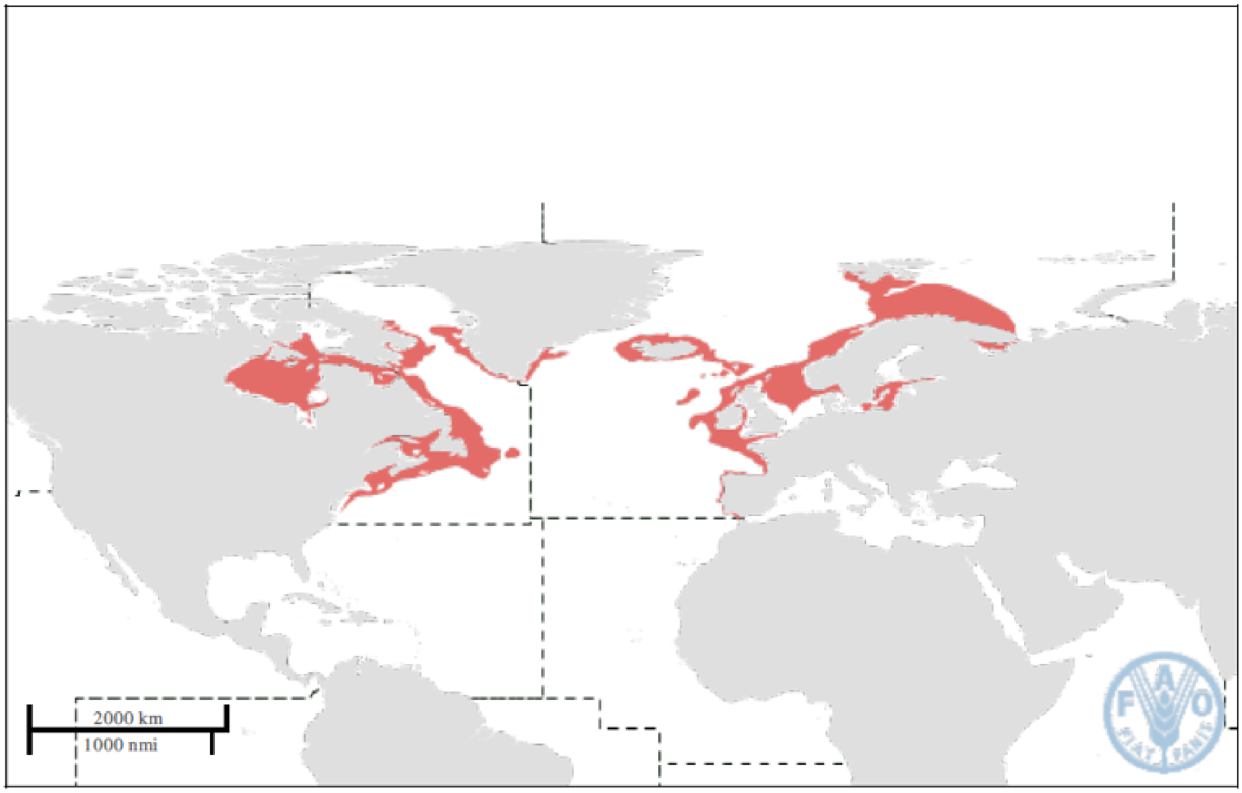

Figure 2. Map of the global distribution of Common Lumpfish. Source: Food and Agriculture Organization of the United Nations species profile.

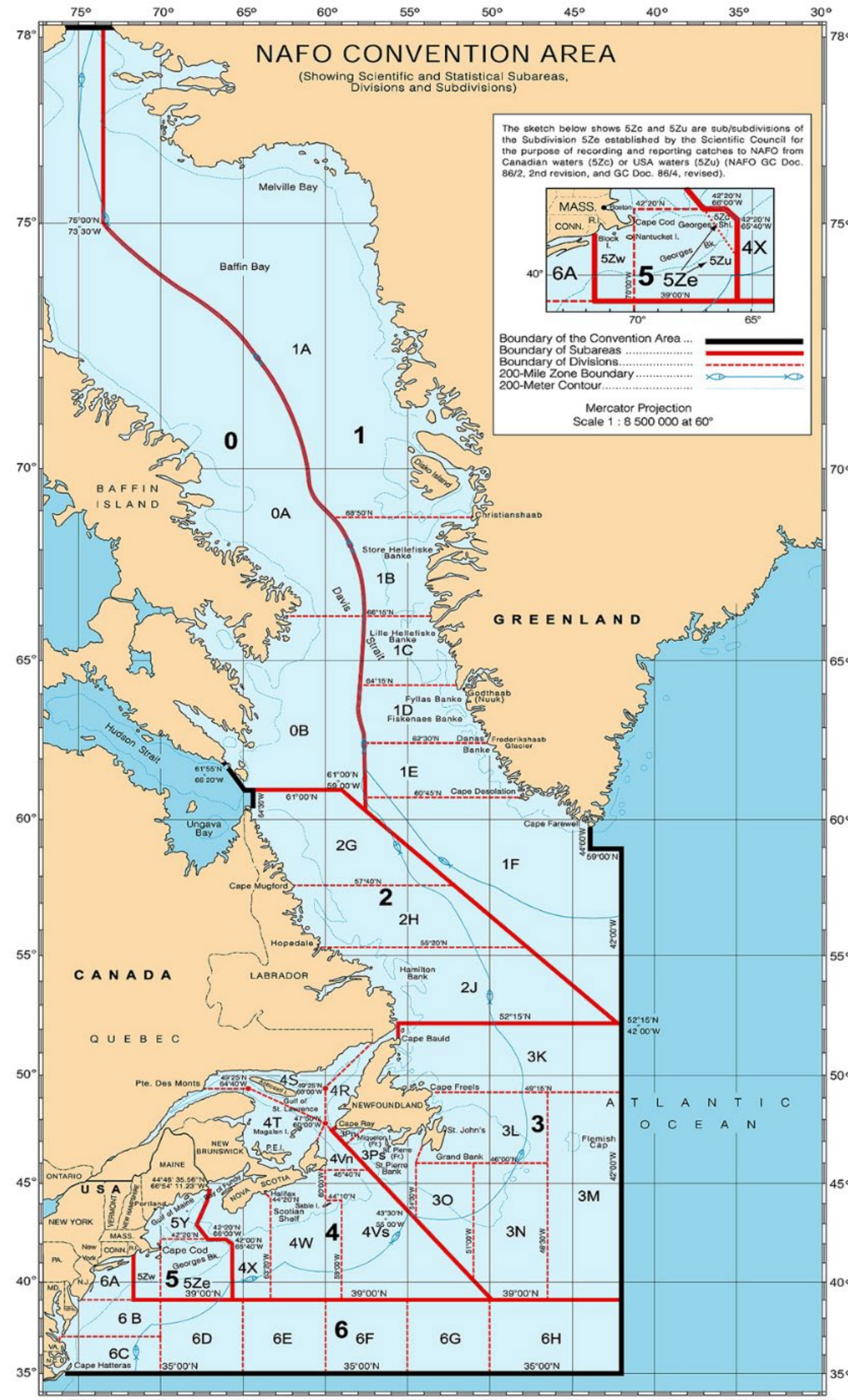

Figure 3. Map of areas mentioned in the text. Canada's EEZ is delineated by the thin blue line (emphasized with fish outlines), NAFO Subareas by thick red lines, NAFO Divisions by thick dashed red lines, and a 200 m contour by the thin blue dashed line.

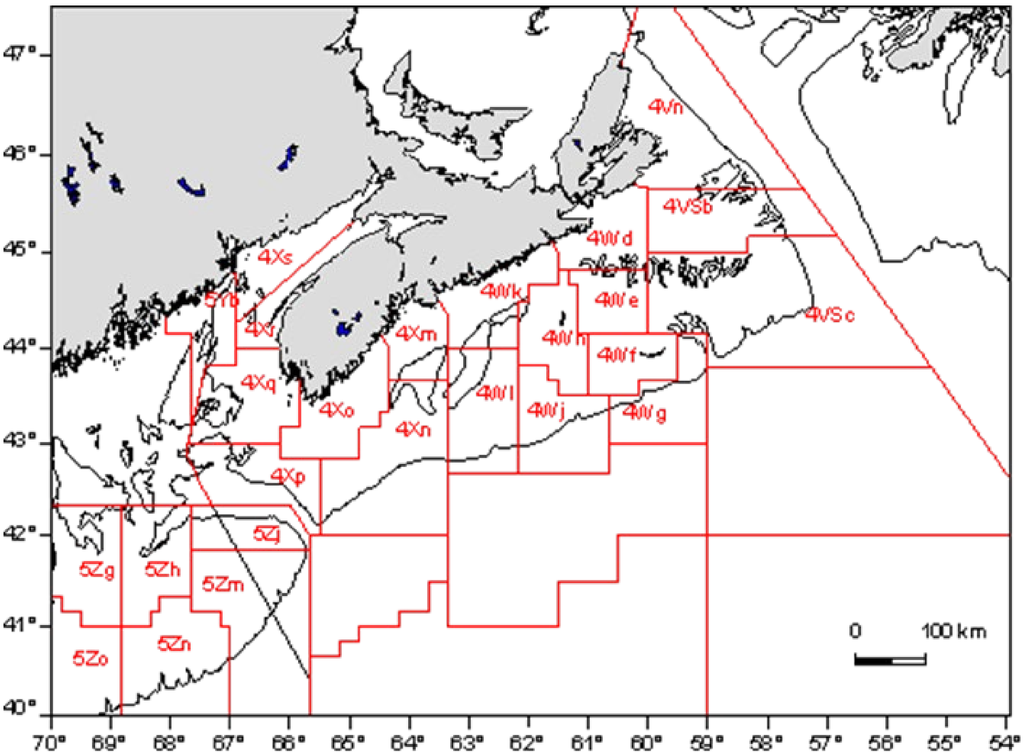

Figure 4. NAFO Unit Areas comprising the Scotian Shelf and Georges Bank.

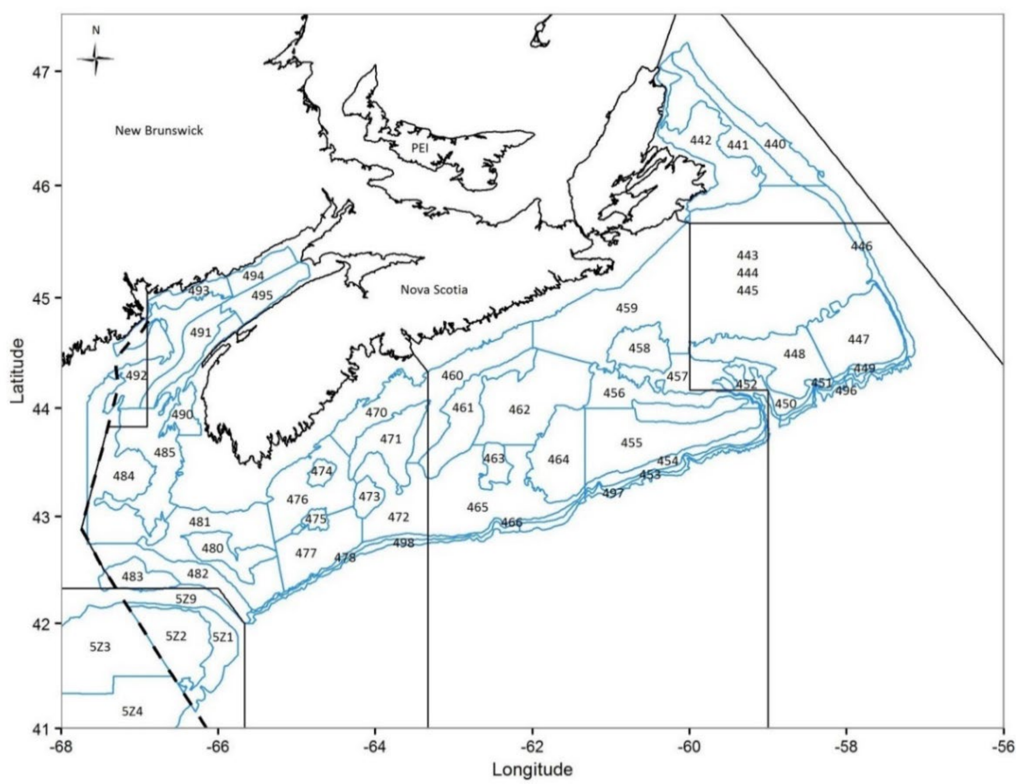

Figure 5. Stratification scheme used for the DFO-MAR Summer RV survey.

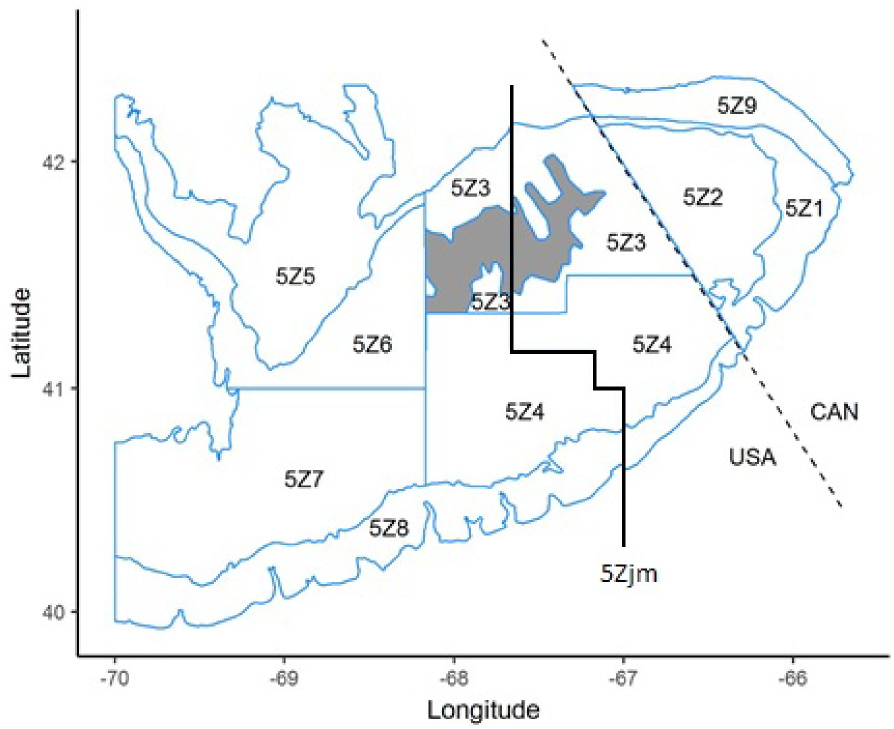

Figure 6. Stratification scheme used for the DFO-MAR Georges Bank RV survey.

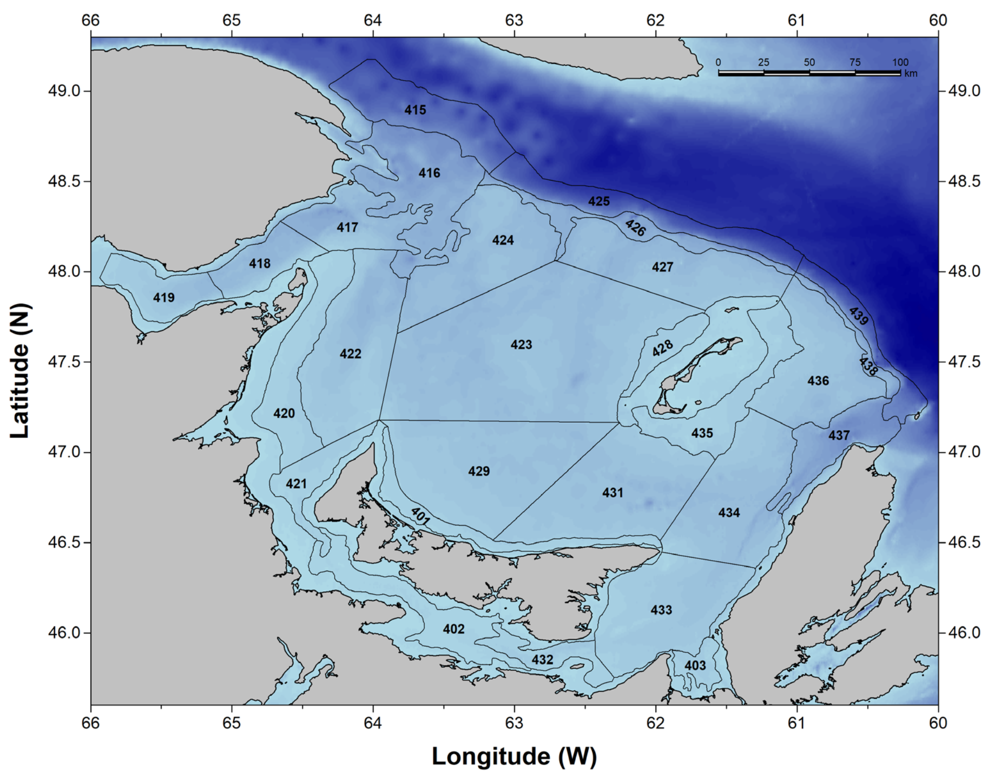

Figure 7. Stratification scheme used for the sGSL DFO research survey, 1971–2017.

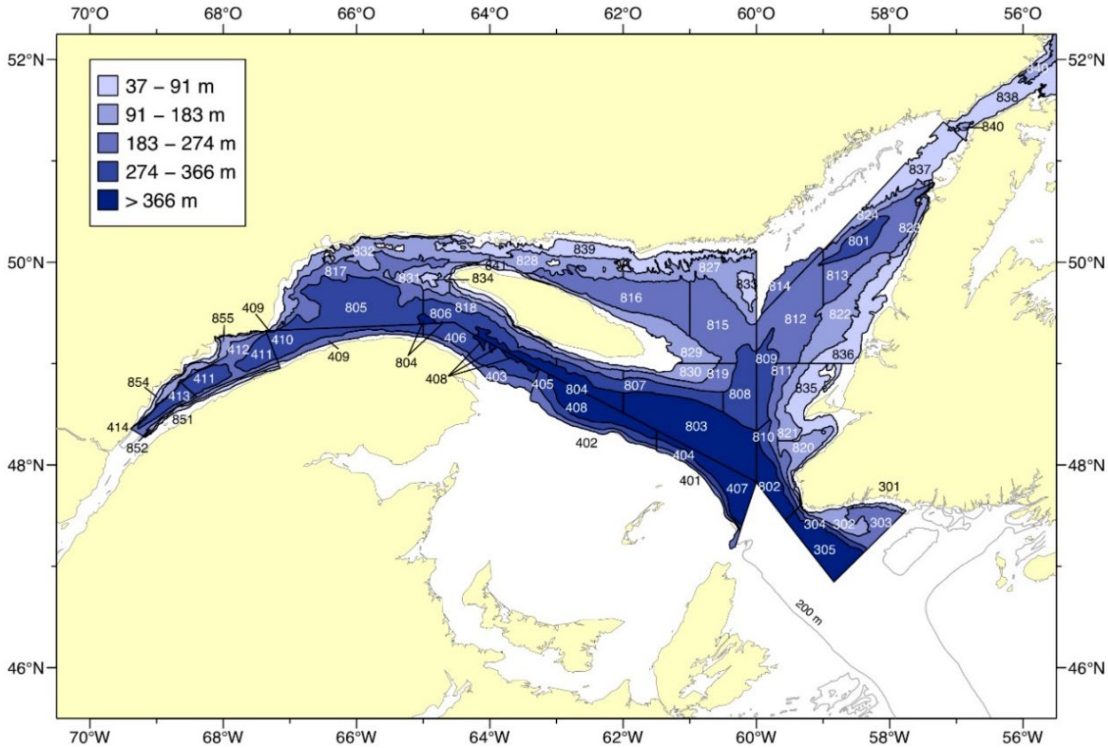

Figure 8a. Stratification scheme used for the DFO groundfish and shrimp research survey in the Estuary and nGSL.

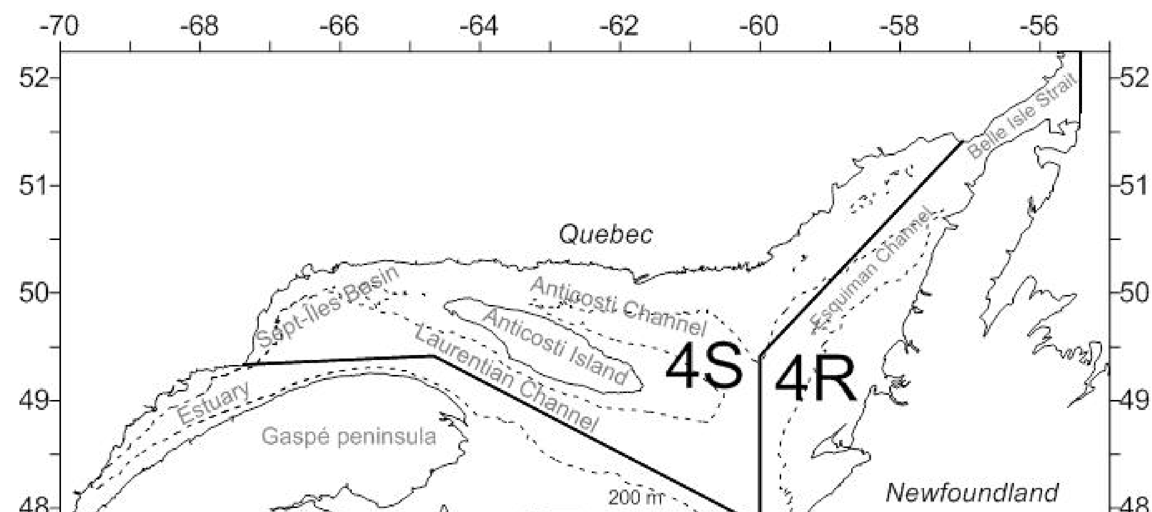

Figure 8b. Gulf of St. Lawrence with NAFO Divisions and locations cited.

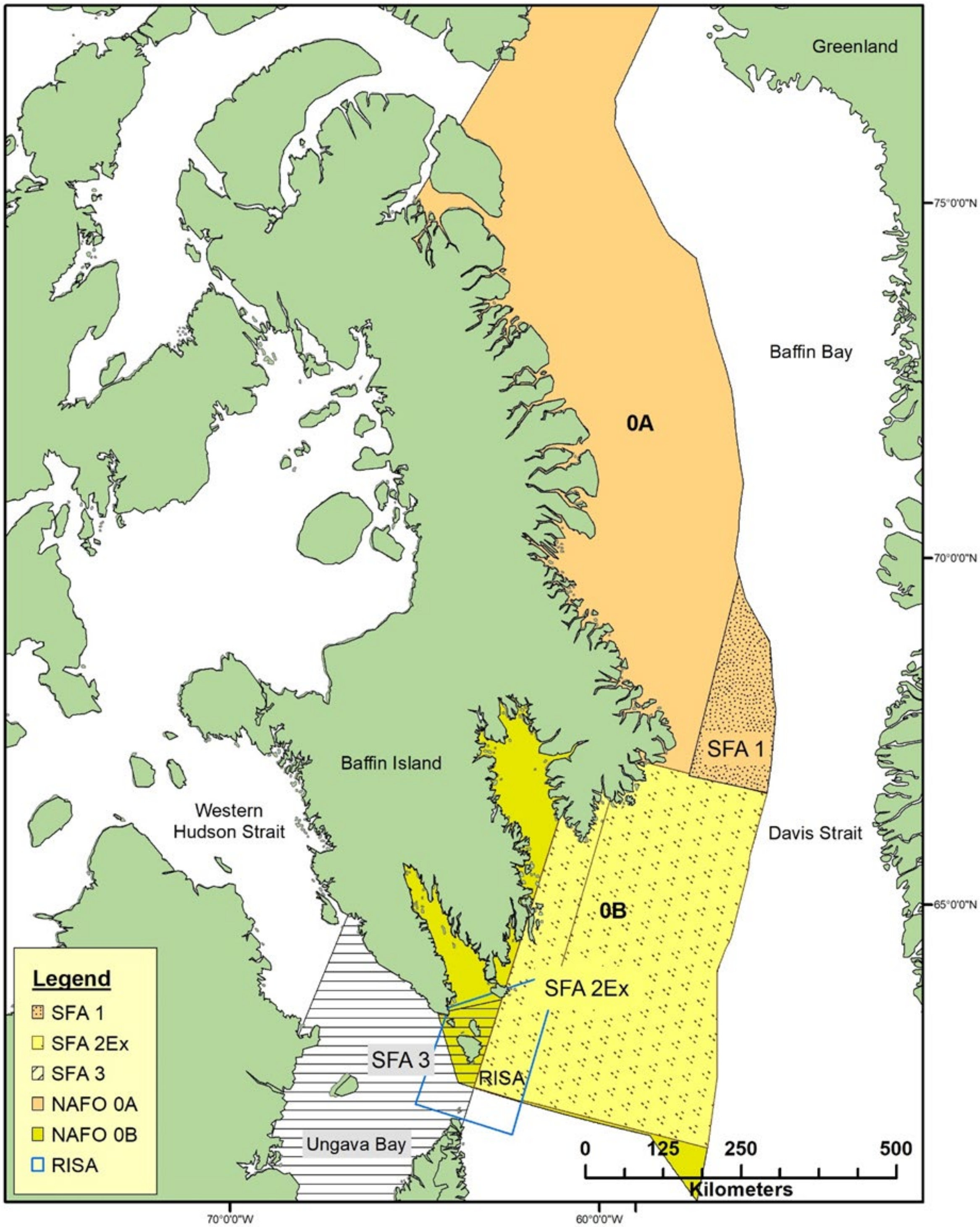

Figure 9. Survey areas for Fisheries and Oceans and NSRF surveys. Canadian Shrimp Fishing Areas (SFA 1, 2Ex, 3, and RISA) overlap NAFO Divisions 0A and 0B.

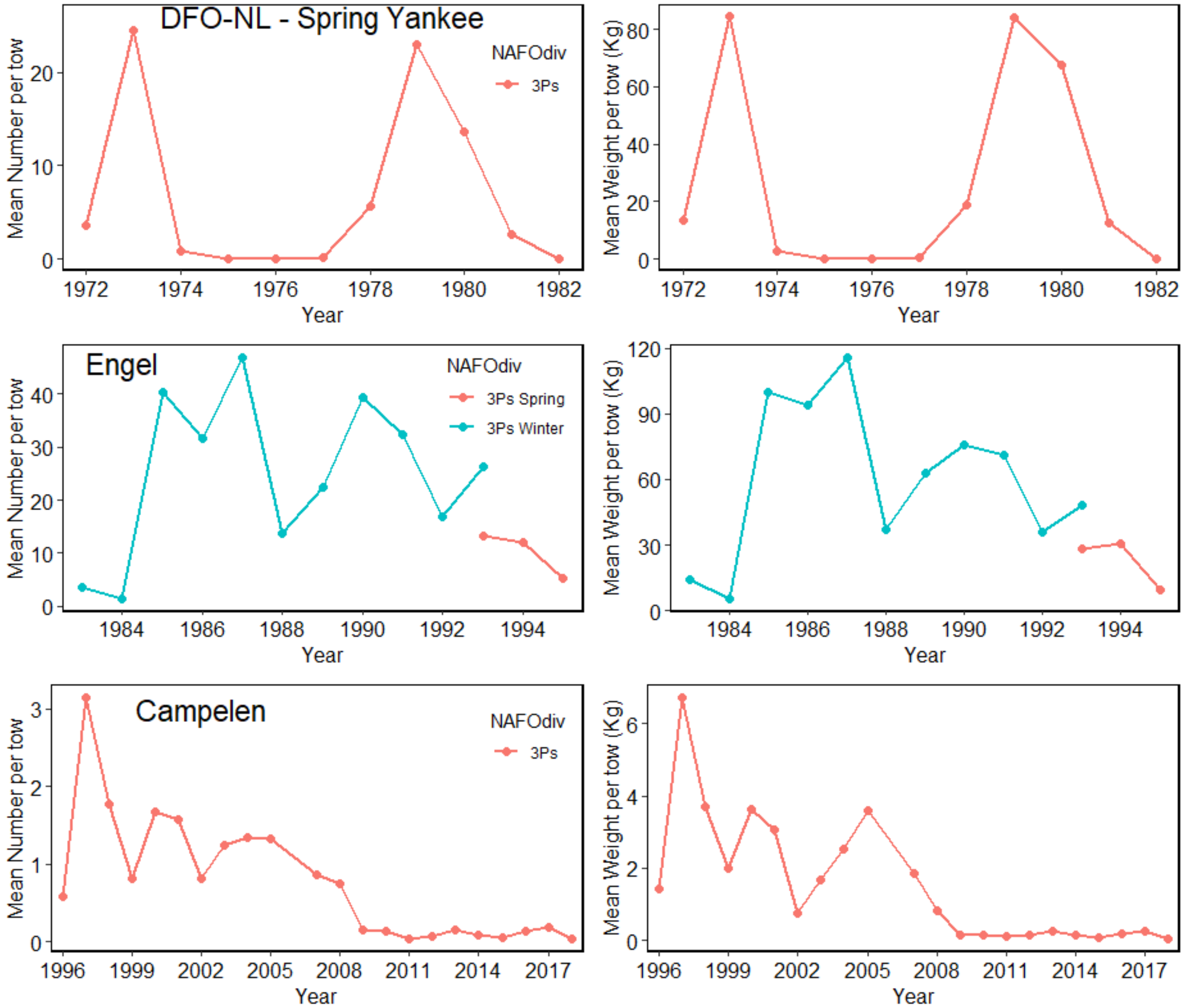

Figure 10. Mean numbers (left panels) and mean weights (kg; right panels) per tow of Common Lumpfish from DFO-NL spring research surveys in Subdiv. 3Ps, 1972–2018.

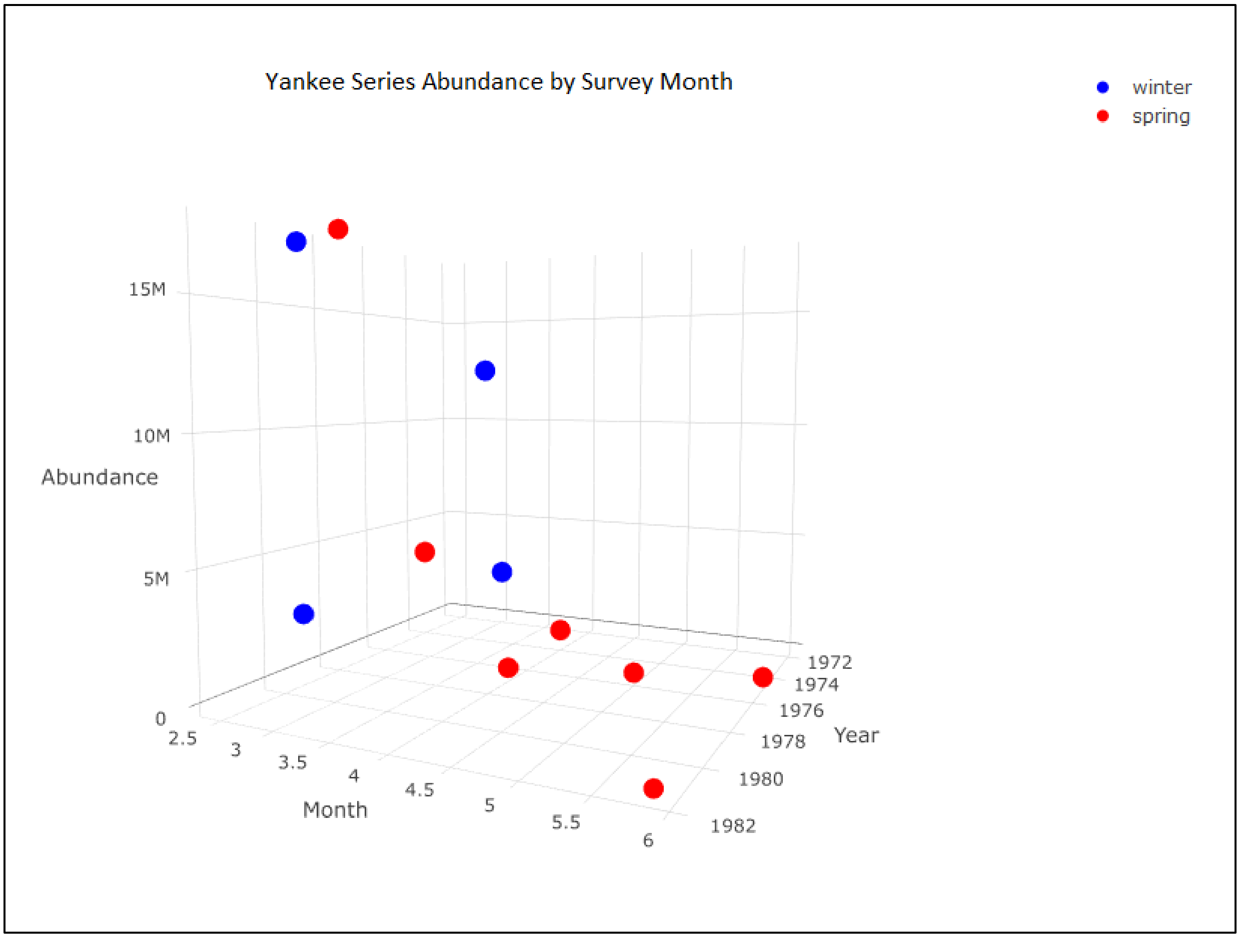

Figure 11. Observed Abundance of Common Lumpfish in Subdiv. 3Ps Yankee trawl series surveys by average month in which sampling occurred.

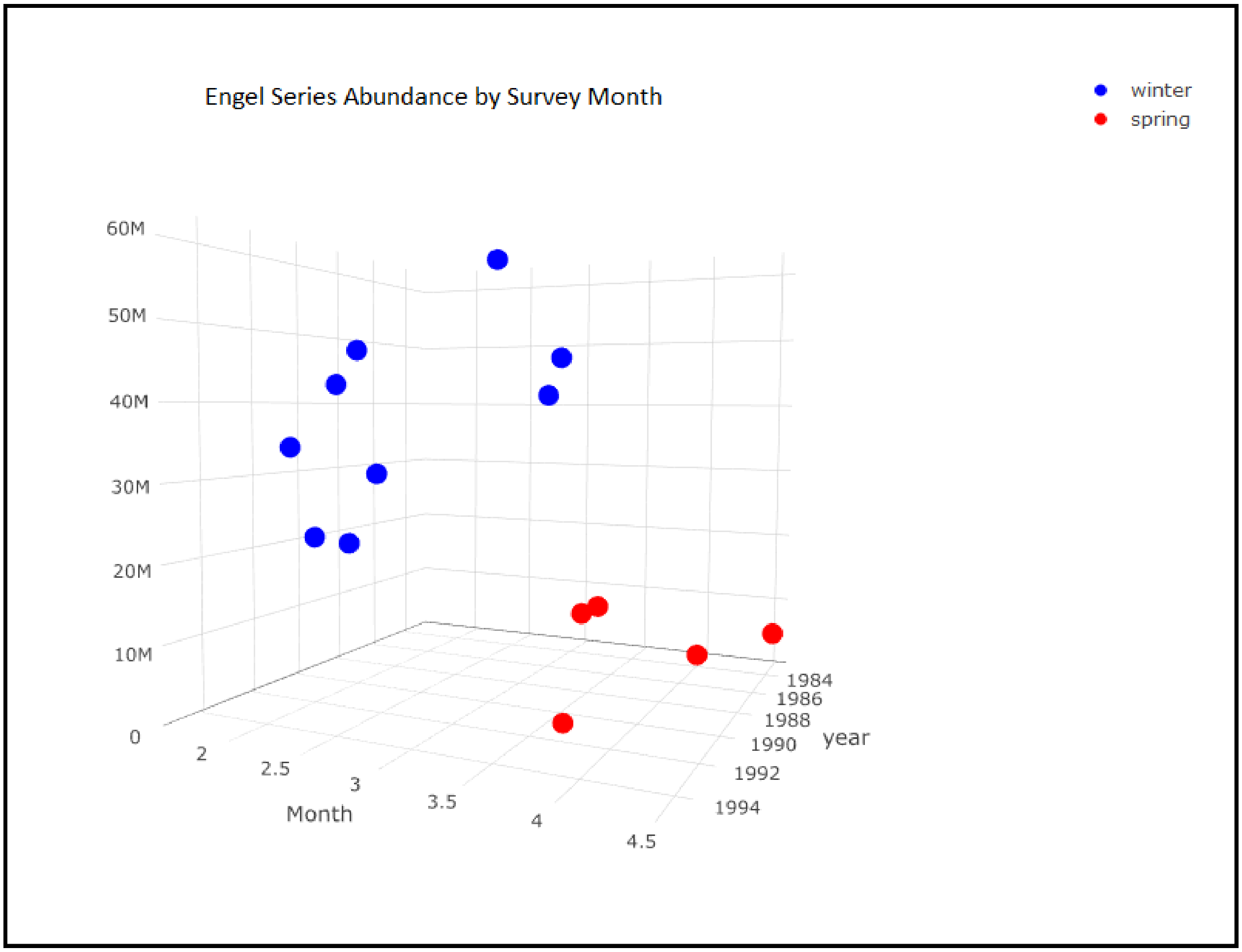

Figure 12. Observed Abundance of Common Lumpfish in Subdiv. 3Ps Engel trawl series surveys by average month in which sampling occurred.

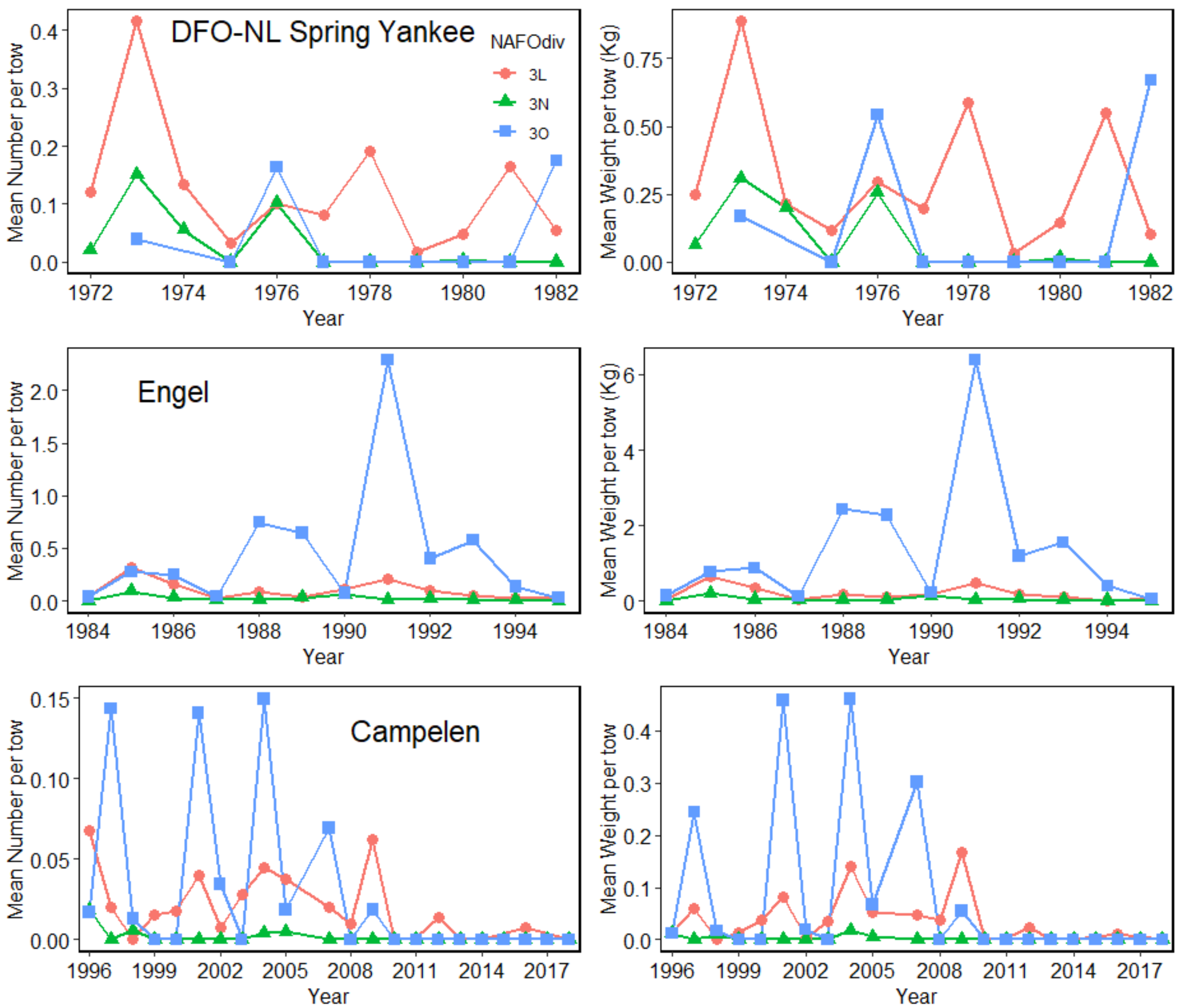

Figure 13. Mean numbers (left panels) and mean weights (kg; right panels) per tow of Common Lumpfish from DFO-NL spring research surveys in Div. 3LNO, 1972–2018. Note that Yankee, Engel, and Campelen data are not comparable. Note that scales differ dramatically across the series.

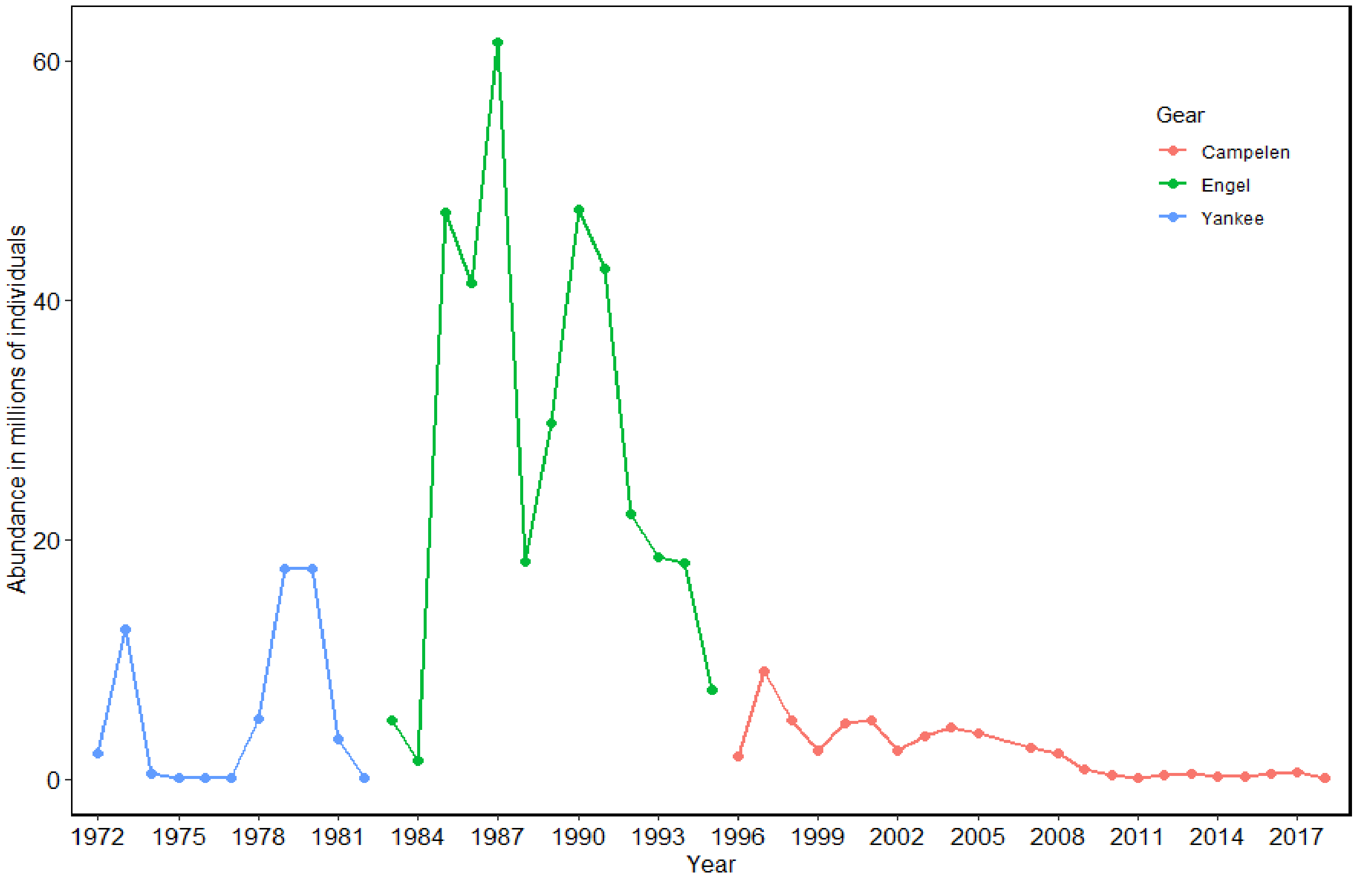

Figure 14. Total abundance of Common Lumpfish in DFO-NL spring research surveys in NAFO Div. 3LNO and Subdiv. 3Ps, 1972–2018.

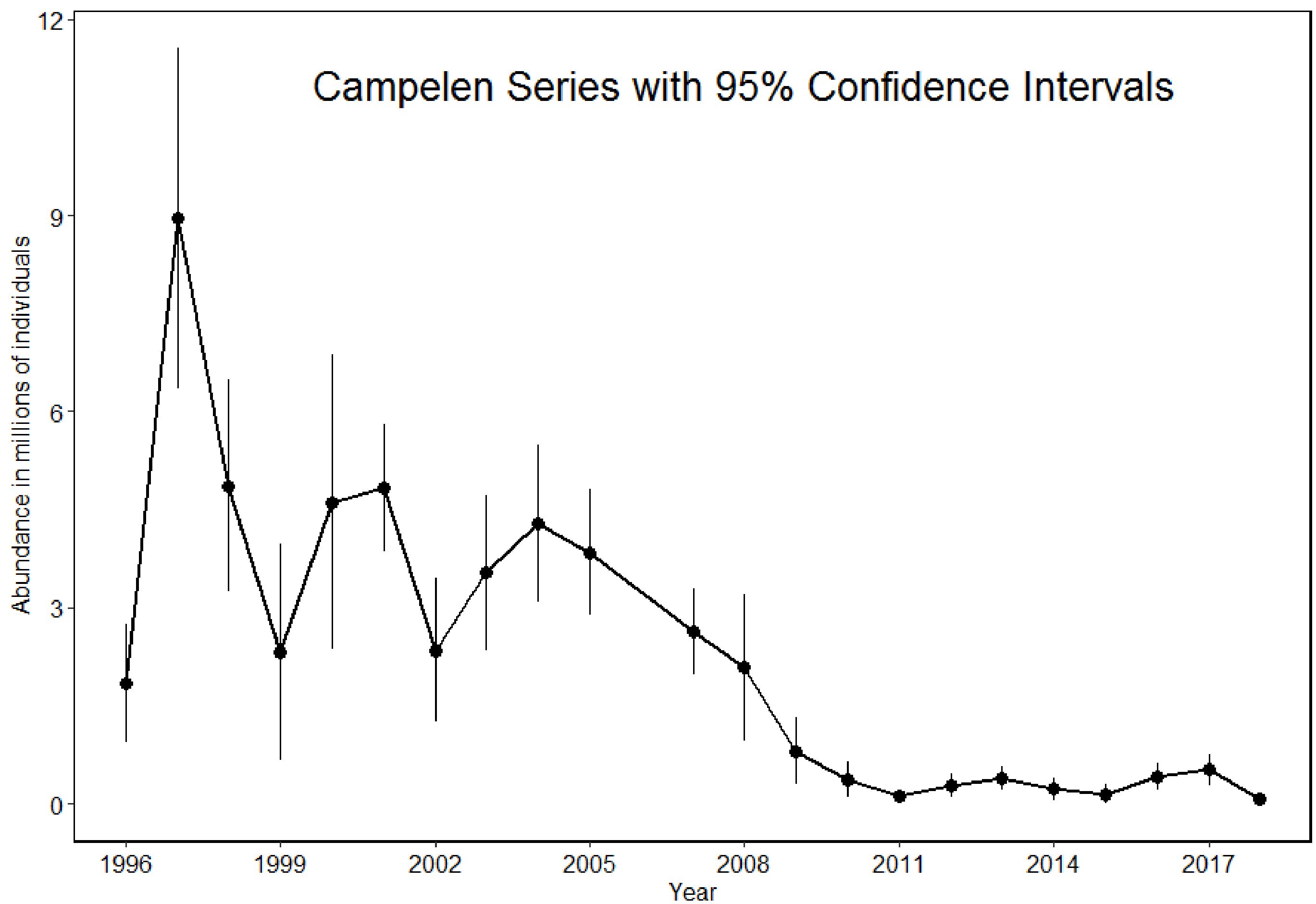

Figure 15. Total abundance of Common Lumpfish in DFO-NL spring research surveys in Div. 3LNO and Subdiv. 3Ps, utilizing the Campelen 1800 trawl. Vertical bars represent 95% CIs.

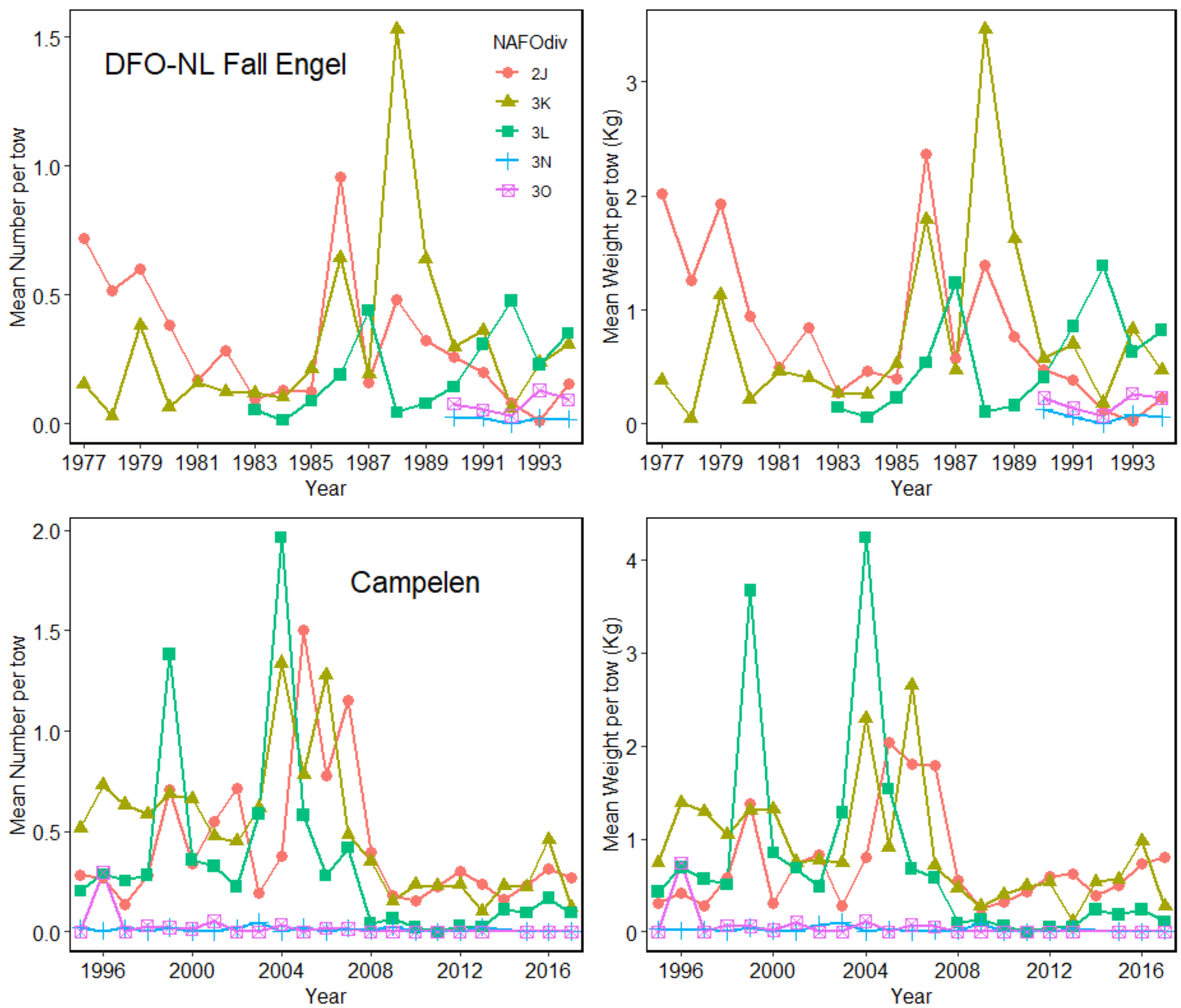

Figure 16. Mean numbers (top panels) and mean weights (kg; bottom panels) per tow of Common Lumpfish from DFO-NL fall research surveys in Div. 2J3KLNO, 1977–2017. Note that Engel and Campelen data are not comparable.

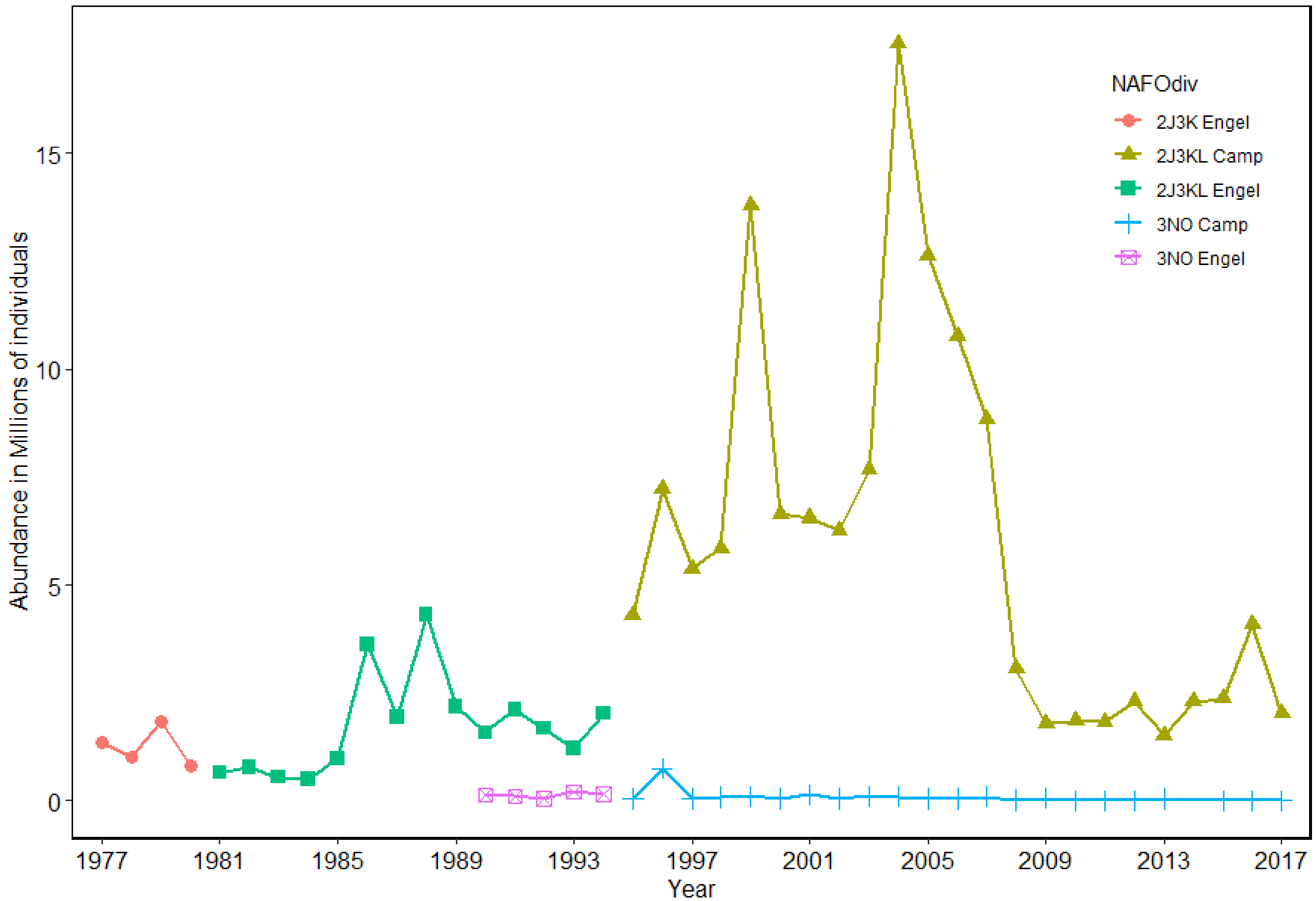

Figure 17. Total abundance of Common Lumpfish in DFO-NL fall research surveys in Div. 2J3KLNO.

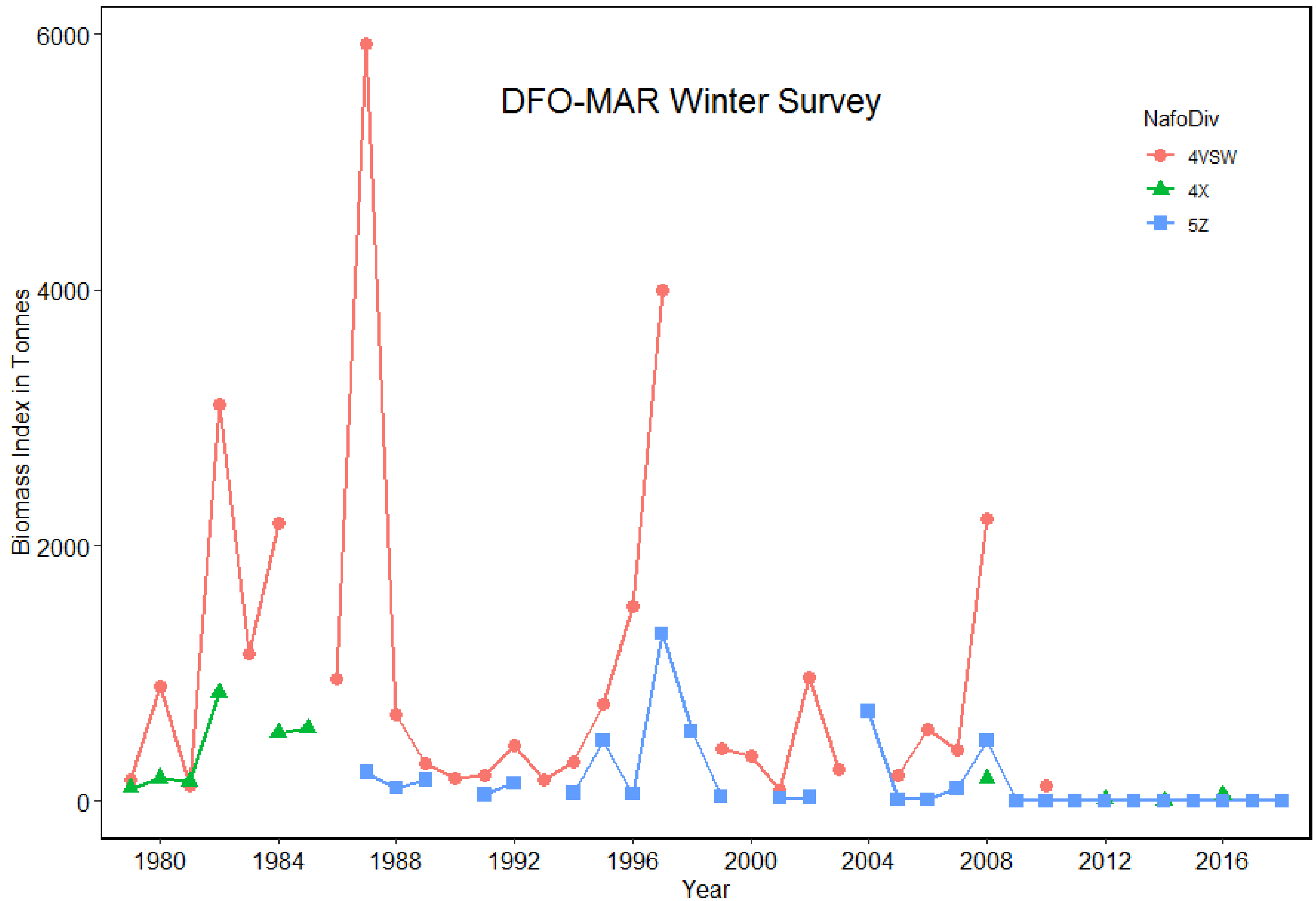

Figure 18. Total Common Lumpfish biomass (in kg) for Div. 4VsW, 4X and 5Z from the DFO-MAR winter survey, 1979–2018.

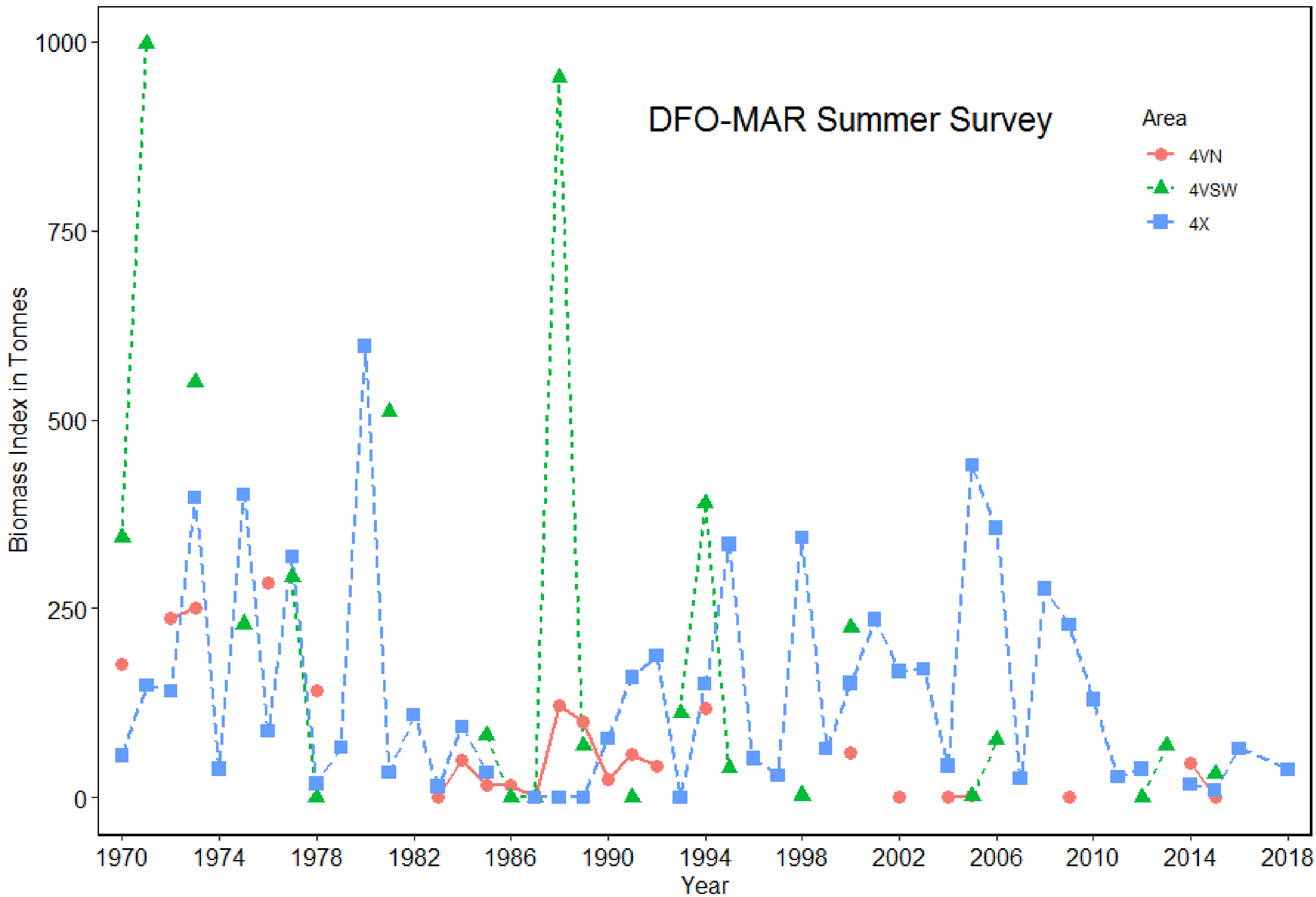

Figure 19. Total Common Lumpfish biomass (in kg) for Div. 4Vn, 4VsW, and 4X from the DFO-MAR summer survey, 1970–2018.

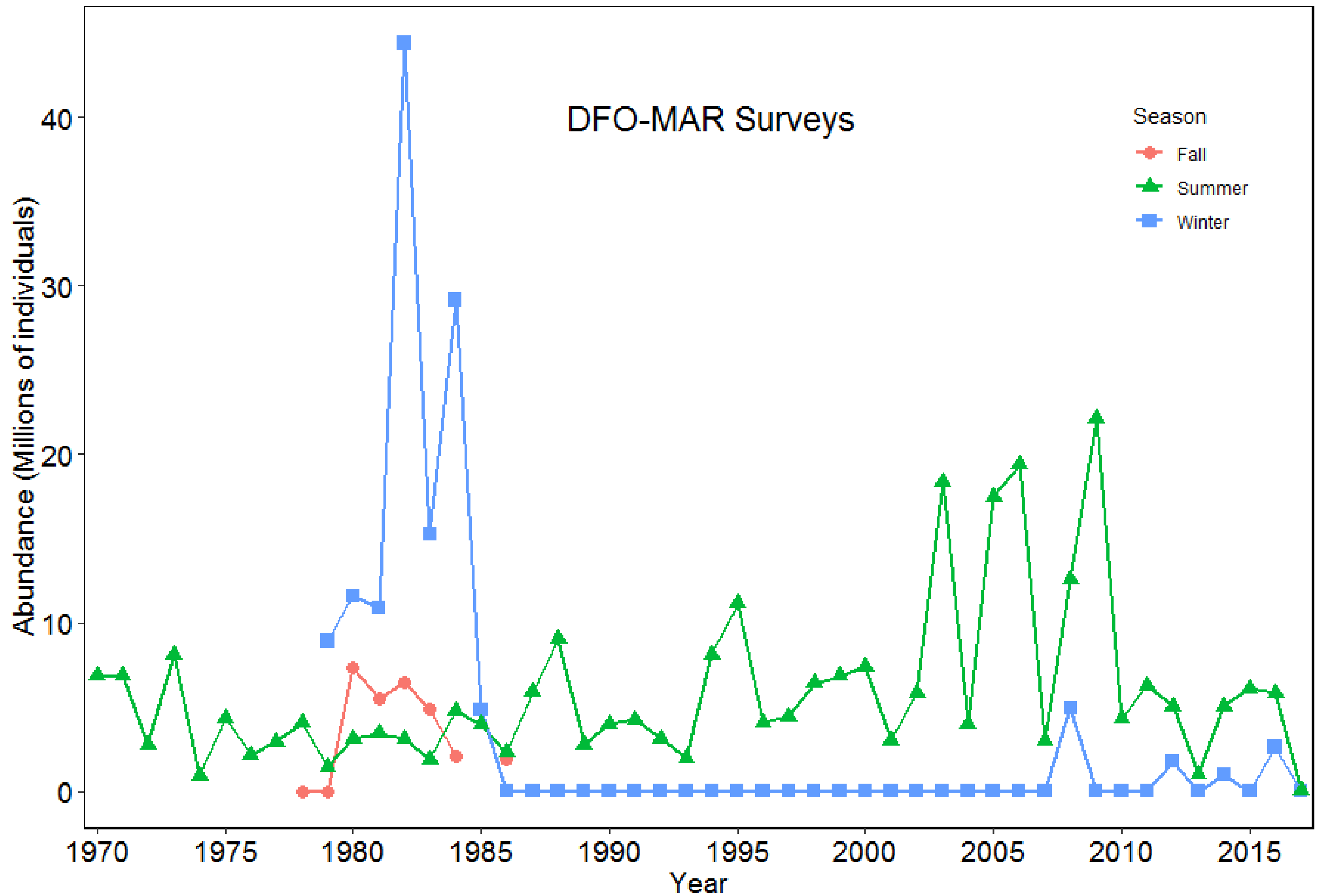

Figure 20. Total Common Lumpfish abundance across all DFO-MAR surveys.

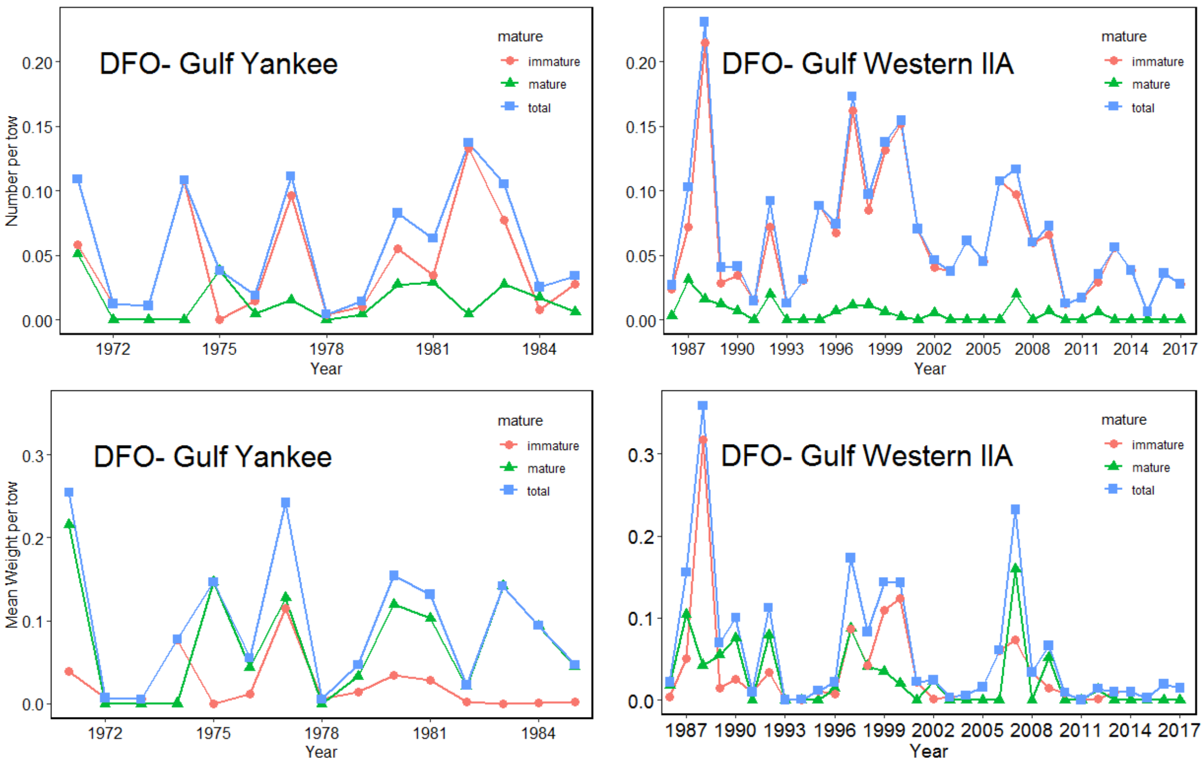

Figure 21. Abundance (mean number per tow; top panels) and biomass (mean weight in kg per tow; bottom panels) indices for all Common Lumpfish (immature+mature) in DFO-Gulf research surveys of Div. 4T, 1971–2017.

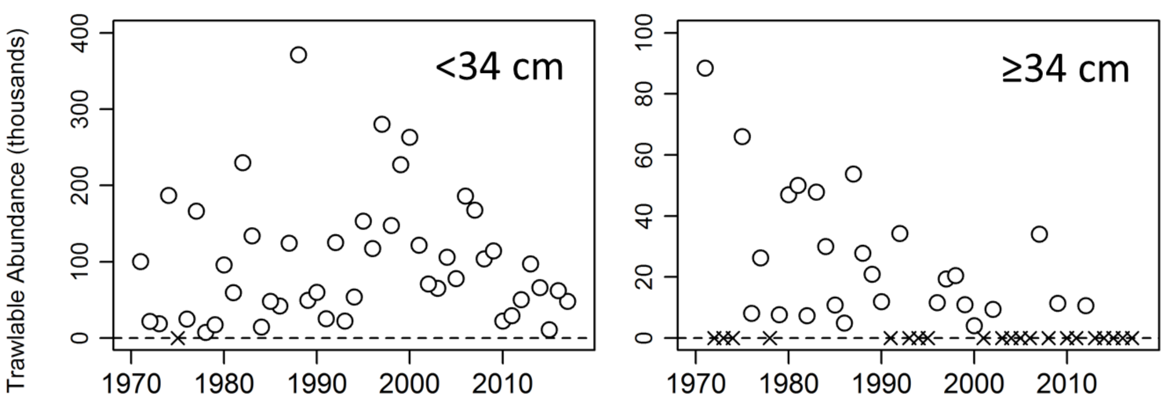

*Figure 22. Abundance of Common Lumpfish less than 34 cm and greater than or equal to 34 cm in DFO-Gulf surveys, 1971–2017. Trawlable abundance=N/tow *(trawlable units/tow area surveyed).*

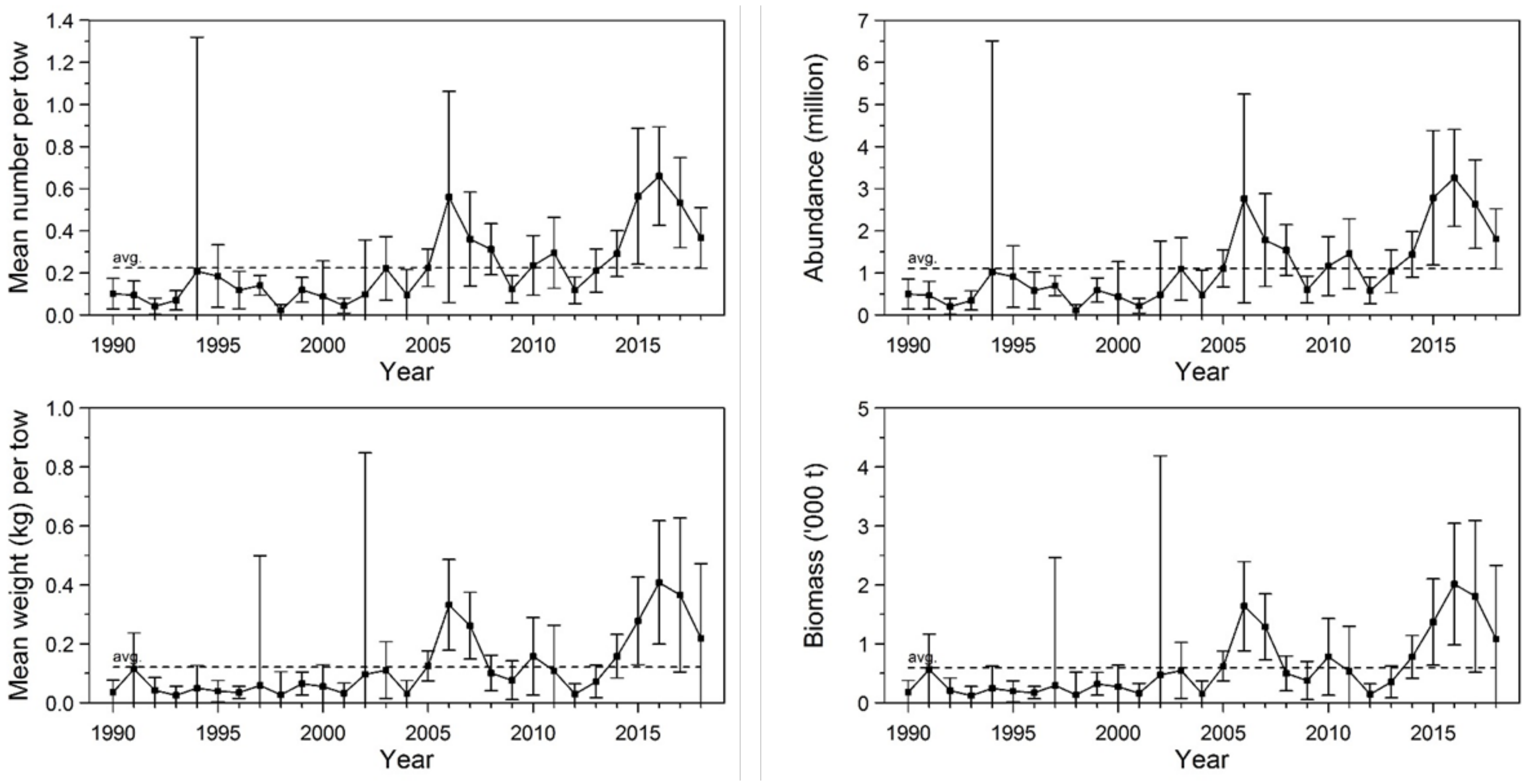

Figure 23. Common Lumpfish abundance (mean number per tow and total abundance) and biomass (mean weight in kg per tow and total biomass) indices in DFO-QC summer survey of Div. 4RST, 1990–2018. Error bars represent 95% CIs, and dashed horizontal lines indicate the mean for this time period.

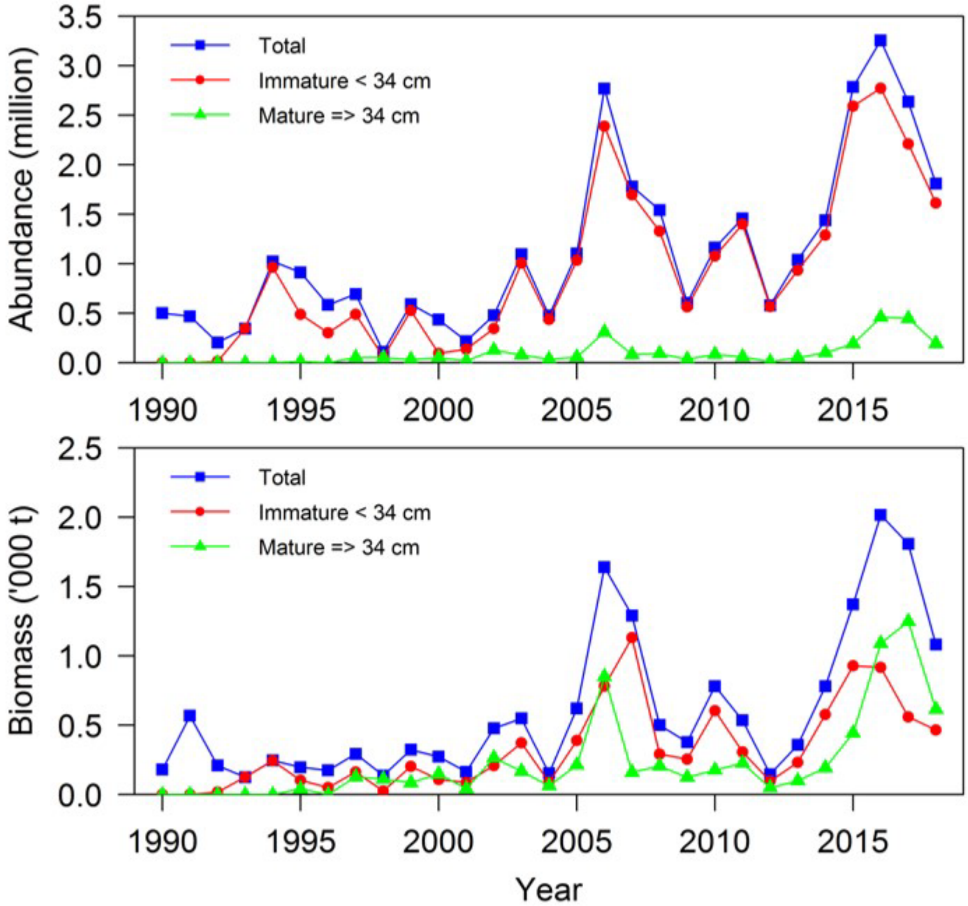

Figure 24. Abundance (top panel) and biomass (bottom panel) estimates for all Common Lumpfish (immature and mature) in DFO-QC research surveys of Div. 4RST, 1990–2018.

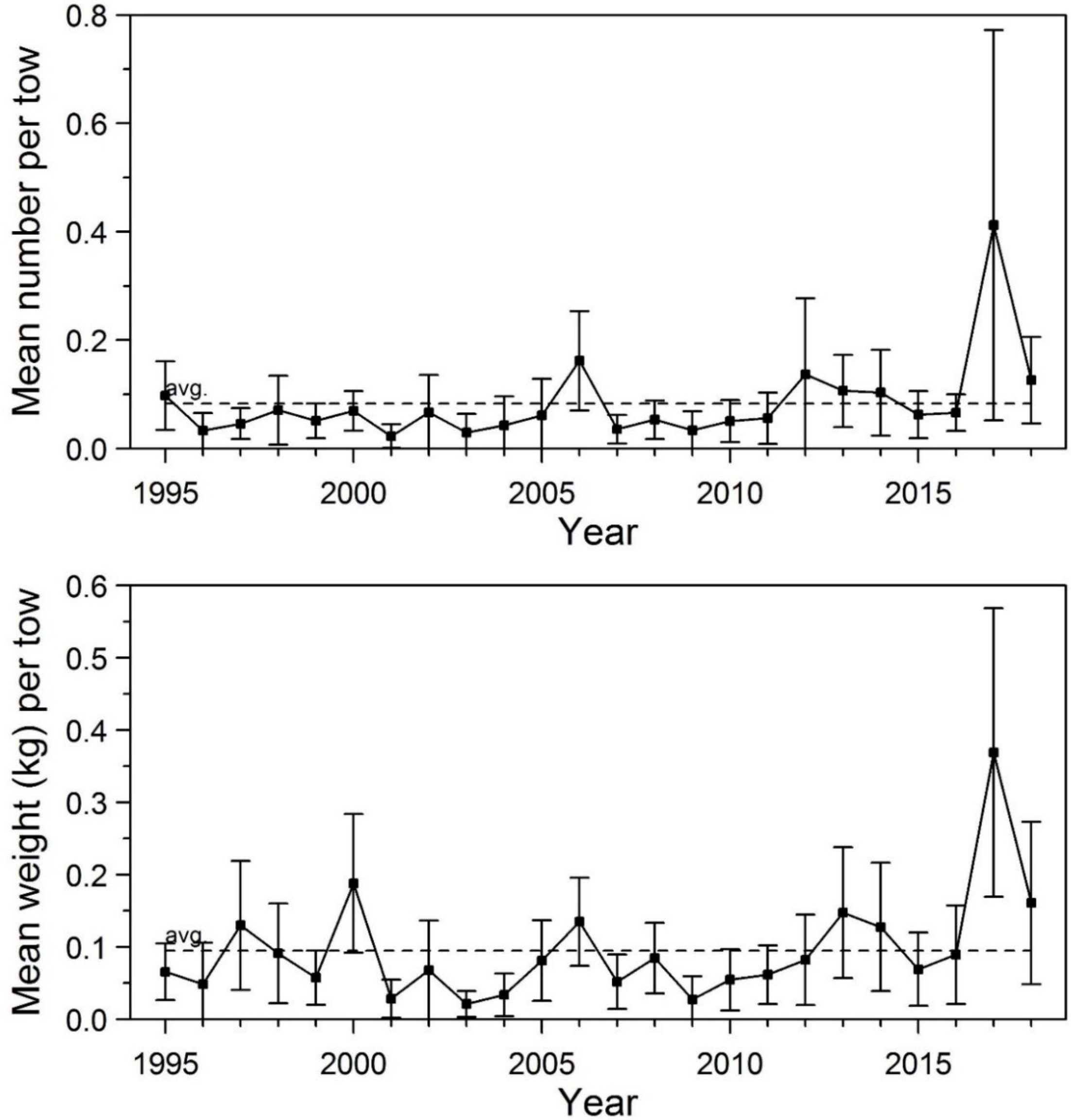

Figure 25. Common Lumpfish abundance (mean number per tow) and biomass (mean weight in kg per tow) indices from nGSL July Sentinel surveys, 1995–2018. Error bars represent 95% CIs, and dashed horizontal lines indicate the mean for this time period.

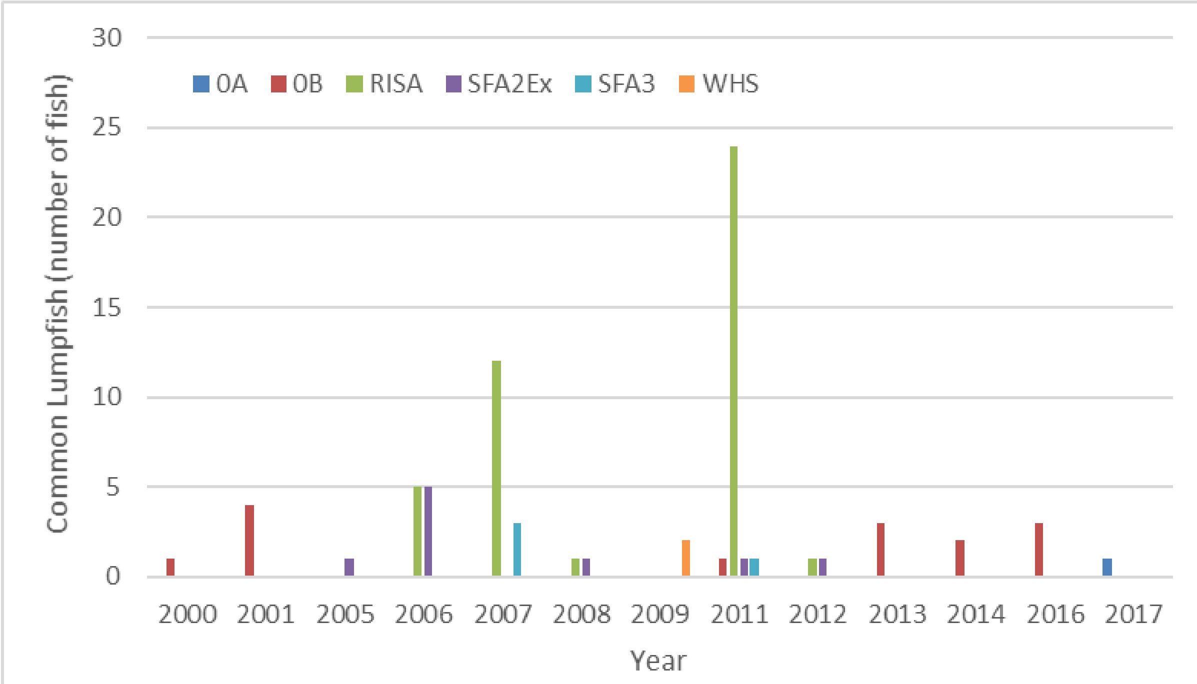

Figure 26. Total number of Common Lumpfish caught in DFO-C&A surveys and NSRF surveys (Div. 0A and 0B, RISA, SFA 2Ex, and 3, and WHS), 1999–2017.

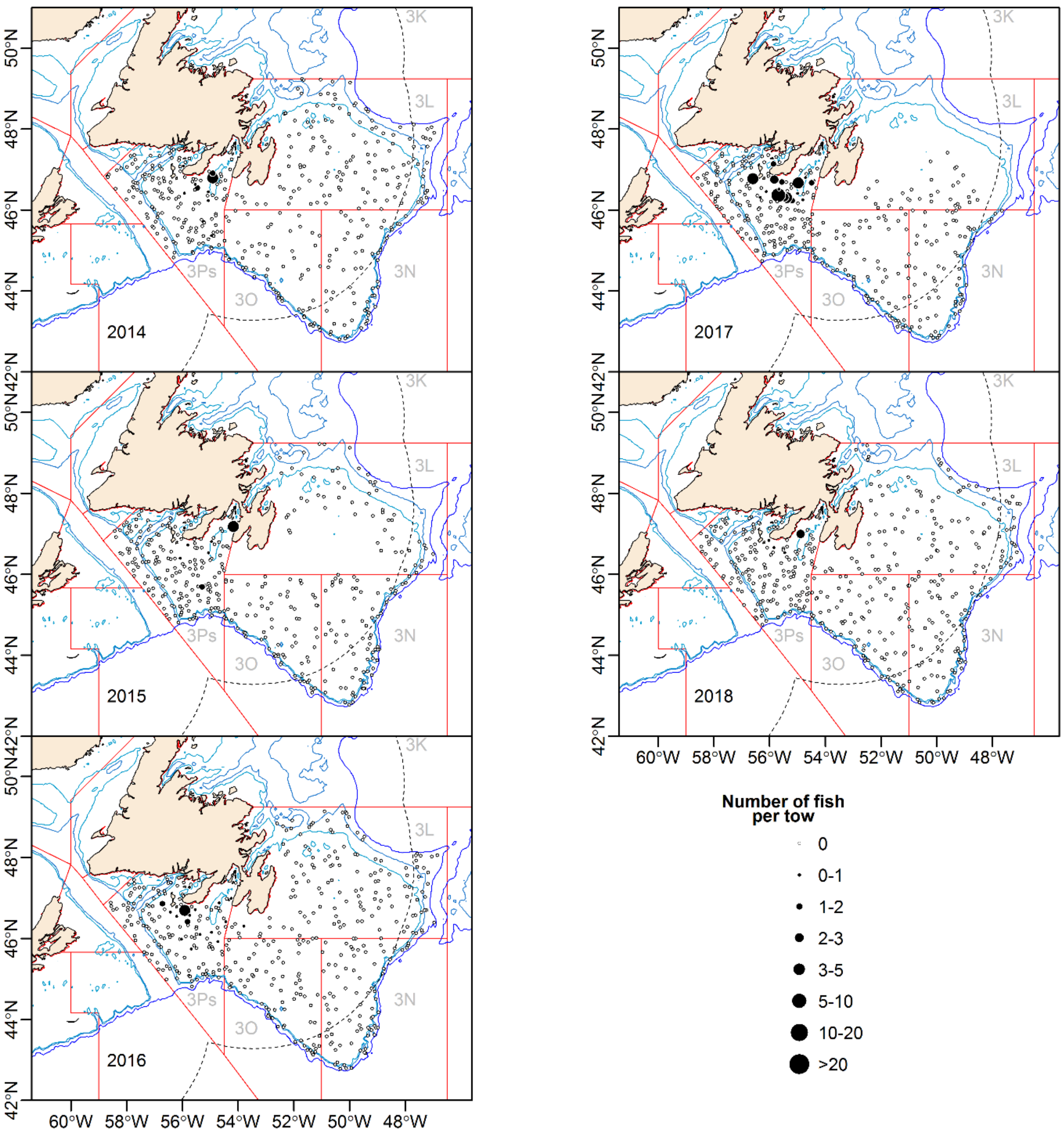

Figure 27. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-NL spring Campelen research surveys in Subdiv. 3Ps and Div. 3LNO, 2014–18.

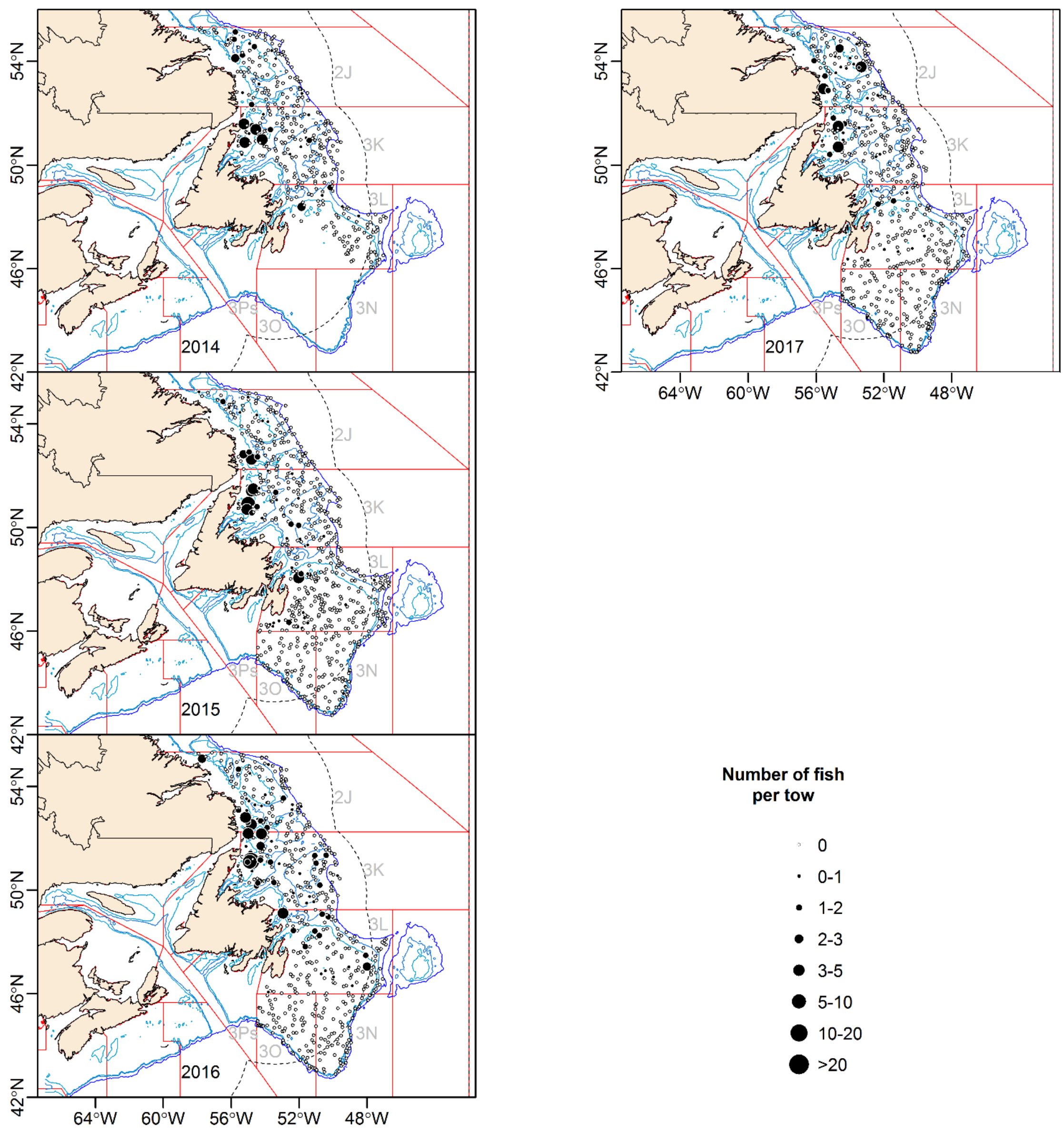

Figure 28. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-NL fall Campelen research surveys, 2014–17.

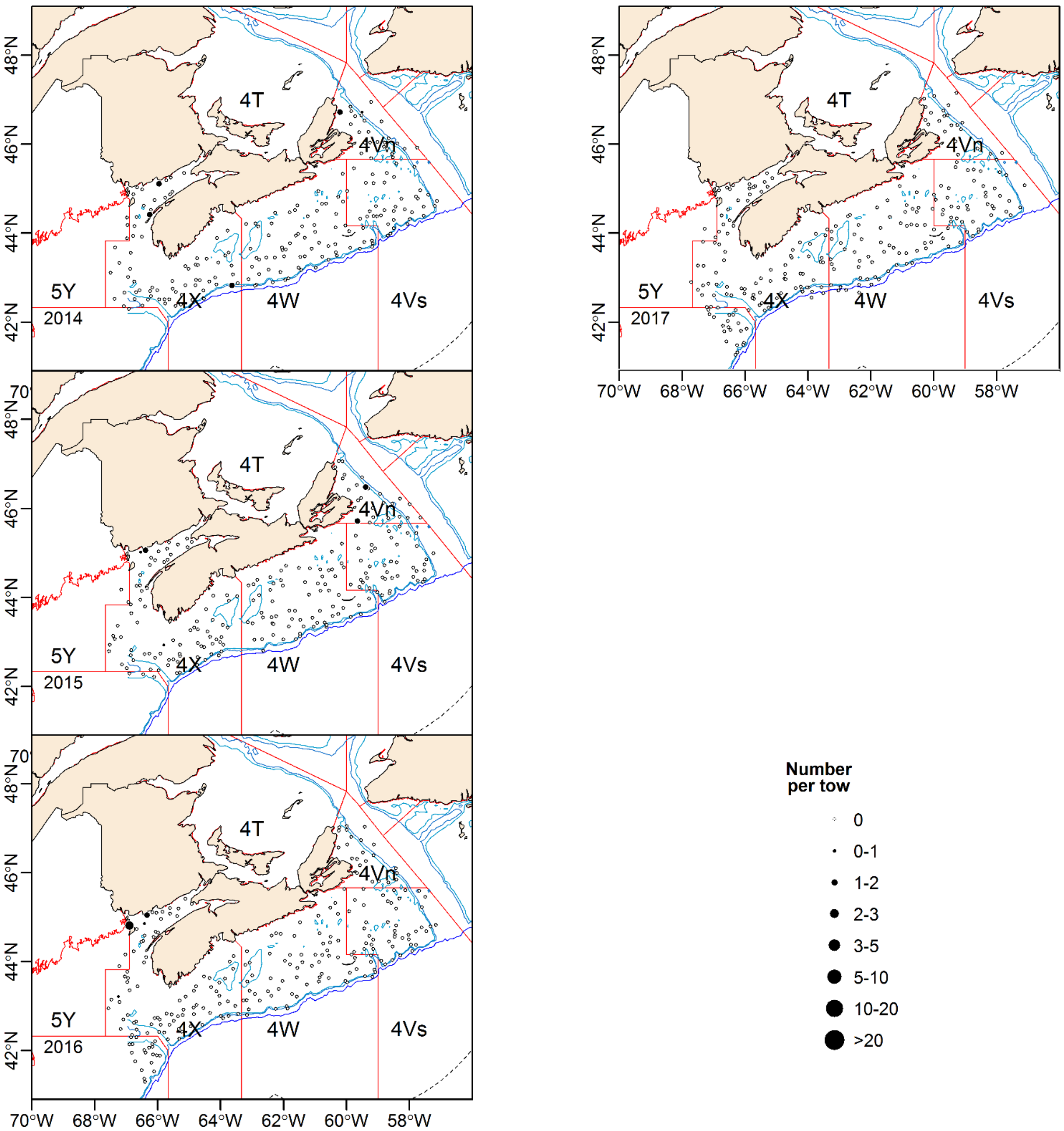

Figure 29. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-MAR summer research surveys in Div. 4VWX, 2014–17.

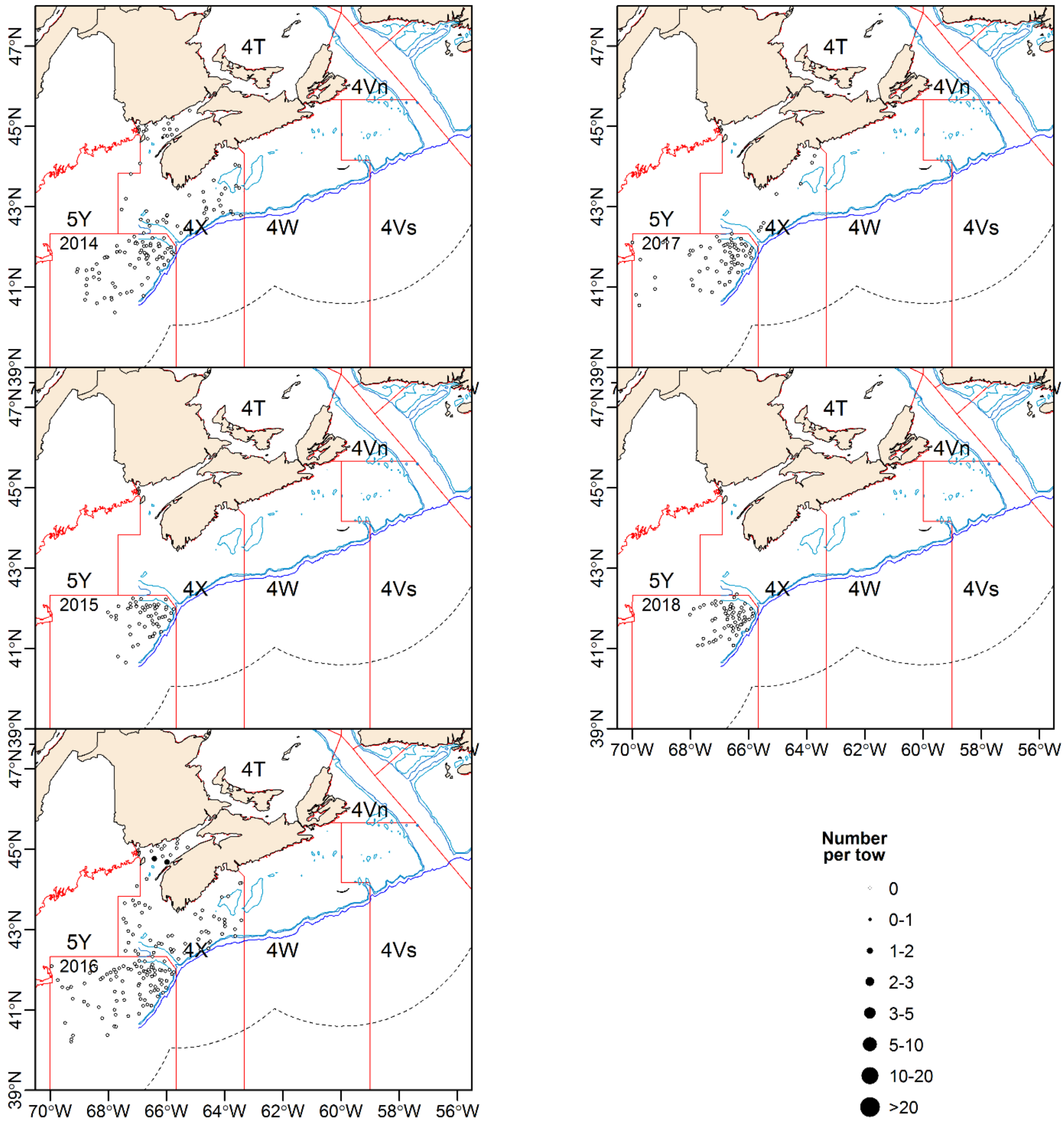

Figure 30. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-MAR Georges Bank spring research surveys, 2014–18.

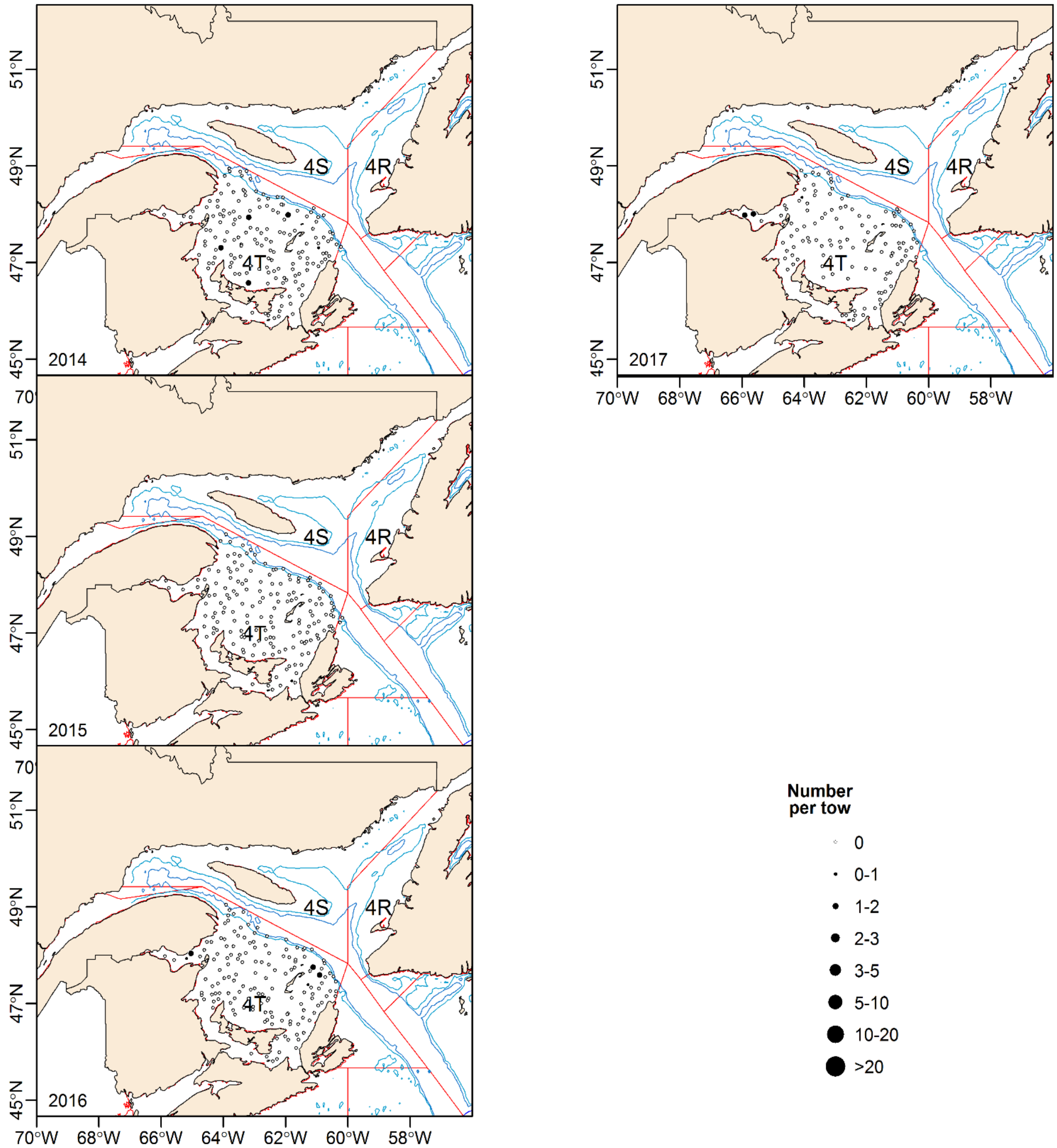

Figure 31. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-Gulf research surveys in the sGSL, 2014–17.

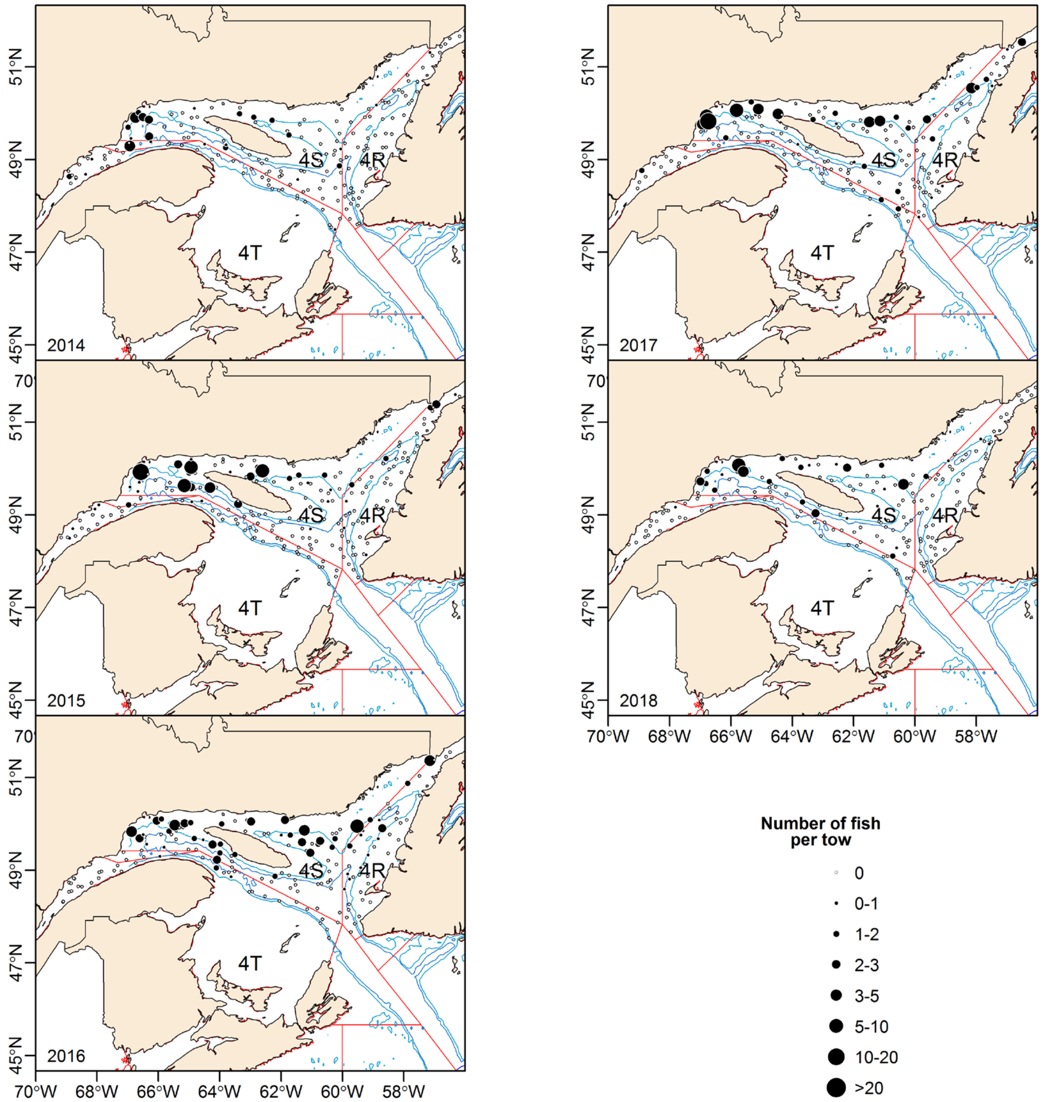

Figure 32. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-QC research surveys in the nGSL, 2014–18.

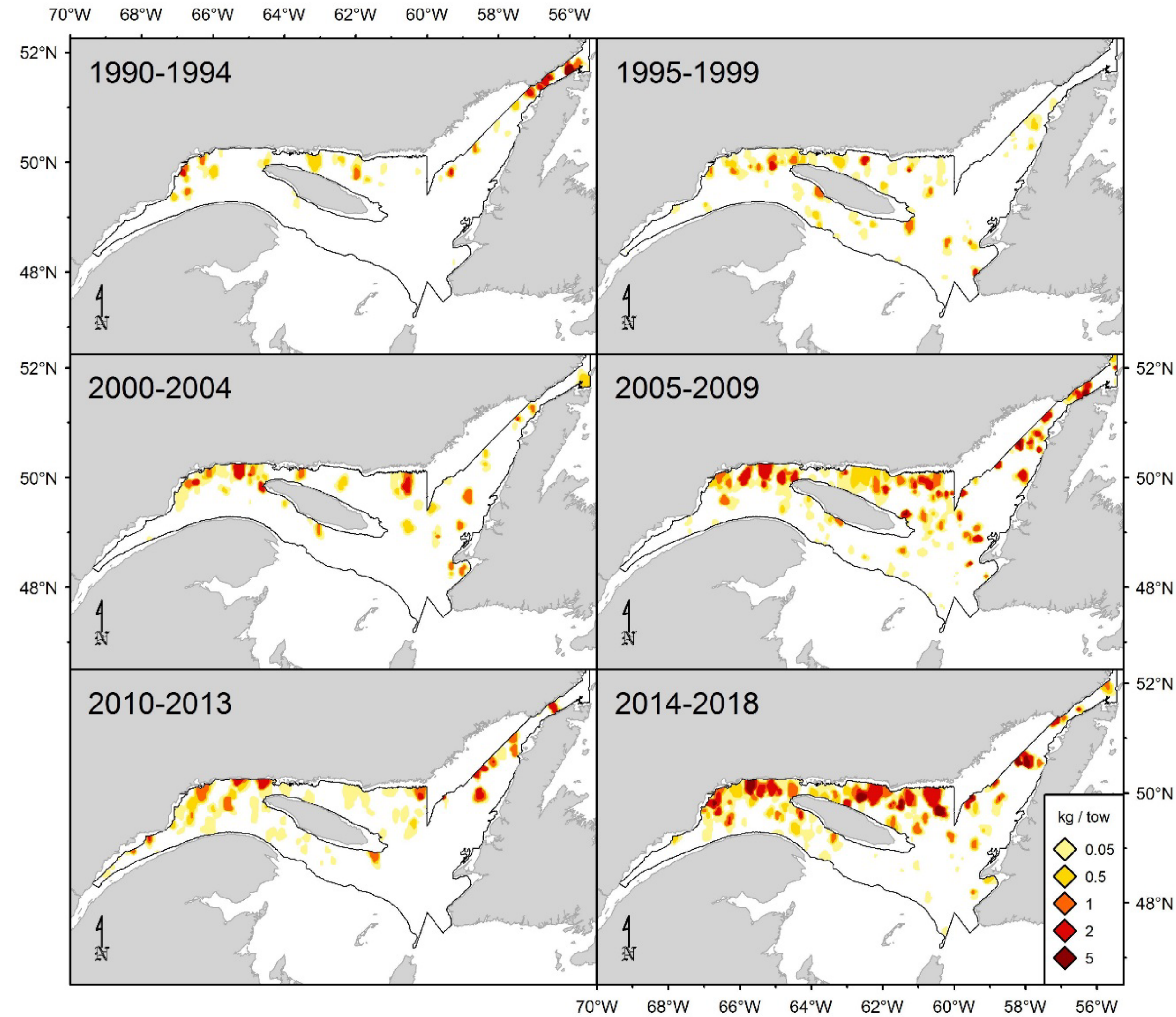

Figure 33. Distribution of Common Lumpfish catches (standardized weight per tow) in DFO-QC nGSL August surveys, 1990–2018. Solid black line defines the perimeter of the surveyed area.

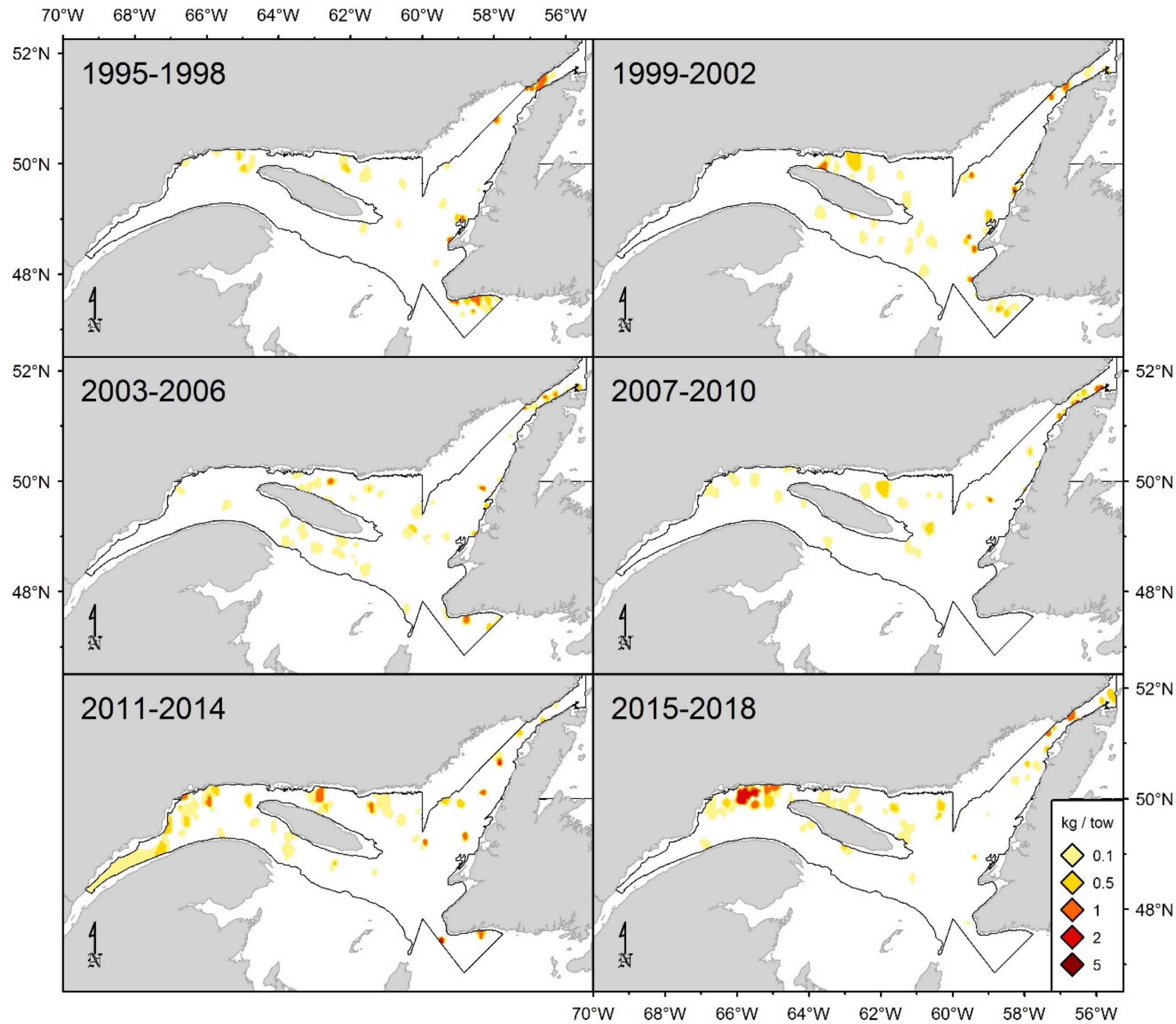

Figure 34. Distribution of Common Lumpfish catches (standardized weight in kg per tow) in nGSL July Sentinel surveys, 1995–2018. Solid black line defines the perimeter of the surveyed area.

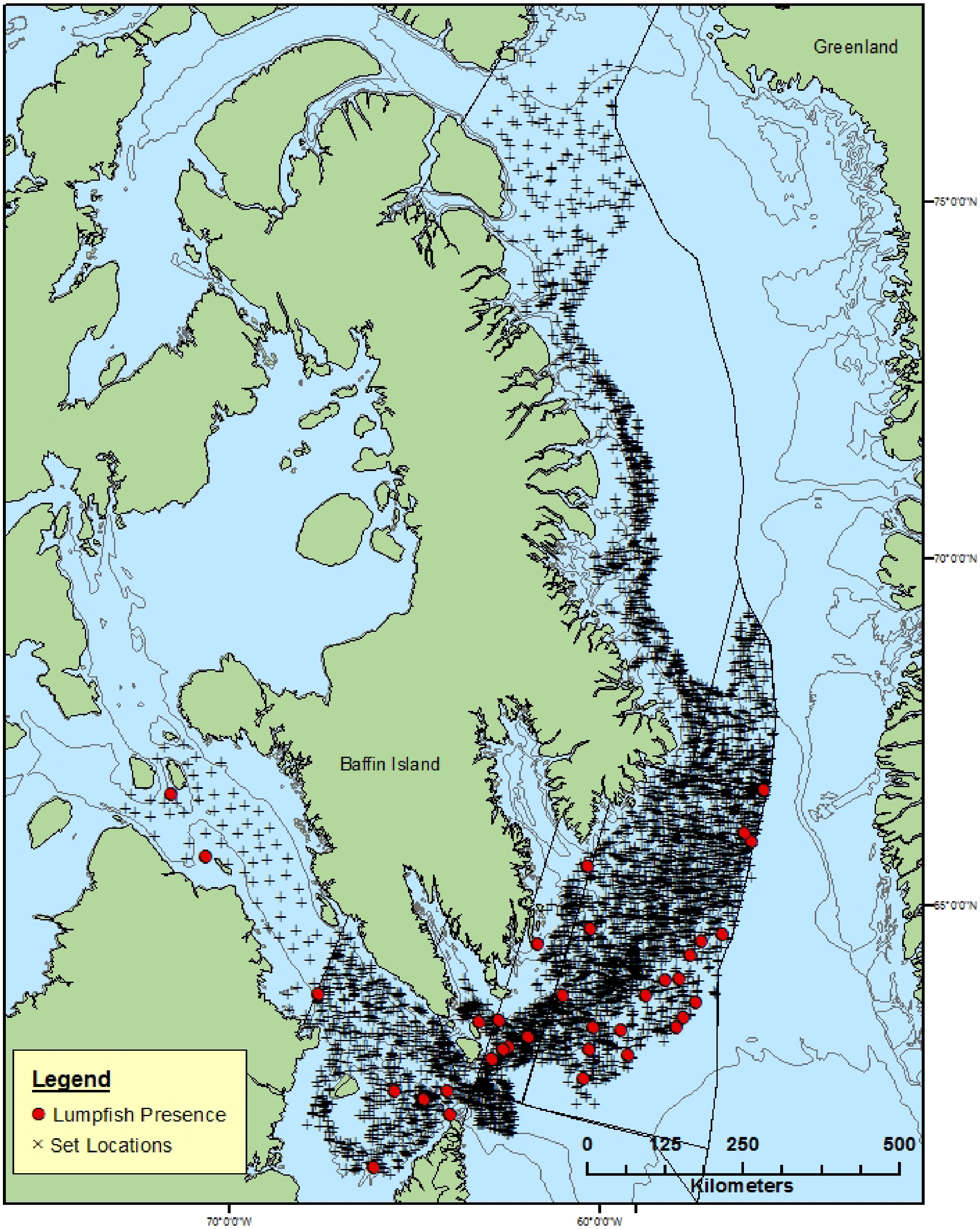

Figure 35. Common Lumpfish catch locations (absence (+) and presence (red circle) from DFO-C&A surveys and NSRF surveys, during 1999–2017.

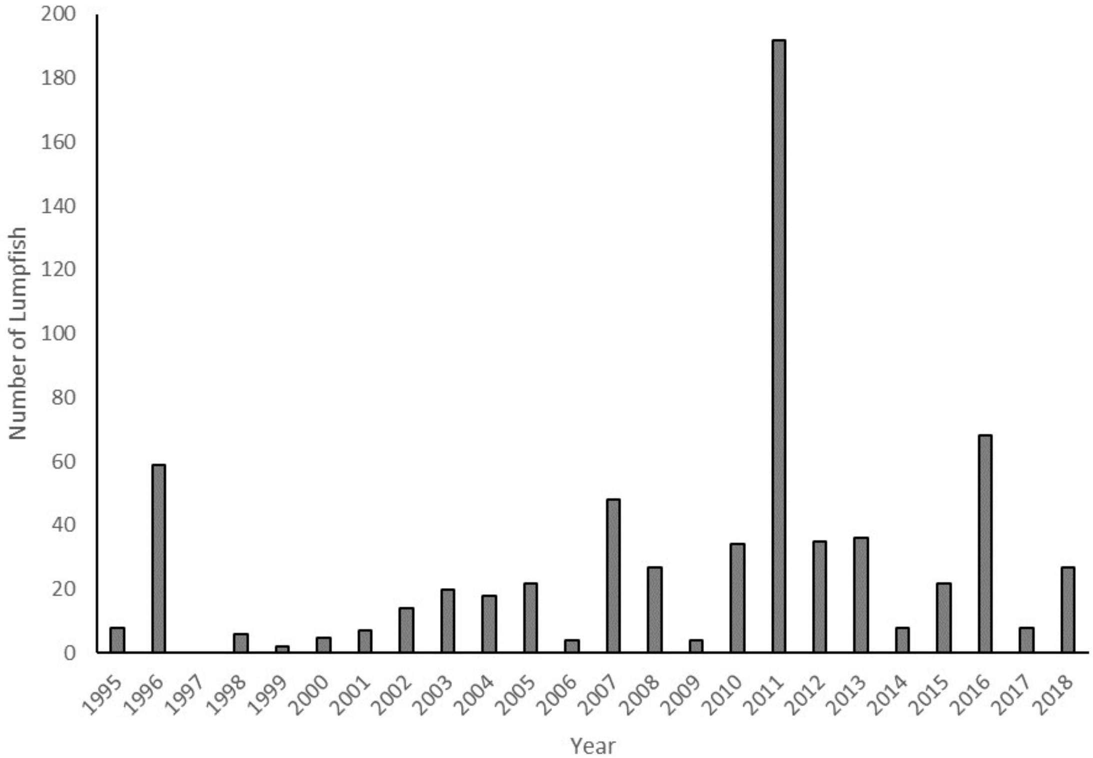

Figure 36. Common Lumpfish annual catch from July to November (1995–2018) in Newman Sound, NL. No sampling occurred in 1997.

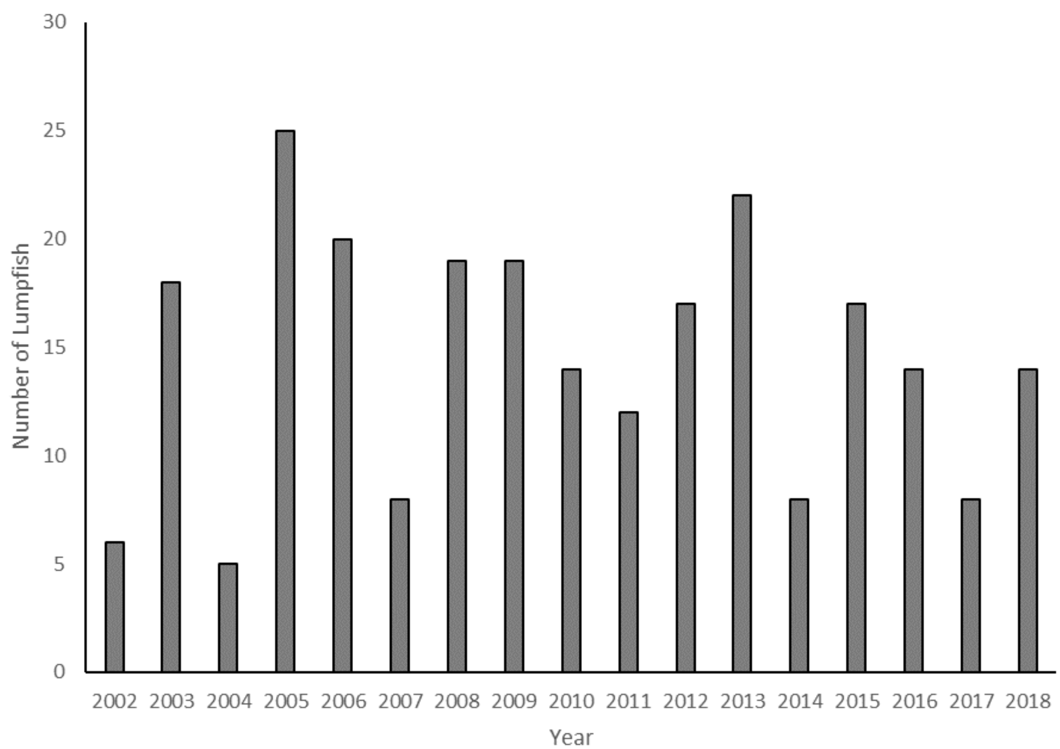

Figure 37. Common Lumpfish annual May catch (2002–18) in Newman Sound, NL.

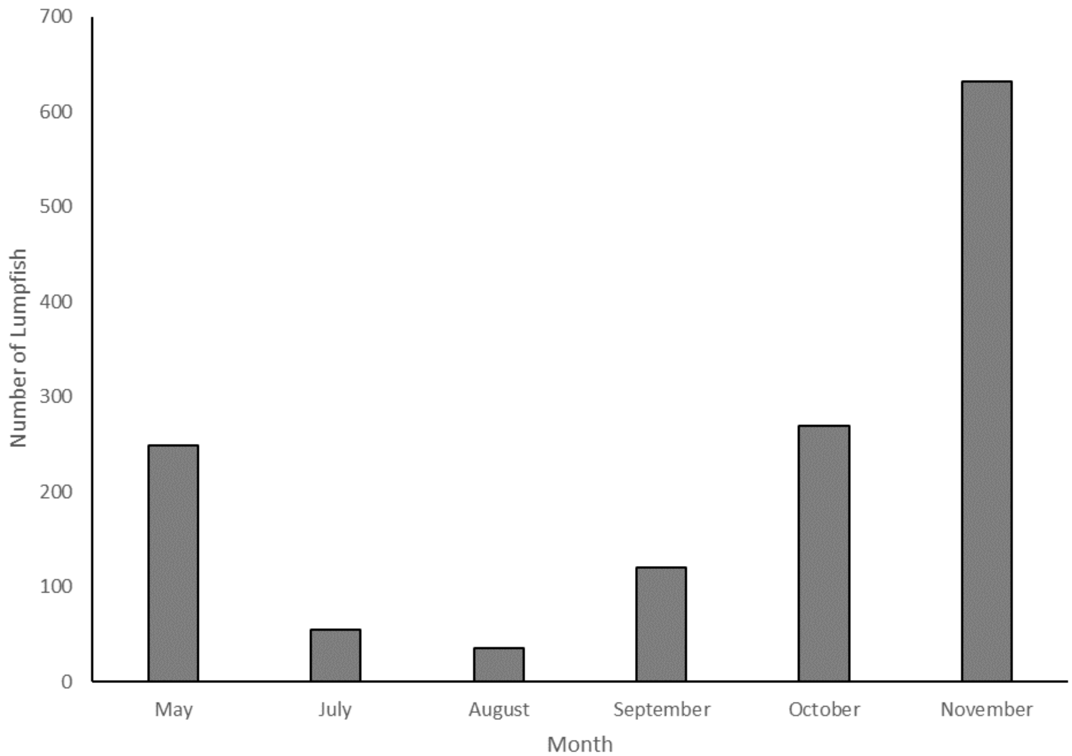

Figure 38. Common Lumpfish cumulative catch by month (1995–2018) in Newman Sound, NL. June and December data removed as sampling occurs infrequently.

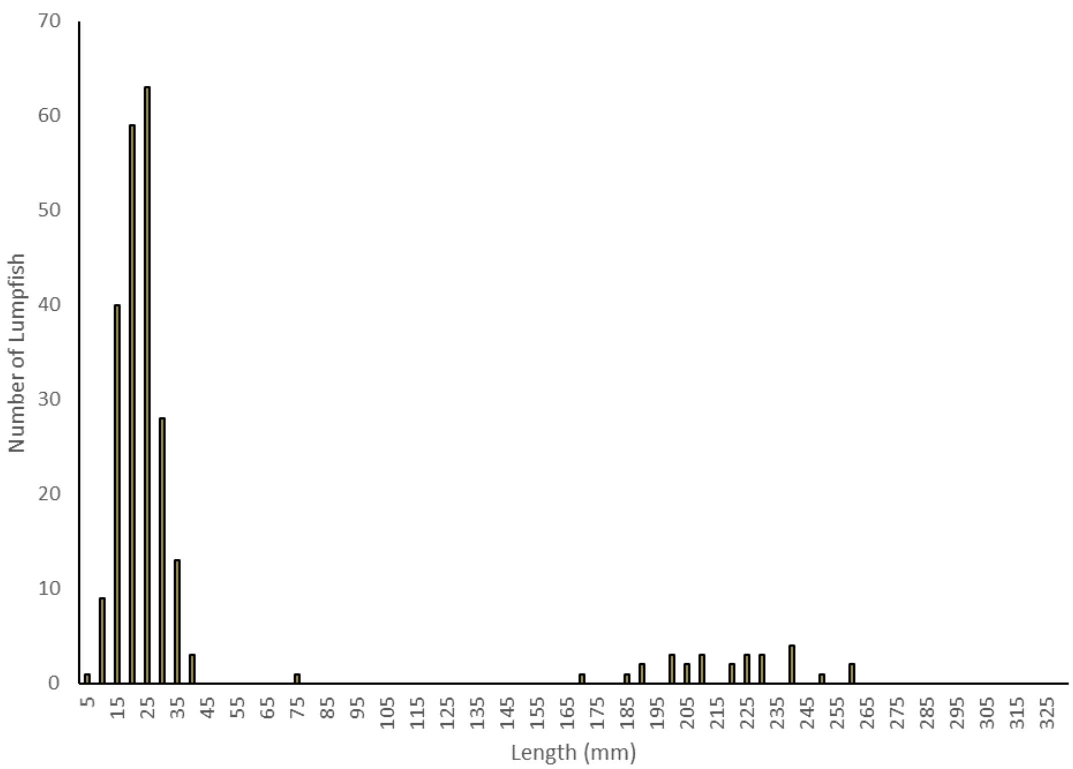

Figure 39. Common Lumpfish lengths, in mm, from samples caught in Newman Sound, NL, May 2002–18.

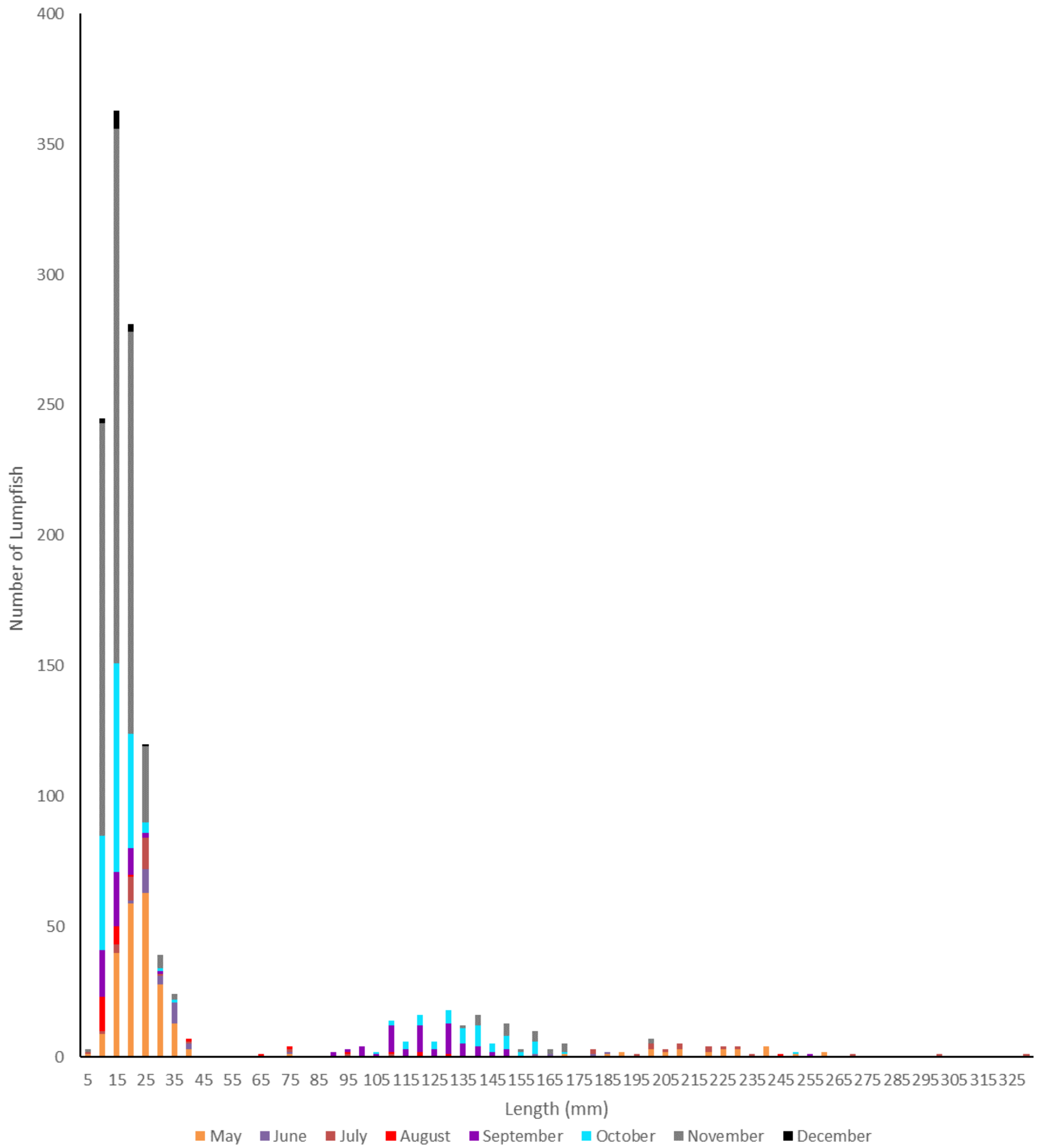

Figure 40. Common Lumpfish lengths (in mm) by month (May-December) from 1995–2018 in Newman Sound, NL. Sampling occurred infrequently in June and December so abundance would be lower for these periods.

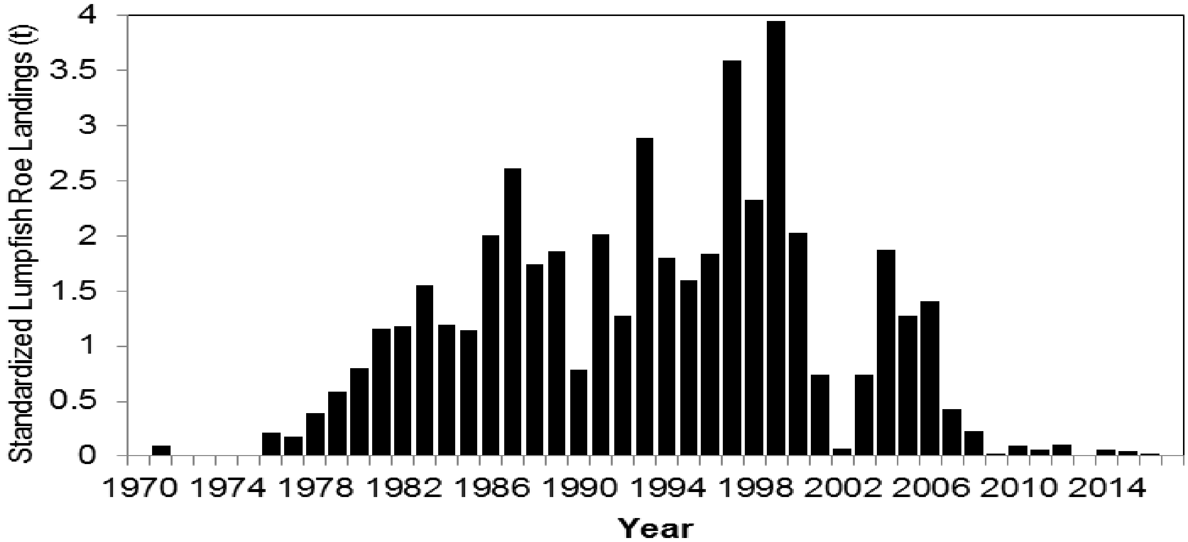

Figure 41. Common Lumpfish roe landings standardized by mean (t) from Div. 3P4RS, 1970–2017 (Source: NAFO STATLANT 21A from 1970–84, and DFO ZIFF from 1985–2017).

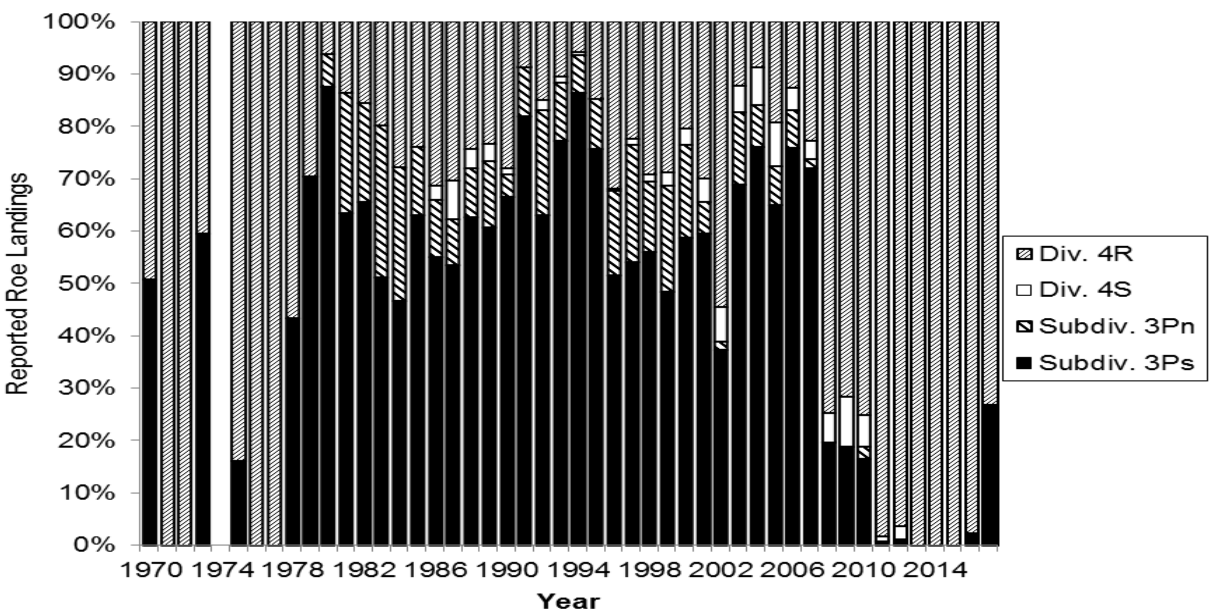

Figure 42. Proportion of Common Lumpfish roe landings from Div. 3P4RS, 1970–2017 (Source: NAFO STATLANT 21A from 1970–84, and DFO ZIFF from 1985–2017).

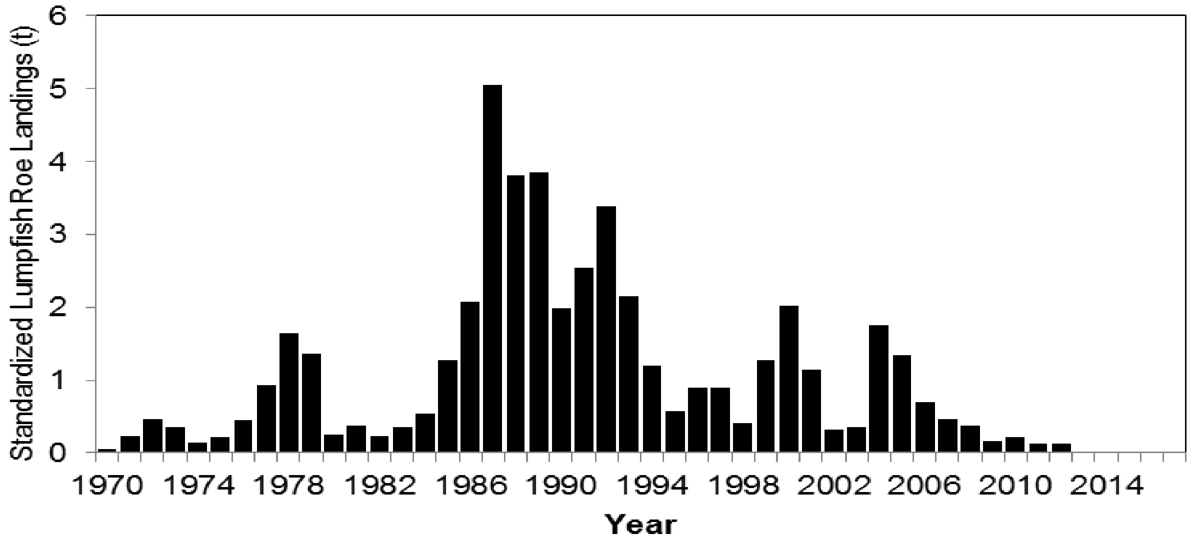

Figure 43. Common Lumpfish roe landings standardized by mean (t) from Div. 2J3KL, 1970–2017. Landings in 2J comprised less than 0.1 % of annual landings in 4 years (Source: NAFO STATLANT 21A from 1970–84, and DFO ZIFF from 1985–2017).

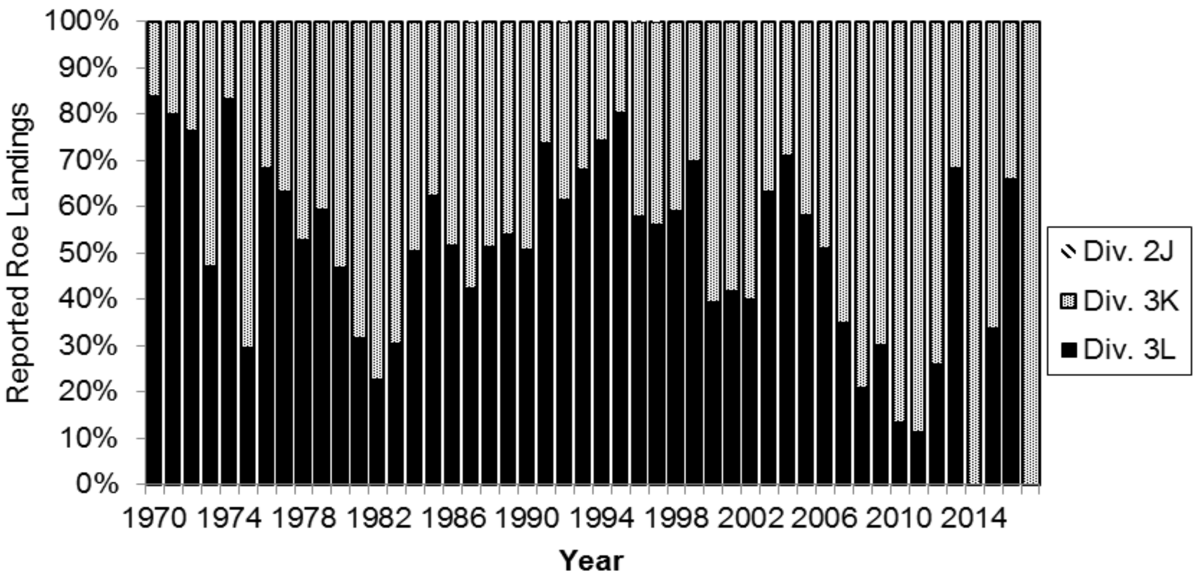

Figure 44. Proportion of Common Lumpfish roe landings from Div. 2J3KL, 1970–2017. Landings in 2J comprised less than 0.1 % of annual landings in 4 years (Source: NAFO STATLANT 21A from 1970–84, and DFO ZIFF from 1985–2017).

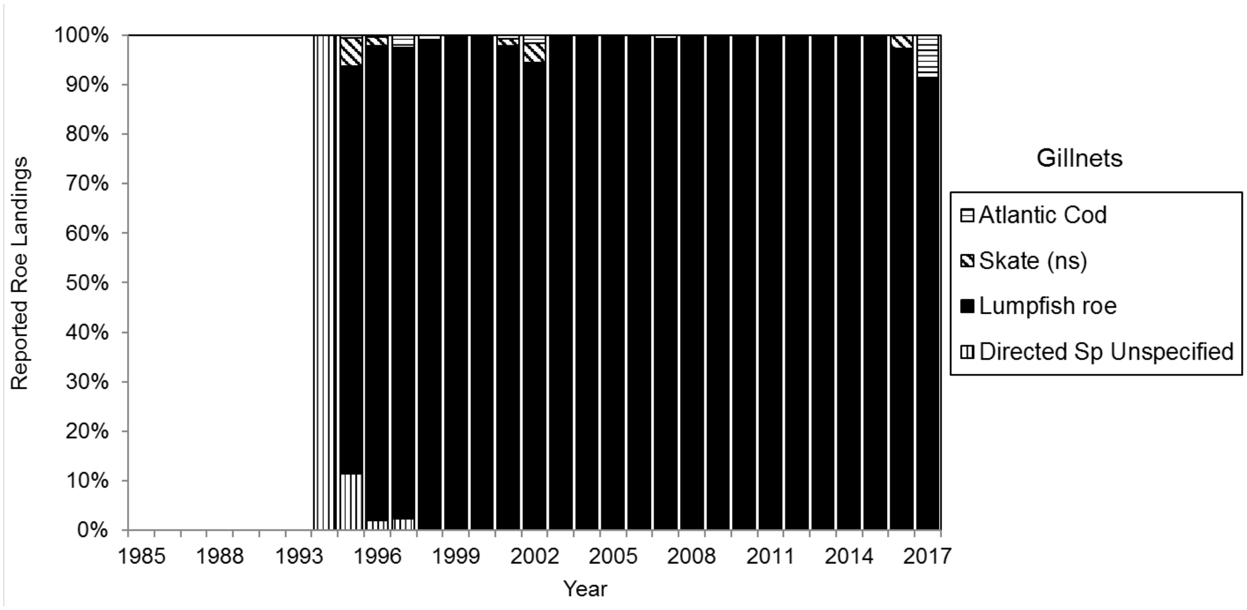

Figure 45. Proportion of Common Lumpfish roe landings from gillnets in Div. 3KLOP by directed species, 1985–2017 (Source: DFO ZIFF).

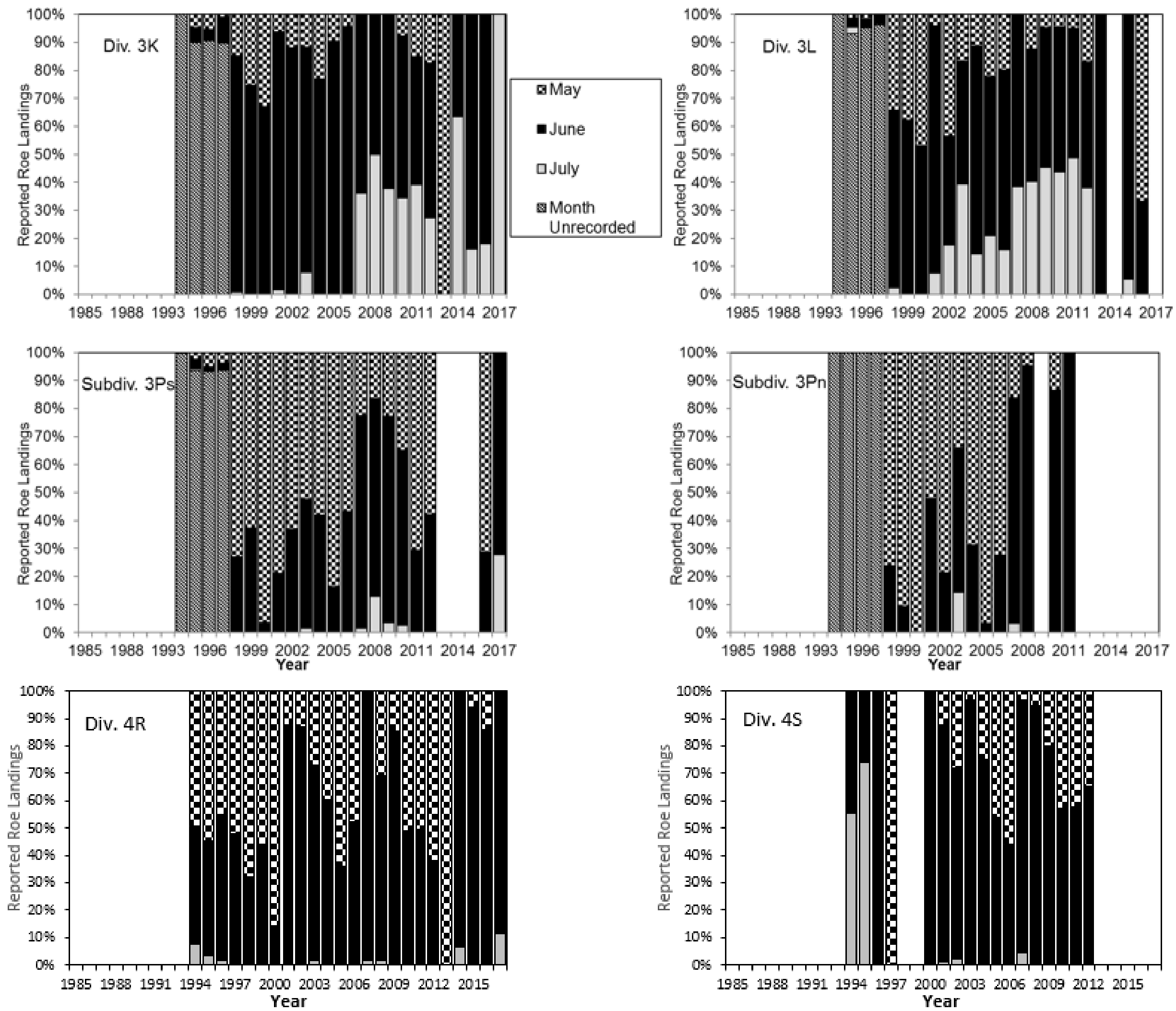

Figure 46. Proportion of Common Lumpfish roe landings from Div. 3KLOP4RS by month, 1994–2017 (Source: DFO ZIFF).

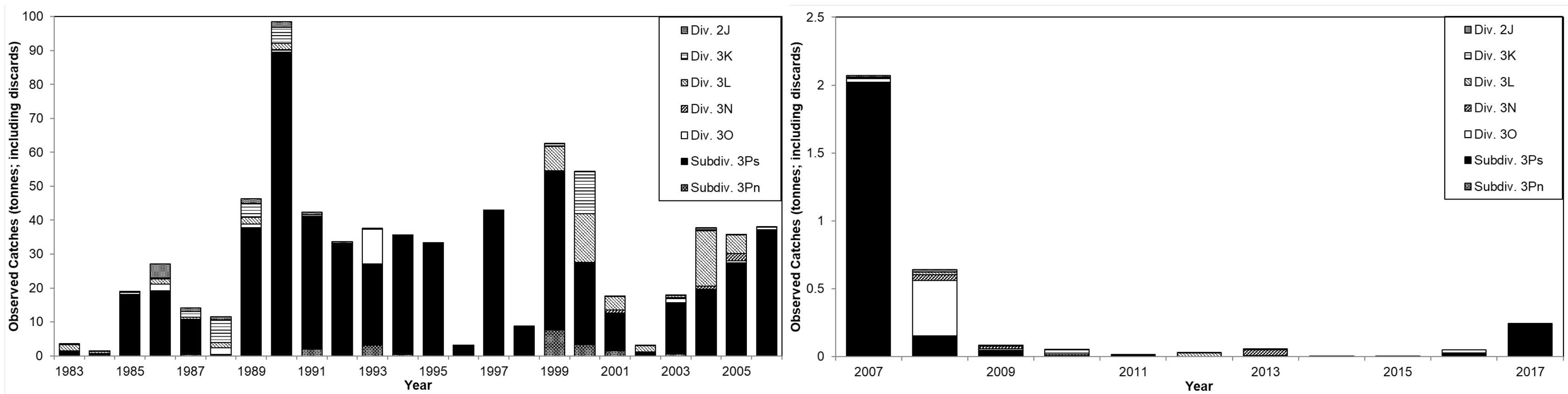

Figure 47. Observed catches (t) of Common Lumpfish in various fisheries in Canada's EEZ of Div. 2J3KLNOP, 1983–2006 and 2007–17. Data are from Canadian ASOs and include discards.

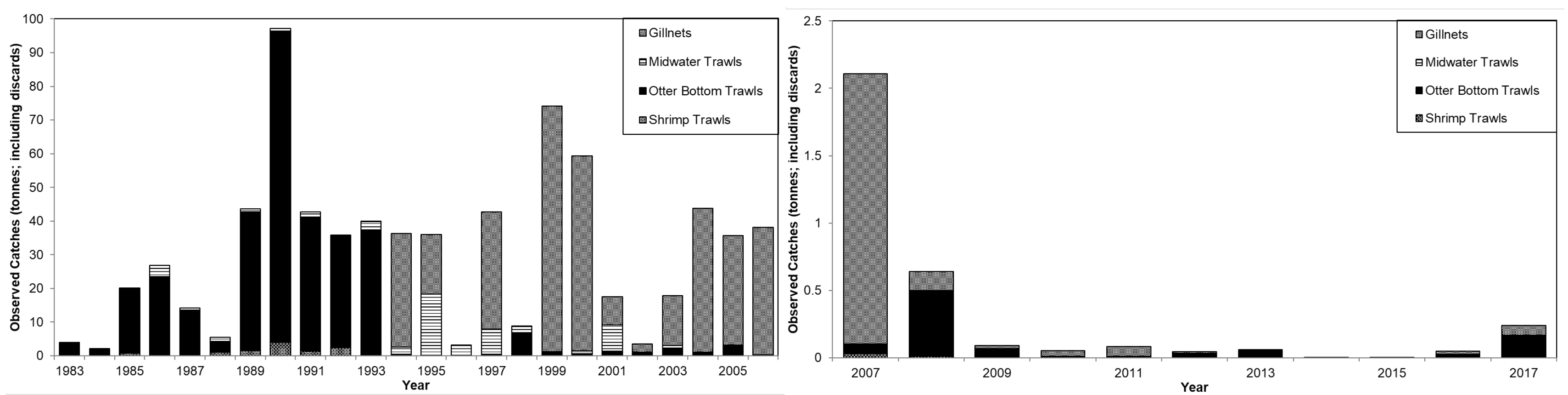

Figure 48. Observed catches (t) of Common Lumpfish by gear type in Canada's EEZ of Div. 2J3KLNOP, 1983–2006 and 2007–17. Data are from Canadian ASOs and include discards.

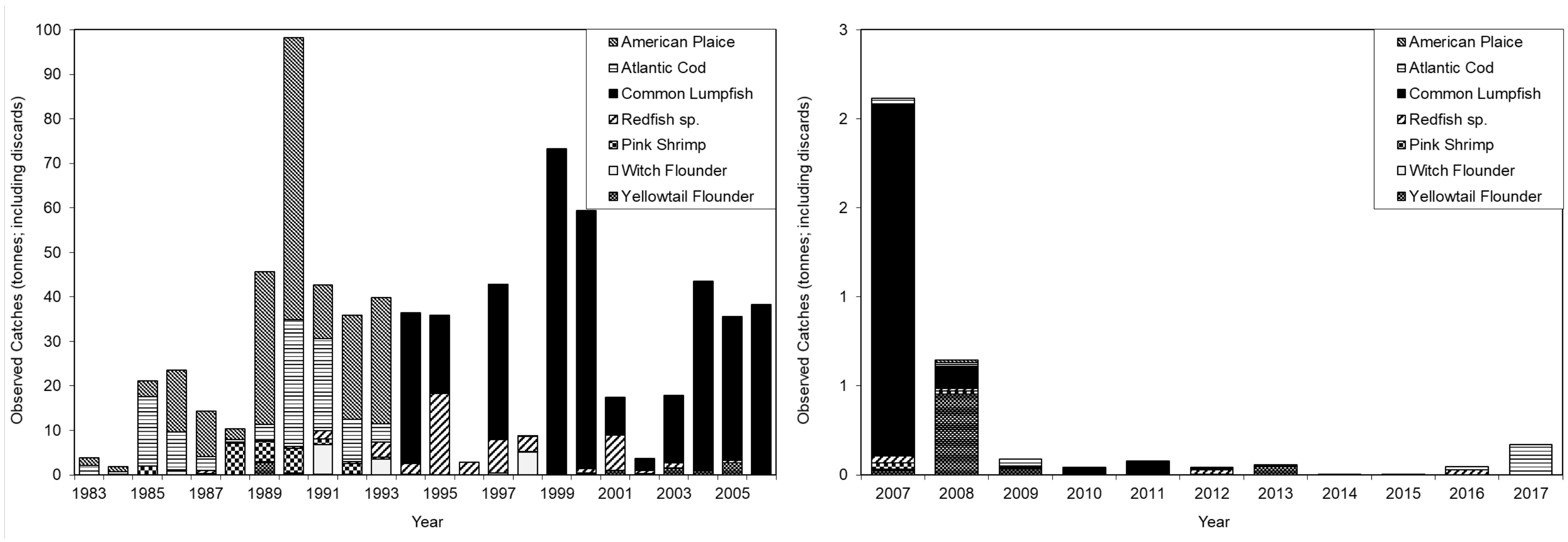

Figure 49. Observed catches (t) of Common Lumpfish by directed species in Canada's EEZ of Div. 2J3KLNOP, 1983–2006 and 2007–17. Data are from Canadian ASOs, and include discards.

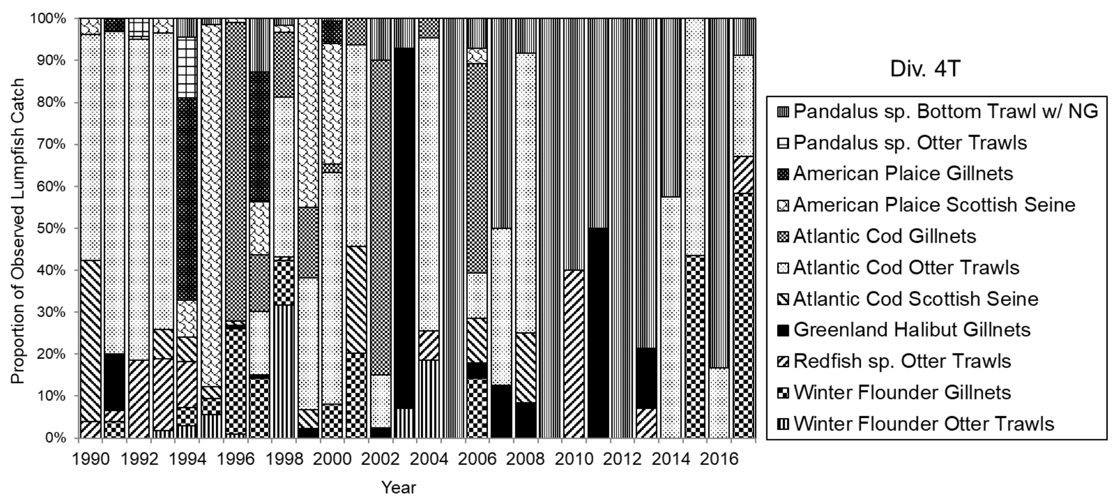

Figure 50. Proportion of observed catches of Common Lumpfish by directed species in Div. 4T, 1990–2017. Data are from Canadian ASOs and include discards.

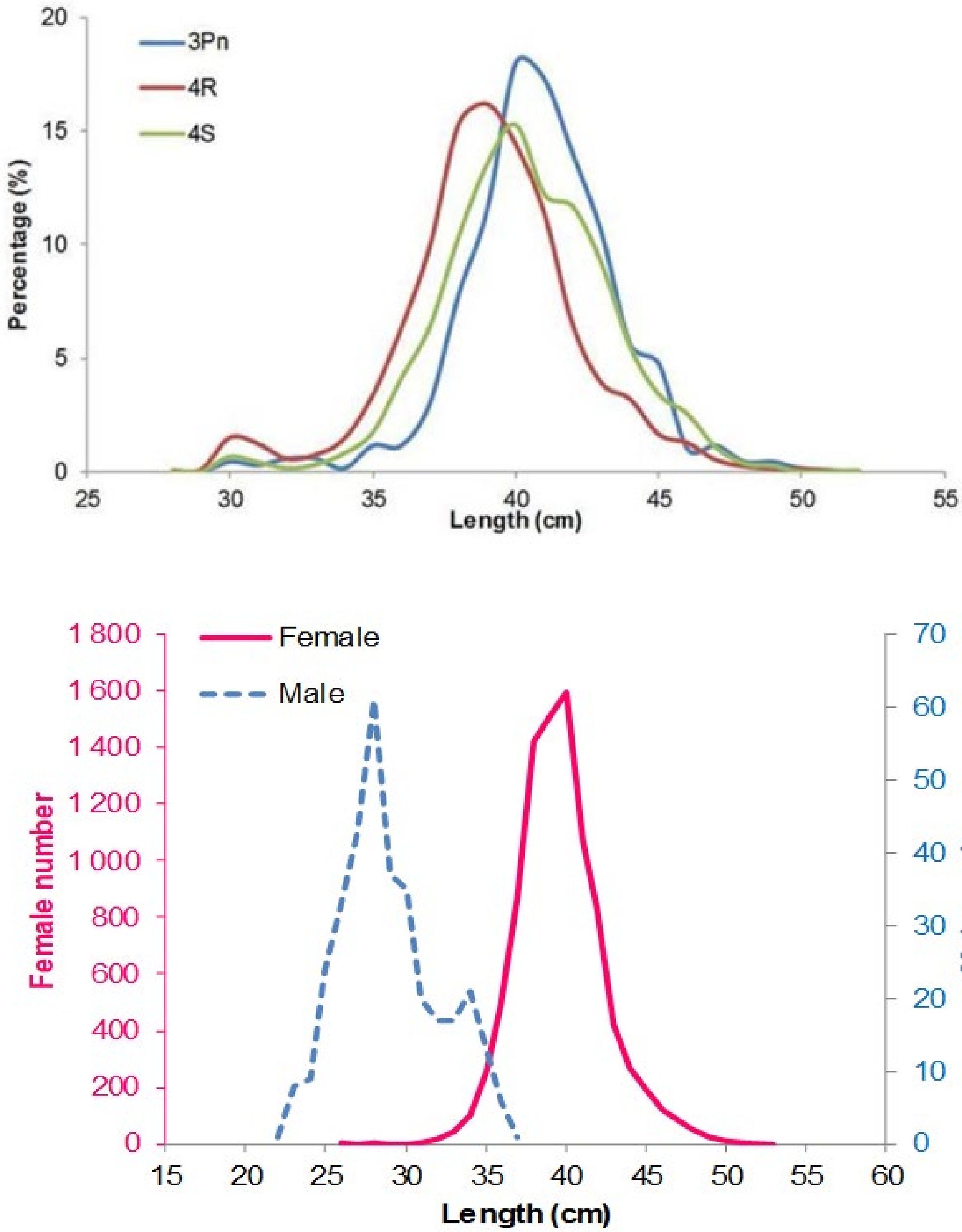

Figure 51. Observed sizes of female Common Lumpfish in Subdiv. 3Pn and Div. 4RS from 2004–12 (top panel). Observed size distribution of Common Lumpfish by sex in Div. 4R in 2017–18 (bottom panel).

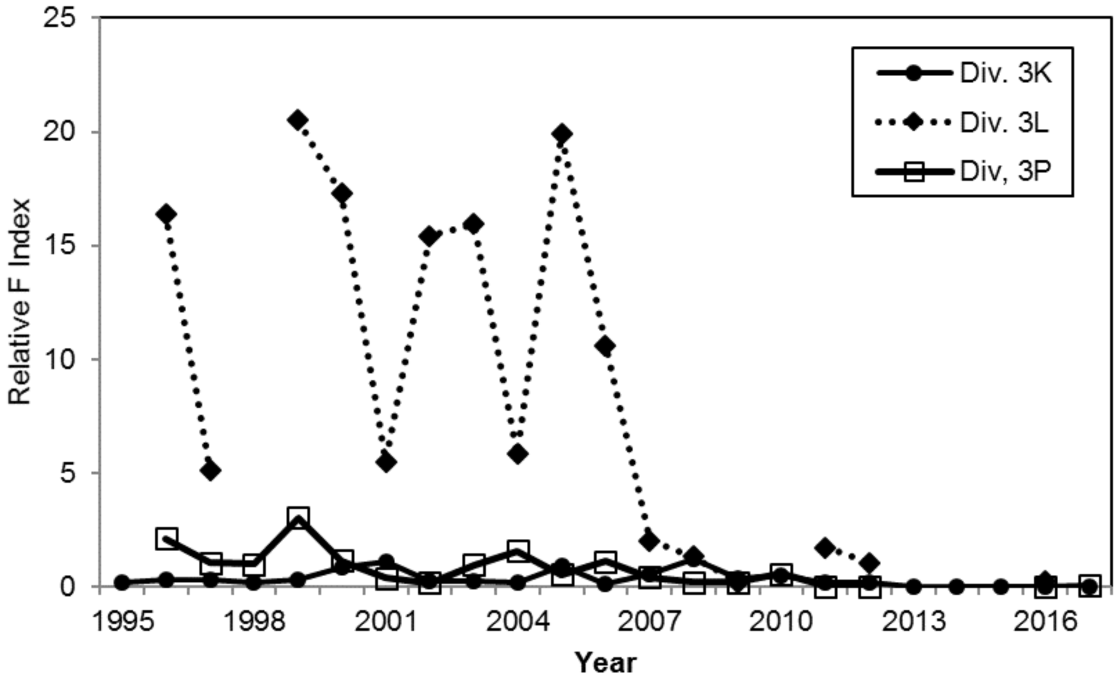

*Figure 52. Relative Fishing Mortality (F) index (=[DFO ZIFF-reported landings of Common Lumpfish roe]*4/DFO-NL Campelen survey biomass of female fish >34 cm) for Div. 3KLP, 1996–2017. Note that fall biomass estimate was used for Div. 3K (1995–2017), spring biomass estimate for Div. 3LP (1996–2017).*

13. APPENDIX 1. SUMMARY TABLE AND CHARACTERIZATION OF THREATS

Threat	Likelihood of Occurrence	Level of Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
Commercial Fishing (Directed)	Known	Medium	High	Medium	Current	Recurrent	Broad
Bycatch	Known	Medium	High	Medium	Current	Continuous	Narrow
Parasitic, viral and bacterial infections	Known	Low	Low	Low	Current	Recurrent	Unknown
Invasive Species	Likely	Low	Low	Low	Current	Continuous	Unknown
Oil and Gas	Known	Unknown	Very Low	Unknown	Current	Recurrent	Unknown
Seismic Exposure	Known	Unknown	Very Low	Unknown	Current	Recurrent	Extensive
Aquaculture	Known	Unknown	Very Low	Unknown	Current	Continuous	Narrow
Inshore Anthropogenic Disturbances	Known	Unknown	Very Low	Unknown	Current	Continuous	Narrow
Climate Change	Known	Unknown	Low	Unknown	Current	Continuous	Extensive

Rationalization for Threat Characterization

<table>
<tr><td colspan="2">Commercial Fishing</td></tr>
<tr><td>Level of Impact: Medium</td><td>Likelihood of Occurrence: Known</td></tr>
<tr><td rowspan="7">• Commercial fisheries targeting Common Lumpfish females (for roe) occur in NAFO Div. 3KLP4RS (Simpson et al. 2016).
• The carcass has little commercial value and is discarded at sea (Kennedy et al. 2018).
• With respect to Canadian reported roe landings (in DFO-NL ZIFF database), a conversion factor of 4 is currently used (Stevenson and Baird 1988) to convert these landings to whole (round) weight of females.</td><td>• The commercial harvesting of Common Lumpfish for roe is managed by DFO.</td></tr>
<tr><td>Causal Certainty: High</td></tr>
<tr><td>• The only quantified anthropogenic threat to recovery of Common Lumpfish is ongoing fishery-related mortality resulting from commercial fisheries directing for this species, (and as bycatch in other fisheries).</td></tr>
<tr><td>Threat Frequency: Recurrent</td></tr>
<tr><td>• This fishery occurs in shallow coastal waters for a few weeks between April and July, and is conducted primarily by <65’ vessels.</td></tr>
<tr><td>Threat Extent: Broad</td></tr>
<tr><td>• Commercial fisheries landings data are collected on directed fisheries for this species.
• Although dependent on the percentage of Canadian ASO coverage of each fishery in each year, ASOs collect data on both landed and discarded biomass. The Common Lumpfish-directed fishery in the NL Region has not had ASO coverage since 2012.</td></tr>
</table>

<table>
<tr><td colspan="2">Bycatch</td></tr>
<tr><td>Level of Impact: Medium</td><td>Likelihood of Occurrence: Known</td></tr>
<tr><td rowspan="3">• According to the DFO-NL ZIFF database, bycatch of Common Lumpfish in the NL Region occurred in a variety of groundfish fisheries using otter trawls, gillnets, and longlines.
• In the MAR Region, the Atlantic cod fishery showed the largest total weight of observed Common Lumpfish (197,243 t), followed by the redfish (62,371 t) and American Plaice (30,616 t) fisheries.</td><td>• Landings and discards are reported by ASOs, while only landings are recorded by fish harvesters and dockside monitors.</td></tr>
<tr><td>Causal Certainty: High</td></tr>
<tr><td>• Aside from directed fishing mortality, the only quantified anthropogenic threat to recovery of Common Lumpfish aside from directed fishing mortality is mortality from bycatch in other directed groundfish fisheries.</td></tr>
</table>

<table>
<tr><th colspan="2">Bycatch</th></tr>
<tr><td rowspan="4">Since 2005, observed bycatch has declined markedly in most fisheries.
• In NAFO Div. 4T, Common Lumpfish bycatch was observed in: Atlantic cod otter trawls, gillnets, and Scottish seines; American Plaice gillnets and Scottish seines; Winter Flounder otter trawls and gillnets; Greenland Halibut gillnets; shrimp trawls; and redfish otter trawls (Simpson et al. 2016).
• In the QC Region, annual bycatch reported as roe in fisheries directing for other species was low from 2000-2017. Approximately 1% of ASO-reported fishing activities bycaught Common Lumpfish, and 99% of bycaught Common Lumpfish was discarded at sea.</td><td>Threat Frequency: Continuous</td></tr>
<tr><td>• Common Lumpfish are caught in various groundfish fisheries that occur throughout the year.</td></tr>
<tr><td>Threat Extent: Narrow</td></tr>
<tr><td>• Current recorded weights of Common Lumpfish bycatch are often less than 10 t per year, with the largest removals of several hundred tonnes.
• However, these numbers are dependent on the percentage of ASO coverage per fishery, which is generally low or non-existent; thus, unreported bycatch has certainly occurred.</td></tr>
</table>

<table>
<tr><th colspan="2">Parasitic, Viral, and Bacterial Infections</th></tr>
<tr><td>Level of Impact: Low</td><td>Likelihood of Occurrence: Known</td></tr>
<tr><td rowspan="3">• Common Lumpfish are hosts to a number of parasitic species, including copepods, protozoans, and helminths.
• In NL waters, they are an intermediate host of the “cod worm” Lernaeocera branchialis (Templeman et al. 1976).
• Common Lumpfish are also a preferred host of the ectoparasitic copepod Caligus elongates, also known as Sea Lice (Øines et al. 2006; Heuch et al. 2007; Øines and Heuch 2007).
• Viral infections have occurred in Common Lumpfish from Iceland and Norway (Skoge et al. 2018; Guðmundsdóttir et al. 2019)
• Bacterial infections of Vibrio sp. Passed from Atlantic Salmon to Common Lumpfish has been recorded in Norwegian and Scottish aquaculture</td><td>• The occurrence of parasitic infections has been more extensively studied in European waters, but there have been studies in NW Atlantic waters, mainly surrounding Newfoundland. The most common parasite, L. branchialis larvae, was found to have no effect on the health of Common Lumpfish, its intermediate host (Smith et al. 2007).
• Chronic mortalities due to intranuclear microsporidian infection were reported for captive farmed Common Lumpfish from eastern Canada (Mullins et al. 1994).
In Canadian waters, the protozoans Cryptobia dahli and Trichodina domerguei are known to infest the stomach and urinary bladder, respectively (Margolis and Arthur 1979).</td></tr>
<tr><td>Causal Certainty: Low</td></tr>
<tr><td>• While the likelihood that parasitic infection would cause decline at the population level is very low, there is the possibility that these infections could jeopardize the survival of individual fish.</td></tr>
</table>

Parasitic, Viral, and Bacterial Infections	
(Powell et al. 2018), and would likely occur in Canadian operations as well.	Threat Frequency: Recurrent
	• Studies by Templeman et al. (1976) found that, in various areas (primarily around Newfoundland), *L. branchialis* infections occurred at different times of year, depending on location.
	Threat Extent: Unknown
	• The impacts of these infections have not been quantified for Common Lumpfish populations in Canada. • Much of the published literature relates to populations from European countries, while less is known about infections of this species in Canadian waters. • It is reasonable to conclude that these infections could occur in both wild and farmed populations of Common Lumpfish in Canadian waters, but the extent of the impact of this threat is unknown.

Invasive Species	
Level of Impact: Low	Likelihood of Occurrence: Likely
• Several aquatic invasive species may have deleterious effects on Common Lumpfish and/or their habitat, though it is not possible to quantify any effects at present. • European Green Crab range from the Bay of Fundy to northeastern New Brunswick and southern Newfoundland (Therriault et al. 2008). It is possible that Green Crabs could consume juvenile Common Lumpfish and egg clusters, while causing destruction of vegetation important to nesting sites and juvenile nursery grounds. • Five invasive tunicate species (Golden Star, Pancake Batter, Vase, Violet, and Compound Sea Squirt) may reduce available habitat for egg denning and juvenile Common Lumpfish rearing by outcompeting other	• The affects of invasive species on Common Lumpfish have not been quantified at present, but there is a high likelihood that the ranges of these species overlap with Common Lumpfish and could have negative effects on the population. Causal Certainty: Low • There is only a theoretical link between invasive species and Common Lumpfish population decline, but there is a possibility that invasive species could negatively impact juvenile survival and affect Common Lumpfish at the population level. Threat Frequency: Continuous • Common Lumpfish and invasive species coexist continuously over time, so it is plausible that the threat to the population is continuous. Threat Extent: Unknown

Invasive Species	
bottom dwelling species for space (Carman et al. 2016).	• The impacts of invasive species on Common Lumpfish population survival and recovery have not been quantified in Canada. • Invasive species have been shown to affect larval settling behaviour in other species, but this has not been documented for Common Lumpfish.

Oil and Gas	
Level of Impact: Unknown	Likelihood of Occurrence: Known
• The occurrence of oil/chemical spills could all potentially have impacts on lumpfish, their predators and prey.	• 4 active oil producing projects in NL waters: Hebron, Hibernia, Terra Nova and White Rose.
	Causal Certainty: Low
	• Common Lumpfish has been identified as a species which is vulnerable to potential oil spills in the Gulf of St Lawrence (Desjardins et al. 2018)
	Threat Frequency: Recurrent
	• Sizable spills occur infrequently,
	Threat Extent: Broad
	• Although active oil production platforms are operationally centered in NAFO Div. 3L and the Scotian Shelf, spilled crude oil could potentially be transported by oceanic currents, and thus impact multiple areas.

Seismic Exposure	
Level of Impact: Low/unknown	Likelihood of Occurrence: Known
• No species specific research is available. Theoretically could impact Common Lumpfish, as well as their predators and prey.	• Seismic exploration occurs continuously in the North Atlantic; especially in NL waters.
	Causal Certainty: Very Low

Seismic Exposure	
	• No species-specific research is available, and studies on other marine species indicate conflicting results with respect to possible damage. Eggs and larvae may also be impacted (Carroll et al. 2017).
	Threat Frequency: Recurrent
	• The Canada-Newfoundland & Labrador Offshore Petroleum Board (C-NLOPB) lists these activities for Newfoundland waters and although the annual frequency has decreased, there is still some annual activity, mostly in the summer months.
	Threat Extent: Extensive
	• Since seismic airgun blasts can travel a great distance, and are often repeated every 10 seconds over a 24 hour cycle for weeks, the potential for impact is extensive.

Aquaculture	
Level of Impact: unknown	Likelihood of Occurrence: Known
• No species specific studies available. Common Lumpfish have been utilized to control sea lice infestations in farmed Atlantic Salmon. Medicated feed and waste products from sites may result in eutrophication.	• 45% of Canadian aquaculture production is based in Atlantic Canada.
	Causal Certainty: Very Low
	• No evidence or studies implying impact on Common Lumpfish. However, expanded use of lumpfish as cleaner fish may result in mixing of wild and hatchery fish with potential consequences.
	Threat Frequency: Continuous
	• Aquaculture sites operate year-round.
	Threat Extent: Narrow
	• As most aquaculture occurs in coastal areas, impacts are possible during adult migration and spawning, as well as juvenile stages.

<table>
<tr><td colspan="2">Inshore Anthropogenic Disturbances</td></tr>
<tr><td>Level of Impact: Unknown</td><td>Likelihood of Occurrence: Known</td></tr>
<tr><td rowspan="7">No species-specific research available. Many factors could impact Common Lumpfish, their predators and prey.
Harmful eutrophication can be caused by the runoff of chemicals/fertilizers/waste from agriculture and other industries.
Light and noise pollution in coastal areas.
Release of freshwater from hydroelectric generating stations.</td><td>Siltation, destruction of habitat, and pollution (sound, light, waste products) occur despite prevention methods.</td></tr>
<tr><td>Causal Certainty: Low</td></tr>
<tr><td>No species specific data available</td></tr>
<tr><td>Threat Frequency: Continuous</td></tr>
<tr><td>Anthropogenic disturbances are possible through the range.</td></tr>
<tr><td>Threat Extent: Narrow</td></tr>
<tr><td>With vital life stages and activities occurring near shore anthropogenic disturbances could have impact on Common Lumpfish during reproduction, larval and juvenile stages.</td></tr>
</table>

<table>
<tr><td colspan="2">Climate Change</td></tr>
<tr><td>Level of Impact: Unknown</td><td>Likelihood of Occurrence: Known</td></tr>
<tr><td rowspan="7">Common Lumpfish are tolerant of a wide range of temperatures. However, temperatures less than 5°C are preferred. Warmer waters, particularly those in excess of 15°C, are associated with increased mortality, as well as the formation of cataracts and the development of abnormal swimming behaviour (Hvas et al. 2018).
Climate change can indirectly affect populations through a cascade of changes including a shift in prey availability, seasonal mismatch of trophically linked species, declining recruitment success, and the decoupling of phenological relationships (Edwards and Richardson 2004).
Warming may have complex effects on Common Lumpfish ontogeny and may impact efficiency of</td><td>Effects of climate change are known and quantified, however the scale of these effects on individual species are less clear.</td></tr>
<tr><td>Causal Certainty: Low</td></tr>
<tr><td>While there is strong evidence that climate change has significant effects on a number of different species both directly and indirectly, there is less data surrounding the specific impacts on this species.</td></tr>
<tr><td>Threat Frequency: Continuous</td></tr>
<tr><td>The direct and indirect effects of climate change are continuous and may be exerting pressures on one or more Regions at any given time.</td></tr>
<tr><td>Threat Extent: Extensive</td></tr>
<tr><td>Ocean warming and altered circulation, as a consequence of climate change, may reduce the survival of Common Lumpfish on an</td></tr>
</table>

Climate Change	
protein resorption by embryonic fish (Rusyaev et al. 2019). • The metric most commonly studied is ocean warming, which contributes to a cascade of ecosystem changes. • The effects of climate change are complex and often synergistic, and at this time it is difficult to specifically attribute what level of impact climate change has on the decline of this species.	extensive scale, with over 70% of the population experiencing these effects at any given time.