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Assessment of Lumpfish (*Cyclopterus lumpus*) in the Gulf of St. Lawrence (3Pn, 4RS) in 2015

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Foreword

This series documents the scientific basis for the assessment of aquatic resources and ecosystems in Canada. It addresses the issues of the day in the time frames required. 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

The Quebec Region of Fisheries and Oceans Canada (DFO) conducted an initial assessment of the status of the Lumpfish (*Cyclopterus lumpus*) in the northern Gulf of St Lawrence (nGSL) in winter 2006. During that assessment, the frequency of advisories was set at five years (DFO 2006, DFO 2011, DFO 2014, DFO 2016). Since the population structure and the identification of Lumpfish stocks are unknown, the assessment focuses on Divisions 4R and 4S and on Subdivision 3Pn of the Northwest Atlantic Fisheries Organization. This choice is based on areas of interest where there is a directed fishery for this species. Few data are available for this assessment. The main indicators of the status of the nGSL Lumpfish are derived from statistical data on the fishery, sampling of commercial catches, DFO's bottom trawl survey and from the mobile surveys of the sentinel fishery program. This document describes the biology, fishery, as well as data and analyses that were used to produce the advice on the assessment of the Lumpfish (*Cyclopterus lumpus*) of the Gulf of St. Lawrence (3Pn, 4RS) in 2015. (DFO 2016).

Lumpfish fishery in the nGSL is relatively recent, having developed in the mid-1970s. It is aimed exclusively at females for the caviar market and takes place in spring. Lumpfish roe landings have decreased considerably, from an annual average of 349 t for the 1986–2009 period, to 35 t for the 2010–2015 period. The number of active fish harvesters has also decreased greatly, from an annual average of 404 participants, to 65 for the same periods. Fishing is practised mainly in unit area 4Sw, Subdivision 3Pn and Division 4R. Since 2013, all fishing activities have been concentrated in unit area 4Ra.

Factors such as market conditions, the synchronization of the fishery with the arrival of females in coastal waters, weather conditions and the possibility of more lucrative fisheries could partly explain the decline in landings and fishing effort. The sharp decline in landings and effort suggests a significant decline in resource abundance. This resource's abundance seems to fluctuate on a cyclical basis and is at a low. Although the reasons for this low abundance are uncertain, the resource's vulnerability to recruitment overfishing suggests a very cautious approach.

RÉSUMÉ

La région du Québec de Pêches et Océans Canada (MPO) a réalisé une première évaluation de l'état de la lompe (*Cyclopterus lumpus*) du nord du golfe du Saint-Laurent (nGSL) à l'hiver 2006. Lors de celle-ci, la fréquence des avis a été fixée à cinq ans (MPO 2006, MPO 2011, MPO 2014, MPO 2016). La structure de population et l'identification des stocks de lompe n'étant pas connues, l'évaluation porte sur les divisions 4R et 4S ainsi que la sous-division 3Pn de l'Organisation des pêches dans l'Atlantique nord-ouest. Ce choix est basé sur des secteurs d'intérêt où se déroule une pêche dirigée pour cette espèce. On dispose de peu de données pour cette évaluation. Les principaux indicateurs de l'état de la lompe du nGSL proviennent des données des statistiques de pêche, de l'échantillonnage des captures commerciales, du relevé au chalut de fond du MPO et des relevés mobiles du programme des pêches sentinelles. Le présent document décrit la biologie, la pêche ainsi que les données et analyses ayant servi à produire l'avis sur l'évaluation de la lompe (*Cyclopterus lumpus*) du golfe du Saint-Laurent (3Pn, 4RS) en 2015. (MPO 2016).

La pêche à la lompe dans le nGSL est relativement récente s'étant développée au milieu des années 1970. Elle vise exclusivement les femelles pour le marché du caviar et se déroule au printemps. Les débarquements d'œuf de lompe ont diminué considérablement passant d'une moyenne annuelle de 349 t pour la période 1986-2009 à 35 t pour la période 2010-2015. Le nombre de pêcheurs actifs a également grandement diminué passant d'une moyenne annuelle de 404 participants à 65 pour les mêmes périodes. La pêche se pratique principalement dans la zone unitaire 4Sw, la sous-division 3Pn et la division 4R. Depuis 2013, toutes les activités de pêche sont concentrées dans la zone unitaire 4Ra.

Des facteurs, telles les conditions de marché, la synchronisation de la pêche avec l'arrivée des femelles dans les eaux côtières, les conditions météorologiques et la possibilité de pêches plus lucratives, pourraient en partie expliquer la diminution des débarquements et de l'effort de pêche. La forte diminution de l'effort et des débarquements suggèrent toutefois un déclin important de l'abondance de la ressource. Cette ressource semble fluctuer en abondance de façon cyclique et se situerait dans un creux. Malgré les incertitudes sur les causes de la faible abondance, la vulnérabilité de cette ressource à la surpêche du potentiel reproducteur milite en faveur d'une approche très prudente.

INTRODUCTION

The structure of Lumpfish populations and the identification of Lumpfish stocks (*Cyclopterus lumpus*) (also known as the Seahen) of the Gulf of St. Lawrence are unknown. This document deals with Subdivision 3Pn and Divisions 4R and 4S of the Northwest Atlantic Fisheries Organization (NAFO) (Figure 1). This choice is based on areas of interest where there is a directed fishery for this species. Although its population structure in the Gulf of St. Lawrence is unknown, a recent, large-scale genetic study (Pampoulie et al. 2014) identified three genetically distinct groups based on geographical distribution: a western Atlantic group (Maine – Canada – Greenland); an eastern Atlantic group (Iceland – Norway); and a Baltic Sea group. However, that study included only one sampling site in the Gulf of St. Lawrence, located in the Strait of Belle Isle. A more recent genetic study (Garcia-Mayoral et al. 2016), which included a greater number of individuals sampled at various spawning sites in Greenland, confirms that the Lumpfish population of western Greenland is differentiated from the populations of Iceland and Canada.

The species is currently the subject of an assessment by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and the report is expected for November 2017.

Fisheries and Oceans Canada (DFO) conducts a review and assessment process of the Lumpfish in the northern Gulf of St Lawrence every five years. The most recent review was conducted on February 18, 2016. In support of that review (DFO 2016), this document presents the data, techniques, analyses and findings of that assessment following the 2015 fishing season.

BIOLOGY

The Lumpfish is distinguished by its massive body, with a rounded shape compressed laterally and forming a dorsal crest (Figure 2). This fish has a thick skin, without scales and covered by tubercles. The mouth is small, as is the slightly rounded caudal fin. The pelvic fins are modified and surrounded by a circular skin fold, forming a suction cup that allows the Lumpfish to fix onto solid surfaces. The colour of the Lumpfish's body often blends with its environment, a phenomenon that is more common in juveniles. In adults, the body may take on a colouration of slate blue, bluish grey, olive, brownish to yellow-green, or chocolate brown, whereas the belly is yellowish to whitish (Bigelow and Schroeder 1953) (Figure 3).

The Lumpfish is largely distributed in the temperate waters of both sides of the North Atlantic. These fish are semi-pelagic (Davenport 1985), spending much of their adult lives in the pelagic zone and can be captured in both bottom trawls and midwater trawls (Holst 1993, Wienerroither et al. 2011, Sheehan et al. 2012, Wienerroither et al. 2013, Eriksen et al. 2014). A recent Icelandic study, involving Lumpfish tagging with data storage tags, confirms that adult females make daily vertical migrations in the water column, spending a significant part of their time in both the pelagic and demersal zones (Kennedy et al. 2015). Several tagging studies have also shown that the Lumpfish was able to travel long distances, for example a tagged Lumpfish travelled more than 300 km over a period of three months in the northern Gulf of St. Lawrence (nGSL) (Fréchet et al. 2006, Fréchet et al. 2011). In Iceland, the longest distance travelled in one day was 49 km and the longest distance ever reported was 587 km over 18 days (Kennedy et al. 2014). These studies also showed that a high proportion of individuals tagged in their spawning sites were recaptured a year later near the site.

The Lumpfish would not produce the plasma proteins that are known to improve resistance to cold among certain fish (King et al. 1989). This means it would have a low probability of survival

if exposed to temperatures < 0 °C, temperatures that may be present in the coastal area of the nGSL in winter. This could partly explain the fall migration of the Lumpish to deeper and relatively warmer waters.

In early spring, the Lumpfish migrates along the coast for spawning, which can continue until summer. The males arrive first in shallow waters and build nests. The females reach the spawning sites at different times, allowing the males to spawn with several females. Lumpfish are sexually dimorphic and females grow to be larger than males. During courtship, there is also a state of dichromacy; females are grey-blue and males are orange-red on their underside and fins (Figure 2). Females lay their eggs on the surface of the nest, where they are fertilized by the male. They can lay 2 to 3 egg masses at intervals of 8 to 14 days. Each mass can contain from 10 000 to 200 000 eggs. After spawning, they leave the coastal area. Males remain near the nest during the incubation period, providing parental care for the eggs, aerating them and protecting them against certain predators. Incubation can last more than 60 days.

Upon hatching, larvae measure approximately 5 mm. During the early stages of life, the Lumpfish can be found under floating algae or attached to rocks, lobster traps or other solid objects via its adhesive pelvic disk. Juveniles can be found in coastal areas, in eelgrass beds and in the high seas.

DIET

The diet of the Lumpfish of the Gulf of St. Lawrence, as determined from 57 fish sampled in August 2015 during a DFO research survey, is comparable to its diet described elsewhere in the Atlantic Ocean (Davenport 1985). In general, the Lumpfish diet consists mainly of a variety of invertebrates, including crustaceans such as crab larvae, euphausiids, amphipods, gelatinous zooplankton (jellyfish and comb jellies) and polychaetes (Figure 4).

PREDATION

Few fish have been identified as predators of the Lumpfish. Studies on the stomach contents of Wolffish (*Anarhichas spp*) and Greenland Halibut (*Reinhardtius hippoglossoides*), conducted in the northwestern Atlantic, have identified the Lumpfish as a rare prey of these species (Chumakov and Podrazhanskaya 1986, Simpson et al. 2013). For the nGSL, a review of a database of the stomach contents of several thousand Atlantic Cod (~ 19 000 individuals), Greenland Halibut (~ 17 000 individuals) and Atlantic Halibut (~ 400) sampled during bottom trawl research surveys from 1994 to 2015 has identified the presence of the Lumpfish in only seven fish stomachs, i.e., three Atlantic Cod and four Atlantic Halibut (D. Chabot, DFO Quebec Region, pers. comm.) (Table 1). The size of the cod varied from 57 to 61 cm, whereas the size of the Atlantic Halibut varied from 101 to 149 cm. It is interesting to note that the four Atlantic Halibut captured in 2008 and 2015 were from the same area, i.e., west of Anticosti Island, between Sept-Îles and Pointe-des-Monts (Figure 5).

Marine mammals are known predators of the Lumpfish. In the nGSL, studies have identified the Grey Seal (*Halichoerus grypus*) as one of its predators (Benoît and Bowen 1990a and 1990b, Hammill and Stenson 2000, Hammill et al. 2007). The proportion of Lumpfish in the stomachs of Grey Seals is highly variable, and the highest values were reported in the stomachs sampled on Anticosti Island during the Lumpfish breeding period. It should be noted that the Grey Seal population in the Gulf has increased significantly in recent decades (DFO 2014).

HABITAT

Eelgrass beds are recognized as highly productive environments that provide vital habitats to many animal species in coastal areas (Hemminga and Duarte 2000; Polte and Asmus 2006).

The complex structure of the beds provides refuge and food to a significant number of species during critical stages of their life cycles (Orth et al. 1984; Lazzari et al. 2003). There is a greater abundance of fish in eelgrass beds than in habitats without vegetation (Heck et al. 1989). Between 2005 and 2010, 11 eelgrass beds in the St. Lawrence were sampled from May to November (Table 2 and Figure 6 ; Nellis et al. 2012, P. Nellis, DFO, pers. comm.). Lumpfish captures were noted at stations added in 2009 and 2010. Lumpfish were harvested in five eelgrass beds, including 61 Lumpfish in Sept-Îles, 1 Lumpfish in Baie-Saint-Ludger, 34 Lumpfish in Longue-Rive, 1 Lumpfish in Mingan and 22 Lumpfish in Unamen Shipu. In total, 119 Lumpfish were caught, 117 of which were juveniles < 80 mm. The largest individuals measured between 208 and 309 mm.

The Comité ZIP Côte-Nord du Golfe, a non-profit organization, has a mission to protect and improve the Gulf of St. Lawrence, to increase public awareness of the environmental issues related to it and to promote action for the ecological rehabilitation of that ecosystem (Lavoie 2015). In 2011, the ZIP Committee set up the Community Aquatic Monitoring Program (CAMP), aimed at involving various schools and young volunteers in the monitoring of estuaries. The objective of the CAMP is to create a database on the general health status of the ecosystems at the mouths of the area's rivers while making young people aware of their importance. From 2011 to 2015, four estuaries and two bays were sampled with a beach seine net from June to September. They consisted of Baie des Îles de Mai, Baie des Sept Îles, Rivière Moisie, Rivière Sheldrake, Rivière Saint-Jean and Petite rivière Natashquan (Figure 6). Juvenile Lumpfish (< 55 mm, n = 106) were harvested in each year of sampling in the Baie de Sept Îles. Three Lumpfish measuring more than 200 mm were also harvested there. In August 2015, juvenile Lumpfish (< 25 mm) were harvested in the Baie des Îles de Mai. No Lumpfish were harvested in the river mouths, as these locations are not favourable for this species due to the low salinity (< 3 ppt). The ZIP Committee provided its data to us, which allowed us to chart the size of the fish according to the months in which they were caught (Figure 7). This chart suggests substantial growth in the juvenile Lumpfish, which can double their size between July and October, from an average of 16 mm to 36 mm.

STUDY ON THE FECUNDITY OF THE LUMPFISH (*CYCLOPTERUS LUMPUS*) OF THE GULF OF ST. LAWRENCE

A study was conducted in the nGSL with the goal of estimating, for the first time, the fecundity of the Lumpfish. It was conducted in 2004 and 2005 and funded by the Fisheries Science Collaborative Program (FSCP) to fulfill a request from the fishing industry.

Fecundity, like growth and mortality, is one of the most important factors for measuring the regenerative capacity of a population or stock (Quinn and Deriso 1999). In that respect, fecundity estimates are particularly used to describe the impact fishing has on a species (Rothschild 1986, Tserpes et al. 2006, Fudge and Rose 2008) or to assess abundance based on its annual egg production (Saville 1964 and 1977, Lasker 1985, Hunter and Lo 1993, Pepin 2002, Hunter and Macewicz 2003).

MATERIAL AND METHODS

The Lumpfish used in this study were sampled during the regular commercial fishing activities of the 2004 and 2005 seasons. Total length, total weight and ovary weight were noted with a precision of 0.5 mm and 0,5 g, respectively. Ovaries were preserved in a formaldehyde solution until their analysis in the laboratory. Oocytes (unfertilized eggs) were counted according to the Bagenal and Braum gravimetric method (1978). Oocyte counts were conducted on sub-samples of ovaries of known weight. Using the total weight of the corresponding ovaries, the numbers

obtained were converted to total fecundity (number) and relative fecundity (number/g of somatic weight). Ovaries that had already lost oocytes due to spawning—after visual inspection—were excluded from the calculation of fecundity.

Histological sections were also prepared from another sample of 127 ovaries in 2004. Twenty-eight ovaries originated from Lumpfish harvested in Subdivision 3Pn, 50 from Division 4R, and 49 from Division 4S. Each sample was placed in an embedding cassette identified and sent to the CTRR Clintrials Bioresearch company, which prepared the histological sections according to the usual protocol of dehydration, paraffin embedding and Harris hematoxylin and eosin Y staining. The sections were analyzed using a Leitz Laborlux K microscope coupled with a model TK-12800 JVC camera and a Q500MC Leica image analyzer. Maturity stages were determined and the maximum diameter of the hydrated oocytes was measured (0.5 mm) at a magnification of 25x.

Lengths and somatic weights were examined in order to detect measurement errors or extreme values. This data mining was conducted using graphical tools (e.g., box-and-whisker plot and scatter plot) in accordance with the protocol proposed by Zuur et al. (2010). A two-way analysis (Zar 1999) was applied to these data and to ovary weight data in order to detect significant differences based on the Northwest Atlantic Fisheries Organization (NAFO) Division or the harvest year.

A global test of the validation of the linear model assumptions (Peña and Slate 2006) was first applied to the residuals of the linear regression between total fecundity and ovary weight using the R gvlma library (Peña and Slate 2014). Following validation of the assumptions, the parameters of linear regression were compared with the NAFO Divisions through an analysis of covariance (ANCOVA) (Zar 1999) conducted with the R car library (Fox and Weisberg 2011).

The results of these analyses were presented graphically, using R ggplot2 libraries (Wickham 2016), ggExtra (Attali 2016), gridExtra (Auguie 2016) and gplots (Warnes et al. 2016). Descriptive statistics on length, weight and fecundity were calculated using the R pastecs library (Grosjean and Ibanez 2014). All of these libraries were used with version 3.3.1 of the R software (R Core Team 2016). Lastly, the significance threshold of the statistical tests was set at 0.01.

RESULTS

A total of 247 ovaries were sampled in 2004 and 145 in 2005 (Table 3). This difference is the result of a reduction in the target number of ovaries to be sampled, which was reduced from 100 to 50 ovaries between 2004 and 2005 for Subdivision 3Pn and Division 4R. A few extreme values were detected upon examining the box-and-whisker plots and the scatter plot between the somatic weight and length data (Figure 8). These values were retained because of their low number and the limited scope of the data, which did not permit the researchers to define in its entirety the weight–length relationship (of potency) or to exclude or include these values using arbitrary criteria (e.g., predictability intervals). The descriptive statistics of the variables of length, somatic weight and ovary weight are presented in Appendix 1.

The two-way analysis detected significant differences in the average length and average weight of the Lumpfish sampled in the various NAFO Divisions ($p < 0.001$). That difference is also seen in the examination of the frequency distributions presented in Figure 8. However, average ovary weights show significant differences between Divisions and years (ANOVA; $p<0.01$).

The global validation test indicates that linear relationship assumptions were respected. In addition, the analysis of covariance indicates that the slopes of the relationships between

fecundity and ovary weight are not significantly different ($p > 0.05$), contrary to the y-intercepts ($p < 0.01$) (Figure 9).

Total fecundity does not show any significant differences between divisions and years (ANOVA; $p > 0.04$). The average value for all data is 122 078 ± 42 205 eggs (Table 4). Furthermore, the analysis of variance did not detect significant differences ($p > 0.03$) for relative fecundity, the average value being 62.1 ± 19.9 eggs/g.

The analysis of variance detected significant differences between the average diameters of hydrated oocytes ($p < 0.001$). These differences are located between Divisions 3Pn-4R and 3Pn-4S (Tukey's test; $p < 0.001$). For Subdivision 3Pn, the average oocyte diameter is 1.59 ± 0.24 mm compared to 1.64 ± 0.22 mm and 1.63 ± 0.21 mm for Divisions 4R and 4S (Figure 10). The similarity of the diameters of hydrated oocytes and the presence of immature, smaller oocytes suggest that Lumpfish spawning is of the “batch fecundity” type, i.e., it occurs more than once in the same reproduction season.

COMMERCIAL FISHERY

In Canada, the Lumpfish fishery exclusively targets females for their eggs, which are processed as a caviar substitute. This fishery is relatively recent, having developed in the Gulf of St. Lawrence in the mid-1970s. It is practised in spring, in coastal waters (< 30 m), on boats measuring under 35 feet. Fishing takes place over a few weeks and the majority of landings (> 95%) take place in May and June, when the fish migrate to the coast to spawn. Management is done by controlling the fishing effort: 1) a fishing season of only a few weeks and 2) a limit of 50 gillnets measuring 91.44 m (50 fathoms) with a minimum mesh size of 267 mm (10.5 inches). There is no total allowable catch (TAC) in effect for this fishery.

FISHERIES MANAGEMENT

In the Gulf of St. Lawrence, the Lumpfish fishery is managed according to two different Conservation and Harvesting Plans (CHPs). DFO's Quebec Region manages the fishery in Division 4S, whereas DFO's Newfoundland and Labrador Region manages the fishery in Subdivision 3Pn and Division 4R.

Quebec's CHP applies to groundfish licence holders with a Class A-52 boat (< 13.72 m or < 45 feet) from the Quebec Region, directing their Lumpfish (Seahen) fishery in Area 4S (Appendix 2). That CHP includes, among other things, mandatory hail-outs, 10% coverage of activities by the observer program, a protocol on bycatches and the obligation to complete a logbook. The 10% coverage by observers was added to the fishing plan in 2010. However, no Lumpfish directed fishery activities were covered by that program between 2010 and 2012. Since 2013, no directed fishing was done in that Division. The remoteness of the fishing regions, the early start (May), the low number of activities and the short duration of this fishery are the main reasons for the lack of coverage by observers. Dockside monitoring at 100% was added to the fishing plan for the 2010–2011 and 2011–2012 seasons. That measure was subsequently removed from the fishing plan. The logbook that must be completed is included in the Combined Form, which also includes the weight out summary and purchase slip. Fishers must complete the logbook section every fishing day, prior to docking. The completed form must be sent to DFO's Sept-Îles office on Saturday of every week, when fishing operations have been carried out. The logbook section must be completed even if no catch is made. Since 2004, this has ensured the availability of close to 100% of information on landings, fishing effort (amount of gear, soak time), fishing dates and positions in official fishing statistical files (Zonal Interchange File Format (ZIFF)).

The Conservation Harvesting Plan (CHP) of Newfoundland and Labrador (3Pn, 4R) applies to groundfish licence holders for vessels under 19.81 m (65 feet) of the Newfoundland and Labrador Region directing their Lumpfish fishery in Northwest Atlantic Fisheries Organization (NAFO) Divisions 2J3KLP4R (Appendix 3). That CHP includes, among other things, 5% coverage by the observers program, 100% mandatory dockside monitoring for groundfish bycatches other than Lumpfish, and a protocol on bycatches. The vast majority of fishers who direct their Lumpfish activity in 3Pn and 4R are of the fleet of vessels less than 10.7 m (35 feet). For that fleet, the logbook to be completed is a document that has been issued since 1995 by DFO's Science Sector of Newfoundland, which is known as the *Groundfish fixed gear logbook for the less than 35 foot vessel sector*. Fishers must return that completed logbook to the Newfoundland Region's Science Sector, which forwards the documents, for fishing activities carried out in 3Pn and 4R, to Quebec's Science Sector at the Maurice Lamontagne Institute (MLI) in Mont-Joli. The information contained in those logbooks is entered in Excel files at the MLI. In addition to information on vessels, the targeted species, bycatches and landings, information on fishing effort is recorded in it. However, although it is a licence condition, very few fishers return that logbook for directed Lumpfish fishery. In recent years, the activities reported in these logbooks totalled between 0% and 16% of annual landings for Subdivision 3Pn and Division 4R. Official statistics (Zonal Interchange File Format (ZIFF)) on Lumpfish fishery for 3Pn and 4R stem either from dockside monitoring, when there are bycatches of other groundfish species, or from purchase slips. Those statistics do not contain any information on fishing effort and positions.

LANDINGS AND PARTICIPATION

Reported Lumpfish landings for directed fishery and for bycatches in other fisheries were taken into account using fishery statistics from ZIFF files for the period from 1986 to 2015. Data from previous years stem from the following publications: Stevenson and Baird (1988), Chouinard et al. (1992) and Grégoire (1998). Data from 1970 to 1985 for Division 4R and Subdivision 3Pn were provided by the Policy and Economics Section of Newfoundland. The various data sources were cross-referenced for validation.

In directed Lumpfish fishery, the gonads of females are collected at sea and carcasses are generally discarded there. In official statistics, directed fishery landings are recorded according to the weight of the roe (eggs). Landings are exceptionally in the form of whole fish, mainly when the Lumpfish is captured as a bycatch in other directed fisheries. ZIFF files reflect this situation and the *targeted species* variable indicates COSTACA code 176 for whole Lumpfish and 928 for roe landings. No factor is applied to convert roe weight into whole fish weight in those ZIFF files.

The study on the fecundity of Gulf of St. Lawrence Lumpfish revealed that the gonads of females, during commercial fishing, represented an average of 28% of the total weight of individuals. That result is comparable to the values of 19 to 31% reported by Stevenson and Baird (1988). As proposed in that publication, a conversion factor of 4 was used to convert the weight of roe landings into the weight of whole Lumpfish. During fishing, the eggs are released from the gonad envelope and placed into a net that allows for a certain level of drainage. It is that post-drainage weight that is compiled in statistics on landings. A project funded by the Fisheries Science Collaborative Program will attempt to determine a more realistic conversion factor between the weight of roe recorded in ZIFF files and the weight of whole Lumpfish for the future.

The evolution of annual Lumpfish landings in NAFO Subdivision 3Pn and in Divisions 4R and 4S is presented in Table 5 and in figures 11 and 12. Landings are presented as reported in ZIFF

files, i.e., as roe or as whole Lumpfish. Total landings are estimated by converting roe weight into whole Lumpfish.

Roe landings (928) in 3Pn, 4R and 4S have decreased considerably, from an annual average of 356 t for the 1986–2009 period, to 35 t for the 2010–2015 period (Table 5 and Figure 11A). Most landings occur in May and June (tables 6a and b) using gillnets (Table 7). The number of participants in this fishery has also decreased constantly since 1997, from an average of 404 fishers between 1986–2009, to 65 for the 2010–2015 period (Table 8 and Figure 13).

In Division 4R, Lumpfish fishing began in 1970. Two more significant landings have been observed: one in the late 80s, with a maximum of 470 t in 1987, and a second in the late 90s, with a maximum of 673 t in 1999 (Table 5 and Figure 11A). From 1970 to 2009, the annual landing average was 182 t compared to 35 t for the 2010–2015 period. In the history of this fishery, landings were recorded in all Unit Areas, i.e., 4Ra, 4Rb, 4Rc and 4Rd. However, since 2008, fishing has been very localized, and more than 95% of landings stem from Unit Area 4Ra (figures 1 and 14). The number of participants in this fishery, estimated by the number of vessels active each year, has varied greatly (Table 8 and Figure 13). From 1986 to 2015, the maximum recorded number of participants was 664 in 1987 and the average for the 1986–2009 series was 247 fishers, compared to 56 for the recent period (2010–2015).

In Subdivision 3Pn, directed Lumpfish fishery began in 1980. The most significant landings were recorded in 1997 and 1999, with 478 t and 471 t, respectively (Table 5). Between 1980 and 2009, the annual landings average was 127 t. For the 2010–2015 period, the average dropped to less than one tonne. There were no landings in 2009 and from 2012 to 2015. The maximum number of participants was 199 in 1997, with an average of 100 fishers between 1986 and 2008 (Table 8 and Figure 13).

In Division 4S, fishing began in 1986 and the most significant landing was recorded at the beginning of this fishery, in 1987, with 114 t. Fishing is concentrated in Unit Area 4Sw, which accounts for nearly 90% of landings; the other landings are from Unit Area 4Sv (Figures 1 and 15). From 1986 to 2009, the annual landing average was 27 t, compared to less than one tonne for the 2010–2015 period (Table 5, Figure 11). There were no landings in that Division from 2013 to 2015.

CATCH PER UNIT EFFORT – FISHERY PERFORMANCE INDEX

The databases of the observers programs of Quebec and Newfoundland, as well as those from the logbooks of fleets less than 10.7 m (35 feet) from Newfoundland and from the ZIFF files, were analyzed in order to detect trends in the catch rates for this fishery. Catch per unit effort (CPUE) is considered as a performance indicator, not as a Lumpfish abundance index. The database of the observers program and that of the logbooks for fleets less than 10.7 m from Newfoundland do not contain enough data to draw conclusions on Lumpfish fishing. Data originating from ZIFF files are the only source containing enough information to draw certain conclusions on directed fishery catch rates between 1986 and 2015. Since the variable of fishing effort for amount of gear is not available for all areas, catch rates were assessed in terms of total annual catches out of the number of annual activities for NAFO Subdivision 3Pn and Divisions 4R and 4S (Figure 16). Between 1986 and 2015, for Subdivision 3Pn and Divisions 4R and 4S, annual landings generally correlated with the number of activities. The fishing performance index, the CPUE (sum of the annual capture/number of activities) shows synchronous cyclical variations in each area. This index was low from 2009 to 2012. For 4Ra in 2015, the index was the same as the average for 1986–2014. The CPUE of commercial fishing cannot be used as an indicator of Lumpfish population abundance because CPUE is influenced by many factors, including market conditions, climatic conditions, synchronism between fishing

and the arrival of females in coastal areas, the short duration of the fishing season and competition from more lucrative fisheries.

BIOLOGICAL DATA

Since 2006, DFO's sampler program has collected limited data on the size of Lumpfish caught in the 4S commercial fishery. The difficulty in collecting that information lies in the fact that eggs are collected at sea and Lumpfish carcasses are discarded there. An agreement was formed with a fisher to land whole Lumpfish, thereby allowing for the collection of size data for a limited number of activities.

Data were collected in 2006, 2007, 2008 and 2010. The annual number of Lumpfish measured varied from 79 to 395 individuals. The length frequency distributions for Lumpfish captured in 4S are shown in Figure 17. There is little variation in the average size from one year to the next due to the selectivity of fishing gear (267 mm gillnet). Average size was 40 cm in 2006 and 2008, 41 cm in 2010 and 42 cm in 2007. The largest Lumpfish measured was 52 cm.

BYCATCHES

From 2010 to 2014, according to data from ZIFF files, there were no reported landings of whole Lumpfish or roe in fishing activities that were not directed Lumpfish activities.

The information provided by the observer database indicates that from 2005 to 2014, there were unrecorded Lumpfish releases in directed cod, rockfish, Greenland Halibut, American Plaice, Witch Flounder and shrimp fisheries (Bourdages and Marquis 2014). Annually, those releases represented less than 100 kg per fishery.

ECONOMIC ASPECTS

Lumpfish fishery is strongly influenced by market conditions, and annual landings vary according to demand and prices. The price for roe is negotiated annually before the start of fishing, and depends partly on the surplus from the previous year. After the fishing season, the price may be adjusted according to markets. If prices are low, some fishers may focus on other fisheries until prices recover. The landing prices available in the ZIFF files are shown in Table 9 and in Figure 18. The kg price of roe shows cyclical variations. In Division 4R, it increased from $1.98 in 2006 to a historic maximum value of $9.85 in 2010, then decreased to $2.60 in 2015. In Division 4S, kg price of roe varied in phase with that of 4R but at lower values, increasing from $1.98 to $4.71 between 2006 and 2010. There has not been any fishing in this area since 2013.

RESEARCH SURVEYS

DFO'S BOTTOM TRAWL SURVEY

DFO's bottom trawl survey in August, which has been conducted annually since 1990, is not an optimal tool for monitoring Lumpfish abundance, partly because it is a bottom trawl survey and the semi-pelagic nature of the Lumpfish reduces its catchability, and partly because the survey is conducted in August, when a number of mature individuals are still in coastal waters (mainly males, to care for the nests) and therefore outside the sampling area.

Research surveys conducted in the Barents Sea have shown: 1) greater catchability of Lumpfish in midwater trawls than in bottom trawls during surveys conducted simultaneously in August, and 2) greater catchability of Lumpfish in bottom trawls in winter than in August (Wienerroither et al. 2011 and 2013).

Between 1990 and 1994, two bottom trawl surveys were conducted in the northern Gulf of St. Lawrence (nGSL): one in January (MV Gadus Atlantica with an Engel 145 trawl) and the other in August (CCGS Alfred Needler with a URI trawl). A comparison of distributions of Lumpfish catches during these surveys shows a marked difference in seasonal catchability, with Lumpfish being caught in 46% of tows in winter versus 8% in summer (Figure 19). The fact that catches were higher in winter might indicate an aggregation of Lumpfish on the bottom, making them more available to the trawl during that period of the year. 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.

Geographic distribution

The long series (> 30 years) and the extent of the area covered by DFO's bottom trawl survey in August provide an indication of the general distribution of the species in the nGSL (Figure 20). A recurring concentration is observed at the entrance to the Strait of Belle Isle, where directed Lumpfish fishery is still carried out. A distribution is also observed along the entire North Shore, with a concentration northwest of Anticosti between Sept-Ïles and Pointe-des-Monts, in the area where Atlantic Halibut were caught with Lumpfish in their stomach (Figure 5). Several samples of eelgrass beds in that region have also indicated the presence of juvenile and adult Lumpfish (Figure 6).

A map of Lumpfish catches by size class is shown in Figure 21 for 1992 to 2015 of DFO's August survey, where Lumpfish sizes were measured. Four size classes were defined: those under 80 mm, which represent immature individuals and the first mode observed in August in the size distribution of the DFO survey; individuals from 80-170 mm, which represent the second mode and the most significant observed during the DFO survey; an intermediate class from 170-340 mm; and a class ≥ 340 mm, which represents individuals targeted by fishing and possibly the mature population. This map indicates that juvenile Lumpfish, < 170 mm, are present in the entire area of the survey, whereas mature individuals (≥ 340 mm) are absent from the Laurentian Channel to the estuary (only one individual caught). Juvenile Lumpfish were caught in the areas where depths reached more than 300 m. Catches of mature individuals are distributed along the 200 m isobath on the northern flank of the Esquiman Channel and up to the Strait of Belle Isle, north of Anticosti and in the Bay of Sept-Îles.

The Lumpfish's area of occupancy, based on the data from the survey, is stable and represents close to 16% of the sampled surface (Figure 22).

Size structure

The size of the Lumpfish caught during DFO's research survey varies from 3 to 48 cm (Figure 23A). The length distribution shows a first mode at 4 cm, most likely representing one year Lumpfish, followed by a second mode at 12 cm, representing 2-years-old fish. It is noted that there are few fish in the 15–20 cm size range. That interval between the mode of 12 cm and the next could represent the annual growth of fish between the ages of 2 and 3 years. Only 7% of Lumpfish caught during the survey are of commercial size (≥ 35 cm), which does not allow for proper monitoring of the individuals targeted by the fishery.

Females reach a larger size than males and represent the majority of fish ≥ 35 cm (Figure 23B). The weight–length relationship is shown in Figure 23C.

Mean number and weight per tow

Every year in August, about 30 Lumpfish are caught in the nGSL during DFO's bottom trawl survey. In 2015, 75 individuals were caught. The mean number and weight per 15-minute tow

show an increase between 2012 and 2015 (Figure 24). The 2015 values are comparable to those of 2006 and are above the 1990–2014 average.

SENTINEL PROGRAM

Since 1994, a sentinel program has been in place in the nGSL. This is a collaborative program between DFO's Science Sector and fishermen's associations, consisting of two components: fixed gear and mobile gear surveys. From 1995 to 2002, two mobile gear surveys were conducted in the nGSL—one in July and the other in October. Subsequently, only the July survey was retained. Those two surveys are comparable and were conducted according to a stratified random sampling plan similar to that of DFO's August survey. They include close to 300 randomly selected stations and were conducted by fishers on commercial vessels from Newfoundland and Labrador and from Quebec (Brassard et al. 2016).

Geographic distribution

Lumpfish catches during mobile sentinel fishery surveys were low. An average of 17 Lumpfish per survey were caught in July and 59 in October. The proportion of tows containing Lumpfish was 5% in July and 12% in October (Figure 25). This variation in the proportion of tows containing Lumpfish could partly be explained by the fact that the July survey is conducted at a time when a proportion of mature individuals are still in coastal waters and therefore outside the sampling area. This information supports the hypothesis that the catchability of Lumpfish in bottom trawl varies seasonally and, as the data from the January and August DFO survey show, catchability is better in bottom trawl in winter.

The distribution of Lumpfish observed during the mobile surveys of the sentinel fisheries program of July and October was similar to that observed in August in the DFO survey for Divisions 4R and 4S. The sentinel fishery surveys also cover Subdivision 3Pn and show an absence of Lumpfish off of this Subdivision (Figure 25). The catchability of Lumpfish during this survey is unknown, but it is probably low for the same reasons mentioned for the DFO survey.

Size structure

There is very little data on the sizes of Lumpfish caught in these surveys (57 individuals) and they vary from 3 to 38 cm, which is comparable to the sizes of Lumpfish caught in the DFO survey.

Catch rates

From 1995 to 2015, the catch rates in mean number per tow in the July survey were variable and low, with an average of 0.07 Lumpfish per 30-minute tow. They do not show a trend (Figure 25).

CONCLUSION

Commercial Lumpfish fishery began in the mid-1970s in the nGSL. The DFO Science Sector of the Quebec Region has been assessing that resource for NAFO Subdivision 3Pn and Divisions 4R and 4S every five years since 2006 (DFO 2006, 2011, 2014 and 2016). The species is currently the subject of an assessment by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), for which the report is expected in November 2017.

Information on the commercial fishery indicates a significant decrease in landings and in the number of participants in that fishery. Since 2013, the directed fishery has only been practised in Unit Area 4Ra. It was practised in 4Sw, 4Sv, 3Pn, 4Rb, 4Rc and 4Rd in years in which landings were good. In the absence of data on effort in terms of the number of nets and soak

time for most directed fishering activities, annual CPUEs are calculated by the sum of catches out of the total number of activities. This indicator suggests that the resource fluctuates in abundance, on a cyclical basis, and is currently at a low.

There are few tools to monitor the abundance of this species in the nGSL. Annually, less than about 20 individuals are caught during the July survey of the sentinel fisheries program for mobile gear and about 30 during DFO's August mission, and less than 7% of Lumpfish are of commercial size in the latter survey. These low catches could be explained partly by the midwater nature of the Lumpfish, which reduces its catchability during bottom trawl surveys, and by the fact that surveys are conducted in July and August, when a proportion of mature individuals are in coastal waters and therefore outside the sampling area. Abundance measured during those two surveys varied, without any indication of a trend. In 2015, the average number per tow in the DFO survey was above the series average, at a value comparable to that of 2006. For the mobile gear sentinel survey in 2015, the average number per tow was the same as the series average.

The decline in landings and fishing effort could be due in part to factors such as market conditions, the synchronization of fishing with the arrival of females in coastal waters, weather conditions and the possibility of more lucrative fisheries. Despite uncertainty as to the causes of this low abundance, the vulnerability of this resource to recruitment overfishing argues for a very prudent approach.

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TABLES

Table 1. Occurrence of Lumpfish identified in the stomachs of fish sampled during bottom trawl research surveys in the northern Gulf of St. Lawrence between 1994 and 2015.

Year	Month	NAFO	Depth (m)	Predator	Size of Predator (cm)	Biomass of Prey (g)
1995	7	3Pn	145	Cod	57	8
1994	5	4R	320	Cod	61	31
1998	8	4S	183	Cod	58	33
2008	8	4S	282	Atlantic Halibut	101	88
2008	8	4S	256	Atlantic Halibut	104	28
2015	8	4S	231	Atlantic Halibut	149	239
2015	8	4S	270	Atlantic Halibut	121	244

Table 2. Presence of Lumpfish in Eelgrass beds sampled in the Gulf of St. Lawrence between 2005 and 2010. Greyed-out cells identify years in which the station was sampled, and the number in the cell refers to the number of Lumpfish caught. See Figure 6 for the location of Eelgrass beds (Nellis et al. 2012 and P. Nellis, DFO, pers. comm.).

		Year					
Eelgrass bed	**Station**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Old Harry Bay	1				0	0	
Baie-Saint-Ludger	1					1	
Bassin aux Huîtres	1	0	0	0		0	0
Cacouna	1				0	0	0
	2					0	0
	3					0	0
	4					0	0
Longue-Rive	1					34	
Mingan	1					0	
	2					1	
Old Harry	1						0
Penouille	1			0	0	0	0
Pointe Lebel	1					0	
Rimouski	1	0	0	0			
	2			0	0	0	0
Rivière Saint-Jean	1	0	0	0	0	0	0
Sept-Îles	1						9
	Atelier Laforge					52	
	Tourist Information					0	
	Arnaud Street					0	
	Ruisseau Clet	0	0	0	0	0	
Unamen Shipu	1				0	22	
	2					0	

Table 3. Number of Lumpfish ovaries sampled in NAFO Subdivision 3Pn and Divisions 4R and 4S in 2004 and 2005.

Year	NAFO	Date		Number of ovaries
		Month	Day	
2004	3Pn	5	15	35
		5	21	35
		5	29	30
	4R	5	20	12
		5	21	12
		5	22	10
		5	28	35
		6	4	30
	4S	5	20	4
		5	21	2
		5	25	6
		5	26	6
		6	1	3
		6	2	4
		6	6	5
		6	11	3
		6	13	1
		6	15	5
		6	22	6
		6	23	3
	Total			**247**
2005	3Pn	5	18	24
		5	26	23
	4R	5	28	25
		6	8	24
	4S	5	25	4
		5	27	3
		5	30	4
		6	2	3
		6	6	3
		6	9	2
		6	13	4
		6	18	4
		6	19	1
		6	21	3
		6	23	4
		6	27	4
		6	30	4
		7	6	6
	Total			**145**

Table 4. Descriptive statistics on total (number) and relative fecundity (number/g of somatic weight) of Lumpfish sampled in 2004 and 2005 in NAFO Subdivision 3Pn and Divisions 4R and 4S during the fecundity study.

Year	Parameter	NAFO	Statistics					
			Average	**Standard Deviation**	**Minimum**	**Maximum**	**Scope**	**n**
2004	Total fecundity	3Pn	131,439	34,940	58,199	217,511	159,312	39
		4R	103,784	38,213	24,641	220,157	195,516	49
		4S	122,888	31,162	49,632	167,633	118,001	33
		Total	117,908	37,114	58,199	217,511	159,312	121
	Relative fecundity	3Pn	57.2	13.8	25.8	75.9	50.1	39
		4R	59.1	22.8	15.1	108.7	93.6	49
		4S	62.7	16.6	23.8	84.3	60.5	33
		Total	59.5	18.6	15.1	108.7	93.6	121
2005	Total fecundity	3Pn	134,628	31,076	74,165	202,549	128,384	19
		4R	133,882	45,344	57,698	240,574	182,876	28
		4S	120,340	56,782	53,654	304,678	251,024	37
		Total	128,086	48,214	53,654	304,678	251,024	84
	Relative fecundity	3Pn	65.5	12.3	39.3	84.2	44.9	19
		4R	68.8	19.6	32.0	104.5	72.5	28
		4S	63.7	25.8	25.2	136.2	111.0	37
		Total	*65.8*	*21.2*	*25.2*	*136.2*	*111.0*	*84*
2004 and 2005	Total fecundity	3Pn, 4RS	122,078	42,205	24,641	304,678	280,037	205
	Relative fecundity	3Pn, 4RS	62.1	19.9	15.1	136.2	121.1	*205*

Table 5. Reported landings (t) of Lumpfish per year for NAFO Subdivision 3Pn and Divisions 4R and 4S as whole fish, roe and total.

Whole Lumpfish landings					Roe landings				Total landings*			
	NAFO				NAFO				NAFO			
Year	3Pn	4R	4S	Total	3Pn	4R	4S	Total	3Pn	4R	4S	Total
1970			-	**-**	-	1	-	**1**	-	3	-	**3**
1971			-	**-**	-	56	-	**56**	-	225	-	**225**
1972			-	**-**	-	3	-	**3**	-	13	-	**13**
1973			-	**-**	-	0**	-	0	-	2	-	**2**
1974			-	**-**	-		-	**-**				
1975			-	**-**	-	0	-	0	-	0	-	0
1976			-	**-**	-	129	-	**129**	-	518	-	**518**
1977			-	**-**	-	105	-	**105**	-	420	-	**420**
1978			-	**-**	-	131	-	**131**	-	525	-	**525**
1979	2		-	**2**	-	103	-	**103**	2	410	-	**412**
1980	46		-	**46**	29	30	-	**59**	162	119	-	**281**
1981	180		-	**180**	156	93	-	**249**	804	373	-	**1,177**
1982	18		-	**18**	132	108	-	**240**	546	432	-	**978**
1983			-	**-**	266	182	-	**448**	1,064	727	-	**1,791**
1984			-	**-**	181	197	-	**378**	724	788	-	**1,512**
1985			-	**-**	88	162	-	**250**	352	650	-	**1,002**
1986			-	**-**	128	371	34	**533**	512	1484	134	**2,130**
1987	0	1	0	**1**	134	469	114	**718**	538	1878	458	**2,874**
1988	1		-	**1**	95	250	39	**384**	382	1001	156	**1,539**
1989			-	**-**	140	258	36	**434**	561	1031	143	**1,735**
1990			-	**-**	20	131	5	**157**	81	523	22	**626**
1991		-	1	**1**	111	104	1	**217**	444	417	7	**868**
1992			-	**-**	150	114	15	**279**	601	456	59	**1,116**
1993	0	0	-	**0**	189	179	21	**389**	756	717	85	**1,558**
1994	1	0	0	**1**	77	63	4	**145**	310	253	17	**580**
1995	-	-	-	**-**	89	139	1	**229**	357	557	2	**917**
1996			-	**-**	176	347	5	**528**	705	1388	19	**2,112**
1997	78	62	-	**140**	478	477	22	**977**	1,992	1971	86	**4,049**
1998	-	4	-	**4**	188	402	18	**608**	750	1611	74	**2,435**
1999	0	0	-	0	471	673	59	**1,203**	1,884	2,692	235	**4,811**

Whole Lumpfish landings					Roe landings				Total landings*			
	NAFO				NAFO				NAFO			
Year	3Pn	4R	4S	Total	3Pn	4R	4S	Total	3Pn	4R	4S	Total
2000	-	0	-	**0**	212	246	36	**494**	848	983	143	**1,974**
2001			-	**-**	26	131	20	**177**	105	523	78	**707**
2002			-	**-**	1	22	3	**25**	3	86	10	**99**
2003			-	**-**	61	53	23	**137**	243	213	90	**547**
2004			-	**-**	89	96	81	**266**	356	384	323	**1,063**
2005			-	**-**	55	145	63	**264**	221	581	253	**1,055**
2006			-	**-**	59	106	35	**201**	237	426	142	**805**
2007			-	**-**	4	57	9	**71**	18	229	35	**282**
2008			-	**-**	0	102	8	**109**	1	406	31	**438**
2009			-	**-**	-	10	1	**11**	-	40	5	**45**
2010		-	0	0	1	44	4	**48**	5	174	-	**194**
2011	-	2	4	**6**	0	33	0	**33**	0	134	-	**139**
2012		-	3	**3**	-	62	2	**63**	-	246	-	**256**
2013		-	3	**3**	-	5	-	**5**	-	21	-	**24**
2014***					-	35	-	**35**	-	140	-	**140**
2015***	-	-	-	**-**	-	28	-	**28**	-	110	-	**110**

* Sum of whole Lumpfish landings + (4 × roe landings).

** The zeros indicate that the catch is less than 0.5 tonnes. The missing values indicate that there is no catch.

*** Preliminary data on February 15, 2016.

Table 6a. Lumpfish roe landings (t) by year and month for NAFO Subdivision 3Pn and Divisions 4R and 4S.

Year	Jan.	Feb.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Total
1986		-	0**	7	281	191	20	0	0	-	499
1987		-	0	31	230	304	39	1	0	-	604
1988			-	12	193	117	23	1	0	0	345
1989			-	25	309	95	5			-	434
1990				-	39	115	3			-	157
1991			-	13	125	67	11	0	0	-	217
1992			-	11	168	90	10	0	0	-	279
1993			-	39	176	159	15			-	389
1994			-	2	79	57	7			-	145
1995				-	142	83	4			-	229
1996			-	5	270	249	5	-	0	-	528
1997			-	2	572	402	1			-	977
1998				-	431	176	1	-	0	-	608
1999	-	1	-	1	840	358	0	1	1	-	1,203
2000				-	432	61	1			-	494
2001				-	33	144	0			-	177
2002				-	4	21	0			-	25
2003				-	36	91	10			-	137
2004			-	0	120	146	0			-	266
2005				-	176	88				-	264
2006				-	114	88	0	0		-	201
2007				-	1	68	2			-	71
2008				-	31	76	2			-	109
2009				-	2	10				-	11
2010	0			-	24	25				-	48
2011	0			-	17	17	0			-	33
2012				-	39	25				-	63
2013				-	5					-	5
2014*					-	33	2			-	35
2015*				-	2	26	2			-	28

**** Preliminary data on February 15, 2016.*

*** The zeros indicate that the catch is less than 0.5 tonnes.*

Table 6b. Whole Lumpfish landings (t) by year and month for NAFO Subdivision 3Pn and Divisions 4R and 4S.

Year	Jan.	Feb.	March	May	June	July	Sept.	Nov.	Total
1987		-	0**	1		-	0	-	1
1988			-	1				-	1
1991					-	1		-	1
1993	0	0	0					-	0
1994	0	1	0	0		-	0	0	1
1997			-	114	26			-	140
1998			-	0	4			-	4
1999				-	0			-	0
2000				-	0			-	0
2010	0							-	0
2011	4		-	1	1			-	6
2012	3		-	0				-	3
2013	3			-	0			-	3
2014*									
2015*								-	-

** Preliminary data on February 15, 2016.*
*** The zeros indicate that the catch is less than 0.5 tonnes.*

Table 7. Lumpfish roe landings (t) by gear type for NAFO Subdivision 3Pn and Divisions 4R and 4S.

Year	Pot	Trawl	Gillnet	Hand tool	Longline	Danish seine	Trap	Unknown gear	Total
1986	-	0**	487	0	10	-	2	-	499
1987	-	9	578	0	15	0	1	1	604
1988	-	0	328	-	16	-	1	-	345
1989	-	1	430	-	3	-	0	0	434
1990		-	156	-	0	-	0	-	157
1991		-	207	0	9	-	1	-	217
1992	-	0	256	0	6	-	2	15	279
1993		-	368			-	1	21	389
1994		-	141				-	4	145
1995		-	229				-	1	229
1996	0	-	523			-	0	5	528
1997	0	-	956				-	22	977
1998		-	589			-	0	18	608
1999	3	-	1,140	-	1	-	1	59	1,203
2000	0	-	458				-	36	494
2001		-	177			-	0	-	177
2002		-	25					-	25
2003		-	137					-	137
2004		-	265			-	0	-	266
2005		-	264					-	264
2006		-	201					-	201
2007		-	71					-	71
2008		-	109					-	109
2009		-	11					-	11
2010		-	48				-	0	48
2011		-	33				-	0	33
2012		-	63					-	63
2013		-	5					-	5
2014*	-	-	35	-	-	-	-	-	35
2015*		-	28					-	28

** Preliminary data on February 15, 2016.*

*** The zeros indicate that the catch is less than 0.5 tonnes.*

Table 8. Annual number of participants in directed Lumpfish fishery for NAFO Subdivision 3Pn and Divisions 4R and 4S.

Year	3Pn	4R	4S	Total
1986	77	297	66	440
1987	85	664	175	924
1988	78	399	150	627
1989	71	248	89	408
1990	46	164	40	250
1991	59	93	3	155
1992	94	166	80	340
1993	170	338	89	597
1994	182	183	56	421
1995	164	270	34	468
1996	148	470	75	693
1997	199	497	80	776
1998	174	351	42	567
1999	151	380	74	605
2000	144	247	26	417
2001	93	213	53	359
2002	31	86	29	146
2003	95	144	59	298
2004	79	126	59	264
2005	73	155	53	281
2006	49	142	51	242
2007	31	107	22	160
2008	5	107	38	150
2009	0	80	22	102
2010	12	101	19	132
2011	1	90	8	99
2012	0	66	14	80
2013	0	17	0	17
2014*	0	34	0	34
2015*	0	30	0	30

** Preliminary data on February 15, 2016.*

Table 9. Annual value of a kilogram of roe in Canadian dollars for NAFO Subdivision 3Pn and Divisions 4R and 4S.

	NAFO		
Year	**3Pn**	**4R**	**4S**
1970	-	0.22	
1971	-	0.22	
1972	-	0.22	
1973	-	0.35	
1974			
1975	-	0.38	
1976	-	0.93	
1977	-	0.55	
1978	-	0.62	
1979	-	0.71	
1980	0.70	0.72	
1981	0.70	0.76	
1982	0.69	0.76	
1983	0.71	0.79	
1984	0.72	0.78	
1985	0.83	0.84	
1986	1.52	1.57	1.24
1987	3.20	3.93	3.92
1988	1.81	1.61	1.54
1989	1.50	1.60	1.65
1990	1.10	1.20	1.11
1991	1.85	1.92	2.66
1992	2.90	3.12	2.73
1993	4.63	4.78	3.74
1994	4.92	5.17	4.73
1995	6.53	6.60	5.47
1996	6.60	6.63	6.06
1997	4.88	4.61	4.41
1998	2.20	2.20	2.20
1999	2.41	2.43	2.60
2000	2.20	2.20	2.20
2001	4.72	4.60	2.87
2002	5.98	5.99	3.54
2003	5.52	5.49	4.29
2004	5.40	5.21	4.35
2005	3.75	3.25	3.40
2006	1.98	1.98	1.98
2007	4.40	4.30	2.51
2008	8.28	8.17	4.19
2009	-	9.25	4.71
2010	9.13	9.85	4.14
2011	-	8.23	4.83
2012	-	4.96	6.58
2013	-	3.31	
2014	-	2.75	
2015	-	2.61	-

FIGURES

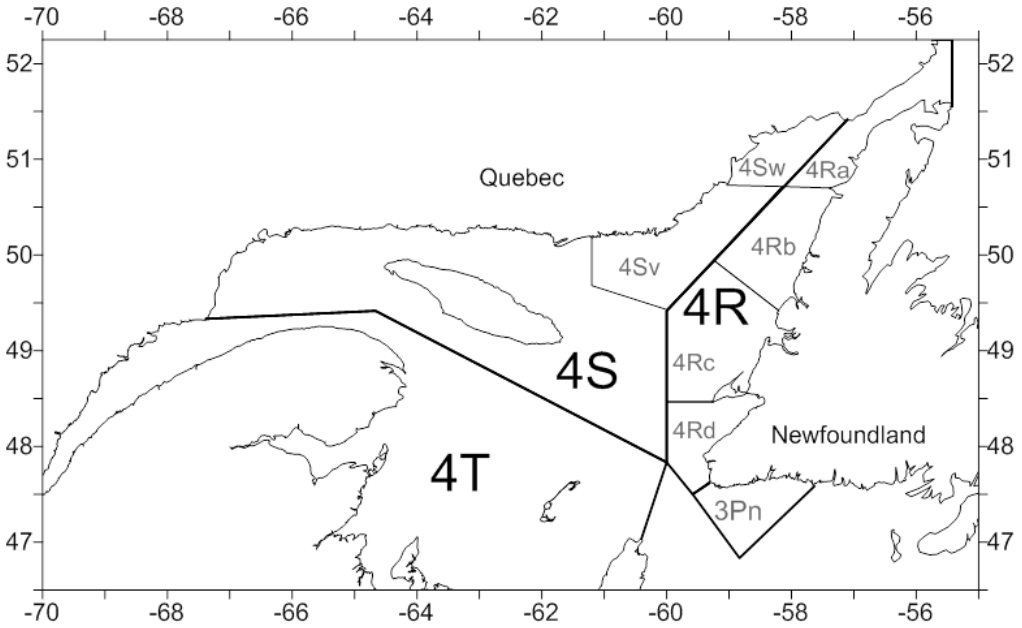


Figure 1. Map of the Gulf of St. Lawrence indicating the limits of NAFO Divisions 4R, 4S and 4T, of Subdivision 3Pn and of certain unit areas cited in the document.

Figure 2. Photos of a female Lumpfish (top photo) and a male Lumpfish (bottom photo) showing the difference in colouration during the breeding period. Photo by Claude Nozères.

Figure 3. Photograph of Lumpfish showing various colour patterns. Photo by Claude Nozères.

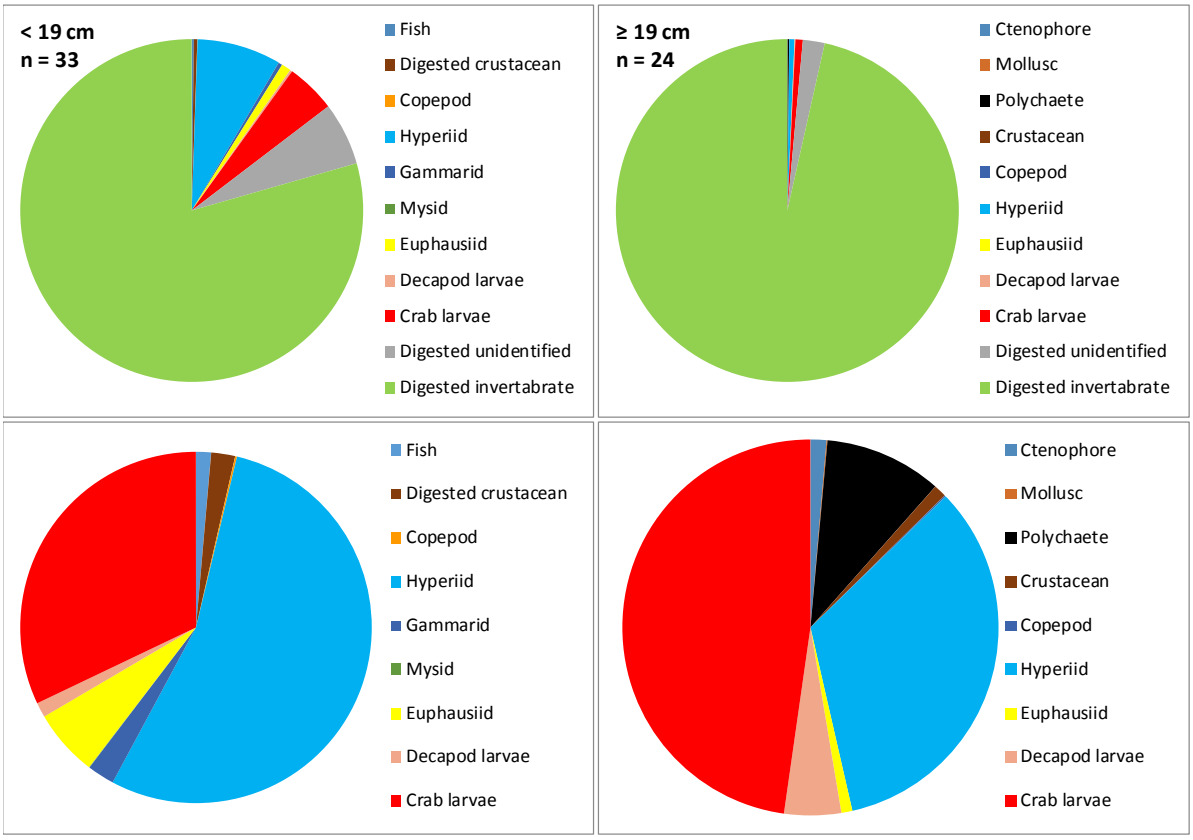


Figure 4.Stomach contents (relative weight in weight percentage) of Lumpfish under 19 cm (left) and 19 cm and above (right) sampled during the DFO bottom trawl survey in August 2015. The top charts show the full data. The bottom charts show the stomach contents once the categories for digested invertebrates and digested unidentified have been removed.

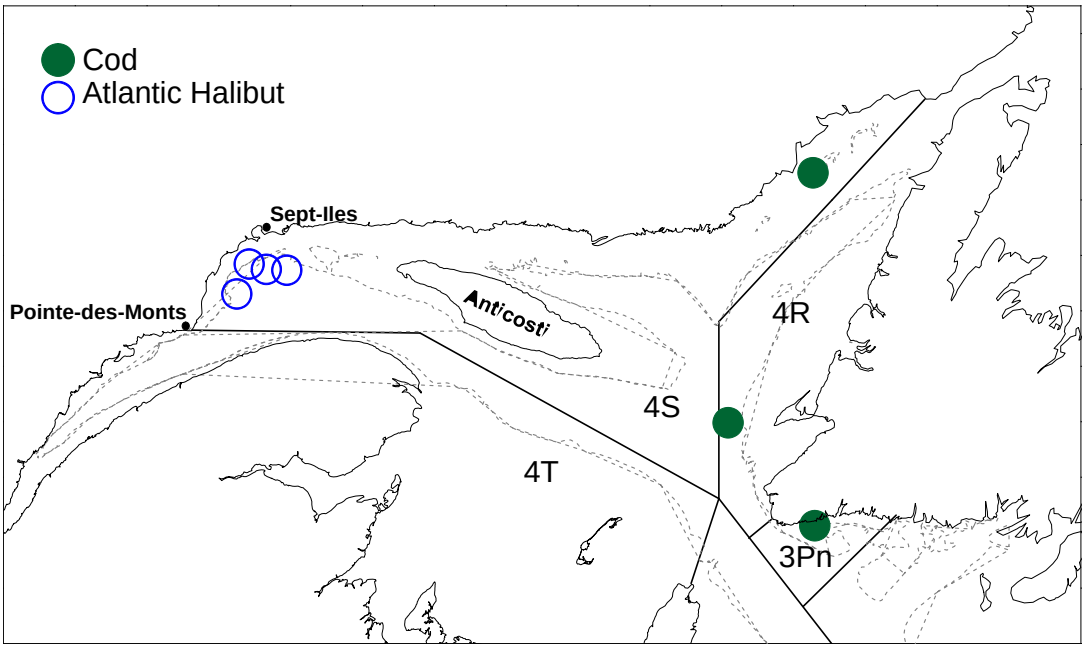


Figure 5. Location of catches of Cod and Atlantic Halibut whose stomachs contained Lumpfish (cf. Table 1 for additional information).

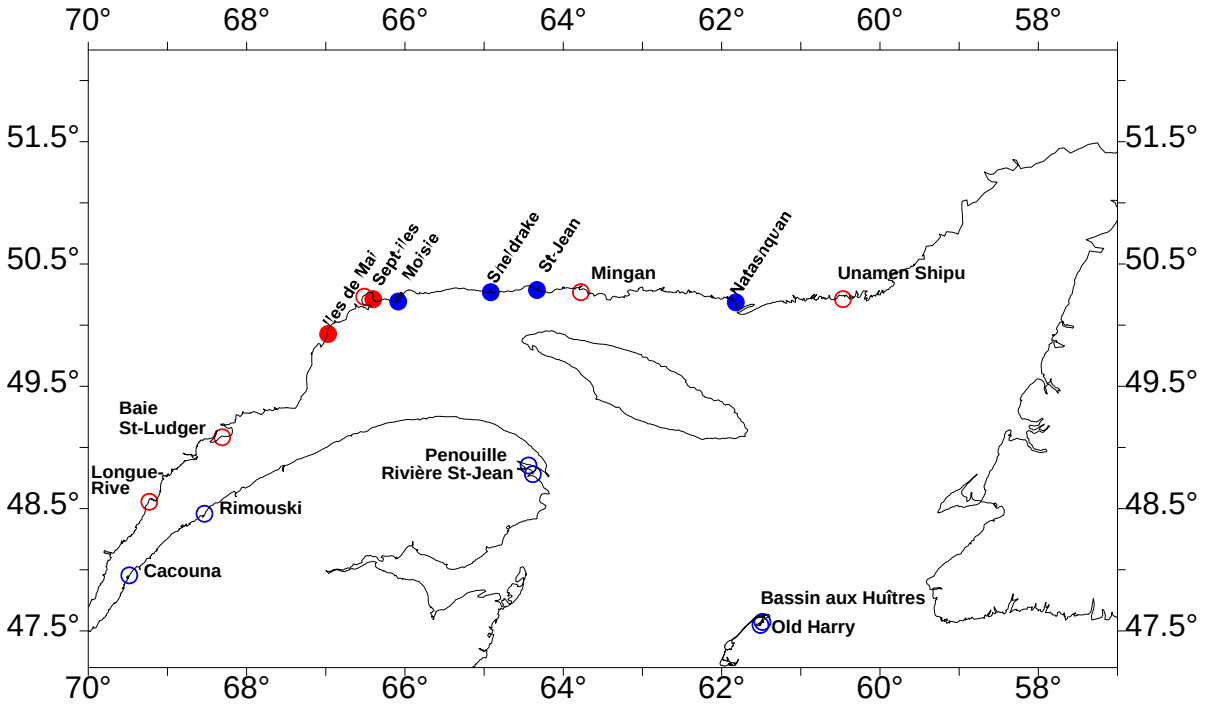


Figure 6. Sampling sites of the Community Aquatic Monitoring Program of the Comité ZIP Côte-Nord du Golfe (full symbols, Lavoie 2015) and of the Eelgrass Monitoring Program (open symbols, Nellis et al. 2012, P. Nellis, DFO, pers. comm.). Red symbols indicate the sites where juvenile Lumpfish were caught and blue symbols indicate the absence of Lumpfish.

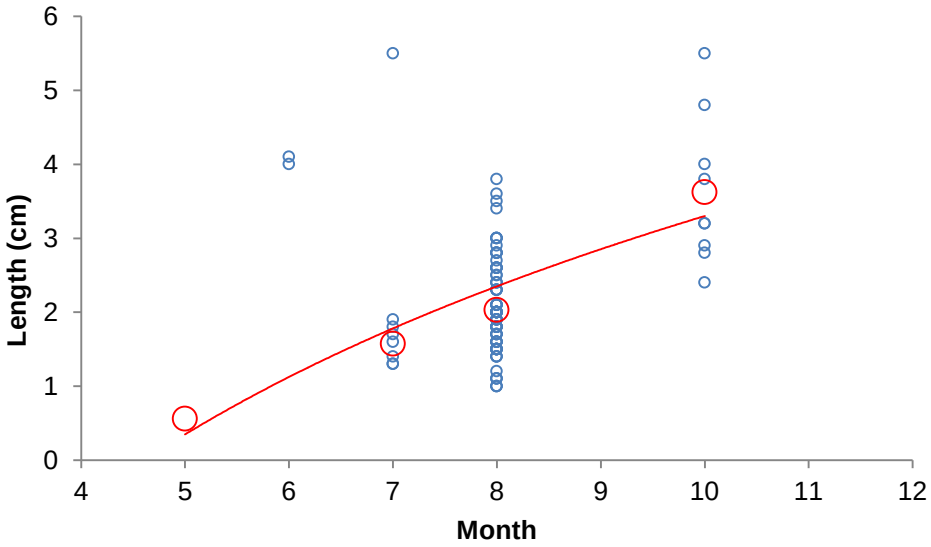


Figure 7. Growth of Lumpfish during their first year, based on data from the Community Aquatic Monitoring Program of the Comité ZIP Côte-Nord du Golfe (Lavoie 2015).

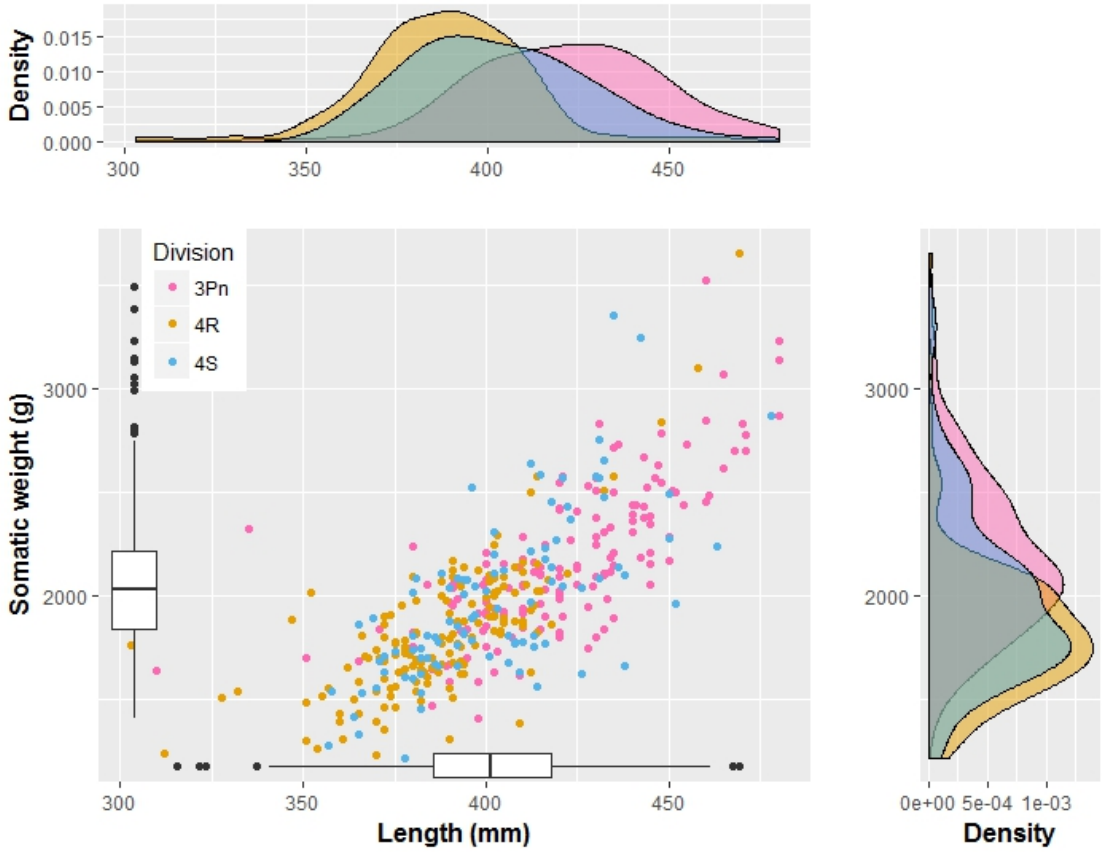


Figure 8. Scatter plot, box-and-whisker plots and distributions of frequencies of somatic weight and length of Lumpfish sampled in NAFO Subdivision 3Pn and Divisions 4R and 4S in 2004 and 2005.

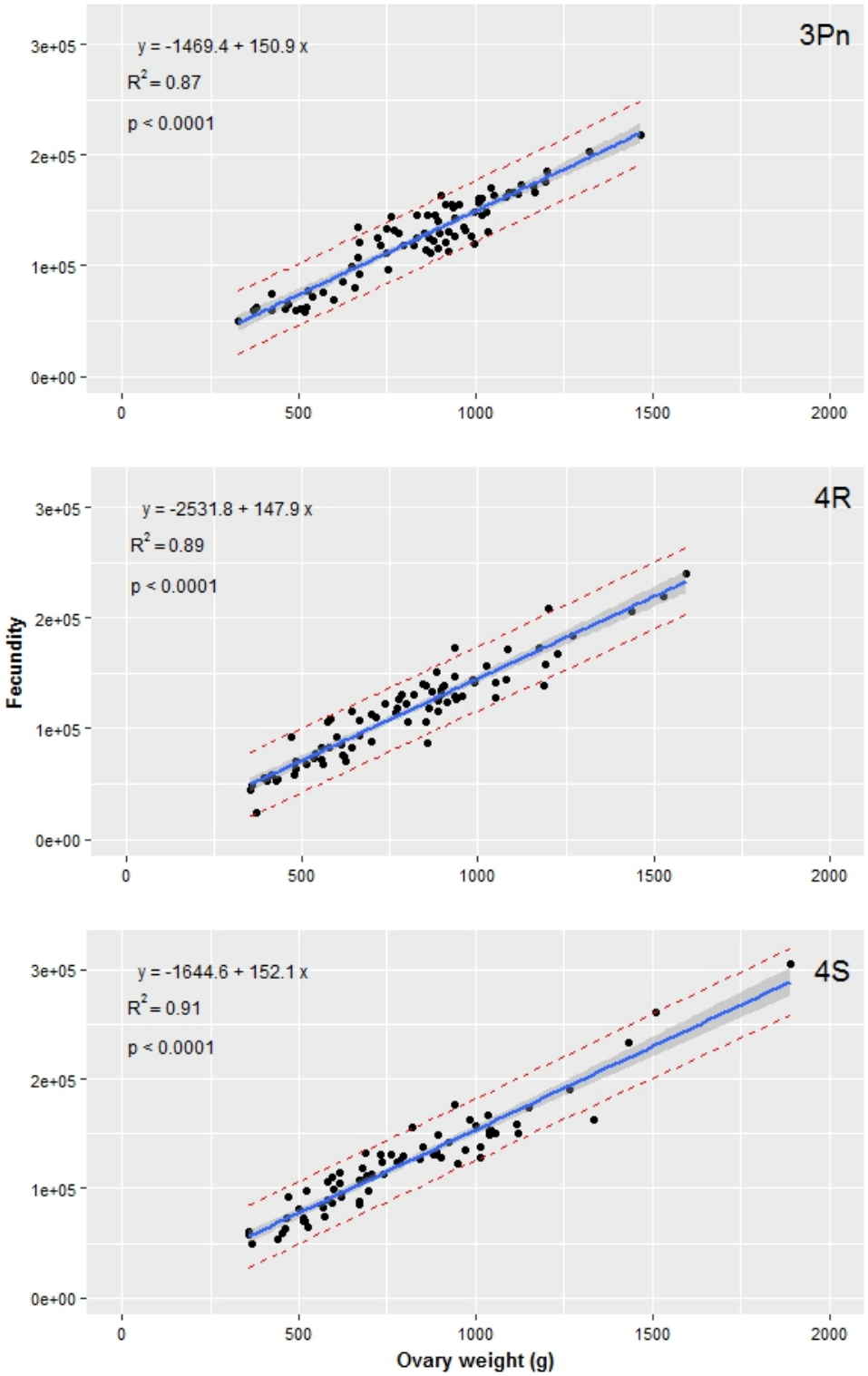


Figure 9. Linear regression (± confidence and prediction intervals at 95%) of total fecundity according to the weight of the ovaries (g) of Lumpfish sampled in 2004 and 2005 in NAFO Subdivision 3Pn and Divisions 4R and 4S during the fecundity study.

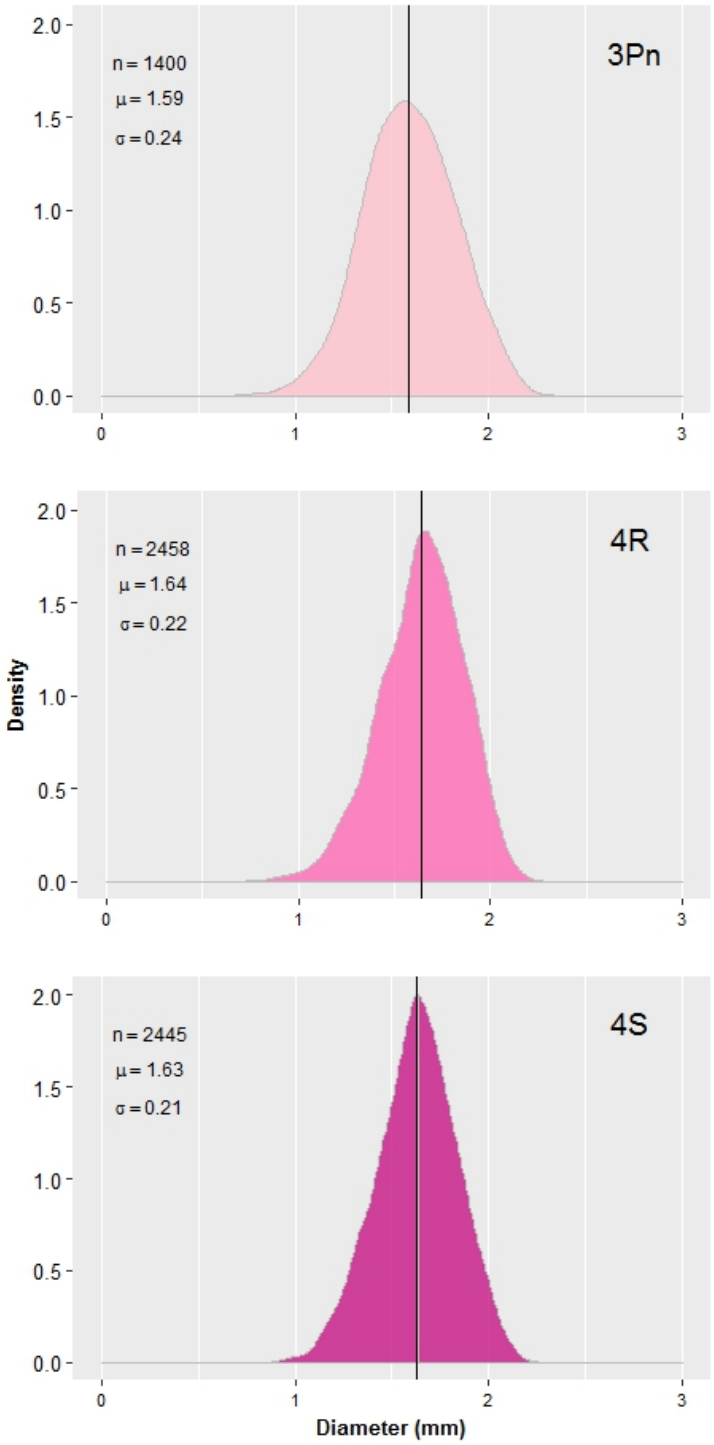


Figure 10. Distribution of frequencies of the diameter (mm) of hydrated oocytes of Lumpfish sampled in 2004 in NAFO Subdivision 3Pn and Divisions 4R and 4S (the black vertical line represents the average diameter).

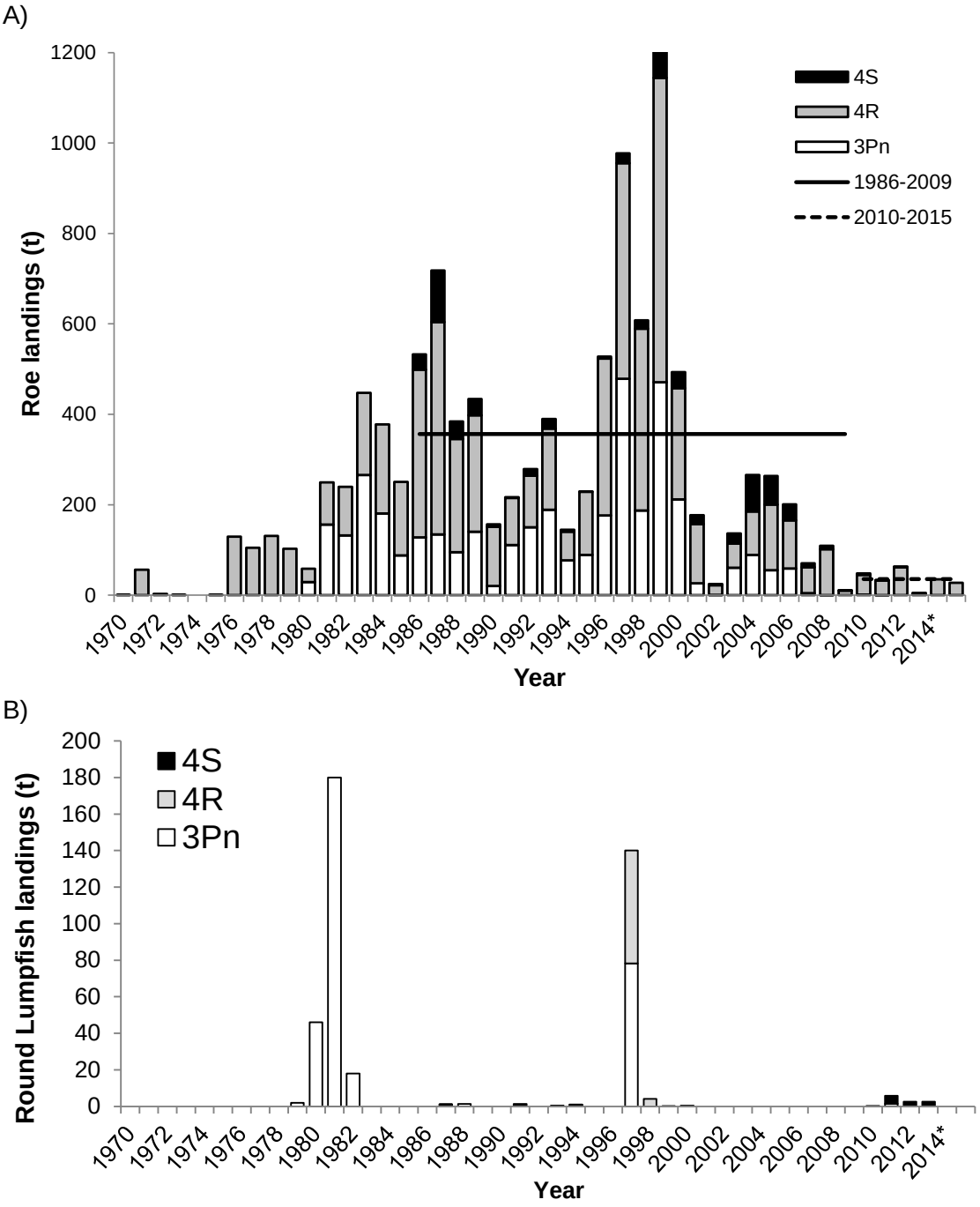


Figure 11. A) Annual landings (t) in the form of Lumpfish roe for NAFO Subdivision 3Pn and Divisions 4R and 4S. The full horizontal line represents average landings from 1986 to 2009, whereas the horizontal dotted line represents the average from 2010 to 2015. B) Annual landings (t) reported in the form of whole Lumpfish for NAFO Subdivision 3Pn and Divisions 4R and 4S. The data from 2014 and 2015 are preliminary.

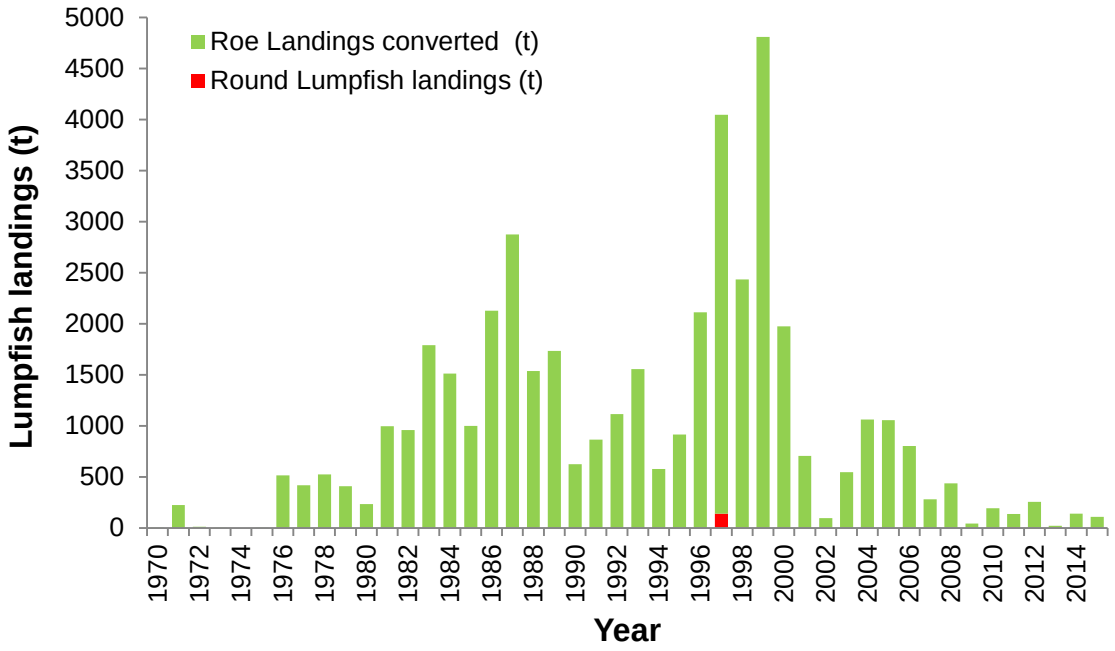


Figure 12. Whole Lumpfish landings (t) for NAFO Subdivision 3Pn and Divisions 4R and 4S. The data from 2014 and 2015 are preliminary.

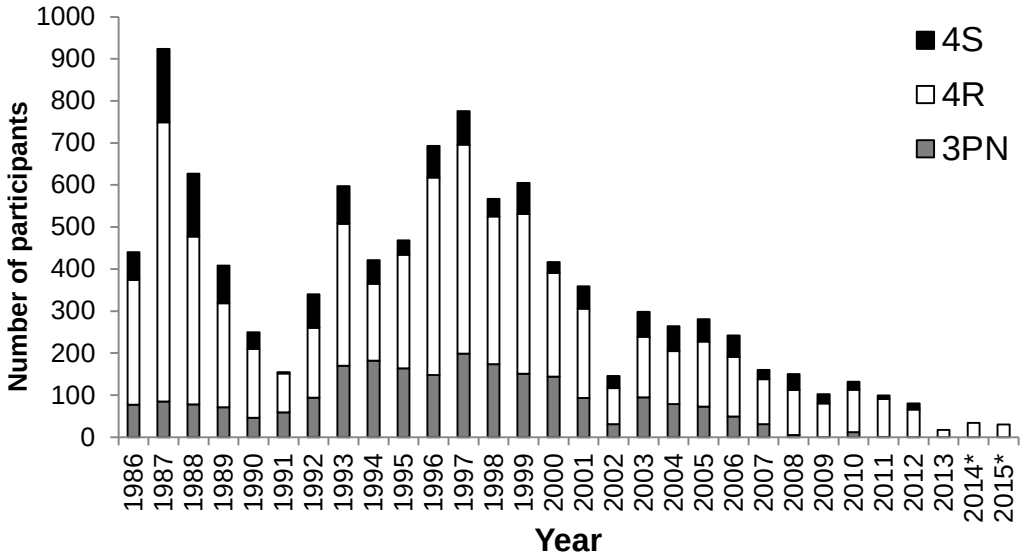


Figure 13. Number of participants in the directed Lumpfish fishery from 1986 to 2015 for NAFO Subdivision 3Pn and Divisions 4R and 4S. The data from 2014 and 2015 are preliminary.

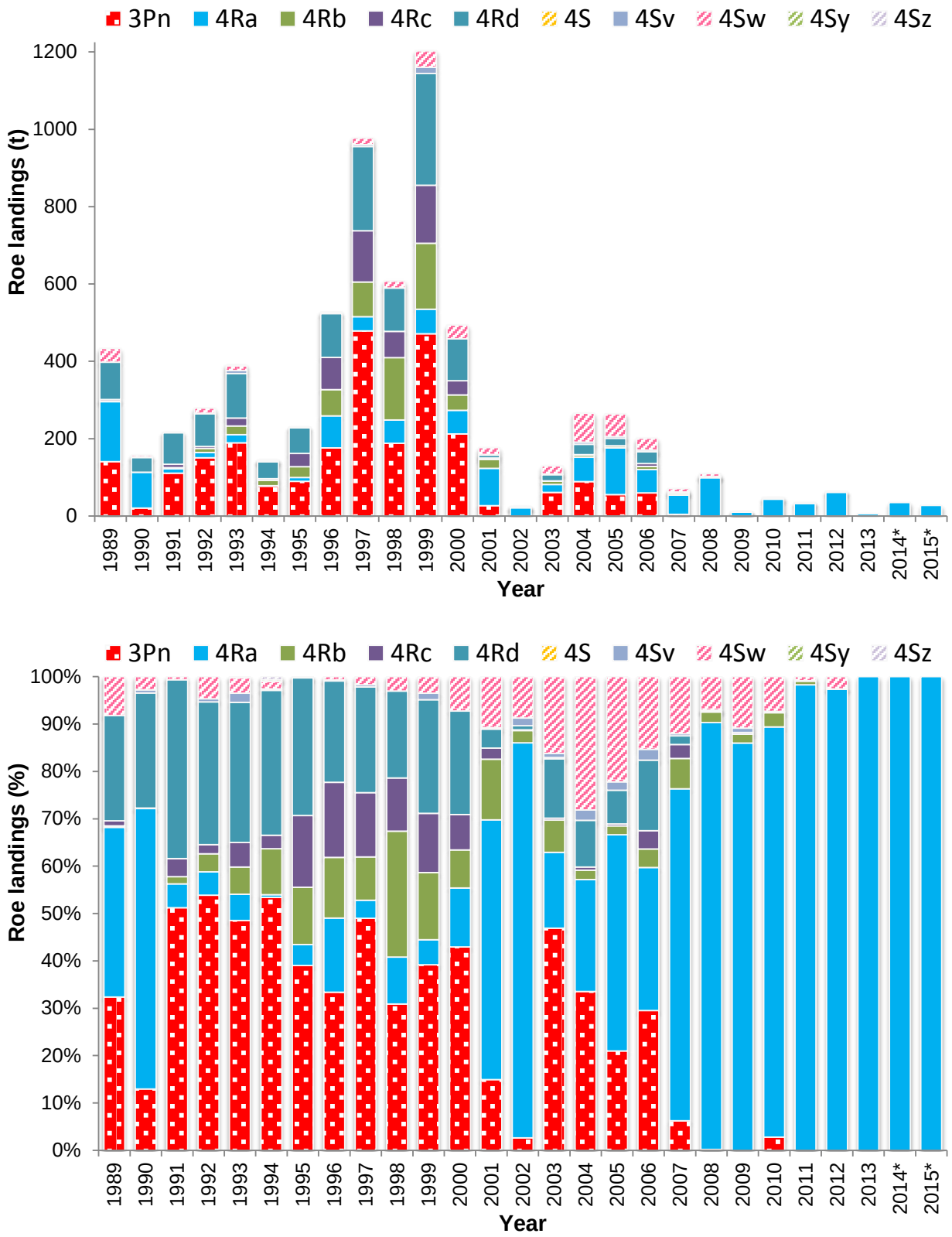


Figure 14. Annual reported roe landings by unit area in weight (top panel) and in proportion (bottom panel).

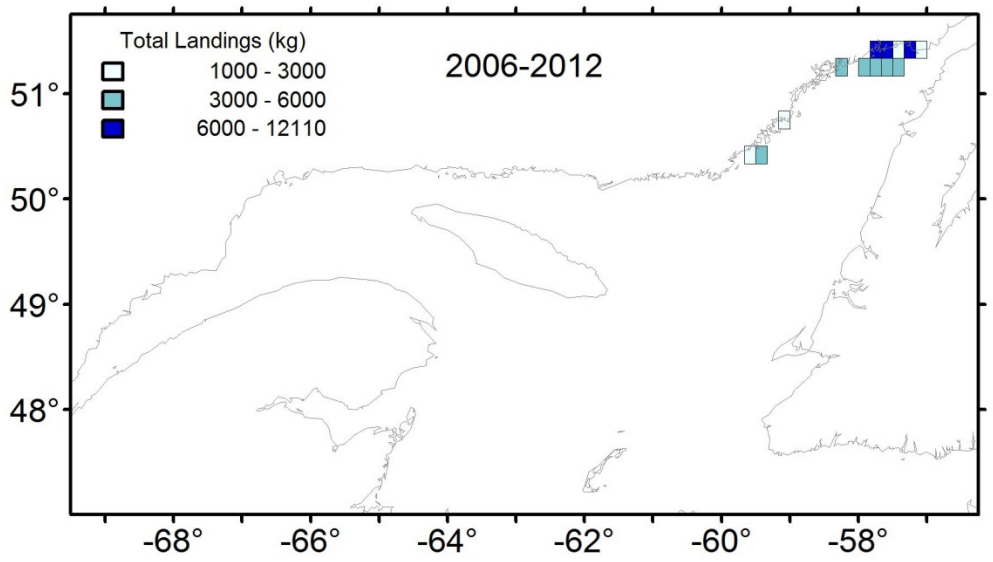


Figure 15. Total Lumpfish catch (kg) by fishing grid in the directed fishery of NAFO Division 4S for the 2006–2012 period. All catches in Division 4S are georeferences for that period.

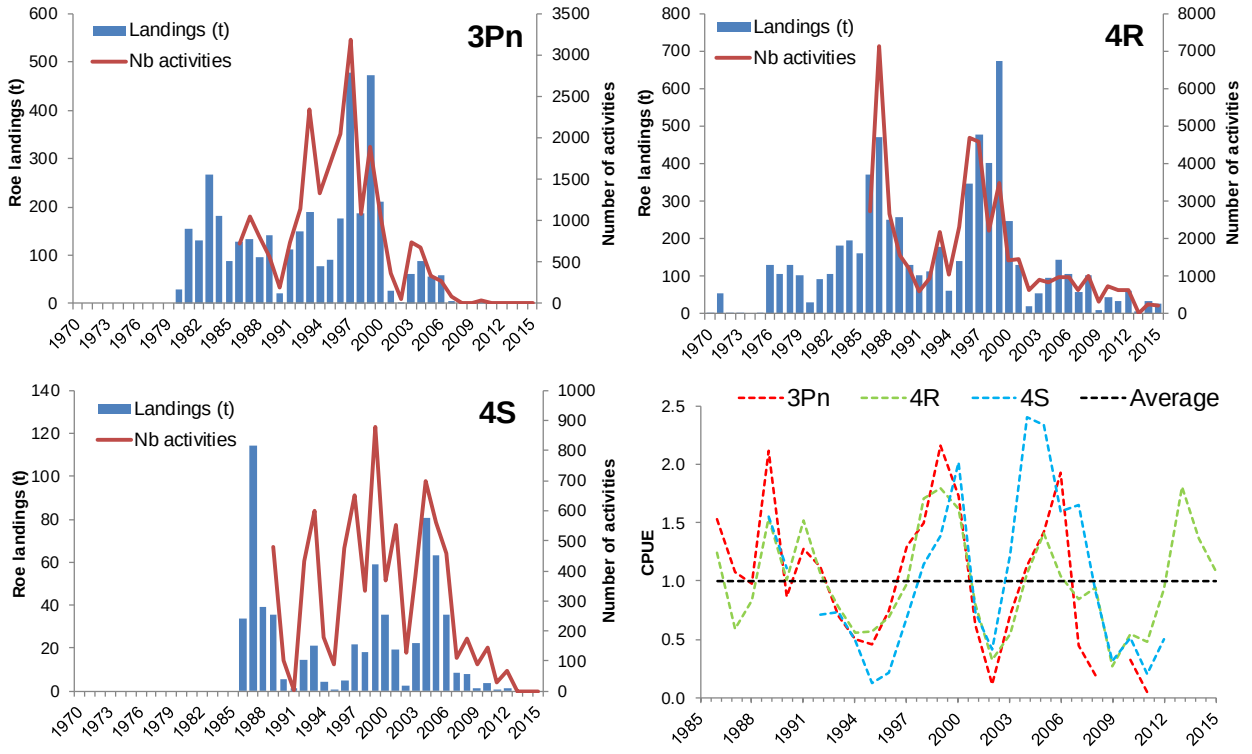


Figure 16. Roe landings (t), number of activities and standardized catch per unit effort (CPUE) (sum of landings/number of activities/series average) by year and by fishing area.

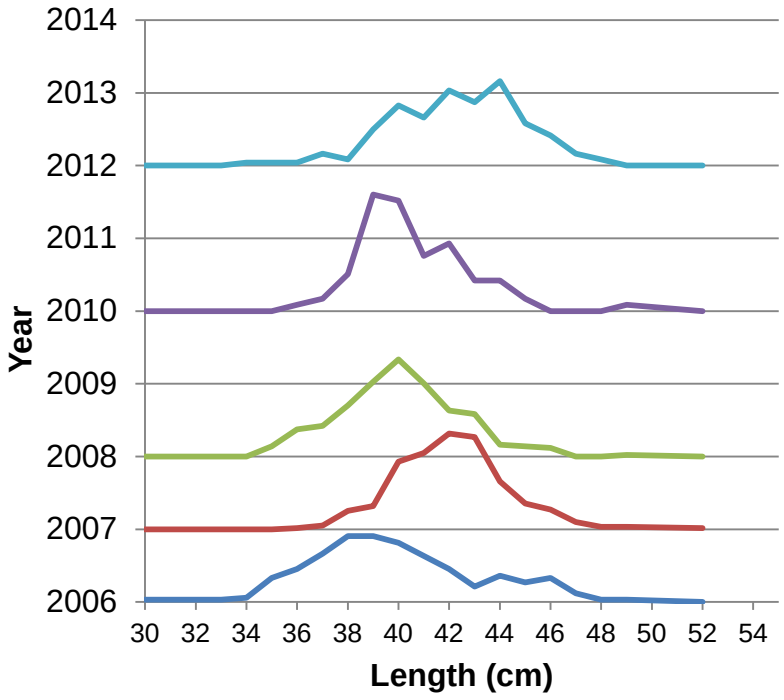


Figure 17. Annual length frequency distribution of Lumpfish sampled in the commercial fishery of NAFO Division 4S.

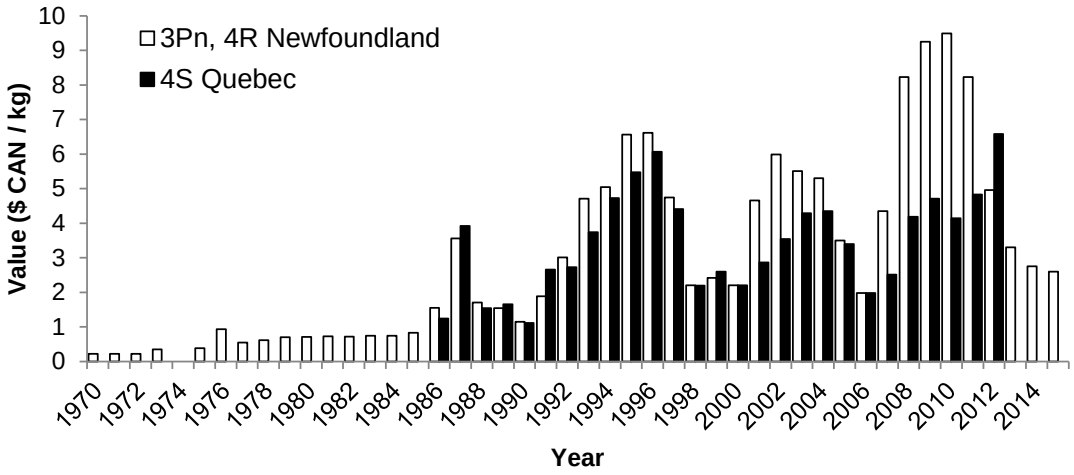


Figure 18. Evolution of the annual value of roe (CAN$ / kg) by province, Newfoundland (NAFO Subdivision 3Pn and Division 4R) and Quebec (NAFO Division 4S).

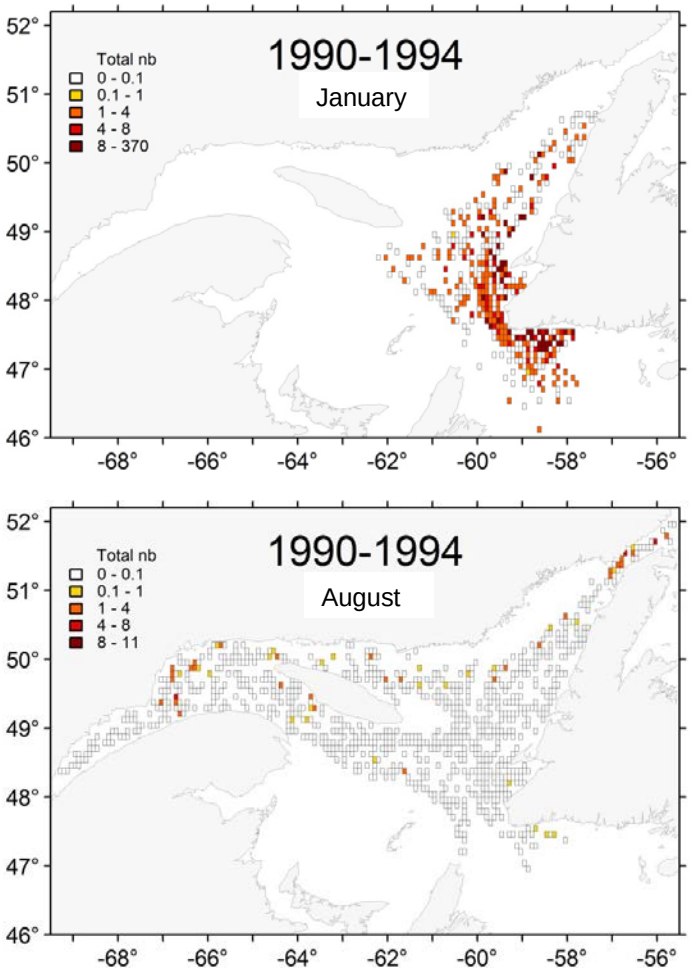


Figure 19. Distribution of total Lumpfish catches per 5-minute square during DFO bottom trawl surveys conducted from 1990 to 1994. The top panel presents the data for the winter survey conducted in January with the Gadus Atlantica vessel, using an Engel 145 trawl, and the bottom panel shows the catches for the summer survey conducted in August with the CCGS Alfred Needler, using a URI trawl.

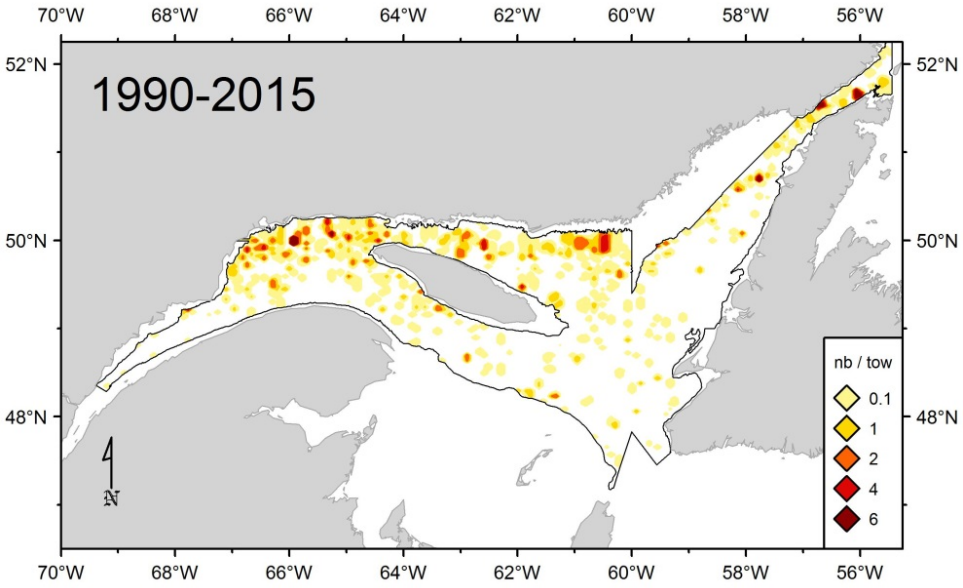


Figure 20. Distribution of catch rates (number/15-minute tow) of Lumpfish from 1990 to 2015 during the DFO bottom trawl research survey in August in the northern Gulf of St. Lawrence. The black line represents the contour of the sampled area.

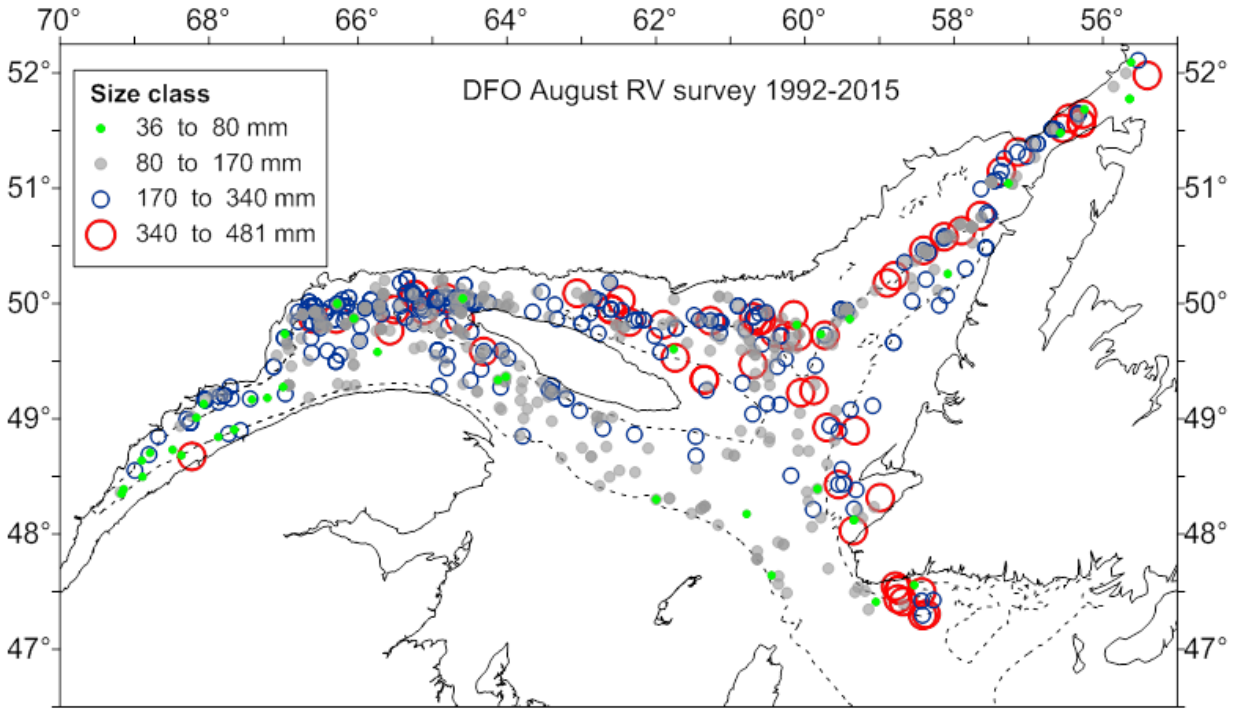


Figure 21. Distribution by size class of all Lumpfish caught during the DFO bottom trawl research survey in August in the northern Gulf of St. Lawrence for the 1992–2015 period.

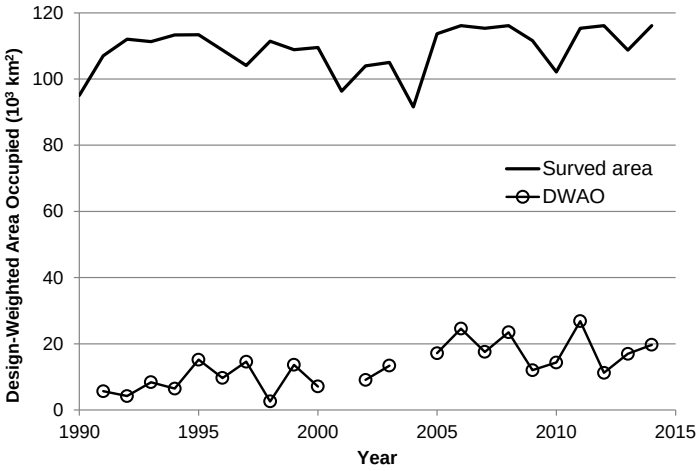
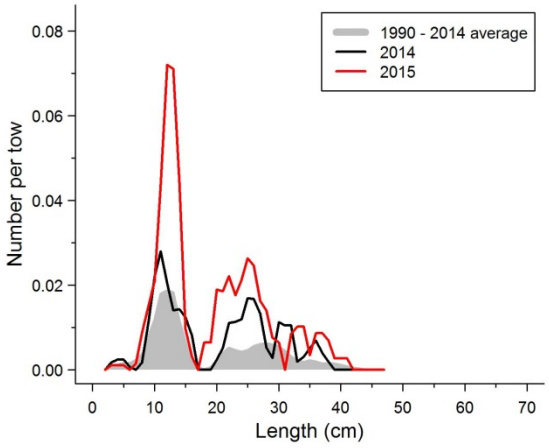
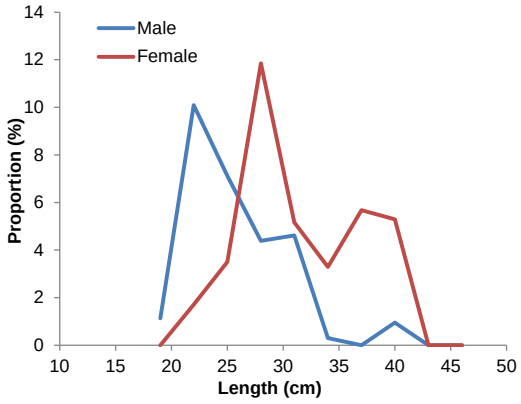


Figure 22. Area of occupancy (design weighted area occupied (DWAO)) of Lumpfish in northern Gulf of St. Lawrence based on data from the DFO bottom trawl research survey in August.

A)



B)



C)

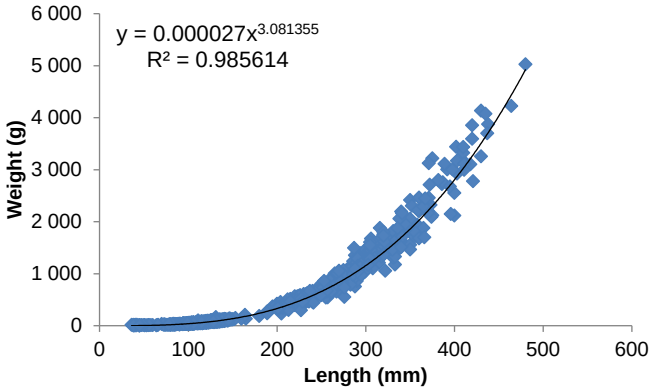


Figure 23. Data on the size of Lumpfish caught during the DFO bottom trawl research survey in August in the northern Gulf of St. Lawrence. A) Distribution of length frequencies (average number per 15-minute tow by year and average). B) Distribution of length frequencies (proportion) by sex for fish ≥ 19 cm. C) Weight-length relationship.

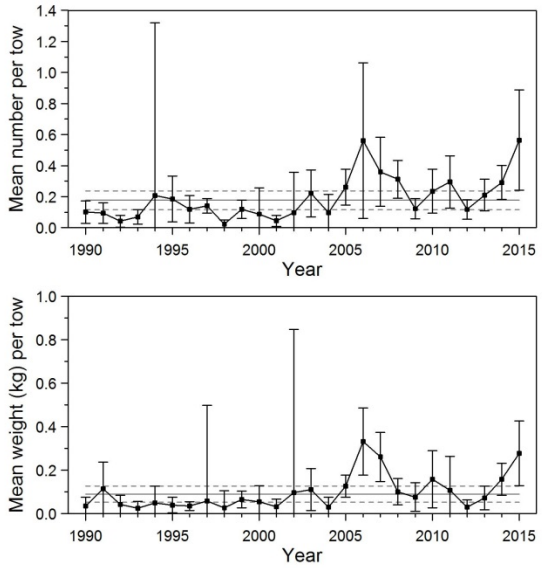


Figure 24. Mean number and weight per 15-minute tow (± confidence interval at 95%) observed during the August DFO bottom trawl survey in the northern Gulf of St. Lawrence for Lumpfish in 4RST. The horizontal lines indicate the average for the 1990–2014 period (full line) as well as upper and lower reference limits (dotted lines).

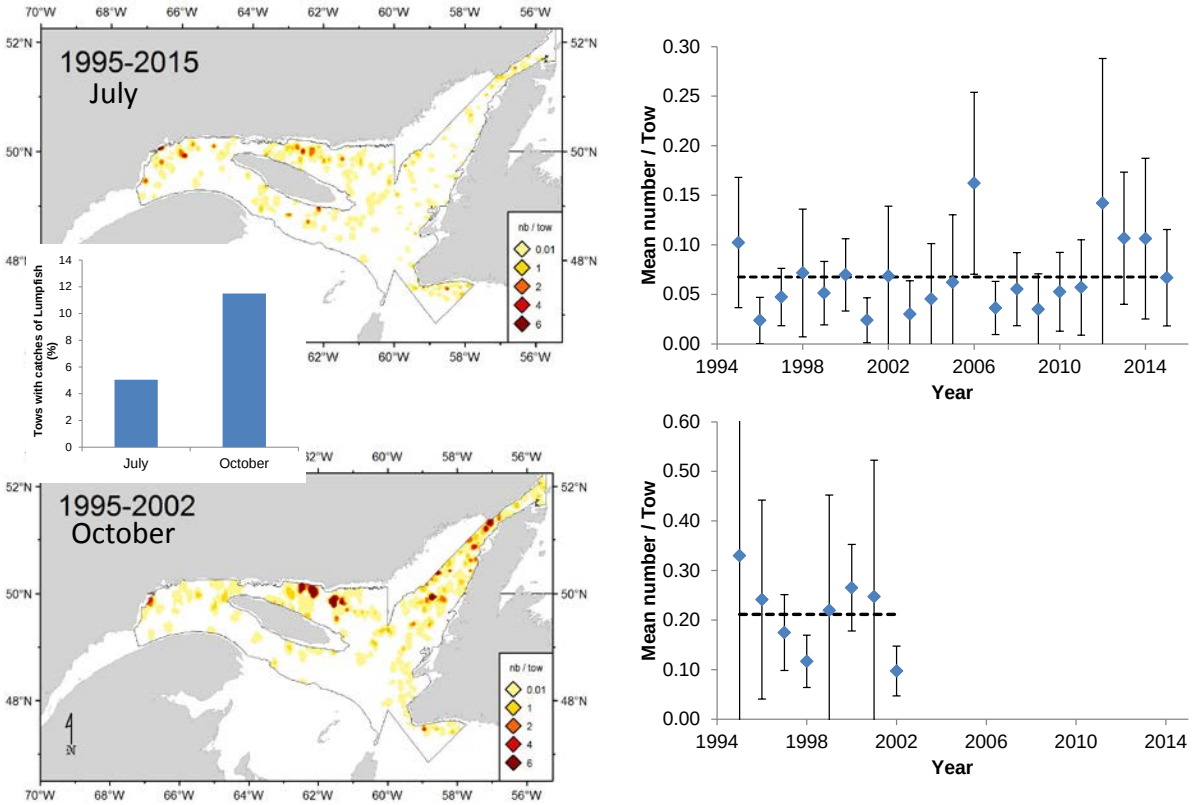


Figure 25. Bottom trawl survey of the sentinel fisheries program in the northern Gulf of St. Lawrence. The maps at left show the catch distribution (nb/tow) for the surveys from July (top) and October (bottom). The box shows the proportion of tows where Lumpfish are found for the entire series. The charts at right show the average number of Lumpfish per tow (± confidence interval at 95%). The dotted horizontal line indicates the series average.

APPENDICES

Appendix 1. Descriptive statistics on total length (mm), somatic weight (g) and ovary weight (g) of Lumpfish sampled in 2004 and 2005 in NAFO Subdivision 3Pn and Divisions 4R and 4S during the fecundity study.

Year	NAFO	Statistic	Length (mm)	Weight (g)	
				Somatic	Ovary
2004	3Pn	Average	427.2	2,228.7	856.6
		Standard Deviation	24.2	334.7	234.3
		Minimum	351	1,581	303
		Maximum	480	3,232	1,465
		Scope	129	1,651	1,162
		n	100	100	100
	4R	Average	384.4	1,769.3	759.3
		Standard Deviation	22.6	322.2	247.1
		Minimum	303	1,233	349
		Maximum	469	3,650	1,525
		Scope	166	2,417	1,176
		n	99	99	98
	4S	Average	401.0	2,024.3	772.8
		Standard Deviation	19.2	346.3	227.4
		Minimum	365	1,327	360
		Maximum	450	3,350	1,332
		Scope	85	2,023	972
		n	48	48	48
2005	3Pn	Average	408.8	2,071.8	773.0
		Standard Deviation	29.8	412.8	244.1
		Minimum	310	1,407	331
		Maximum	480	3,524	1,320
		Scope	170	2,117	989
		n	47	47	47
	4R	Average	395.1	1,940.4	732.8
		Standard Deviation	22.5	322.0	311.6
		Minimum	328	1,464	298
		Maximum	458	3,102	1,592
		Scope	130	1,638	1,294
		n	49	49	49
	4S	Average	404.3	1,934.5	663.0
		Standard Deviation	28.7	432.2	340.6
		Minimum	357	1,219	147
		Maximum	478	3,245	1,888
		Scope	121	2,026	1,741
		n	49	49	49

Appendix 2.

Conservation Harvesting Plan, Quebec Region, Fisheries Management.

Conservation Harvesting Plan

LUMPFISH - AREA 4S
SEASON 2016

Approved June 8th, 2016

Application

This conservation harvesting plan applies to ground fish license holders within Quebec's region A-52 vessel class and directing their activity on lumpfish in area 4S.

Fishing area

Area 4S – Quebec Region

Fishing period

From June 10th 2016 to July 1st 2016

Fishing gear

Authorized gear: Gillnet with a maximum length of 50 fathoms.

Mesh size: Minimum mesh size of 267 mm (10 ½ inches).

Number of nets: Maximum of 50 nets.

All gillnets must be tagged with only one valid tag with a unique identification number, before being put on the vessel for transport to the fishing site. Fishermen must obtain their tags from suppliers approved by the Department of Fisheries and Oceans (DFO), whose list is available at the following address:

http://www.dfo-mpo.gc.ca/fm-gp/sdc-cps/nir-nei/tags-supplier-region-eng.htm

Hail out

Hail out is mandatory.

At sea observer

At sea observer coverage is of 10 %.

Appendix 2. (continued)

Fisheries and Oceans Canada - Quebec Region LUMPFISH – AREA 4S

Combined form

Fishermen must acquire their booklet of combined forms from a prequalified supplier, identified by DFO, whose list is available at the following address:

http://www.dfo-mpo.gc.ca/fm-gp/sdc-cps/nir-nei/log-suppliers-eng.htm

The Logbook section must be filled every fishing day before arrival at port and the completed form must be sent to DFO's office in Sept-Îles, the Saturday of each week in which fishing activities have been realized.

Please remember that the logbook section must be completed for every fishing trip, even if no catch has been realized.

Incidental catches

License holders must immediately return to the water all Atlantic Halibut with a length less than 85 cm and all Skate and if the fish is alive, in a manner that causes it the least harm.

You are also authorized to return to the water all Dogfish, Lumpfish, Sculpin, Atlantic hagfish and Striped wolfish.

Species at Risk Act

Pursuant to the Species at Risk Act (SARA), no person shall kill, harm, harass, capture, take, possess, collect, buy, sell or trade an individual or any part or derivate of a wildlife species designated as extirpated, endangered or threatened.

At the time this Management Plan is promulgated, the Gulf of St. Lawrence and the Atlantic species targeted by these measures are the following ones : Spotted wolffish, Northern wolffish, Leatherback Turtle and Striped Bass (St. Lawrence Estuary population). New species could be added in the course of the year.

All by-catches of species identified above must be returned to the water and released in the exact capture location and, if the fish is still alive, with as little harm as possible. In addition, information regarding interactions with species at risk, including species mentioned above as well as the North Atlantic Right Whale, the Blue Whale (Atlantic population) and the Beluga Whale (St. Lawrence Estuary population) must be recorded in the Species at risk section of the logbook.

License Conditions

To obtain their license conditions, license holders must log on to the National Online Licensing System (NOLS) and place a request. License conditions according to the request will be available through the NOLS following payment of the license and at the latest 48 hours before the opening of the fishery.

Appendix 2. (continued)

Fisheries and Oceans Canada - Quebec Region LUMPFISH – AREA 4S

For National Online Licensing System assistance, please contact customer support by phone at 1-877-535-7307, or by email at **3** / **3**

For National Online Licensing System assistance, please contact customer support by phone at 1-877-535-7307, or by email at fishing-peche@dfo-mpo.gc.ca.

Approved by:

Andrew Rowsell
Area Director
Fisheries and Oceans Canada
North Shore

For questions regarding this harvesting plan

Fisheries and Oceans Canada
North Shore Area
1-800-463-1729 or 418 962-6314

Isabel Calderón
Act. Chief, Resource Management, Aboriginal Affairs, Aquaculture and Species at Risk

Daniel Dickner
Act. Area Chief, Conservation and Protection

Appendix 3. Conservation Harvesting Plan. Newfoundland and Labrador Region, Fisheries Management.

CONSERVATION HARVESTING PLAN
LUMPFISH
VESSELS LESS THAN 65 FEET
FIXED GEAR
NAFO Divisions 2J3KLP4R

This Conservation Harvesting Plan (CHP) applies to all vessels less than 65 feet in length, regardless of homeport, fishing Lumpfish in NAFO Divisions 2J3KLP4Rn effective 2016.

GENERAL PROVISIONS

A **fishing trip** will start from the time the fish harvester leaves port, and will end when the fish harvester returns to port for any reason, whether or not any fish is caught.

A) FISHING GEAR

1. The only gear permitted to be used is a gillnet having a minimum mesh size of 268mm (10.5 inches).
2. The maximum number of gillnets permitted to be fished is 50 and each gillnet is not to exceed 50 fathoms in length.
3. Lost gillnets must be reported to the nearest DFO office within 72 hours, if the loss is noticed before the closure of a fishing area. If the fishing area is already closed, the loss must be reported within 24 hours.
4. Fish harvesters cannot fish with, nor have onboard their vessel, a groundfish gillnet unless a tag, issued under the authority of the Minister for the current year, is securely attached to the head-rope of the net in a manner for which the tag was designed.
5. The gillnet tag must be affixed to the head rope of each gillnet within 1.85 meters (6 feet) from the side rope on the end of the net where the float or buoy identifies the Vessel Registration Number.

B) FISHING RESTRICTIONS

1) Fishing is authorized to be conducted in water depths less than 25 fathoms only.

2) Season Dates will be determined annually, following consultations between DFO and the FFAW, and may be subject to in-season adjustments due to ice conditions.
Fishing for Lumpfish is only permitted in the following areas:

2J3KL
2J Lodge Bay to Postville
Cape Bauld to Granite Point
Granite Point to Little Harbour Deep Head
Little Harbour Deep Head to Cape St. John
Cape St. John to North Head
North Head to Cape Freels
Bonavista Bay (north)
Bonavista Bay (south)
Trinity Bay
Conception Bay
Southern Shore
St. Mary's Bay
3Ps
Cape St. Mary's to Ship Harbour Point
Ship Harbour Point to Lawn Head
Lawn Head to Dantzic Point
Dantzic Point to Grand Bank Cape
Grand Bank Cape to Point Rosie
Point Rosie to Western Head (Hare Bay)
Western Head (Hare Bay) to Cinq Cerf in 3Pn

4R3Pn subject to the 72 hour requirement (i.e. 72 hrs. in advance of commercial Cod fishery openings)
Cinq Cerf to Cape Ray
Cape Ray to Johnson's Cove
Johnson's Cove to Cape St. George
Cape St. George to Cape St. Gregory
Cape St. Gregory to Point Riche
Point Riche to Cape Bauld
Quebec Border to Cape St. Charles

In NAFO Division 4R, closures may be introduced on short notice if high levels of bycatch of Atlantic Halibut occur.

In NAFO Divisions 4R3Pn, the fishery will close 72 hours in advance of any opening of the commercial Cod fishery, and will not be considered for re-opening until 72 hours after the closure of the commercial Cod fishery.

Fish harvesters are restricted to fishing the Lumpfish area of their homeport, unless they elect to fish in an alternate area.

Fish harvesters are permitted to change Lumpfish areas only **ONCE** each year..

If a Fish harvester wishes to fish in a Lumpfish area other than their homeport, they must contact the DFO Licensing Center **PRIOR** to the opening of the season in their homeport area, and prior to the opening date of the area they intend to fish. Completion and submission of Schedule 14 is necessary to make this change.

C) MONITORING

1. Industry-funded at-sea observer coverage is required. The targeted level of coverage will be 5% of the fleet sector quota for observer coverage.
2. Although Lumpfish landings are not subject to dockside monitoring requirements, 100% of groundfish bycatch landed in the directed Lumpfish fishery is subject to comprehensive Dockside Monitoring Program (DMP). It is required that fishers contact a certified Dockside Monitoring Company to report any landings of groundfish bycatch and a dockside observer may be deployed to monitor the offloading, or an authorization number will be provided to the fisher.

Test Fisheries

1. If a fishery is closed due to incidental catch or small fish problems, it will not reopen until it can be effectively monitored and controlled.
2. Closures will be in effect for a minimum of 10 days.
3. If a fishery in a particular area is closed twice during the year, it may remain closed for the remainder of the year.
4. Where test fishing is conducted, a fishing plan will be developed which will include:
   - areas to be tested
   - quantity of gear to be used
   - depth strata to be tested
   - vessels to be used
   - dates when test fishing will be carried out
   - provision for at-sea observer coverage
5. Test fishing will not commence until the fishing plan has been approved by DFO.

D) INCIDENTAL CATCH

For the purposes of this CHP, the following definitions apply:
"Directed species" means the permitted species, or combination of species, retained on board and taken by the fish harvester at a time, in an area and by a means that is authorized in species specific licence conditions.

"Incidental catch" means the catch retained on board of any species other than a directed species as defined above.

Unless otherwise stated, incidental catch restrictions are always expressed as daily limits (00:01 hours to 24:00 hours local time) calculated using round weights and are always calculated as a percentage of the round weight of the directed species retained onboard.

When fishing Lumpfish in NAFO Divisions 2J3KL and Subdivision 3Ps, the following incidental catch provisions apply:

1. Unless otherwise specified below or in species specific provisions, incidental catch of Cod may not exceed 10% or 200 pounds; whichever is greater.
2. When fishing in NAFO Division 3L, the incidental catch of Redfish, American plaice and Yellowtail flounder may not exceed 5%.

When fishing Lumpfish in 4R3Pn, incidental catch of Cod may not exceed 10%.

Where there are widespread incidental catch problems, an entire area may be closed to the fleet sector.

E) DISCARDING

1. In NAFO Divisions 2+3KLP, all Atlantic Halibut less than 81 cm (or in NAFO Division 4R all Atlantic Halibut less than 85cm), and Northern and Spotted wolfish must be released to the place from which it was taken and, when alive, in a manner that causes the least harm.
2. Dogfish and Lumpfish may be returned to the water immediately, dead or alive.
3. Live Winter flounder less than 25cm and American plaice less than 20 cm in length may be returned to the water immediately.

F) OTHER

Other conservation measures may be identified and implemented during the year as required.