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Assessment of Northern Shortfin Squid (*Illex illecebrosus*) in Subareas 3+4 for 2012

by

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Abstract

Two general levels of productivity have been identified for the Subareas 3+4 component of the Northern shortfin squid (*Illex illecebrosus*) stock based on trends in relative biomass indices and squid mean body weights derived from the Canadian bottom trawl surveys conducted during July in Division 4VWX (Rivard *et al*., 1998; Hendrickson, 1999). A period of high productivity (1976-1981) occurred between two low productivity periods (1970-1975 and 1982-2011). During 2010-2012, relative biomass indices from the Division 4VWX surveys remained at levels well below the average for the low productivity period (3.0 kg per tow), and in 2012, the index was 1.5 kg per tow. The mean body weight of squid caught during the 2012 survey (87 g) was slightly above the 1982-2011 average (80 g). Since 1999, there has been no directed fishery in Subarea 4 and the majority of the catches from Subareas 3+4 have been from Subarea 3. During 2009-2012, relative fishing mortality indices in Subareas 3+4 (0.01) were the lowest in the time series. Based on these trends, the Subareas 3+4 stock component remained in a state of low productivity during 2012.

1.0 Introduction

Northern shortfin squid (*Illex illecebrosus*), a species with a lifespan of less than one year (Dawe and Beck, 1997; Hendrickson, 2004), is considered to constitute a unit stock throughout its range in the Northwest Atlantic Ocean, from Southern Labrador to Florida (Dawe and Hendrickson, 1998). Although the resource is continuously distributed between Cape Hatteras, North Carolina and inshore Newfoundland during summer through autumn, the population is considered for management purposes to consist of two stock components. The northern stock component (Subareas 3+4) is managed by the Norwest Atlantic Fisheries Organization (NAFO; formerly the International Commission for Northwest Atlantic Fisheries or ICNAF) and includes Northern shortfin squid within the 200 mile fishing zone of Canada, which surrounds most of Newfoundland, and international waters near the edges of the Grank Bank and surrounding the Flemish Cap in Division 3M (Subarea 3, Fig. 1). The northern stock component also includes squid from the Scotian Shelf, Bay of Fundy, and Gulf of St. Lawrence (Subarea 4). The southern stock component (Subareas 5+6) includes Northern shortfin squid inhabiting the 200 mile fishing zone of the USA from the Gulf of Maine to Cape Hatteras, North Carolina and international waters beyond. Although fishery and survey data are presented herein for both stock components, because of their relationship to one another as a unit stock, the focus of the assessment is the northern stock component.

The onset and duration of the fisheries in each Subarea generally reflect the timing of squid migrations through each fishing area. Subarea 3 catches are primarily from a small-boat jig fishery that occurs in the shallow, nearshore waters of Newfoundland. During 1987-2001, Northern shortfin squid were harvested from Subarea 4 by an international, mixed-species, bottom trawl fishery for silver hake (*Merluccius bilinearis*), *I. illecebrosus* and argentine (*Argentina* sp.) that occurred on the Scotian Shelf (Hendrickson *et al*., 2002). International fleets,

comprising midwater and bottom trawlers, began directed fisheries for Northern shortfin squid in Subareas 5+6 in 1967 (Lange and Sissenwine, 1980). Since 1987, catches from Subareas 5+6 have been solely from a USA bottom trawl fishery that occurs primarily in the Mid-Atlantic Bight (NEFSC, 1999).

Management of Northern shortfin squid in the Northwest Atlantic Ocean (Subareas 3-6) began with the establishment of a pre-emptive Total Allowable Catch (TAC) of 71 000 t, by ICNAF, during 1974-1975 for *I. illecebrosus* and *Doryteuthis* (*Amerigo*) *pealeii* (formerly *Loligo pealeii*) combined. During 1975-1979, Northern shortfin squid catches increased rapidly with the development of an international offshore fishery and increased catches in the inshore jig fishery in Subarea 3 (Dawe, 1981) and international offshore fisheries in Subarea 4 (Amaratunga et al., 1978). During 1976-1979, TACs for the Northern shortfin squid increased from 25 000 to 120 000 t, respectively, each time the TACs were exceeded (Lange, 1978; Table 1). A TAC of 150 000 t was in place during 1980-1998, but was reduced to 75 000 t in 1999, because catches in Subareas 3+4 declined rapidly after 1979 and were well below 150 000 t. Since 2000, the TAC has been 34 000 t based on limit reference point calculations (Rivard et al., 1998).

The Subareas 5+6 stock component has been managed in the USA by the Mid-Atlantic Fishery Management Council since 1977 based on a Fishery Management Plan and annual fishery specifications. The southern stock component is not assessed annually. During 1978-1995, the TAC for Subareas 5+6 was 30 000 t based on the results of a yield-per-recruit model. After 1995, TACs for Subareas 5+6 consisted of either MSY-based biological reference points, or proxies thereof (e.g., %MSP), computed using several different stock assessment models. The TAC was 24 000 t during 2000-2009 and was 23 328 t during 2011-2013. The TACs for Subareas 5+6 were exceeded during 1998 and 2004 (Table 1).

During 2002-2006, the Subareas 3+4 stock component was assessed by the NAFO Scientific Council every other year instead of annually. There was no Designated Expert available to conduct the assessments during 2007-2009. Therefore, the Scientific Council used trends in the nominal catch data from SA 3+4 and the Div. 4VWX survey indices during 2006-2008 to assess stock status. The most recent assessment was conducted by the Designated Expert in 2010 (Hendrickson and Showell, 2010) and interim monitoring reports were used to assess the 2010 and 2011 stock status. The current assessment provides an evaluation of the status of the Subareas 3+4 stock component based on trends in commercial fishery data, research survey indices, and relative fishing mortality indices through 2012.

2.0 Materials and Methods

2.1 Commercial Fishery Data

All catches presented herein represent nominal catches. Catches have been recorded from the Subarea 3 fishery since 1911 (Dawe, 1981) and from the Subarea 4 fishery since 1920 (ICNAF, 1973). During the early 1970's, most countries reported their prior squid catches to ICNAF by species, but those that did not do so were prorated for Subareas 5+6 based on the squid catch composition of countries that did report their catches by squid species (Lange and Sissenwine 1980). Squid catches from Subareas 5+6 were not recorded by species prior to 1978, and instead, represent prorated estimates (Lange and Sissenwine, 1980). Nominal catches are presented for 1953-2012 from Subarea 3 and Subarea 4 and for 1963-2012 from Subareas 5+6. Catch data for the three most recent years of each time series are considered preliminary and were updated as needed.

Catches from Subarea 3 include Canadian catches from the Fishery Statistics Division of the Newfoundland Region of the Canada Department of Fisheries and Oceans (Earl Dawe, CA DFO, pers. comm.) and catches reported in the NAFO STATLANT 21A Database by international fleets. Subarea 4 catches were obtained from the MARFIS Database, maintained by the CA DFO (Maritimes Region), which contains catches by Canadian vessels and international vessels with Canadian catch allocations. During 1987-1998, the Subarea 4 catches also include the kept fraction of Northern shortfin squid catches from the international mixed-species fishery for silver hake, *I. illecebrosus* and argentine. These catches were obtained from the DFO Observer Program Database during a period of 100% observer coverage of international fisheries and are considered highly accurate because the catch data were collected on a tow-by-tow basis (Showell and Fanning, 1999). Since 1999, foreign-flagged vessels have not been licensed to fish on the Scotian Shelf. Catches from Subareas 5+6 were obtained from the Commercial Fisheries

Database maintained by the Northeast Fisheries Science Center (NEFSC) of the U.S. National Marine Fisheries Service.

2.2 Research Survey Data

Fishery-independent indices of relative abundance (stratified mean number per tow) and biomass (stratified mean kg per tow) were derived for Northern shortfin squid in Subarea 3, Subarea 4 and Subareas 5+6 using data collected during multi-species bottom trawl surveys. All of the surveys incorporated stratified-random sampling designs with stratification based on depth. Surveys were conducted by the CA DFO: in Div. 3LNO during the fall (mainly during October-December, 1995-2012) and spring (mainly during May-June, 1996-2012); in Div. 4T (southern Gulf of St. Lawrence) during September (1971-2012); and in Div. 4VWX (Scotian Shelf and Bay of Fundy) during July (1970-2012). Minimum biomass and abundance estimates were also derived using area-swept data from bottom trawl surveys conducted by the EU in Div. 3M (Flemish Cap), primarily during July (1988-2012).

Relative abundance and biomass indices were derived for the southern stock component using data from bottom trawl surveys conducted by the NEFSC, between Cape Hatteras, North Carolina and the Gulf of Maine, mainly during September-October (1967-2012). Sampling during all surveys was conducted around-the-clock with the exception of the Div. 3M surveys and the 1971-1984 Div. 4T surveys which were both conducted solely during the daytime.

2.2.1 Subarea 3

Relative abundance and biomass indices for the spring (1996-2012) and fall (1995-2012) DFO surveys conducted in Div. 3LNO were revised to address a 2010 research recommendation (NAFO, 2010) made by the NAFO Scientific Council's Standing Committee on Fisheries Science (STACFIS). For Northern shortfin squid in Subareas 3+4, STACFIS recommended that *"abundance and biomass indices from the Canadian multi-species bottom trawl surveys conducted during spring and autumn in Div. 3LNO, beginning with 1995, be derived using the two subsets of strata listed in SCR Doc. 06/45 in order to improve the precision of the indices"*.

The revised time series of Div. 3LNO relative abundance and biomass indices were computed using data from only those strata within which Northern shortfin squid were consistently caught (Hendrickson, 2006). Both spring and fall surveys were also conducted prior to 1995, but catches of *I. illecebrosus* were not consistently quantified (Earl Dawe, CA DFO, pers. comm.). The strata set used to compute the spring indices included: 328-337, 340, 344, 351-358, 361, 385-386, 392, 717-722, 724-727, 730, 734-736, 761,765, 769, 771, 773, 775, 784, 786, 789, 790, 792-793 and 800, spanning a depth range of 34-726 m (Fig. 2). The strata set used to compute the fall indices included: 332-337, 345, 348, 355-360, 364-366, 368-370, 374, 376-383, 385-392, 712, 717-718, 720-733, 735-736. Not all strata were common to both surveys, in part, because additional deepwater strata were sampled solely during autumn surveys (Brodie, 2005). Survey sampling designs and protocols are provided in Doubleday (1981). Since 1995, a Campelen 1800 shrimp trawl has been used to conduct both surveys, but various survey vessels have been utilized. The Div. 3LNO spring surveys were conducted by the CCGS *Wilfred Templeman* during 1996-2008, but have since been conducted by the CCGS *Alfred Needler* (Healey et al., 2012). During 1995-2008, the Div. 3LNO fall surveys were conducted by the CCGS *Wilfred Templeman,* which sampled stations at depths of 30-731 m, and the CCGS *Teleost*, which sampled the deeper stations (depths of 732-1,460 m) as well as some of the shallow stations. A third vessel, the CCGS *Alfred Needler*, also sampled some of the fall survey stations during 1996, 2001, 2005 and 2008. Since 2008, the fall surveys in Div. 3LNO have solely been conducted by the CCGS *Alfred Needler* and the CCGS *Teleost* (Healey et al., 2012). The multiple ships used to conduct each of the surveys were assumed to have similar catchabilities.

Survey indices were also derived using data from the July EU bottom trawl surveys of the Flemish Cap in Div. 3M. Swept area estimates of minimum abundance and biomass were derived using all of the Div. 3M survey strata; strata 1-19 during 1988-2002 and strata 1-34 from 2003 onwards (Fig. 3). Strata 1-19 include depths of 125 m to 730 m and strata 1-34 include depths of 125 m to 1 460 m (Vázquez, 2010). The Div. 3M surveys are only conducted during the daytime 0600-2200. A Lofoten bottom trawl has consistently been used to conduct the surveys, but different vessels have been used during some years. During 1988 and 1991-2002, the R/V *Cornide de Saavedra* conducted the surveys. Two different vessels were used during 1989 and 1990 and the R/V *Cornide de Saavedra*

was replaced by the R/V *Vizconde de Eza* in 2003 (Vázquez, 2010). Indices from 1988 to 2002 were adjusted for differences in vessel catchability by multiplying the R/V *Cornide de Saavedra* indices by 0.81, the ratio of R/V *Cornide de Saavedra* catches, in weight, to R/V *Vizconde de Eza* catches (Antonio Vázquez, Instituto de Investigaciones Marinas, Spain, pers. comm.).

2.2.2 Subarea 4

Relative abundance and biomass indices for Div. 4VWX were derived using survey catches from strata 440-495, encompassing a depth range of about 50-400 m (Fig. 4). Indices were previously derived using all survey strata (400-495), but were revised herein in order to include only those strata which allowed for the computation of coefficients of variation. The survey design, gear characteristics, and sampling protocols are provided in Halliday and Koeller (1981). The surveys were conducted by the RV *A.T. Cameron*, with a Yankee 36 bottom trawl, during 1970-1981. A Western IIA bottom trawl has been used to conduct the surveys since 1982, but with several different vessels, including: the RV *Lady Hammond* (1982); CCGS *Alfred Needler* (1983-2003 and 2005-2012) and the CCGS *Teleost* (2004, Clark and Emberley, 2011). There are no gear or vessel conversion factors available with which to standardize the *I. illecbrosus* survey indices prior to 2004 (Fanning, 1985). However, during July of 2005, a comparative fishing study was conducted with the CCGS *Alfred Needler* and the CCGS *Teleost*. For Northern shortfin squid, Fowler and Showell (2009) found that the catchabilities of the two vessels were not significantly different at an α level of 0.05 ($p = 0.095$).

Relative abundance and biomass indices for Div. 4T were derived using catches from all survey strata (Fig. 4), encompassing a depth range of 20-274 m. The sampling design, gear characteristics, and survey sampling protocols are provided in Halliday and Koeller (1981). Vessel changes during the Div. 4T surveys included use of the CCGS *Wilfred Templeman* during 2003 and the CCGS *Needler* and CCGS *Teleost* during 2004 and 2005 (Hugues Benoît, CA DFO, pers. comm.). The survey has been conducted solely with the CCGS *Teleost* since 2006. During 2003, there was also a reduction in the number of strata sampled. The Div. 4T survey indices were adjusted for diel and vessel catchability differences for 1985-2002 (Benoît and Swain, 2003) and for vessel catchability differences during 2004-2005 (Benoît, 2006). There were no data available to adjust the 2003 indices for vessel catchability differences and not enough data available to determine whether there was a significant diel effect between the CCGS *Teleost* and the CCGS *Needler* (Hugues Benoît, CA DFO, pers. comm.).

2.2.3 Subareas 5+6

Relative abundance and biomass indices were derived for Subareas 5+6 using data from all offshore survey strata (depths of 27-366 m) located between the Gulf of Maine and Cape Hatteras, North Carolina, with the exception of strata 31-33 because these strata were not consistently sampled (Fig 5). Survey design and sampling protocols are described in Azarovitz (1981). Indices were adjusted for survey gear and vessel catchability differences that occurred during 1967-2008 (NEFSC, 1999). Indices for 2009 onward were adjusted for catchability differences between the RV *Albatross IV* and its replacement vessel, the FRV *Henry B. Bigelow*. The applied vessel calibration factors were 1.38 for numbers per tow and 1.41 for weight per tow indices (Miller *et al*., 2010).

2.3 Fishing Mortality

Relative fishing mortality indices for Subareas 3+4 were computed, for 1970-2012, by dividing the annual catches from Subareas 3+4 (in tons) by the annual biomass indices from the July Div. 4VWX surveys (in kg/tow) then dividing the result by 10,000 to scale the values.

3.0 Results and Discussion

3.1 Catches

3.1.2 Subareas 3+4

Catches in Subareas 3+4 increased during the 1970s and reached a peak of 162,092 t in 1979 (Table 1, Fig. 6). During 1976-1981, total catches (Subareas 3-6) were dominated by those from Subareas 3+4; averaging 80,645 t in Subareas 3+4 and 19,661 t in Subareas 5+6. Following the 1979 peak, Subareas 3+4 catches declined sharply to less

than 1,000 t during 1983-1988 (Fig. 6). During 1997, Subareas 3+4 catches (15,614 t) reached their highest level since 1981 and were primarily from the Subarea 3 inshore jig fishery (12,748 t). During 1999-2006, catches from Subareas 3+4 were highly variable, ranging from 57 t in 2001 to 6,981 t in 2006. Since then catches in Subareas 3+4 have been less than 800 t and only totaled 46 t in 2012 (Table 1, Fig. 6).

Catches in Subarea 4 increased rapidly, from 13 945 t in 1975 to a peak of 74 259 t in1979, with the development of international bottom trawl and midwater trawl fisheries on the Scotian Shelf (Amaratunga et al., 1978), but then declined rapidly to 1 744 t in 1982 (Table 1). During 1983-1999, catches in Subarea 4 were primarily from the international mixed-species fishery for silver hake, argentine and *I. illecebrosus*, ranging between 110 t and 6 535 t. Since 2000, there has been no directed fishery for *I. illecebrosus* in Subarea 4 (NAFO, 2003) and catches have been primarily from bycatch in Canadian small-mesh bottom trawl fisheries (e.g., silver hake) which have generally totaled less than 50 t (Table 1, Fig. 6). Since 2000, small amounts of *I. illecebrosus* bycatch by international vessels have also occurred; 12 t in 2000 and 4 t in 2003 by Russia (NAFO, 2003) and 13 t in 2005 by Korea (T.-Y. Oh, National Fisheries Research and Development Institute, Korea, pers. comm.). The catch in Subarea 4 during 2012 was 29 t.

Beginning in 2004, catches of Northern shortfin squid in Subarea 4 may be underestimated because a majority of the squid catches in the STATLANT 21A Database, from the Maritimes Region of CA, were listed as either *Loligo pealeii* or "unspecified squid" (i.e., NAFO species code = 509, representing "Ommastrephidae sp. or Loliginidae sp."). The *Loligo pealeii* catches totaled 102 t in 2004 and 240 t in 2005. The "unspecified squid" catches were very high during 2008 (2,154 t), 2009 (1,821 t), and 2011 (1,110 t). However, these catches were not recorded in the official Canadian database (MARFIS) for the Maritimes Region and did not appear in the STATLANT 21B Database. Further research on the topic with the MARFIS Database staff from the Maritimes Region, as well as the NAFO database staff, did not resolve the issue. Therefore, the "unspecified squid" and *L. pealeii* catches in the STATLANT 21A Database were not included in the stock assessment. In the future, removal of the "unspecified squid" species code (509) from the list of NAFO species codes should be considered in order to avoid the potential for underestimation of *I. illecebrosus* catches.

Since 1953, catches in Subarea 3 have been predominately from the Newfoundland inshore jig fishery which expanded during the 1950's as a result of new markets, and after 1964, with the use of Japanese mechanized jigs (Dawe, 1981). Although international fisheries occurred offshore in Subarea 3 during 1970-1979, the peak catch from these fisheries in 1978, 5 700 t in 1978, only comprised a small percentage (14%) of the total landings from Subarea 3 (Dawe, 1981). Total catches from Subarea 3 increased rapidly the 1970's, from 3 751 t in 1975 to a peak of 88 833 t in 1979, but then declined rapidly to 5 t in 1983 (Table 1, Fig. 6). Since 1983, catches from Subarea 3 have been highly variable and predominately from the inshore jig fishery. During 1987-1997, catches ranged from 48 t in 1995 to 12 748 t in 1997; the highest level since 1981. Catches generally increased from 23 t in 2001 to 6 957 t in 2006, with only small amounts of catch taken by international vessels (i.e., 16 t during 2004 and 2-79 t during 2006-2008). During 2009-2012, Subarea 3 catches declined from 676 t to 18 t, respectively.

3.1.3 Subareas 5+6

During 1964-1966, the Russian fleet began landing Northern shortfin squid bycatch in Subareas 5+6. Directed bottom and midwater trawl fisheries, by international fleets (mainly Japan, Spain, Italy, Russia, and Poland), developed in 1967 (Lange and Sissenwine 1980) and occurred through 1986 (NEFSC 1999). During this time period, total catches for Subareas 5+6 increased rapidly to a peak of 24,936 t in 1976 (Table 1, Fig. 6). Since 1987, the directed fishery has consisted solely of domestic bottom trawlers (NEFSC 1999). During 1987-1997, catches were generally in the range of 10,000-18,000 t. Domestic fishery catches peaked in 1998 (23,597 t), but the fishery was closed for the year in August because the TAC (19,000 t) was exceeded. During 1999-2003, catches from Subareas 5+6 ranged from 2,750 t in 2002 to 9,011 t in 2000. The fishery was closed again in September of 2004, when the highest catch on record (26,097 t) was landed and the quota of 24,000 t was exceeded. Landings declined to 9,022 in 2007 then increased again to 18,418 t in 2009. The Subareas 5+6 catch in 2012 was 11,709 t.

3.1.4 Subareas 3-6

The timing and duration of the Northern shortfin squid fisheries vary by Subarea. Since 1992, most of the catches in the Subarea 4 and 5+6 fisheries have occurred during June-October, with peak catches occurring in July. The

Subarea 3 fishery has occurred about one month later, during July-November, with peak catches occurring in September (Hendrickson *et al*., 2002).

Total catches from Subareas 3-6 increased rapidly from 4,211 t in 1970 to a time series peak of 179,333 t in 1979, but then declined rapidly to 6,788 t in 1985 (Table 1, Fig. 6). Total catches declined further to 2,769 t in 1988, but then increased to 29,243 t in 1997. Since then, catches in Subareas 3-6 have been predominately from the Subareas 5+6 fishery. During 2004, the Subareas 3-6 catches (28,671 t) reached the second peak since 1982. Total catches declined during 2009-2012 from 19,136 t to 11,755 t, respectively.

3.2 Survey Abundance and Biomass Indices

Of the three surveys with the longest time series, surveys in Div. 4VWX, Div. 4T and Subareas 5+6 (Tables 2 and 3, Fig. 7), the Div. 4VWX survey occurs during July, a time when the species is most available within the continental shelf survey area. The Div. 4VWX survey is a measure of pre-fishery biomass because it precedes the directed fishery in Subarea 3 and occurs nearest the start of the fisheries in Subareas 4-6. The autumn surveys conducted in Subareas 5+6 and Div. 4T occur near the end of the directed fisheries in Subareas 4-6, so both sets of indices are considered as measures of post-fishery biomass, particularly since 1998 when total catches have been predominately from the USA fishery which ends in September during most years.

Despite using data from the revised strata sets, biomass indices computed for the Canadian spring surveys conducted in Div. 3LNO were of a much lower magnitude than the Div. 4VWX biomass indices and the trends for the two time series were dissimilar (Fig. 8). Trends in the fall Div. 3LNO biomass indices were also dissimilar to the trends in the fall biomass indices for the Div. 4T and Subareas 5+6 surveys (Fig. 8). These dissimilarities were likely due to low availability of the species to the spring and fall surveys when the population is migrating on and off the Grand Bank, respectively (Hendrickson, 2006). Thus, the Div. 3LNO indices were considered to be poor indicators of the relative biomass of Northern shortfin squid in Subareas 3+4. The fall Div. 4T survey encompasses a much smaller habitat area than the Div. 4VWX survey, and like the fall Subareas 5+6 survey, the availability of Northern shortfin squid within the Div. 4T survey area may be problematic depending on the timing of the species' off-shelf migration. In summary, the Div. 4VWX survey is considered the most representative measure of Northern shortfin squid relative biomass and abundance in Subareas 3+4.

Although the Div. 4VWX biomass indices showed a high degree of interannual variability, a period of high productivity occurred during 1976-1981, averaging 13.2 kg/tow (% CV range of 22-38%), followed by a low productivity period during 1982-2011, averaging 3.0 kg/tow (average %CV = 38%, Table 2, Fig. 7). After 1981, large increases in the biomass index occurred during 2004 (12.9 kg/tow) and 2006 (10.2 kg/tow), but they were followed by very low indices in subsequent years (i.e., 0.7 kg/tow in 2005 and 1.5 kg/tow in 2007). The 2004 index estimate was also very imprecise (%CV = 65%). During 2010-2012, relative biomass indices from the Div. 4VWX surveys were well below the average for the low productivity period (3.0 kg per tow), and in 2012, the index dropped further to 1.5 kg per tow (%CV=19%).

The EU survey in Div. 3M is also conducted mainly during July, but it covers a smaller area of *Illex* habitat than the Div. 4VWX survey and mainly consists of deeper, oceanic habitat. Biomass indices for the Div. 3M surveys were very low during most years (<100 t) and were similar to the trends in the Div. 4VWX indices only during periods of high biomass in Div. 3M, which also coincided with additional sampling of deeper strata (731-1 460 m) and the use of a different survey vessel (R/V *Vizconde de Eza*) from 2003 onwards (Table 4, Fig. 9). Length composition data from vessel comparison studies indicate that the R/V *Vizconde de Eza* catches a higher proportion of small squid (5-16 cm DML) than the R/V *Cornide de Saavedra* (Pérez-Rodriguez and Koen-Alonso, 2010). During 2003-2012, catches of Northern shortfin squid in the deeper strata were highly variable, but generally low and comprised between 0 and 15% of the annual relative abundance index. Since 1988, biomass indices suggest that the Flemish Cap represents marginal *Illex* habitat during most years (< 100 t). Minimum biomass estimates were highest during 2006-2009, reaching a peak of 5,143 t in 2008 then declining to 1,363 t in 2009. However, these high indices were not attributable to high squid abundances within strata deeper than 730 m, because the latter comprised 0 to 1.2% of the annual relative abundance indices during this time period. During 2010-2012, the biomass indices for Div. 3M were low (< 100 t).

Relative biomass indices for the fall Div. 4T survey, with the exception of the high productivity period (1976-1981), were of much lower magnitude and exhibited different trends than the fall Subareas 5+6 biomass indices (Table 3, Fig. 7). Consequently, the Div. 4T survey area appears to represent marginal *Illex* habitat during the fall of most years. Similar to the Div. 4VWX biomass indices, the Subareas 5+6 biomass indices were consistently high during 1976-1981, but have since been highly variable and generally of lower magnitude than the Div. 4VWX indices (Fig. 7). The 2006 time series peak in the Subareas 5+6 relative abundance indices (29.5 squid per tow), and the secondary peak in 2003 (28.5 squid per tow), were due to large catches at one or two stations and represent squid of a much smaller mean body size than during 1976-1981. In contrast, during 1981 (a high productivity year), the abundance index (27.1 squid per tow) was similar to the indices for 2003 and 2006, but the 1981 catch rates were high at multiple stations. Again, the biomass indices for Subareas 5+6 reflect post-season *Illex* fishery removals in addition to off-shelf migration patterns. Since 1982, biomass indices for Subareas 5+6 have exhibited two general rise-and-fall periods; a rise to the highest level since the high productivity period, in 1989, which was followed by a general decline through 1999. A second rise, to the highest level since 1989, occurred in 2006 (2.8 kg per tow) but was followed by a decline to 0.5 kg per tow during 2010-2012 (Table 3).

3.5 Body Size

Mean body weights of squid were highest during the high productivity period (1976-1981) and lower during the low productivity periods in both the Div. 4VWX July survey and the Subareas 5+6 autumn survey (Fig. 10). Mean weights were much larger in the Subareas 5+6 surveys (average of 284 g) than in the Div. 4VWX surveys (average of 150 g) during the high productivity period. However, this size disparity subsequently decreased after 1994 due to a gradual decline in the mean size of squid caught in the Subareas 5+6 surveys, such that squid from both surveys were of similar size (about 70-90 g) during 1995-2003. The average body weight of squid caught in the Div. 4VWX surveys declined after 2006 and averaged (93 g) during 2007-2011, while the mean weight of squid from Subareas 5+6 averaged less, 85 g, during the same time period. In 2012, the mean weight of squid caught in the Div. 4VWX survey was 87 g, slightly above the 1982-2011 mean of the low productivity period (80 g).

3.6 Relative Fishing Mortality Indices

Relative fishing mortality indices for Subareas 3+4 were highest during 1977-1982, reaching a peak of 4.20 in 1978 and averaging 1.78 (Table 5, Fig. 11). During 1983-2011, relative fishing mortality indices were much lower, averaging 0.12, with a peak of 0.96 in 1996. During 2009-2012, relative fishing mortality indices were at the lowest levels on record (≤ 0.01).

3.7 Limit Reference Points

For data-poor stocks, such as the Subareas 3+4 *Illex* stock component, the NAFO Study Group on Limit Reference Points recommended that 85% of the maximum observed biomass index be used as a proxy for B_{lim}, assuming that the highest index is equal to B_{MSY} (SCS Doc. 04/12). For all NAFO stocks, F_{lim} is considered as F_{MSY} or a proxy thereof. However, *Illex* is an annual, semelparous species. Recruitment is strongly influenced by environmental conditions (Dawe and Warren, 1993; Dawe et al., 2007), and as a result, the Subareas 3+4 stock component has experienced low and high productivity states. Since the onset of the 1982 low productivity period, the magnitude of the Div. 4VWX biomass index has not consistently reflected the magnitude of the fishery removals during each respective year. Given the inconsistent response of the annual relative biomass indices to fishery removals and the lack of a stock-recruitment relationship, limit reference point proxies were developed (Rivard et al. 1998).

The current management advice for this stock component is based on the potential yield depending on whether the stock is in a low or high productivity state. The method used to compute potential yield only applies to the low productivity period, does not account for effects of environmental conditions on yield, and assumes that the high relative fishing mortality indices which occurred during 1976-1981 (which were followed by a rapid decline in the Div. 4VWX biomass indices) are appropriate for the current low productivity period. Potential yields for the low productivity period were computed as: 1.) the average catch during 1976-1981*(average Div. 4VWX biomass index during 1982-1997/average biomass index during 1976-1981) = 19,000 tons and 2.) the catch during the 1979 peak*(average Div. 4VWX biomass index during 1982-1997/biomass index during 1979) = 34,000 tons (Rivard et al. 1998). Both potential yields are assumed to represent limit reference points.

4.0 Summary

Two general levels of productivity have been identified for the Subareas 3+4 component of the Northern shortfin squid (*Illex illecebrosus*) stock based on trends in nominal catches and relative biomass indices and squid mean body weights derived from the Canadian bottom trawl surveys conducted in Division 4VWX during July (Rivard *et al*., 1998; Hendrickson, 1999). A period of high productivity (1976-1981) occurred between two low productivity periods (1970-1975 and 1982-2011). During 2010-2012, relative biomass indices from the Division 4VWX surveys remained at levels well below the average for the low productivity period (3.0 kg per tow), and in 2012, the index was 1.5 kg per tow. The mean body weight of squid caught during the 2012 survey (87 g) was slightly above the 1982-2011 average (80 g). During 2009-2012, relative fishing mortality indices in Subareas 3+4 were the lowest in the time series (0.01). Based on these trends, the Subareas 3+4 stock component remained in a state of low productivity in 2012.

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Table 1. Nominal catches (t) of *Illex illecebrosus* in NAFO Subareas 3 and 4, during 1953-2012, and Subareas 5+6, during 1963-2012, and TACs (t) for Subareas 3+4 and Subareas 5+6.

Year	Subarea 3[2] (t)	Subarea 4[3] (t)	Total Subarea 3+4 (t)	Subareas 5+6[4] (t)	Total Subareas (3-6)[5] (t)	TAC (t)[1] 3+4	TAC (t)[1] 5+6
1953	4,460	51	4,511		4,511		
1954	6,700	115	6,815		6,815		
1955	7,019	269	7,288		7,288		
1956	7,779	450	8,229		8,229		
1957	2,634	335	2,969		2,969		
1958	718	84	802		802		
1959	2,853	258	3,111		3,111		
1960	5,067	24	5,091		5,091		
1961	8,971	50	9,021		9,021		
1962	482	587	1,069		1,069		
1963	2,119	103	2,222	810	3,032		
1964	10,408	369	10,777	360	11,137		
1965	7,831	433	8,264	522	8,786		
1966	5,017	201	5,218	570	5,788		
1967	6,907	126	7,033	995	8,028		
1968	9	47	56	3,271	3,327		
1969	21	65	86	1,537	1,623		
1970	111	1,274	1,385	2,826	4,211		
1971	1,607	7,299	8,906	6,614	15,520		
1972	26	1,842	1,868	17,641	19,509		
1973	622	9,255	9,877	19,155	29,032		
1974	48	389	437	20,628	21,065		71,000
1975	3,751	13,945	17,696	17,926	35,622		71,000
1976	11,257	30,510	41,767	24,936	66,703	25,000	30,000
1977	32,754	50,726	83,480	24,795	108,275	25,000	35,000
1978	41,376	52,688	94,064	17,592	111,656	100,000	30,000
1979	88,833	73,259	162,092	17,241	179,333	120,000	30,000
1980	34,780	34,826	69,606	17,828	87,434	150,000	30,000
1981	18,061	14,801	32,862	15,571	48,433	150,000	30,000
1982	11,164	1,744	12,908	18,633	31,541	150,000	30,000
1983	5	421	426	11,584	12,010	150,000	30,000
1984	397	318	715	9,919	10,634	150,000	30,000
1985	404	269	673	6,115	6,788	150,000	30,000
1986	1	110	111	7,470	7,581	150,000	30,000
1987	194	368	562	10,102	10,664	150,000	30,000
1988	272	539	811	1,958	2,769	150,000	30,000
1989	3,101	2, 870	5,971	6,801	12,772	150,000	30,000
1990	4,440	6,535	10,975	11,670	22,645	150,000	30,000
1991	1,719	1,194	2,913	11,908	14,821	150,000	30,000
1992	924	654	1,578	17,827	19,405	150,000	30,000
1993	276	2,410	2,686	18,012	20,698	150,000	30,000
1994	1,954	3,997	5,951	18,350	24,301	150,000	30,000
1995	48	1,007	1,055	13,976	15,031	150,000	30,000
1996	8,285	457	8,742	16,969	25,711	150,000	21,000

Year	Subarea 3[2] (t)	Subarea 4[3] (t)	Total Subarea 3+4 (t)	Subareas 5+6[4] (t)	Total Subareas (3-6)[5] (t)	TAC (t)[1] 3+4	TAC (t)[1] 5+6
1997	12,748	2,866	15,614	13,356	28,970	150,000	19,000
1998	815	1,087	1,902	23,568	25,470	150,000	19,000
1999	19	286	305	7,388	7,693	75,000	19,000
2000	328	38	366	9,011	9,377	34,000	24,000
2001	23	34	57	4,009	4,066	34,000	24,000
2002	230	30	260	2,750	3,010	34,000	24,000
2003	1,087	46	1,133	6,391	7,524	34,000	24,000
2004	2,540	34	2,574	26,097	28,671	34,000	24,000
2005	548	30	578	12,013	12,591	34,000	24,000
2006	6,957	24	6,981	13,943	20,924	34,000	24,000
2007	230	16	246	9,022	9,268	34,000	24,000
2008	523	11	534	15,900	16,434	34,000	24,000
2009	676	42	718	18,418	19,136	34,000	24,000
2010	102	18	120	15,825	15,944	34,000	24,000
2011	88	50	138	18,797	18,935	34,000	23,328
2012	18	29	47	11,709	11,756	34,000	23,328
AVERAGE							
1976-1981	37,844	42,802	80,645	19,661	100,306		
1982-2011	2,003	917	2,920	12,593	15,513		

[1] TACs during 1974 and 1975, for Subareas 5+6, included *Doryteuthis (Amerigo) pealeii* and, during 1975-1977, 15,000 t and 10,000 t of *I. illecebrosus* were allocated to Russia and Canada, respectively. Countries without allocations were permitted to land 3,000 t from Subareas 3+4 (Dawe 1981).

[2] During some years, SA 3 catches include small amounts from Subarea 2.

[3] SA 4 catches from 1987 onward were updated based on catches in the Canadian Observer Program and MARFIS Databases.

[4] Subareas 5+6 catches during 1963-1978 were not reported by species and are proration-based estimates by Lange and Sissenwine (1980).

[5] Catches from all Subareas during 2010-2012 are provisional.

Table 2. Indices of relative abundance (stratified mean number/tow) and biomass (stratified mean kg/tow) for *Illex illecebrosus* catches in bottom trawl surveys conducted during July in Div. 4VWX (1970-2012). Indices in columns one and four were used in prior assessments and were derived using all survey strata (strata 400-495). The revised indices were used in the current assessment, and include only strata 440-495, in order to allow the computation of coefficients of variation (CVs, %).

Year	Number/tow	Revised Number/tow	CV (%)	Kg/tow	Revised Kg/tow	CV (%)
1970	5.6	5.8	37	0.4	0.4	39
1971	28.5	27.6	39	2.8	2.8	38
1972	6.6	6.6	20	0.7	0.7	22
1973	10.9	10.9	57	1.5	1.5	61
1974	13.4	12.4	16	1.8	1.6	18
1975	44.8	44.8	35	5.0	5.0	34
1976	231.2	247.2	40	42.7	45.6	38
1977	50.9	50.9	28	9.5	9.5	31
1978	16.4	16.1	27	2.3	2.2	30
1979	91.4	94.2	20	14.2	14.6	22
1980	23.3	23.3	34	2.2	2.2	28
1981	35.5	35.5	34	4.9	4.9	36
1982	26.0	25.5	54	2.1	2.1	53
1983	76.9	77.0	60	2.1	2.1	55
1984	14.1	14.1	42	1.5	1.5	48
1985	80.2	81.0	70	2.7	2.7	55
1986	7.7	7.7	43	0.4	0.4	43
1987	4.9	4.9	33	0.4	0.4	37
1988	47.3	47.2	34	2.7	2.7	36
1989	26.3	25.4	26	2.7	2.5	28
1990	40.6	41.3	32	4.8	4.3	33
1991	27.1	27.1	22	1.8	1.8	21
1992	121.7	121.7	69	7.3	7.3	72
1993	79.0	79.0	42	5.4	5.4	29
1994	45.3	45.3	28	4.2	4.2	14
1995	33.9	34.5	36	2.4	2.5	35
1996	11.9	12.2	28	0.9	0.9	26
1997	52.0	53.5	34	4.8	5.0	38
1998	10.0	10.0	24	0.9	0.9	21
1999	16.7	17.0	38	2.0	2.1	36
2000	4.0	4.0	40	0.1	0.1	23
2001	3.3	3.3	31	0.2	0.2	35
2002	13.0	13.0	50	1.1	1.1	53
2003	12.1	12.1	39	0.9	0.9	36
2004	119.3	119.3	61	12.9	12.9	65
2005	9.6	9.6	38	0.7	0.7	38
2006	74.4	74.4	31	10.2	10.2	29
2007	15.5	15.4	28	1.5	1.5	31
2008	29.4	28.7	38	3.1	3.0	40
2009	69.9	69.9	39	6.0	6.0	38
2010	19.6	19.6	28	1.8	1.8	34
2011	23.3	23.4	31	1.9	1.9	27
2012		16.9	20		1.5	19
AVERAGE						
1976-1981	74.8	77.9	30	12.6	13.2	31
1982-2011	37.2	37.2	39	3.0	3.0	38

Table 3. Indices of relative abundance (stratified mean number/tow) and biomass (stratified mean kg/tow) for *Illex illecebrosus* caught during fall bottom trawl surveys conducted in Subareas 5+6 (mainly Sept.-Oct., 1967-2012), Div. 3LNO (mainly Oct.-Dec., 1995-2012), and Div. 4T (Sept., 1971-2012).

	Subareas 5+6		Div. 3LNO		Div. 4T	
Year	**Number/tow**	**Kg/tow**	**Number/tow**	**Kg/tow**	**Number/tow**	**Kg/tow**
1967	1.6	0.2				
1968	1.6	0.3				
1969	0.6	0.1				
1970	2.3	0.3				
1971	1.7	0.3			0.72	0.20
1972	2.2	0.3			0.05	0.02
1973	1.5	0.4			0.08	0.03
1974	2.8	0.4			0.06	0.02
1975	8.7	1.4			2.47	0.54
1976	20.6	7.0			30.77	8.29
1977	12.6	3.7			25.74	7.62
1978	19.3	4.5			52.83	15.04
1979	19.4	6.1			28.47	8.19
1980	13.8	3.3			18.05	4.61
1981	27.1	9.3			5.76	1.70
1982	3.9	0.6			0.39	0.13
1983	1.7	0.2			0.09	0.02
1984	4.5	0.5			0.04	0.02
1985	2.4	0.4			0.32	0.12
1986	2.1	0.3			0.12	0.01
1987	15.8	1.5			0.22	0.05
1988	23.2	3.0			1.33	0.42
1989	22.4	3.3			0.97	0.24
1990	16.6	2.4			1.37	0.29
1991	5.2	0.7			0.17	0.03
1992	8.2	0.8			0.65	0.11
1993	10.4	1.6			0.83	0.13
1994	6.8	0.9			0.79	0.18
1995	8.0	0.7	0.1342	0.0049	0.32	0.03
1996	10.8	0.9	0.1584	0.0183	1.09	0.19
1997	5.8	0.5	0.9824	0.1333	0.89	0.14
1998	14.6	1.4	0.4045	0.0851	1.34	0.30
1999	1.4	0.2	0.0079	0.0018	0.47	0.11
2000	7.4	0.7	0.3186	0.0303	0.27	0.03
2001	4.5	0.3	0.1669	0.0281	0.08	0.01
2002	6.4	0.4	0.6145	0.0879	0.11	0.02
2003	28.5	1.9	0.6964	0.1281	0.22	0.05
2004	5.1	0.4	0.0752	0.0178	1.61	0.37
2005	11.0	0.7	0.0923	0.0169	0.46	0.10
2006	29.5	2.8	0.5678	0.1704	2.33	0.54
2007	15.7	1.3	0.2196	0.0600	7.27	1.43
2008	10.4	1.0	0.1139	0.0275	0.53	0.10
2009	8.7	0.9	0.0142	0.0042	0.88	0.18
2010	10.0	0.5	0.0048	0.0002	0.86	0.18
2011	6.3	0.5	0.0032	0.0001	0.42	0.10
2012	7.9	0.5	0.2162	0.0275	0.64	0.12

Table 4. *Illex illecebrosus* minimum biomass (t) and abundance (000's of squid) estimates derived from EU bottom trawl surveys conducted in Div. 3M during July, 1988-2012.

Year	Biomass (t)	SE	Abundance (000's squid)	SE
1988	4	2	44	22
1989	6	3	70	28
1990	1,334	382	15,138	4,338
1991	939	250	11,707	3,124
1992	53	11	727	149
1993	1	0	20	10
1994	171	21	2,432	303
1995	1	0	46	23
1196	70	10	1,042	144
1997	52	7	774	109
1998	58	7	954	121
1999	15	2	540	75
2000	2	1	142	35
2001	6	1	380	54
2002	6	1	350	62
2003	225	61	3,879	1,052
2004	479	55	4,781	546
2005	82	8	1,669	158
2006	3,553	1,245	27,506	9,638
2007	411	64	6,023	934
2008	5,143	2,392	49,026	22,800
2009	1,694	346	23,434	4,790
2010	43	7	628	102
2011	90	19	734	153
2012	20	4	351	66

Table 5. Relative fishing mortality indices (SA 3+4 nominal catch/Div. 4VWX July survey biomass index) of Northern shortfin squid (*Illex illecebrosus*) in Subareas 3+4 during 1970-2012. Indices were divided by 10,000 to scale the values.

Year	SA 3+4 Nominal Catch (t)	Div. 4VWX July Survey Biomass Index (kg/tow)	Relative Fishing Mortality Indices
1970	1,385	0.4	0.34
1971	8,906	2.8	0.32
1972	1,868	0.7	0.29
1973	9,877	1.5	0.65
1974	437	1.8	0.03
1975	17,696	5.0	0.36
1976	41,767	45.6	0.09
1977	83,480	9.5	0.88
1978	94,064	2.2	4.20
1979	162,092	14.6	1.11
1980	69,606	2.2	3.21
1981	32,862	4.9	0.67
1982	12,908	2.1	0.61
1983	426	2.1	0.02
1984	715	1.5	0.05
1985	673	2.7	0.02
1986	111	0.4	0.03
1987	562	0.4	0.14
1988	811	2.7	0.03
1989	5,971	2.5	0.24
1990	10,975	4.3	0.26
1991	2,913	1.8	0.17
1992	1,578	7.3	0.02
1993	2,686	5.4	0.05
1994	5,951	4.2	0.14
1995	1,055	2.5	0.04
1996	8,742	0.9	0.96
1997	15,614	5.0	0.31
1998	1,902	0.9	0.20
1999	305	2.1	0.01
2000	366	0.1	0.28
2001	57	0.2	0.02
2002	260	1.1	0.02
2003	1,133	0.9	0.13
2004	2,574	12.9	0.02
2005	578	0.7	0.09
2006	6,981	10.2	0.07
2007	246	1.5	0.02
2008	534	3.0	0.02
2009	718	6.0	0.01
2010	120	1.8	0.01
2011	138	1.9	0.01
2012	46	1.5	<0.01
Average			
1976-1981	80,645	13.2	1.69
1982-2011	2,920	3.0	0.13

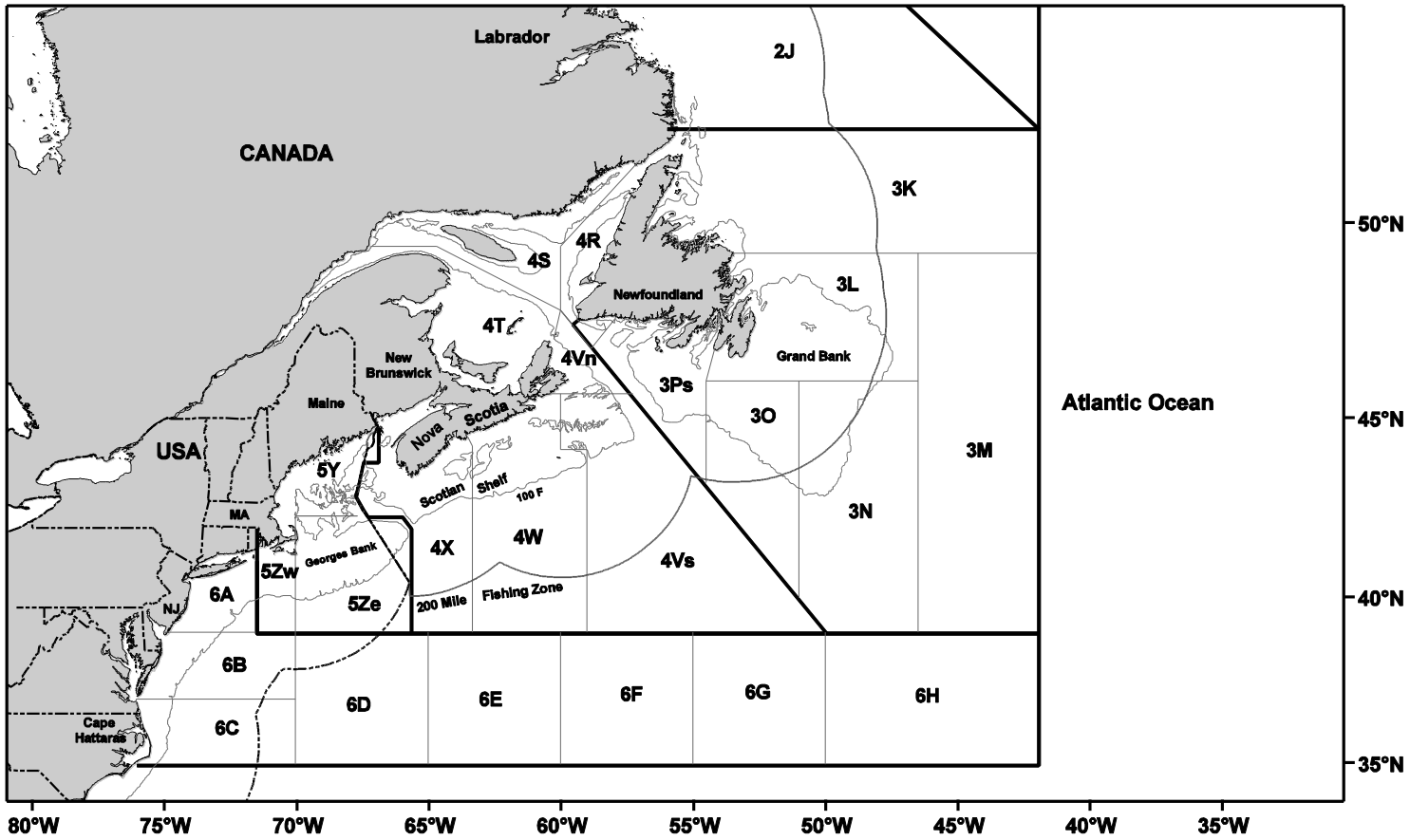

Figure 1. Northwest Atlantic Fisheries Organization (NAFO) nominal catch reporting areas, Subareas 3-6 and associated Divisions, for fisheries occurring in the Northwest Atlantic Ocean.

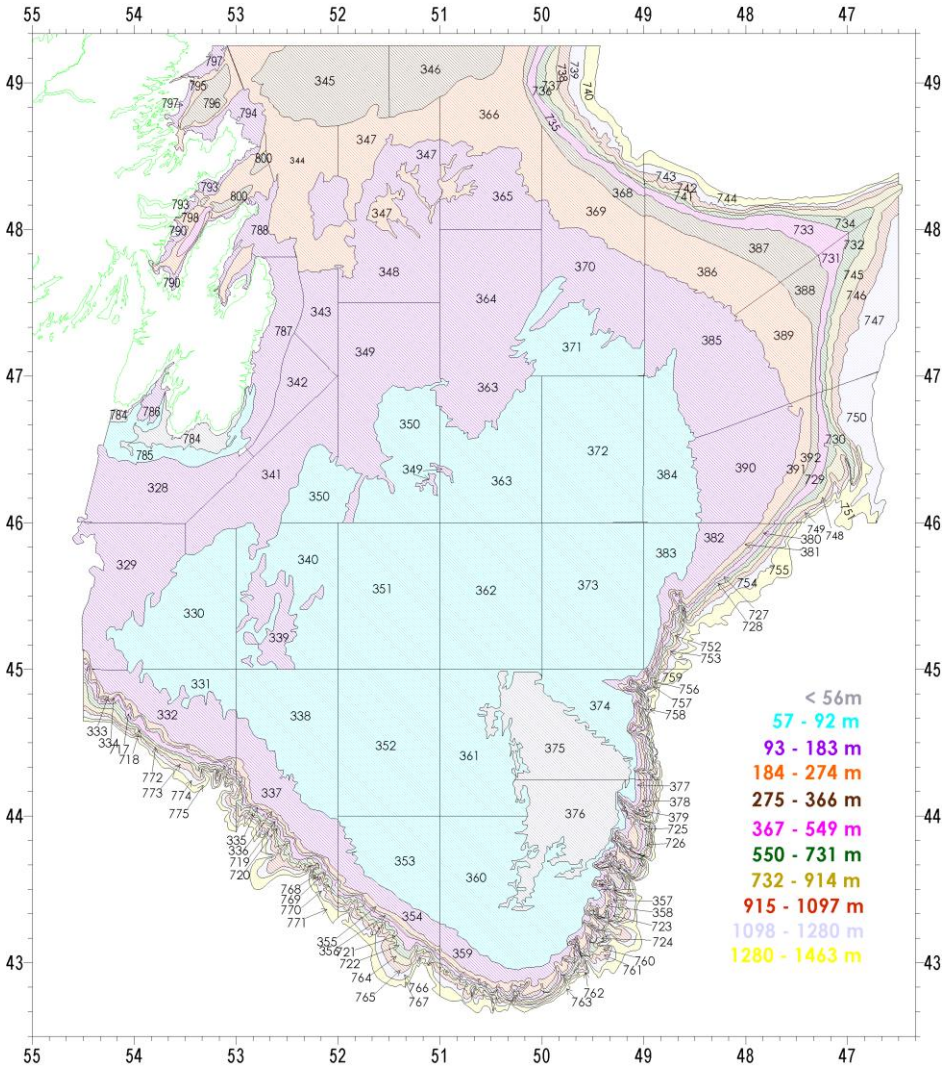

Figure 2. Depth strata sampled during spring and fall bottom trawl surveys conducted in Divisions 3LNO by the Canada Department of Fisheries and Oceans.

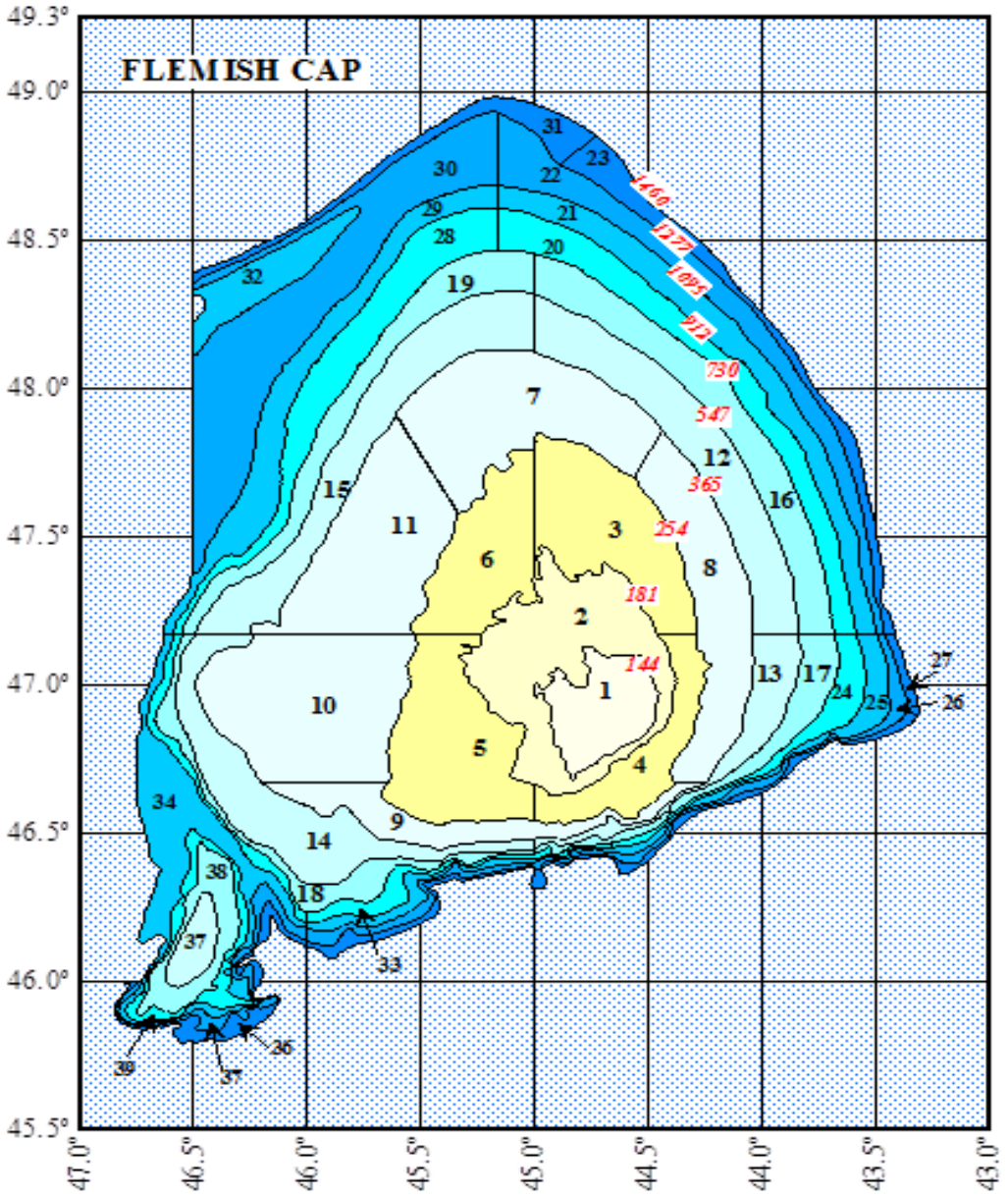

Figure 3. Depth strata sampled during bottom trawl surveys conducted by the European Union on the Flemish Cap, in Division 3M, primarily during July.

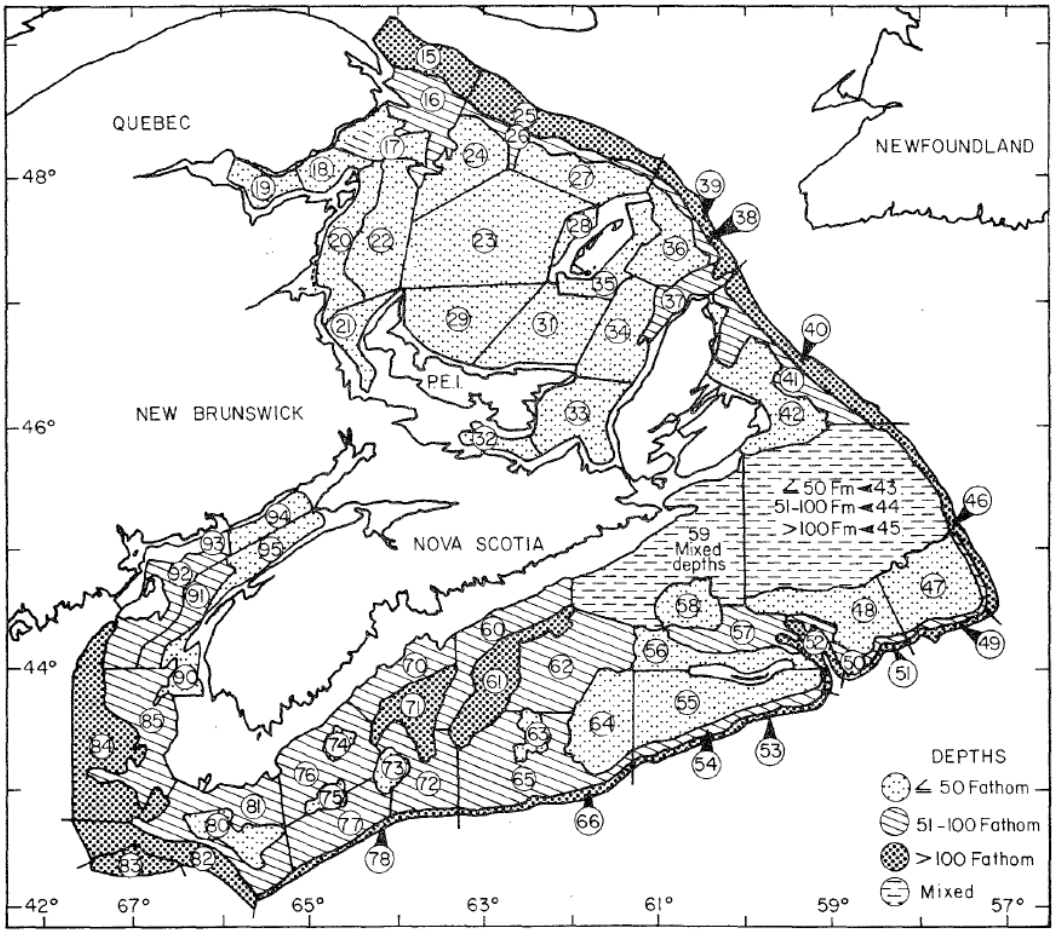

Figure 4. Depth strata sampled during bottom trawl surveys conducted in Division 4T (the southern Gulf of St. Lawrence, strata 15-39) during September, and in Division 4VWX (the Scotian Shelf and Bay of Fundy, strata 40-95) during July, by the Canada Department of Fisheries and Oceans. Strata are now referenced as three-digit numbers with a "4" preceeding the strata numbers shown in the figure.

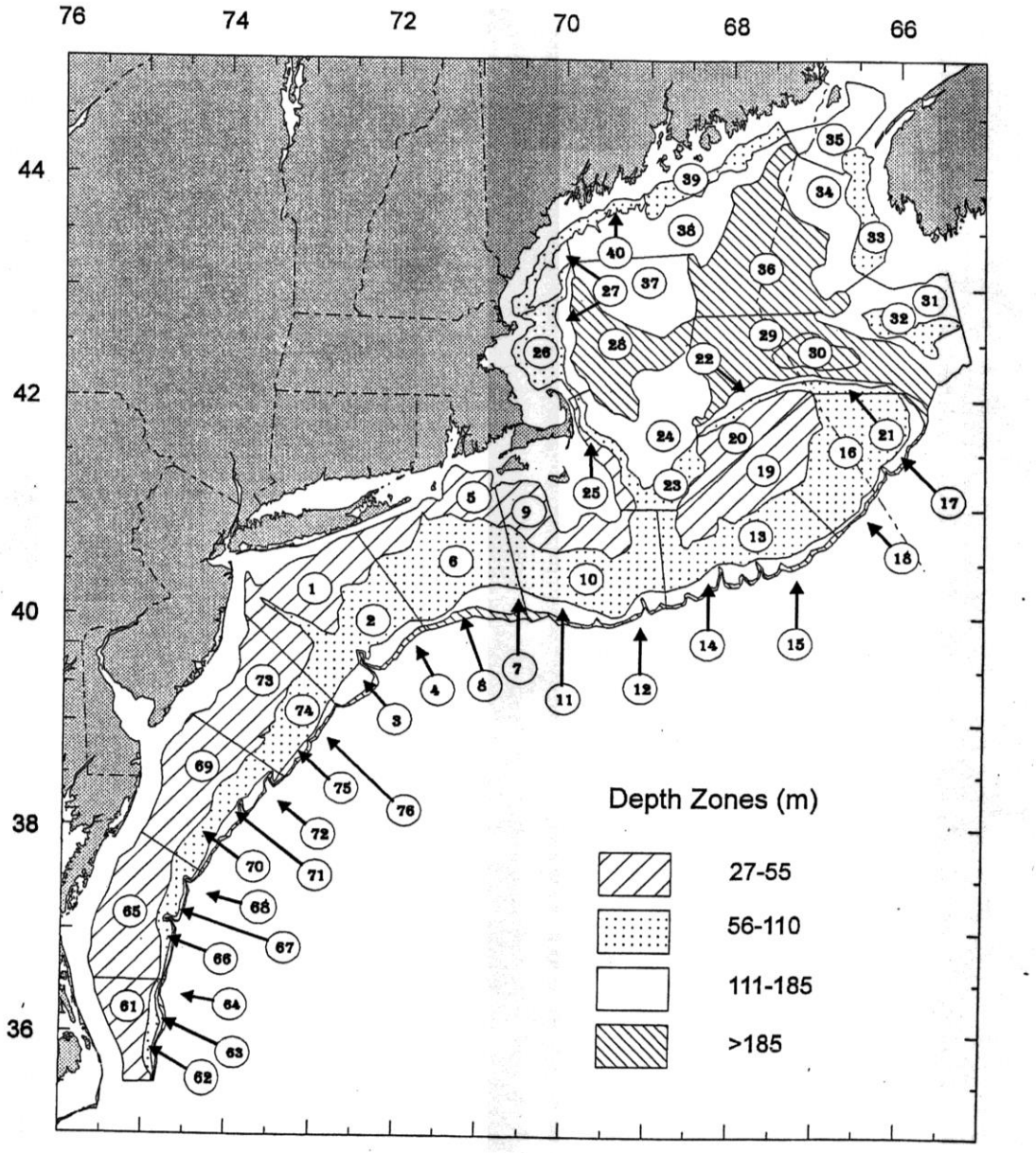

Figure 5. Offshore depth strata sampled during fall bottom trawl surveys conducted off east coast of the USA, in Subareas 5+6, by the Northeast Fisheries Science Center.

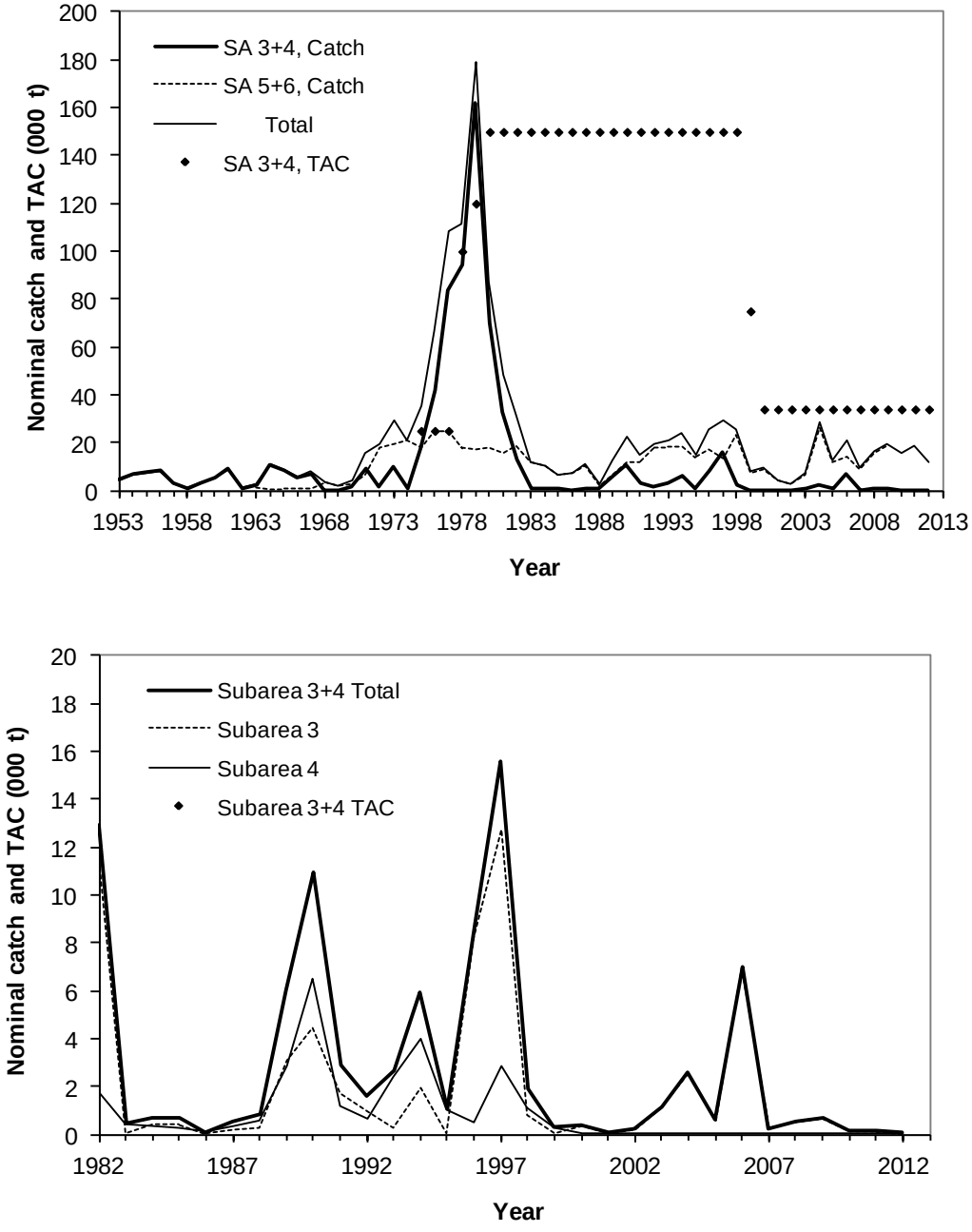

Figure 6. Nominal catches ('000 t) of *Illex illecebrosus* and TACs ('000 t) in Subareas 3+4 during 1953-2012, and in Subareas 5+6 during 1963-2012 (top), and nominal catches in Subarea 3 and Subarea 4 during 1982-2012 (bottom).

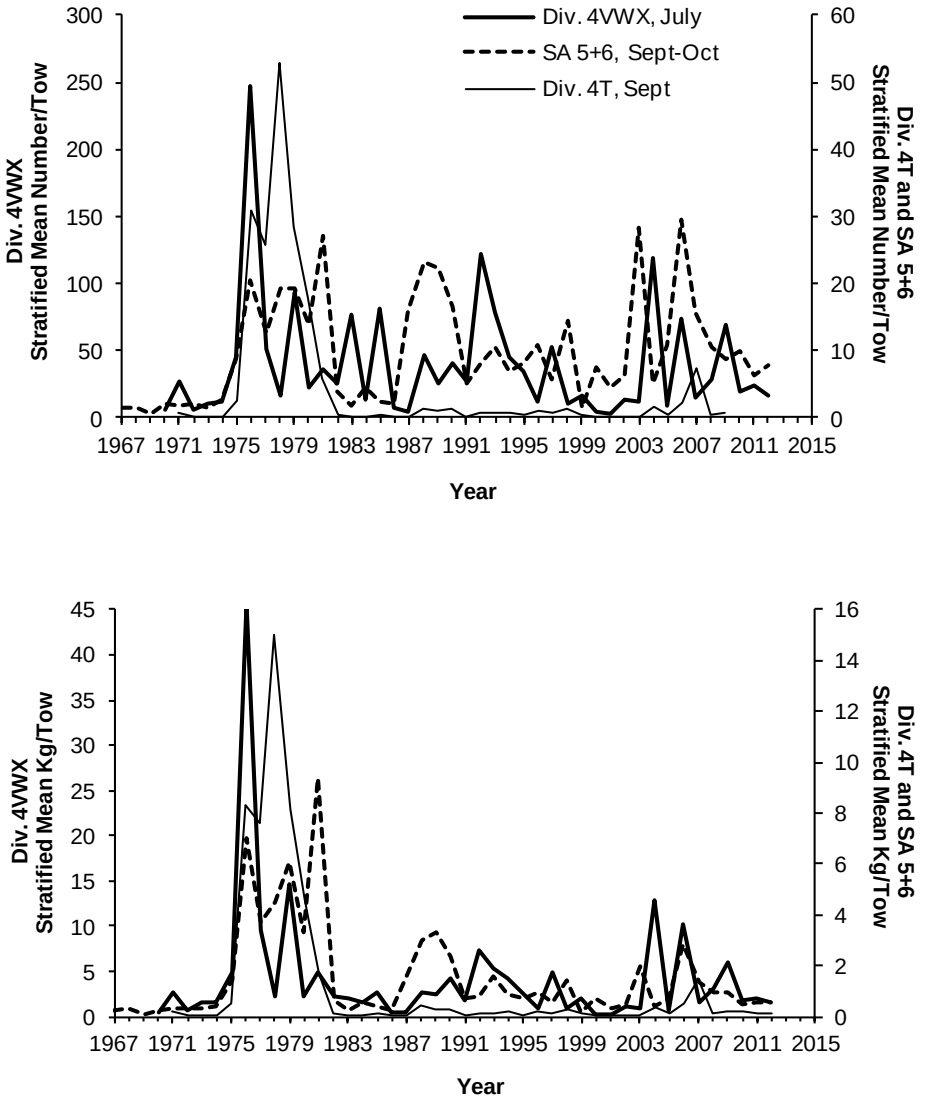

Figure 7. *Illex illecebrosus* relative abundance (stratified mean number/tow) (top) and biomass indices (stratified mean kg/tow) (bottom) from the Canadian Div. 4VWX (July, 1970-2012) and Div. 4T surveys (September, 1971-2012), and the U.S. bottom trawl surveys in Subareas 5+6 (September-October, 1967-2012).

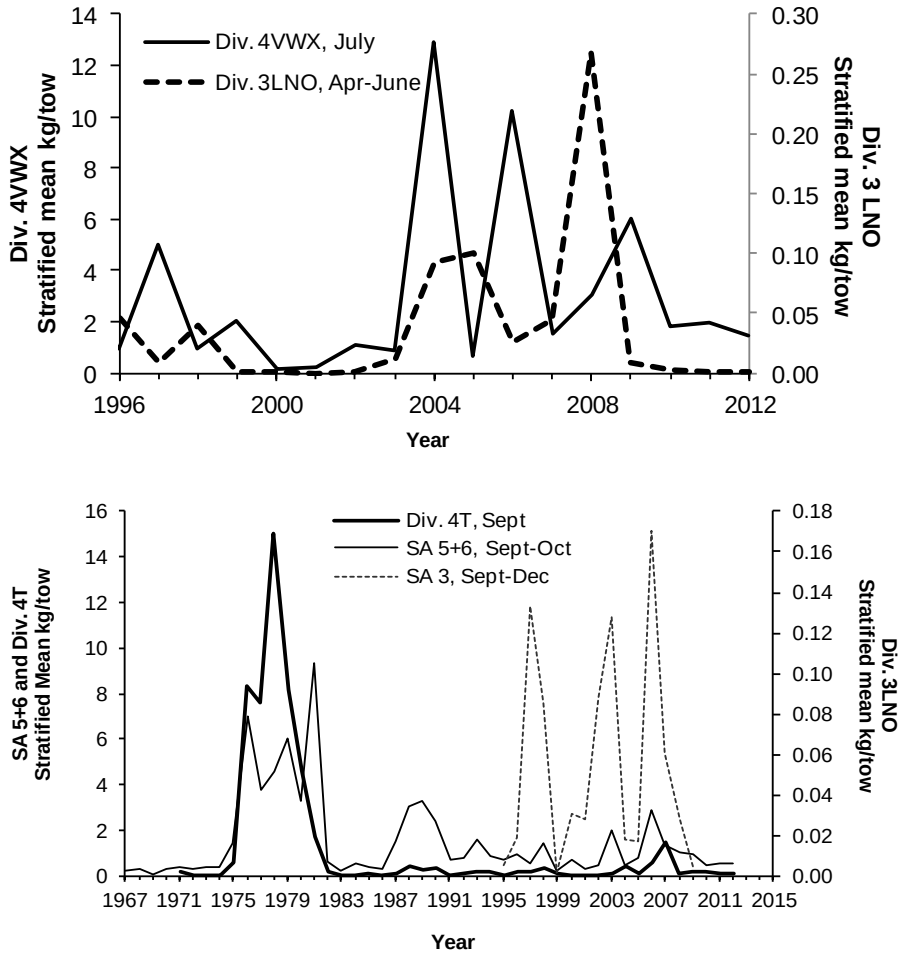

Figure 8. Relative biomass indices (stratified mean kg/tow) of *Illex illecebrosus* derived from the July Div. 4VWX surveys and the April-June surveys in Div. 3LNO for 1996-2012 (top) and biomass indices from fall surveys conducted in Div. 4T, Subareas 5+6, and Div. 3LNO (bottom).

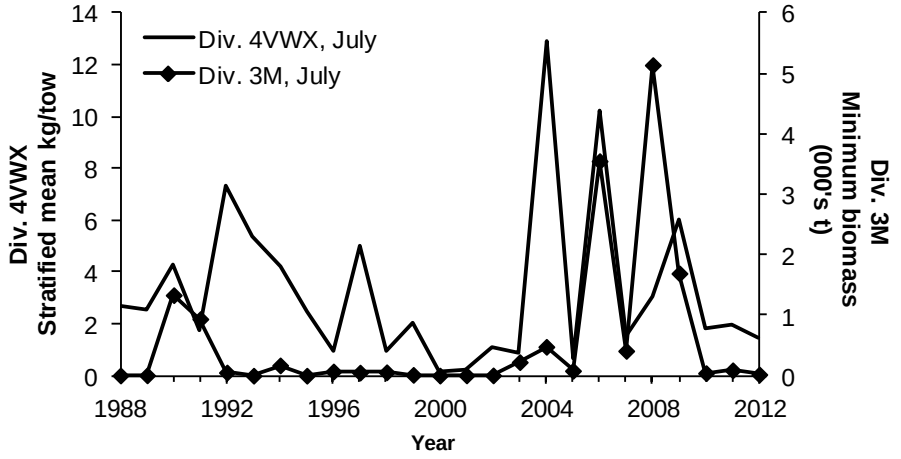

Figure 9. Relative biomass indices (stratified mean kg/tow) of *Illex illecebrosus*, derived from the July Div. 4VWX surveys, and minimum biomass estimates (000's t) derived from the July EU surveys on the Flemish Cap in Div. 3M for 1988-2012.

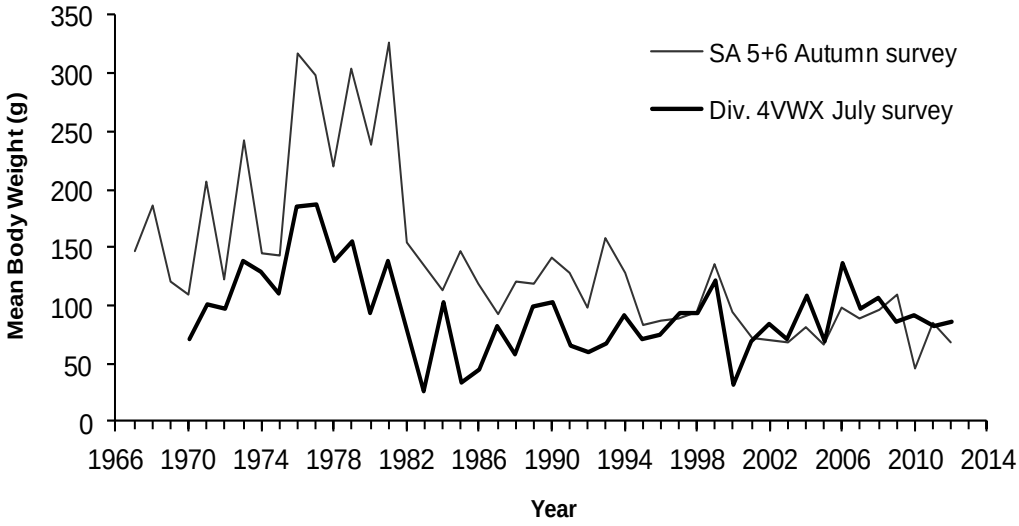

Figure 10. Mean weight per individual (g) of *Illex illecebrosus* caught in the Subareas 5+6 autumn bottom trawl surveys (1967-2012) and Canadian Div. 4VWX July bottom trawl surveys (1970-2012).

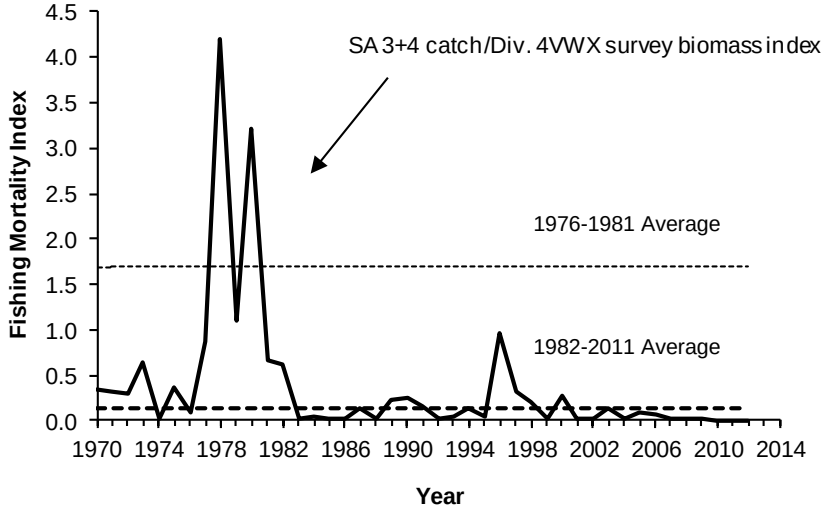

Figure 11. Relative fishing mortality indices (SA 3+4 nominal catch/Div. 4VWX July survey biomass index) in Subareas 3+4 during 1970-2012, and averages during the high (1976-1981) and low (1970-1975 and 1982-2012) productivity periods. Indices were divided by 10,000 to scale the values.