NOT TO BE CITED WITHOUT PRIOR
REFERENCE TO THE AUTHOR(S)

Northwest Atlantic Fisheries Organization

Serial No. 6577 **SCR Doc. 16/34REV**

SCIENTIFIC COUNCIL MEETING – JUNE 2016

Assessment of Northern Shortfin Squid (*Illex illecebrosus*) in Subareas 3+4 for 2015

by

L. C. Hendrickson[1] and M. A. Showell[2]

[1] U. S. National Marine Fisheries Service, Northeast Fisheries Science Center,
166 Water St., Woods Hole, MA 02543
[2] Department of Fisheries and Oceans, Bedford Institute of Oceanography
P. O. Box 1006, Dartmouth, Nova Scotia B2Y 4A2

Abstract

This report pertains to the assessment of the northern component of the Northern shortfin squid (*Illex illecebrosus*) stock, in Subareas 3+4, which is managed by the Northwest Fisheries Organization (NAFO). However, research survey biomass indices and catch data for the southern stock component in Subareas 5+6, which is managed by the United States of America, are also presented because the species is considered to constitute a single stock throughout its range in Subareas 2-6. Two general levels of productivity have been identified for the Subareas 3+4 stock component 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 1982-2014). During the high productivity period, relative biomass indices averaged 13.2 kg per tow and squid mean body weights averaged 150 g. During the 1982-2014 low productivity period, relative biomass indices averaged 2.8 kg per tow and squid mean body weights averaged 80 g. Mean body weight decreased from a low productivity period high of 137 g in 2006 to 42 g in 2013 but was above average during 2006-2015, with the exception of 2013, and was 96 g in 2015. Relative biomass indices generally declined after 2004 and were below the low productivity period average during 2010-2014. During 2015, the biomass index was the third lowest value in the time series (0.2 kg per tow). Trends in the biomass indices for fall bottom trawl surveys conducted in Division 4T and Subarea 5+6 were compared with those for Division 4VWX because all three time series are correlated, as are the mean body weights for the Subareas 5+6 and Division 4VWX surveys. Since 1999, there has been no directed fishery in Subarea 4 and the majority of catches from Subareas 3+4, during 2000-2011, were from the Subarea 3 inshore jig fishery. Jig fishery catches have been well below the 1982-2014 average (205 t) since 2007 and there were no catches of squid during 2013-2015. Relative fishing mortality indices in Subareas 3+4 were generally well below the average for the low productivity period during 2001-2015. Based on these trends, the Subareas 3+4 stock component remained in a state of low productivity during 2015.

1.0 Introduction

Northern shortfin squid (*Illex illecebrosus*) is a species with a lifespan of less than one year (Dawe and Beck, 1997; Hendrickson, 2004). The population 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 the Northern shortfin squid resource located within the 200-mile Exclusive Economic Zone (EEZ) of Canada, which surrounds most of Newfoundland, and international waters on the "tail" and "nose" of the Grank Bank and on 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 resource located within the 200-Exclusize Economic Zone of the East Coast of the USA, from the Gulf of Maine to Cape Hatteras, North Carolina, and international waters shown in Fig. 1. Fishery and research survey data are presented herein for both stock components, because of their relationship to one another as a unit stock, however, the focus of the subject assessment is the northern stock component. Details about the fisheries that occur in each Subarea area and the management of the resource is described in Arkhipkin et al. (2015) and details about the habitat and life history of the species are described in Hendrickson and Holmes (2004).

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 along the edge of the continental shelf in the Mid-Atlantic Bight (NEFSC, 1999).

Management of Northern shortfin squid stock (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 Northern shortfin squid were increased from 25 000 to 120 000 t, respectively, each time the TACs were exceeded (Lange, 1978; Table 1). Despite a rapid decline in the catches from both Subarea 3 and Subarea 4 after a 1979 peak catch of 162 092 t, which was followed by a collapse of the northern stock component in 1983, a TAC of 150,000 t remained in place for Subareas 3+4 during 1980-1998. The TAC was reduced to 75,000 t in 1999, and since 2000, the TAC has been 34,000 t. The 34,000-t TAC is a proxy for F_{lim} that represents the maximum potential yield which the northern stock component may be able to sustain under the current low productivity regime (Rivard et al., 1998). However, this proxy does not account for the effects of environmental conditions on squid yield and assumes that the high relative fishing mortality indices that occurred during 1976-1981 (which were followed by a rapid decline in the Div. 4VWX biomass indices) are appropriate for the current low productivity regime.

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 set at 30 000 t based on the results of a yield-per-recruit model. After 1995, TACs for Subareas 5+6 consisted of the catches associated with either MSY-based biological reference points, or proxies thereof (e.g., %MSP) and were computed using several different types of stock assessment models. The TAC was 24 000 t during 2000-2010, 23 328 t during 2011, 22 915 t during 2012-2014 and 22 445 t during 2015. 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 2013 (Hendrickson and Showell, 2013) and interim monitoring reports were used to assess the 2013 and 2014 stock status. The subject 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 2015.

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 1953-2015 from Subarea 3 and Subarea 4 and for 1963-2015 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, DFO, pers. comm.) and catches reported in the NAFO STATLANT 21 Database for the international squid fleets. Subarea 4 catch data were obtained from the MARFIS Database, maintained by the DFO (Maritimes Region), which contains catches by Canadian vessels and international vessels with Canadian catch allocations. During 1987-1998, the Subarea 4 catches also included 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 and biomass were derived for Northern shortfin squid using data from stratified, random multi-species bottom trawl surveys conducted in Subarea 3 and Subarea 4. All of the surveys incorporated stratified-random sampling designs with stratification based on depth. Surveys have been conducted by CA DFO: in Div. 3LNO during the fall (mainly during October-December, since 1995) and spring (mainly during May-June, since 1996); in Div. 4T (southern Gulf of St. Lawrence) during September (since 1971); and in Div. 4VWX (Scotian Shelf and Bay of Fundy) during July (since 1970). Minimum biomass and abundance estimates were also derived using area-swept data from bottom trawl surveys conducted by the EU-Spain/Portugal in Div. 3M (Flemish Cap), primarily during July (since 1988).

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 (since 1967). 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 conducted solely during the daytime.

2.2.1 Subarea 3

Relative abundance and biomass indices were derived for the spring (1996-2015) and fall (1995-2015) DFO bottom trawl surveys conducted in Div. 3LNO using data from the strata within which Northern shortfin squid were consistently caught (Hendrickson, 2006). Although the spring and fall surveys were also conducted prior to 1995, catches of *I. illecebrosus* were not consistently quantified (Earl Dawe, CA DFO, pers. comm.). The strata set used to compute the spring survey 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 survey 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) which are "sister" ships. 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 bottom trawl surveys conducted by the EU-Spain/Portugal on the Flemish Cap in Div. 3M. Survey design and sampling protocols are described in Vázquez (2010) and Vázquez et al. (2013). Strata 1-19 (depths of 120-730 m) were sampled during 1988-2003 and strata 1-25 and 28-34 (depths of 730-1 460 m) were sampled from 2004 onward (Fig. 3). All surveys were conducted during the daytime (0600-2200) and occurred primarily during July, but some sampling also occurred during June. A Lofoten bottom trawl was consistently used to conduct the surveys with a codend mesh size of 35 mm during most years (exceptions were codend mesh sizes of 40 mm in 1994, 25 mm in 1998 and 30 mm in 1999; Vázquez, 2010). Different vessels have also been used to conduct the survey. During 1988 and 1991-2002, the surveys were conducted with the R/V *Cornide de Saavedra*, but two different vessels were used during 1989 and 1990. The R/V *Cornide de Saavedra* was replaced by the R/V *Vizconde de Eza* in 2003 and has been used since then (Vázquez, 2010). Indices used in the assessment included swept-area estimates of minimum abundance and biomass, derived for 1988-2015 with data from strata 1-19. Minimum biomass and abundance estimates for 2004-2015 were also derived using data which included strata deeper than 730 m (strata 1-25 and 28-34) and these indices were compared to the indices from strata 1-19. Data from comparative fishing trials, conducted during 2003 and 2004, were used to estimate new vessel conversion factors for the 1988-2002 biomass and abundance indices (González-Troncoso, 2016).

2.2.2 Subarea 4

Relative abundance and biomass indices for Div. 4VWX were derived, for 1970-2015, using survey catches from strata 440-495, encompassing a depth range of about 50-400 m on the Scotian Shelf and Bay of Fundy (Fig. 4A). 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 2005-2015) and the CCGS *Teleost* (2004; (Clark and Emberley, 2011)). There are no gear or vessel conversion factors available with which to standardize the *I. illecebrosus* 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, for 1971-2015, using data from all survey strata (Fig. 4B), encompassing a depth range of 20-274 m in the southern Gulf of St. Lawrence. 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 FSV *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 1970-2015, 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 rapidly and the Subareas 3+4 fishery collapsed in 1983. Catches in Subareas 3+4 totaled 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. During 2007-2011, catches in Subareas 3+4 ranged between 120 t and 718 t, then decreased again from 47 t in 2012 to 14 t in 2015 (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 decreased 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* and ranged between 110 t and 6,535 t. Since 2000, there has been no directed fishery for *I. illecebrosus* in Subarea 4 (NAFO, 2003) rather catches have been primarily from bycatch in the Canadian small-mesh bottom trawl fishery for silver hake and 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.). During 2000-2010, catches averaged 29 t, but have since decreased from 38 t in 2011 to 14 t in 2015.

Beginning in 2004, a majority of the squid catches in the STATLANT 21A Database, from the Maritimes Region of CA, were listed as either *Loligo pealeii* (now known as *Doryteuthis pealeii*) or "unspecified squid" (i.e., the latter designation represents either "Ommastrephidae sp. or Loliginidae sp. of squid"). The *L. 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. Discussions with the MARFIS Database staff from the Maritimes Region, as well as the NAFO database staff, did not resolve the issue. Catch data from the MARFIS Database were included in the stock assessment because they were considered more accurate because, since 1999, there has not been a directed fishery in Subarea 4 because foreign-flagged vessels have not been licensed to fish on the Scotian Shelf. Based on the fact that very small catches of *L. pealeii* occurred infrequently in the July Div. 4VWX surveys, and that small amounts of *L. pealeii* were reported as such in the MARFIS Database, the small amounts of "unspecified squid" catch included in the MARFIS Database (0.001-22 t during 2006-2015) were considered to be *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, 5,700 t in 1978, only comprised a small percentage (14%) of the total landings from Subarea 3 (Dawe, 1981). Small amounts of *I. illecebrosus* bycatch have occurred in Div. 3M (average = 12 t during 1976-2015) but there has never been a directed fishery. Total catches from Subarea 3 increased rapidly during the 1970's, from 3,751 t in 1975 to a peak of 88,833 t in 1979, but then decreased 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. During 1998-2005 catches were highly variable and averaged 699 t. The largest recent catch from Subarea 3 was 6,957 t in 2006. During 2009-2012, Subarea 3 catches declined from 676 t to 18 t, respectively, and there were no *Illex* catches during 2013-2015.

3.1.3 Subareas 5+6

During 1964-1966, the Russian fleet began landing Northern shortfin squid 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 reached a peak of 23,597 t in 1998, but the fishery was closed for the year beginning 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) occurred and the quota of 24,000 t was exceeded. During 2005-2012, catches averaged 14, 453 t, but then decreased during 2013-2015 and averaged 4,994 t. The catch during 2015 was 2,423 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 generally 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 1998, 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 highest level since 1982. Total catches declined during 2009-2014 from 19,136 t to 8,788 t, respectively, and totalled 2,437 t in 2015.

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 is the best indicator of shortfin squid biomass in Subareas 3+4 because the survey occurs during July, a time when the species is most available in the continental shelf survey area, and because the survey occurs prior to the Subarea 3 fishery and nearest the start of the fisheries in Subareas 4-6. In addition, the Div. 4VWX survey covers the largest area of shortfin squid habitat in Subareas 3+4. Thus, indices for the spring/summer surveys in Div. 4VWX, Div. 3M and Div. 3LNO can be considered as measures of pre-fishery biomass. Indices for the autumn surveys conducted in Subareas 5+6 and Div. 4T can be considered as measure of post-fishery biomass because they occur near the end of the directed fisheries in Subareas 4-6, particularly since 1998, when total catches have been predominately from the Subareas 5+6 fishery which ends in September or early October during most years.

3.2.1 Subareas 3+4

Biomass indices for the Div. 3LNO spring and fall surveys were very low, and during 1996-2014, averaged 0.036 kg per tow and 0.047 kg per tow, respectively. Only the fall survey indices for Div. 3LNO were presented because they were the higher of the two time series (Table 3). The low biomass indices were likely due to low availability of the species to the spring and fall surveys because the population is migrating on and off the Grand Bank, respectively (Hendrickson, 2006). As a result, the Div. 3LNO spring and fall survey indices were considered to be poor indicators of the relative biomass of Northern shortfin squid in Subareas 3+4.

The Div. 4VWX biomass indices showed a high degree of interannual variability. However, a period of high productivity occurred during 1976-1981, averaging 13.2 kg/tow (average % CV = 31%), followed by low productivity periods during 1970-1975 and 1982-2014, averaging 2.0 kg/tow and 2.8 kg/tow (average % CVs = 35% and 36%), respectively (Table 2, Fig. 7). During the 1982-2014 low productivity period, the biomass index was highest in 2004 (12.9 kg/tow) and the second highest in 2006 (10.2 kg/tow), but both indices were followed by very low indices in subsequent years (e.g., 0.7 kg/tow in 2005 and 1.5 kg/tow in 2007). The estimate of the 2004 index was very imprecise (% CV = 65%) but the 2006 index was fairly precise (% CV = 29%). Biomass indices generally declined after 2004 and were below the 1982-2014 low productivity period average during 2010-2014. During 2015, the biomass index was the third lowest value in the time series (0.2 kg per tow, % CV = 39%).

The Div. 3M survey of the Flemish Cap is also conducted primarily during July, but the survey covers a smaller area of *Illex* habitat than the Div. 4VWX survey. In addition, the Flemish Cap is more isolated from the continental shelf *Illex* habitats in Subarea 3 due to its location farther offshore and separation from the Grand Bank by the deep waters of the Flemish Pass. The fit for the vessel conversion factor for biomass (1.279) was very good (R^2 = 0.8225, p < 0.00001). However, the fit for the abundance conversion factor was very poor (R^2=0.0113) so it was not utilized to standardize the abundance indices and the abundance indices were not presented. With respect to biomass, the R/V *Vizconde de Eza* was 28% more efficient at catching *Illex* than the R/V *Cornide de Saavedra* (González-Troncoso, 2016). Biomass indices during 1988-2015 were low, less than 100 t during most years, with the exception of 1990-1991, 2006, and 2008-2009. Biomass indices averaged 593 t and ranged between 0 t and 5,137 t (Table 4, Fig. 8). During 2004-2015, catches of Northern shortfin squid at depths between 730 m and 1,460 m were highly variable, but were low during most years and averaged an additional 1.5% in biomass (range of 0-7.9%). Biomass indices were highest during 2006-2009, reaching a peak of 5,137 t in 2008 then declining to 1,363 t in 2009. However, these high biomass indices were not attributable to high squid biomass in strata deeper than 730 m, because the latter comprised only 0 to 0.4% of the annual biomass indices during this time period. There were no catches of *Illex* during 2013 and 2015 and only 3 t in 2014. It is possible that the magnitude of the 3M survey indices are influenced by the timing of the annual inshore migration of the species which generally occurs during July (Dawe, 1981), however, the residence time of the species on the Flemish Cap is unknown. Trends in the Div. 3M biomass indices were similar to the trends in the Div. 4VWX biomass indices only during periods of high biomass in Div. 3M. This suggests that the Flemish Cap represents marginal *Illex* habitat in July during most years, but that the survey indices are useful biomass indicators for Subareas 3+4 when squid biomass is high on the Flemish Cap (Fig. 8).

Similar to the Div. 4VWX survey biomass indices, biomass indices for both the Div. 4T and Subareas 5+6 fall surveys were much higher during 1976-1981 than thereafter. There were no *Illex* catches in the Div. 4T survey during 2015 and biomass indices during 2013 and 2014 were very low, similar to the 2013-2015 biomass indices for Div. 4VWX. Trends in the biomass indices for the both surveys were correlated with those for the Div. 4VWX surveys during 1970-1997 (Dawe and Hendrickson 1998), despite the fact that the 4T survey area covers only a small portion of shortfin squid habitat in Subarea 4.

3.2.1 Subareas 5+6

Similar to the Div. 4VWX biomass indices, the Subareas 5+6 biomass indices were consistently high during 1976-1981 (average = 5.7 kg per tow), but have since been much lower (1982-2014 average = 1.0 kg per tow) and highly variable (Table 3, Fig. 7). Since 1982, biomass indices for Subareas 5+6 have exhibited two general rise-and-fall periods; an increase to a peak of 3.3 kg per tow, in 1989, which was followed by a general decline through 1999. A second biomass increase, 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 in 2010, a level at which the index has generally remained since then. With respect to recent relative abundance indices, the 2003 (28.5 squid per tow) and 2006 (29.5 squid per tow) spikes were due to large catches at one or two stations. In contrast, during 1981 (year during the high productivity period), 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 many stations. The variabilities of these post-fishery survey indices are also affected by the timing of the species' annual off-shelf migration.

3.5 Body Size

Trends in squid mean body size reflect the combined effects of emigration/immigration, recruitment, growth and mortality of these semelparous species (NEFSC, 1999; Hendrickson, 2004). For *I. illecebrosus*, these factors are primarily influenced by environmental conditions (Dawe et al., 2007). Mean body weights were highest during the high productivity period (1976-1981 average = 150 g) and lower during the 1982-2014 low productivity period (average = 80 g) in the Div. 4VWX July survey (Fig. 9A). Similarly, mean body weights in the Subareas 5+6 autumn surveys were highest during 1976-1981 (average = 284 g) and lower during 1982-2014 (average = 101, Fig. 9B). During 1970-2015, there was a fairly strong, positive correlation between the mean body weights of squid from both surveys ($r = 0.64$, $p < 0.0001$, Fig. 10). During 1982-1994, the mean body weight of squid caught in the Subareas 5+6 survey averaged 127 g and was generally above the low productivity period average, but then declined (average during 1995-2014 = 85 g) and was mainly below the average during 2000-2015 (Fig. 9B). Trends in mean body weights from the Div. 4VWX survey were slightly different during 1982-2014. Since 1982, the mean body weight of squid caught in the Div. 4VWX surveys has fluctuated widely around the 1982-2014 low productivity period average, but was generally at or below the average (although increasing) during 1982-1996 and was generally above the average during 2002-2015 (Fig. 9A). After reaching a low productivity period peak of 137 g in 2006, mean body weight declined to the fourth lowest value in the time series during 2013, but then increased and was 96 g in 2015.

3.6 Relative Fishing Mortality Indices

Relative fishing mortality indices for Subareas 3+4 were highest during 1977-1982 and reached a peak of 4.20 in 1978. During 1976-1981, relative fishing mortality indices averaged 1.69 but were much lower during 1983-2014; averaging 0.12 with a peak of 0.96 in 1996 (Table 5, Fig. 11). The indices have consistently been below 0.12 since 2004, and during 2009-2015, were the lowest values in the time series.

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 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 relative biomass indices and squid mean body weights derived from the July Div. 4VWX bottom trawl surveys and relative fishing mortality indices (Rivard *et al*., 1998; Hendrickson, 1999). A period of high productivity (1976-1981) occurred between two low productivity periods (1970-1975 and 1982-2014). During the high productivity period, relative biomass indices averaged 13.2 kg per tow and squid mean body weights averaged 150 g. During the 1982-2014 low productivity period, relative biomass indices averaged 2.8 kg per tow and squid mean body weights averaged 80 g. Relative biomass indices generally declined after 2004 and were below the low productivity period average during 2010-2014. During 2015, the biomass index was the third lowest value in the time series (0.2 kg per tow). Biomass indices for Div. 3M and Div. 4T were the lowest in the time series during 2013-2015. Mean body weights of squid in Div. 4VWX decreased from a low productivity period high of 137 g in 2006 to 42 g in 2013 but was above average during 2006-2015, with the exception of 2013. During 2015, mean body weight (96 g) was above the low productivity period mean but was smaller than the 2014 value and much smaller than the values for the high productivity period. With the exception of 2013, relative fishing mortality indices for Subareas 3+4, during 2009-2015, 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 2015.

Acknowledgements

We are grateful to the following individuals for providing us with data for the stock assessment: Hugues Benoît, Antonio Vázquez, Diana González-Troncoso, Jim Simon, Earl Dawe, Don Stansbury and Will Coffey.

References

Arkhipkin, Alexander, I., Paul G. K. Rodhouse, Graham J. Pierce, Warwick Sauer, Mitsuo Sakai, Louise Allcock, Juan Arguelles, John R. Bower, Gladis Castillo, Luca Ceriola, Chih-Shin Chen, Xinjun Chen, Mariana Diaz-Santana, Nicola Downey, Angel F. González, Jasmin Granados Amores, Corey P. Green, Angel Guerra, Lisa C. Hendrickson, Christian Ibáñez, Kingo Ito, Patrizia Jereb, Yoshiki Kato, Oleg N. Katugin, Mitsuhisa Kawano, Hideaki Kidokoro, Vladimir V. Kulik, Vladimir V. Laptikhovsky, Marek R. Lipinski, Bilin Liu, Luis Mariátegui, Wilbert Marin, Ana Medina, Katsuhiro Miki, Kazutaka Miyahara, Natalie Moltschaniwskyj, Hassan Moustahfid, Jaruwat Nabhitabhata, Nobuaki Nanjo, Chingis M. Nigmatullin, Tetsuya Ohtani, Gretta Pecl, J. Angel A. Perez, Uwe Piatkowski, Pirochana Saikliang, Cesar A. Salinas-Zavala, Michael Steer, Yongjun Tian, Yukio Ueta, Dharmamony Vijai, Toshie Wakabayashi, Tadanori Yamaguchi, Carmen Yamashiro, Norio Yamashita and Louis D. Zeidberg. 2015. World squid fisheries. Rev. in Fish. Sci. & Aquacult., 23:2, 92-252. DOI: 10.1080/23308249.2015.1026226.

Amaratunga, T., M. Roberge, and L. Wood. 1978. An outline of the fishery and biology of the short-finned squid *Illex illecebrosus* in eastern Canada. *In* Proceedings of the workshop on the squid *Illex illecebrosus*. Dalhousie University, Halifax, Nova Scotia. May, 1978. Balch, N., T. Amaratunga, and R. K. O'Dor (Eds.) Fisheries and Marine Service Technical Report No. 833. Fisheries and Oceans, Canada.

Arazovitz, T.R. 1981. A brief historical review of the Woods Hole Laboratory trawl survey time series. Pp. 62-67 in W.G. Doubleday and D. Rivard (eds.), *Bottom Trawl Surveys*. Canadian Special Publication of Fisheries and Aquatic Sciences 58.

Benoît, H.P. 2006. Standardizing the southern Gulf of St. Lawrence bottom-trawl survey time series: Results of the 2004-2005 comparative fishing experiments and other recommendations for the analysis of the survey data. DFO Can. Sci. Advis. Sec. Res.Doc. 2006/008. 80 p.

Benoît, H.P. and D. P. Swain. 2003. Accounting for length- and depth-dependent diel variation in catchability of fish and invertebrates in an annual bottom-trawl survey. ICES J. Mar. Sci. 60: 1298-1317.

Brodie, W. 2005. A description of the autumn multispecies surveys in SA 2+Divisions 3KMNO from 1995-2004. NAFO SCR Doc. 05/8, Ser. No. N5083, 21 p.

Clark, D.S. and J. Emberley. 2011. Update of the 2010 summer Scotian Shelf and Bay of Fundy research vessel survey. Can. Data Rep. Fish. Aquat. Sci. 1238, 98 p.

Dawe, E. G. 1981. Development of the Newfoundland squid (*Illex illecebrosus*) fishery and management of the resource. J. Shellfish Res. 1: 137-142.

Dawe, E. G. and P. C. Beck. 1997. Population structure, growth and sexual maturation of short-finned squid at Newfoundland, Canada, based on statolith analysis. Can. J. Fish. Aquat. Sci. 54: 137-146.

Dawe, E. G., P. C. Beck, H. J. Drew and A. L. Pardy. 2004. Biological characteristics of squid (*Illex illecebrosus*) in the Newfoundland area (NAFO Subarea 3) during 2001-2003. SCR Doc. 04/52, Ser. No. N5005, 12 p.

Dawe, E. G. and L. C. Hendrickson. 1998. A review of the biology, population dynamics, and exploitation of short-finned squid in the northwest Atlantic Ocean, in relation to assessment and management of the resource. NAFO SCR Doc. 98/59, Ser. No. N3051, 33 p.

Dawe, E. G., L. C. Hendrickson, E. B. Colburne, K. F. Drinkwater, and M. A. Showell. 2007. Ocean climate effects on the relative abundance of short-finned (*Illex illecebrosus*) and long-finned (*Loligo pealeii*) squid in the Northwest Atlantic Ocean. Fish. Oceanog. 16 (4): 303–316.

Doubleday, W.G. 1981. Manual on groundfish surveys in the northwest Atlantic. NAFO Sci. Coun. Studies. 2: 55 p.

Fanning, L. P. 1985. Intercalibration of research survey results obtained by different vessels. CAFSAC Res. Doc. 85/3. 42 p.

González-Troncoso, D. 2016. Calculation of the calibration factors for witch flounder and squid from the comparative experience between the R/V *Cornide de Saavedra* and the R/V *Vizconde de Eza* in Flemish Cap in 2003 and 2004. SCR Doc. 16/21, Ser. No. N6564, 25 p.

Fowler, G. M. and M. A. Showell. 2009. Calibration of bottom trawl vessels: comparative fishing between the Alfred Needler and Teleost on the Scotian Shelf during the summer of 2005. Can. Tech. Rep. Fish. Aquat. Sci. 29 p.

Halliday, R. G. and P. A. Koeller. 1981. A history of Canadian groundfish trawling surveys and data usage in ICNAF Divisions 4TVWX. *In*: Bottom trawl surveys, W. G. Doubleday and D. Rivard. (Eds.) Can. Spec. Publ. Fish. Sci. 58: 27-41.

Healey, B. P., W. B. Brodie, D. W. Ings and D. J. Power. 2012. Performance and description of Canadian multi-species surveys in NAFO Subarea 2+Divisions 3KLMNO, with emphasis on 2009-2011. NAFO SCR Doc. 12/019, Ser. No. N6043, 26 p.

Hendrickson, L.C. 1999. Fishery effects on spawner escapement in the Northwest Atlantic *Illex illecebrosus* stock. NAFO SCR Doc. 99/66, Ser. No. N4125, 8 p.

Hendrickson, L.C. 2004. Population biology of Northern shortfin squid (*Illex illecebrosus*) in the Northwest Atlantic Ocean and initial documentation of a spawning area. ICES J. Mar. Sci. 61: 252-266.

Hendrickson, L.C. 2006. Distribution of Northern shortfin squid (*Illex illecebrosus*) in Subarea 3 based on multi-species bottom trawl surveys conducted during 1995-2005. NAFO SCR Doc. 06/45, Ser. No. N5270, 5 p.

Hendrickson, L. C., and E. M. Holmes. Essential fish habitat source document: northern shortfin squid, *Illex illecebrosus*, life history and habitat characteristics, 2nd Ed. NOAA Tech. Memo. NMFS-NE-19, 36 p.

Hendrickson, L. C. and M. A. Showell. 2013. Assessment of Northern shortfin squid (*Illex illecebrosus*) in Subareas 3+4 for 2012. NAFO SCR Doc. 13/031, Ser. No. N6185, 25 p.

Hendrickson, L.C., E.G. Dawe and M.A. Showell. 2002. Assessment of Northern shortfin squid (*Illex illecebrosus*) in Subareas 3+4 for 2001. NAFO SCR Doc. 02/56, Ser. No. N4668, 17 p.

ICNAF [International Commission for the Northwest Atlantic Fisheries]. 1973. Nominal catch of squid in Canadian Atlantic waters (Subareas 2-4), 1920-68. ICNAF Redbook 1973, Part III: 154-161.

Koeller, P. A. 1980. Distribution, biomass and length frequencies of squid (*Illex illecebrosus*) in Divisions 4TVWX from Canadian research vessel surveys: an update for 1979. NAFO SCR Doc. 80/II/17, Ser. No. N049, 11 p.

Lange, A. M. T. 1978. Historical trends and current status of the squid fisheries off the Northeastern United States. *In* Proceedings of the workshop on the squid *Illex illecebrosus*. Dalhousie University, Halifax, Nova Scotia. May, 1978. Balch, N., T. Amaratunga, and R. K. O'Dor (Eds.) Fisheries and Marine Service Technical Report No. 833. Fisheries and Oceans, Canada.

Lange, A. M. T. and M. Sissenwine. 1980. Biological considerations relevant to the management of squid *Loligo pealeii* and *Illex illecebrosus* of the Northwest Atlantic. Mar. Fish. Rev. 42(7-8): 23-38.

Miller T. J., C. Das, P. J. Politis, A. S. Miller, S. M. Lucey, C. M. Legault, R. W. Brown, and P. J. Rago (eds). 2010. Estimation of *Albatross IV* to *Henry B. Bigelow* calibration factors. Northeast Fisheries Science Center Ref. Doc. 10-05. 233 p.

Northeast Fisheries Science Center [NEFSC]. 1999. Report of the 29th Northeast Regional Stock Assessment Workshop (29th SAW): Stock Assessment Review Committee SARC) Consensus Summary of Assessments. Northeast Fisheries Science Center Ref. Doc. 99-14, 347 p.

Northeast Fisheries Science Center [NEFSC]. 2006. 42nd Northeast Regional Stock Assessment Workshop (42nd SAW) Stock Assessment Report Part A: Silver Hake, Mackerel, & Northern Shortfin Squid. Northeast Fisheries Science Center Ref. Doc. 06-09a, 284 p.

Northwest Atlantic Fisheries Organization [NAFO]. 2003. Historical nominal catches for selected stocks. NAFO SCS Doc. 03/12, Ser. No. N4838, 7 p.

Northwest Atlantic Fisheries Organization [NAFO]. 2004. Report of the NAFO Study Group on Limit Reference Points, Lorient, France, 15-20 April, 2004. NAFO SCS Doc. 04/12, Ser. No. N4980, 72 p.

Northwest Atlantic Fisheries Organization [NAFO]. 2010. NAFO Scientific Council Reports-2010 Part B: Scientific Council meeting, 3-16 June 2010. 224 p.

Rivard, D., L. C. Hendrickson and F. M. Serchuk. 1998. Yield estimates for short-finned squid (*Illex illecebrosus*) in SA 3-4 from research vessel survey relative biomass indices. NAFO SCR Doc. 98/75, Ser. No. N3068, 4 p.

Showell, M.A. and L.P. Fanning. 1990. Assessment of the Scotian Shelf silver hake population in 1998. Canadian Stock Assessment Research Document. 99/148, 41 p.

Vázquez, A. 2010. Results from the bottom trawl survey on Flemish Cap of June-July 2009. NAFO SCR Doc. 10/23, Ser. No. N5781, 45 p.

Vázquez, A., J. M. Casas and R. Alpoim. 2013. Protocols of the EU bottom trawl survey of Flemish Cap. NAFO SCR Doc. 13/021, Ser. No. N6174, 51 p.

Table 1. Nominal catches (t) of *Illex illecebrosus* in NAFO Subareas 3 and 4, during 1953-2015, and Subareas 5+6, during 1963-2015, 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	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	22,915
2013	0	27	27	3,792	3,819	34,000	22,915
2014	0	21	21	8,767	8,788	34,000	22,915
2015	0	14	14	2,423	2,437	34,000	22,445
AVERAGE							
1976-1981	37,844	42,802	80,645	19,677	100,322		
1982-2014	1,822	835	2,657	12,183	14,840		

[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 2013-2015 are provisional.

Table 2. Indices of relative abundance (stratified mean number per tow) and biomass (stratified mean kg per tow), and CVs (%) for *Illex illecebrosus* catches in bottom trawl surveys conducted during July in Div. 4VWX (1970-2015). Indices were derived using data from strata 440-495.

Year	Number per tow	CV (%)	Kg per tow	CV (%)
1970	5.8	37	0.4	39
1971	27.6	39	2.8	38
1972	6.6	20	0.7	22
1973	10.9	57	1.5	61
1974	12.4	16	1.6	18
1975	44.8	35	5.0	34
1976	247.2	40	45.6	38
1977	50.9	28	9.5	31
1978	16.1	27	2.2	30
1979	94.2	20	14.6	22
1980	23.3	34	2.2	28
1981	35.5	34	4.9	36
1982	25.5	54	2.1	53
1983	77.0	60	2.1	55
1984	14.1	42	1.5	48
1985	81.0	70	2.7	55
1986	7.7	43	0.4	43
1987	4.9	33	0.4	37
1988	47.2	34	2.7	36
1989	25.4	26	2.5	28
1990	41.3	32	4.3	33
1991	27.1	22	1.8	21
1992	121.7	69	7.3	72
1993	79.0	42	5.4	29
1994	45.3	28	4.2	14
1995	34.5	36	2.5	35
1996	12.2	28	0.9	26
1997	53.5	34	5.0	38
1998	10.0	24	0.9	21
1999	17.0	38	2.1	36
2000	4.0	40	0.1	23
2001	3.3	31	0.2	35
2002	13.0	50	1.1	53
2003	12.1	39	0.9	36
2004	119.3	61	12.9	65
2005	9.6	38	0.7	38
2006	74.4	31	10.2	29
2007	15.4	28	1.5	31
2008	28.7	38	3.0	40
2009	69.9	39	6.0	38
2010	19.6	28	1.8	34
2011	23.4	31	1.9	27
2012	16.9	20	1.5	19
2013	1.4	23	0.1	17
2014	10.1	28	1.1	30
2015	2.4	31	0.2	39
AVERAGE				
1976-1981	77.9	30	13.2	31
1982-2014	34.7	38	2.8	36

Table 3. Indices of relative abundance (stratified mean number per tow) and biomass (stratified mean kg per tow) for *Illex illecebrosus* caught during fall bottom trawl surveys conducted in Subareas 5+6 (mainly Sept.-Oct., 1967-2015), Div. 3LNO (mainly Oct.-Dec., 1995-2015), and Div. 4T (Sept., 1971-2015). The Div. 3LNO fall survey was not conducted during 2014 due to vessel problems.

	Subareas 5+6		Div. 3LNO		Div. 4T	
Year	Number per tow	Kg per tow	Number per tow	Kg per tow	Number per tow	Kg per 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	8.0	0.5	0.2162	0.0275	0.64	0.12
2013	4.7	0.4	0.0098	0.0017	0.11	0.01
2014	8.3	0.6	-	-	0.28	0.06
2015	9.5	0.5	0.0886	0.0062	0.00	0.00

Table 4. *Illex illecebrosus* minimum biomass (t) estimates derived from EU bottom trawl surveys conducted on the Flemish Cap (Div. 3M) during July, 1988-2015. Catches in survey strata 1-19 (depths ≤ 730 m) were used to derive the indices. Minimum biomass estimates for 1988-2002 were converted from R/V *Cornide de Saavedra* units to R/V *Vizconde de Eza* units. Minimum abundance estimates are not presented because a vessel conversion factor is currently not available.

Year	Biomass (t)	SE
1988	6	4
1989	9	4
1990	2,107	604
1991	1,483	395
1992	83	18
1993	1	1
1994	269	33
1995	1	1
1196	113	15
1997	81	12
1998	92	12
1999	22	4
2000	3	1
2001	10	3
2002	8	3
2003	222	60
2004	470	55
2005	79	8
2006	3,541	1,244
2007	411	64
2008	5,137	2,392
2009	1,688	346
2010	43	7
2011	89	19
2012	38	8
2013	0	
2014	3	1
2015	0	
Average (1988-2014)	953	

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 1970-2015. 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 Index
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	47	1.5	< 0.01
2013	27	0.1	0.05
2014	21	1.1	< 0.01
2015	14	0.2	0.01
Average			
1976-1981	80,645	13.2	1.69
1982-2014	1,822	2.8	0.12

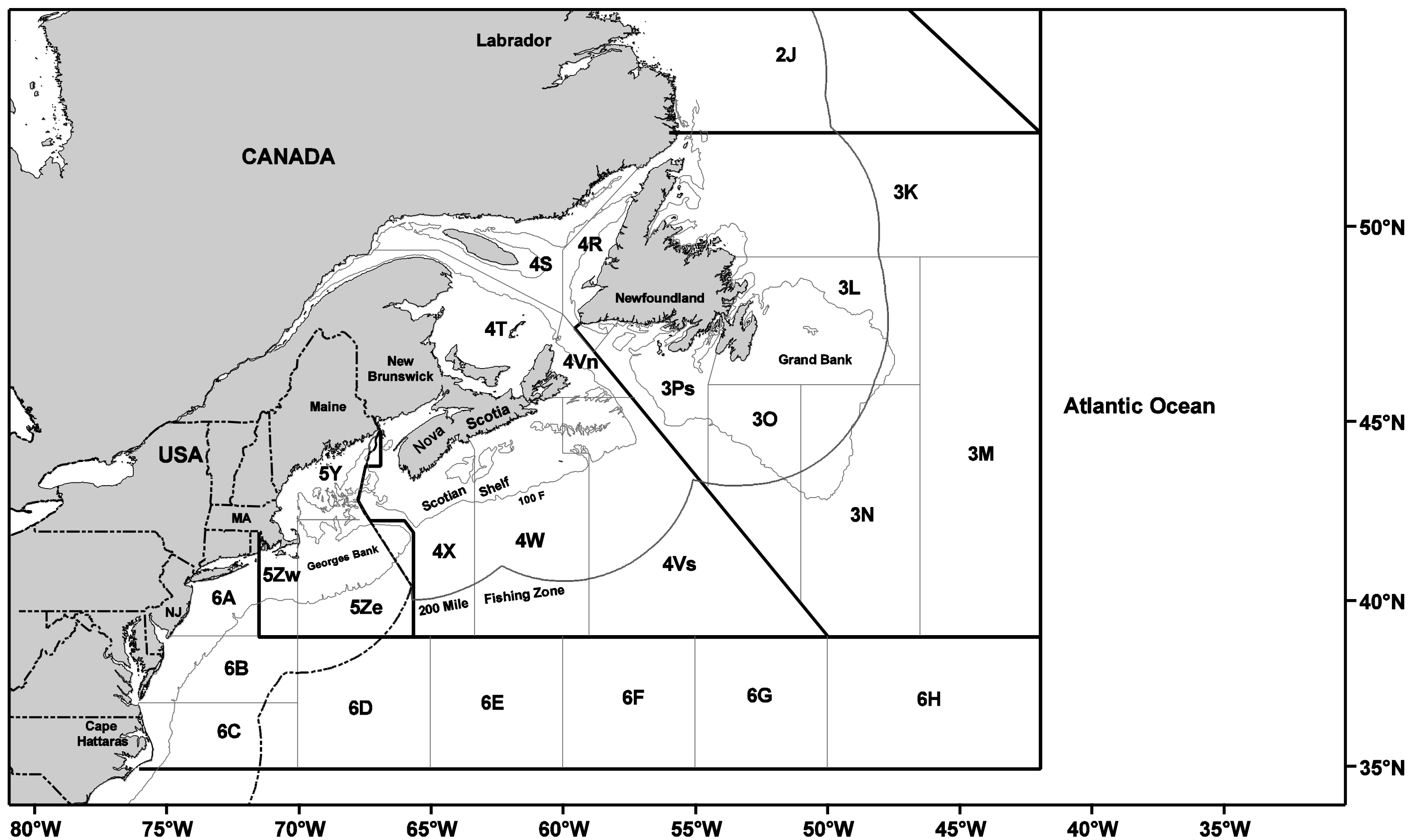


Fig.1. Northwest Atlantic Fisheries Organization (NAFO) nominal catch reporting areas, Subareas 3-6 and associated Divisions, for fisheries occurring in the Northwest Atlantic Ocean.

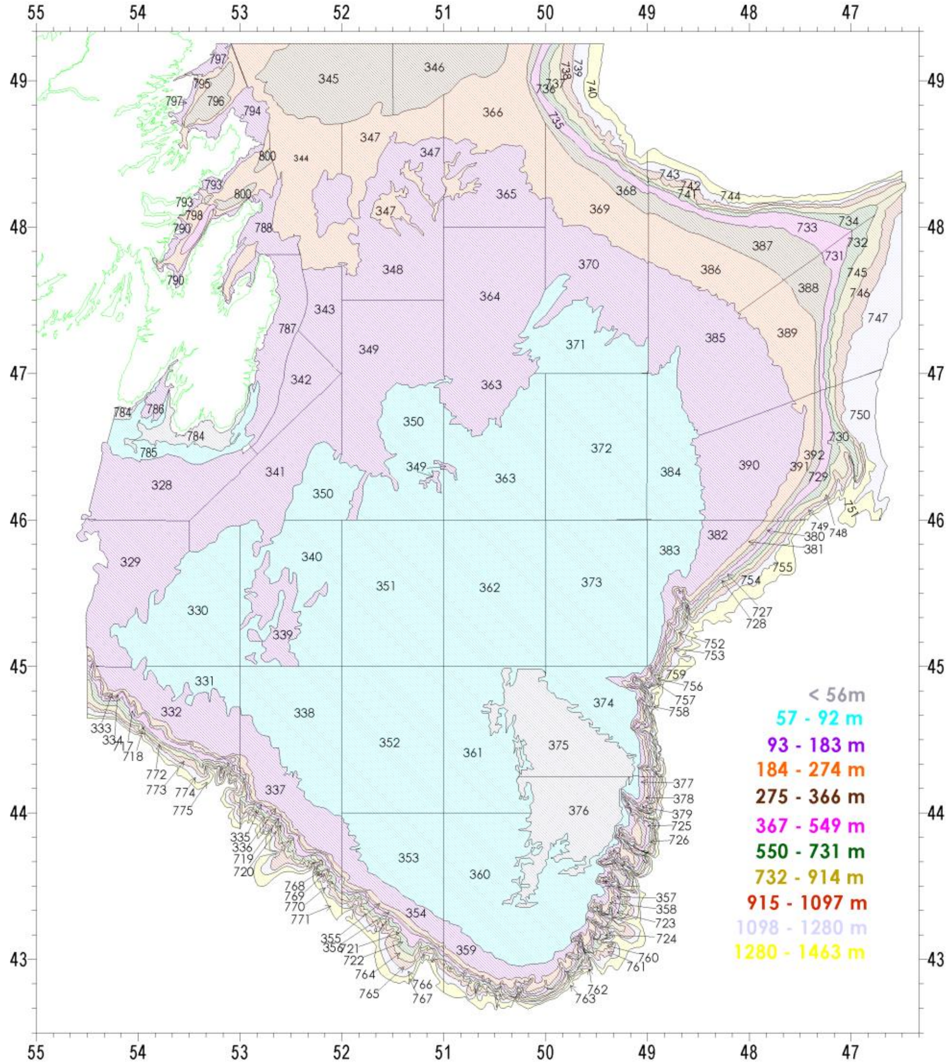


Fig.2. Depth strata sampled during spring and fall bottom trawl surveys conducted in Divisions 3LNO by the Canada Department of Fisheries and Oceans.

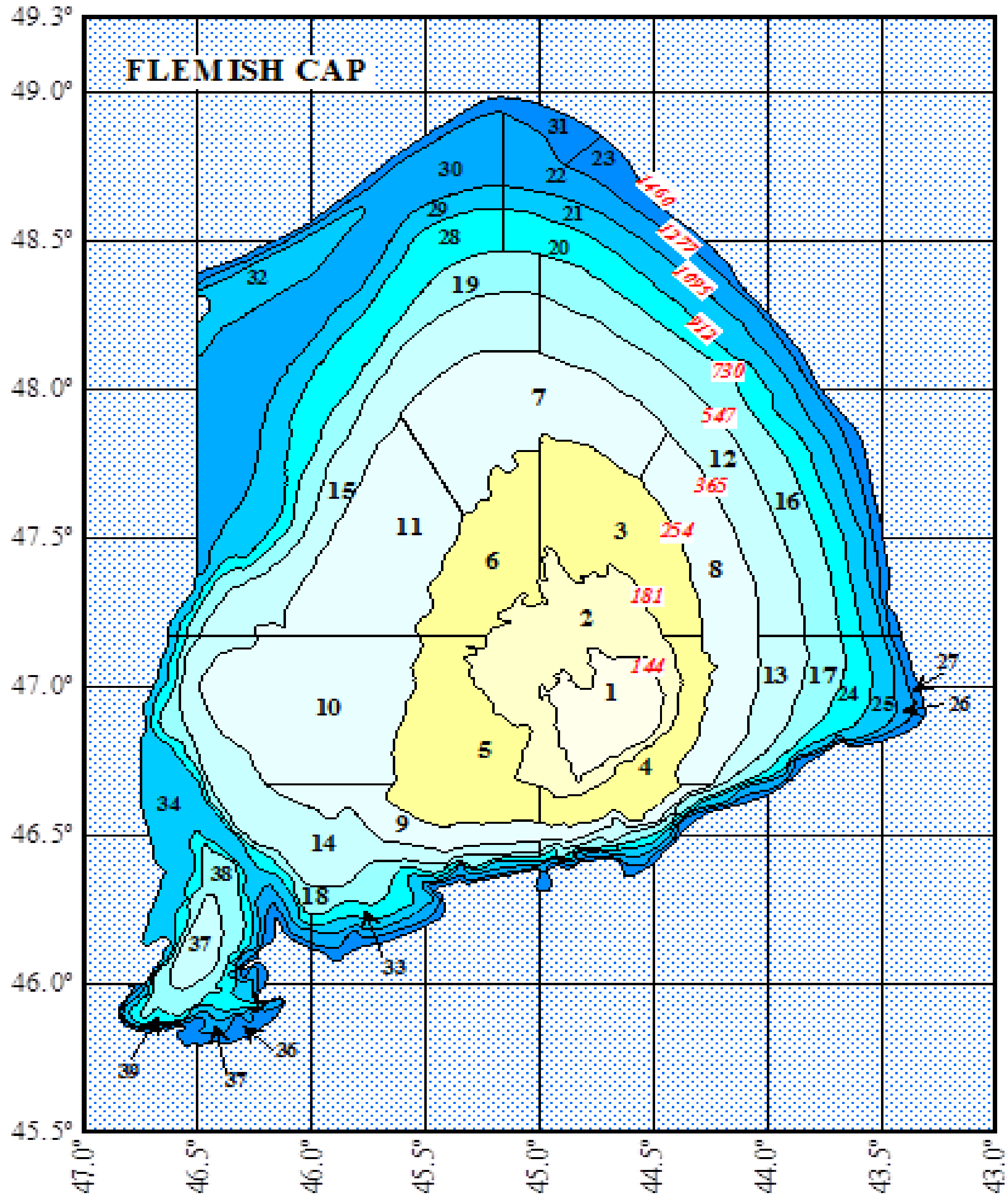


Fig. 3. Depth strata sampled during bottom trawl surveys conducted by the European Union (EU-Spain/Portugal) on the Flemish Cap, in Division 3M, primarily during July. Strata 1-19 were sampled during 1988-2003 and strata 1-25 and 28-34 were sampled from 2004 onward.

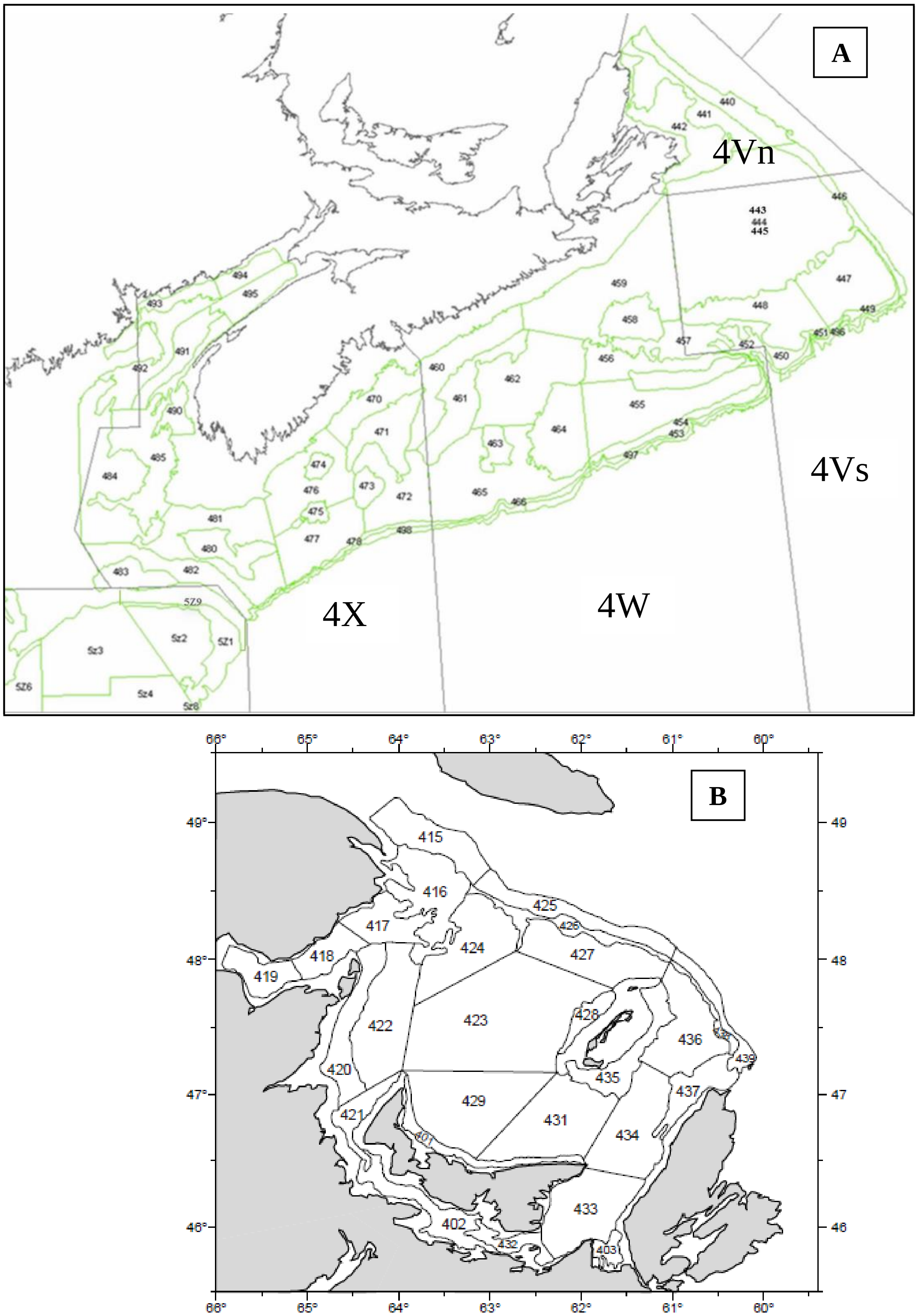


Fig. 4. Depth strata sampled during bottom trawl surveys conducted in (A) Division 4VWX (the Scotian Shelf and Bay of Fundy) during July and in (B) Division 4T (the southern Gulf of St. Lawrence) during September by the Canada Department of Fisheries and Oceans.

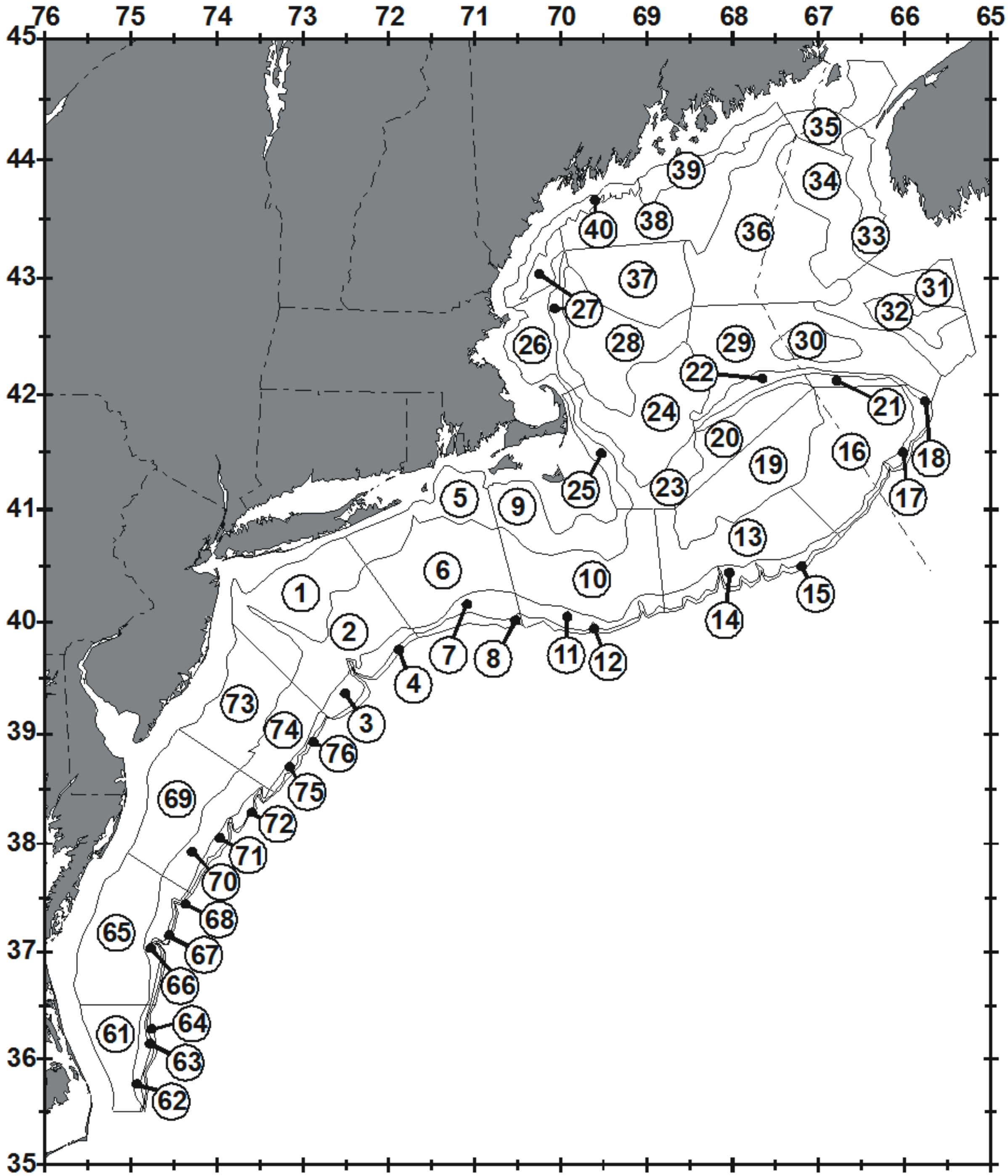
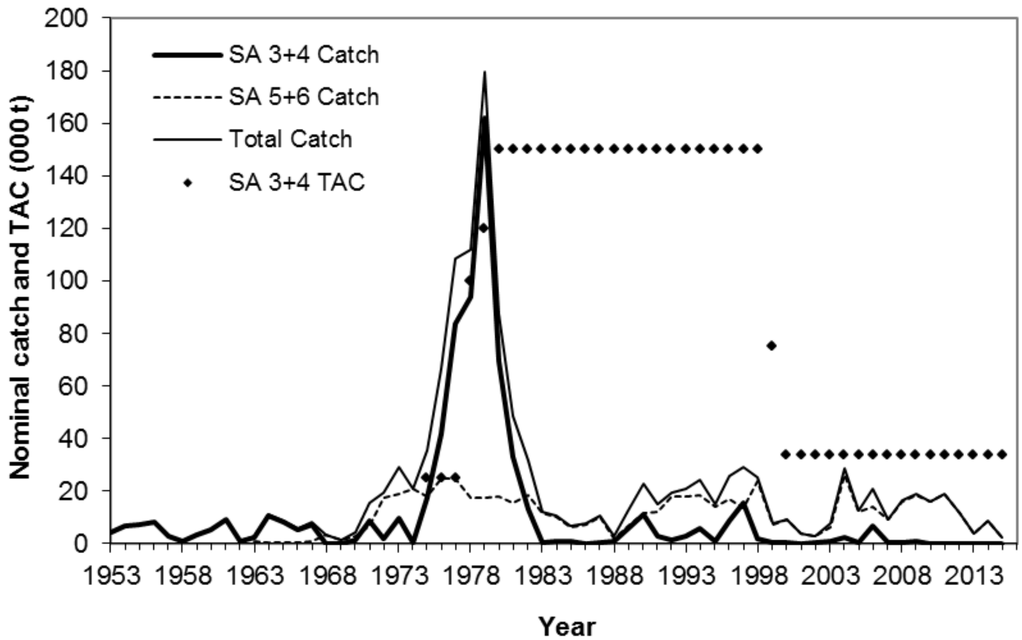


Fig. 5. Offshore depth strata sampled during fall bottom trawl surveys conducted off the East Coast of the USA, in NAFO Subareas 5+6, by the Northeast Fisheries Science Center.



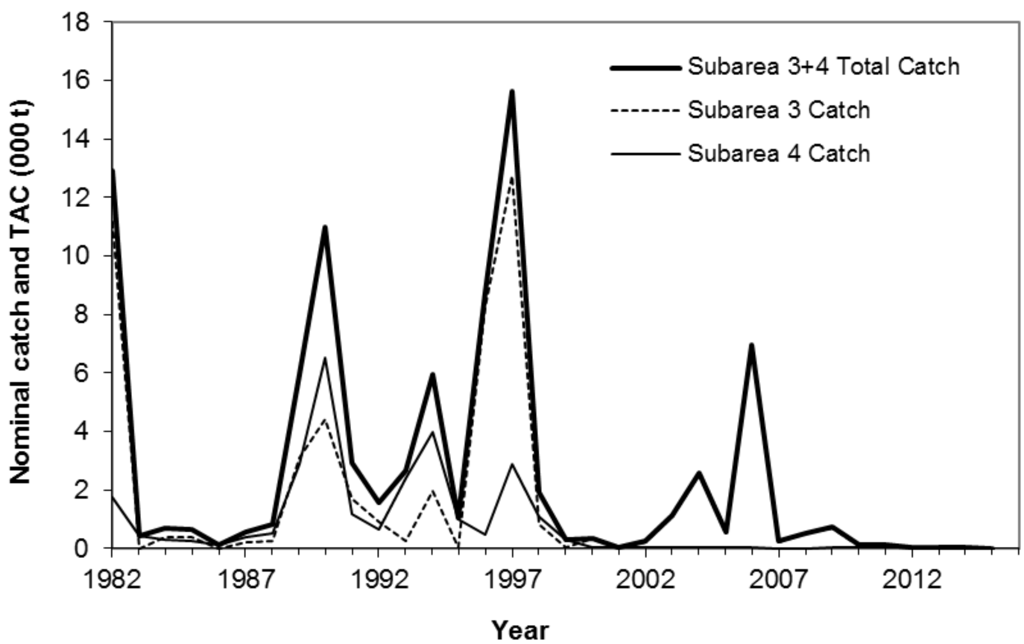


Fig. 6. Nominal catches ('000 t) of *Illex illecebrosus* and TACs ('000 t) in Subareas 3+4 (SA 3+4) during 1953-2015, and in Subareas 5+6 (SA 5+6) during 1963-2015 (top), and nominal catches in Subarea 3 and Subarea 4 during 1982-2015 (bottom).

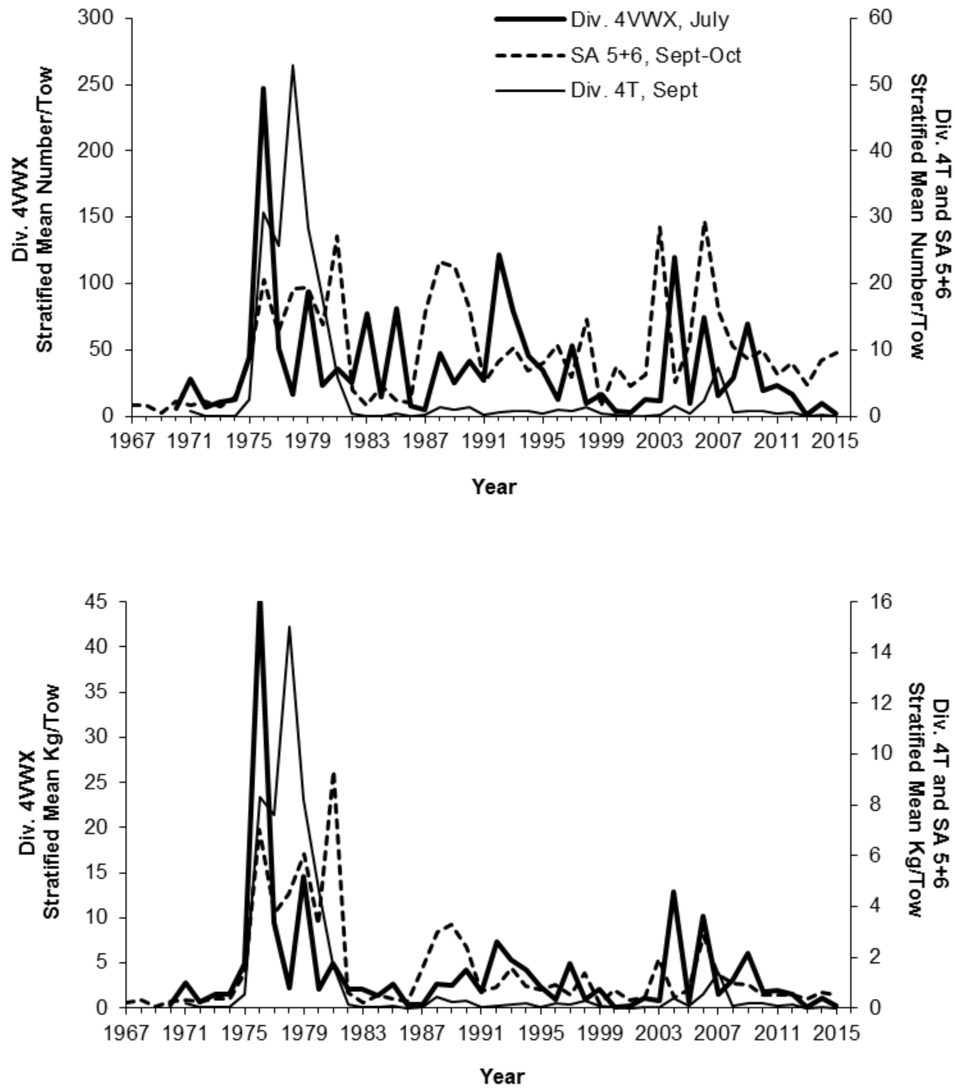


Fig. 7. *Illex illecebrosus* relative abundance (stratified mean number/tow) (top) and biomass indices (stratified mean kg/tow) (bottom) from the Canadian bottom trawl surveys conducted in Div. 4VWX (July, 1970-2015) and Div. 4T (September, 1971-2015), and the U.S. bottom trawl surveys conducted in Subareas 5+6 (September-October, 1967-2015).

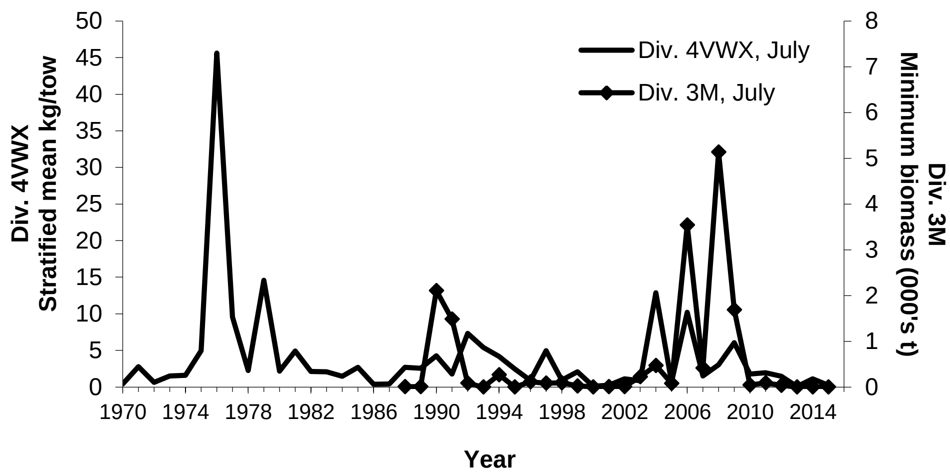


Fig. 8. Relative biomass indices (stratified mean kg/tow) of *Illex illecebrosus*, derived from the July Div. 4VWX surveys, and minimum biomass estimates (000's t) derived from the July EU surveys on the Flemish Cap in Div. 3M for 1988-2015.

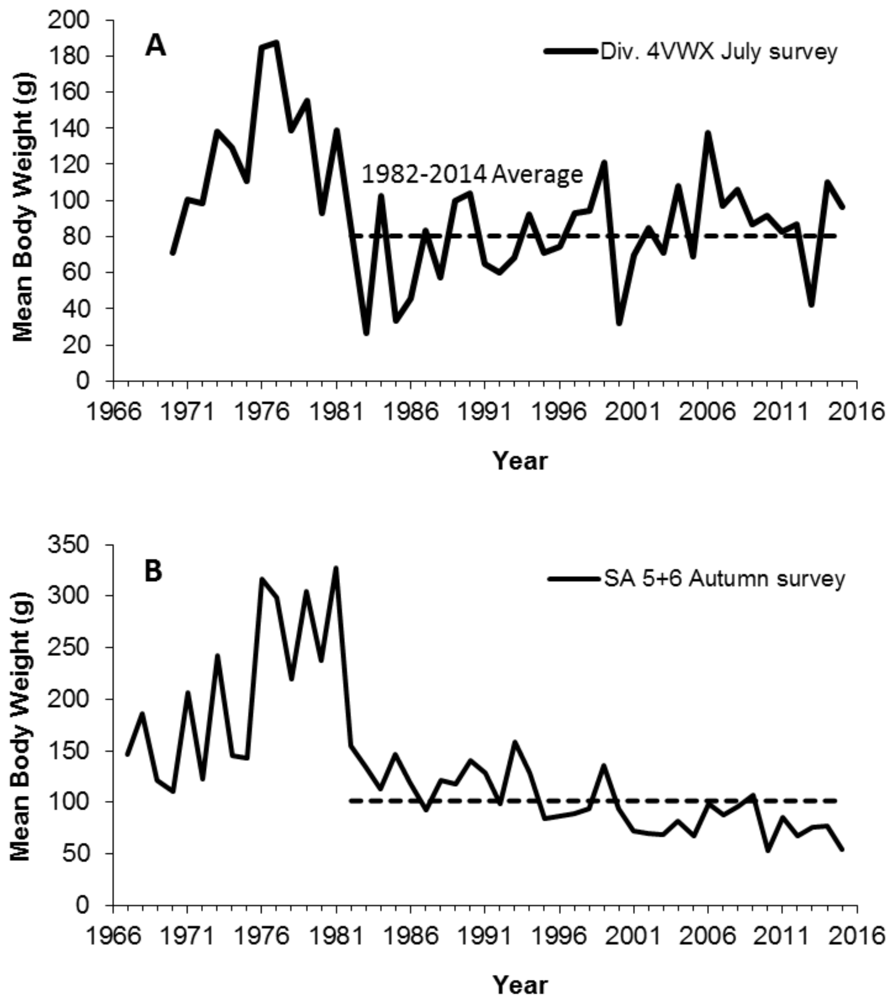


Fig. 9. Mean body weight (g) of *Illex illecebrosus* caught in the (A) Canadian Div. 4VWX July bottom trawl surveys (1970-2015) and the (B) Subareas 5+6 autumn bottom trawl surveys (1967-2015).

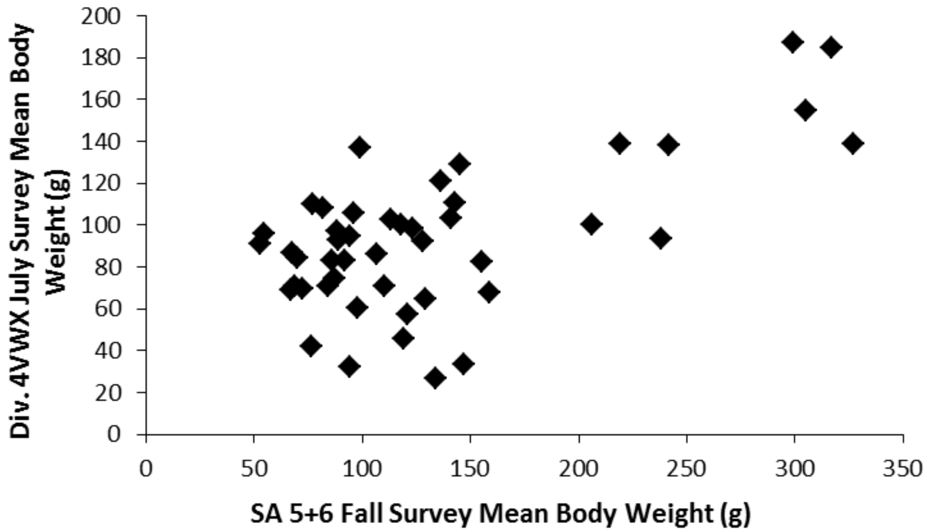


Fig. 10. Relationship between the mean body weights of *Illex illecebrosus* caught in the SA 5+6 fall bottom trawl surveys and the Division 4VWX July bottom trawl surveys during 1970-2015.

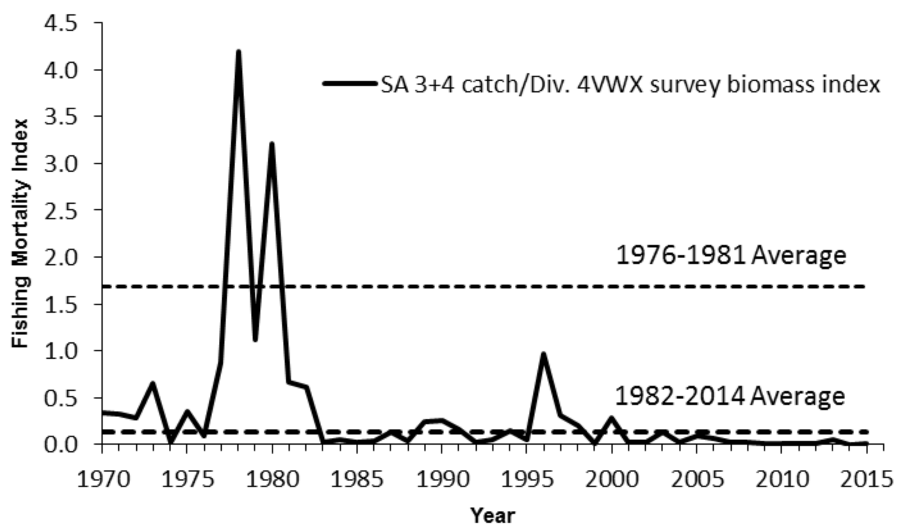


Fig. 11. Relative fishing mortality indices (SA 3+4 nominal catch/Div. 4VWX July survey biomass index) in Subareas 3+4 during 1970-2015, and averages during the high (1976-1981) and low (1970-1975 and 1982-2015) productivity periods. Indices were divided by 10,000 to scale the values.