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**Assessment of Thorny Skate (*Amblyraja radiata* Donovan, 1808) in NAFO Divisions 3LNO
and Subdivision 3Ps**

by

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Abstract

Available information on the fishery, management, biology, and assessment of Thorny Skate in NAFO Divisions 3LNO and Subdivision 3Ps was reviewed to determine the status of this stock. Based on the continuous distribution of this species, and lack of physical barriers between Div. 3LNO and Subdiv. 3Ps, Thorny Skate in Div. 3LNOPs is considered to constitute a single stock. In 2012-2016, an average of 3 990 tons of Thorny Skate from Div. 3LNO was commercially landed. STACFIS-agreed total landings from Div. 3LNO were 4 259 t in 2017. Reported landings in Subdiv. 3Ps averaged 476 t in 2012-2016, and totaled 407 t in 2017. An Index of Fishing Mortality for Div. 3LNO increased from the late 1980s to a peak of 29% in 1997, then decreased and stabilized at approximately 17% during 1998-2004. In 2005, this Index declined to 4%, then increased slightly and has since remained around 5%. The Fishing Mortality Index in Subdiv. 3Ps has remained below 5% in most years since 1985. After a drastic decline over 1985-1995, Canadian spring research surveys indicated that biomass and abundance of Thorny Skate in Div. 3LNO were relatively stable at low levels. Thorny Skate distribution in Div. 3LNOPs over 2007-2017 continued to be concentrated on the southwestern Grand Banks, in Subdiv. 3Ps, and northward along the edge of the Bank.

Introduction

Thorny Skates (*Amblyraja radiata* Donovan, 1808) are widely distributed in temperate and arctic waters of the North Atlantic. In the western Atlantic, Thorny Skate are distributed from Greenland to South Carolina, with the centre of distribution on the Grand Banks (Fig. 1) in NAFO Divisions 3LNO. Commercial catches of skates consist mainly Thorny Skate, with about 95% in Canadian skate catches (Kulka and Miri 2007; Kulka and Mowbray 1999); similar to the proportion of Thorny Skate in EU-Spain research survey catches in Div. 3NO (González-Troncoso *et al.* 2018). Thus, the skate fishery on the Grand Banks can be considered a directed fishery for Thorny Skate.



Fishery and Management

TAC Regulation

Thorny Skate came under quota regulation in 1995, after a directed skate fishery was established in 1994 by Canada in its Exclusive Economic Zone (EEZ). A Total Allowable Catch (TAC) of 5 000 tons for Divisions 3LNO and 1 000 t for Subdivision 3Ps were adopted by Canada in 1995. In 1996, the TAC was raised to 6 000 t for Div. 3LNO and 2 000 t for Subdiv. 3Ps. In 1997, the TAC was reduced to 1 950 t for Div. 3LNO and 1 050 t for Subdiv. 3Ps.

Outside Canada's EEZ, catch was unregulated until September 2004, when the Northwest Atlantic Fisheries Organization (NAFO) Fisheries Commission set a TAC of 13 500 t for 2005-2009 in the NAFO Regulatory Area (NRA) of Div. 3LNO (Fig. 2). This TAC was lowered to 12 000 t for 2010-2011, and to 8 500 t for 2012. The TAC was further reduced to 7 000 t for 2013-2018.

Landings Trends

On the Grand Banks, Kulka and Mowbray (1998) reported that significant bycatch of skates have been taken since commencement of offshore fishing in the late 1940s, initially by non-Canadian fleets and later by Canadian vessels. Prior to the mid-1980s, non-Canadian fleets comprised the largest component of offshore fisheries on the Grand Banks, and took several thousand tons of skate as bycatch each year. The bycatch derived primarily from the Greenland Halibut fishery and from the Canadian mixed fishery for Thorny Skate, White Hake (*Urophycis tenuis*), and Monkfish (*Lophius americanus*; Kulka and Mowbray 1999). Kulka and Mowbray (1998) estimated that approximately 5 000 t, on average, were discarded annually by Canadian fleets during the 1980s and early 1990s, although only a few hundred tons were recorded in Canada's annual landings statistics during that period.

Catches for Div. 3LNO (Table 1; Fig. 2) increased in the mid-to-late 1980s with the commencement of a directed fishery for Thorny Skate. In 1985, Spain began targeting skate in a non-regulated fishery in the NRA (Junquera and Paz 1998; del Río and Junquera 2001). During 1985-1991, landings averaged 17 058 t and peaked at approximately 28 400 t in 1991 (STATLANT-21A). This fishery was mainly prosecuted by Spain, Portugal, USSR, and the Republic of Korea. Non-Canadian landings declined significantly to 5 059 t in 1992 (Table 1). In 2000, Russia joined the directed fishery for Thorny Skate. Due to a new Canadian directed fishery that began in 1994, Canadian landings increased during 1994-1999, to an average of 1 590 t (Simpson and Miri 2012). Since 2000, total reported landings of skate by all countries in Div. 3LNO declined (Fig. 2). In 2012-2016, an average of 3 990 t of Thorny Skate was landed from Div. 3LNO. STACFIS-agreed landings from Div. 3LNO in 2017 totaled 4 463 t.

In Subdiv. 3Ps, STATLANT-21A data indicated that Canadian fleets reported the majority of Thorny Skate landings in recent years, while St. Pierre and Miquelon (EU-France) annually reported smaller amounts of landings of this species (Table 2; Fig. 2). Prior to 1994, Canadian landings of Thorny Skate in Subdiv. 3Ps rarely exceeded a few hundred tons. Total reported landings in Subdiv. 3Ps averaged 1 328 t from 1994-2008, 870 t from 2009-2011, and 476 t over 2012-2016. In Subdiv. 3Ps, STATLANT reported landings totaled 605 t in 2017.

Commercial Size

Sampling of Canadian commercial catches by Canadian At-Sea Fisheries Observers indicated that skates caught by Canadian gillnetters directing for Monkfish in Div. 3O in 2012 were 62-87 cm Total Length (TL), with a mode of 73-74 cm (Fig. 3a; see Simpson and Miri 2012 for previous years). Skates trawled in the Div. 3L Greenland Halibut (*Reinhardtius hippoglossoides*) fishery in 2013 varied between 35-82 cm in length (modes of 44-45, 50, 62, 69, and 72 cm), and 22-44 cm (modes of 29-30 and 32 cm; large skates were not measured) in the 2015 redfish (*Sebastes* sp.) fishery. In 2014, Canadian longliners directing for Atlantic Cod (*Gadus morhua*) in Subdiv. 3Ps caught 53-87 cm skates, with a mode of 72 cm. Thorny Skates caught in Div. 0B+2GHJ3K shrimp fisheries (*Pandalus* sp.; using a trawl-mounted, size-selective groundfish excluder) ranged between 9-41 cm (modes: 11, 16) in 2015, and 9-37 cm (modes: 11, 18) in 2016; indicating that young-of-the-year skates were also bycaught. Skates trawled in the Div. 3L redfish fishery varied between 31-93 cm (mode of 36 cm) in 2016, and 27-83 cm in 2017 (modes of 35-36 and 38 cm). Skates caught by Canadian trawlers in the Div. 3NO Yellowtail Flounder (*Limanda ferruginea*) fishery in 2016 and 2017 were 24-101 cm (modes: 42, 72) and 25-91 cm (modes: 58, 74), respectively. In 2017, Thorny

Skates trawled in the Div. 30 Witch Flounder (*Glyptocephalus cynoglossus*) fishery ranged between 42-100 cm, with a mode of 80 cm.

From skate-directed trawl fisheries (280 mm mesh) in the NRA of Div. 3LNO over 2011-2017, EU-Spain reported a range of 19-97 cm TL skates (no distinct modes), with a small number of young-of-the-year (<21 cm) caught in 2013-2014 and 2017 (Fig. 3b; see Simpson and Miri 2012 for previous years). In 2011, EU-Portugal directed for skates with a smaller mesh size (200 mm), and a 32-82 cm TL range with a mode of 60 cm skates was observed in a very small sample. In 2013, EU-Portugal caught 26-85 cm TL skates (mode of 49-50 cm) in Div. 3N (280 mm mesh).

In other directed trawl fisheries (130-135 mm mesh) of Div. 3LNO (NRA), EU-Portugal reported skate bycatch ranging from 30-84 cm TL with modes of 60 and 76 cm TL in 2011, 25-84 cm with 49 cm and 70 cm modes in 2013, and 46-88 cm with a mode of 72 cm in 2017 (Fig. 3c; see Simpson and Miri 2012 for previous years). EU-Portugal did not sample Div. 3LNO skate bycatch in 2014-2016, while EU-Spain have not done so since 2009 (see Simpson and Miri 2012 for previous years).

Russia sampled only 38 specimens during the Div. 3L Greenland Halibut fishery in 2011 (Fig. 3c; see Simpson and Miri 2012 for previous years). Thorny Skates varied between 43-103 cm in length (mean=62.8 cm), while 3 specimens of 115, 148, and 166 cm TL were probably misidentified Spinytail Skates (*Bathyrhaja spinicauda*). In 2012, 64 sampled Thorny Skates ranged from 33-78 cm TL (mean=66.7 cm) in the Div. 3L Greenland Halibut fishery, and 15 skates in Div. 3N varied between 24-66 cm TL (mean=47.9 cm). In the Div. 3L redfish fishery during 2013-2014, a total of 21 sampled Thorny Skates varied from 58-84 cm TL, with a mean of 71.5 cm (2013) and 61.3 cm (2014). In 2015, 127 sampled skates from the Div. 3LO redfish fishery ranged from 35-89 cm TL (mean=60.8 cm in Div. 3L; mean=68.0 cm in Div. 3O). In 2016, 71 sampled Thorny Skates from the Div. 3O redfish fishery varied from 39-71 cm TL (mean=47.2 cm).

Research Survey Data

Canadian Spring Surveys

Stratified-random surveys have been conducted by Canadian research vessels in the spring (April-June) of each year from 1971 to 2017. A summary of the stratified-random survey design adopted by the DFO-NL Region can be found in Doubleday (1981). While survey design has remained constant, additional strata have been included, and some of the original strata have been modified (Bishop 1994). A significant change in the surveys was the addition of shallower and deeper strata after 1993. Additional causes of variation in spring survey coverage are discussed in detail by Rideout *et al.* (2017), Power *et al.* (2016), Healey *et al.* (2012), Healey and Brodie (2009), and Brodie and Stansbury (2007). The spring survey can be split into three time series, based on the trawl used in each period: 1971-1982 (Yankee 41.5), 1984-1995 (Engel 145), and 1996-2017 (Campelen 1800; McCallum and Walsh 1996; Walsh and McCallum 1996). Conversion factors exist for the Engel to Campelen gear change (Simpson and Kulka 2005), but not for the Yankee to Engel gear change. In 2006, most of Subdiv. 3Ps was not surveyed, and only shallow strata in Div. 3NO (to 77 m in Div. 3N; to 103 m in Div. 3O) were surveyed, due to Canadian research vessels' mechanical difficulties. Therefore, survey estimates for that year are not comparable to others in the Campelen time series. In 2015 and 2017, several strata were not sampled in Div. 3L, thus impacting biomass and abundance estimates of Thorny Skate (Rideout and Ings 2018).

Historical abundance and biomass indices from Canadian spring surveys in Div. 3LNOPs are provided in Table 3(a,b) and Figures 4a and 5. Since the mid-1990s, spring biomass indices for Thorny Skate in Div. 3LNOPs were generally increasing, following a drastically declining trend over 1985-1995. In 2016, biomass estimates for Thorny Skate in Div. 3L, 3N, and 3O were 9 324 t, 17 422 t, and 86 328 t (respectively), and in 2017 were 277 t, 36 484 t, and 55 096 t. In 2017, the survey in Div. 3L was incomplete (with some unsampled strata) and therefore is not representative of stock biomass. The biomass index in Div. 3N was lower in 2016, but increased in 2017. In Div. 3O, an estimated biomass of 86 328 t in 2016 was above the 2011-2015 average of 63 162 t. In 2017, the biomass estimate of 55 096 t was below this average. Furthermore, the current biomass estimate of 91 857 t for Div. 3LNO in 2017 was below the 2012-2016 average of 115 102 t. In Subdiv. 3Ps, the biomass index was 46 290 t in 2017; slightly above the 2012-2016 average of 37 385 t.

Comparisons were made between NAFO div. 3LNO and subdivision 3Ps survey catch in relation to depth. In NAFO division 3LNO, the majority of the biomass was found in depths less than 91m. When corrected for the amount of area sampled at depth, the relative biomass was concentrated in strata less than 55m in depth. In subdivision 3Ps, the majority of biomass was in strata shallower than 183m, however when standardized by area a greater proportion of the catch was concentrated in the deeper sets.

Canadian Fall Surveys

Annual stratified-random fall surveys have been conducted by Canada in Div. 3L from 1981 to 2017. In 1990-2017, fall surveys also extended onto the southern Grand Banks in Div. 3NO. Canadian surveys were originally conducted with an Engel 145 trawl, then a Campelen 1800 trawl in 1995-2017. Although fall surveys sample deeper maximum depths (~1 400 m) than those in spring (~750 m), they do not cover the entire stock area, and thus are not considered spatially complete. For this reason, Canadian spring surveys are used as the primary source of biomass and abundance estimates for Thorny Skate. However, fall indices are still considered in assessments of this stock, because this survey is conducted when a greater proportion of Thorny Skate is available to survey trawls. During fall, Thorny Skates are concentrated on the shelf; in spring, part of this population has moved to the shelf edge, and a proportion apparently moves outside of the survey area (Kulka *et al.* 2004). When using spring estimates of biomass and abundance to examine trends in this stock, it is assumed that the proportion of skate that moves outside of the surveyed area remains consistent between years. Additional causes of variation in fall survey coverage are discussed in detail by Rideout and Ings (2018), Power *et al.* (2016), Healey *et al.* (2012), Healey and Brodie (2009) and Brodie and Stansbury (2007).

Historical abundance and biomass indices from Canadian fall surveys in Div. 3LNO are provided in Table 4(a,b) and Figure 4b. Fall abundance indices of Thorny Skate remained stable at low levels since 1995; except for a slight increase in biomass estimates over 2007-2008. Div. 3NO was not surveyed in fall 2014. In 2017, biomass estimates in Div. 3L, 3N, and 3O were 23 568 t, 65 010 t, and 65 422 t (respectively). In Div. 3L, the 2017 biomass index was above the 2012-2016 average of 20 524 t. In Div. 3N, the 2017 biomass estimates were close to the 2015-2016 average of 63 951 t, while those for Div. 3O were above the two-year average of 51 976 t. The 2017 biomass estimate of 154 000 t for Div. 3LNO was above the 2015-2016 average of 137 157 t.

EU-Spain 3NO Survey

Spain initiated a stratified-random survey in the NRA of Div. 3NO in 1995. Initially, this survey was carried out in spring with the C/V *Playa de Menduïña* using a Pedreira bottom trawl. Since 2001, the R/V *Vizconde de Eza* replaced that research vessel, and a Campelen trawl replaced Pedreira gear (González-Troncoso *et al.* 2018).

Abundance and biomass of Thorny Skate were estimated from EU-Spain surveys in the NRA of Div. 3NO from 1997-2017. The survey biomass index showed a consistent increase from 5 000 tons in 1995 to a peak of 50 000 t in 2000. Since 2001, this index fluctuated on an annual basis, averaging 36 307 t in 2001-2006, and then declined over 2007-2011 to an average of 19 276 t. Biomass estimates increased in 2012 to 28 867 t; however, there was a further decline over 2013-14 to 6 624 t (the lowest in this time-series). In 2015, this index increased to 16 085 t, but declined to 14 126 t and 11 121 t in 2016 and 2017, respectively. The 2017 biomass estimate remained below the 1997-2017 average of 24 994 t.

A comparison of the Canadian Campelen spring biomass indices to those of the Spanish Div. 3NO surveys in 1997-2017 indicated that the trends have diverged since 2007: the EU-Spain index declined until 2011, while the Canadian index generally increased (Fig. 6). A correlation analysis of biomass estimates in strata that were sampled by both surveys was conducted in 2012. While overall indices diverged, the average correlation of stratified catch in strata common to both surveys over 1997-2010 has increased relative to 1997-2007. Differences in the indices appear to result from poor catch rates in the EU-Spain survey since 2007 in deeper strata 752-759, which are not sampled in the Canadian survey. In 2012, both indices increased. Although the EU-Spain index declined in 2013 and remained variable at low levels, the Canadian index increased in 2013 to the highest point in this time-series, and then declined over 2014-2017 in a pattern similar to that of the Spanish index, but lagged by one year (as of 2012). It should be noted that the Canadian spring survey covers the entire area of Div. 3NO, whereas the Spanish survey is limited to the NRA of Div. 3NO.

EU-Spain 3L Survey

Spain initiated a stratified-random summer bottom trawl survey in the NRA of Div. 3L in 2003. This survey was conducted with the R/V *Vizconde de Eza* using a Campelen trawl. Due to the vessel's mechanical difficulties, the survey was not conducted in 2005, and some strata were missed in 2003-2004 (Román *et al.* 2018).

Abundance and biomass estimates of Thorny Skate were available from EU-Spain surveys in the NRA of Div. 3L from 2003-2017 (excluding 2005). The biomass estimate (mean weight per tow) averaged 15 kg per tow in 2003-2004; although some strata were missed. This index increased from 20 kg per tow to 25 kg over 2006-2007, and then declined to its lowest level (8 kg per tow) in 2011. Since 2011, the Spanish index increased to an average of 17.8 kg per tow over 2014-2016. In 2017, this index was 9.4 kg per tow with lower catches in all strata.

A comparison of the Canadian Campelen Div. 3L spring biomass indices to those of the Spanish Div. 3L survey in 2003-2016 indicated similar patterns until 2014, when they diverged: the EU-Spain index followed an increasing trend to 2015, while Canadian biomass estimates appeared stable at lower levels (Fig. 7). Due to an incomplete survey, there was not an update of the Canadian Spring survey in 3L. Canadian Campelen Div. 3L fall biomass indices reflected a similar pattern of those from the Spanish survey, except for the decline in recent years. It should be noted that the Canadian surveys cover the entire area of Div. 3L, whereas the Spanish survey is limited to the NRA of Div. 3L.

Index of Fishing Mortality

A relative Fishing Mortality Index (Relative $F = \text{STACFIS-agreed commercial landings} / \text{Canadian spring survey biomass}$) was calculated for Thorny Skate in Div. 3LNO and Subdiv. 3Ps for 1996-2017. Relative F for Div. 3LNO increased from the late 1980s to a peak of 29% in 1997, then decreased and remained stable at approximately 17% during 1998-2004 (Fig. 8). In 2005, this Div. 3LNO index declined to 4%, and remained around 5% since then. Since 1985, relative fishing mortality in Subdiv. 3Ps was constant; remaining below 5% (except for 7% in 2001-2002).

Survey Size Structure

Lengths of Thorny Skates caught in Canadian Campelen spring surveys of Div. 3LNO and Subdiv. 3Ps in 2004-2017 ranged from 5-105 cm TL (Fig. 9). For most areas and years, a peak of young-of-the-year skates (YOY: 5-20 cm TL) was observed, and averaged 15 cm TL. A dominant peak of skates can be seen in each year of the spring survey data, with the following modes: 55 cm in 2004 and 2005; 62 cm in 2006; 66 cm in 2007; 69 cm in 2008; 71 cm in 2009 and 2010, 72 cm in 2011; 74 cm in 2012; 77 cm in 2013, 69 cm in 2014, and 73 cm in 2015. Dominate modes were less obvious in 2016 and 2017, but appeared to occur at 74 and 75 cm (respectively).

Lengths of Thorny Skate caught in the EU-Spain 3NO survey during 1997-2017 ranged from 11-104 cm. A cohort which was recruited in 1997 can be followed through time to 2017 (González-Troncoso *et al.* 2018). There has been no recruitment visible in recent years. In the EU-Spain 3L survey, Román *et al.* (2018) observed a higher proportion of small Thorny Skates with a mode of 30 cm (range: 22-36 cm) in 2015; indicating a recruitment pulse that was also seen in 2016. A cohort observed in 2003 can be followed through time to 2017 (Román *et al.*, 2018).

Life Stages

Numbers of Thorny Skate at length that were caught by Canadian Campelen spring surveys in Div. 3LNOs during 1996-2017 were partitioned into young-of-the-year (YOY), immature, and mature components (Fig. 10). In 1996-2009, Thorny Skate YOY abundance appeared to be relatively stable. During 2010-2012, this index increased, but subsequently declined in 2013-2015 for both males and females. This index has increased slightly since 2015. Abundance estimates of immature skates (of both sexes) have fluctuated, but have generally been stable throughout the time period. Mature skates of both sexes declined over 2012-2015; after which the male portion increased, while the number of female adults continued to decline.

A standardized index of Thorny Skate recruitment, based on the number of skates <21 cm TL, is illustrated in Figure 11. This recruitment index declined from 1.5 in 1996 to below the 1996-2017 average of 1.0, with the lowest value of 0.5 in 1999 and 2004. Although this index remained above 1.0 over 2010-2013, a peak of 2.3 in 2012 was followed by a steep decline to 0.6 in 2015. The recruitment index then increased to 1.3 in 2017. The 2006 index is not presented, because Canadian survey coverage was incomplete over that spring.

Distribution

In Div. 3LNO and Subdiv. 3Ps, the distribution of Thorny Skate has changed significantly since the 1980s. In the early 1980s, Thorny Skates were widely distributed over the entire Grand Banks in moderate to high concentrations (Kulka and Miri 2007). By the late 1990s, much of the biomass was concentrated in the southwest. In 2001-2005, the area of high concentration expanded northward and along the Bank edge. It is important to note that part of this population moves to the shelf edge in spring, thereby moving outside of the Canadian spring survey area; they are concentrated on the shelf during the fall (Kulka *et al.* 2004). In 2008-2017, Thorny Skate distribution in Div. 3LNOPs continued to be concentrated on the southwestern Grand Banks, in Subdiv. 3Ps, and northward along the edge of the Bank in the spring survey (Fig. 12a,b). Strata-biomass plots show the expansion of skate biomass along the southwestern slopes and into Subdiv. 3Ps (Fig. 13a,b). In the Canadian fall survey, Thorny Skate continued to be concentrated along the shelf edge; although higher densities were also apparent on the Grand Banks (Fig. 14a,b).

Modelling

Various formulations of a Bayesian surplus production model were developed, however poor diagnostics such as large process error were considered to invalidate the models. An additional approach, employing a surplus production model in continuous time (SPiCT) has been tested. To date, formulations of the SPiCT model have poorly estimated the productivity of the stock. Retrospective analyses indicated that model estimates were influenced by each successive year of new data.

Summary

Thorny Skate underwent a decline in Div. 3LNO over the late 1980s, suddenly increased in 1990-1991, declined again over 1992-1996, then stabilized at a low level (except for a slight increase in 2007-2008). Thorny Skate distribution in Div. 3LNOPs for 2007-2015 continued to be concentrated on the southwestern Grand Banks, in Subdiv. 3Ps, and northward along the edge of the Bank. An Index of Fishing Mortality for Div. 3LNO increased from the late 1980s to a peak of 29% in 1997, and stabilized at approximately 17% during 1998-2004. In 2005, this Index declined to 4%, and remained around 5% since then. From a peak of 18 277 tons in 2000, total reported landings of skate by all countries in Div. 3LNO declined to an average of 5 600 t in 2005-2009. In 2010-2014, average reported landings from Div. 3LNO further declined to 4 810 t, then to 3 412 t over 2015-2016. In 2017 the STACFIS reported catch was 4 463 t. The 2017 TAC of 7 000 t for skates in the NRA of Div. 3LNO continues to exceed the average commercial catch during a period when minimal or no rebuilding of this stock has occurred.

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Table 1. NAFO-reported landings (tons) of skates in Div. 3LNO, 1960-2017 (STATLANT-21A).

Year	Canada	Other	Total
1960	0	73	73
1961	0	119	119
1962	0	99	99
1963	0	65	65
1964	0	145	145
1965	17	199	216
1966	75	347	422
1967	212	188	400
1968	128	31	159
1969	68	1,123	1,191
1970	99	539	638
1971	125	77	202
1972	64	487	551
1973	10	413	423
1974	638	1,690	2,328
1975	180	2,535	2,715
1976	260	1,006	1,266
1977	551	1,266	1,817
1978	816	1,015	1,831
1979	382	657	1,039
1980	351	1,027	1,378
1981	244	1,467	1,711
1982	52	756	808
1983	4	1,277	1,281
1984	0	2,013	2,013
1985	9	10,390	10,399
1986	52	14,277	14,329
1987	195	18,301	18,496
1988	91	18,675	18,766
1989	15	14,222	14,237

Year	Canada	Other	Total
1990	44	14,726	14,770
1991	18	28,390	28,408
1992	78	5,059	5,137
1993	78	5,992	6,070
1994	1,554	6,601	8,155
1995	2,412	4,912	7,324
1996	1,314	4,804	6,118
1997	2,165	9,903	12,068
1998	1,013	8,501	9,514
1999	1,081	10,864	11,945
2000	498	17,779	18,277
2001	354	14,507	14,861
2002	1,107	10,648	11,755
2003	671	13,592	14,263
2004	352	11,476	11,828
2005	685	2,853	3,538
2006	249	5,255	5,504
2007	101	6,110	6,211
2008	243	6,867	7,110
2009	435	5,286	5,721
2010	50	5,314	5,364
2011	69	5,479	5,548
2012	185	4,144	4,329
2013	21	4,323	4,344
2014	1	4472	4,474
2015	3	3322	3326
2016	1	556	557
2017	5	620	625

Table 2. NAFO-reported landings (tons) of Thorny Skate in Subdiv. 3Ps, 1960-2017 (STATLANT-21A).

Year	Canada	Other	Total	Year	Canada	Other	Total
1960	0	11	11	1990	5	549	554
1961	0	17	17	1991	1	639	640
1962	0	11	11	1992	13	46	59
1963	0	58	58	1993	22	11	33
1964	0	145	145	1994	1,566	3	1,569
1965	0	85	85	1995	1,866	4	1,870
1966	0	126	126	1996	603	2	605
1967	0	162	162	1997	829	3	832
1968	86	67	153	1998	1,251	6	1,257
1969	0	353	353	1999	1,102	4	1,106
1970	35	229	264	2000	935	21	956
1971	303	213	516	2001	1,769	39	1,808
1972	8	184	192	2002	1,413	238	1,651
1973	7	231	238	2003	1,705	82	1,787
1974	122	641	763	2004	1,190	87	1,277
1975	9	490	499	2005	967	15	982
1976	91	230	321	2006	910	78	988
1977	521	360	881	2007	1,347	491	1,838
1978	454	256	710	2008	763	632	1,395
1979	545	121	666	2009	645	354	999
1980	554	609	1,163	2010	342	529	871
1981	558	520	1,078	2011	513	228	741
1982	117	395	512	2012	354	224	578
1983	0	516	516	2013	286	271	557
1984	21	602	623	2014	201	145	346
1985	21	944	965	2015	168	75	243
1986	7	1,576	1,583	2016	404	250	654
1987	52	787	839	2017	413	192	605
1988	2	781	783				
1989	0	1,685	1,685				

Table 3a. Abundance of Thorny Skate from Canadian spring research surveys in Div. 3LNOPs, 1971-2017. Surveys were conducted with a Yankee trawl (1971-1982), an Engel trawl (1984-spring 1995; converted to Campelen-equivalents), and a Campelen trawl (spring 1996-2017).

Year	3L	3N	3O	3Ps	3LNOPs
Yankee Series – Unconverted					
1971	11,533	3,921			15,454
1972	11,037	15,634		5,615	32,285
1973	12,114	11,033	12,830	6,822	42,800
1974	26,621	11,627		11,136	49,383
1975	24,762	8,273	12,183	1,654	46,871
1976	28,294	21,419	28,595	19,118	97,427
1977	25,240	16,375	7,518	8,840	57,973
1978	21,879	10,117	7,578	11,911	51,485
1979	23,370	13,859	7,496	8,310	53,034
1980	19,206	15,847	16,788	12,200	64,041
1981	33,223	9,694	5,912	12,195	61,024
1982	21,391	23,623	11,055	3,562	59,632
1983				12,249	12,249
Engel series - Campelen Equivalents					
1984	7,574	25,226	24,615	9,417	66,832
1985	63,081	45,278	50,123	55,214	213,697
1986	51,231	53,394	21,134	36,153	161,911
1987	39,151	33,538	34,041	28,113	134,844
1988	35,030	26,474	42,991	19,043	123,538
1989	40,350	30,030	17,678	25,863	113,921
1990	43,938	71,656	40,118	21,344	177,055
1991	34,779	44,549	35,195	50,254	164,777
1992	37,475	20,645	35,567	21,510	115,198
1993	27,765	17,068	15,025	21,580	81,437
1994	15,999	17,565	19,105	19,221	71,891
1995	9,320	7,017	26,781	19,493	62,611
Campelen Series					
1996	10,418	10,636	22,731	25,591	69,376
1997	6,804	13,554	25,635	18,379	64,372
1998	7,764	10,140	34,130	22,781	74,815
1999	8,263	15,967	36,042	20,212	80,484
2000	12,512	16,027	28,525	18,574	75,638
2001	8,521	16,276	33,321	17,606	75,724
2002	5,920	8,469	32,902	17,560	64,851
2003	6,737	9,645	34,734	24,615	75,732
2004	4,762	8,925	21,153	24,256	59,095
2005	11,011	15,986	26,621	26,399	80,016
2006	8,450	23,618	17,778		49,846
2007	11,357	24,065	23,317	11,440	70,180
2008	10,572	14,477	22,738	31,239	79,027
2009	5,810	15,560	18,132	19,128	58,629
2010	10,964	20,714	32,747	26,447	90,872
2011	7,226	12,731	31,576	23,409	74,942
2012	13,342	15,866	24,268	21,848	75,324
2013	10,681	20,682	35,416	35,067	101,846
2014	7,668	27,140	23,675	23,081	81,564
2015	5,265	10,500	23,590	21,535	60,889
2016	9,154	10,154	27,085	45,191	91,584
2017		25,020	23,173	40,199	88,477

Table 3b. Biomass of Thorny Skate from Canadian spring research surveys in Div. 3LNOPs, 1971-2017. Surveys were conducted with a Yankee trawl (1971-1982), an Engel trawl (1984-1995; converted to Campelen-equivalents), and a Campelen trawl (1996-2017).

Year	3L	3N	3O	3Ps	3LNOPs
Yankee Series - Unconverted					
1971	35,100	11,307			46,408
1972	23,391	36,084		16,422	75,897
1973	17,993	27,241	23,288	13,417	81,940
1974	40,252	21,823		22,428	84,503
1975	31,191	21,579	25,328	5,719	83,817
1976	40,242	39,416	80,235	29,506	189,399
1977	63,601	44,092	19,632	12,326	139,651
1978	37,944	16,394	17,803	10,266	82,407
1979	44,377	23,877	19,820	10,094	98,168
1980	41,247	26,141	21,488	21,149	110,025
1981	55,274	17,293	12,311	11,450	96,329
1982	37,768	30,161	22,868	7,363	98,161
1983				13,704	13,704
Engel series - Campelen Equivalents					
1984	17,269	57,720	61,026	20,318	156,333
1985	102,351	86,438	110,322	36,954	336,065
1986	69,864	110,325	46,634	47,728	274,551
1987	82,037	60,535	51,007	40,697	234,276
1988	70,143	49,686	87,375	29,993	237,197
1989	73,291	49,142	40,172	44,271	206,875
1990	45,312	47,479	61,946	24,264	179,002
1991	22,197	28,925	99,003	61,534	211,659
1992	11,945	23,047	57,929	38,693	131,615
1993	8,546	18,550	35,113	16,256	78,465
1994	3,920	10,193	28,874	16,539	59,526
1995	2,798	2,824	32,323	24,924	62,869
Campelen Series					
1996	4,993	11,010	35,529	21,851	73,382
1997	3,969	9,703	28,293	20,705	62,669
1998	5,807	13,186	42,351	28,629	89,972
1999	7,266	26,254	54,045	32,062	119,626
2000	14,011	27,861	40,917	22,528	105,317
2001	10,383	29,197	59,078	24,566	123,223
2002	8,580	13,986	38,025	22,127	82,718
2003	8,411	18,216	49,707	37,072	113,406
2004	7,806	20,425	39,740	38,354	106,325
2005	19,266	33,757	46,515	32,702	132,240
2006	16,193	56,698	25,252		98,143
2007	25,044	54,188	48,369	21,080	148,682
2008	23,344	32,196	42,220	38,509	136,270
2009	7,765	29,478	52,619	27,788	117,651
2010	14,944	34,303	68,435	39,968	157,650
2011	10,046	21,239	57,020	44,310	132,615
2012	14,828	38,621	53,443	33,699	140,592
2013	11,713	43,547	76,358	34,455	166,072
2014	11,497	53,229	59,285	43,580	167,591
2015	7,179	23,031	69,703	34,788	134,701
2016	9,324	17,422	86,328	40,403	153,477
2017		36,484	55,096	46,290	138,147

Table 4a. Abundance of Thorny Skate from Canadian fall research surveys in Div. 3LNO, 1981-2017. Surveys were conducted with an Engel trawl (1981-1994), and a Campelen trawl (1995-2017).

Year	Div. 3L	Div. 3N	Div. 3O	3LNO
Engel Series				
1981	33,523			
1982	36,223			
1983	103,303			103,303
1984	70,979			70,979
1985	86,070			86,070
1986	75,424			75,424
1987	80,879			80,879
1988	86,633			86,633
1989	76,793			76,793
1990	116,758	43,855	53,191	213,803
1991	73,576	61,128	29,680	164,384
1992	94,058	33,854	24,675	152,587
1993	61,501	31,073	41,382	133,957
1994	44,205	50,141	30,748	125,094
Campelen Series				
1995	23,299	37,322	30,582	91,203
1996	23,483	22,694	45,145	91,321
1997	13,448	30,540	50,047	94,035
1998	8,917	21,132	29,785	59,834
1999	10,448	25,116	31,847	67,411
2000	12,536	31,419	39,918	83,873
2001	12,655	21,352	42,095	76,103
2002	7,541	30,925	24,488	62,954
2003	9,363	19,203	34,556	63,121
2004	6,369	21,068	32,343	59,780
2005	11,346	20,027	30,553	61,927
2006	8,888	23,211	27,688	59,787
2007	13,372	36,453	29,768	79,594
2008	15,856	48,011	40,944	104,811
2009	17,145	28,813	42,965	88,922
2010	18,429	30,859	28,137	77,426
2011	16,841	26,907	36,711	80,459
2012	21,202	30,226	51,813	103,240
2013	15,693	25,196	35,785	76,674
2014	24,555			24,555
2015	12,555	30,530	20,287	63,372
2016	17,646	33,054	26,358	77,058
2017	20,499	34,883	31,239	86,621

Table 4b. Biomass of Thorny Skate from Canadian fall research surveys in Div. 3LNO, 1981-2017. Surveys were conducted with an Engel trawl (1981-1994), and a Campelen trawl (1995-2017).

Year	Div. 3L	Div. 3N	Div. 3O	3LNO
Engel Series				
1981	36,467			
1982	65,293			
1983	165,500			165,500
1984	149,061			149,061
1985	141,054			141,054
1986	113,170			113,170
1987	87,843			87,843
1988	107,910			107,910
1989	67,877			67,877
1990	95,586	67,459	97,496	260,540
1991	52,655	103,959	75,526	232,141
1992	40,289	52,980	42,383	135,652
1993	24,096	35,528	64,294	123,918
1994	16,212	50,950	31,929	99,090
Campelen Series				
1995	11,306	40,775	44,653	96,734
1996	14,459	28,629	36,969	80,057
1997	7,534	43,075	58,160	108,770
1998	9,205	34,279	39,280	82,764
1999	13,614	32,609	42,608	88,831
2000	17,722	61,202	40,861	119,786
2001	16,420	34,311	62,156	112,886
2002	11,068	52,855	40,593	104,517
2003	14,463	36,829	46,123	97,416
2004	11,327	45,678	26,361	83,366
2005	20,107	37,442	61,595	119,143
2006	18,610	54,372	50,605	123,587
2007	30,089	70,198	56,976	157,263
2008	27,182	83,861	75,892	186,935
2009	22,848	40,801	63,200	126,849
2010	21,051	27,270	54,857	103,178
2011	16,150	51,955	69,053	137,158
2012	19,124	43,739	107,777	170,640
2013	20,752	44,160	92,042	156,954
2014	20,283			20,283
2015	19,540	66,638	48,720	134,898
2016	22,921	61,263	55,231	139,415
2017	23,568	65,010	65,422	154,000

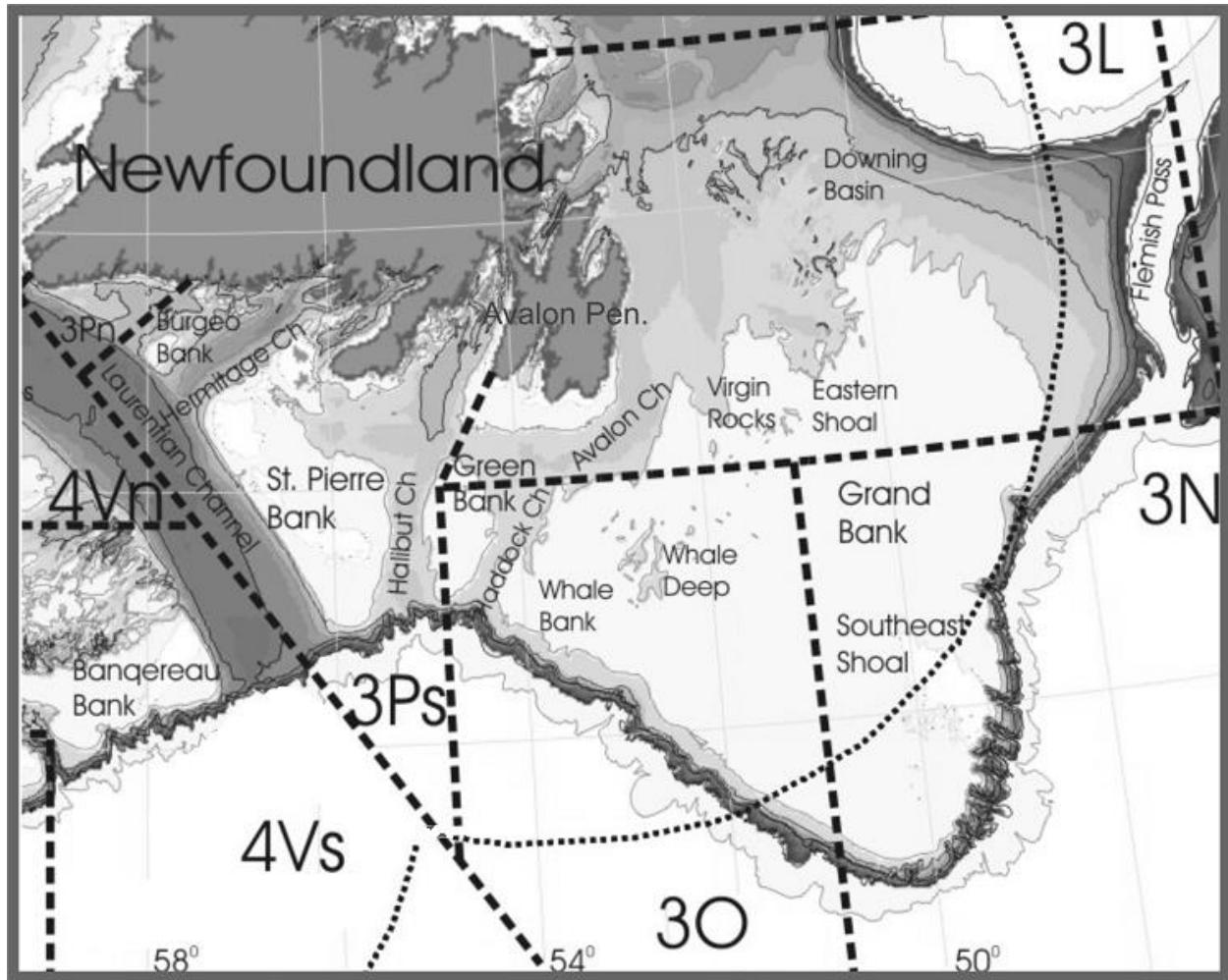


Fig. 1 Map of NAFO Divisions 3LNO and Subdivision 3Ps in relation to Canada's Exclusive Economic Zone (thin black dotted line)

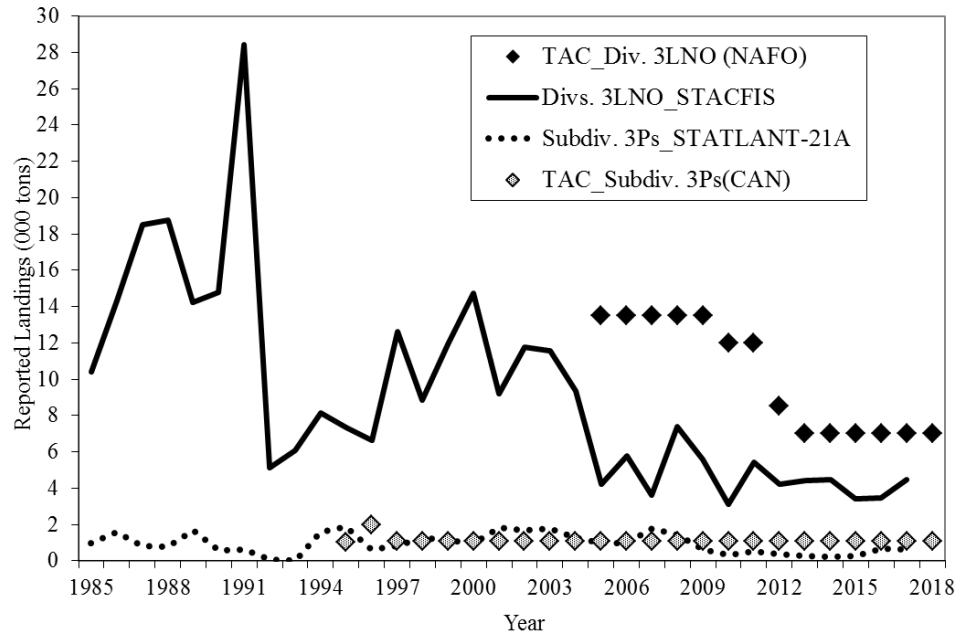


Fig. 2 Total reported landings and Total Allowable Catch (TAC) of Thorny Skate in Div. 3LNO (STACFIS) and Subdiv. 3Ps (STATLANT-21A), 1985-2018.

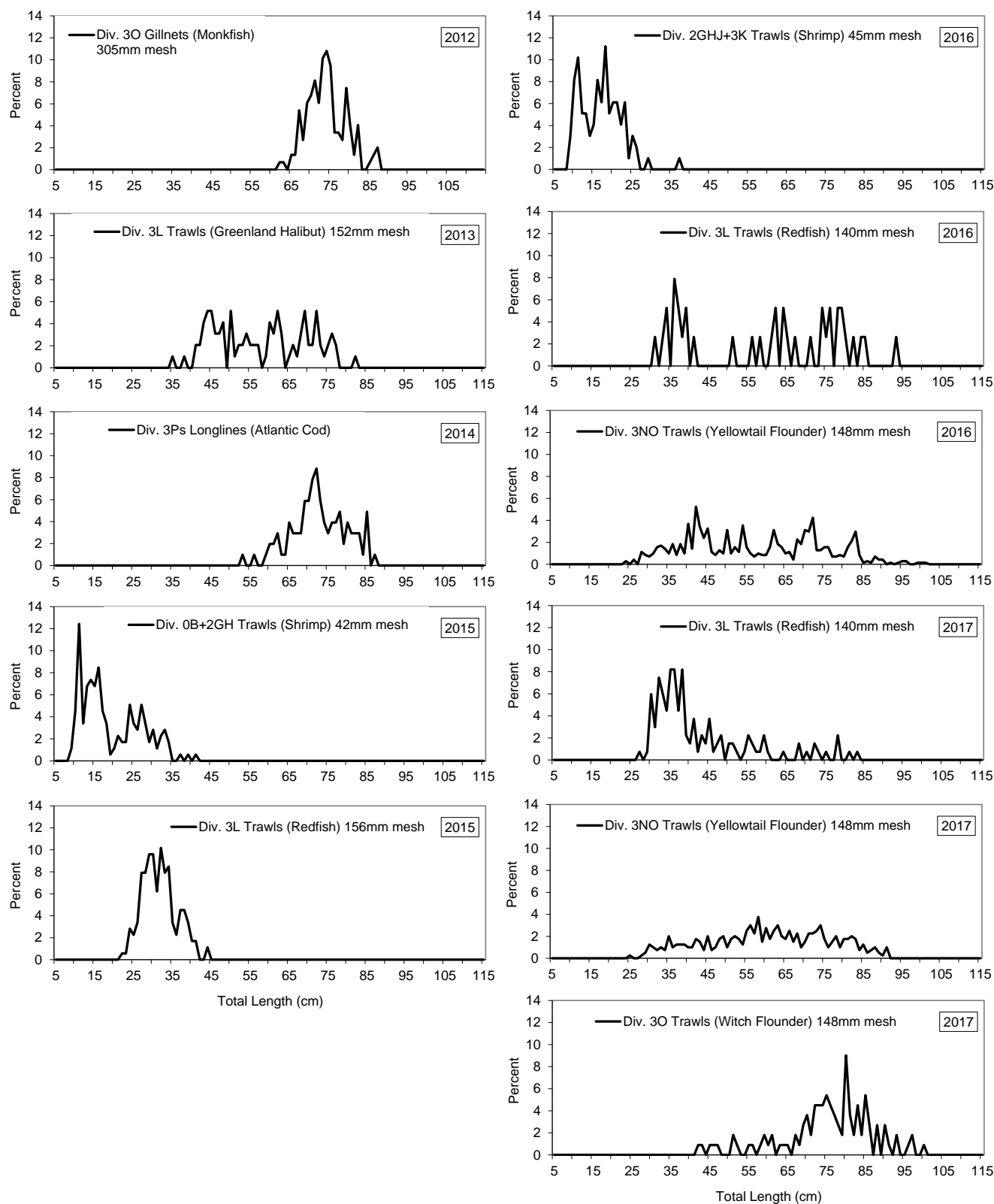


Fig. 3a Length distributions of Canadian commercial catches (sexes combined) in Div. 0B and Subareas 2+3 from skate bycatch fisheries, 2012-2017. Data are from Canadian At-Sea Fisheries Observers, and include discards

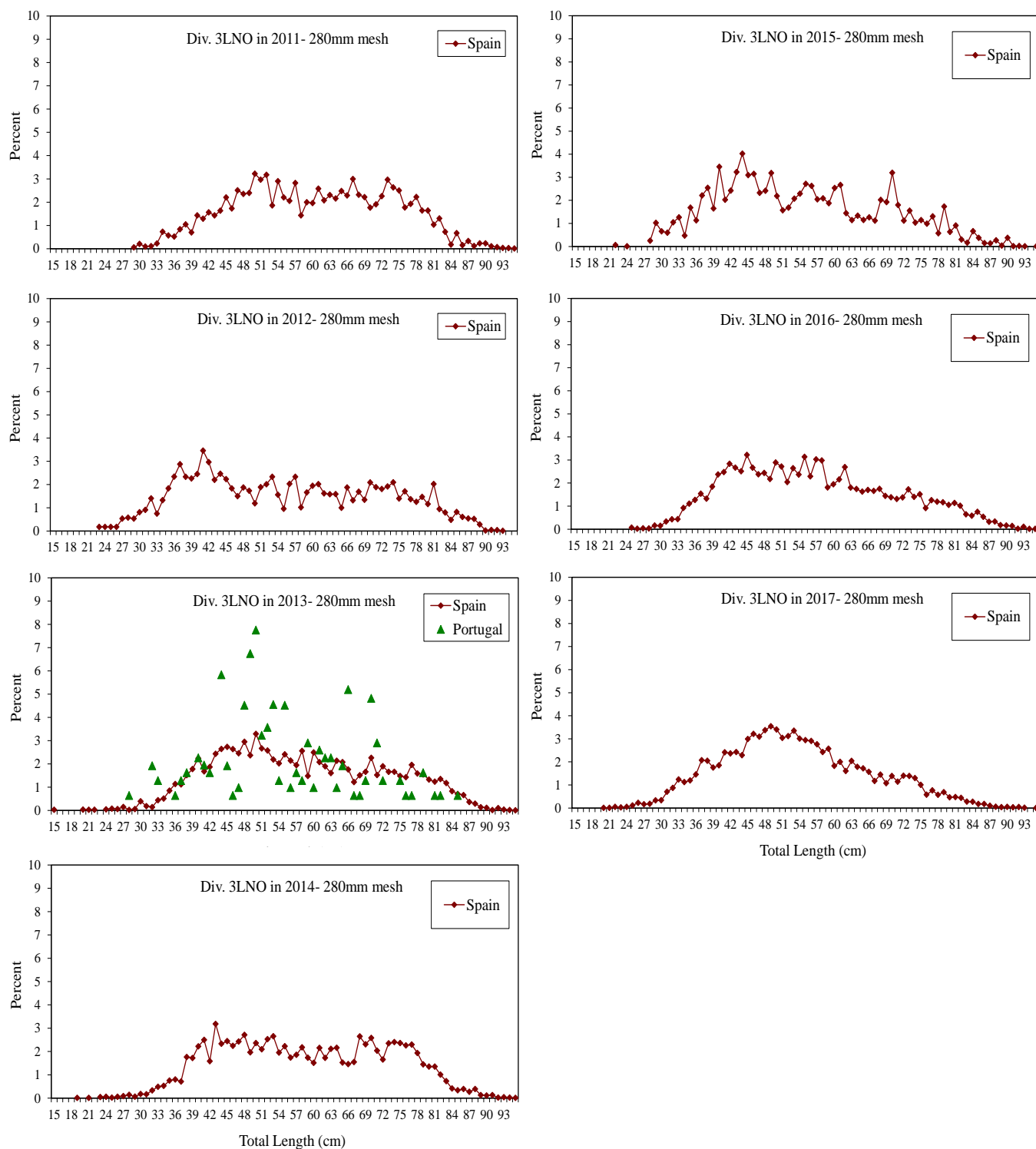


Fig. 3b Length distributions of commercial catches (sexes combined) in Div. 3LNO by country for the skate-directed (280 mm) trawl fishery, 2011-2017

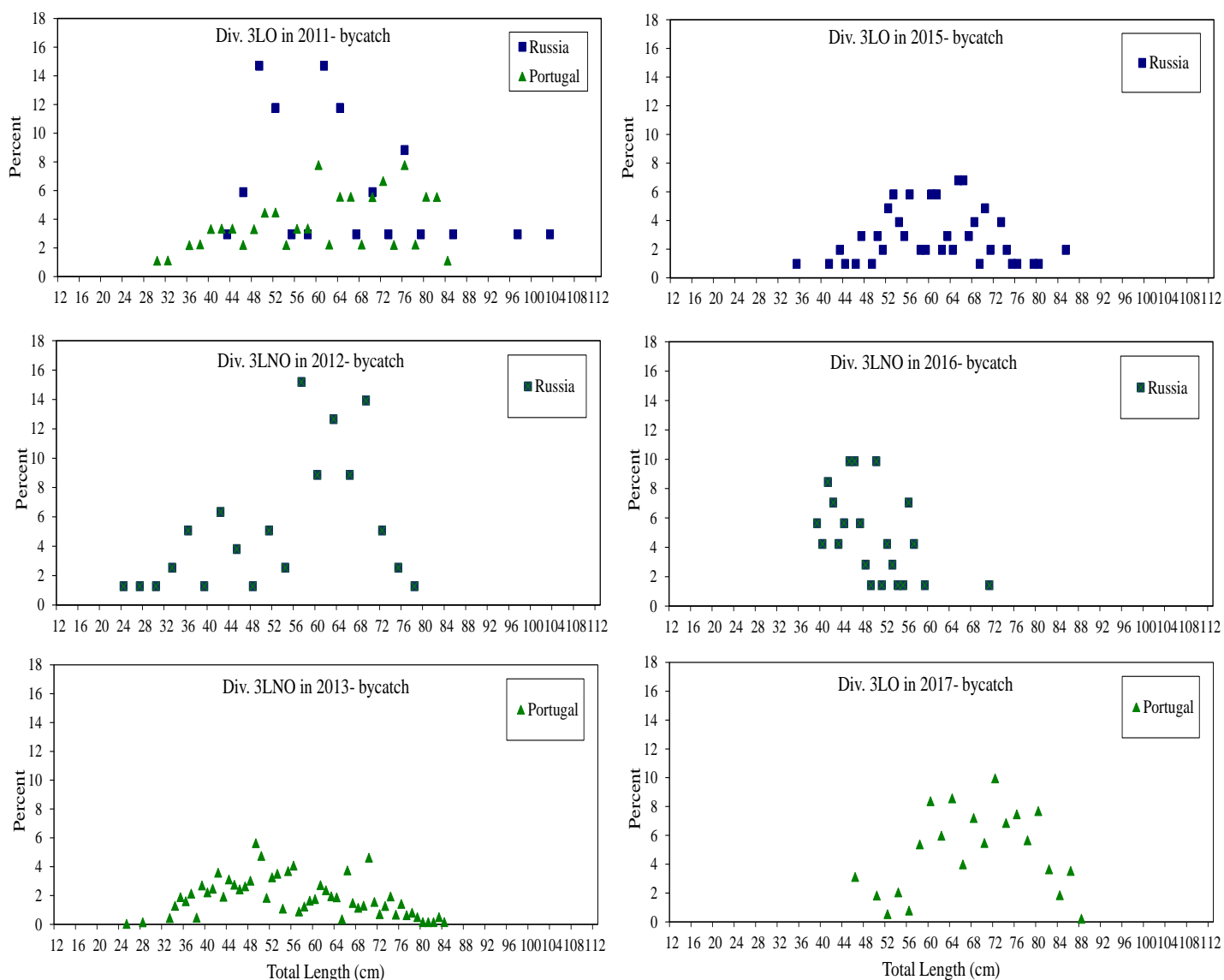
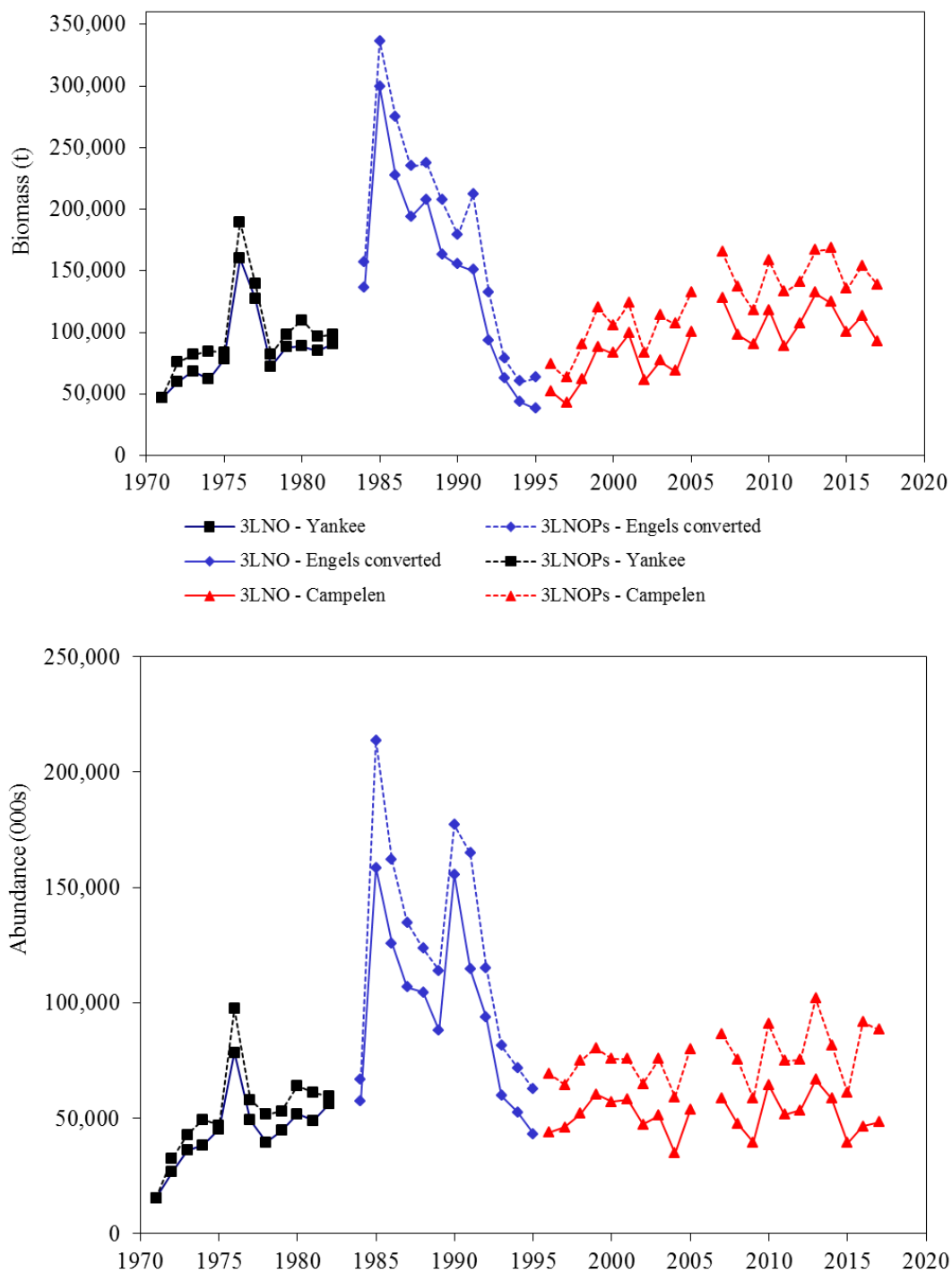


Fig. 3c Length distributions of commercial catches (sexes combined) in Div. 3LNO by country for skate bycatch (130-135 mm) trawl fisheries, 2011-2013 and 2015-2017.

**Fig. 4a**

Relative biomass and abundance indices for Thorny Skate from Canadian spring research surveys in NAFO Div. 3LNO and 3LNOPs, 1971-2017. Div. 3LNO were not surveyed in 1983, and the deeper (>103 m) portion of Div. 3NO, as well as Subdiv. 3Ps, were not surveyed in 2006.

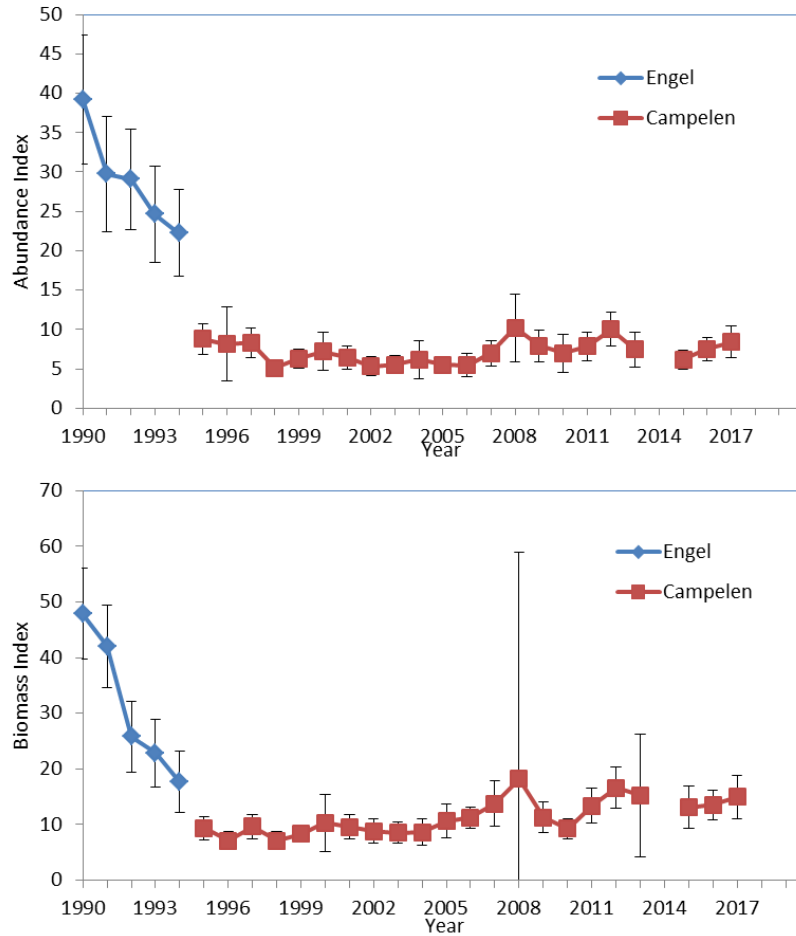


Fig. 4b Canadian fall research survey biomass and abundance indices for Thorny Skate in NAFO Div. 3LNO, 1990-2017. Deep strata of Div. 3NO were not surveyed in 2003, 2004, 2006, 2008, and both Divisions were not surveyed in 2014.

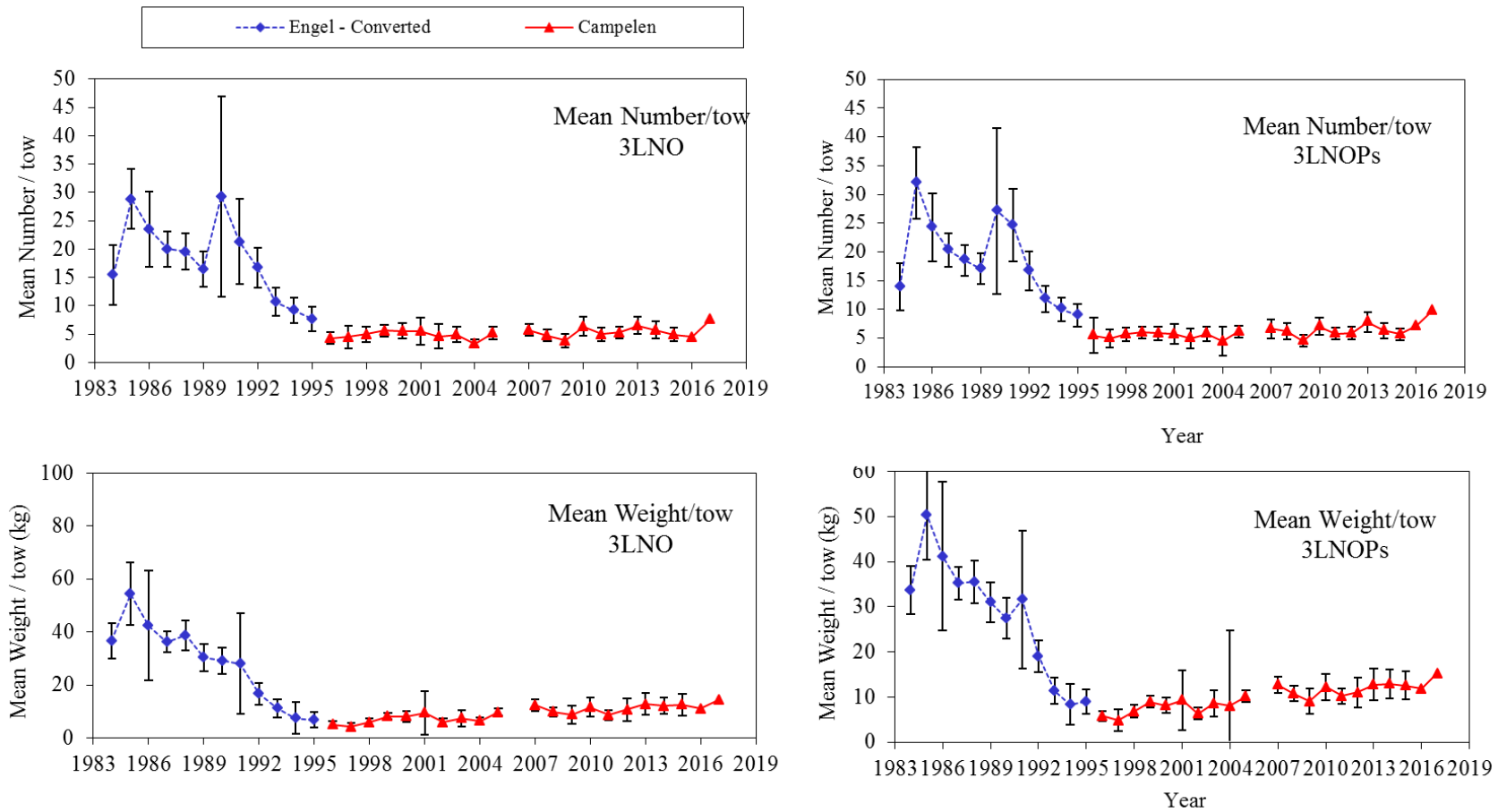


Fig. 5 Mean numbers and weights (kg) per tow (+/- 95% CI) of Thorny Skate from Canadian spring surveys in NAFO Div. 3LNO and 3LNOPs, 1983-2017. Div. 3LNO were not surveyed in 1983; and the deeper (>103 m) portion of Div. 3NO, as well as Subdiv. 3Ps, were not surveyed in 2006

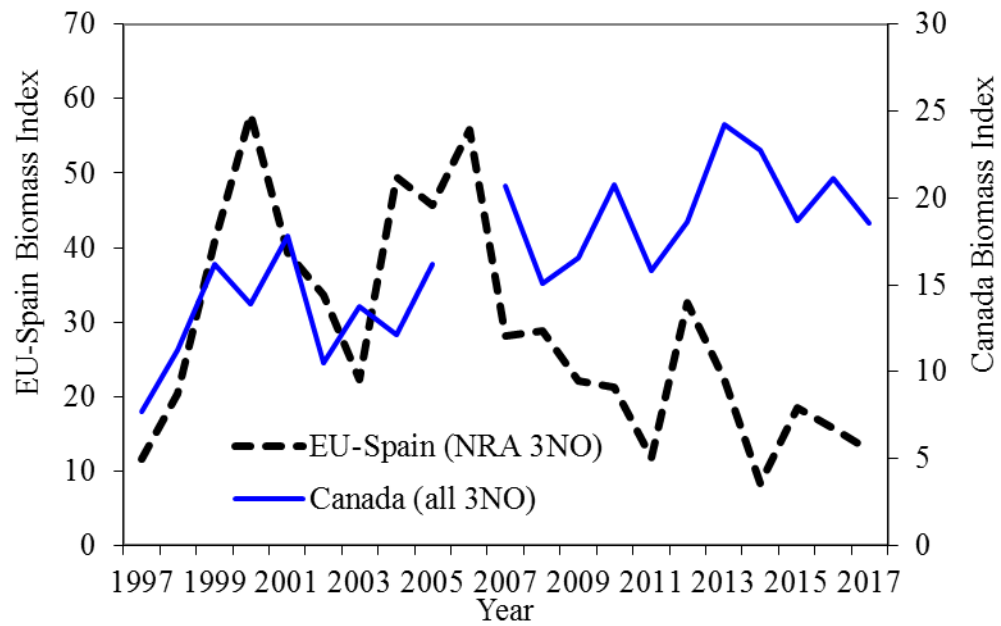
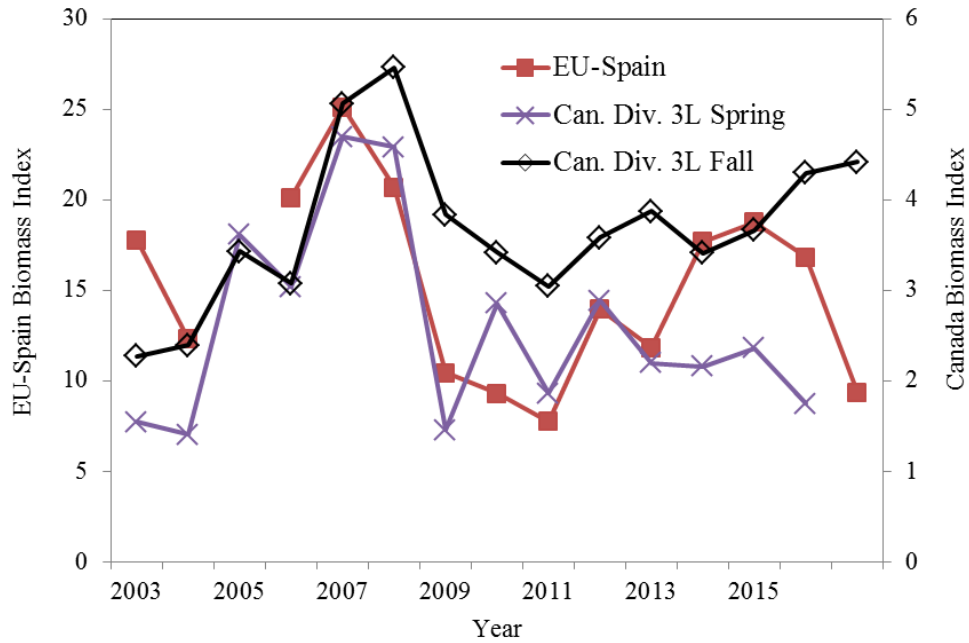


Fig. 6 Comparison of Thorny Skate biomass indices from the Canadian Campelen spring survey and the Spanish spring survey in Div. 3NO, 1997-2017. Note that Spanish surveys occur only in the NAFO Regulatory Area (NRA) of Div. 3NO.

**Fig. 7**

Comparison of Thorny Skate biomass indices from Canadian Campelen surveys and the Spanish summer survey in Div. 3L, 2003-2017. The Canadian spring survey was incomplete in 2015 and 2017, and Spanish surveys occur only in the NAFO Regulatory Area (NRA) of Div. 3L.

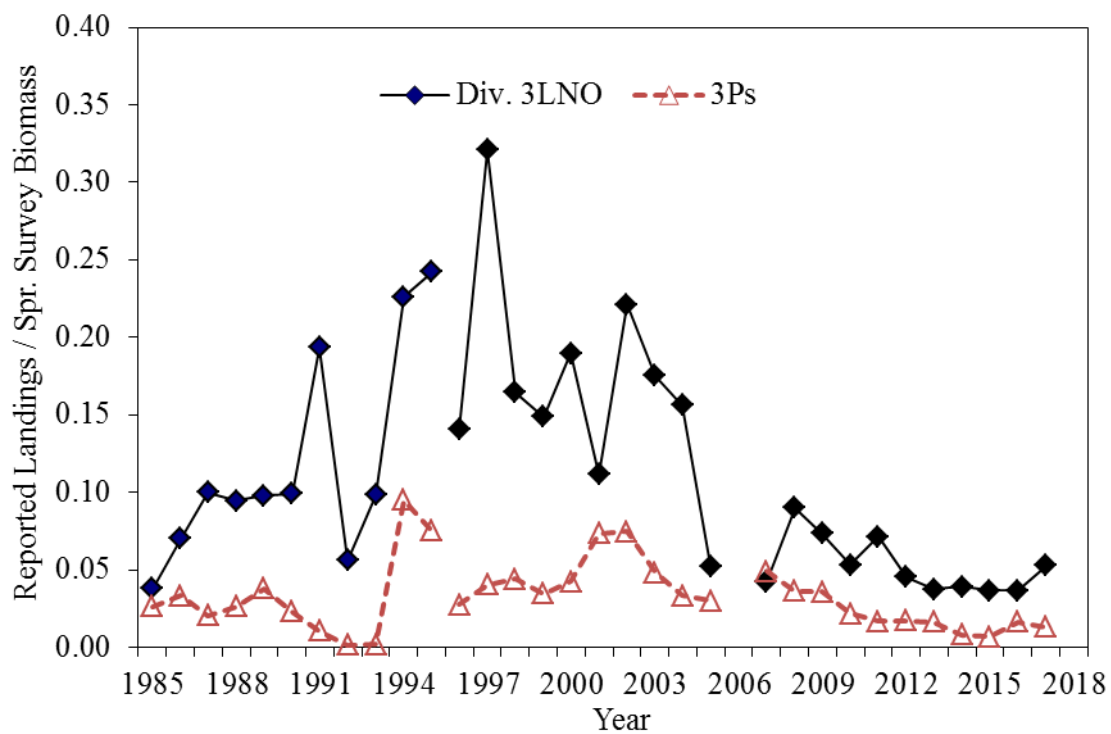


Fig. 8 Fishing Mortality Index (reported landings/spring survey biomass) for Div. 3LNO and Subdiv. 3Ps, 1985-2017. Commercial landings are STACFIS-agreed; biomass indices are from Canadian spring research surveys. The deeper (>103 m) portion of Div. 3NO, as well as Subdiv. 3Ps, were not surveyed in 2006.

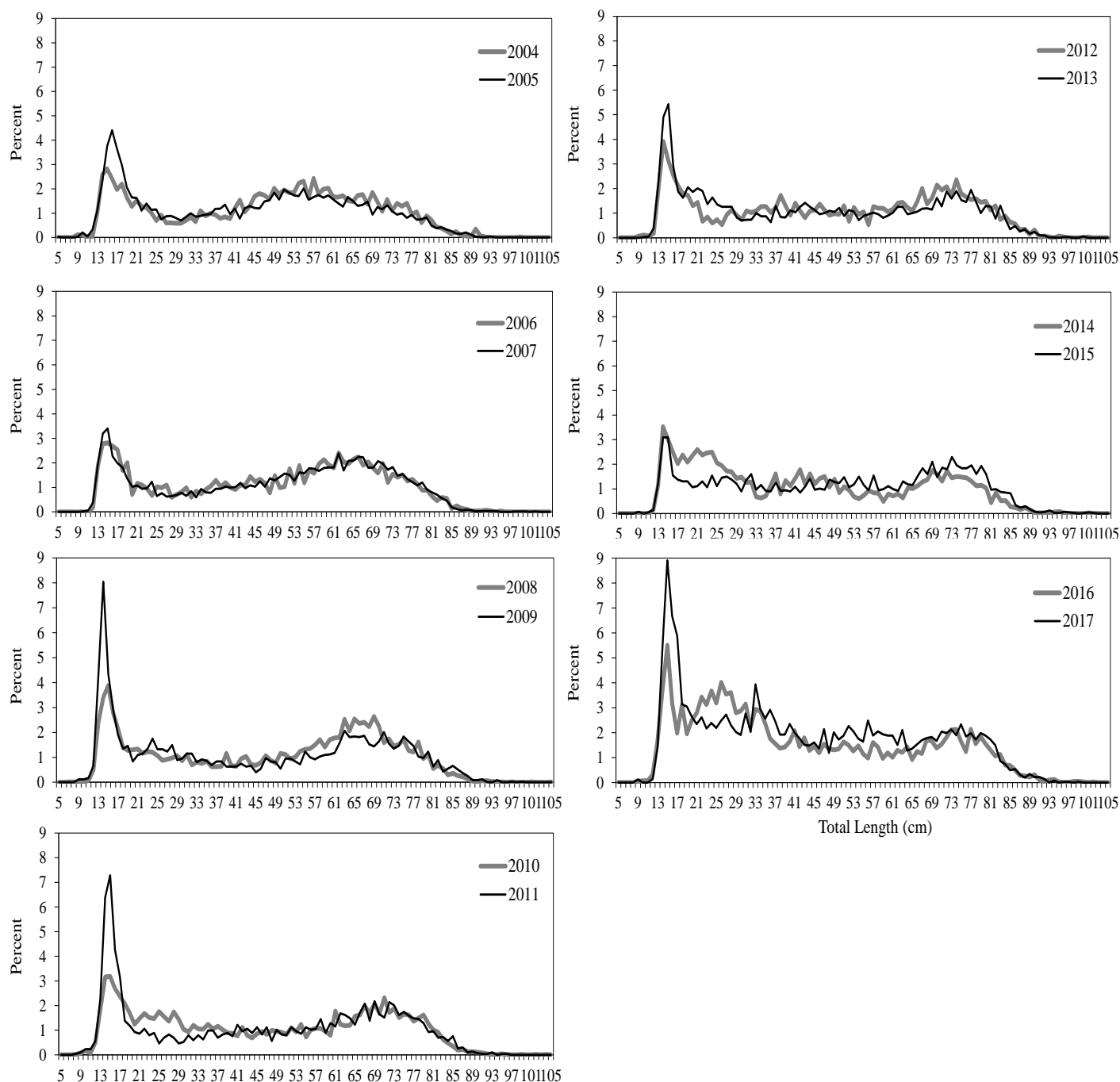


Fig. 9 Length distributions of Thorny Skate from Canadian Campelen spring surveys in Div. 3LNO and Subdiv. 3Ps, 2004-2017. The deeper (>103 m) portion of Div. 3NO, as well as Subdiv. 3Ps, were not surveyed in 2006.

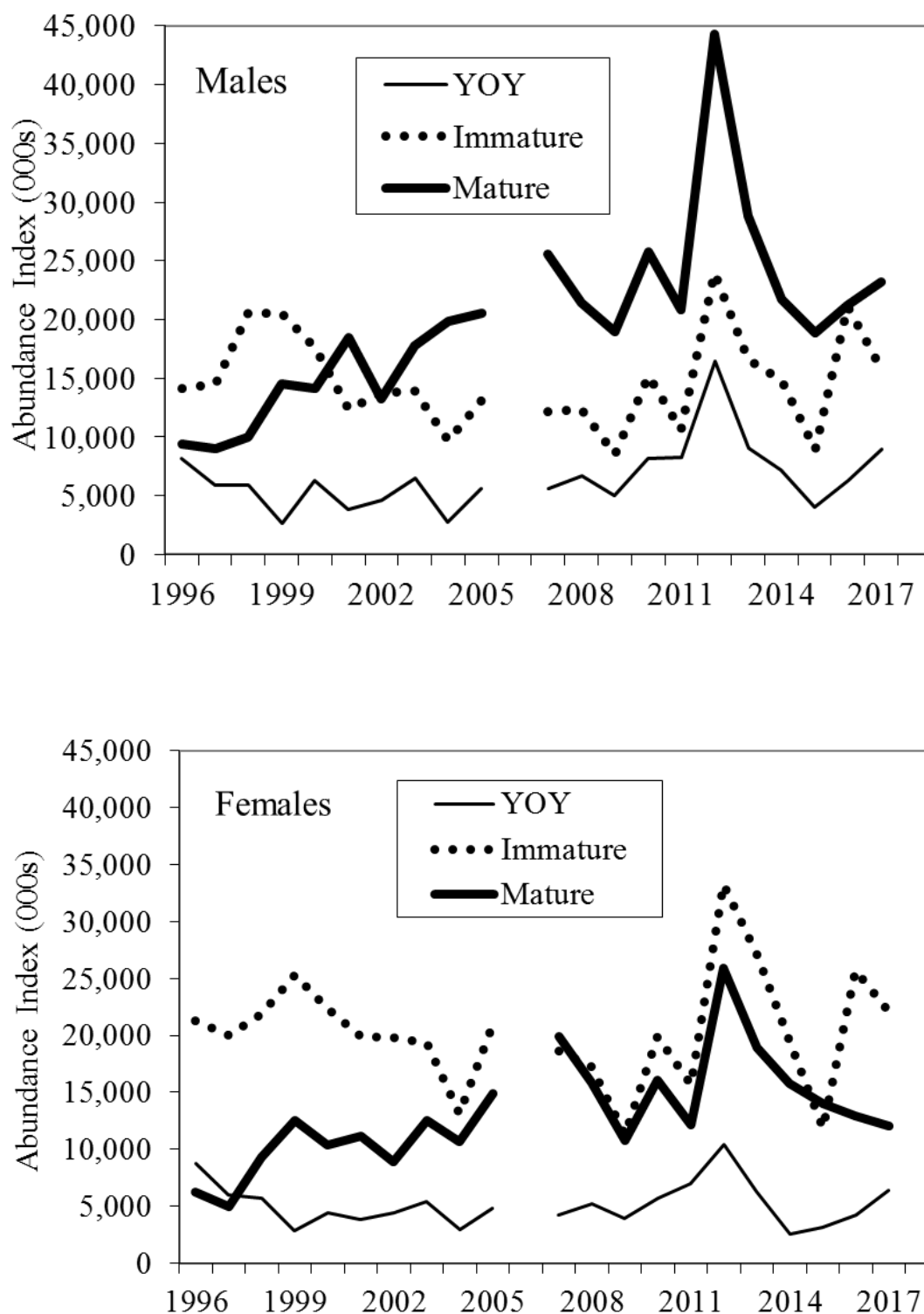


Fig. 10 Estimated abundances of male and female Thorny Skates by life stage in Div. 3LNOPs from Canadian Campelen spring surveys, 1996-2017. The deeper portion (>103 m) of Div. 3NO, as well as Subdiv. 3Ps, were not surveyed in 2006

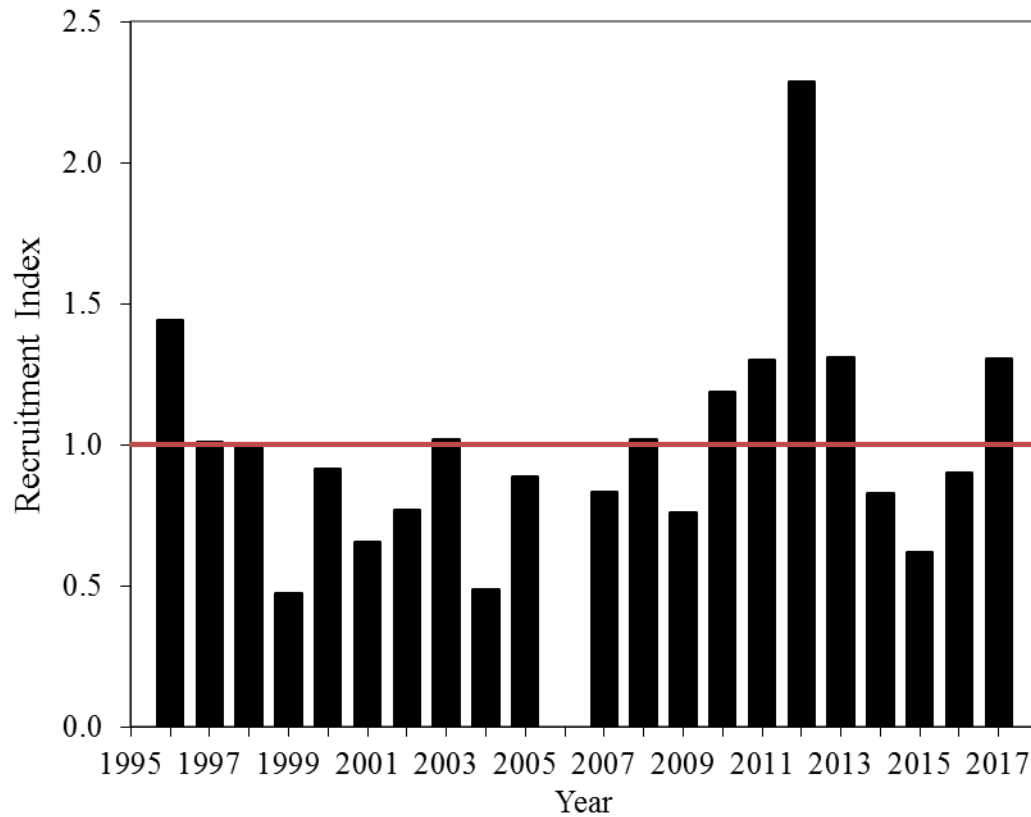


Fig. 11 Standardized recruitment index (Thorny Skate <21 cm) from Canadian spring surveys in Div. 3LNOPs, 1996-2017. The deeper portion (>103 m) of Div. 3NO, as well as Subdiv. 3Ps, were not surveyed in 2006. The red, horizontal line depicts the standardized average recruitment for 1996-2017.

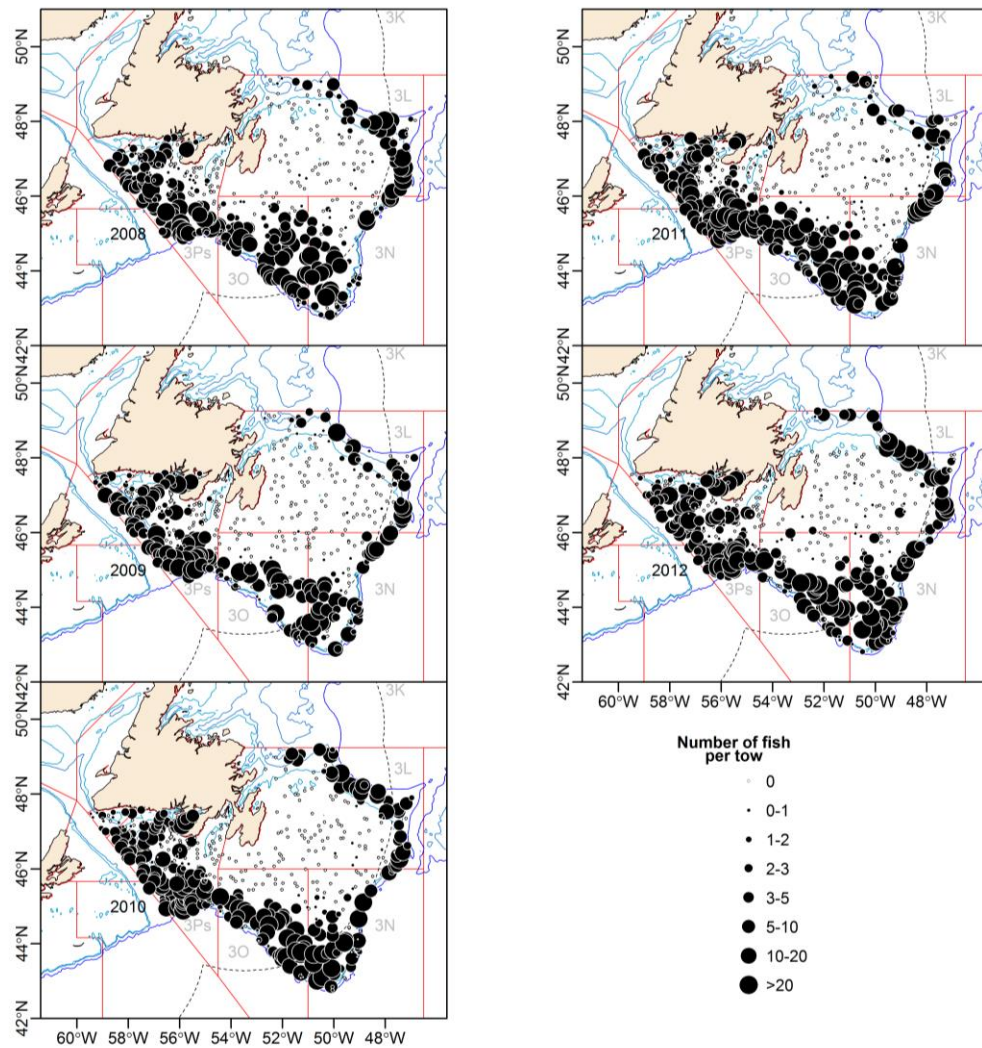
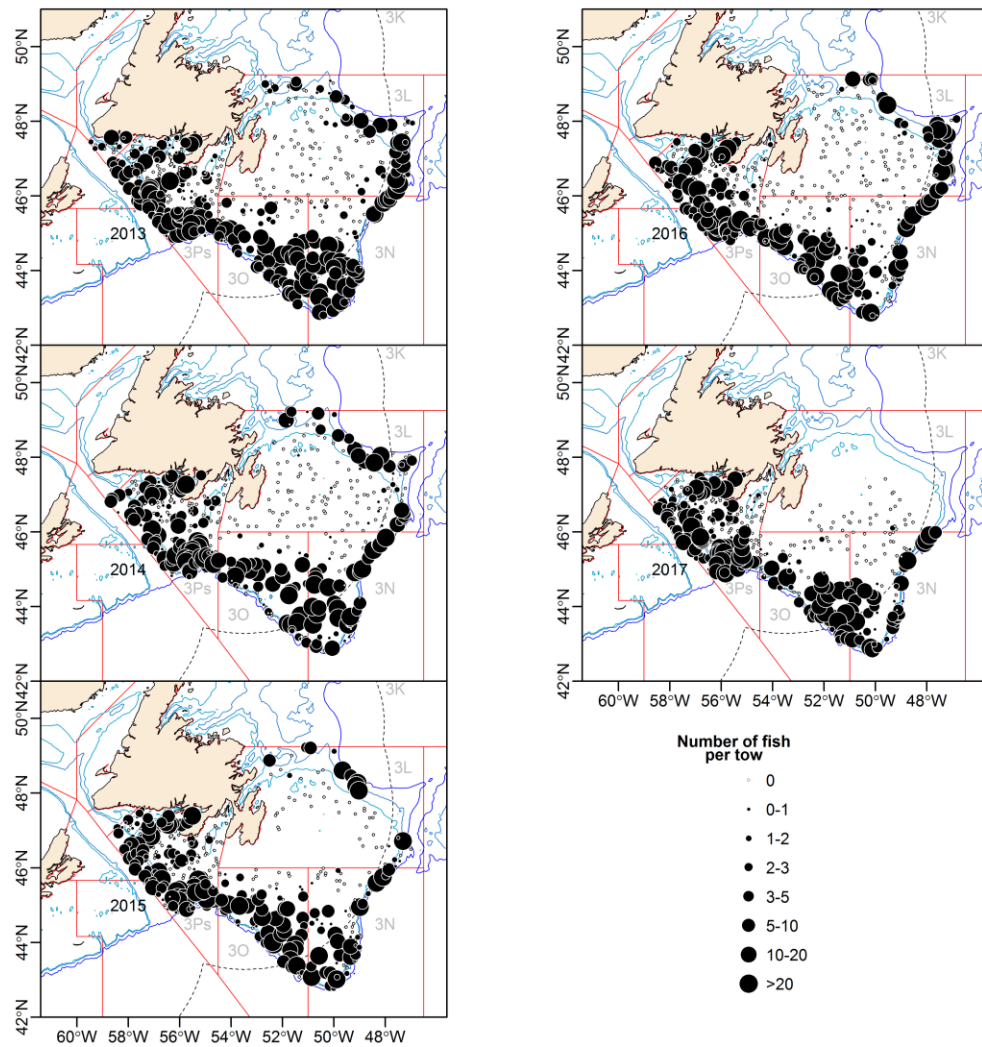
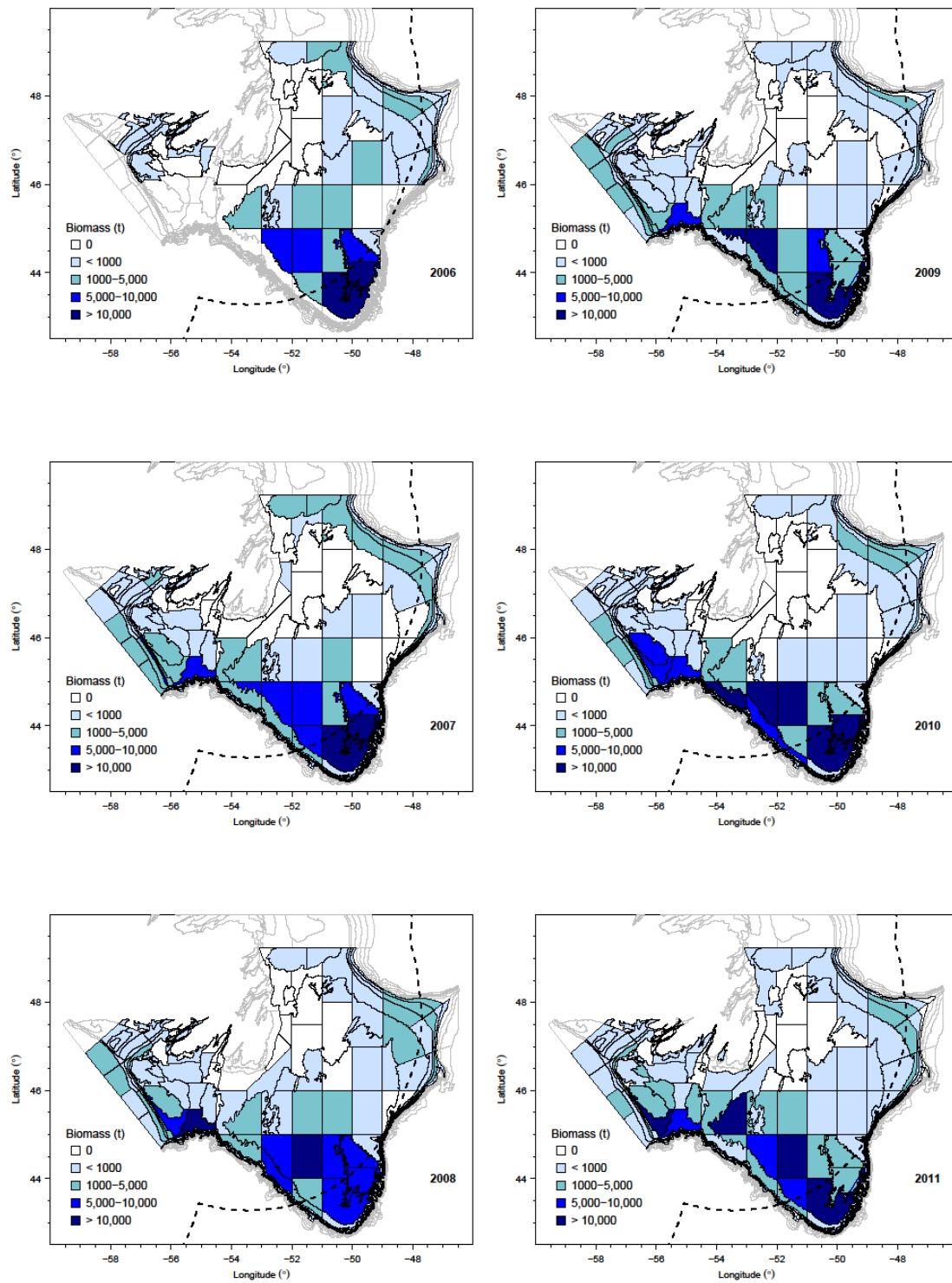


Fig. 12a Distribution (number of skates per tow) of Thorny Skate on the Grand Banks (Div. 3LNOPs) during Canadian spring surveys, 2008-2012.

**Fig. 12b**

Distribution (number of skates per tow) of Thorny Skate on the Grand Banks (Div. 3LNOPs) during Canadian spring surveys, 2013-2017. The Div. 3L survey was incomplete in 2015 and 2017.

**Fig. 13a**

Distribution (biomass in tons) of Thorny Skate on the Grand Banks (Div. 3LNOPs) during Canadian spring surveys, 2006-2011. Deeper (>103 m) portions of Div. 3NO, as well as Subdiv. 3Ps, were not surveyed in 2006.

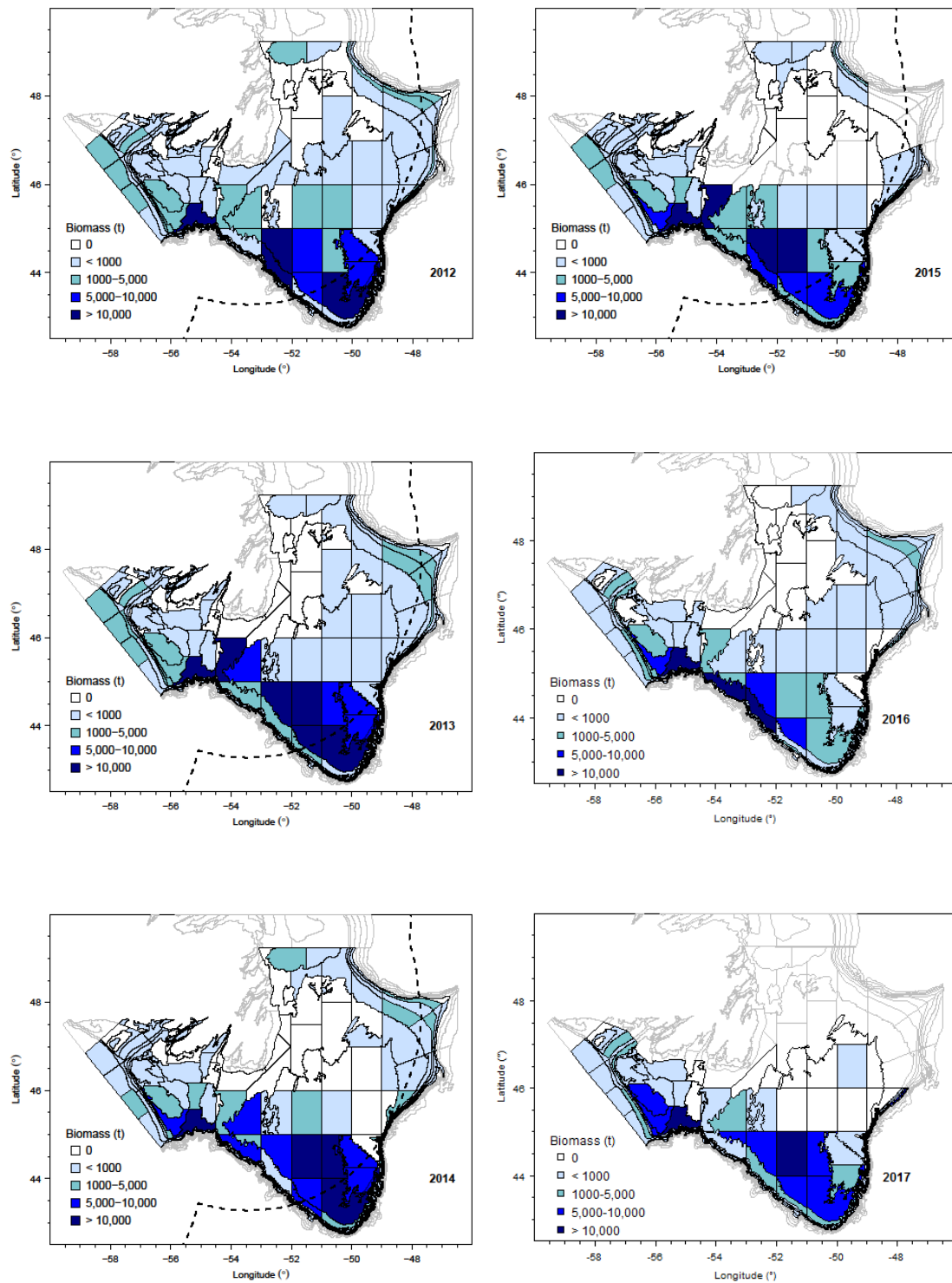


Fig. 13b Distribution (biomass in tons) of Thorny Skate on the Grand Banks (Div. 3LNOPs) during Canadian spring surveys, 2012-2017. The Div. 3L survey was incomplete in 2015 and 2017.

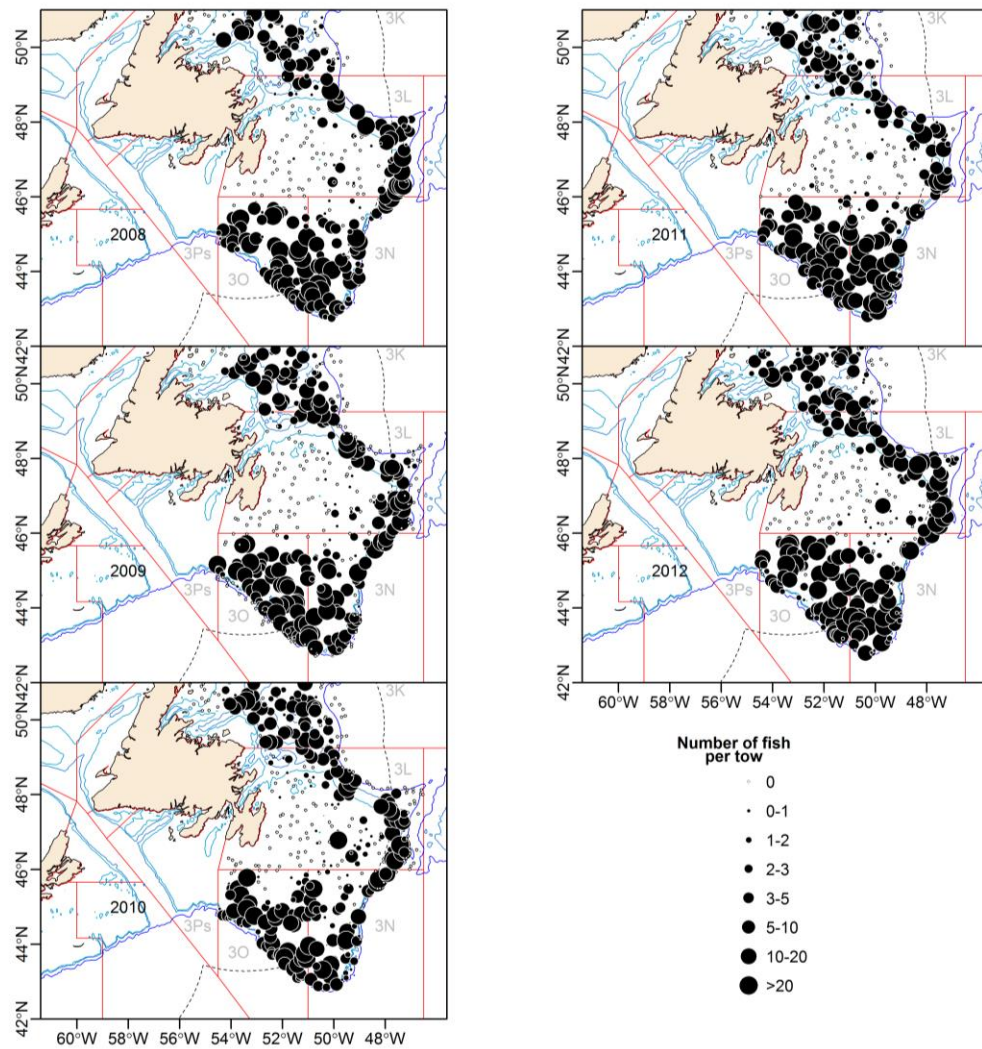


Fig. 14a Distribution (number of skates per tow) of Thorny Skate on the Grand Banks (Div. 3LNO) during Canadian fall surveys, 2008-2012. Deep strata in Div. 3NO were not surveyed in 2008.

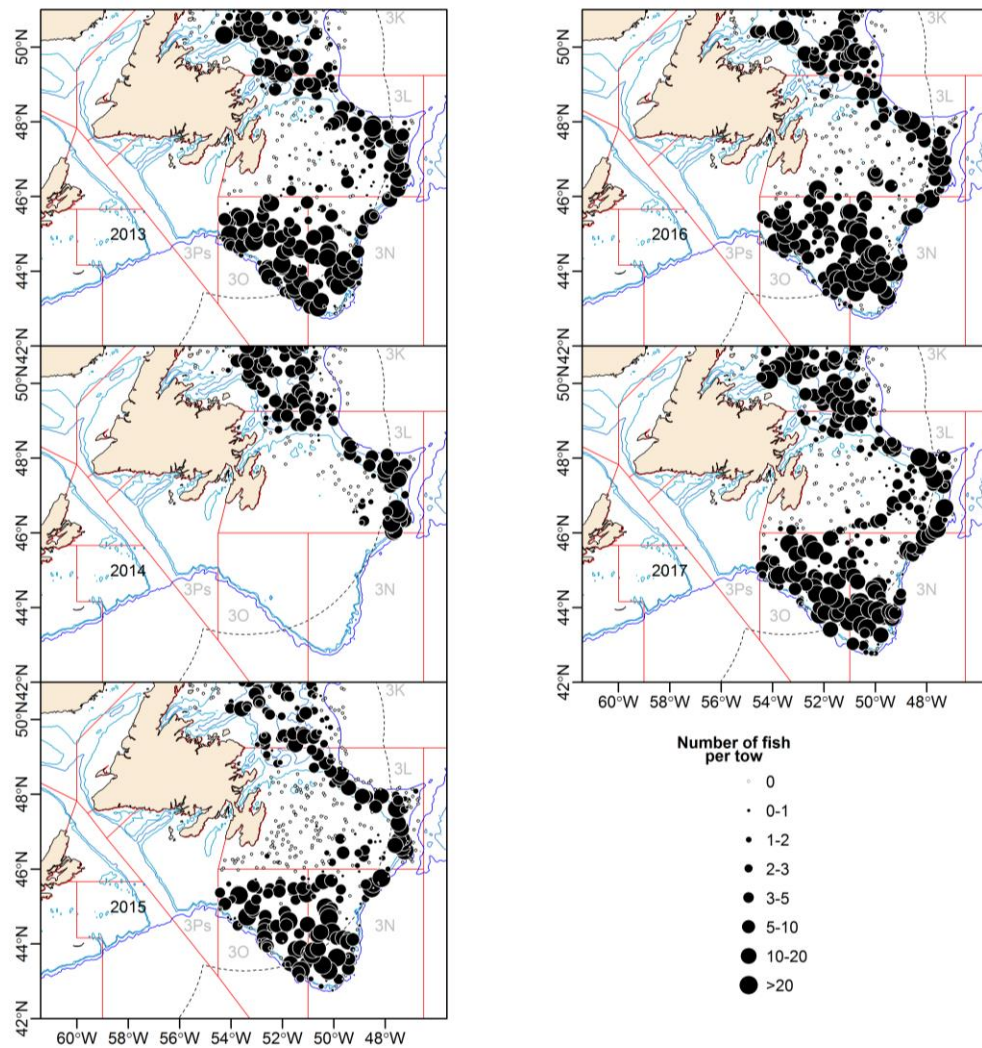


Fig. 14b Distribution (number of skates per tow) of Thorny Skate on the Grand Banks (Div. 3LNO) during Canadian fall surveys, 2013-2017. Div. 3NO were not surveyed in 2014.