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**An Assessment of White Hake (*Urophycis tenuis*, Mitchill 1815)
in
NAFO Divisions 3N, 3O, and Subdivision 3Ps**

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ABSTRACT

White Hake in NAFO Divisions 3NO and Subdivision 3Ps inhabit the southern Grand Bank and St. Pierre Bank of Newfoundland and Labrador. The spring survey index for Div. 3NOPS peaked in 2000, due to a very large 1999 year-class. Annual landings, which were at low levels in 1995-2001 (422-t average), increased to 6 718 tons in 2002 and 4 823 tons in 2003, following recruitment of the very large 1999 year-class. Since 2004, the stock has remained at a level of abundance similar to that observed in the mid1990s. In 2002-2016, the population has exhibited little recruitment; as indicated by staged abundance analysis. Increases in White Hake spawner biomass in Div. 3NOPS will require a number of large year-classes that survive to maturity.

INTRODUCTION

White Hake (*Urophycis tenuis*, Mitchill 1815) is a highly fecund gadoid species distributed in the Northwest Atlantic from Cape Hatteras to southern Labrador. Present knowledge of its biology for the Grand Banks has been summarized in previous stock assessments of this species (Han and Kulka 2007, Simpson *et al.* 2012, Simpson and Miri 2013, Simpson *et al.* 2015).

Formerly one of the commercially important species in the Southern Gulf of St. Lawrence (NAFO Division 4T) and the Scotian Shelf (Div. 4VWX and 5), White Hake stocks have declined in those regions in recent years. Their status as a commercial resource was assessed by Fisheries and Oceans Canada for Div. 4T in 2012 (Swain *et al.* 2012), and for Div. 4VWX/5 in 2012 (Simon and Cook 2013). More recently, White Hake populations in Atlantic Canada have been assessed by Fisheries and Oceans Canada within a Species at Risk recovery potential context (Nozères *et al.* 2015, Guénette and Clark 2016, Simpson *et al.* 2016, Swain *et al.* 2016). Stock structure of White Hake has been investigated using morphological and parasite loads (Hurlburt and Clay 1998, Melendy *et al.* 2005), tagging work (Kohler 1971), and allozyme data (Clay *et al.* 1992). More recently, polymorphic micro-



satellite loci have been applied to investigate stock structure in White Hake (Seibert and Ruzzante 2006, Zinck 2007, Roy *et al.* 2012). Three genetically-distinct populations were identified, which straddle several NAFO Divisions and overlap in their distribution (Roy *et al.* 2012). One such population of White Hake includes Div. 3OPs.

This paper presents an updated assessment of White Hake in Div. 3NO and Subdiv. 3Ps (Fig. 1); focusing on the available research survey information and fisheries data.

Fisheries and Management

A. TAC Regulation

White Hake in Div. 3NO came under quota regulation in September 2004, when the Fisheries Commission decided that a Total Allowable Catch (TAC) of 8 500 t be established for 2005-2007, and maintained for 2008-2009. In September 2009, Fisheries Commission reduced the TAC for White Hake in Div. 3NO to 6 000 t for 2010-2011. The TAC was further reduced to 5 000 t for 2012, and to 1 000 t for 2013-2017.

B. Catch Trends

Reported landings of White Hake in Div. 3NO (all countries combined; STATLANT-21A) peaked in 1985 and 1987 at approximately 8 100 tons, with about half of that reported by non-Canadian sources as bycatch, then declined to an average of 1 765 t from 1988 to 1994 (Table 1; Fig. 2). With the restriction of fishing by other countries to areas outside Canada's 200-mile limit (Div. 3NO in the NAFO Regulatory Area, or NRA) in 1992, reported non-Canadian landings fell to zero. Average landings were lowest in 1994-2001 (406 t), then increased to 5 365 t in 2002 and 6 158 t in 2003; following recruitment of the very large 1999 year-class. Reported landings decreased to an average of 400 t in 2007-2014, and were 411 t and 356 t in 2015 and 2016 (respectively; Table 2).

Commercial landings of White Hake in Subdiv. 3Ps were less variable (Tables 1, 2; Fig. 2): averaging 1 114 tons in 1985-93, then decreasing to an average of 619 t in 1994-2002. Subsequently, reported landings increased to an average of 1 374 t in 2003-2007, then decreased to a 342-t average in 2008-2014. Subdiv. 3Ps landings were 331 in 2015, and 400 t in 2016.

Fisheries Interactions

White Hakes are captured in directed fisheries in Div. 3NOPs, and as bycatch primarily in those targeting Atlantic Cod (*Gadus morhua*), Atlantic Halibut (*Hippoglossus hippoglossus*), Monkfish (*Lophius americanus*), Redfish (*Sebastes* spp.), and Witch Flounder (*Glyptocephalus cynoglossus*; Fig. 3). White Hakes are also caught mainly by gillnets, longlines, and otter trawls (Fig. 4). In White Hake-directed fisheries, bycatch of other commercially important species occurs, including Atlantic Cod, Haddock (*Melanogrammus aeglefinus*), American Plaice (*Hippoglossoides platessoides*), Atlantic Halibut, and Monkfish.

Size

Length distributions of White Hake taken in Canadian commercial directed fisheries in Div. 30 from 2012-2016 indicated that gillnets captured 48-107 cm fish with a 66 cm and 72-74 cm modes (152 mm mesh; Fig. 5a; no gillnet samples taken after 2012). Canadian longlines in Div. 30 caught a larger range in 2016: 36-114 cm range with a 70 cm mode (Fig. 5a). In Subdiv. 3Ps, Canadian longlines captured a contracted range of 52-102 cm and 68 cm mode in 2013 (Fig. 5a). The Witch Flounder otter trawl fishery (152-155 mm mesh) in Div. 30 captured 34-110 cm White Hakes with a 62 cm mode in 2015-2016, while this fishery caught 49-87 cm fish (65, 68, and 75 cm modes) in Subdiv. 3Ps in 2015 (Fig. 5a). The Atlantic Cod longline fishery in Subdiv. 3Ps caught a contracted range of 45-73 cm White Hakes in 2012, with a mode at 55 cm (Fig. 5a).

Commercial catches of White Hake by Portuguese trawlers (130 mm mesh) in the NRA of Div. 30 in 2012-2015 contained 24-76 cm fish (42-45 cm modes in 2012-2014, 52 cm mode in 2015; Fig. 5b). EU-Portugal reported 30-65 cm White Hakes (43 cm mode) in 2016. Russian trawl fisheries in the NRA of Div. 3NO in 2013-2015 captured 32-84 cm White Hakes; except for a very contracted range of 35-45 cm fish in 2014 (Fig. 5c). Russia reported 5 White Hakes of 38-44 cm from Div. 30 in 2016. Spanish trawlers using 130-135 mm mesh in the NRA of Div. 3NO in 2012 caught 27-52 cm White Hakes (37 cm mode), 21-80 cm fish (30-33 cm mode) in 2014, and 15-81 cm hakes in 2016 with the majority around 18-22 cm (Fig. 5di). Using 280 mm mesh gear in Div. 3NO, EU-Spain also captured a range of 34-78 cm fish (49-50 cm mode) in 2012, 20-95 cm fish (33-34 cm mode) in 2014, and 41-90 cm hakes in 2015 (42 cm mode; Fig. 5dii).

C. Research Surveys

Canadian Research Surveys -Spring

Stratified-random demersal surveys have been conducted by Canadian research vessels in the spring (April-June) of each year from 1971 to the present. The most significant alterations in Canadian standardized survey design are changes in survey gear. The spring survey can be separated into three time periods, based on the trawl used in each period: 1971-1983 (Yankee 41.5), 1984-spring 1995 (Engel 145), and spring 1996 to the present (Campelen 1800). McCallum and Walsh (1996) and Walsh and McCallum (1996) described the geometry and specifications of the Engel and Campelen trawls. While survey design remained constant, additional strata were included, along with modifications to some of the original strata (Bishop 1994). A significant change in the surveys is the addition of shallower and deeper strata after 1993. Additional causes of variation in spring survey coverage are discussed in detail by Brodie and Stansbury (2007), and Healey and Brodie (2009). No size-based conversion factors for the two gears were derived from comparative surveys for White Hake; therefore, catch rate data and resulting biomass and abundance indices cannot be directly compared between trawl types. Similarly, no conversion factor exists for White Hake between Yankee and Engel trawls.

In the 2006 Canadian spring survey, 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. Thus, survey estimates for that year are not comparable to others in the Campelen time series.

Spring Survey Biomass and Abundance Indices

Spring survey estimates of biomass and abundance are presented in Table 5a for Div. 3NO and Subdiv. 3Ps. Mean weights and mean numbers per tow with 95% confidence intervals are presented in Figure 6a.

The spring biomass index for White Hake on the Grand Banks in Div. 3NOPs increased rapidly in 1999-2000 to approximately 26 000 tons, but then steeply declined and is presently at low levels comparable to earlier estimates in the Campelen time series. During the Canadian spring survey of 2000, the estimated abundance of about 117 000 000 fish was 10-times greater than that observed in either the first years of the Campelen series or during recent years, due to the very large 1999 year-class. In 2011, the abundance index increased from low levels to about 27 000 000 fish (3 times the 2007-2009 average), primarily due to a moderate 2010 year-class. Average spring abundance estimates were 15 042 000 White Hakes in 2012-2016. Average biomass during this period was 11 149 t.

Canadian Research Surveys -Autumn

Stratified-random autumn surveys have been conducted by Canada in Div. 3NO from 1990 to the present. Beginning in autumn 1995, Canadian survey gear was changed from the Engel 145 otter

trawl to the Campelen 1800 shrimp trawl. Additional causes of variation in autumn survey coverage are discussed in detail by Brodie and Stansbury (2007), and Healey and Brodie (2009). In addition, Canada does not survey Subdiv. 3Ps in autumn. Furthermore, autumn surveys reach deeper maximum depths (~1 400 m) than those in spring (~750 m). Therefore, autumn survey data are not directly comparable to spring survey data. Because the autumn series is not spatially complete over the designated stock area, Canadian spring surveys are used as the primary estimator of biomass and abundance trends for White Hake. It must also be noted that Canadian research vessels' mechanical difficulties prevented the surveying of: deep strata in Div. 3NO in 2003, 2004, and 2006; strata deeper than 730 m in 2008; and Div. 3NO in autumn 2014.

Autumn Survey Biomass and Abundance Indices

Autumn biomass and abundance estimates (1990-present) are restricted to Div. 3NO. These indices show a large increase in Div. 3NO White Hake between 1998 and 1999 (Table 5b; Fig. 6b), primarily due to the presence of large numbers of Young-of-the-Year (YOY). Of particular interest is the large increase in abundance in Div. 3N in 1999 to levels never previously observed (~83 000 000 fish). The pattern of Campelen autumn indices is offset by one year (earlier) as compared to that from spring surveys, because autumn surveys catch newly-settled YOY that were spawned in the previous spring (Kulka *et al.* 2005b). About twenty-five weeks later, the next spring survey samples the previous year's cohort as 1-year-old White Hakes. This pattern was most apparent when a very large year-class was produced in 1999. After 2003, autumn abundance indices drastically declined to low levels (5 000 000-average annually in 2004-2010); comparable to those of 1995-1998. In 2011-2013, the autumn abundance index for Div. 3NO increased to 2001-2002 levels at approximately 16 000 000 fish. Biomass has declined from the 2010-2013 average of 9 423 t to an average of 6 862 t over 2015-2016. Similarly, abundance declined from an average of 13 780 000 fish in 2010-2013 to an average of 5 369 000 fish over 2015-2016.

EU-Spain Div. 3NO Spring Surveys

Spain initiated a survey in the NRA of Div. 3NO in 1995. Initially, the 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 the C/V *Playa de Menduïña*, and a Campelen 1800 trawl replaced the Pedreira (González-Troncoso *et al.* 2016). Results of this survey are available for White Hake from 2001 onwards.

EU-Spain biomass indices were highest in 2001, declined to 2003, increased to a small peak in 2005, then declined to its lowest level in 2008 (Fig. 7). In 2009-2013, the EU-Spain index indicated a gradually increasing trend relative to 2008. In 2014, this trend reversed with a decline in biomass. The generally increasing trend over 2008-2013 is similar to that depicted by Canadian spring surveys, which cover all of Div. 3NO (Fig. 7). The Canadian index continued to increase in 2014, followed by declines in 2015 and 2016; whereas the EU-Spain index has increased in recent years following a decline in 2014. Both trends are also reflected in abundance at length data from EU-Spain and Canadian spring surveys (Fig. 8). In 2011, Canada observed a moderate peak of 21-26 cm fish (Age 1); representing the 2010 year-class. In 2012, EU-Spain observed a small peak of 36-45 cm fish with a mode of 44 cm, while a similar peak of 37-45 cm White Hakes (mode of 42 cm) was found in the Canadian spring survey. The majority of these Age-2+ juveniles represent the 2010 cohort. In 2013, both EU-Spain (total range: 13-89 cm) and Canada (total range: 11-79 cm) observed a small peak of 13-26 cm fish with modes of 22 and 25 cm (representing the 2012 year-class). Few Age 1 White Hakes were found in 2014 by Canada (total range: 14-95 cm), and none by EU-Spain (total range: 33-74 cm). In 2015, Canada observed a small peak of 15-23 cm fish (total range: 11-71 cm) with a 20-21 cm mode (representing the 2014 year-class), while Spanish surveys did not; although the latter reported a larger size range: 15-100 cm. Few Age 1 White Hakes were found in 2016 by EU-Spain (total range: 16-98 cm), and almost none by Canada (total range: 19-80 cm).

Landings/ Biomass Ratios

Using NAFO STACFIS-reported landings and the Canadian spring survey biomass index, estimates of Relative F were calculated for White Hake in Div. 3NO and Div. 3NOs. Relative fishing mortality (Rel. F = NAFO-reported landings/Can. spring biomass) declined to low levels in 1999-2001, increased to a high peak in 2002-2003 supported by the very large 1999 year-class, then declined to its lowest levels in 2011-2016 (Fig. 9). Relative F was higher in Div. 3NO than in Subdiv. 3Ps during 2002-2003, because of new directed fisheries for White Hake by EU-Spain, EU-Portugal, and Russia; coupled with very low recruitment after 1999.

D. Biological Studies

Stage-based Analysis

Maturity analysis from data collected by Canadian Campelen spring surveys in 1996-2016 indicated that length at 50% maturity is different between sexes; but very similar for each sex among years and between areas (Div. 3NO versus Subdiv. 3Ps; Fig. 10). Females reach 50% maturity at 53 cm, and males do so at 38 cm.

Information on White Hake abundance by life stage from Canadian spring surveys is presented for 2004-2016 in Figure 11. White Hakes in their first year correspond to lengths ≤ 26 cm, while 27-57 cm represents Age 2+ juveniles, and 58+ cm fish are primarily mature adults (Kulka *et al.* 2005a). A 2010 cohort was seen as a moderate peak of 1-year-olds in 2011, as a small peak of 2+ juveniles in 2012, and as a small peak of larger immatures in 2013. Note that almost all of the Age 1 White Hakes were found in Div. 3NO, except in 2016 when 82% were found in Subdiv. 3Ps. Furthermore, 2+ juveniles were observed almost equally in Div. 3NO and in Subdiv. 3Ps, except in 2016 when 78% were found in Subdiv. 3Ps. For mature White Hakes (58+ cm), percent abundance was higher in Div. 3NO relative to Subdiv. 3Ps, except in 2014 when almost all adults surveyed were found in Div. 3NO.

Partitioned by sex, relative numbers at length data from Canadian spring surveys of Div. 3NO in 2009-2016 indicated that no Age 1 fish were observed in 2009, while a small peak of 58-61 cm males were found (with a total of 44% female; Fig. 12a). A very small 2010 peak of 1-year-olds was 38% female. A larger peak of 1-year-olds (2010 year-class) observed in 2011 was 31% female, while a small peak of 23-29 cm females was also found. In 2012, a moderate peak of 35-47 cm White Hakes was observed; primarily representing the 2010 year-class, and 30% of all immatures were female. In 2013, a small peak of 1-year-olds (2012 year-class) was 23% female, and another small peak of 40-56 cm fish was also seen (43% of all immatures being female; some fish representing the 2010 cohort). Few Age 1 White Hakes were found in 2014, while a small peak of 2+ juveniles (31-43 cm fish; mostly representing the 2012 year-class) and another small peak of 48-56 cm immatures (39% of all juveniles being female) were observed. In 2015, a small peak of 1-year-olds (2014 year-class) was 33% female, and another small peak of 41-46 cm fish was also seen (36% of all immatures being female). Few Age 1 White Hakes were found in 2016, with no significant peaks over the range of fish caught (40% of all juveniles were female) in Div. 3NO.

In Subdiv. 3Ps over 2009-2016, relative abundance from Canadian spring surveys indicated that a small peak of Age 1 White Hakes was observed (33% female) in 2009. This 2008 cohort was also found as juveniles in 2010; with 23% of all immatures comprised of 32-42 cm females, and 30% being 29-39 cm males. In 2011, 35-57 cm females dominated the immatures (52%), and a peak of 32-41 cm males (31%) was also observed. Results were similar for immature females (54%) and males (27%) in 2012. In 2013, a small peak of 1-year-olds (46% female; 2012 year-class), and other small peaks of 28-32 cm females (20% of all immatures), 46-49 cm females (9%), 27-30 cm males (14%), and 43-48 cm males (10%) were seen. In 2014, almost no Age 1 or mature White Hakes were found in

Subdiv. 3Ps, and 71% of 2+ juveniles were observed in a 28-39 cm range (34% female). Few Age 1 fish were found in 2015 and 2016. In 2015, two peaks of males (28-32 cm, 35-39 cm) dominated the immatures (72%), while females comprised 80% of the few adults seen (8% in total). In 2016, a small peak of 37-44 cm females (21% of all immatures) and a larger peak of 35-41 cm males were observed (21%), while females comprised 92% of the 8% mature White Hakes caught in Subdiv. 3Ps.

Stage-based analysis of abundance from Canadian spring surveys in Div. 3NOPS for 2001-2016 indicated that immature White Hakes (sexes combined) older than two years dominated the population (Fig. 13); similar to what was observed for this stock prior to 2000 (Kulka *et al.* 2005b). A small peak of 1-year-old fish (13% female) was observed in 2005; depicting the 2004 year-class. Although spawning stock abundance was low in 2010-2013, small peaks of Age 1 fish were observed in 2011 (31% female; representing the 2010 cohort), 2013 (27% female; representing the 2012 year-class), and 2015 (29% female; representing the 2014 cohort). There are currently no indications of increased abundance of mature White Hakes.

In Canadian spring research surveys, the number of White Hakes ≤ 26 cm in length is assumed to be an index of recruitment at Age 1. Abundance of Age 1 White Hakes in 2000 was very large, but no large year-classes were observed since 1999 (Fig. 14). The index of recruitment (sexes combined) for 2011 was comparable to that seen in 1999, and a smaller peak in 2013 was similar to one in 2005. Although an even smaller peak was observed in 2015, the index was very low in 2016.

E. Stock Distribution

White Hake in Div. 3NO and Subdiv. 3Ps are confined largely to an area associated with the warmest bottom temperatures (4-8°C) along the southwest fringe of the Grand Banks, edge of the Laurentian Channel, and the south-west coast of Newfoundland (Kulka *et al.* 2005a).

Distributions of White Hake from Canadian spring surveys in Div. 3NOPS during 2007-2016 are shown in Figures 15a,b. Earlier distribution maps are available in Simpson *et al.* (2016). As in previous years, this stock continues to occupy the southwest shelf edge areas of Div. 3NO. In Subdiv. 3Ps, White Hake are distributed along the shelf edge, and in the Laurentian and Hermitage Channels. Strata with higher stratified biomass estimates on the slope edge of Div. 3O over 2011-2014 and less so in 2015, are not present in 2016 (Fig. 16).

F. Assessment Results

Precautionary Reference Points & Quantitative models

Different approaches to the estimation of limit reference points and modeling White Hake in Div. 3NOPS were investigated. These include surplus production modeling under a Bayesian framework (Simpson *et al.* 2015), surplus production modeling using ASPIC (Prager 1994, 2014), and catch-resilience models (Martell and Froese 2013). Progress was made in the development of the Bayesian surplus production model but concerns on model diagnostics prevented the model being used as an assessment tool.

Resource Status

Recent spring survey indices indicate that the White Hake stock size in Div. 3NOPS remains at levels comparable to those observed during the Canadian Campelen spring surveys of 1996-1999.

Age-structured assessment of this stock is currently not feasible. However, population abundance at length estimates from Canadian spring surveys suggest that no significant recruitment has occurred for White Hake in Div. 3NO. In fact, there has been extremely low recruitment since that generated by the very large 1999 year-class.

Given that good recruitment rarely occurs and remains unpredictable for this White Hake population, commercial fishing pressure should be regulated in the NRA of Div. 3NO by a TAC set at a level that will allow survival and growth to maturity of larger year-classes: a strategy crucial to rebuilding this stock.

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Table 1. NAFO STATLANT-21A reported landings of White Hake (tonnes) by NAFO Division in 1960-2016.

Year	3N			3O			3Ps			3NO	3NOPs
	non-Can	Canada	Total	non-Can	Canada	Total	non-Can	Canada	Total	Total	Total
1960	164	37	201	210	181	391	500	232	732	592	1324
1961	9	17	26	25	152	177	32	100	132	203	335
1962	1	2	3	1384	406	1790	1	74	75	1793	1868
1963		12	12	5	129	134	8	103	111	146	257
1964		14	14		113	113		124	124	127	251
1965	125	5	130	18	28	46	60	71	131	176	307
1966	4	9	13	102	51	153	45	39	84	166	250
1967	549	24	573	967	34	1001	43	67	110	1574	1684
1968		5	5	22	64	86	20	403	423	91	514
1969	9	1	10	7	49	56	6	375	381	66	447
1970	21	48	54	44	107	151	227	397	624	205	829
1971	366	132	498	4110	2584	6694	221	1443	1664	7192	8856
1972	259	34	293	1594	1998	3592	115	2062	2177	3885	6062
1973	33	59	92	307	2508	2815	84	1330	1414	2907	4321
1974	214	31	245	358	2476	2834	18	1305	1323	3079	4402
1975	1186	43	1227	2430	1926	4356	765	1432	2197	5583	7780
1976	663	237	900	1272	1225	2497	10	1344	1354	3397	4751
1977	1005	22	1027	976	1095	2071		1683	1683	3098	4781
1978	670	42	712	1199	682	1881		1051	1051	2593	3644
1979	246	44	290	919	360	1279		660	660	1569	2229
1980	209	242	451	1856	311	2167		546	546	2618	3164
1981	809	22	831	564	310	874		1030	1030	1705	2735
1982	687	5	692	913	336	1249		773	773	1941	2714
1983	271	30	301	1912	683	2595		425	425	2896	3321
1984	400	108	508	3182	645	3827		683	683	4335	5018
1985	1542	110	1652	2835	1672	4507		1156	1156	6159	7315
1986	473	394	867	1569	2169	3738	14	1228	1242	4605	5847
1987	4019	1321	5340	990	1731	2721		1318	1318	8061	9379
1988	866	830	1696	111	954	1065	12	683	695	2761	3456
1989	5	878	883	23	1103	1126	3	706	709	2009	2718
1990	228	832	1060	7	1053	1060	35	1441	1476	2120	3596
1991	1507	20	1527		960	960	36	1445	1481	2487	3968
1992		19	19		1647	1647		1208	1208	1666	2874
1993		18	18		1004	1004		741	741	1022	1763

Table 1. continued-

Year	3N			3O			3Ps			3NO	3NOPs
	non-Can	Canada	Total	non-Can	Canada	Total	non-Can	Canada	Total	Total	Total
1994	20	16	36	4	253	257		382	382	293	675
1995	5		5	1	276	277		420	420	282	702
1996	28		28	1	311	312		362	362	340	702
1997	92		92	6	329	335		315	315	427	742
1998	81		81	8	188	196	1	561	562	277	839
1999	51	43	94	13	322	335		575	575	429	1004
2000	124	21	145	29	393	422	134	976	1110	567	1677
2001	73	18	91	49	493	542	10	920	930	633	1563
2002	1221		1221	3132	1014	4146	3	915	918	5367	6285
2003	2688		2688	3053	417	3470	3	1105	1108	6158	7266
2004	170	6	176	1364	375	1739	22	1361	1383	1915	3298
2005	21	0	21	258	685	943	23	1615	1638	964	2602
2006	73	2	75	178	950	1128	1	1484	1485	1203	2688
2007	12	10	22	74	627	701	2	1253	1255	723	1978
2008	26	6	32	60	778	838	6	659	665	870	1535
2009	19	3	22	70	389	459	3	362	362	481	843
2010	20	13	33	65	174	239		378	378	272	650
2011	3	0	3	94	66	160		200	200	163	363
2012	3	3	9	84	49	131	5	208	207	140	347
2013	10	10	10	112	101	195	-	191	167	205	372
2014	26	15	30	216	59	243	1	384	354	273	627
2015	18	18	36	269	106	375	1	330	331	411	742
2016	6	6	12	234	186	420	3	397	400	432	832

Table 2. White Hake NAFO STACFIS estimates (000s of tonnes), STATLANT-21A reported landings, and Total Allowable Catch (TAC) quotas for NAFO Divisions 3NO and Subdivision 3Ps.

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Div. 3NO:												
TAC	8.5	8.5	8.5	8.5	6	6	5	1	1	1	1	1
STATLANT-21A ¹	1.2	0.7	0.9	0.5	0.3	0.2	0.1	0.2	0.3	.4	.3	
STACFIS	1.1	0.6	0.9	0.4	0.2	0.3	0.1	0.2	0.3	.5	.4	
Subdiv. 3Ps:												
STATLANT-21A	1.5	1.3	0.7	0.4	0.4	0.2	0.2	0.2	0.4	.3	.4	

Table 5a. Biomass and abundance of White Hake from Canadian spring research vessel surveys, 1971-2016. Surveys were conducted with a Yankee bottom trawl (1971-1983), an Engel trawl (1984-spring 1995), and a Campelen trawl (spring 1996-2016). NAFO Subdiv. 3Ps was not surveyed in 1971, 2006; Div. 3O was not surveyed in 1971, 1972, 1974, 1983; and Div. 3N was not surveyed in 1983. Note that deep strata in Div. 3NO were not surveyed in spring 2006.

Year	Biomass (tonnes)				Abundance (000s)			
	3N	3O	3Ps	3NOPs	3N	3O	3Ps	3NOPs
Yankee series								
1971	0	0		0	0	0		0
1972	354		2,725	3,079	61		1,556	1,618
1973	36	1,532	465	2,033	11	327	247	585
1974	0		5,224	5,224	0		2,055	2,055
1975	0	3,173	4,491	7,664	0	1,080	2,646	3,726
1976	110	5,623	4,778	10,511	32	1,413	3,856	5,301
1977	50	1,339	7,168	8,557	43	466	3,935	4,444
1978	0	6,188	6,774	12,962	0	4,361	4,058	8,420
1979	165	1,978	6,310	8,453	34	1,065	3,077	4,176
1980	0	1,385	3,970	5,356	0	1,015	2,053	3,068
1981	139	96	7,448	7,682	28	93	4,743	4,865
1982	0	1,058	4,283	5,342	0	399	1,340	1,739
1983			0	0			0	0
Engel series								
1984	258	3,531	2,558	6,348	57	1,085	1,179	2,321
1985	46	2,878	5,303	8,227	8	1,315	3,045	4,368
1986	356	2,438	11,105	13,899	70	574	4,186	4,830
1987	43	2,752	9,866	12,661	95	1,114	4,438	5,647
1988	32	5,431	13,005	18,469	63	690	5,533	6,286
1989	0	925	6,884	7,809	0	251	4,130	4,382
1990	0	754	3,988	4,742	0	236	2,941	3,177
1991	0	1,039	4,591	5,630	0	1,118	3,800	4,918
1992	0	606	3,008	3,614	0	574	2,699	3,274
1993	0	522	2,929	3,451	0	301	2,670	2,970
1994	0	1,079	2,433	3,512	0	885	2,274	3,159
1995	0	334	2,334	2,668	0	189	2,104	2,294
Campelen series								
1996	4	2,020	6,282	8,306	75	2,982	8,089	11,145
1997	4	2,221	8,507	10,733	91	2,987	12,432	15,510
1998	7	2,205	4,007	6,219	79	2,249	4,765	7,093
1999	20	12,194	8,236	20,450	29	26,010	8,654	34,693
2000	30	15,900	10,294	26,224	716	104,360	11,743	116,819
2001	269	14,908	8,092	23,269	517	39,384	13,792	53,692
2002	96	10,808	10,118	21,022	105	11,334	15,098	26,537
2003	234	7,981	5,762	13,977	176	7,250	6,904	14,330
2004	33	10,369	6,622	17,024	53	8,477	6,977	15,506
2005	20	5,932	5,249	11,205	35	9,725	5,506	15,306
2006	247	12,267		12,517	69	10,370		10,463
2007	2	3,510	6,940	10,452	7	2,734	6,061	8,802
2008	108	4,660	3,633	8,400	23	5,689	3,991	9,703
2009	183	4,656	2,582	7,435	152	2,804	4,547	7,548

Table 5a. continued-

Year	Biomass (tonnes)				Abundance (000s)			
	3N	3O	3Ps	3NOPs	3N	3O	3Ps	3NOPs
Campelen series								
2010	52	4,283	3,739	8,074	30	5,085	5,285	10,400
2011	571	6,423	4,727	11,722	2,175	17,834	6,745	26,754
2012	1,548	6,215	3,686	11,449	2,933	7,383	4,657	14,972
2013	49	7,755	3,987	11,792	178	11,807	5,581	17,566
2014	482	9,494	3,630	13,606	529	8,342	5,834	14,705
2015	71	6,102	3,596	9,769	31	9,999	6,032	16,062
2016	468	3,613	5,050	9,131	231	3,135	8,537	11,903

Table 5b. Biomass and abundance of White Hake from Canadian autumn research vessel surveys in Div. 3NO, 1990-2016. Surveys were conducted with an Engel trawl (1990-autumn 1994), and a Campelen trawl (autumn 1995-2016). Note that Canadian research vessels' mechanical difficulties prevented the surveying of: deep strata in Div. 3NO in 2003, 2004, and 2006; strata deeper than 730 m in 2008; and Div. 3NO in 2014.

Year	Biomass (tonnes)			Abundance (000s)		
	3N	3O	3NO	3N	3O	3NO
Engel series						
1990	0	1,784	1,784	0	863	863
1991	0	2,805	2,805	0	2,047	2,047
1992	22	471	493	63	448	511
1993	0	748	748	0	490	490
1994	0	1,445	1,445	0	1,341	1,341
Campelen series						
1995	94	4,099	4,193	306	5,409	5,715
1996	3	3,960	3,966	219	3,850	3,993
1997	151	4,192	4,264	46	5,361	5,425
1998	134	2,897	3,067	862	5108	7,115
1999	3,028	4,043	7,071	83,220	11,583	94,803
2000	1,165	9,551	10,716	2,875	22,750	25,625
2001	946	10,740	11,686	1,077	18,207	19,284
2002	2,753	11,384	14,137	2,126	13,434	15,561
2003	906	13,374	14,280	748	10,628	11,376
2004	1,847	2,237	4,083	2,084	1,492	3,576
2005	539	4,739	5,277	109	4,001	4,110
2006	212	2,088	2,299	98	2,288	2,386
2007	276	10,337	10,613	543	7,859	8,402
2008	620	2,557	3,177	415	2,426	2,841
2009	132	4,189	4,321	73	4,123	4,195
2010	630	3,695	4,325	2,508	3,465	5,973
2011	270	7,293	7,563	947	13,410	14,357
2012	8,842	2,902	11,745	12,307	5,768	18,075
2013	857	13,201	14,058	993	15,721	16,714
2014	ns	ns	ns	ns	ns	ns
2015	211	10,626	10,837	356	8,687	9,043
2016	259	2,629	2,888	350	1,345	1,695

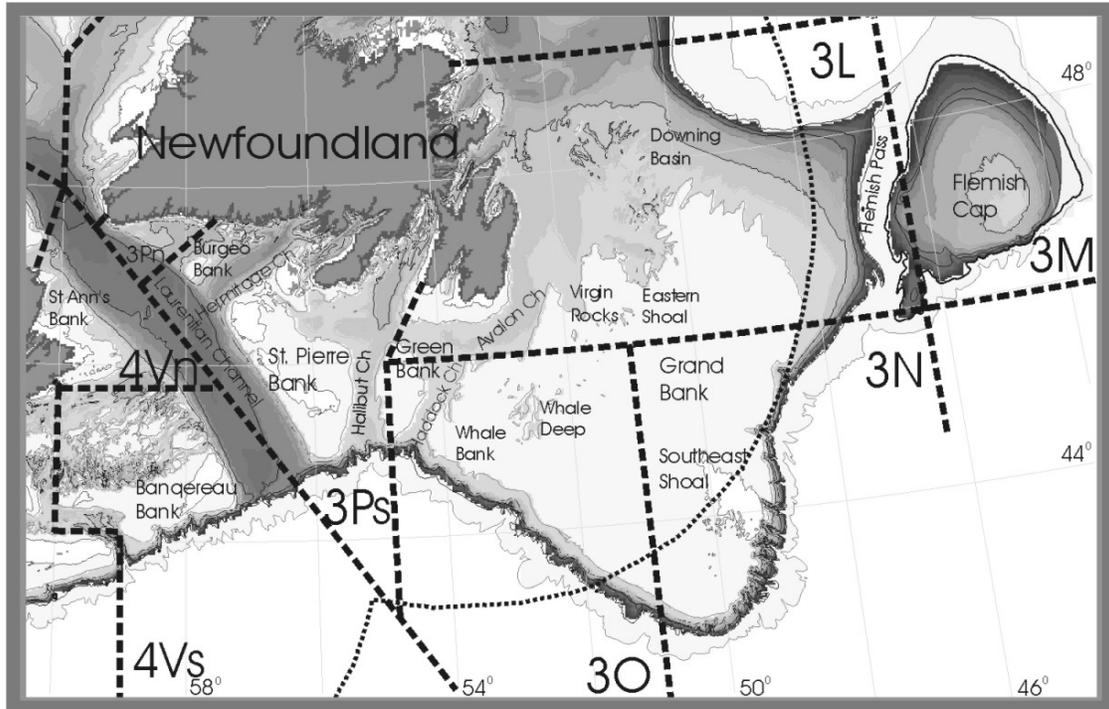


Fig. 1. Map of the Grand Banks showing various banks, basins, and NAFO Divisions. Thick dotted lines delineate NAFO Divisions. The thin dotted curved line shows Canada's 200-mile limit: delineating Canadian territory from the NAFO Regulatory Area (NRA).

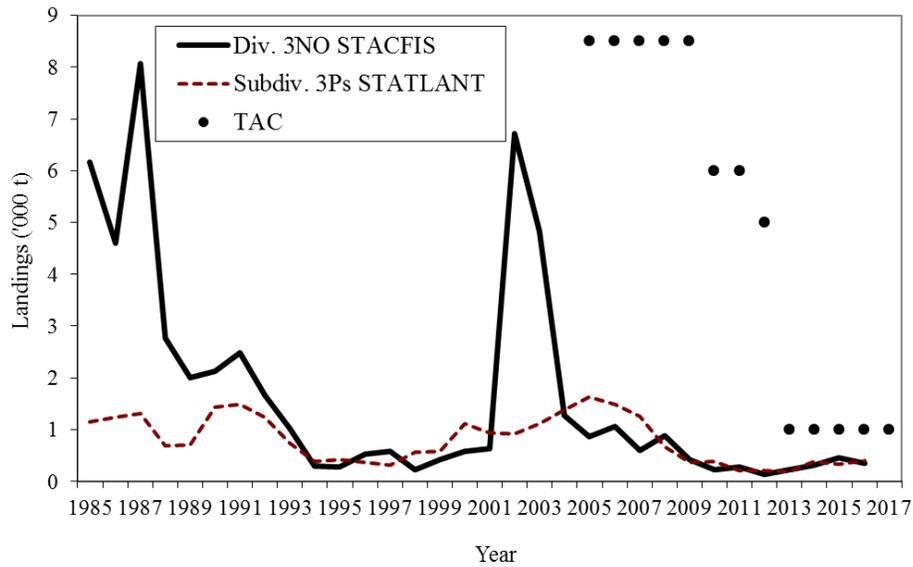


Fig. 2. Total reported landings of White Hake and TAC (for the NRA of Div. 3NO) in Div. 3NO (STACFIS) and Subdiv. 3Ps (STATLANT-21A), 1985-2016.

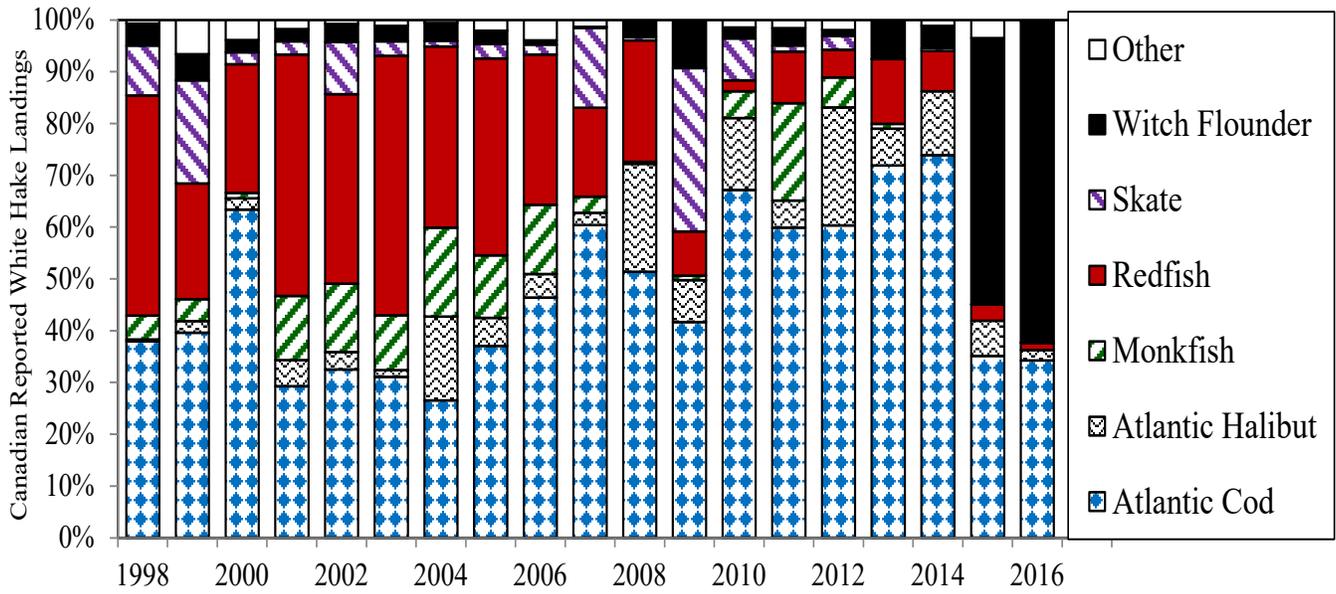


Fig. 3. Canadian reported landings of White Hake bycatch from various fisheries in Div. 3NOPs, 1998-2016.

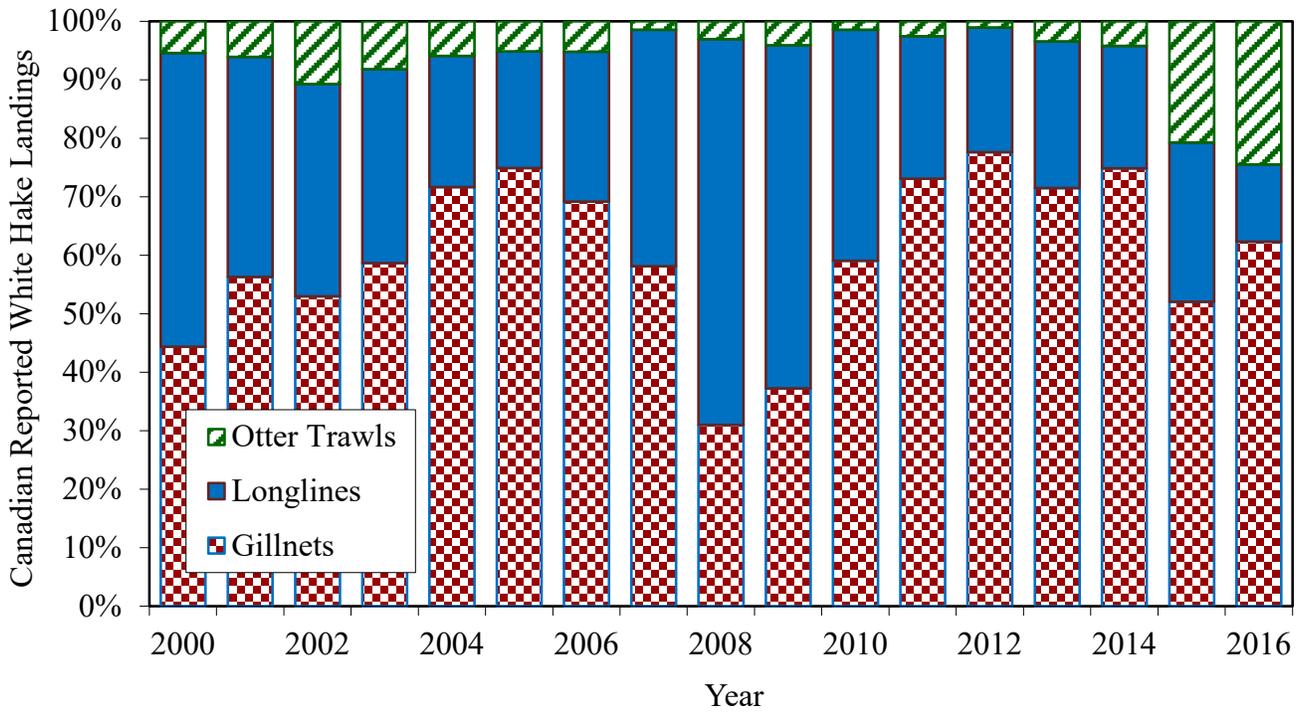


Fig. 4. Canadian reported landings of White Hake by gear in Div. 3NOPs, 2000-2016.

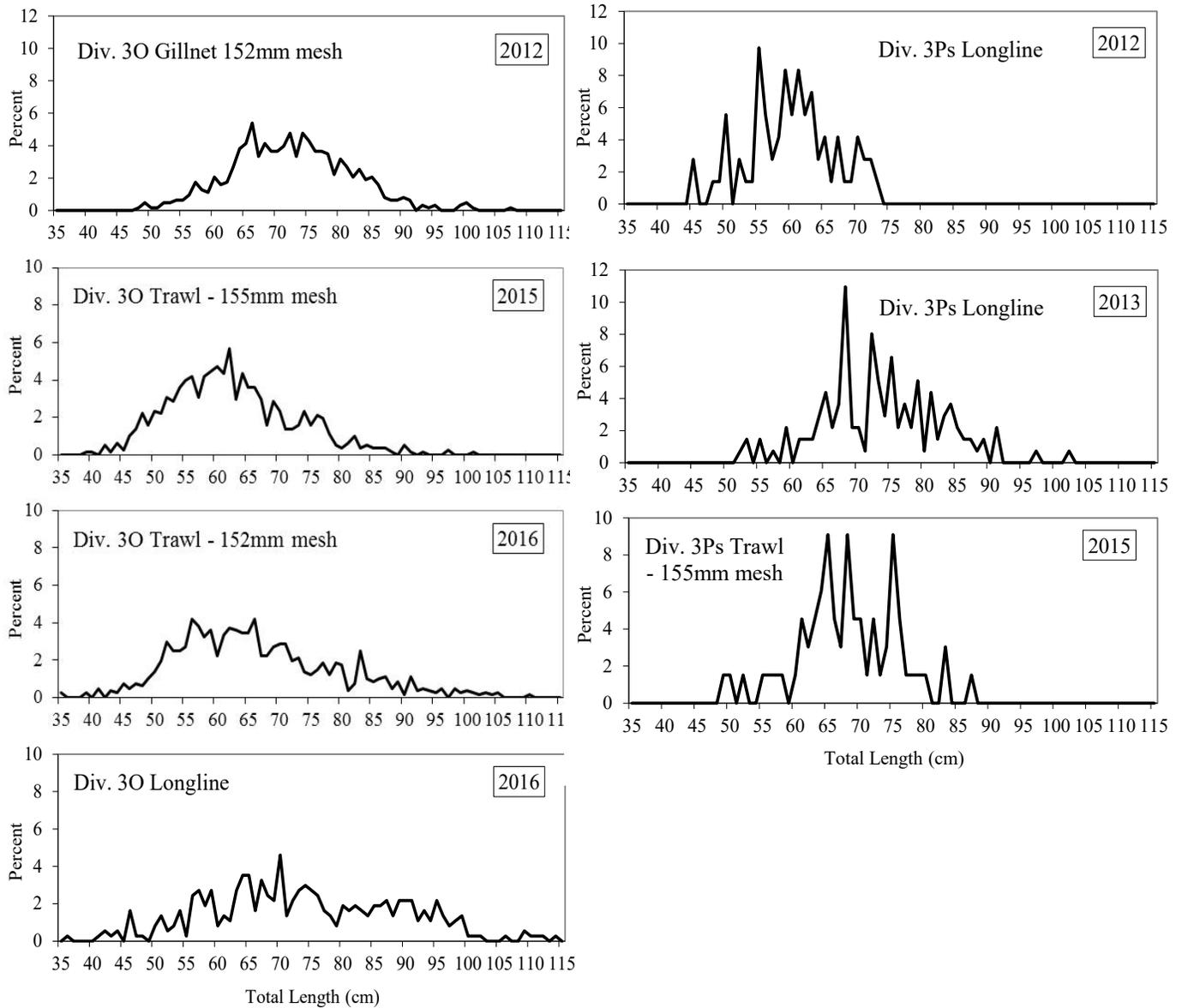


Fig. 5a. Length frequencies (in cm) for White Hake bycatch in Canadian commercial fisheries in Div. 30 (Left Panels) and Subdiv. 3Ps (Right Panels), 2012-2016. Note that different gears are represented in separate graphs. Data are from Canadian At-Sea Fisheries Observers, and include discards.

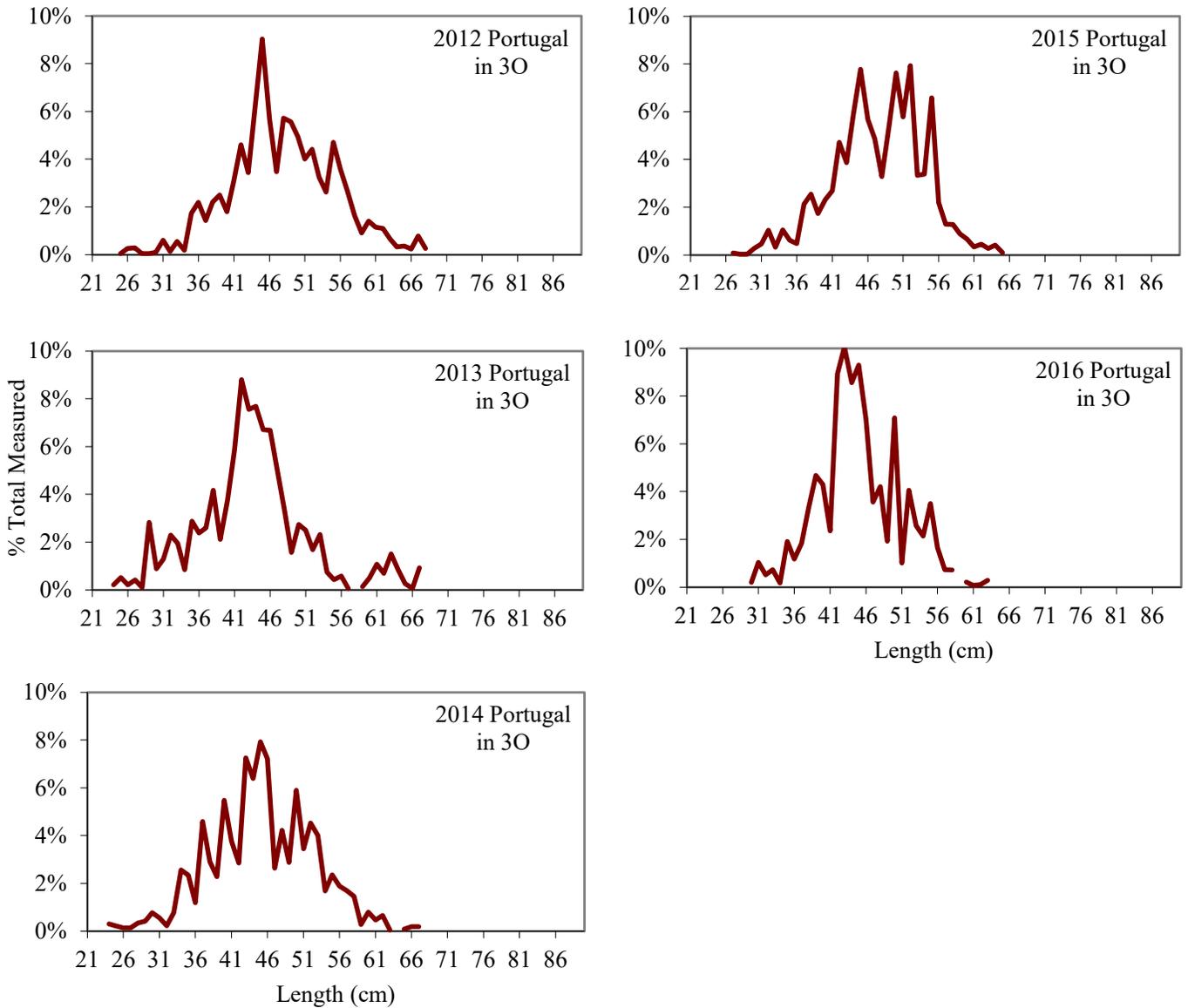


Fig. 5b. Length frequencies (in cm) for White Hake bycatch in EU-Portugal commercial trawl fisheries (130mm codend mesh size) in the NAFO Regulatory Area of Div. 30, 2012-2016.

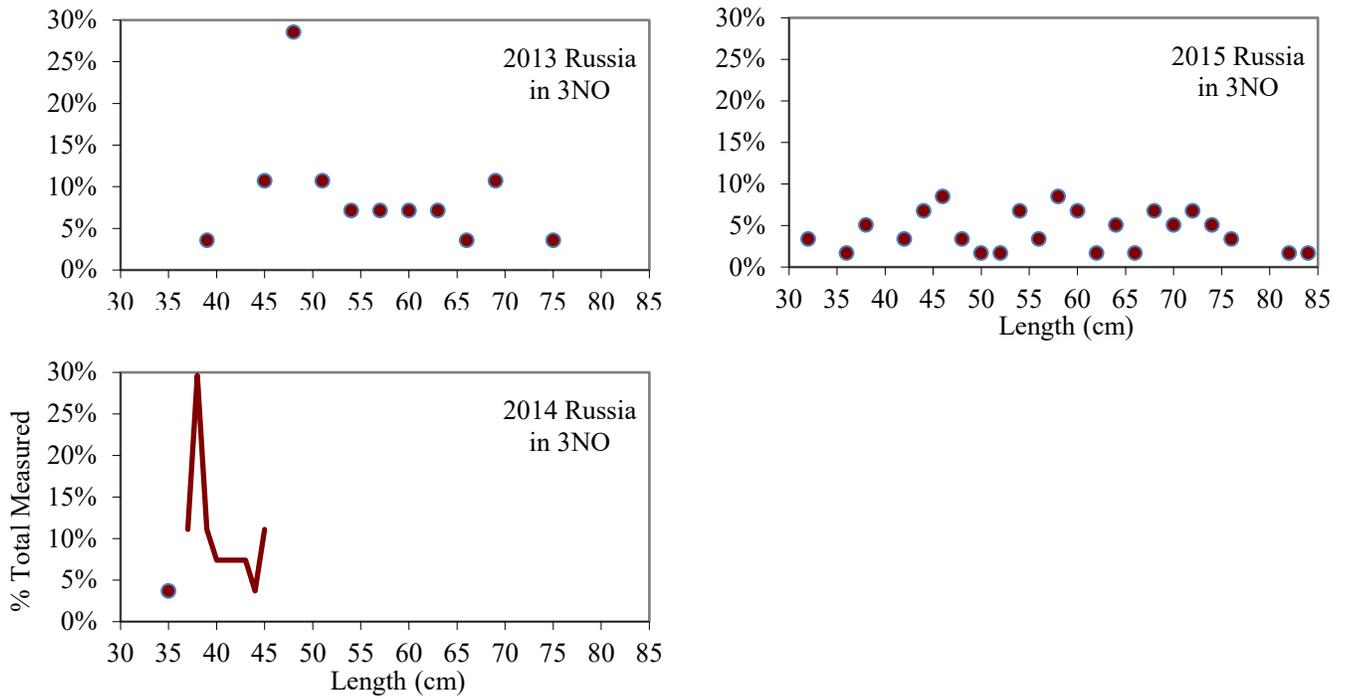


Fig. 5c. Length frequencies (in cm) for White Hake bycatch in Russian commercial trawl fisheries in the NAFO Regulatory Area of Div. 3NO, 2013-2015. Russia did not sample commercial White Hakes in 2012, and the number of hakes sampled in 2013 & 2014 was very small.

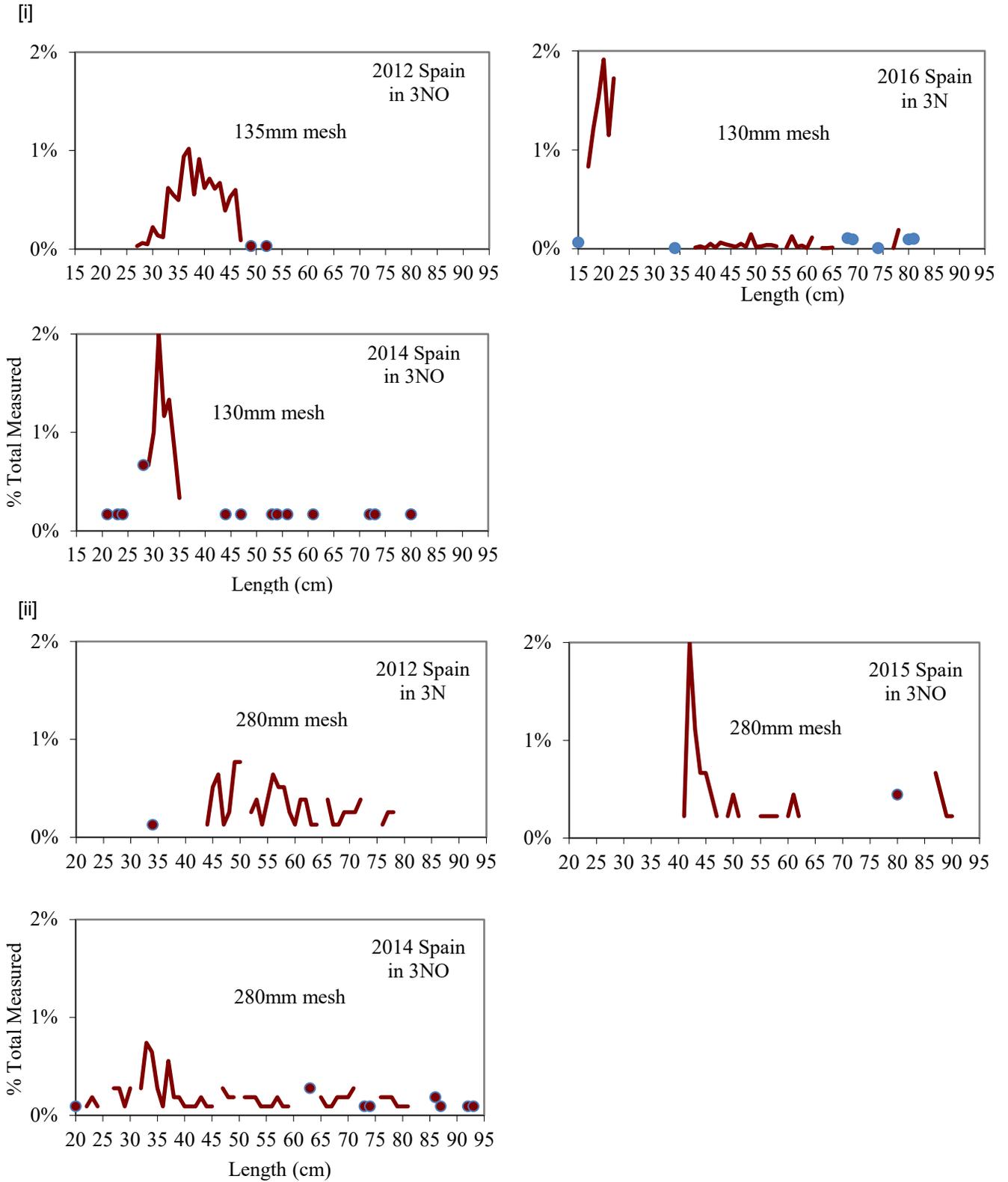


Fig. 5d. Length frequencies (in cm) for White Hake bycatch in Spanish commercial trawl fisheries ([i] 130-135mm codend mesh size; [ii] 280mm codend mesh) in the NAFO Regulatory Area of Div. 3NO, 2012-2016. EU-Spain did not sample commercial White Hakes in 2013.

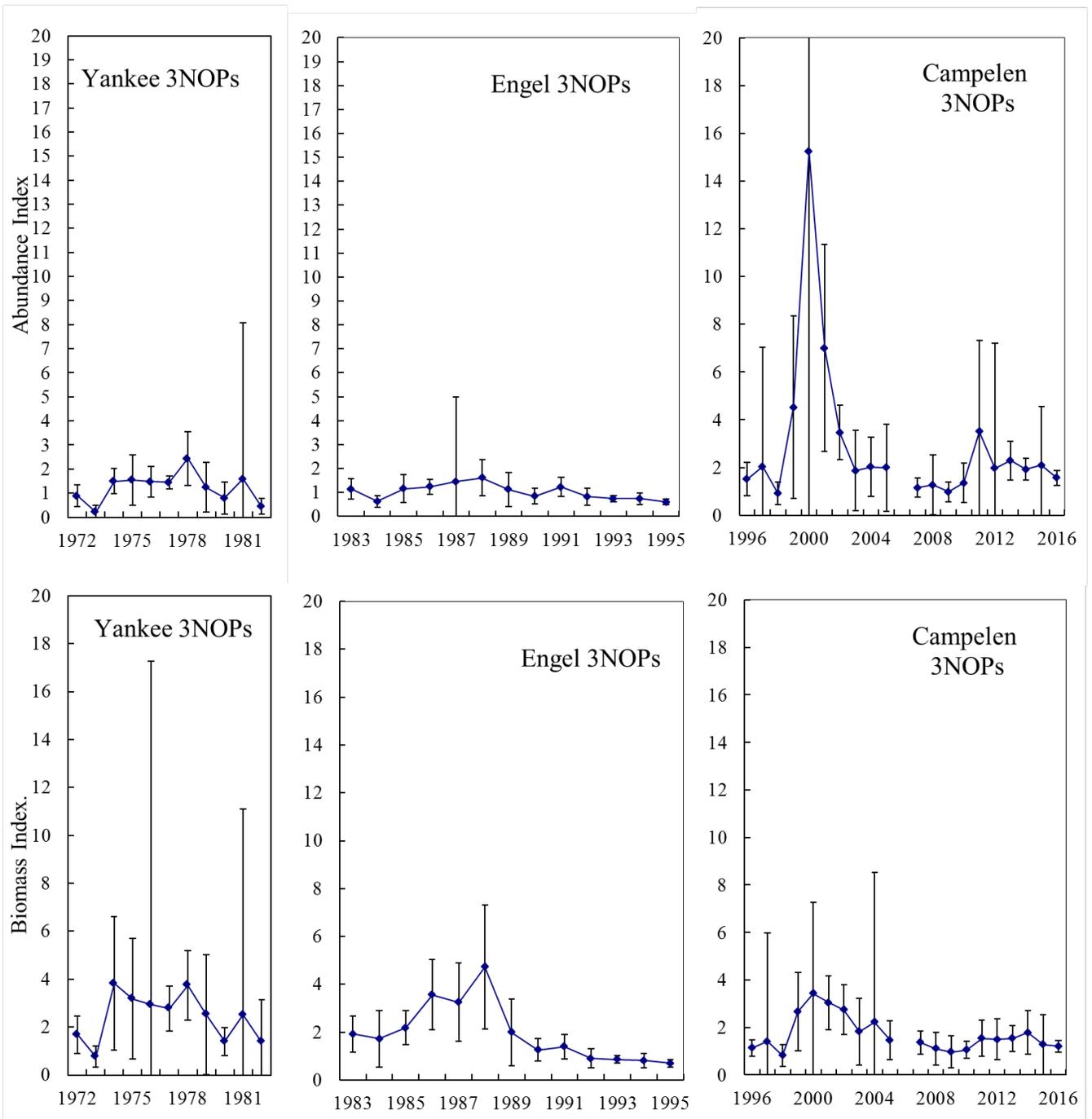


Fig. 6a. White Hake mean numbers (top panels) and mean weights (kg; bottom panels) per tow (+95% CI) from Canadian spring research surveys in Div. 3NO and Subdiv. 3Ps, 1972-2016. Yankee, Engel, and Campelen time series are not standardized, and thus are presented on separate panels. Note that deep strata in Div. 3NO and all of Subdiv. 3Ps were not surveyed in spring 2006, due to Canadian research vessels' mechanical difficulties. The bounds of the error bars in 1976, 1981, 1987, 2000, 2012, and 2015 in some panels extend above/below the graph limits.



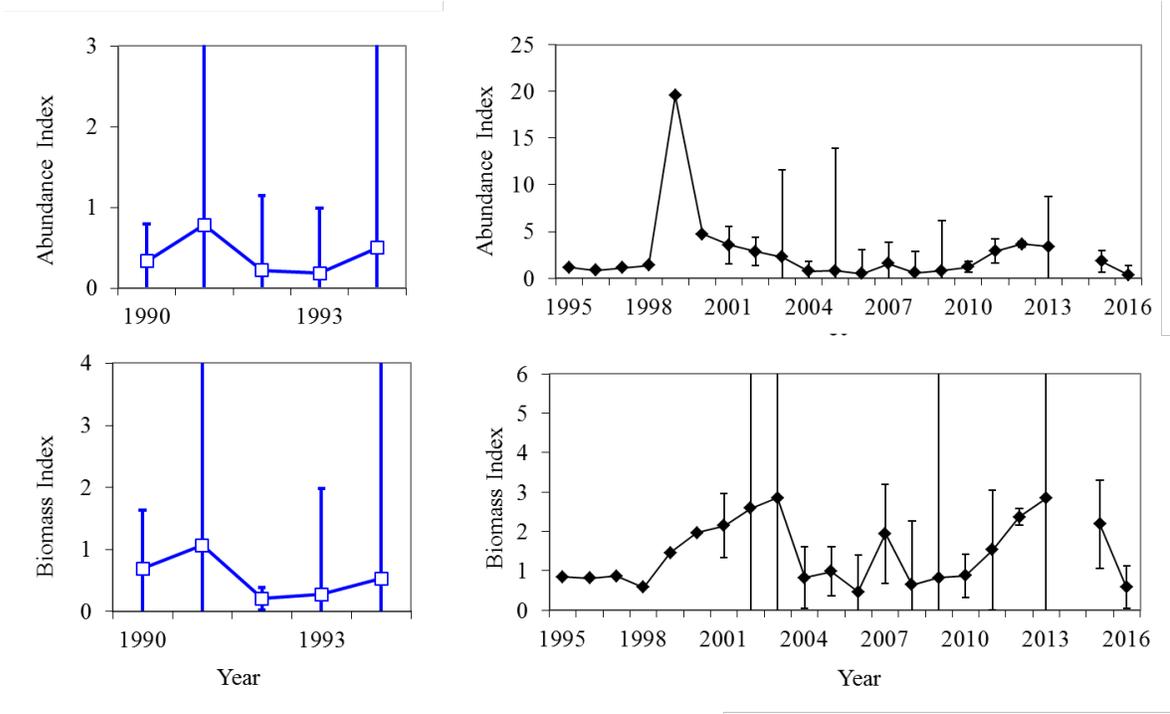


Fig. 6b. White Hake mean numbers (top panels) and mean weights (kg; bottom panels) per tow (+95% CI) from Canadian autumn research surveys in Div. 3NO, 1990-2016. Engel (■, 1990-1994) and Campelen (◆, 1995-2016) time series are not standardized. Note that Canadian research vessels' mechanical difficulties prevented the surveying of: deep strata in Div. 3NO in autumn of 2003, 2004, and 2006; strata deeper than 730 m in autumn 2008; and Div. 3NO in autumn 2014. The bounds of the error bars in 1990-1994, 2002-2009, 2013, and 2016 in some panels extend above/below the graph limits.

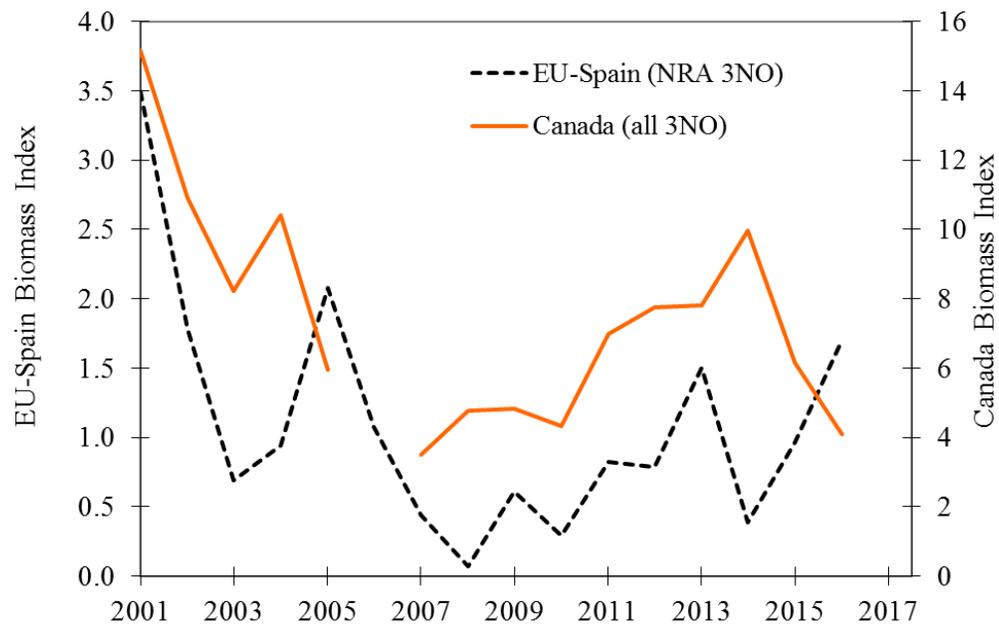


Fig. 7. White Hake biomass indices (000s tonnes) in Div. 3NO: EU-Spain spring surveys in the NRA of Div. 3NO compared to Canadian spring surveys in all of Div. 3NO, 2001-2016. Note that deep strata in Div. 3NO were not surveyed by Canada in spring 2006, due to research vessels' mechanical difficulties.

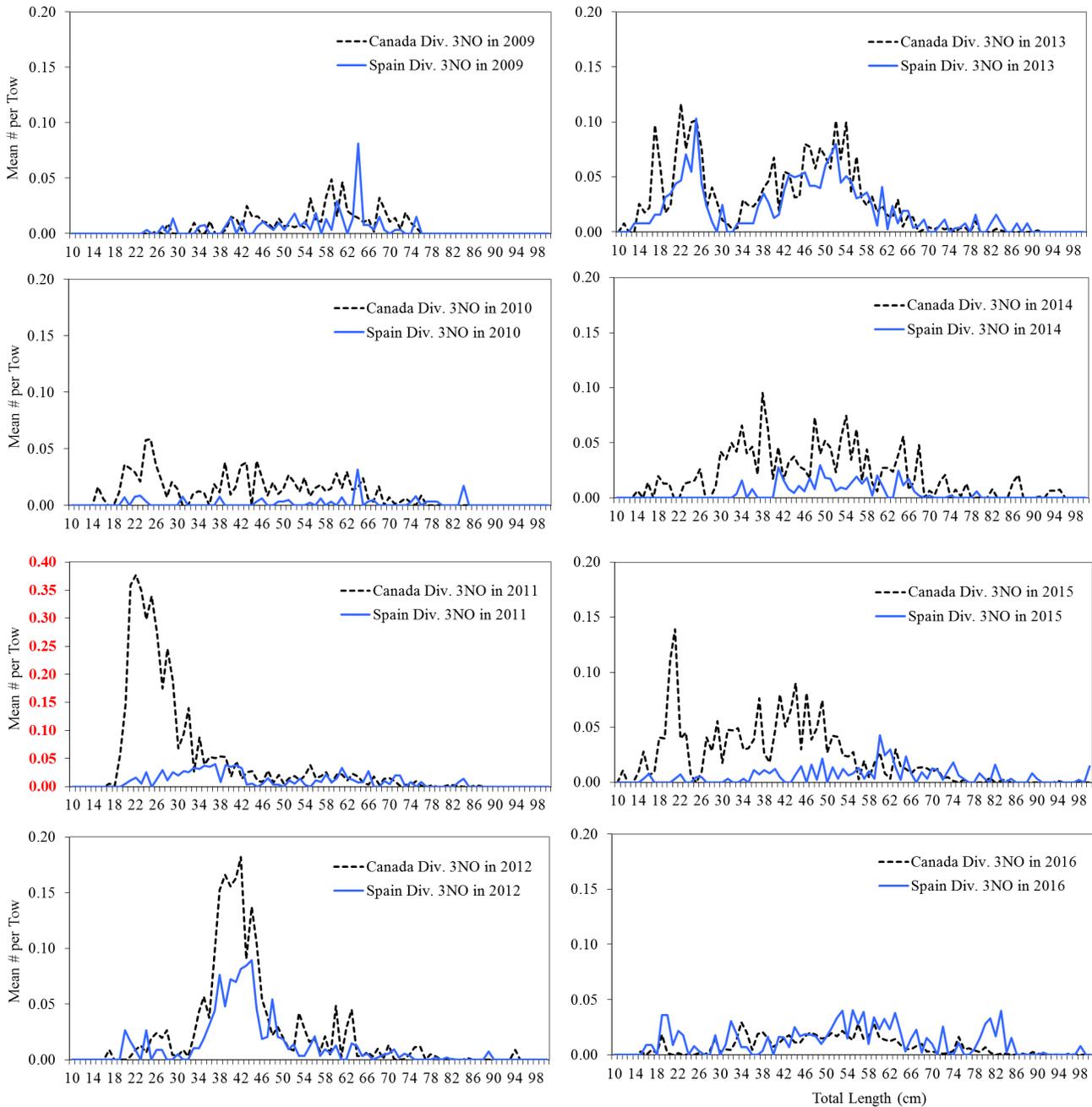


Fig. 8. Abundance at length from Canadian Campelen and EU-Spain Campelen spring research surveys in Div. 3NO (EU-Spain surveys limited to NRA), 2009-2016. Note that Y-axis values for 2011 are double those for 2009-2010 and 2012-2016.

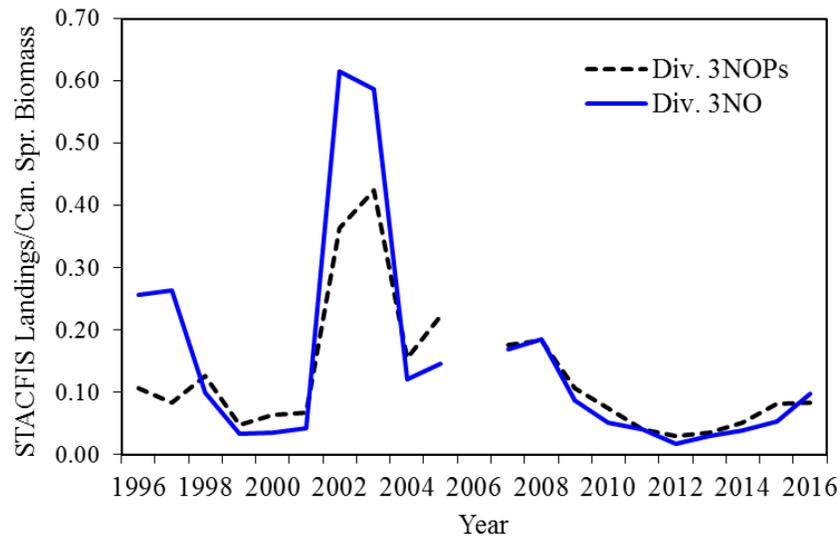


Fig. 9. Relative F index (= STACFIS commercial landings/Canadian Campelen spring survey biomass) for White Hake in Div. 3NO and Div. 3NOPs, 1996-2016. Note that deep strata in Div. 3NO and all of Subdiv. 3Ps were not surveyed in 2006, due to Canadian research vessels' mechanical difficulties.

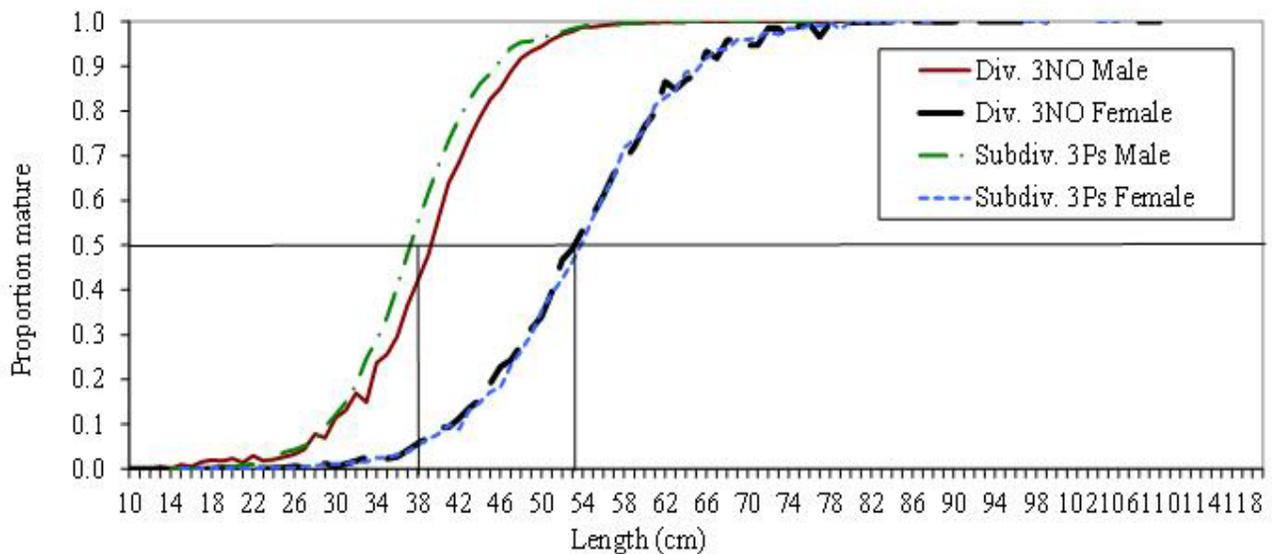


Fig. 10. White Hake in Div. 3NO and Subdiv. 3Ps: Maturity ogives calculated for each sex from Canadian Campelen spring surveys, and averaged over 1996-2016 (excluding 2006). Note that deep strata in Div. 3NO and all of Subdiv. 3Ps were not surveyed in 2006, due to Canadian research vessels' mechanical difficulties.

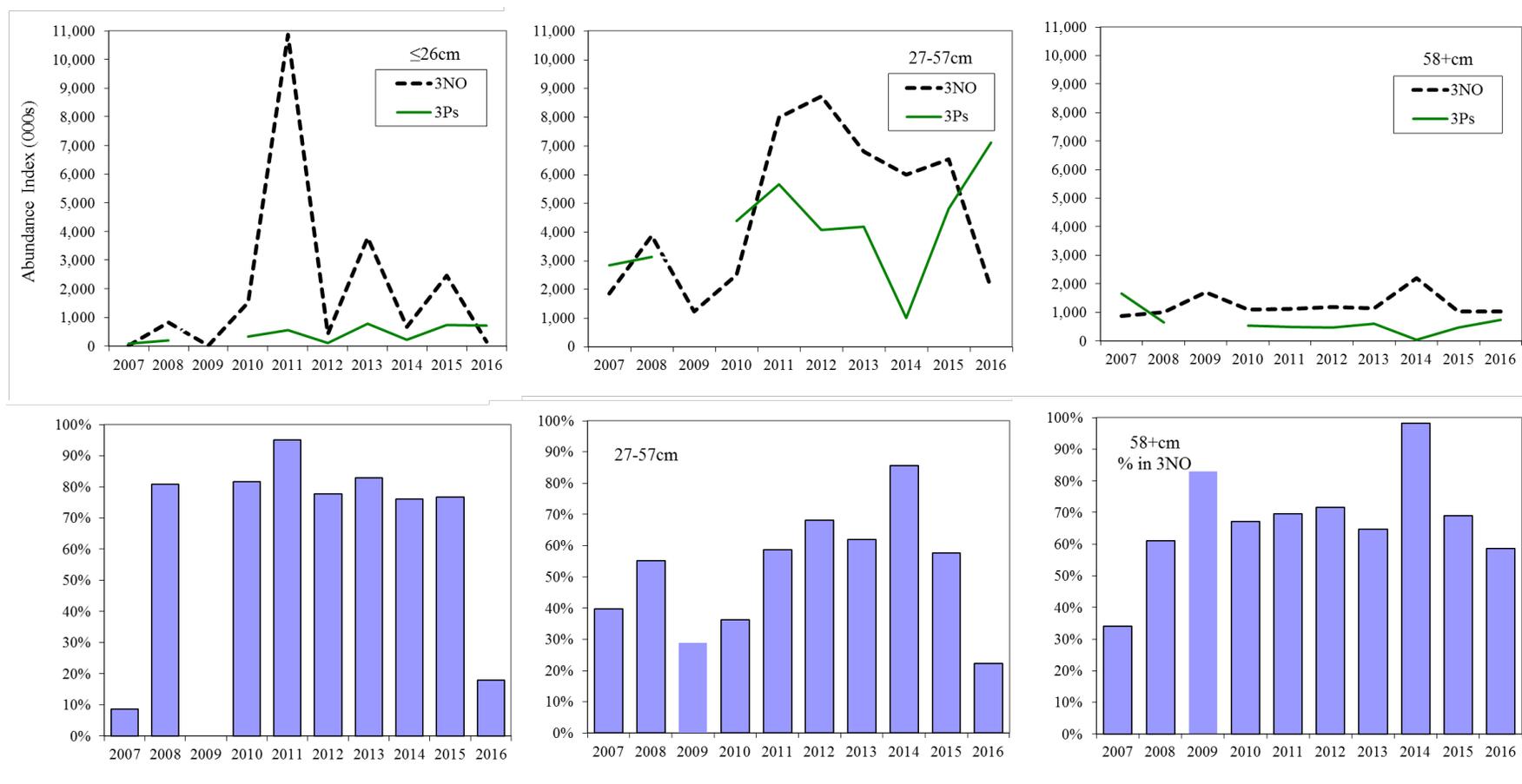


Fig. 11. Abundance Index of White Hake by life stage, 2007-2016: Less than or Equal to 26 cm is mainly year-class 1; 27-57 cm contains mainly juveniles; and 58+ cm is mainly mature fish. Upper panel: Abundance Index (000s). Lower panel: Percent abundance in Div. 3NO as compared to the entire area of Div. 3NOPS.

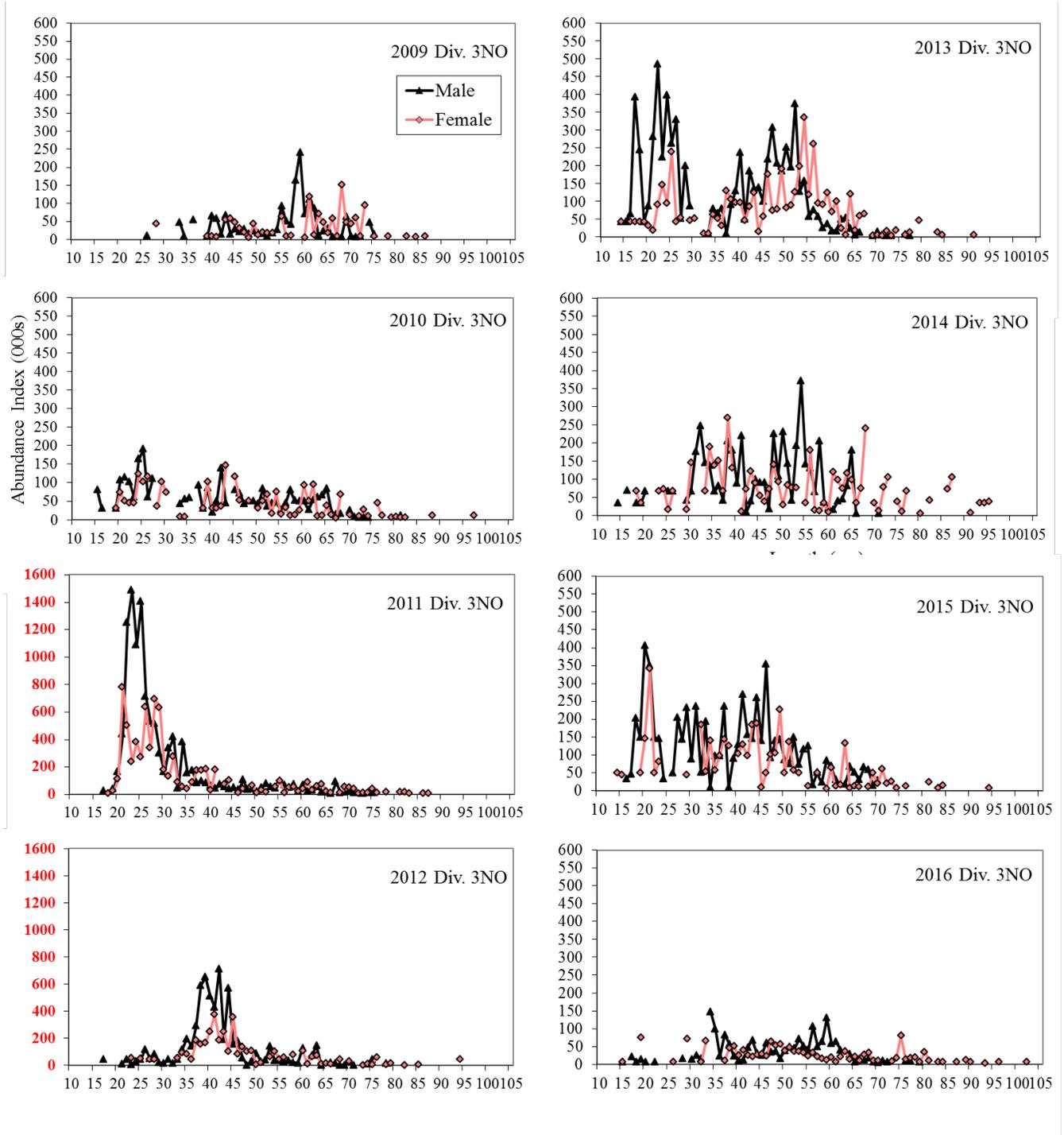


Fig. 12a. Abundance Index at length of male and female White Hakes from Canadian spring research surveys in Div. 3NO, 2009-2016. Note that Y-axis values for 2011 and 2012 are larger than those for 2009-2010 and 2013-2016.

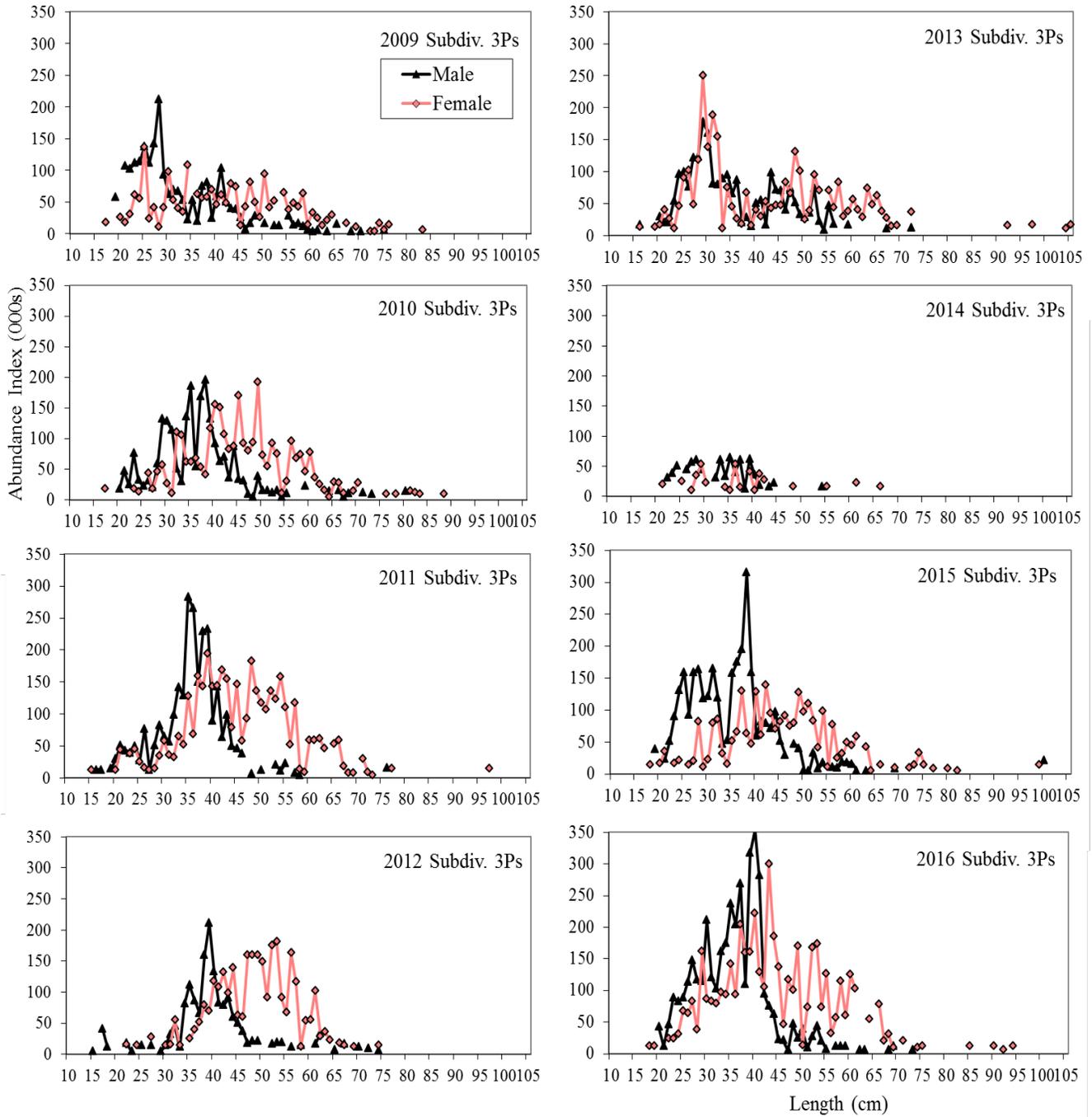


Fig. 12b. Abundance Index at length of male and female White Hakes from Canadian spring research surveys in Subdiv. 3Ps, 2009-2016.

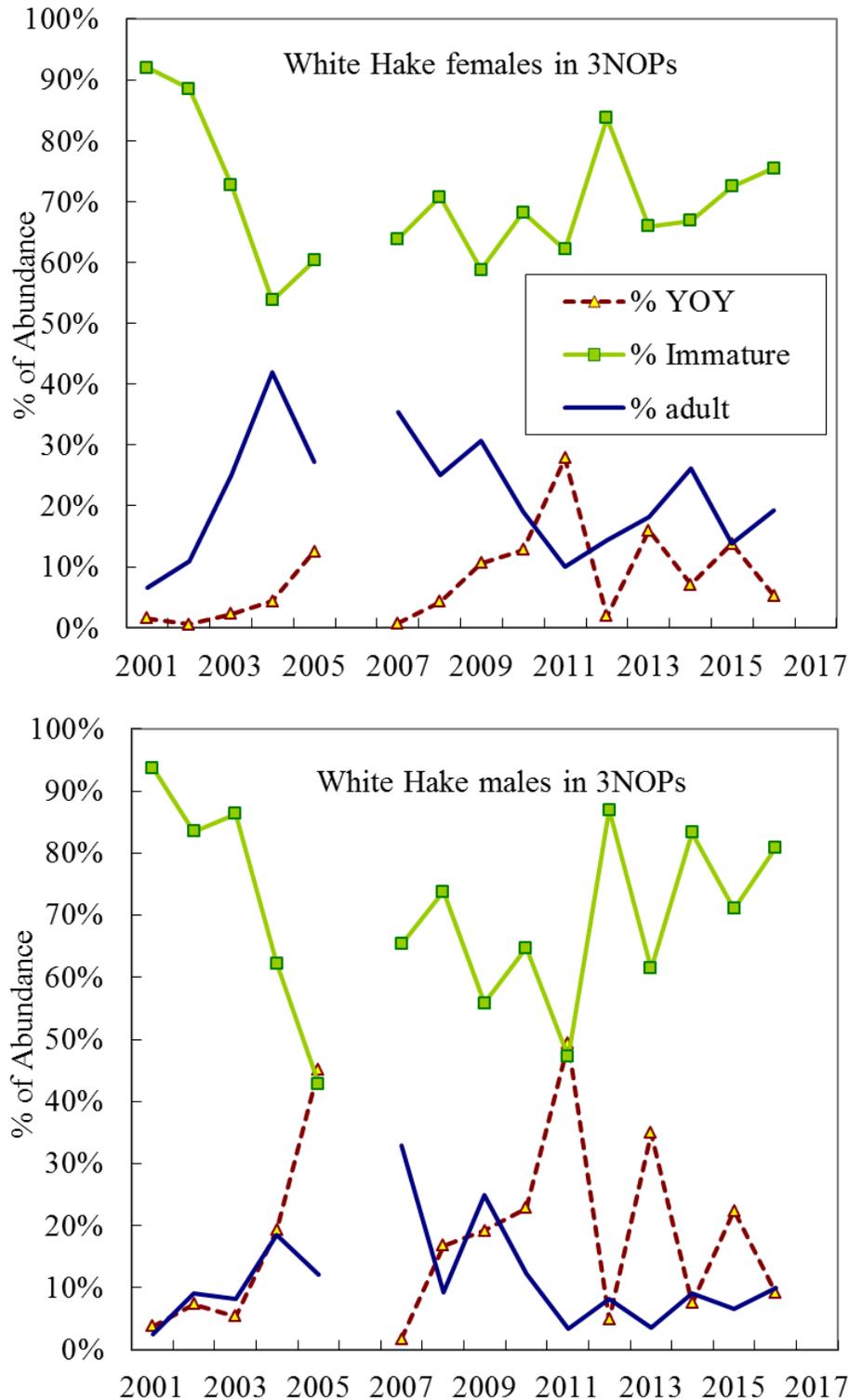


Fig. 13. Staged trends in relative abundance of 1-year-olds (YOY), immature (juveniles Age 2+ years), and mature female (upper panel), and male (lower panel) White Hake from Canadian Campelen spring surveys in Div. 3NO and Subdiv. 3Ps, 2001-2016. Note that deep strata in Div. 3NO and all of Subdiv. 3Ps were not surveyed in 2006, due to Canadian research vessels' mechanical difficulties.

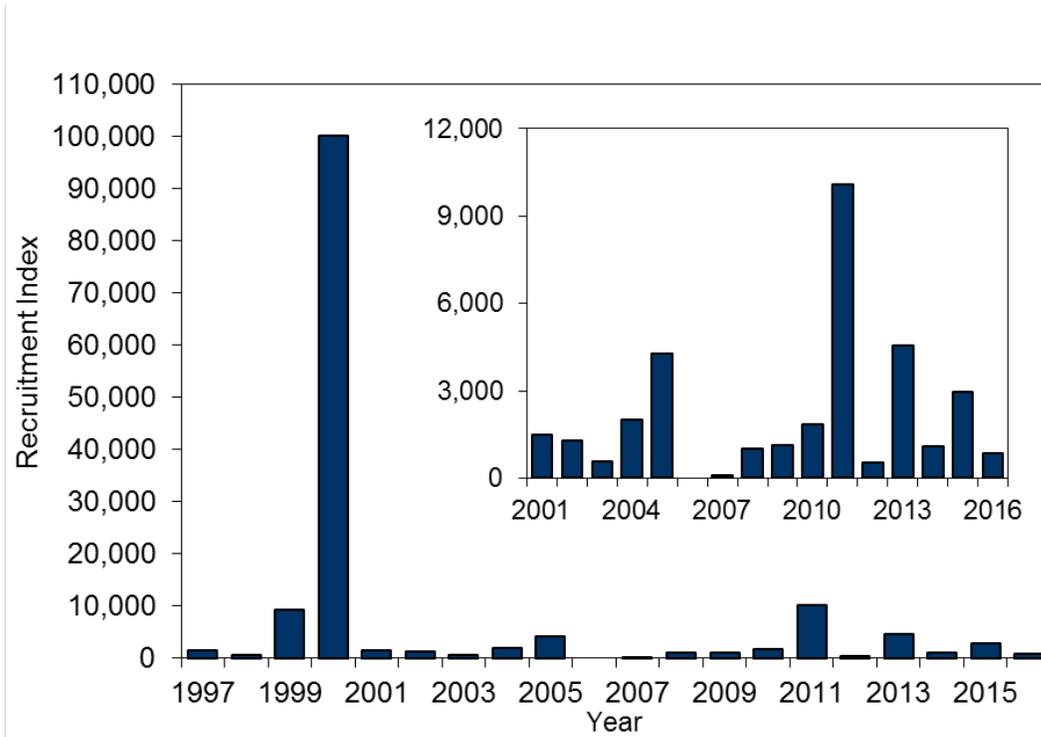


Fig. 14. White Hake recruitment index for Age 1 males and females (combined) from Canadian Campelen spring surveys in Div. 3NO and Subdiv. 3Ps, 1997-2016. Inset plot depicts 2001-2016 on a smaller scale. Estimates from 2006 are not shown, since survey coverage in that year was incomplete.

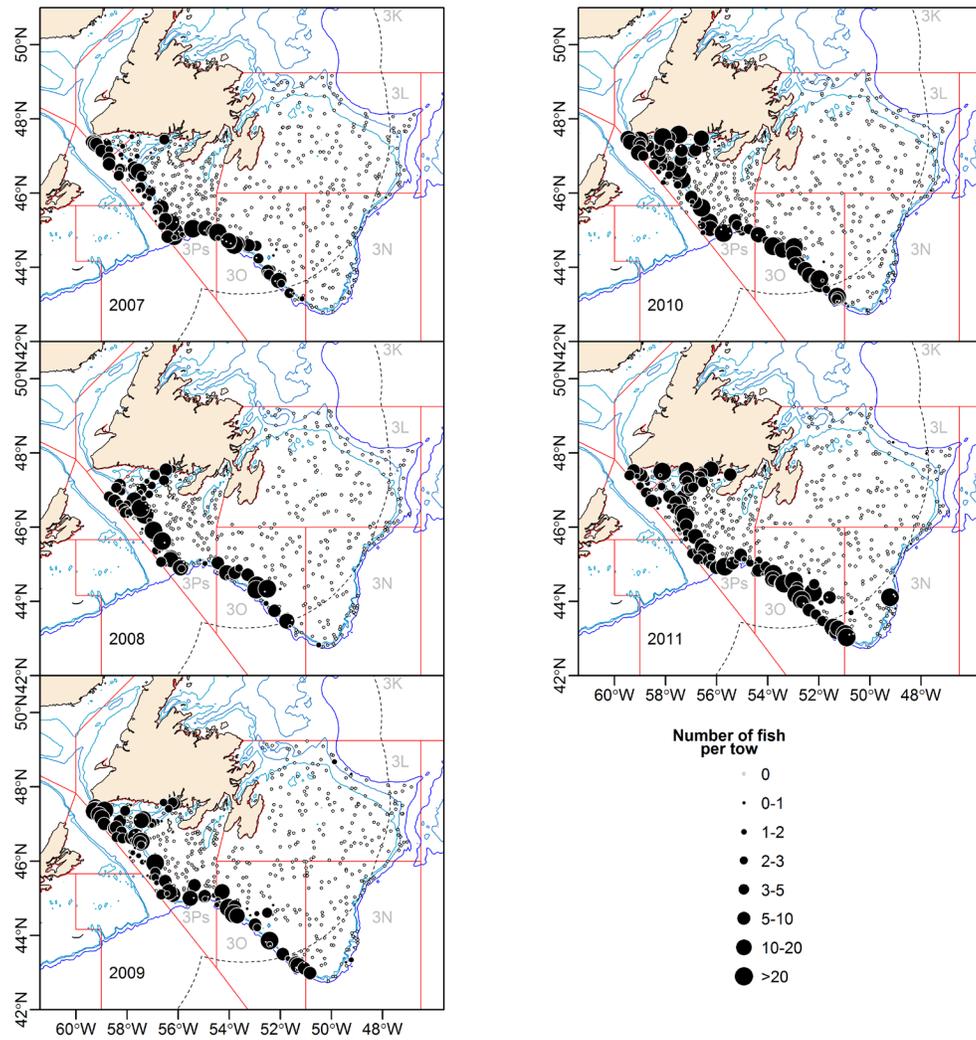


Fig. 15a. Distribution of White Hake mean numbers per tow in Div. 3NO and Subdiv. 3Ps, based on Canadian spring research surveys in 2007-2011.

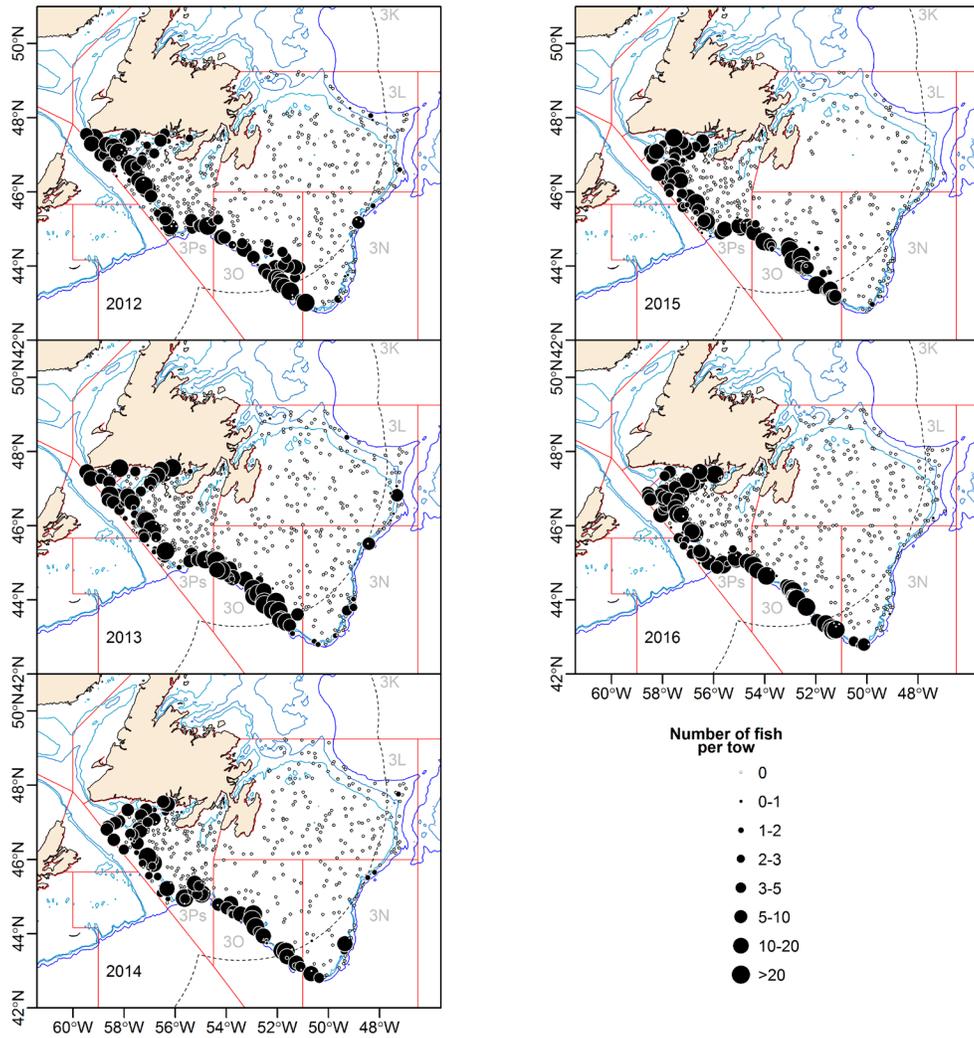


Fig. 15b. Distribution of White Hake mean numbers per tow in Div. 3NO and Subdiv. 3Ps, based on Canadian spring research surveys in 2012-2016.

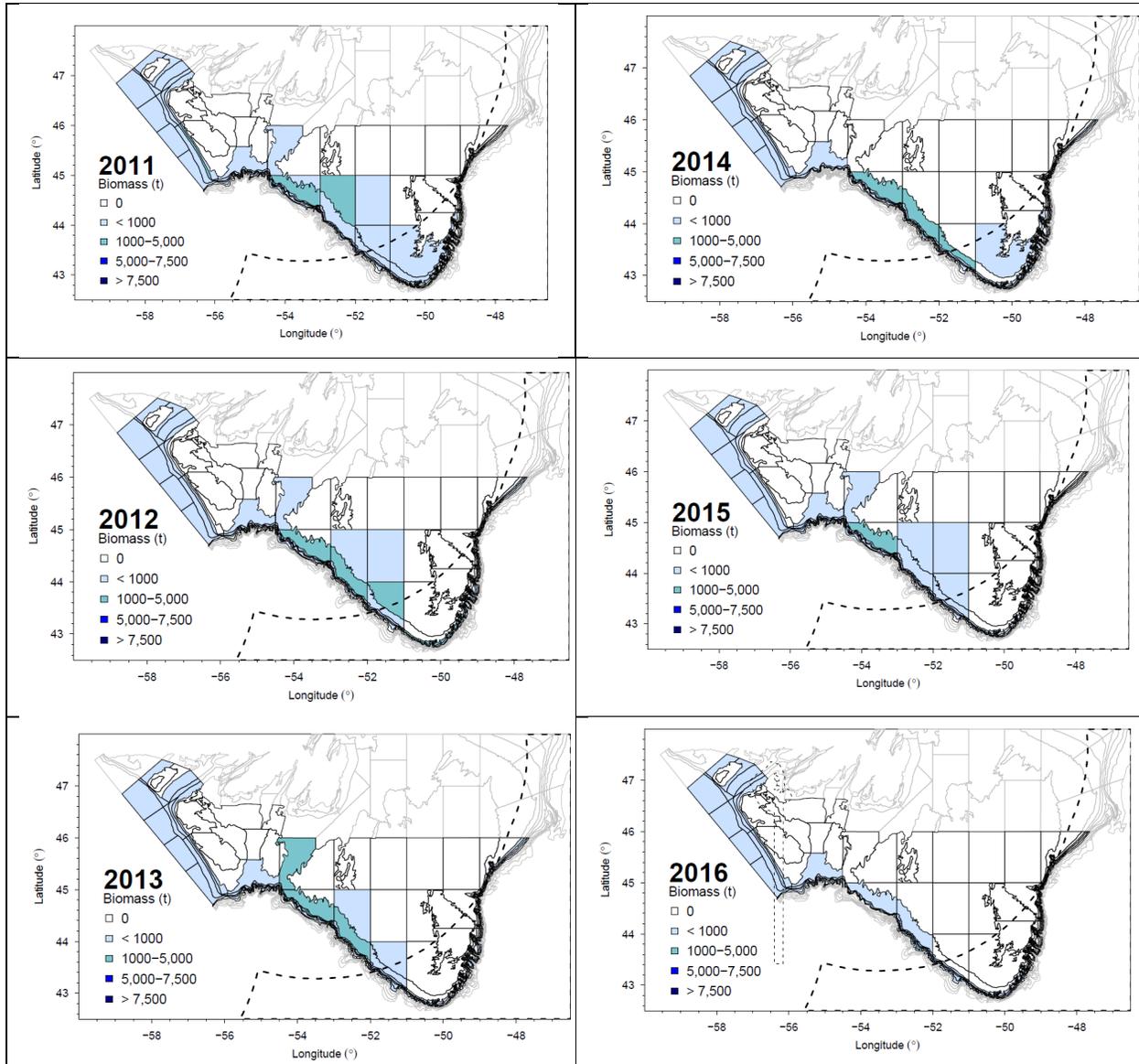


Fig. 16. Distribution of White Hake stratified biomass (tonnes) in Div. 3NO and Subdiv. 3Ps, based on Canadian spring research surveys in 2011-2016.