10.4 Atlantic salmon at West Greenland

10.4.1 Summary of the advice for 2015–2017

The previous advice provided by ICES (2015) indicated that there were no mixed-stock fishery catch options for 2015–2017 at West Greenland. The NASCO Framework of Indicators for the West Greenland Commission for 2015 did not indicate the need for a revised analysis of catch options and the management advice provided in the multiyear advice from 2015 for 2016 and 2017 remains unchanged. The assessment for the contributing stock complexes was updated to 2015 and the stock status is consistent with the previous years' assessments and catch advice.

10.4.2 NASCO has asked ICES to describe the key events of the 2015 fishery

Catches of Atlantic salmon at West Greenland (Figure 10.4.2.1 and Table 10.4.2.1) increased through the 1960s, reaching a peak reported harvest of approximately 2700 t in 1971 and then decreasing until the closure of the commercial fishery for export in 1998. However, the fishery for internal use only has been increasing in recent years. From 2002, licensed fishers have been allowed to sell salmon to hotels, institutions, and local markets only. From 2012, licensed fishers were also allowed to land catches to factories, although the export ban persisted and the landed salmon could only be sold within Greenland. In 2012 and 2013 a quota of 35 t was set by the Government of Greenland and applied to the factory landings only. The factory quota was reduced to 30 t in 2014. In 2015 the Government of Greenland unilaterally set a quota for all components of the fishery (private, commercial, and factory landings) of 45 t, as a quota could not be agreed to by all parties of the West Greenland Commission of NASCO.

A total catch of 56.8 t of salmon was reported for the 2015 fishery, compared to 57.9 t in 2014, a decrease of < 1 t (Figure 10.4.2.1 and Table 10.4.2.2). Landings were reported across all NAFO divisions and a harvest of 1 t was also reported from ICES Subarea 14 (East Greenland). Despite increased effort to improve the in-season reporting and monitoring of the quota, the total landings exceeded the quota set by the Government of Greenland by 11.8 t. Both commercial and private landings in 2015 increased over the 2014 reported values (Table 10.4.2.3). In total, 89% of the landings in 2015 came from licensed fishers. For private landings, 35% (5.9 t) came from unlicensed fishers and 69.5% (13.3 t) from licensed fishers. Although not allowed to sell their catch, 0.4% (147 kg, approximately 50 fish) of the commercial landings were reported as coming from unlicensed fishers.

Phone surveys were conducted after the 2014 and 2015 fishing seasons to gain further information on catch and effort. A total unreported catch of 12.2 t in 2014 and 5 t for 2015 were identified from these surveys. These "adjusted landings (survey)" were added to the reported landings and used in stock assessment efforts. Since 2002, comparison of reported landings to the sample data have been made to evaluate if non-reporting of harvest was evident. When non-reporting of harvest is identified, these "adjusted landings (sampling)" are also added to the reported landings to estimate the total "landings for assessment". The time-series of reported landings, adjusted landings (sampling), adjusted landings (survey), and landings for assessment is presented in Table 10.4.2.4. Landings for assessment (including adjusted landings) do not replace the official reported statistics.

Reported 2015 commercial catch	Reported 2015 private consumption catch	Reported 2015 factory catch	Total reported catch for 2015	Total landings for assessment 2015	Unreported catch for 2015
33.8 t	19.2 t	3.8 t	56.8 t	60.9 t	10 t

The international sampling programme continued in the fishery in 2015 (Figure 10.4.2.2). In total, 79.9% of the salmon sampled were determined to be of North American origin and 20.1% of European origin. The North American origin contribution to the fishery has remained high since the mid-1990s (Figure 10.4.2.3). More detailed results from recent genetic analyses on the stock composition of salmon caught at West Greenland are presented in Section 10.4.6.

The One-Sea-Winter (1SW) age group dominated the 2015 catch at >95% (Table 10.4.2.5). Approximately 13 500 (~44.6 t) North American origin fish and approximately 3900 (~11.2 t) European origin fish were harvested in 2015. These totals remain among the lowest in the time-series, although they are the highest estimates since 1997 (Figure 10.4.2.4).

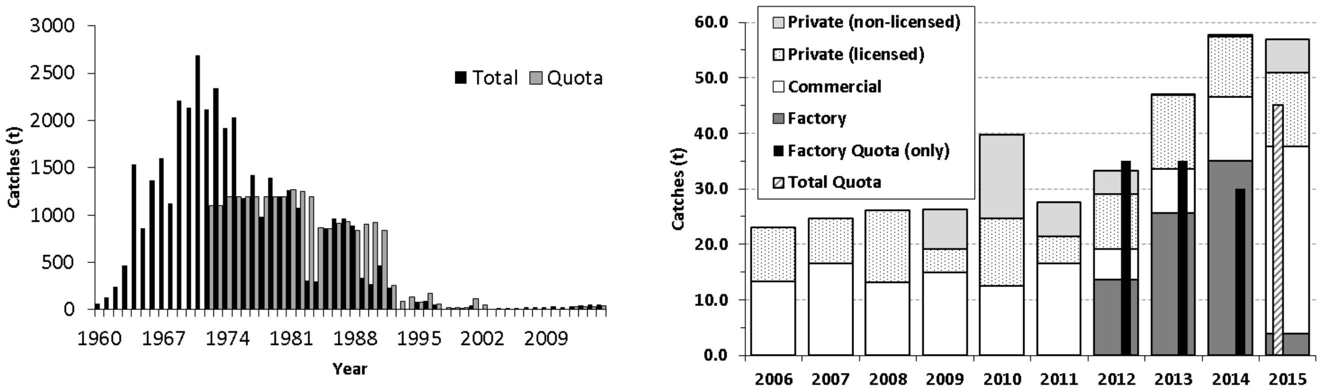

Figure 10.4.2.1 Nominal catches and commercial quotas (t, round fresh weight) of salmon at West Greenland for 1960–2015 (left panel) and 2006–2015 (right panel). Total reported landings from 2006 to 2015 are displayed by landings type. No quotas were set from 2003 to 2011, a factory-only quota was set from 2012 to 2014, and a single quota of 45 t for all components of the fishery was applied in 2015.

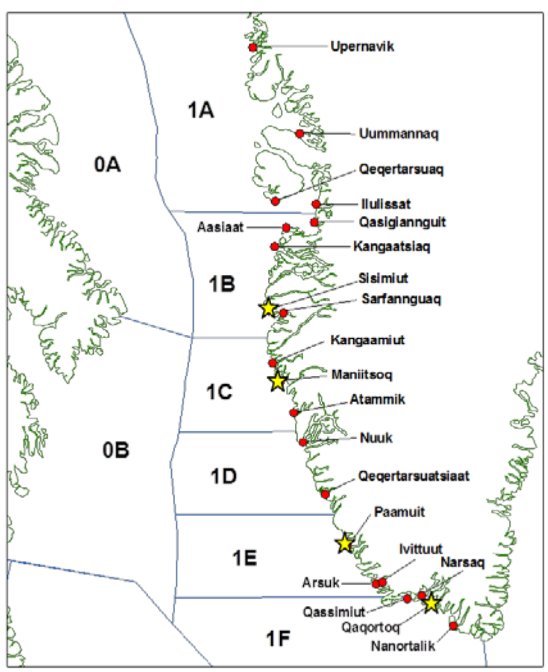

Figure 10.4.2.2 Location of NAFO divisions along the coast of West Greenland. Yellow stars identify where sampling occurred within a community in 2015.

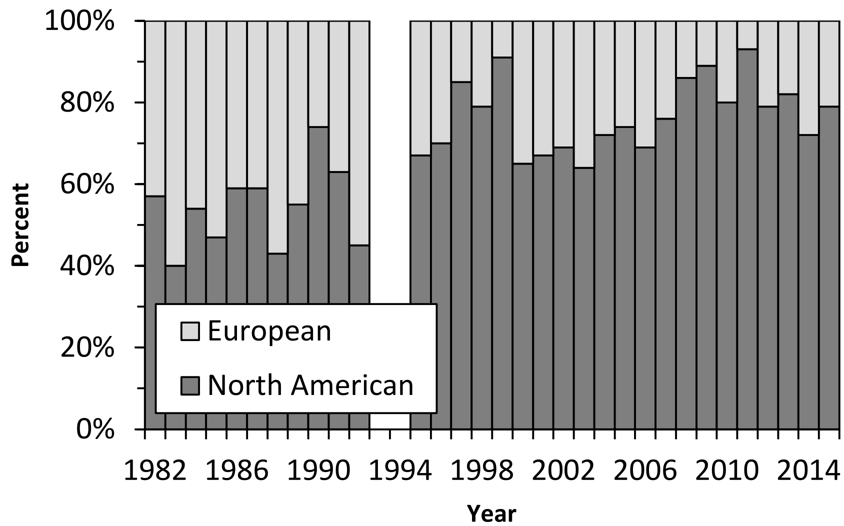

Figure 10.4.2.3 Percent of the sampled catch by continent of origin for the 1982 to 2015 Atlantic salmon West Greenland fishery.

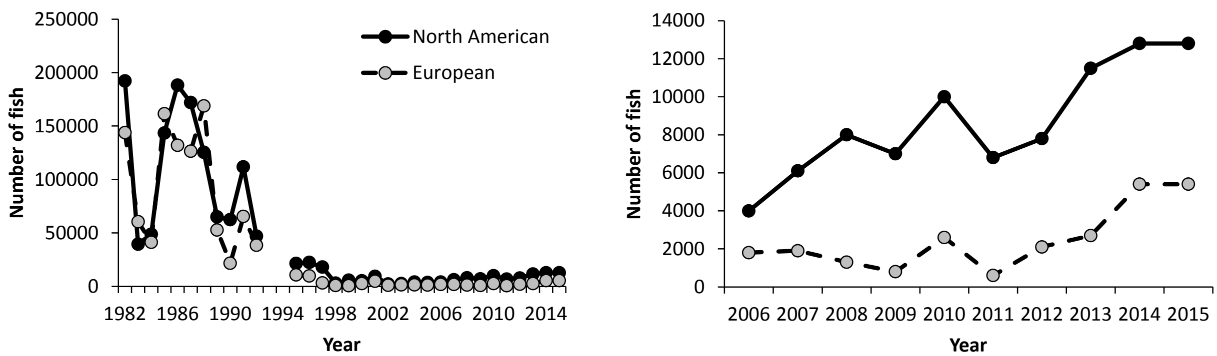

Figure 10.4.2.4 Number of North American and European Atlantic salmon caught at West Greenland from 1982 to 2015 (left panel) and 2006 to 2015 (right panel). Estimates are based on continent of origin by NAFO division, weighted by catch (weight) in each division. Numbers are rounded to the nearest hundred fish. Unreported catch is not included in this assessment.

Table 10.4.2.1 Nominal catches of salmon at West Greenland since 1960 (t, round fresh weight) by participating nations. For Greenlandic vessels specifically, all catches up to 1968 were taken with set gillnets only and catches after 1968 were taken with set gillnets and driftnets. All non-Greenlandic vessel catches from 1969 to 1975 were taken with driftnets. The quota figures applied to Greenlandic vessels only and entries in parentheses identify when quotas did not apply to all sectors of the fishery.

Year	Norway	Faroes	Sweden	Denmark	Greenland	Total	Quota	Comments
1960	-	-	-	-	60	60		
1961	-	-	-	-	127	127		
1962	-	-	-	-	244	244		
1963	-	-	-	-	466	466		
1964	-	-	-	-	1539	1539		
1965	-	36	-	-	825	858		Norwegian harvest figures not available, but known to be less than Faroese catch.
1966	32	87	-	-	1251	1370		
1967	78	155	-	85	1283	1601		
1968	138	134	4	272	579	1127		
1969	250	215	30	355	1360	2210		
1970	270	259	8	358	1244	2139		Greenlandic total includes 7 t caught by longlines in the Labrador Sea.
1971	340	255	-	645	1449	2689	-	
1972	158	144	-	401	1410	2113	1100	
1973	200	171	-	385	1585	2341	1100	
1974	140	110	-	505	1162	1917	1191	
1975	217	260	-	382	1171	2030	1191	
1976	-	-	-	-	1175	1175	1191	
1977	-	-	-	-	1420	1420	1191	
1978	-	-	-	-	984	984	1191	
1979	-	-	-	-	1395	1395	1191	
1980	-	-	-	-	1194	1194	1191	
1981	-	-	-	-	1264	1264	1265	Quota set to a specific opening date for the fishery.
1982	-	-	-	-	1077	1077	1253	Quota set to a specific opening date for the fishery.
1983	-	-	-	-	310	310	1191	
1984	-	-	-	-	297	297	870	
1985	-	-	-	-	864	864	852	
1986	-	-	-	-	960	960	909	
1987	-	-	-	-	966	966	935	
1988	-	-	-	-	893	893	840	Quota for 1988–1990 was 2520 t with an opening date of August 1. Annual catches were not to exceed an annual average (840 t) by more than 10%. Quota adjusted to 900 t in 1989 and 924 t in 1990 for later opening dates.
1989	-	-	-	-	337	337	900	
1990	-	-	-	-	274	274	924	

Year	Norway	Faroes	Sweden	Denmark	Greenland	Total	Quota	Comments
1991	-	-	-	-	472	472	840	
1992	-	-	-	-	237	237	258	Quota set by Greenland authorities.
1993	-	-	-	-			89	The fishery was suspended. NASCO adopted a new quota allocation model.
1994	-	-	-	-			137	The fishery was suspended and the quotas were bought out.
1995	-	-	-	-	83	83	77	Quota advised by NASCO.
1996	-	-	-	-	92	92	174	Quota set by Greenland authorities.
1997	-	-	-	-	58	58	57	Private (non-commercial) catches to be reported after 1997.
1998	-	-	-	-	11	11	20	Fishery restricted to catches used for internal consumption in Greenland.
1999	-	-	-	-	19	19	20	
2000	-	-	-	-	21	21	20	
2001	-	-	-	-	43	43	114	Final quota calculated according to the *ad hoc* management system.
2002	-	-	-	-	9	9	55	Quota bought out, quota represented the maximum allowable catch (no factory landing allowed), and higher catch figures based on sampling programme information are used for the assessments.
2003	-	-	-	-	9	9		Quota set to nil (no factory landing allowed), fishery restricted to catches used for internal consumption in Greenland, and higher catch figures based on sampling programme information are used for the assessments.
2004	-	-	-	-	15	15		same as previous year
2005	-	-	-	-	15	15		same as previous year
2006	-	-	-	-	22	22		Quota set to nil (no factory landing allowed) and fishery restricted to catches used for internal consumption in Greenland.
2007	-	-	-	-	25	25		Quota set to nil (no factory landing allowed), fishery restricted to catches used for internal consumption in Greenland, and higher catch figures based on sampling programme information are used for the assessments.
2008	-	-	-	-	26	26		same as previous year
2009	-	-	-	-	26	26		same as previous year
2010	-	-	-	-	40	40		No factory landing allowed and fishery restricted to catches used for internal consumption in Greenland.
2011	-	-	-	-	28	28		same as previous year

Year	Norway	Faroes	Sweden	Denmark	Greenland	Total	Quota	Comments
2012	-	-	-	-	33	33	(35)	Unilateral decision made by Greenland to allow factory landing with a 35 t quota for factory landings only, fishery restricted to catches used for internal consumption in Greenland, and higher catch figures based on sampling programme information are used for the assessments.
2013	-	-	-	-	47	47	(35)	same as previous year
2014	-	-	-	-	58	58	(30)	Unilateral decision made by Greenland to allow factory landing with a 30 t quota for factory landings only, fishery restricted to catches used for internal consumption in Greenland, and higher catch figures based on sampling programme information and phone surveys are used for the assessments.
2015	-	-	-	-	57	57	45	Unilateral decision made by Greenland to set a 45 t quota for all sectors of the fishery, fishery restricted to catches used for internal consumption in Greenland, and higher catch figures based on sampling programme information and phone surveys are used for the assessments.

Table 10.4.2.2 Distribution of nominal catches (metric tonnes) by Greenland vessels since 1960. NAFO division is represented by 1A–1F. Since 2005, gutted weights have been reported and converted to total weight by a factor of 1.11.

Year	1A	1B	1C	1D	1E	1F	Unknown	West Greenland	East Greenland	Total
1960							60	60		60
1961							127	127		127
1962							244	244		244
1963	1	172	180	68	45			466		466
1964	21	326	564	182	339	107		1539		1539
1965	19	234	274	86	202	10	36	861		861
1966	17	223	321	207	353	130	87	1338		1338
1967	2	205	382	228	336	125	236	1514		1514
1968	1	90	241	125	70	34	272	833		833
1969	41	396	245	234	370		867	2153		2153
1970	58	239	122	123	496	207	862	2107		2107
1971	144	355	724	302	410	159	560	2654		2654
1972	117	136	190	374	385	118	703	2023		2023
1973	220	271	262	440	619	329	200	2341		2341
1974	44	175	272	298	395	88	645	1917		1917
1975	147	468	212	224	352	185	442	2030		2030
1976	166	302	262	225	182	38		1175		1175
1977	201	393	336	207	237	46	-	1420	6	1426
1978	81	349	245	186	113	10	-	984	8	992
1979	120	343	524	213	164	31	-	1395	+	1395
1980	52	275	404	231	158	74	-	1194	+	1194
1981	105	403	348	203	153	32	20	1264	+	1264
1982	111	330	239	136	167	76	18	1077	+	1077
1983	14	77	93	41	55	30	-	310	+	310
1984	33	116	64	4	43	32	5	297	+	297
1985	85	124	198	207	147	103	-	864	7	871
1986	46	73	128	203	233	277	-	960	19	979
1987	48	114	229	205	261	109	-	966	+	966
1988	24	100	213	191	198	167	-	893	4	897
1989	9	28	81	73	75	71	-	337	-	337
1990	4	20	132	54	16	48	-	274	-	274
1991	12	36	120	38	108	158	-	472	4	476
1992	-	4	23	5	75	130	-	237	5	242
1993*	-	-	-	-	-	-	-	-	-	-
1994*	-	-	-	-	-	-	-	-	-	-
1995	+	10	28	17	22	5	-	83	2	85
1996	+	+	50	8	23	10	-	92	+	92
1997	1	5	15	4	16	17	-	58	1	59
1998	1	2	2	4	1	2	-	11	-	11
1999	+	2	3	9	2	2	-	19	+	19
2000	+	+	1	7	+	13	-	21	-	21
2001	+	1	4	5	3	28	-	43	-	43
2002	+	+	2	4	1	2	-	9	-	9
2003	1	+	2	1	1	5	-	9	-	9
2004	3	1	4	2	3	2	-	15	-	15
2005	1	3	2	1	3	5	-	15	-	15
2006	6	2	3	4	2	4	-	22	-	22
2007	2	5	6	4	5	2	-	25	-	25
2008	4.9	2.2	10.0	1.6	2.5	5.0	0	26.2	0	26.2
2009	0.2	6.2	7.1	3.0	4.3	4.8	0	25.6	0.8	26.3

Year	1A	1B	1C	1D	1E	1F	Unknown	West Greenland	East Greenland	Total
2010	17.3	4.6	2.4	2.7	6.8	4.3	0	38.1	1.7	39.6
2011	1.8	3.7	5.3	8.0	4.0	4.6	0	27.4	0.1	27.5
2012	5.4	0.8	15.0	4.6	4.0	3.0	0	32.6	0.5	33.1
2013	3.1	2.4	17.9	13.4	6.4	3.8	0	47.0	0.0	47.0
2014	3.6	2.8	13.8	19.1	15.0	3.4	0	57.8	0.1	57.9
2015	0.8	8.8	10.0	18.0	4.2	14.1	0	55.9	1.0	56.8

* The fishery was suspended.
+ Small catches, < 5 t.
- No catch.

Table 10.4.2.3 Reported landings (t) by landing category, the number of fishers reporting, and the total number of landing reports received for licensed and unlicensed fishers in 2012–2015. Empty cells identify categories with no reported landings and 0.0 entries represent reported values of < 0.5.

NAFO/ICES areas	Licensed	No. of Fishers	No. of Reports	Comm.	Private	Factory	Total		Licensed	No. of Fishers	No. of Reports	Comm.	Private	Factory	Total
	2015								**2014**						
1A	NO	5	6		0.1		0.1		NO	1	1		0.1		0.1
1A	YES	13	29	0.1	0.6		0.7		YES	20	87	3.0	0.5		3.5
1A	**TOTAL**	**18**	**35**	**0.1**	**0.7**		**0.8**		**TOTAL**	**21**	**88**	**3.0**	**0.6**		**3.6**
1B	NO	3	5		0.1		0.1		NO						
1B	YES	15	96	7.3	1.5		8.7		YES	8	28	2.1	0.7		2.8
1B	**TOTAL**	**18**	**101**	**7.3**	**1.5**		**8.8**		**TOTAL**	**8**	**28**	**2.1**	**0.7**		**2.8**
1C	NO	16	58	0.1	1.7		1.8		NO	5	18	0.6			0.6
1C	YES	42	181	2.9	3.9	1.5	8.2		YES	35	212	1.5	2.1	9.7	13.2
1C	**TOTAL**	**58**	**239**	**3.0**	**5.6**	**1.5**	**10.1**		**TOTAL**	**40**	**230**	**2.1**	**2.1**	**9.7**	**13.8**
1D	NO	20	35		0.8		0.8		NO	6	10	0.2	0.3		0.5
1D	YES	11	161	14.3	0.5	2.4	17.1		YES	14	115	0.4	5.5	12.8	18.6
1D	**TOTAL**	**31**	**196**	**14.3**	**1.3**	**2.4**	**18.0**		**TOTAL**	**20**	**135**	**0.6**	**5.7**	**12.8**	**19.1**
1E	NO	3	5	0.1	0.2		0.2		NO	1	1	0.2			0.2
1E	YES	11	71	2.0	1.9		3.9		YES	9	102	1.4	0.8	12.6	14.8
1E	**TOTAL**	**14**	**76**	**2.1**	**2.1**		**4.2**		**TOTAL**	**10**	**103**	**1.6**	**0.8**	**12.6**	**15.0**
1F	NO	20	69		2.4		2.4		NO	3	3	0.1	0.1		0.2
1F	YES	21	173	7.1	4.6		11.7		YES	11	80	2.0	1.2		3.2
1F	**TOTAL**	**41**	**242**	**7.1**	**7.0**		**14.1**		**TOTAL**	**14**	**83**	**2.1**	**1.3**		**3.4**
XIV	NO	8	32		0.6		0.6		NO						0.0
XIV	YES	1	17	0.0	0.4		0.4		YES	1	12	0.1	0.0		0.1
XIV	**TOTAL**	**9**	**49**	**0.0**	**0.9**		**1.0**		**TOTAL**	**1**	**12**	**0.1**	**0.0**		**0.1**
ALL	NO	75	210	0.1	5.9		6.0		NO	16	33	1.2	0.4		1.6
ALL	YES	114	728	33.7	13.3	3.8	50.8		YES	98	636	10.5	10.7	35.0	56.2
ALL	**TOTAL**	**189**	**938**	**33.8**	**19.2**	**3.8**	**56.8**		**TOTAL**	**114**	**669**	**11.6**	**11.2**	**35.0**	**57.8**

NAFO/ICES areas	Licensed	No. of Fishers	No. of Reports	Comm.	Private	Factory	Total		Licensed	No. of Fishers	No. of Reports	Comm.	Private	Factory	Total
	2013								**2012**						
1A	NO	10	32	0.3	0.0		0.3		NO	8	25		0.6		0.6
1A	YES	18	94	1.2	1.6		2.8		YES	27	142	1.3	3.5		4.8
1A	**TOTAL**	**28**	**126**	**1.5**	**1.6**		**3.1**		**TOTAL**	**35**	**167**	**1.3**	**4.1**		**5.4**
1B	NO	2	5	0.2			0.2		NO	3	3		0.2		0.2
1B	YES	6	14	1.3	0.9		2.2		YES	6	19	0.1	0.5		0.5
1B	**TOTAL**	**8**	**19**	**1.4**	**0.9**		**2.4**		**TOTAL**	**9**	**22**	**0.1**	**0.7**		**0.8**
1C	NO								NO	2	6		0.3		0.3
1C	YES	21	205	2.2	3.5	12.3	18.0		YES	30	172	1.8	0.8	12.1	14.7
1C	**TOTAL**	**21**	**205**	**2.2**	**3.5**	**12.3**	**18.0**		**TOTAL**	**32**	**178**	**1.8**	**1.2**	**12.1**	**15.0**
1D	NO	10	23	0.4	0.0		0.5		NO	5	15	0.0	0.4		0.4
1D	YES	9	112	0.1	4.8	8.0	12.9		YES	3	23	1.4	1.2	1.6	4.2
1D	**TOTAL**	**19**	**135**	**0.5**	**4.9**	**8.0**	**13.4**		**TOTAL**	**8**	**38**	**1.4**	**1.6**	**1.6**	**4.6**
1E	NO	1	1	0.1			0.1		NO	13	22		1.3		1.3
1E	YES	6	41	0.8	0.2	5.3	6.4		YES	3	45	0.8	1.9		2.7
1E	**TOTAL**	**7**	**42**	**0.9**	**0.2**	**5.3**	**6.4**		**TOTAL**	**16**	**67**	**0.8**	**3.2**		**4.0**
1F	NO	5	10	0.3			0.3		NO	6	17		0.7		0.7
1F	YES	6	15	1.0	2.4		3.4		YES	10	40	0.1	2.2		2.3
1F	**TOTAL**	**11**	**25**	**1.4**	**2.4**		**3.8**		**TOTAL**	**16**	**57**	**0.1**	**2.8**		**3.0**
XIV	NO	1	1	0.0			0.0		NO	6	24		0.5		0.5
XIV	YES								YES	0	0				
XIV	**TOTAL**	**1**	**1**	**0.0**			**0.0**		**TOTAL**	**6**	**24**		**0.5**		**0.5**
ALL	NO	29	72	1.3	0.1		1.4		NO	43	112	0.0	4.1		4.1
ALL	YES	66	481	6.6	13.4	25.6	45.6		YES	79	441	5.5	9.9	13.7	29.1
ALL	**TOTAL**	**95**	**553**	**7.9**	**13.4**	**25.6**	**47.0**		**TOTAL**	**122**	**553**	**5.5**	**14.1**	**13.7**	**33.2**

Table 10.4.2.4 Reported and adjusted landings. Adjusted landings (sampling) made by comparing the weight of salmon seen by the sampling teams and the corresponding community-specific reported landings. Dashes '-' indicate that no adjustment was necessary. Adjusted landings (survey) made from phone survey estimates of unreported catch (no phone surveys were conducted from 2002 to 2013). Landings for assessment are the summation of reported and adjusted landings (sampling and surveys).

Year	Reported landings (West Greenland only)	Adjusted landings (sampling)	Adjusted landings (survey)	Landings for assessment
2002	9.0	0.7		9.8
2003	8.7	3.6		12.3
2004	14.7	2.5		17.2
2005	15.3	2.0		17.3
2006	23.0	-		23.0
2007	24.6	0.2		24.8
2008	26.1	2.5		28.6
2009	25.5	2.5		28.0
2010	37.9	5.1		43.1
2011	27.4	-		27.4
2012	32.6	2.0		34.6
2013	46.9	0.7		47.7
2014	57.7	0.6	12.2	70.5
2015	55.9	-	5.0	60.9

Table 10.4.2.5 Summary of biological characteristics of catches at West Greenland in 2015 (NA – North America, E – Europe).

River-age distribution (%) by origin								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
NA	0.1	31.6	40.6	21.6	6.0	0.2	0	0
E	9.2	54.9	28.8	5.8	1.2	0	0	0

Length and weight by origin and sea age								
	1 SW		**2 SW**		**Previous spawners**		**All sea ages**	
	Fork length (cm)	Whole weight (kg)	Fork length (cm)	Whole weight (kg)	Fork length (cm)	Whole weight (kg)	Fork length (cm)	Whole weight (kg)
NA	65.6	3.36	84.1	7.52	74.2	4.53	n/a	3.42
E	64.4	3.13	82.5	7.10	67.2	3.81	n/a	3.18

Continent of origin (%)	
North America	**Europe**
79.9	20.1

Sea-age composition (%) by continent of origin			
	1SW	**2SW**	**Previous spawners**
NA	97.0	0.7	2.3
E	98.2	1.2	0.6

10.4.3 Status of the stocks

Currently reliable estimates of stock status of wild fish populations in West Greenland are not available. Stock status is inferred from the status of the populations in their homewaters. Recruitment (pre-fishery abundance (PFA)) estimates of non-maturing 1SW salmon suggest continued low abundance of North American (Figure 10.3.4.2 in ICES, 2016a) and Southern NEAC (North-East Atlantic Commission; see Figure 10.2.4.1 in ICES, 2016b) salmon at Greenland. In 2015, North American Two-Sea-Winter (2SW) spawner estimates were below conservation limits (CLs) in four of the six regions (Quebec, Gulf, Scotia–Fundy, and the USA) and for the North American Commission area (NAC) overall (Figure 10.3.4.3 in ICES, 2016a); median estimates for both Labrador and Newfoundland were above the CLs. Within each of the geographic areas in NAC there are varying numbers of individual river stocks which are failing to meet CLs, particularly in Scotia–Fundy and the USA. The Southern NEAC non-maturing 1SW stock complex was considered to be suffering reduced reproductive capacity (Figure 10.2.4.1 in ICES, 2016b) prior to the commencement of distant-water fisheries. Within the Southern NEAC area there are individual countries and varying numbers of rivers which are failing to met CLs, particularly in the southern portion of the region.

The exploitation rate (catch in Greenland/PFA) on NAC fish in 2014 was 9.4%, which is lower than the 2013 estimate (11.1%) and the previous five-year mean (8.3%, 2009–2013), and also the second highest since 2001 (Figure 10.4.3.1). The 2014 Southern NEAC exploitation rate was 2.0%, an increase from the previous year's estimate (0.9%) and the previous five-year mean (0.4%, 2009–2013), but remains among the lowest in the time-series. The abundance of salmon within the West Greenland area is thought to be low compared to historical levels. This is broadly consistent with the general pattern of decline in marine survival in most monitored stocks. Despite major changes in fisheries management in the past few decades and increasingly more restrictive fisheries measures since then, returns in many of these regions have remained near historical lows. In Scotia–Fundy and USA, in particular, many populations are currently threatened with extirpation and are receiving special protection under federal legislation. The continued low abundance of salmon stocks across North America and in the Northeast Atlantic, despite significant fishery reductions, further strengthens the conclusions that factors other than fisheries are constraining production.

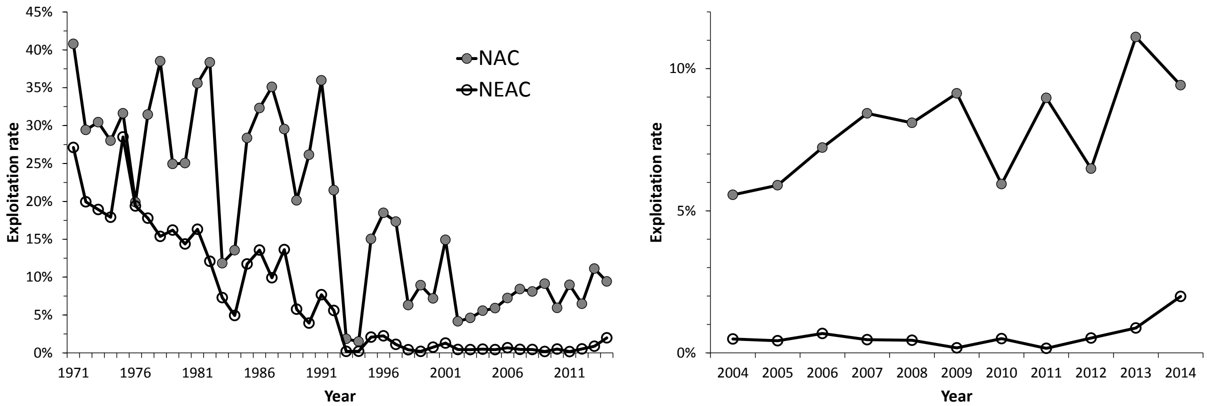

Figure 10.4.3.1 Exploitation rate (%) for NAC 1SW non-maturing and southern NEAC non-maturing Atlantic salmon at West Greenland, 1971–2014 (left panel) and 2005–2014 (right panel). Exploitation rate estimates are only available to 2014, as 2015 exploitation rates are dependent on 2016 returns.

10.4.4 NASCO has requested ICES to compare contemporary indices of abundance of salmon in the West Greenland fishery to historical estimates and to suggest options for improving future estimates

At its 2001 meeting, NASCO implemented an *ad hoc* management programme that provided for in-season adjustments to allocated quota based on real-time observation of catch per unit effort (CPUE) in the fishery at West Greenland (NASCO, 2001). In 2002, ICES Working Group on North Atlantic Salmon (WGNAS) examined an apparent relationship between annual CPUE estimates for the West Greenland fishery and pre-fishery abundance (PFA) estimates for the North American stock complex for a series of years, from 1987 to 1992 and 1997 to 2001. Despite the limitations of using CPUE data described by the working group at the time (ICES, 2002), these data have been updated to include more recent data from 2012 to 2015 to allow for the estimation of contemporary relative abundance of fish at West Greenland from these effort data.

Between 1997 and 2015, the number of trips reporting commercial landings of Atlantic salmon ranged from 712 trips (1997) to 56 trips (2015). Distribution of trips across NAFO Divisions and weeks has been variable through time, and the number of trips within given weeks was often very low, as observed during the 1998 and 1999 fisheries (Figure 10.4.4.1). In 2000, the fishery opened on the 14th August and closed four days later as the quota of 20 t was reached. In 2015, landings to factories occurred very late in the season (weeks 41 to 43, in late October).

Available commercial CPUE corresponds to the North American 1SW non-maturing PFA estimates, with the exception of the large outlier in 2000 resulting from the early closure of the fishery. Data from 2015 were not included in the regression analysis as 2015 PFA estimates are dependent on 2016 2SW returns (Figure 10.4.4.2). There also appears to be a significant relationship between commercial CPUE and the Southern European 1SW non-maturing PFA, with the exception of the same outlying point in 2000 (again, 2015 CPUE data were not included).

The previous conclusion (ICES, 2002) that CPUE, during the harvest period, accurately reflects the overall PFA level appears to remain valid when updated with data for 2012 to 2015. The recent CPUE values are low compared to historical estimates; this supports the previous conclusions from ICES (2015) that stock abundance is low at West Greenland. Anecdotal reports of high abundance of salmon at Greenland may be the result of localized concentrations of abundance, localized catch success, or shifting baseline of perception.

Despite concerns about the use of CPUE data to inform stock abundance, WGNAS endorses the general principle of using these fishery-dependant indices to infer stock abundance over time. Comprehensive reporting of data characterizing fishing effort (e.g., vessel size, gear type, amount of gear deployed, soak time, documentation of zero landings trips and private sales trips) would allow for a more detailed analyses of CPUE data to characterize availability of Atlantic salmon in West Greenland. Development of alternative in-season measures of abundance should also be explored.

Similarly, there is scope to explore alternative fishery-independent methods to estimate stock abundance at Greenland, such as:

- Hydro-acoustic surveys at West Greenland.
- Standardized gillnet surveys or test fishing as conducted for Pacific salmon on the west coast of the USA.
- Open-trawl surveys (open codend with video camera observation as a means of surveying large areas with minimal or no harvest).

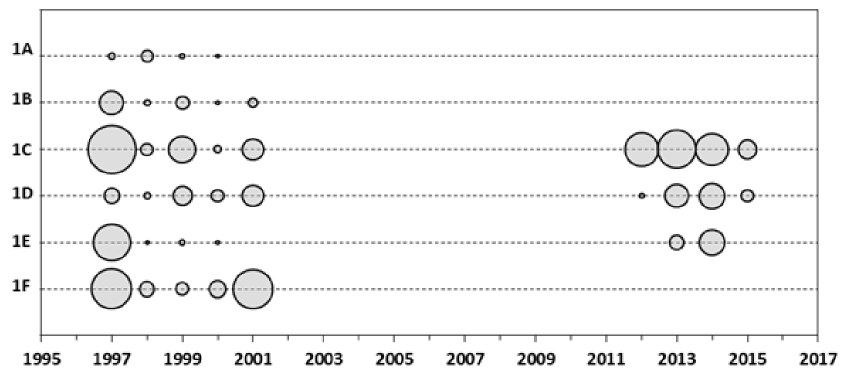

Figure 10.4.4.1 Distribution of commercial effort (number of trips reporting salmon landings) by NAFO division in the fisheries at West Greenland (NAFO divisions 1A to 1F) from 1997 to 2001 and 2012 to 2015. Circle sizes indicate the number of commercial trips reported in each year and area. Largest circle = 253 trips and smallest = 1 trip.

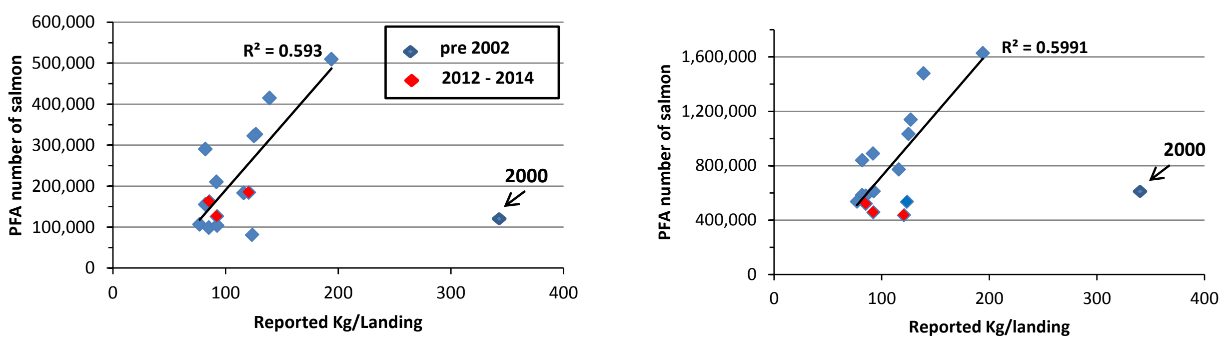

Figure 10.4.4.2 Relationship between CPUE and pre-fishery abundance estimates for the non-maturing 1SW component of the North American (left panel) and Southern European stock complexes (right panel). Input data have been updated with revised PFA values and CPUE data are slightly different than those previously reported by ICES. Regression relationships exclude the outlying point for 2000. Red points indicate available contemporary data (2012–2014).

10.4.5 NASCO has requested ICES to estimate the effects of modifying the timing of the West Greenland salmon fishery, including altering the start date, with regard to harvest and exploitation of contributing stocks

Atlantic salmon feeding at West Greenland grow rapidly over the period of August to November. The increase in weight of individual fish over the fishing season at West Greenland prompted managers to ask whether increased returns to homewaters could be realized by fishing later in the season for a comparable total allowable catch option established in weight of fish harvested. The following analysis examines the relative consequence on predicted returns to homewaters of a fixed total allowable catch according to variations in opening and duration of the fishing season at West Greenland (Table 10.4.5.1). The consequence on returns to homewaters was examined by moving fish at the pre-fishery abundance stage through the fishery, adjusting their size (in weight) over time (by standard week based on analysis of over 18 000 salmon sampled for biological charcateristics during the 2002–2015 West Greenland fisheries), removing fish based on weekly catches (set at a proportion of the total allowable catch for the year), and correcting for natural mortality (at about 3% per month) as the fish mature from the PFA stage, through the fishery, and to their return to homewaters.

The relative change in returns to homewaters from a base condition was examined. The base condition for the fishery was an opening date of 30 July (week 31) with a fishing season that extended to 11 November (week 44). As the relative change in returns to homewaters is the metric of interest, the total allowable catch and the pre-fishery abundance are simply scaling factors; characteristics of the fish in the fishery and the pre-fishery abundance values are reported by ICES (2015). Uncertainties in the PFA values and fishery characteristics were simulated by 5000 independent Monte Carlo draws.

The relative difference ((estimate from scenario – estimate from base) / estimate from base) in the catches of 1SW non-maturing salmon of NAC and NEAC, in the estimated PFA abundance post-fishery week 44, and in the returns as 2SW salmon to NAC and NEAC for the fishery scenarios are shown in Table 10.4.5.2.

The number of harvested non-maturing 1SW salmon decreases as the opening of the season is delayed; the highest catches in numbers of fish are realized for a short fishing season that opens early (scenario B1), and the lowest catches are realized from the fishery that opens the latest and is of shortest duration (scenario C1; Table 10.4.5.2). As predicted, the number of harvested salmon decreases for a fixed TAC as the opening of the fishery is delayed. The relative gain in returns to homewaters as 2SW salmon is reduced by the consequences of natural mortality acting on the fish over the migration period. The largest relative increase in abundance of returns for NAC salmon is 2.5% for the shortest and latest opening of the fishery season (scenario C1). As the fishery effect at West Greenland is small (harvests of 5000 fish from a PFA estimate of almost 400 000 fish) there is no discernible difference in the relative gain of 2SW NEAC salmon returns to homewaters.

This analysis indicates that the relative gain in returns to homewaters associated with a delay of the fishery season for a fixed TAC option is dependent upon the exploitation rate on the stock being exploited. The more heavily exploited component benefits the most from a delay in the opening of the season. The realized gains are also dependent upon the growth rates in weight of the fish during the fishery season, and on the assumed natural mortality rate. If growth rates are lower or natural mortality higher, the relative gains to escapement would be reduced from those provided here. If growth rates are higher or natural mortality lower, the relative gains will be more important.

Based on characteristics of the fish in the fishery, the estimated changes in weights over the period of sampling (weeks 31 to 44), and the assumed natural mortality rate of salmon, there would be some small gains in escapement (2.5% for NAC) which could be realized from delaying the opening of the fishery season to at least mid-September (week 38). However, the number of fish harvested would be reduced by almost 15% from the base scenario, which would result in a lower exploitation rate on the stock overall, and could favour protection of weaker stocks assuming equal availability to the fishery.

Scenarios for season closures after week 44 were not examined. There are no contemporary samples from the fishery after week 44 (4–11 November) with which to assess whether salmon continue to increase in weight into the early winter.

Table 10.4.5.1 Fishing season scenarios examined (shaded cells) and predicted geometric mean weight of salmon in the fishery at West Greenland by standard week of the fishery.

Standard week	31	32	33	34	35	36	37	38	39	40	41	42	43	44
Pred. weight (kg)	2.59	2.68	2.78	2.88	2.99	3.10	3.21	3.33	3.45	3.58	3.71	3.85	3.99	4.14
Base														
A1														
A2														
A3														
A4														
A5														
B1														
B2														
B3														
B4														
C1														

Table 10.4.5.2 Estimated tonnes harvested, and relative changes from the base fishing scenario of catches of 1SW non-maturing salmon from NAC and southern NEAC (N.NAC.1SWnmat; N.NEAC.1SWnmat), of surviving abundance post-fishery week 44 of NAC and southern NEAC 1SW non-maturing salmon (PFA.NAC45, PFA.NEAC45), and returns as 2SW salmon to homewaters (NAC.Ret.2SW, NEAC.Ret.2SW). The values shown for the base period are the mean values of the corresponding components. The relative changes shown are the means of 5000 Monte Carlo draws.

		Relative change from base fishing season					
Fishing season scenario	**Tonnes harvested**	**N.NAC.1SWnmat**	**N.NEAC.1SWnmat**	**PFA.NAC45**	**PFA.NEAC45**	**NAC.Ret.2SW**	**NAC.Ret.2SW**
Base	102.5	24 230	4911	112 200	339 800	90 980	275 500
A1	102.5	−1.90%	−1.90%	−0.10%	0.10%	−0.10%	0.00%
A2	102.1	−4.20%	−4.20%	0.60%	−0.10%	0.60%	−0.10%
A3	101.7	−6.40%	−6.40%	1.00%	0.10%	0.90%	0.10%
A4	101.9	−8.00%	−8.00%	1.10%	0.10%	1.00%	0.10%
A5	102.4	−9.40%	−9.30%	1.20%	0.20%	1.20%	0.20%
B1	102.2	10.30%	10.30%	−1.70%	−0.10%	−1.70%	−0.10%
B2	102.2	2.60%	2.60%	0.00%	−0.10%	−0.10%	−0.10%
B3	102.2	−4.50%	−4.50%	0.70%	0.10%	0.60%	0.10%
B4	102.0	−11.30%	−11.20%	1.70%	0.00%	1.70%	0.00%
C1	102.2	−14.50%	−14.50%	2.60%	0.20%	2.50%	0.10%

10.4.6 NASCO has requested ICES to advise on changes to temporal and/or spatial fishery patterns that may provide increased protection for weaker stocks

ICES has previously provided information on estimated catches at West Greenland by stock origin and described their spatial and temporal distribution based on available contemporary data (ICES, 2015). ICES summarized available data from genetic sampling to determine:

- The continent of origin by standard week and by NAFO division (2006–2015).
- Division-specific sub-continental (regional) numbers and proportions for both European (2002, 2004–2012) and North American (2011–2014) fish.

Collectively, these summaries represent the most robust estimates available that describe the composition of the West Greenland harvest at the sub-continent level and they could be used to evaluate options for temporal and/or spatial focused management options aimed at protecting weaker stocks at West Greenland.

One option for investigating the existence of temporal and/or spatial fishery patterns would be to evaluate the individual regional assignments for the samples previously reported on by ICES (2015). Unfortunately, the individual assignment results were not available to the working group.

In the absence of individual assignment data, the mixture analysis results reported for the European component of the stock complex by ICES (2015) and the North American component of the stock, which has been updated by Bradbury *et al.* (accepted), can provide insights to temporal and spatial patterning of the contributing stocks to the West Greenland fishery. Three regional groupings (North Scotland and North and West Ireland, Irish Sea, and South and East Scotland) contributed approximately 90% to the European harvest, and three other regional groupings (Central Labrador, Gaspé, and Southern Gulf of St. Lawrence) contributed approximately 75% of the North American fish harvested. Weaker performing stocks originating from the more southerly regions of North America (Nova Scotia, Inner Bay of Fundy, and USA) and Europe (North and West France and South France and Spain) generally contributed less than 2% of the harvest.

Historical tag return data suggest that salmon originating from the USA were more prominent in southern portions of the fishery than were Canadian salmon (Reddin *et al.*, 2012). Bradbury *et al.* (accepted) explicitly tested for differences in spatial distribution of salmon from different regions and detected no significant spatial structuring. Cluster analysis indicated no structuring and none of the variance in catch composition was attributable to location or year, further supporting the suggestion that the contributing stocks are mixed off the coast of West Greenland. However, salmon from USA and other more southerly populations are relatively rare in the harvest and the power to detect spatial or temporal patterning may be influenced by sample size. Bradbury *et al.* (accepted) did detect a tendency for salmon from southern regions to arrive slightly earlier in the season, but this relationship was not significant. Further analyses on regional contributions of the European component of the stock complex, beyond that presented by ICES (2015), were not undertaken, but there is no evidence to suggest that the dynamics deviate from the North American patterning.

Given that the temporal estimates of stock composition at West Greenland (ICES, 2015; Bradbury *et al.,* accepted) and the modelled estimates of MSW stock abundance (ICES, 2015) are highly correlated, the genetic estimates appear to be accurately resolving stock composition in the harvest. In view of their low representation it is difficult to ascertain if there are spatial or temporal patterns to the harvest of the weaker performing stocks, but it is unlikely considering the lack of patterns for the larger contributors. As such, there does not appear to be any obvious temporal and/or spatial patterns to the regional contributions to the harvest that would allow for management options to provide increased protection for weaker stocks.

WGNAS also investigated for spatial or temporal trends in fishery contribution by continent of origin or river age, as river age is considered a proxy for latitude of origin. Approximately 11 000 samples were available for analysis from the 2006–2015 fisheries. The analysed data included origin (North American or European), river age (1–6), NAFO division (1A–1F), and standard weeks (31–44) for individuals sampled. Standard week 31 refers to 30 July to 05 August in every year and sequentially increases by one every seven days.

There appears to be a slight increase in the contribution of European origin salmon as the fishing season progresses (Figure 10.4.6.1), with low contributions in the early part of the fishery (~6% in weeks 31 and 32) and higher contributions later in the fishing season (28% and 44% in weeks 42 and 44, respectively). Care should be taken when interpreting these results as the sample sizes for these four weeks represent less than 5% of the available samples.

There was no clear pattern of continental-specific contributions across NAFO divisions (Figure 10.4.6.1). The two divisions with the highest European contribution also had the lowest sample sizes (Divisions 1A and 1E).

There was no clear pattern of river-age contributions across standard week for either North American or European fish (Figure 10.4.6.2). The contribution of river-age one North American fish ranged from 1% to 2% across all standard weeks with the exception of a 5% contribution in week 31, which consisted of only three fish, all sampled in a single year/community/day. Although there appears to be an increasing contribution of river-age 1 European fish as the fishery progresses, week 42 only contained a single river-age 1 fish, no samples were collected in standard week 43, and the six European age one fish collected in week 44 all came from a single year/community/day.

There is no evidence of clear patterns of North American or European river-age contributions across NAFO divisions (Figure 10.4.6.3). North American river-age 1 contributions were approximately 1% across all divisions and river-age 2 contributions ranged from 25% to 29%. European river-age 1 fish had a larger contribution in NAFO Division 1A (44%), but sample size was low and the remaining divisions ranged from zero to 11% with no clear patterns. Although there appears to be a potential weak association between European river-age 1 fish contribution in higher proportions in the more northern areas (NAFO Division 1A), overall there appears to be similar contributions across all other NAFO divisions.

Neither the results presented here, by ICES (2015), or by Bradbury *et al.* (accepted) provide clear evidence of temporal and/or spatial management options for the fishery at West Greenland that would provide increased protection for weaker stocks. Although sample sizes may not be optimal, the best available information suggests that the contributing North American and European stocks sufficiently mix along the coast of West Greenland and across the fishing season. The contributions to the harvest by the regional stock groupings closely mirrors the modelled estimates of MSW stock abundance, further supporting the suggestion that the stocks are well mixed within the fished complex. Although some weak relationships were identified (e.g. a higher contribution of North American river-age 1 fish in week 31, greater European river-age 1 fish in the north), these relationships remain preliminary and further analysis of these data, increased genetic sampling of the fishery, and further refinement in the genetic baselines used for regional assignments may be needed to investigate these patterns further.

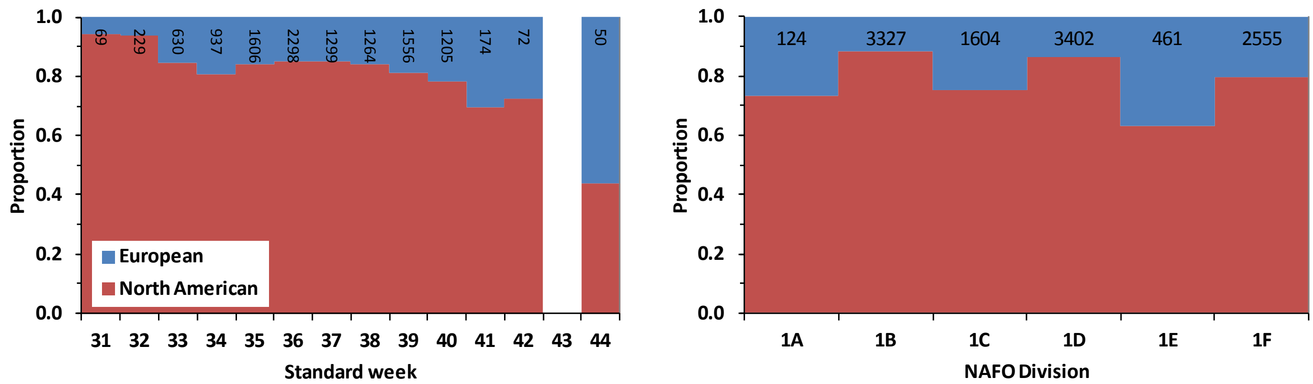

Figure 10.4.6.1 Continent of origin of sampled salmon from the West Greenland fishery (2006–2015) by standard week(left panel) and NAFO division (right panel). Standard week 31 corresponds to 30 July to 05 August in every year. No samples were collected during week 43. (Numbers along the top represent sample sizes.)

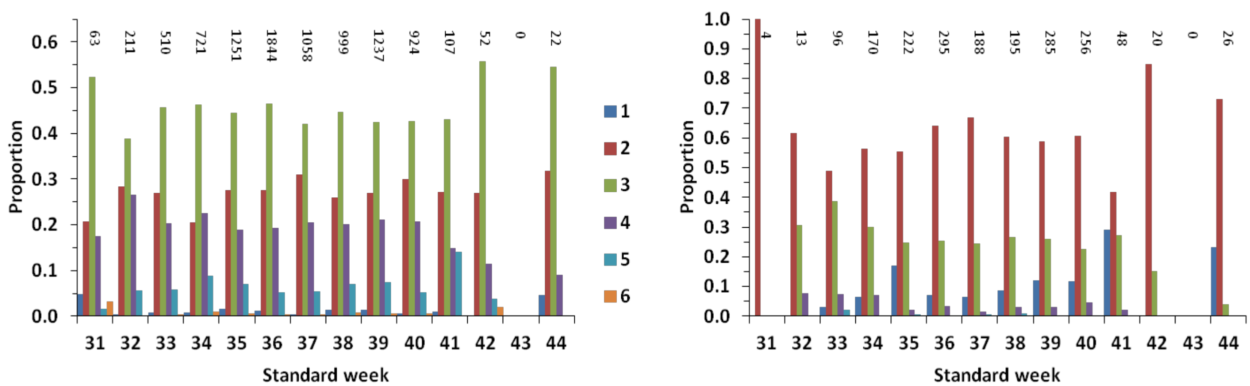

Figure 10.4.6.2 River age of North American origin (left panel) and European origin (right panel) sampled salmon from the West Greenland fishery (2006–2015) by standard week. Standard week 31 corresponds to 30 July to 05 August in every year. No samples were collected during week 43. (Numbers along the top represent sample sizes.)

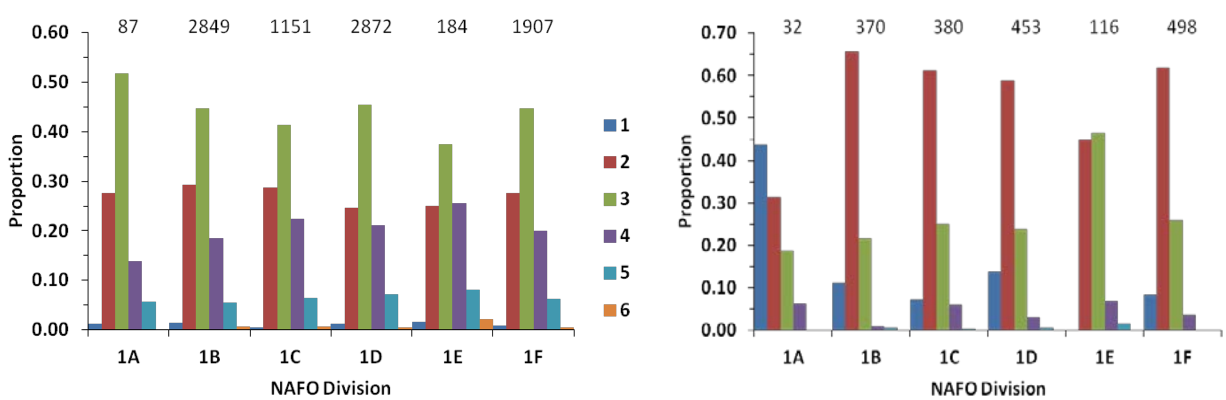

Figure 10.4.6.3 River age of North American origin (left panel) and European origin (right panel) sampled salmon from the West Greenland fishery (2006–2015) by NAFO division. (Numbers along the top represent sample sizes.)

References

Bradbury, I. R., Hamilton, L. C., Sheehan, T. F., Chaput, G., Robertson, M. J., Dempson, J. B., Reddin, D., *et al.* Accepted. Genetic mixed stock analysis disentangles spatial and temporal variation in composition of the West Greenland Atlantic Salmon fishery. ICES Journal of Marine Science.

ICES. 2002. Report of the Working Group on North Atlantic Salmon (WGNAS), 3–13 April 2002, ICES Headquarters, Copenhagen. ICES CM 2002/ACFM: 14. 299 pp.

ICES. 2015. Report of the Working Group on North Atlantic Salmon (WGNAS), 17–26 March 2015, Moncton, Canada. ICES CM 2015/ACOM:09. 461 pp.

ICES. 2016a. Atlantic salmon from North America. *In* Report of the ICES Advisory Committee, 2016. ICES Advice 2016, Book 10, Section 10.3.

ICES. 2016b. Atlantic salmon from the Northeast Atlantic. *In* Report of the ICES Advisory Committee, 2016. ICES Advice 2016, Book 10, Section 10.2.

ICES. 2016c. ICES Compilation of Microtags, Finclip and External Tag Releases 2015 by the Working Group on North Atlantic Salmon, 30 March–8 April 2016, Copenhagen, Denmark. ICES CM 2016/ACOM:10. 23 pp.

NASCO. 2001. Report of the Eighteenth Annual Meetings of the Commissions. Mondariz, Galicia, Spain, 4–8 June 2001.

Reddin, D. G., Hansen, L. P., Bakkestuen, V., Russell, I., White, J., Potter, E. C. E., Sheehan, T. F., *et al.* 2012. Distribution and biological characteristics of Atlantic salmon (*Salmo salar*) at Greenland based on the analysis of historical tag recoveries. ICES Journal of Marine Science, 69(9): 1589–1597.

Annex 1 Glossary of acronyms and abbreviations

1SW *(one-sea-winter).* Maiden adult salmon that has spent one winter at sea.

2SW *(two-sea-winter).* Maiden adult salmon that has spent two winters at sea.

CL, i.e. S_{lim} *(conservation limit).* Demarcation of undesirable stock levels or levels of fishing activity; the ultimate objective when managing stocks and regulating fisheries will be to ensure that there is a high probability that undesirable levels are avoided.

CPUE *(catch per unit of effort).* A derived quantity obtained from the independent values of catch and effort.

ICES (*International Council for the Exploration of the Sea*).

NAC (*North American Commission*). A commission under NASCO.

NAFO (*Northwest Atlantic Fisheries Organisation*). NAFO is an intergovernmental fisheries science and management organization that ensures the long-term conservation and sustainable use of the fishery resources in the Northwest Atlantic.

NASCO (*North Atlantic Salmon Conservation Organization*).

NEAC (*North East Atlantic Commission*). A commission under NASCO.

PFA *(pre-fishery abundance).* The numbers of salmon estimated to be alive in the ocean from a particular stock at a specified time. In the previous version of the stock complex Bayesian PFA forecast model two productivity parameters are calculated, for the *maturing* (PFAm) and *non-maturing* (PFAnm) components of the PFA. In the updated version only one productivity parameter is calculated and used to calculate total PFA, which is then split into PFAm and PFAnm based upon the *proportion of PFAm* (p.PFAm).

TAC *(total allowable catch).* TAC is the quantity of fish that can be taken from each stock each year.