Narwhal, *Monodon monoceros*, Catch Statistics in Greenland, 1862–2017

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Introduction

For the development of management advice on sustainable harvest levels of narwhals, *Monodon monoceros*, it is important that a complete history of removals by humans be reconstructed. Catch statistics for narwhals go back to 1862, but they are not complete and have never included the struck-but-lost whales. The completeness of the catch statistics has fluctuated not necessarily because of fluctuations in the harvest but because a large number of catches were not included in the records. This fraction of unreported catches and the number of struck-but-lost whales cannot be determined precisely, but estimates can be made using certain assumptions during limited periods.

A special problem with the catch statistics for Monodontids from West Greenland is that the catches that are taken from whale pods entrapped in the ice are included in the official catch statistics. It has been suggested that the occasional mortality in ice entrapments is part of the natural mortality (Siegstad and Heide-Jørgensen, 1994). To allow for analyses of removals without catches in ice entrapments, these are shown separately from the mortality genuinely caused by humans.

Narwhals have a complex population structure (Heide-Jørgensen et al., 2013) and for the assessment of the sustainability of the hunt it is critical that catches are correctly distributed on the stocks that are supplying the hunt in the various hunting areas. To the extent possible this compilation of the catch history follows the allocation of catches to hunting grounds that is used in the assessments (Watt et al., 2019). For assessment purposes it is furthermore important to be able to model the dynamics of populations using catch statistics that include options for corrections of unreported catches and whales that are struck-but-lost (Witting et al., 2019; Watt et al., 2019). It is important to maintain transparency in the corrections deployed to allow for different selections of the catch history in assessment models (Butterworth et al., 2002; Innes and Stewart, 2002; Alvarez-Flores and Heide-Jørgensen, 2004). The objective of this paper is to provide a complete catch record (1862–2017) that can be used in assessment models to provide sustainable catch levels for the indigenous narwhal hunt in Greenland.

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ABSTRACT—Information and statistics including trade statistics on catches of narwhals, Monodon monoceros*, in Greenland since 1862 are reviewed. Detailed statistics split by hunting grounds are missing for most of the years until 1993. For the northernmost area, Avanersuaq, only sporadic reporting exists. Based on statistics from the recent three decades, a time series is constructed for West Greenland with catches split into hunting grounds and corrected for underreporting assessed from purchases of whale skin called "mattak," for periods without catch records and from rates of struck-but-lost whales ("low," "medium," and "high option"). This reveals a time series of somewhat realistic catch levels from 1862 through 2017. Since 1993 catches have declined in West Greenland, especially in Uummannaq and Disko Bay where the decline is significant. In East Greenland, there has been an increase in catches from Ittoqqortoormiit and a decrease in catches from Tasiilaq from 1993 to 2017.*

Methods

This compilation utilizes statistics on narwhal catches in West Greenland between 1862 and 1891 from Winge (1902) and Anonymous (1944), between 1907 and 1934 from Heide-Jørgensen (1994) and Anonymous (1944), between 1954 and 1974 from Kapel (1977), between 1975 and 1990 from unpublished statistics from the Ministry of Greenland, and from 1993 to 2017 from "Piniarneq"[1]. For the periods 1862–1921, 1934–1948, and 1954–1963 catches were reported for the period 1 April through 31 March, but for the tabulation here all catches are allocated to the first of the years reported. This was done in order to compare data between calendar years, although some catches might belong to the following calendar year.

In addition to catch and hunter records, commercial records of narwhal mattak (whale skin) are also available from Midwest (Disko Bay) and Southwest Greenland (south of Disko Bay). Mattak was sold to factories that sold to markets for local consumption. In the three northernmost communities (Uummannaq, Upernavik, and Qaanaaq: Fig. 1A), most mattak is purchased by factory facilities providing sale figures that can be used to validate the numbers of harvested whales reported through "Piniarneq." Mattak not purchased by the factories were consumed by local hunters and

[1]"Piniarneq" refers to a booklet in which hunters note their catches; since 1993, it has provided catch figures. It also functions as an official hunting license and is reissued once a year upon submission of the completed records from the previous year.

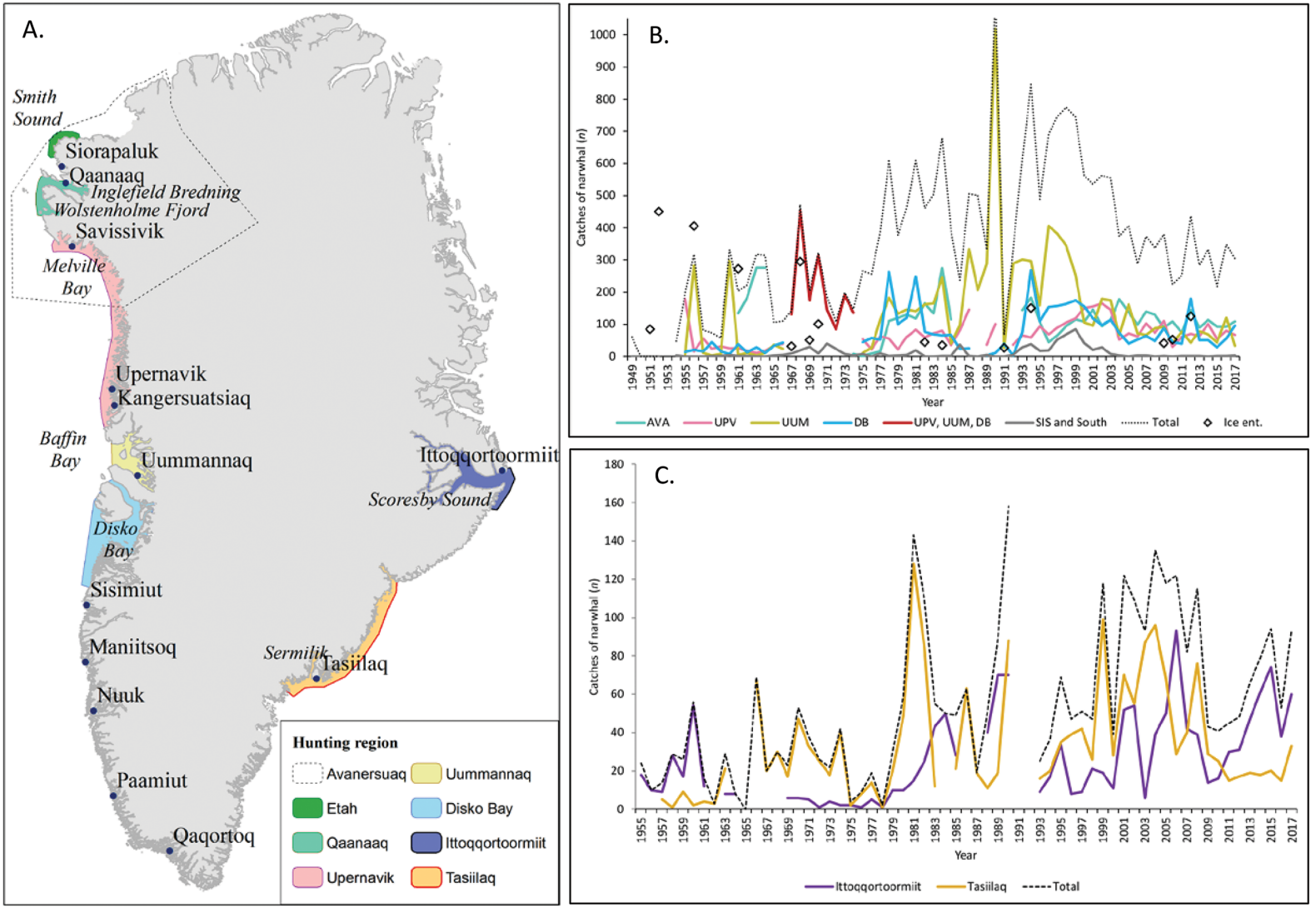

Figure 1.—A. Greenland with hunting regions, towns, settlements, and localities indicated. B. Catches of narwhals from official reports by municipality for 1954 to 2017, based on data presented in Table 2. Abbreviations: AVA=Avanersuaq, UPV=Upernavik, UUM=Uummanaaq, DB=Disko Bay (Ilulissat, Kangaatsiaq, Qasigiannguit, Qeqertarsuaq, Aasiaat), SIS=Sisimiut, MAN=Maniitsoq, NUU=Nuuk, PAA-QAQ=Paamiut-Qaqortoq, SIS=Sisimiut, ICE ENT=Ice Entrapment. C. Reported catches of narwhals in Ittoqqortoormiit and Tasiilaq, East Greenland, from 1955 through 2017, based on data presented in Table 5.

residents in the community where the whales were taken.

Average mattak yield per whale was estimated from measurements of 40 narwhals harvested in Uummannaq in November 1993 where a mean of 132 kg mattak/whale (95% confidence limits: 111–152 kg) was obtained (Heide-Jørgensen[2]). Unfortunately, mattak purchases for narwhals and belugas, *Delphinapterus leucas*, were pooled until 1993.

Data on ice entrapments extracted from Siegstad and Heide-Jørgensen (1994), Heide-Jørgensen et al. (2002), Laidre et al. (2012), and unpublished data from 2012 (the Greenland Institute of Natural Resources (GINR)) were analyzed to subtract entrapment mortality from reported catches for the period 1984–2014.

In this compilation the uncorrected catch statistics (after 1962) are presented together with corrections referred to as "low," "medium," and "high options" (Heide-Jørgensen and Rosing-Asvid, 2002, and references therein). The "low" and "medium" options correct for biases caused by either an absence of catch reports from some municipalities during certain periods or by a general trend towards underreporting. The "high option" corrects the catches for an estimate of struck-but-lost whales in different hunting situations. The three options are intended for modeling different scenarios of the dynamics of the population to be used in assessments.

Table 1.—Catches of narwhal in West Greenland between 1862 and 1934 compiled from Winge (1902). The catches are divided into three regions: Upernavik, Uummannaq, and Disko Bay. No data are available from other areas. Catches are corrected for the combined reporting of narwhals and belugas by assuming that 25% were narwhals (see text).

Year	Upernavik	Uummannaq	Disko Bay	Total
1862	29	4	45	78
1863	24	12	43	79
1864	42	30	70	142
1865	16	30	35	81
1866	32	20	72	124
1867	38	22	96	156
1868	17	11	55	83
1869	46	37	136	219
1870	23	80	106	209
1871	32	35	102	169
1872	22	46	103	171
1873	29	21	88	138
1874	32	13	106	151
1875	22	17	73	112
1876	24	23	80	127
1887–1888	32	38	117	187
1892–1893	31	42	102	175
1903–1909	33	35	70	138
1910–1919	50	62	112	224
1920–1924	46	42	74	162
1925–1929	43	55	58	156
1930–1934	43	53	87	183

Results

West and North Greenland, 1862–1876

For the areas north of Sisimiut, annual catch data are available for 1862 through 1876 but only for belugas and narwhals combined. For these areas, Winge (1902) states that the catch was predominantly belugas, and Anonymous (1944) claims that, based on trade in narwhal tusks, narwhals only constituted about 20% of the catch. Catch numbers are also available for some of the years from Sisimiut and south (1874–1890), but all those catches are considered to be belugas (Winge, 1902; Anonymous, 1944).

When comparing beluga and narwhal catches from 1954 to 1970 (Anonymous, 1953–71), the proportion of narwhals taken in North Greenland was about 25%, which is the correction factor applied here (Table 1). Catches were fairly constant in Upernavik (mean = 29/yr, SD 9) but varied in Uummannaq (mean = 27/yr, SD 19) and Disko Bay (mean = 81/yr, SD 28) for the period 1862–1876 (Table 1). No catch information exists from Thule[3], and no specific information on ice entrapments of narwhals exists from this period. No catch data have been located for the period 1876–87.

West and North Greenland, 1887–1934

Only sporadic statistics on average catches over periods and areas are available from Anonymous (1944) (Table 1). Catches given as averages for the areas north of Sisimiut, where both belugas and narwhals were pooled (Anonymous, 1944), were assumed to be comprised of 25% narwhals. The catches for this period seem slightly higher than for the previous period as the weighted (weight = number of years) averages are 42/yr (SD 17) for Upernavik, 49/yr (SD 26) for Uummannaq, and 87/yr (SD 51) for Disko Bay. No catch information is available from Thule for this period, but Vibe (1950) estimated that around 125 narwhals were taken annually in Thule in the late 1930's, and statistics on trade in narwhal tusks indicate large catches from 1938 (Reeves and Heide-Jørgensen, 1994).

The ice entrapment records include incidents from Disko Bay, Uummannaq, and Upernavik but only the reports from 1915 are specified as narwhals; the others may include both belugas and narwhals (Siegstad and Heide-Jørgensen, 1994). The entrapment in 1915 included more than 1,100 narwhals in Disko Bay (Porsild, 1918; Anonymous, 1944), but these numbers apparently did not appear in the catch statistics (Table 1).

West and North Greenland, 1949–54

Only fragmentary information on the catches exists for this period (Fig.

[2]Heide-Jørgensen, M. P., Greenland Institute of Natural Resources, Nuuk. Personal commun., January, 1994.

[3]Thule was previously a trading station in North Greenland. The place name Thule in this compilation is used until 1950 and covers catches taken in northern Greenland. From 1951 to present, the county name Avanersuaq is used for northern Greenland. The name covers catches recorded for the community Qaanaaq and the settlements Savissivik and Siorapaluk.

1B, Table 2). Catches reported in 1949 (Prime Minister's Second Department, 1951) and 1954 seem unrealistically low compared to both earlier and later catch estimates. During this period all catches in Thule/Avanersuaq[3] are assumed to be from the Inglefield Bredning stock of narwhals, as hunters were not able to travel long distances in kayaks to catch narwhals from other areas.

West and North Greenland, 1955–74

The statistics for the period 1954–74 probably provide a fairly realistic picture of the level of narwhal hunting except for Avanersuaq, which only reported catches for 1961–64 (Fig. 1B, Table 2). For 1961–64, reported catches for Qaanaaq are used directly with no corrections and the average of the period (= 217 catches) is used to estimate a linear decline in catches from 217 catches in 1965 to 120 catches in 1977, which is the mean catch in 1978–81. Bruemmer[4] estimated that around 90–120 narwhals were taken annually around 1970.

Catch records cannot be separated into municipalities for the period 1967–74 and corrections for unreported catches can therefore not be assigned to specific areas (Fig. 1B, Table 2). For periods with compatible data there is a trend for an increase in catches especially in the Disko Bay area as the distribution of catches changed from 1955–60, when Upernavik took 44% of the narwhals, Uummannaq took 35%, and Disko Bay took 21%, to 1978–82 when Upernavik declined to 15%, Uummannaq increased to 43%, and Disko Bay increased to 41%. Ice entrapments in Uummannaq and Upernavik in 1956 and in Uummannaq in 1961 are subtracted from the catch report from the previous year.

[4]Bruemmer, F. 1971. Notes on sea mammals, Thule District, Greenland. Report to the Arctic Biological Station Fisheries Research Board of Canada. Ste. Anne de Bellevue, Quebec. Unpubl. manuscr., 29 p.

West and North Greenland, 1975–85

Avanersuaq started to report a realistic level of catches in 1978, but for the period 1965–74 catches have been corrected for the trade in mattak. The large amount of mattak purchased in Avanersuaq (22 t) in 1984 is reflected in the catch statistics for narwhals and is not sustained by the reported catch of 21 belugas (Heide-Jørgensen and Rosing-Asvid, 2002; Table 3). The period (1975–85) had few reported catches in Sisimiut. Narwhal entrapments are reported for Disko Bay and Uummannaq during this period (Siegstad and Heide-Jørgensen, 1994) (Fig. 1B, Table 2).

West and North Greenland, 1986–92

The catch reporting system deteriorated during this period while the economic value of the mattak increased. No official catch statistics were received in any of these years from Avanersuaq and Sisimiut municipality. The hunt in Avanersuaq is supplied by narwhals from three different stocks: the Inglefield Bredning stock is the largest contributor, the Melville Bay stock provides narwhals to the southern community (Savissivik) in Avanersuaq, and the Smith Sound stock provides only a few narwhals (Fig. 1A; Watt et al., 2019). Catches from the Inglefield Bredning stock can be estimated from the linear trend in catches in Avanersuaq (after subtraction of catches in Melville Bay) from 1983–85 to 1993–95. Trade statistics on purchases of mattak do not distinguish between narwhals and belugas, and assumptions about the proportion of narwhals are required if the trade statistics are to be used for correcting narwhal catch statistics. No official statistics are available for 1991 and 1992 (Fig. 1B, Table 2). No ice entrapments are reported for this period.

West and North Greenland, 1993–2017

In 1993 the new catch reporting system "Piniarneq" started to provide data. It operates with hunting seasons, but data are compiled following calendar years. Since 1996, the hunters have also been asked to fill out "special reports[5]" that provide more detailed information about the hunt including hunting dates and locality, hunting method, and length and sex of the whales. Yet, in some years, only a small fraction of the catches was documented in the "special reports," but in recent years (2005–17), after the installation of quotas in 2004, the "special reports" are considered the most complete source of catch statistics. Data from the "special reports" are used to split catches between the hunting regions in Avanersuaq (Qaanaaq, Siorapaluk, Savissivik).

Data on mattak trade of narwhals are available for Avanersuaq, Upernavik, Uummannaq, and Disko Bay (Table 3). When calculating the number of whales required to sustain the mattak purchases, under the assumption of 132 kg/narwhal, there is on average a reporting of three times as many catches as needed to sustain the purchases of mattak in Upernavik and Uummannaq during 1994–99. The only exception is 1997 in Upernavik where the catches reported were approximately half of what is needed to sustain the mattak purchases. In Avanersuaq, the reported catches are only slightly larger than the purchases of mattak but this varies between years. A large proportion of mattak is consumed locally in Qaanaaq, Siorapaluk, and Savissivik and the reported catches seem therefore to underestimate the actual hunting level.

No reliable data exist on the trade in narwhal mattak from the Disko Bay area, Sisimiut, or south of Sisimiut. Most mattak in these areas is sold directly by the hunters and no statistics are kept on the amount being traded.

From 1 July 2004, a quota system for narwhal hunting in West Greenland was instituted, and the decline in catches in 2004 is partly due to the new catch limits. Five ice entrapments are

[5]The "special reports" are called "særmeldeskemaer" in Danish.

Table 2.—Catches of narwhals from official reports by municipality with corrections for underreporting in parentheses (see text) from 1954 to 2017. AVA=Avanersuaq (until 1950 called Thule), UPV=Upernavik, UUM=Uummanaaq, DB=Disko Bay (Ilulissat, Kangaatsiaq, Qasigiannguit, Qeqertarsuaq, Aasiaat), SIS=Sisimiut, MAN=Maniitsoq, NUU=Nuuk, PAA-QAQ=Paamiut-Qaqortoq, ICE ENT=Ice Entrapment. Numbers in square brackets are from "special reports." Numbers in italics are catch numbers for the areas UPV, UUM, DB, and for SIS, NUU, MAN, PAA-QAQ. Data were compiled from Prime Minister's Second Department (1951), Kapel (1977), Kapel and Larsen (1984), Kapel (1985), Born and Kapel (1986), and Born (1987).

YEAR	AVA	UPV	UUM	DB	SIS	MAN	NUU	PAA-QAQ	TOTAL	ICE ENT
1949	38	16	1	6					61	
1950										
1951										85 DB
1952										450 DB
1954			*45*		1			1	47	
1955		179	2	14					195	
1956		15	282	21					318	156 UPV, 250 UUM
1957		55	11	15					81	
1958		24	3	45		1			73	
1959		32	8	16				1	57	
1960		25	296	7	1	1	1	1	332	
1961	134	25	5	38				1	203	272 UUM
1962	182	17	11	12				1	223	
1963	275	10	3	29					317	
1964	275	17	11	11					314	
1965		33	37	33	1	1			105	
1966		39	23	43		3	2		110	
1967			*131*				*9*		140	31 DB
1968			*454*				*18*		472	161 DB, 50 UPV, 84 UUM
1969			*174*				*30*		204	Some DB, 50 UPV
1970			*313*				*9*		322	100 DB
1971			*146*				*40*		186	
1972			*84*				*23*		107	
1973			*191*				*8*		199	
1974	8		*136*				*3*		147	
1975	1	54	11	44		6		1	266 (149)	
1976	9	22	27	57					256 (141)	
1977	16	62	113	53	8	1			387 (134)	
1978	110	56	183	262		1			612	
1979	120	22	132	100			3		377	
1980	130	61	146	120		4	1		462	
1981	118	83	140	249			18	1	609	
1982	164	59	162	76					461	45 DB
1983	135 (25)	72 (30)	164	68 (10)					504 (65)	
1984	274	80	245	66 (15)	1				681 (15)	35 UUM
1985	115 (115)	34 (20)	39	67		1			391 (135)	
1986		81	97	23		36			237	
1987		145	334	25			1		505	
1988			206						500 (294)	
1989		37	288	2			5		332	
1990		100 (73)	1,019	11					1,203 (73)	
1991			27	> 40					> 67	27 UUM
1992		37	288	2			5		332	
1993	144	66	301	75	10	6	4	8	614	
1994	183	59	297	268	6	14	7	11	845	150 DB
1995	107	94	159	108	4	5	8		485	
1996	45	69	405	154	10	4	2	2	691	
1997	66	90	381	156	13	5	9	26	746	
1998	94	105	344	163	21	18	6	24	775	
1999	115	119	253	174	28	24	17	15	745	
2000	109	150	106	155	27	8	0	6	561	
2001	145	155	95	119	1	2	15	3	535	
2002	94	164	180	97	12	11	3	2	563	
2003	113	146	174	114	4	0	2	2	555	
2004	178	53	67	73	2	1	0	0	374	
2005	137 [70]	71 [74]	161 [137]	39 [47]	0	0	0	0	408 [328]	
2006	99 [94]	62 [58]	72 [55]	53 [4]	1	2	0		289 [211]	
2007	139 [21]	102 [17]	67 [52]	63 [56]	0	2	0	1	374 [146]	
2008	[129]	[74]	[87]	[47]	[0]	[0]	[0]	[0]	[337]	
2009	[90]	[110]	[91]	[88]	[0]	[0]	[0]	[1]	[380]	41 in Qaanaaq
2010	[108]	[30]	[42]	[45]	[0]	[0]	[0]	[0]	[225]	53 in Qaanaaq
2011	[74]	[60]	[77]	[39]	[0]	[0]	[0]	[1]	[251]	
2012	[144]	[70]	[42]	[179]	[0]	[0]	[0]	[1]	[436]	125 at Kangersuatsiaq
2013	[90]	[64]	[78]	[50]	[0]	[0]	[0]	[1]	[283]	
2014	[114]	[101]	[69]	[50]	[0]	[0]	[0]	[0]	[334]	
2015	[92]	[54]	[42]	[29]	[0]	[0]	[1]	[0]	[218]	
2016	[93]	[79]	[120]	[55]	[0]	[0]	[1]	[0]	[348]	
2017	[108]	[67]	[33]	[95]	[0]	[2]	[0]	[0]	[305]	

Table 3.—Purchases (in tons) of narwhal mattak (1965–1992 data from Heide-Jørgensen (1994); 1994–1999 data from Greenland Statistics). Mattak data for 1965–1992 was for narwhals and belugas combined, but after 1993 only narwhal data are shown. The factory ship mainly operated in Uummannaq and Disko Bay.

Year	Avanersuaq	Upernavik	Uummannaq	Disko Bay	Factory ship	Total
1965	1.5					1.5
1966	5.3	0.1				5.4
1967	3.9	0.1				4.0
1975		2.9				2.9
1976	11	0.4				11.4
1977	14	9.1				23.1
1978	6	2.8				8.8
1979	14					14
1980	14					14
1981	26.5	25.0				51.5
1982	24.0	21.2				45.2
1983	12.8	21.1				33.9
1984	21.9	20.7				42.6
1985		5.8				5.8
1986		1.7				1.7
1987		32.6	4.4	0		37
1988	2.4	27.3	7.3	4.9		41.9
1989		19.3	31.0	0.8		51.1
1990	9.2	18.5	63.6	18.7		110.0
1991	15.1	26.1	29.4	1.4		72.0
1992	12.2	46.3	13.3	7.5		79.3
1994	12.6	3.0	31.6	<0.1		47.3
1995	10.7	9.9	4.8	<0.1		25.5
1996	4.3	6.1	25.5	<0.1		36.0
1997	10.6	21.1[1]	19.5	<0.1		51.3
1998	14.1	3.4[2]	6.5		8.5	32.5
1999	12.4	1.9		<0.1	10.3	24.7

[1]Including 0.29 tons purchased in Savissivik.
[2]Including 2.4 tons purchased in Savissivik.

reported during this period (Siegstad and Heide-Jørgensen, 1994; Heide-Jørgensen et al., 2002; Laidre et al., 2012), and one entrapment where 125 narwhals were taken occurred 10 km west of the hamlet of Kangersuatsiaq, Upernavik, in February 2012 (GINR[6]).

Construction of Time Series for West Greenland From 1862 Through 2017

Utilization of whales in Inglefield Bredning by Inughuit (the people living in Avanersuaq) during the 19th century probably included few narwhals because Inughuit did not have access to rifles and they were no longer using kayaks. However, expeditions and foreign whalers sold guns and ammunition to Inughuit and this must eventually have increased the hunting pressure on narwhals during the 19th century. The wintering of several of Robert E. Peary's large expeditions in the area around the turn of the century could also have increased the hunting pressure on narwhals in Inglefield Bredning. Finally, the reintroduction of kayaks after 1865 also added to the hunting pressure.

To account for the lack of statistics the catches for Inglefield Bredning was arbitrarily set to 25 whales per year for 1862–1899 and to 50 for 1900–34. From 1935 to 1960 catches increased linearly from 50 to 134 (catch reported in 1961) in Inglefield Bredning. This gives values about half of what Vibe (1950) estimated for the locality in 1939–40 but considerably larger than the 38 narwhals reported to be taken in 1949 (Table 2; Prime Minister's Second Department, 1951).

For the other areas, catches were created as the average of 5 years before and 2 years after the periods 1877–1886 and 1889–1891, respectively. Catches for the period 1894–1902 were set to the average of 5 years before and after that period. The period 1935–48 was constructed as linear extrapolations of the catches before and after the period. Catches for the period for 1949–54 were calculated as the average of the catches for 1955–58 (excluding ice entrapments), again assuming that catches were larger than reported in 1949 (Prime Minister's Second Department, 1951).

During 1949–75 catches were not available per municipality or hunting ground and coarse assumptions about underreporting and splitting on hunting grounds are needed to reconstruct the catches for that period. Catches during 1975–77 include an overall correction for underreporting.

A "low option" for catches during 1984–2005 is provided by correcting the reported catches with estimates for years with missing data calculated as averages of three years before and after the missing year (Table 4). Catches from the stocks in Inglefield Bredning, Melville Bay, and Uummannaq were corrected for underreporting assessed from the purchases of mattak.

For the period 1965–92, mattak from reported harvests of belugas were subtracted, assuming average mattak yields of 70 kg/beluga (Heide-Jørgensen and Rosing-Asvid, 2002). The remaining mattak is assumed to be from narwhals, and the catch is calculated on the basis of 132 kg/narwhal (Table 3). For Uummannaq, all mattak purchases during 1987–92 were assumed to be from narwhals. Catches of belugas are the only alternative source of mattak and low levels of beluga catches were reported for Uummannaq during that period.

For the years after 1992, mattak purchases were separated by species, and estimates of narwhal catches needed to sustain mattak purchases were made per area. Narwhal harvested during ice entrapments were subtracted because ice entrapments are considered part of natural mortality and should be excluded from hunting mortality (Siegstad and Heide-Jørgensen, 1994). Catches from Savissivik are assumed to be taken in the Melville Bay area and are therefore allocated to the Melville Bay stock together with all catches from Upernavik.

For Avanersuaq for 1995–99, a "low option" and a "medium option" is the reported catches. For Disko Bay a "medium option" would be to correct for the generally low reporting between 1986 and 1992 by using the average of the periods 1978–85 and 1993–2000 (average = 156).

A "high option" is to correct the catches for whales that are struck-but-lost. It is generally assumed that the

[6]GINR, Nuuk, March 2012. Unpubl. data.

Table 4.—Estimated number of narwhals caught annually from 1862 through 2017 by stock. Catches during 1877–1886 and 1889–1891 were created as the average of five years before and two years after the period. Catches between 1894 and 1902 were set to the average of five years before and after the period. The period 1935–1948 was constructed as linear extrapolations of the catches before and after the period. Catches for the period for 1949–1954 and 1959–1960 were calculated as the average of the catches for the period 1955 to 1958 (minus ice entrapments). Catches for Inglefield Bredning was arbitrarily set to 25 whales per year for 1862 to 1899 and to 50 for 1900 to 1934. From 1935 to 1960 catches were increased linearly from 50 to 134 in Inglefield Bredning. For 1959 to 1974 catches were distributed between Upernavik, Uummannaq, and Disko Bay in proportion to the relative change in catch levels before and after that period.

After 1983 catches in Savissivik in Avanersuaq are allocated to the Upernavik–Melville Bay stock (for stock delineation see Watt et al., 2019) together with catches from Upernavik municipality. From 1993 to 2010 catches in Siorapaluk are subtracted from the catches in Inglefield Bredning as they are assumed to be from the Smith Sound stock; however in 2011 this practice was changed to allocate any catches with location data north of Siorapaluk to the Smith Sound. Catches from all areas south of Disko Bay are assumed to come from the Disko Bay stock. Narwhals harvested in ice entrapments are not included in the catches. Values for years with no catch reporting are constructed as the average of three years before and after the missing year. In the "low option" catches from Inglefield Bredning and Melville Bay are corrected for under-reporting needed to sustain the purchases of mattak. The "medium option" applies only for Disko Bay and correct for the generally low reporting between 1986 and 1992 by using the average of the periods 1978–1985 and 1993–2000. Before 1950 all catches under the "high option" are corrected for a loss rate of 5%. After 1950, catches in Inglefield Bredning and Smith Sound under the "high option" are corrected for a 5% loss rate, catches in Melville Bay are corrected for a 15% loss rate, and catches in Uummannaq and Disko Bay are corrected for a 30% loss rate. The quality of the data is assessed based on the number of corrections needed where LQ = low quality, MQ = moderate quality, and R = reliable.

		Smith Sound			Inglefield Bredning			Melville Bay			Uummannaq			Disko Bay and south		
Stock Year	Quality of data	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H
1862	LQ				25	25	26	29	29	30	4	4	4	45	45	47
1863	LQ				25	25	26	24	24	25	12	12	13	43	43	45
1864	LQ				25	25	26	42	42	44	30	30	32	70	70	74
1865	LQ				25	25	26	16	16	17	30	30	32	35	35	37
1866	LQ				25	25	26	32	32	34	20	20	21	72	72	76
1867	LQ				25	25	26	38	38	40	22	22	23	96	96	101
1868	LQ				25	25	26	17	17	18	11	11	12	55	55	58
1869	LQ				25	25	26	46	46	48	37	37	39	136	136	143
1870	LQ				25	25	26	23	23	24	80	80	84	106	106	111
1871	LQ				25	25	26	32	32	34	35	35	37	102	102	107
1872	LQ				25	25	26	22	22	23	46	46	48	103	103	108
1873	LQ				25	25	26	29	29	30	21	21	22	88	88	92
1874	LQ				25	25	26	32	32	34	13	13	14	106	106	111
1875	LQ				25	25	26	22	22	23	17	17	18	73	73	77
1876	LQ				25	25	26	24	24	25	23	23	24	80	80	84
1877	LQ				25	25	26	28	28	29	28	28	29	98	98	103
1878	LQ				25	25	26	28	28	29	28	28	29	98	98	103
1879	LQ				25	25	26	28	28	29	28	28	29	98	98	103
1880	LQ				25	25	26	28	28	29	28	28	29	98	98	103
1881	LQ				25	25	26	28	28	29	28	28	29	98	98	103
1882	LQ				25	25	26	28	28	29	28	28	29	98	98	103
1883	LQ				25	25	26	28	28	29	28	28	29	98	98	103
1884	LQ				25	25	26	28	28	29	28	28	29	98	98	103
1885	LQ				25	25	26	28	28	29	28	28	29	98	98	103
1886	LQ				25	25	26	28	28	29	28	28	29	98	98	103
1887	LQ				25	25	26	32	32	34	38	38	40	117	117	123
1888	LQ				25	25	26	32	32	34	38	38	40	117	117	123
1889	LQ				25	25	26	29	29	30	35	35	37	105	105	110
1890	LQ				25	25	26	29	29	30	35	35	37	105	105	110
1891	LQ				25	25	26	29	29	30	35	35	37	105	105	110
1892	LQ				25	25	26	31	31	33	42	42	44	102	102	107
1893	LQ				25	25	26	31	31	33	42	42	44	102	102	107
1894	LQ				25	25	26	31	31	33	36	36	38	87	87	91
1895	LQ				25	25	26	31	31	33	36	36	38	87	87	91
1896	LQ				25	25	26	31	31	33	36	36	38	87	87	91
1897	LQ				25	25	26	31	31	33	36	36	38	87	87	91
1898	LQ				25	25	26	31	31	33	36	36	38	87	87	91
1899	LQ				25	25	26	31	31	33	36	36	38	87	87	91
1900	LQ				50	50	53	31	31	33	36	36	38	87	87	91
1901	LQ				50	50	53	31	31	33	36	36	38	87	87	91
1902	LQ				50	50	53	31	31	33	36	36	38	87	87	91
1903	LQ				50	50	53	33	33	35	35	35	37	70	70	74
1904	LQ				50	50	53	33	33	35	35	35	37	70	70	74
1905	LQ				50	50	53	33	33	35	35	35	37	70	70	74
1906	LQ				50	50	53	33	33	35	35	35	37	70	70	74
1907	LQ				50	50	53	33	33	35	35	35	37	70	70	74
1908	LQ				50	50	53	33	33	35	35	35	37	70	70	74
1909	LQ				50	50	53	33	33	35	35	35	37	70	70	74
1910	LQ				50	50	53	50	50	53	62	62	65	112	112	118
1911	LQ				50	50	53	50	50	53	62	62	65	112	112	118
1912	LQ				50	50	53	50	50	53	62	62	65	112	112	118
1913	LQ				50	50	53	50	50	53	62	62	65	112	112	118
1914	LQ				50	50	53	50	50	53	62	62	65	112	112	118
1915	LQ				50	50	53	50	50	53	62	62	65	112	112	118
1916	LQ				50	50	53	50	50	53	62	62	65	112	112	118
1917	LQ				50	50	53	50	50	53	62	62	65	112	112	118
1918	LQ				50	50	53	50	50	53	62	62	65	112	112	118
1919	LQ				50	50	53	50	50	53	62	62	65	112	112	118
1920	LQ				50	50	53	46	46	48	42	42	44	74	74	78
1921	LQ				50	50	53	46	46	48	42	42	44	74	74	78
1922	LQ				50	50	53	46	46	48	42	42	44	74	74	78
1923	LQ				50	50	53	46	46	48	42	42	44	74	74	78
1924	LQ				50	50	53	46	46	48	42	42	44	74	74	78
1925	LQ				50	50	53	43	43	45	55	55	58	58	58	61

Table continued.

Table 4.—*Continued*.

Stock Year	Quality of data	Smith Sound			Inglefield Bredning			Melville Bay			Uummannaq			Disko Bay and south		
		L	M	H	L	M	H	L	M	H	L	M	H	L	M	H
1926	LQ				50	50	53	43	43	45	55	55	58	58	58	61
1927	LQ				50	50	53	43	43	45	55	55	58	58	58	61
1928	LQ				50	50	53	43	43	45	55	55	58	58	58	61
1929	LQ				50	50	53	43	43	45	55	55	58	58	58	61
1930	LQ				50	50	53	43	43	45	53	53	56	87	87	91
1931	LQ				50	50	53	43	43	45	53	53	56	87	87	91
1932	LQ				50	50	53	43	43	45	53	53	56	87	87	91
1933	LQ				50	50	53	43	43	45	53	53	56	87	87	91
1934	LQ				50	50	53	43	43	45	53	53	56	87	87	91
1935	LQ				53	53	56	42	42	44	50	50	53	83	83	87
1936	LQ				56	56	59	41	41	43	48	48	50	78	78	82
1937	LQ				59	59	62	40	40	42	45	45	47	74	74	78
1938	LQ				62	62	65	39	39	41	42	42	44	70	70	74
1939	LQ				66	66	69	38	38	40	39	39	41	65	65	68
1940	LQ				69	69	72	37	37	39	37	37	39	61	61	64
1941	LQ				72	72	76	36	36	38	34	34	36	57	57	60
1942	LQ				75	75	79	36	36	38	31	31	33	52	52	55
1943	LQ				78	78	82	35	35	37	28	28	29	48	48	50
1944	LQ				81	81	85	34	34	36	26	26	27	44	44	46
1945	LQ				84	84	88	33	33	35	23	23	24	39	39	41
1946	LQ				87	87	91	32	32	34	20	20	21	35	35	37
1947	LQ				90	90	95	31	31	33	17	17	18	31	31	33
1948	LQ				94	94	99	30	30	32	15	15	16	26	26	27
1949	LQ				97	97	102	29	29	30	12	12	13	22	22	23
1950	LQ				100	100	105	29	29	30	12	12	13	22	22	23
1951	LQ				103	103	108	29	29	33	12	12	16	22	22	29
1952	LQ				106	106	111	29	29	33	12	12	16	22	22	29
1953	LQ				109	109	114	29	29	33	12	12	16	22	22	29
1954	LQ				112	112	118	29	29	33	12	12	16	22	22	29
1955	LQ				115	115	121	23	23	26	2	2	3	14	14	18
1956	LQ				118	118	124	15	15	17	32	32	42	21	21	27
1957	LQ				122	122	128	55	55	63	11	11	14	8	8	10
1958	LQ				125	125	131	24	24	28	3	3	4	46	46	60
1959	LQ				128	128	134	25	25	29	11	11	14	21	21	27
1960	LQ				131	131	138	24	24	28	12	12	16	24	24	31
1961	MQ				134	134	141	29	29	33	15	15	20	26	26	34
1962	MQ				182	182	191	12	12	14	7	7	9	12	12	16
1963	MQ				275	275	289	16	16	18	10	10	13	16	16	21
1964	MQ				275	275	289	16	16	18	11	11	14	18	18	23
1965	LQ				210	210	221	35	35	40	25	25	33	40	40	52
1966	LQ				203	203	213	36	36	41	28	28	36	47	47	61
1967	LQ				196	196	206	33	33	38	28	28	36	50	50	65
1968	LQ				189	189	198	50	50	58	46	46	60	83	83	108
1969	LQ				182	182	191	37	37	43	37	37	48	82	82	107
1970	LQ				175	175	184	61	61	70	66	66	86	99	99	129
1971	LQ				168	168	176	39	39	45	46	46	60	103	103	134
1972	LQ				161	161	169	21	21	24	27	27	35	60	60	78
1973	LQ				154	154	162	46	46	53	64	64	83	92	92	120

Table continued.

loss rate was low before 1950, where all catches have been corrected by 5% to account for some losses. No studies of losses have been conducted in Greenland, but inferences can be made from studies in other areas. In Avanersuaq local hunting rules requires the attachment of hand-harpoons on the whales before they can be shot. This severely reduces the loss rate, and a loss rate of 5% is arbitrarily applied to the catches in Inglefield Bredning to account for both whales that are struck-but-lost and calves that are separated from mothers.

Catches from the Melville Bay stock, however, come from hunting in both Avanersuaq and Upernavik, which does not require the use of hand-harpoons. Roughly half the whales from the Melville Bay stock are taken under the harpoon requirement (5% loss rate) and the other half is taken in ice-edge and open-water situations. For narwhal hunting in open water in Canada, Weaver and Walker (1988) reported loss rates between 32% and 55% or catch correction factors of 1.5–2.2. Roberge and Dunn (1990) reported catch correction factors for narwhals in Canada to range from 1.11 in open water to 1.41 at the ice crack and 1.56 at the floe edge or ice edge.

For Greenland, it is assumed under the "high option" that a catch correction factor of 1.30 covers both the open-water hunt and the hunt from ice cracks and the ice edge. An exception is for the Melville Bay-Upernavik area where a factor of 1.15 is used. The correction factor of 1.30 also covers the open-water hunt in late autumn just before freeze-up, which is a type of hunt where loss rates have not been estimated. If anything, the correction factor of 1.30 applied here is downward biased and might underestimate hunting losses. Thus, after 1950, catches in Inglefield Bredning and Smith Sound are under the "high option" and are corrected for a 5% loss rate, catches in Melville Bay are corrected for a 15% loss rate, and catches in Uummannaq and Disko Bay are corrected for a 30% loss rate.

Table 4.—*Continued.*

Stock Year	Quality of data	Smith Sound			Inglefield Bredning			Melville Bay			Uummannaq			Disko Bay and south		
		L	M	H	L	M	H	L	M	H	L	M	H	L	M	H
1974	LQ				147	147	154	30	30	35	47	47	61	64	64	83
1975	LQ				140	140	147	54	54	62	11	11	14	51	51	66
1976	LQ				133	133	140	22	22	25	27	27	35	57	57	74
1977	LQ				126	126	132	62	62	71	113	113	147	31	31	40
1978	MQ				110	110	116	56	56	64	183	183	238	263	263	342
1979	MQ				120	120	126	22	22	25	132	132	172	103	103	134
1980	MQ				130	130	137	61	61	70	146	146	190	125	125	163
1981	MQ				160	160	168	83	83	95	140	140	182	268	268	348
1982	MQ				164	164	172	59	59	68	162	162	211	76	76	99
1983	MQ				135	135	142	72	72	83	164	164	213	68	68	88
1984	MQ				274	274	288	80	80	92	210	210	273	67	67	87
1985	MQ				115	115	121	34	34	39	39	39	51	68	68	88
1986	LQ				165	165	173	81	81	93	97	97	126	59	156	203
1987	LQ				155	155	163	145	145	167	334	334	434	26	156	203
1988	LQ				145	145	152	*85*	85	98	226	226	294	*35*	156	203
1989	LQ				136	136	143	37	37	43	288	288	374	7	156	203
1990	LQ				126	126	132	127	127	146	1019	1019	1325	11	156	203
1991	LQ				116	116	122	90	90	104	223	223	290	40	156	203
1992	LQ				106	106	111	37	37	43	288	288	374	7	156	203
1993	R	4	4	4	104	104	109	102	102	117	301	301	391	103	103	134
1994	R	2	2	2	90	90	95	150	150	173	297	297	386	156	156	203
1995	R	0	0	0	88	88	92	113	113	130	159	159	207	125	125	163
1996	R	0	0	0	37	37	39	77	77	89	405	405	527	172	172	224
1997	R	4	4	4	54	54	57	98	98	113	381	381	495	209	209	272
1998	R	3	3	3	68	68	71	128	128	147	344	344	447	227	227	295
1999	R	17	17	18	87	87	91	130	130	150	253	253	329	258	258	335
2000	R	20	20	21	85	85	89	154	154	177	106	106	138	196	196	255
2001	R	30	30	32	98	98	103	172	172	198	95	95	124	140	140	182
2002	R	23	23	24	58	58	61	177	177	204	180	180	234	125	125	163
2003	R	35	35	37	66	66	69	158	158	182	174	174	226	121	121	157
2004	R	52	52	55	111	111	117	68	68	78	67	67	87	76	76	99
2005	R	52	52	55	79	79	83	77	77	89	161	161	209	39	39	51
2006	R	19[1]	19	20	55[1]	55	58	80[2]	80	92	72[3]	72	94	56[3]	56	73
2007	R	0[4]	0	0	134[4]	134	141	107[5]	107	123	67[3]	67	87	66[3]	66	86
2008	R	7	7	7	122	122	128	92	92	106	87	87	113	47	47	61
2009	R	6	6	6	84	84	88	136	136	156	91	91	118	89	89	116
2010	R	9	9	9	99	99	104	40	40	46	42	42	55	45	45	59
2011	R	2	2	2	53	53	56	79	79	91	77	77	100	40	40	52
2012	R	3	3	3	128	128	134	83	83	95	42	42	55	55	55	72
2013	R	0	0	0	83	83	87	71	71	82	78	78	101	51	51	66
2014	R	0	0	0	102	102	107	113	113	130	69	69	90	50	50	65
2015	R	0	0	0	75	75	79	71	71	82	42	42	55	29	29	38
2016	R	0	0	0	81	81	85	91	91	105	120	120	156	56	56	73
2017	R	0	0	0	108	108	113	92	92	106	33	33	43	97	97	126

[1]Based on "special reports."
[2]Based on "special reports" from Savissivik and "Piniarneq" from Upernavik.
[3]Based on "Piniarneq"—"special reports" numbers are too low.
[4]Catches from Siorapaluk are all assumed to be from Inglefield Bredning.
[5]Includes 5 catches reported from Savissivik ("special reports").

East Greenland

The reported catches in East Greenland during 1993–2017 averaged 35 whales annually in Ittoqqortoormiit and 40 in Tasiilaq (Fig. 1C, Table 5).

Observations of three open-water hunts in Ittoqqortoormiit in August 2015 and 2017 showed an average of 64% of whales shot at in open water hunts were retrieved (21 Aug. 2015: 4 of 5 whales retrieved, 22 Aug. 2015: 1 of 2 whales retrieved, and 26–27 Aug. 2017: 2 of 4 whales retrieved) (GINR[7]). It is, however, unknown if the whales that were not retrieved were mortally wounded. Furthermore, netting of narwhals is allowed in East Greenland, and loss rates in nets are considered minimal. About 54% (n = 8 yr; SD = 13) of the catches of narwhals in Ittoqqortoormiit were taken in nets between 2009 and 2017 (Table 5). Most of the hunting in Ittoqqortoormiit takes place during the open-water season (~90%), so a retrieval factor of 0.64 (or a correction factor of 1.57) should be applied to the 46% of the catches that are not taken in nets in Ittoqqortoormiit. In contrast to Ittoqqortoormiit, kayaks and hand-held harpoons are widely used in Tasiilaq, and the correction factor of 5% that is used for the same type of hunt in Qaanaaq can be applied to the catch statistics from Tasiilaq.

[7]Unpubl. data. GINR, Nuuk, 2018.

Discussion

In this compilation, only the coastal catches by inhabitants of Greenland are included, but historically there was also hunting activity by foreign whalers and by the large numbers of expeditions that passed through Baffin Bay in search of the Northwest Passage or with the goal of reaching the North Pole (Mitchell and Reeves, 1981). Whalers were especially known to have taken narwhals during periods when the bowhead whale hunt was unsuccessful. Since the localities of these takes were generally not reported, it was not attempted to include these catches. This of course renders the compilation of catch statistics during

Table 5.—Reported catches of narwhals in Ittoqqortoormiit and Tasiilaq, East Greenland. For Ittoqqortoormiit, the proportion (%) of the community's total annual narwhal catch that was taken using nets is shown for the years 2009 and 2011–2017. Quotas were implemented in 2011 in East Greenland. Data from 1955–1990 from Dietz et al. (1994), and data from 1993–2017 from "Piniarneq[1]."

	Ittoqqortoormiit		Tasiilaq	
Year	Total catch	Caught in nets (%)	Total catch	Total number of catches
1955	18		6	24
1956	10			10
1957	9		5	14
1958	28		1	29
1959	17		9	26
1960	54		2	56
1961	12		4	16
1962			3	3
1963	8		21	29
1964	8			8
1965				0
1966	2		67	69
1967			20	20
1968			30	30
1969	6		17	23
1970	6		47	53
1971	5		33	38
1972	1		25	26
1973	4		18	22
1974	2		40	42
1975	2		2	4
1976	1		8	9
1977	5		14	19
1978	1		1	2
1979	10		20	30
1980	10		49	59
1981	15		128	143
1982	25		84	109
1983	43		12	55
1984	50			50
1985	28		21	49
1986			63	63
1987			19	19
1988	40		11	51
1989	70		19	89
1990	70		88	158
1991				
1992				
1993	9		16	25
1994	17		20	37
1995	34		35	69
1996	8		39	47
1997	9		42	51
1998	21		26	47
1999	19		99	118
2000	11		28	39
2001	52		70	122
2002	54		55	109
2003	6		87	93
2004	39		96	135
2005	50		68	118
2006	93		29	122
2007	42		40	82
2008	39		76[2]	115
2009	14	75	29	43
2010	16		25	41
2011	30	63	15	45
2012	31	35	17	48
2013	47	55	19	66
2014	61	40	18	79
2015	74	57	20	94
2016	38	50	15	53
2017	60	55	33	93

[1]"Piniarneq" refers to a booklet in which hunters note their catches; since 1993, it has provided catch figures. It also functions as an official hunting license and is reissued once a year upon submission of the completed records from the previous year.
[2]55 narwhals taken in ice entrapment in Sermilik.

the 19th century negatively biased to an unknown extent.

The only period where it seems possible to construct a reliable time series is from 1978 through 2017. The time series for that period is, however, suffering from lack of precise catch statistics, especially for the period from 1984 to 1992 when several communities did not always report their catches. Avanersuaq is particularly problematic since there is seven years without catch reports, but also Sisimiut has long periods with inadequate catch reporting. Since 1992, catch reporting from Avanersuaq has been more consistent but with lower catch estimates than those based on the mattak landings. Some unquantifiable underreporting likely occurred during this period in Avanersuaq.

During the past 25 years (1993–2017) the largest narwhal catches have been taken in Uummannaq (mean: 150, SD: 114) followed by Qaanaaq (mean: 112, SD: 32) (Table 2). In the same period, Disko Bay and Upernavik had mean catches of 100 (SD: 59) and 89 (SD: 36), respectively. Catches in Siorapaluk from the Smith Sound stock were rare before 1990 and has not been included in this compilation until 1993. These catches appear to have increased steadily after 1998, perhaps because of less severe ice conditions in spring and/or access to bigger and faster boat. Catches, however, have declined in recent years.

There has been an overall increase in catches in West Greenland during the 20th century, which is especially pronounced after 1950. The increase peaked around 1990, and during the period after 1993 when the new hunting reporting system "Piniarneq" was installed, a significant decline in overall catches has been observed (ANOVA, $p = 0.0001$, $F = 49.6$, $df = 24$), which was mainly caused by the introduction of quotas in 2004. The decline was significant in Uummannaq ($p<0.0001$, $F = 36.3$), Melville Bay ($p = 0.04$, $F = 4.7$), and Disko Bay ($p<0.0001$, $F = 24.3$) but could not be detected in Inglefield Bredning ($p = 0.529$; $F = 0.41$).

For the period 1993–2017, total catches in East Greenland peaked during 1999–2008 with catches of about 120 narwhals for some of the years. In 2009, catches declined but returned to a steady increase in Ittoqqortoormiit after 2011 with an average catch of 49 whales/yr. Catches in Tasiilaq have remained at a lower level during 2009–2017 with an average catch of 21/yr. Catches in Ittoqqortoormiit need to be corrected for whales that are struck-

but-lost in the part of the hunt where whales are shot from boats but not for the part where whales are taken in nets. Corrections are not included in the numbers shown in Table 5. Losses in Tasiilaq are considered to be minimal due to the general use of kayaks and hand harpoons, but catches could be applied a 5% correction factor.

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