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Walrus *Odobenus rosmarus* hunting was conducted for hundreds of years in large parts of the European Arctic. Catch statistics are incomplete, or non-existent, and it is therefore difficult to determine the original population numbers for the different geographical areas. One exception is the Russian archipelago Franz Josef Land. These islands were discovered in 1873, and large-scale walrus hunting started there in the late 1890s and continued for four decades. It is therefore possible to estimate the minimum original population size based on catch statistics from Franz Josef Land for the last century. Using a simple population model backcalculation of the Franz Josef Land population to 1897 produces an estimate of 6,000-12,500 walruses.

Key words: catch history, Europe, Odobenus rosmarus, population size, Russia, walrus

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Throughout their circumpolar distribution walruses *Odobenus rosmarus* have been hunted by man. As a consequence walrus numbers have been drastically reduced in parts of their range, and in some areas they have even been extirpated. North of Europe, hunting for walruses was conducted for more than a millennium, and trade involving walrus ivory from northern Russia and western Siberia, to Europe and the Arab world, has taken place since the tenth century (Chapskii 1939). Svalbard was discovered in 1596, and walrus hunting in this region started at Bjørnøya in 1604 (Poole 1604-09). It is not known how large the original Svalbard population was, but based on the vast number of walruses killed for more than two centuries, Reeves (1978) suggests that it must have been enormous. By the mid-19th century walruses in Svalbard had been harvested to such a degree that their future was threatened (Lamont 1876). None-the-less, hunting continued until 1952 at which time walruses were given total protection. By then they had almost been extirpated. Walrus hunting at Novaya Zemlya and in the Kara Sea started in the 17th century, but remained insignificant until the beginning of the 1830s (Chapskii 1939). Hunting by Russians was intense between 1830 and 1860. At the end of this period sealers from Norway started to dominate the hunt for walruses. Hunting by Norwegians at Novaya Zemlya and in the Kara Sea continued until the end of the 1920s (Chapskii 1939). After the end of the 1920s limited hunting by Russians took place until 1956, when the walruses in these areas also were totally protected by law (Beloborodov & Timoshenko 1974). Franz Josef Land was officially discovered in 1873, but may actually have been visited by Norwegian walrus hunters as early as in 1865 (Horn 1930). Large-scale

hunting in this archipelago started in 1897 and lasted until 1934 when it ceased because the walrus population was exhausted (Chapskii 1939, Gjertz, Hansson & Wiig 1992). Thereafter occasional hunting expeditions took place, but these ceased in 1955 (Beloborodov & Timoshenko 1974).

It is Norwegian policy that Svalbard should be among the best managed wilderness areas in the world (Anon. 1994-95) and according to the Svalbard Treaty of 1920 Norway is to take measures to ensure the preservation and, if necessary, the reconstitution of the fauna in Svalbard (Anon. 1994-95). One aspect of this is to attempt to determine the original population sizes, to get an indication of the carrying capacity of the local species that previously have been reduced by hunting. It is very difficult to determine the original size of most populations from the sometimes fragmentary catch statistics, because walrus hunting in the European Arctic extended over such a long period of time, and was conducted by hunters of many different nationalities. Fedoseev (1976) claimed, based on a rough estimate of catch statistics, that the population of walruses in the Barents and Kara Seas originally had numbered at least 70,000-80,000 animals, but had been reduced to 1,300 animals by 1934. From one area there is, however, good information on the catch history. The large-scale exploitation at Franz Josef Land started in 1897 and ended after only 38 years. For this location it is possible to get a fairly accurate idea of the magnitude of the catches (see Lønø 1972, Gjertz et al. 1992). The aim of the present study is to estimate the minimum size of the original population of walruses at Franz Josef Land, based on reported harvests for the period 1897-1955, and to indicate how large the present population, which now is shared with Svalbard (Gjertz & Wiig 1994,1995, Wiig, Gjertz & Griffiths 1996), may be based on these results.

Methods

A simple recruitment model (Woodby & Botkin 1993) that employs no consideration of density-dependent factors, was used to determine the walrus population size in 1897; the year in which large-scale walrus hunting in Franz Josef Land started. This methodology assumes that the population decreases by the annual kill (K_t) for each year (t), and that the difference between annual recruitment and natural mortality is a constant. Per capita net recruitment rate is R_{net} and P_t is the population size at time t. Based on these assumptions the following relationship was derived:

$$P_{t+1} = (1+R_{net})\,(P_t - K_t)$$

The estimate of the population size in Franz Josef Land in 1956 was taken from Ivashin, Popov & Tsapko (1972). They reported a total number of walruses in Franz Josef Land and Novaya Zemlya combined of 2,000-2,500 animals in 1955 (Ivashin et al. 1972). It is not known, however, what proportion of these came from what geographical area. In this study we therefore assume that approximately half were found in Franz Josef Land, i.e. we assume that about 1,000 walruses were present there in 1956.

The information about walrus catches in Franz Josef Land is derived from five main sources: Horn (1930), Chapskii (1936), Lønø (1972), Gjertz et al. (1992) and Anonymous 1897-1929.

Additionally, the following assumptions were made in our modelling exercise:

1) Walruses in Franz Josef Land constitute a distinct population, i.e. there is no exchange between Franz Josef Land, Svalbard or Novaya Zemlya.
2) Most of the harvest after 1897 was recorded, but the figures for some years may be inaccurate.
3) A loss rate of 62% is applied to the catch data from the years 1897-1899 based on an eye witness in 1897 (Southwell 1898). This loss rate has been applied to the catch data from 1897-1899, as it was largely the same vessels that took part in the hunt during all three years. For all other years we assumed that 25% more animals were killed than were registered (hunting loss was assumed to be 20%). The 20% loss rate is based on Russian walrus hunting in Novaya Zemlya (Chapskii 1936), but is also comparable with losses of walruses from other parts of their Atlantic range (see Born, Gjertz & Reeves 1995).
4) Net maximum recruitment rates of 2, 5 and 7% have been used. We disregard the possibility that there was any large-scale, extraordinary, natural mortality in the period in question, and minimum net recruitment rates have therefore been set to 0%. Little knowledge about the net recruitment rate and other biological parameters for walruses in general exist, primarily because the segregation of different sex and age classes of walruses for most of the year, and the selective hunting pattern of the Inuit, make it very difficult to obtain unbi-

Table 1. Number of walruses killed in Franz Josef Land (FJL) during 1897-1956. Total kill has been used to backcalculate the original population. The total kills marked with an asterisk are not based on 25% loss rate, but on actual observations. Numbers in brackets are given by Lønø (1972), but the origin could not be determined or verified. NFT is an abbreviation of Norsk Fiskeritidende, referred to as Anonymous (1897-1929).

Year	Reported harvest FJL	Reported harvest Origin unknown	Total kill (25% loss rate)	Original source	Other information
1897	761		2000*	Southwell 1898, Bruce & Clark 1898	
1898	597		1800*	NFT 1899, Horn 1930, Lubbock 1937 Bjørvig 1982	
1899	371		1000*	Horn 1930, Abruzzi 1903	
1900	83		103	Horn 1930	
1901	96		120	Horn 1930, NFT 1903	
1902	2		2	NFT 1904	
1903	110		138	Horn 1930	
1904	32		40	Fiala 1907	
1905		228		Hjort & Knipowitsch 1907	One boat at FJL this year
1906	60		75	Horn 1930	
1907		22		NFT 1909	One boat at FJL this year
1908	264		330	Horn 1930, Hansen 1882-1912	
1909	127		159	Horn 1930	
1910	10		12	Horn 1930	
1911	7		10	Horn 1930	
1912		9		NFT 1913	One boat at FJL this year
1913		113		NFT 1914	One boat at FJL this year
1914		39		NFT 1915	One boat at FJL this year
1915		3		NFT 1916	
1916		2		NFT 1917	
1917					
1918		568		NFT 1919	Three boats at FJL this year
1919		883		NFT 1920	
1920		110		NFT 1921	Two boats at FJL this year
1921		7		NFT 1922	
1922	226		282	Horn 1930	
1923	128 (150)		160	Horn 1930 (Lønø 1972)	
1924	285 (500)		356	Hoel 1929 (Lønø 1972)	
1925	445 (1050)		556	Hoel 1929 (Lønø 1972)	
1926	200		250	NFT 1927, Lønø 1972	
1927	700		875	NFT 1928, Horn 1930	
1928	580		725	NFT 1929, Horn 1930	
1929	200		250	Lønø 1972	
1930	350		437	Lønø 1972	
1931	850		1062	Lønø 1972	
1932	448		550	Chapskii 1936	
1933	320		400	Chapskii 1936	
1934	<10		10	Chapskii 1939	
1935					
1936					
1937					
1938					
1939					
1940					War, no hunting
1941					War, no hunting
1942					War, no hunting
1943					War, no hunting
1944					War, no hunting
1945					War, no hunting
1946	100		125	Lønø 1972	
1947					
1948					
1949					
1950	55		68	Lønø 1972	
1951	37		46	Lønø 1972	
1952					
1953	50		62	Lønø 1972	
1954					
1955	300		375	Popov, Timoshenko & Wiig 1990	

ased samples for determining vital biological parameters (Born et al. 1995). This is especially true for uninhabited areas, such as Franz Josef Land where there is no present harvest and where almost no biological work has been undertaken. Walrus demography is usually based on information from both subspecies and only from hunted populations. Male Atlantic walruses are believed to become sexually mature at the age of 5-7 (Chapskii 1936, Mansfield 1958), but the capability of fertilising females is usually not achieved until later, when social or full physical maturity has been reached. The majority of the females experience their first ovulation at the age of seven (range: 5-10)(Mansfield 1958, Born 1990). In northwestern Greenland about 50% of females experience their first ovulation at around the age of six and all have ovulated before the age of 10 (Born 1990). The rates of reproductive failure in walruses appear to be high, and in any given year about 20% of the sexually mature females are resting (Fay 1982). Females may experience reproductive senility. In the Pacific walrus an onset of decline in the productivity of females by the age of 16-18 has been observed (Fay 1982). Pregnancy lasts about 15-16 months and individual walruses therefore give birth to a calf at intervals of two or more years (Mansfield 1958, Fay 1982, Born 1990). The sex ratio at birth is 1:1 with a slightly, though not significantly, higher proportion of males (Fay 1982). The sex ratio in the population is not well known. On the assumption that walruses are polygynous, an adult sex ratio of 1 male to 3 females has been suggested (Fay 1982). Generally, the low rate of reproduction is believed to be balanced by a low rate of natural mortality, mainly secured by a prolonged period of parental care, and a higher recruitment to breeding age than in other pinnipeds (Fay 1982). The natural mortality rate is not known but has been estimated to be 3-5% for the entire population of Pacific walrus (DeMaster 1984, Fay, Kelly & Sease 1989). Even though exact knowledge is lacking, a simulation of a hypothetical walrus population indicated that maximum net productivity ranges between 2 and 5% of total population size (DeMaster 1984). Under favourable environmental conditions and a low density of walruses in relation to the carrying capacity it has been reported to be as high as 7% per year (Sease & Chapman 1988).

Based on net productivity rates of 2, 5 and 7% and population estimates from 1956, the potential growth of the walrus population was calculated up to 1995.

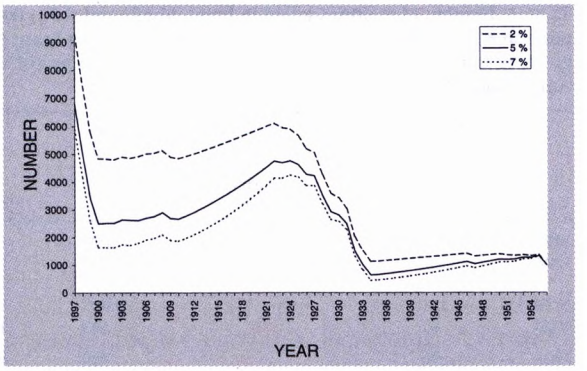

Figure 1. Changes in population size of walruses in Franz Josef Land during 1897-1956 based on net recruitment rates (NRR) of 2, 5 and 7% and a population size of 1,000 animals in 1956.

Results

The estimated kill of walruses in Franz Josef Land during 1897-1955 is given in Table 1 and the back-calculated population sizes, based on net recruitment rates of 2, 5 and 7% and a population of 1,000 animals in 1956, are presented in Figure 1.

Based on a walrus population of 1,000 animals in 1956, a minimum net recruitment rate of 0% and maximum net recruitment rates of 2, 5 and 7%, the original walrus population in Franz Josef Land may have been in the range of 9,300-12,400, 6,800-12,400 and 5,900-12,400 animals, respectively (see Fig. 1). This suggests that in 1956 walrus numbers constituted 11-17% of the original population size.

The population size would be approximately 1,000-2,100, 1,000-6,400 or 1,000-14,000 animals in 1995 based on the model used in this study and maximum net recruitment rates of 2, 5 and 7% respectively. This is 8-23% or 8-94% or 8-237% of the original population.

Discussion

Backcalculation of the walrus population at Franz Josef Land, based on 1,000 walruses in 1956 indicates that the minimum size of the population prior to exploitation was between 6,000 and 10,000 animals. The maximum population size may have been about 12,500. Our findings were compared with results obtained using the simple extrapolation method

described by Wade (1993). When using various combinations of parameters a mean minimum historical population size of 7,593 (range: 5,557-9,739, N = 8) was obtained. The results from the simple recruitment model and the simple extrapolation method are thus similar.

Our estimates are based on very tentative starting points. However, the precision of these values is of minor importance. Assuming that the number of walruses in Franz Josef Land in 1956 was approximately twice as large, i.e. 2,000, the estimated minimum number of walruses in 1897 using a recruitment rate of 2% increased by only 3.5%. For recruitment rates of 5 and 7% the increase was less than 0.3%. In effect, the size of the walrus population in 1956 had little influence on the estimate of the size of the original population by this model.

Apart from the three first years of intensive hunting (i.e. 1897-1899), a hunting loss of 20% was applied to backcalculate the original walrus population in Franz Josef Land. This was based on Chapskii (1939) who claimed that the Russian walrus hunters had this magnitude of hunting loss in 1931. According to a review by Born et al. (1995) hunting losses of 30% are probable in Canada and Greenland. If a similar percentage is used for Franz Josef Land harvests after 1899, the minimum size of the original population will be changed by 2% or less for maximum net recruitment rates of 2, 5 and 7%. This increases the estimated maximum size of the population by about 3%.

When attempting to estimate the original size of the Franz Josef Land population by backcalculation it is necessary to know how many walruses were killed there annually. Unfortunately, there are some gaps in the available data. Because of the ice conditions most hunting occurred in July and August (Gjertz et al. 1992). It is known that little or no hunting occurred in some years because severe ice conditions prevented access to the hunting grounds. This may, in part, explain why the magnitude of the catches could vary greatly among years. The increases in the catches after 1923 were due to the use of more powerful, ice-reinforced vessels (Lønø 1972), which had less difficulty manoeuvring in heavy ice. For some years there is little information about Franz Josef Land, and it is not clear if the boats were there or not. This is especially true for the period 1911-1921. It is possible to get some idea of probable catches for the area during this period by taking relevant reported catches by Norwegians throughout the European Arctic, and subtracting those animals that were known to have been caught elsewhere. In the unlikely event that all of these were caught in Franz Josef Land, a total of 2,826+ walruses would be added to the kills previously registered (Anon. 1897-1929). If a 20% hunting loss is added, about 3,562 walruses were killed in addition to those already considered. Under these circumstances the estimated maximum number of walruses in Franz Josef Land in 1897 would have been about 11,000-16,000 animals, based on a maximum net recruitment rate of 2% and minimum net recruitment rate of 0%. Similarly, it would be about 7,600-16,000 using a net recruitment rate of 5%, and 6,500-16,000 using a rate of 7%. The estimated minimum and maximum number of walruses in 1897 would therefore increase by 10-29%.

In our opinion, a net recruitment rate of 7% is too high. Such rates can occur under very favourable conditions (Sease & Chapman 1988), but based on information from the early hunt in 1897 (Southwell 1898) it is likely that the harvest was focused largely on females and calves. This massive reduction of females would undoubtedly limit the population's potential reproductive output and therefore would reduce the net recruitment rate over time.

There were so few walruses in the archipelago in 1934 that the Russian sealers caught fewer than 10, despite using spotter aircraft (Chapskii 1939). At that time the large-scale Russian hunting in Franz Josef Land was stopped. Commercial harvesting was resumed again in 1955 before being terminated later the same year (Ivashin et al. 1972). Small-scale hunting was still conducted by members of Russian arctic expeditions and wintering crews (Ivashin et al. 1972). The first Russian station on Franz Josef Land was established in 1929 (Horn 1930) and a total of five stations existed by 1990. We must assume that a considerable number of walruses have been killed by station crews through the years, but we have no idea of the magnitude of the harvests. Frantzen (1992) describes one animal killed by the station crew at Hayes Island in 1991.

In this study we assumed that the walruses of Franz Josef Land were an isolated population. Today, it is clear that walruses of Svalbard and Franz Josef Land belong to one common population (Gjertz & Wiig, 1994, 1995, Wiig et al. 1996), but they may originally have been separate populations (Lønø 1972). The existing information is inadequate to determine if there is a link between the walruses in Franz Josef Land and Novaya Zemlya at present, although this

suggestion has been put forward previously (Chapskii 1936, Tsalkin 1937). At Svalbard walruses were almost extirpated prior to their total protection in 1952 (Norderhaug 1969). Similarly, walruses in Franz Josef Land were severely reduced in numbers before they were totally protected in 1956. Their numbers may have been as low as a few hundred in 1966 (Uspenski cited in Norderhaug 1969). Walruses in Novaya Zemlya were reported to number not more than 400 individuals in 1969-70 (Bychkov 1975). Even though all these figures are open to question, it is certain that walruses in all three geographic areas had been severely reduced by the middle of this century. Today, walruses in all three geographic areas constitute recovering populations (Born et al. 1995).

The Svalbard-Franz Josef Land population is currently thought to number at least 2,000 animals (Gjertz & Wiig 1995, Wiig et al. 1996). This must, however, be considered a minimum estimate because Franz Josef Land has not been surveyed recently. The estimates derived in this study indicate that the population in Franz Josef Land could be in the range of 2,100-14,000 animals depending on the maximum net recruitment rate used (2-7%). The highest of these estimates would suggest that walruses today might be close to their historical maximum numbers. However, local surveys of walruses in parts of Franz Josef Land in 1990, 1991, 1992 and 1996 (Ø. Wiig & I. Gjertz, unpubl. data, Knutsen 1993), have at best counted a few hundred walruses. Franz Josef Land has been more or less inaccessible for more than half a century, and little biological work has been undertaken in this area since its discovery. It is therefore not known if walrus behaviour or the carrying capacity of Franz Josef Land has changed since the 1890s. The mean temperature has, however, increased in the Barents Sea during the last century, resulting in reduced ice coverage in August (Vinje 1997). This would, if anything, indicate that conditions for walruses have improved in Franz Josef Land during the last century. Compared with the large numbers of walruses that could be observed around the turn of the last century, it does not seem reasonable to suggest that the present population numbers are close to the original maximum, thus indicating that our highest estimates are not correct.

Walruses in Svalbard were clearly almost gone, if not totally extirpated, by the middle of the 20th century. Thus, Svalbard's walruses have likely originated from Franz Josef Land. If this is true then considerably more than 2,000 walruses, i.e. the total Svalbard - Franz Josef Land population (Gjertz & Wiig 1995, Wiig et al. 1996), must have come from Franz Josef Land. This suggests that the current population size should be at the higher end of the scale. Assuming these figures are correct, the net recruitment rate from 1956 to 1995 should be considerably higher than 2%. We therefore believe that a calculation based on a net recruitment rate of 5% gives a more reliable estimate. To improve this estimate one would need more reliable data on walrus demography and density-dependant factors. To obtain such data it is essential to collect accurate annual harvest data, data on juvenile and adolescent survival and on population size (Fay, Eberhardt, Kelly, Burns & Quakenbush 1997). For Franz Josef Land one would have to use data from investigations conducted on harvested walrus populations elsewhere. Other methods, such as estimating indexes for age structure using remote sensing, are not feasible because walruses tend to haul out very close together thus preventing the measurement of individual animals.

We conclude that even though the simple recruitment model used in this study is rather crude, it does give a reasonable estimate of the original population size of walruses at Franz Josef Land. Depending on the input parameters used, and the number of walruses harvested, the model estimates that the population size likely numbered between 5,900 and 12,400 animals at the end of the 19th century. In the model we have only included walruses that are known to have been harvested in Franz Josef Land. It is likely that these figures underestimate the actual kills. This belief is consistent with estimates of current walrus populations in the Northeast Atlantic.

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