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Abundance of Northwest Atlantic grey seals in the Gulf of St. Lawrence and along the Nova Scotia Eastern Shore

Abondance des phoques gris du Nord-Ouest de l'Atlantique dans le golfe du Saint-Laurent et le long de la côte Est de la Nouvelle-Écosse

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Abstract

Northwest Atlantic grey seals form a single stock, but are often considered as two groups, named for the location of the main pupping locales for management purposes. The largest group whelps on Sable Island, 290 km east of Halifax, Nova Scotia. The second group referred to as 'non-Sable Island' or 'Gulf' animals whelps primarily on the pack ice in the southern Gulf of St. Lawrence, with other smaller groups pupping on small islands in the southern Gulf of St. Lawrence and along the Eastern Shore of Nova Scotia. Incorporating information on pup production, reproduction rates and removals into a population model indicate that the non-Sable Island component of the Northwest Atlantic grey seal population has increased from 20,900 (SE=200) animals in 1970 to 52,500 (SE=7,800) animals by 2004. Under the Objective Based Fisheries Management Plan, grey seals are currently considered as data poor. It is recommended that harvest levels not exceed 2,100 grey seals in the Gulf of St. Lawrence.

Résumé

Les phoques gris du Nord-Ouest de l'Atlantique ne constituent qu'un seul stock, mais, aux fins de gestion, ils sont souvent classés en deux groupes nommés d'après l'emplacement de leur principal lieu de mise bas. Le plus grand groupe met bas sur l'île de Sable, à 290 km à l'est de Halifax (Nouvelle-Écosse). Le deuxième groupe (désigné sous le nom de "autre que l'île de Sable" ou "Golfe") met bas principalement sur la banquise dans le Sud du golfe du Saint-Laurent, et des sous-groupes mettent bas sur de petites îles du Sud du golfe du Saint-Laurent et le long de la côte Est de la Nouvelle-Écosse. L'intégration de données sur la production de petits, les taux de reproduction et les prélèvements dans un modèle de la population révèle que l'effectif de la composante du golfe de la population de phoques gris du Nord-ouest de l'Atlantique est passé de 20 900 (erreur-type = 200) en 1970 à 52 500 (erreur-type = 7 800) en 2004. Dans le cadre du plan de gestion des pêches par objectifs, on considère qu'il existe actuellement très peu de données sur les phoques gris. Il est recommandé que le nombre de captures ne dépasse pas 2 100 phoques gris dans le golfe du Saint-Laurent.

Introduction

The Northwest Atlantic grey seal (*Halichoerus grypus*) forms a single population (Boskovic et al. 1996). However, for management considerations the population is normally divided into two groups; a Sable Island component and a non-Sable Island component. Using pup production as an index of population size and trends, pup production on Sable Island has increased rapidly since the 1970's, from less than 2,000 animals in 1975 to over 25,000 pups in 1997 (Bowen et al 2003) for an annual rate of increase of 12.8%.

Less is known about the non-Sable Island component of the Northwest Atlantic grey seal. This component, also referred to as Gulf grey seals, consists of animals that whelp primarily on the drifting pack ice in Northumberland Strait and off Eastern Shore (Fig. 1). Pup production of this group increased from 6,900 in the mid-1980s to a peak of around 11,100 animals in 1996. Since then, pup production declined to 6,100 animals in 2000. However, an aerial survey completed in 2004 indicated that pup production had increased again to 15,900 (SE=1,200).

In an earlier study, Mohn and Bowen (1996) examined changes in both the Sable Island and Gulf grey seal population between 1967 and 1994. Their study indicated that the Sable Island herd was increasing at an annual rate of 12.8% and numbered 85,300 (95% C.I. 78,000-95,000) animals in 1994.

For the non-Sable Island component of the population, Mohn and Bowen (1996) estimated a 1994 population size of 68,700 (95% C.I.=42,000-100,000) animals, increasing at a rate of 9% per year. In a more recent study, the non-Sable Island grey seal population was estimated to have increased to a maximum of 61,900 (SE=9,500) in 1996 and then declined to 55,700 (SE=9,200) in 2000 (Hammill et al. submitted). The differences between the two estimates result from updated pup production estimates not available for the study by Mohn and Bowen (1996) and different assumptions about adult male mortality rates. When similar input parameters are used, estimated changes in pup production and total population size are similar between Mohn and Bowen (1996) and Hammill et al. (submitted).

Here estimates from the 2004 pup abundance survey, along with information on reproduction and reported removals from the population are incorporated into a population model to determine changes in the Gulf component of the Northwest Atlantic grey seal population until 2004.

Materials and Methods

Population model

Estimates of population size and changes in the population over time were determined by constructing a deterministic, age-structured model, very similar to a Leslie matrix (Mohn and Bowen 1996). The population numbers N[*a;s;y*] are described by a three dimensional matrix having subscripts a,s, and y for age, sex (1=male, 2=female) and year respectively (Mohn and Bowen 1996). The number of pups in any year *y* is

$$N[0;1;y]=N[0;2;y]=0.5 * \sum N[a;2;y] * R[a] \quad (1)$$

Where R is a matrix made up of the age specific reproductive rates information collected from a sample of shot animals harvested in the early 1990s (Hammill and Gosselin 1995).
Age specific mortality for animals 1 year of age and older was incorporated into the model using

$$N[a;s;y] = (n_{a-1,s,y-1} - c_{a-1,s,y-1})\, e^{-(\gamma)m} \qquad (2)$$

where c is the age specific catch during years when culling and bounty hunting occurred and more recently information from scientific collections and pilot harvest programs (Hammill et al. 1998; Table 1), and $-(\gamma)m$ is the mortality rate. Mohn and Bowen (1996) assumed that mortality rates were higher for males than for females for animals greater than five years of age. However, Mansfield and Beck (1977) as well as more recent work (Manske *et al.* 2002; Schwarz and Stobo 2000) found little difference in mortality rates between sexes. Therefore we assumed that there was no difference in mortality between males and females ≤30 years old. An initial population size, independent estimates of pup production, age specific reproductive rates and estimates of mortality (Hammill and Gosselin 1995; Hammill et al. 1998; this paper) were used as initial inputs into the model. The model was fit to estimates of pup production by adjusting the initial population size and a mortality rate multiplier (γ) in equation 2 to minimize the sum of square differences between pup production estimates obtained from total counts, mark-recapture or aerial surveys and estimates of pup production produced by the model.

To incorporate some variability into the model, we assumed that age specific reproductive rates followed a normal distribution with mean (standard deviation) of 0.159 (0.19), 0.736 (0.16), 0.834 (0.13), 0.832 (0.15) and 0.907 (0.053) for ages 4, 5, 6, 7, and 8+ years respectively (Hammill and Gosselin 1995). Model fitting was completed using Risk Optimizer (an Excel spreadsheet add-in from Palisade Corporation 2000). The model started with an initial population, and sampled (Latin Hypercube) values from the defined functions for each parameter (*e.g.* values for reproductive rates and mortality rates). Sampling was repeated 200 times (replicates) and generated a distribution of 200 SS (sum of squares). These constituted a simulation. The model calculated the Mean of these sum of squares (MSS), stored the value and randomly selected a new initial population size and mortality rate values to carry out a new simulation. After 1000 simulations, the model retained the simulation which generated the smallest MSS.

Results

Population size

During the survey period between 1984 and 2000 Non-Sable Island pup production increased from around 7,000 animals to a peak of 11,100 (SE=1,300) animals in 1996. Two subsequent surveys indicate that pup production declined to a minimum of 6,100 (SE=900) by 2000 (Table 2). The most recent survey completed in 2004 estimated a total pup production of 15,900 (SE=1,200). Fitting the model to the available pup production estimates results in an estimated adult survival rate of 0.92, and an estimated initial pup production of 4,300 (SE=100) in 1970 increasing to 11,500 (SE=2,000) by 2004 (Fig. 2). The model fits the pup survey data poorly, with large negative residuals for much of the time series (Figure 2). Total population size increased from 20,900 (SE=200) in 1970, to 52,500 (SE=7,800) animals in 2004 (Fig.3).

Discussion

Pup production on the pack ice in the southern Gulf of St. Lawrence and along the Eastern Shore increased at a relatively constant rate of approximately 4% from 1984 until 1996. Since then, survey estimates indicate that marked inter-annual variation in pup production has occurred. It is unfortunate that surveys have not been conducted more regularly. More frequent estimates from the period between 1990 and 1996 would provide insights into whether pup production had started to slow prior to 1996. If this was true, then the 1996 estimate would reflect the beginning of the downturn in pup production, rather than the end of an increasing phase. Similarly, more frequent estimates from the period 1996 to 2004 would have helped to determine if the declines observed formed part of a larger pattern of highly variable pup production or represent unusual years. This lack of information has an impact on our views of the population and also possible management opportunities under the Objective Based Fisheries Management approach (see below).

The reasons for the large fluctuations in pup production in recent years are not clear, but are thought to result from variable pup mortality rates, emigration from the area or a combination of these factors. Variability in ice conditions during the whelping season may contribute to increased pup mortality or emigration of adult females from the area, but this needs to be investigated. Movements of animals equipped with satellite transmitters, and tag recoveries indicate that grey seals are very mobile and have little trouble moving in and out of the Gulf onto the Scotian shelf in January, and small grey seal pupping colonies are found along the shore (Stobo et al. 1990; Lavigueur and Hammill 1993; Goulet et al. 2001). Visits to these known sites did not detect marked changes in abundance. However, visits to these sites were limited and animals may have left prior to our arrival, or pupped on the islands after our visit. One area that we have little information on abundance, but is known as an area where grey seals have pupped in the past are the French Islands of St. Pierre and Miquelon. Some animals may have moved to this area.

Overall, the non-Sable Island grey seal population has likely increased since the 1980s. Over this period we have assumed that no major changes have occurred in reproductive parameters. Although the model does associate some uncertainty with the age specific rates it is assumed that mean values have not changed. Some limited data would support this assumption, but sample sizes are quite small, and further analyses are required (Table 3).

The Sable Island and non-Sable Island grey seal colonies have had very different population trajectories. These differences likely result from the higher culling and scientific harvests in the Gulf of St. Lawrence and along the Eastern Shore (Stobo and Zwanenburg 1990; Hammill et al. 1998), and the higher mortality rates experienced by animals in the Gulf of St. Lawrence. Higher mortality rates for pups born on the drifting pack ice is consistent with previous studies (Stobo and Zwanenburg 1990; Hammill et al. 1998), but only very slight differences would be expected among adults between the two groups. The population model does not provide an independent measure of mortality rates because it fits to the survey information on pup production by adjusting both the initial population size and the mortality rate. However, reasonable values for this parameter would be expected to be produced by the model. This would appear to be the case with an estimated adult survival rate of 0.92 which is lower than the estimates of 0.976 (SE=0.003) made by Manske et al. (2002), for adults males on Sable Island, but is slightly higher than the rates of 90% estimated by Mansfield and Beck (1977) and higher than rates of around 80% in the United Kingdom (Harwood and Prime 1978). Manske et al. (2002) suggested that they may have over-estimated survival because their observations focused on animals returning to the breeding colony, and hence may have been influenced by males that were larger, stronger and more aggressive than males not sighted in the breeding colony.

Under the Objective Based Fisheries Management Plan adopted for this fishery, a population is considered data rich if at least two of three sources of information are available. These include a combination of any two of : three recent abundance estimates, with the last estimate available within the last 5 years, recent estimates of age specific reproductive rates and/or age specific mortality rates (Hammill and Stenson 2003). If this information is not available then the population is considered as data poor, within the context of the management strategy. In the case of NW Atlantic grey seals, we do not have data on age specific mortality rates, reproductive data are not recent and we do not have at least three recent survey estimates available for the population. For the non-Sable Island component we do have recent survey information, but do not have information on age specific mortality rates, while reproductive information is limited. There is also considerable uncertainty associated with the current population trajectory owing to the apparent marked inter-annual fluctuations in pup production. Finally, an additional level of uncertainty includes the varying seasonal changes in the movement of animals between the Gulf and the Scotian Shelf particularly within the context of recent mild winters. Within this context, grey seals fall into the category of data poor and under this category it has been recommended that harvest levels be estimated using the Potential Biological Removal approach (Hammill and Stenson 2003). This has been defined as:

$$PBR=0.5 \cdot R_{Max} \cdot F \cdot N_{Min},$$

where R_{Max} is the maximum rate of increase for the population , F is a recovery factor with values between 0.1 and 1 and N_{Min} is the estimated population size using the 20th percentile of the log-normal distribution (Wade and Angliss 1997; Wade 1998). R_{Max} is set at a default of 0.12 for pinnipeds unless there is evidence for other more appropriate rates.

Information on acceptable harvest levels were requested by Fisheries and Aquatic Management Branch for two regions, the Gulf of St. Lawrence and the Scotian Shelf. The latter includes Sable Island and the Nova Scotia Eastern Shore. The pup production and population estimates presented in this document include animals born in the Gulf of St. Lawrence and along the Eastern Shore. To separate the two regions, the number of animals at Hay Island, the largest grey seal colony located on the Eastern Shore were subtracted from the minimum population size as defined for PBR. To determine grey seal abundance at Hay Island, I multiplied the number of pups by the average of 4.7 adults per pup, determined from the population model over the period 1970-2004. The total non-Sable population was estimated to be 52,500 animals. For a coefficient of variation of 15%, this results in a N_{min} of 46,300. A total of 2,400 pups were born on Hay Island (Hammill and Gosselin 2005). Subtracting the estimated number of animals at the Hay Island colony (4.7 x 2400), results in a Gulf of St. Lawrence population of 35,000 animals. A recommended harvest based on the PBR approach would be 2,100, assuming a recovery factor of 1. A lower recovery factor was not examined.

Higher harvest levels may be possible, but more regular abundance surveys are needed to understand more about the magnitude of inter-annual variability of pup production on the pack ice in the Gulf of St. Lawrence.

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Table 1. Grey seal removals from the Gulf of St. Lawrence from scientific collections. Juveniles are one to three years old, and adults are four years old and greater.

Year	Pups	Juveniles	Adults
1991	0	0	13
1992	44	119	106
1993	0	1	12
1994	7	11	11
1995	7	2	1
1996	4	10	55
1997	1	2	19
1998	0	0	20
1999	2	11	57
2000	10	14	64
2001	2	10	33
2002	10	29	59
2003	9	13	8
2004	29	32	84
2005	485		

Table 2. Estimates of Non-Sable or Gulf grey seal pup production, from mark-recapture (M-R) and aerial surveys, rounded to the nearest 100. Standard errors are in brackets.

Year	Anticosti M-R[1]	Sable M-R[1]	Within season M-R study[2]	Aerial survey
1984	7,000 (1,200)	7,400 (1,400)		
1985	6,400 (900)	7,800 (1,700)		
1986	5,400 (700)	8,600 (2,800)		
1989	10,400 (3,200)	8,900 (2,100)	9,800 (1,000)	
1990	9,200 (2,700)	8,100 (900)	10,500(1,000)	
1996[3]				11,100 (1,300)
1997[3]				7,300 (800)
2000[3]				6,100 (900)
2004				15,900 (1,200)

[1]Hammill et al. 1998
[2]Myers et al. 1997
[3] Hammill et al. submitted.

Table 3. Reproductive rates of grey seals collected in the Gulf of St. Lawrence (recent data Dussault and Hammill unpublished)

	1994-2001		2002-2004		Model
age	n	%preg	n	%preg	%preg
4	6	33	13	46	16
5	5	40	15	60	74
6	10	80	5	40	83
7	10	80	7	71	83
8	8	63	7	71	91
9	13	69	9	78	91
10+	23	65	33	88	91

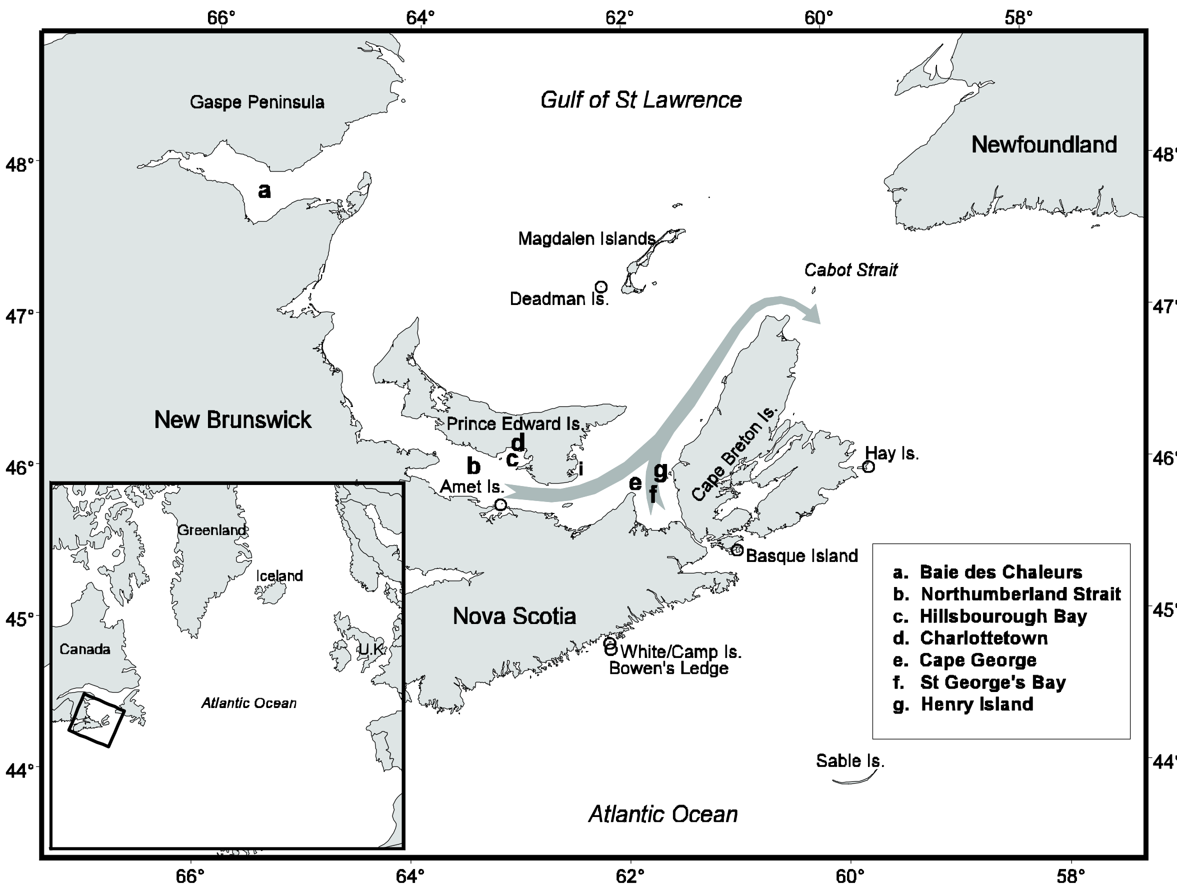
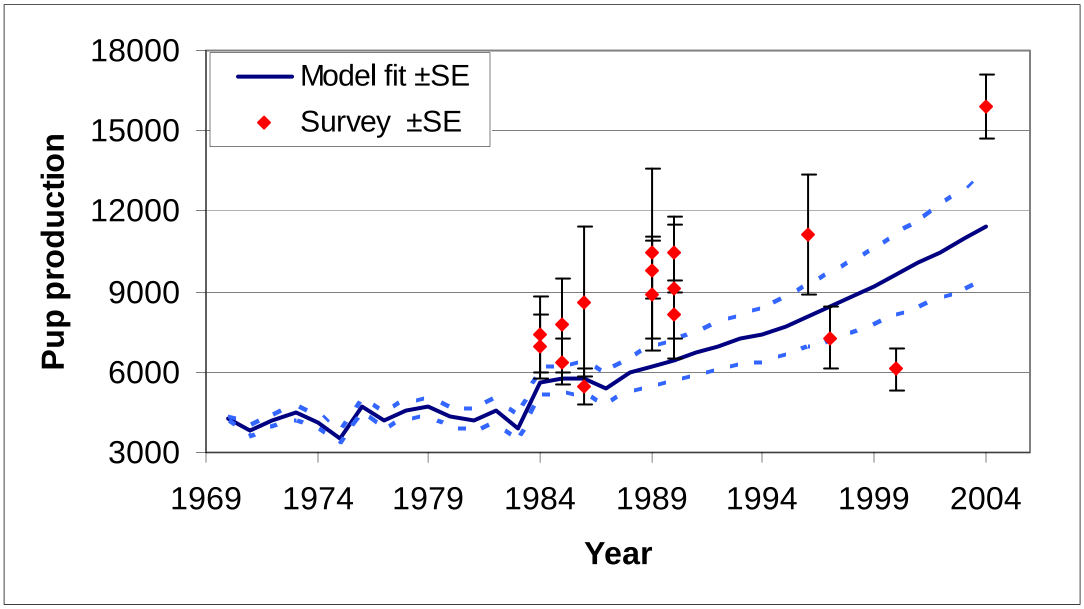


Figure 1. Location of whelping grey seal on the ice in the southern Gulf of St. Lawrence. The large arrow outlines the main pupping area and direction of ice drift during the survey period.



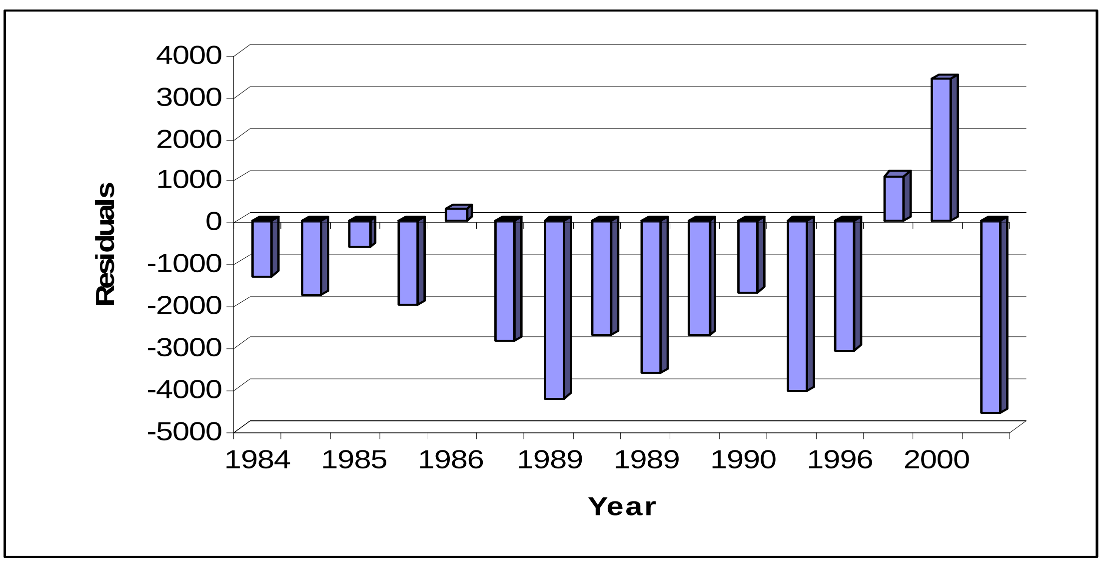


Figure 2. Estimated changes in pup production by fitting the population model to the survey estimates (top), and a graph of residuals (predicted-observed) for each abundance estimate available between 1984 and 2004 (bottom).

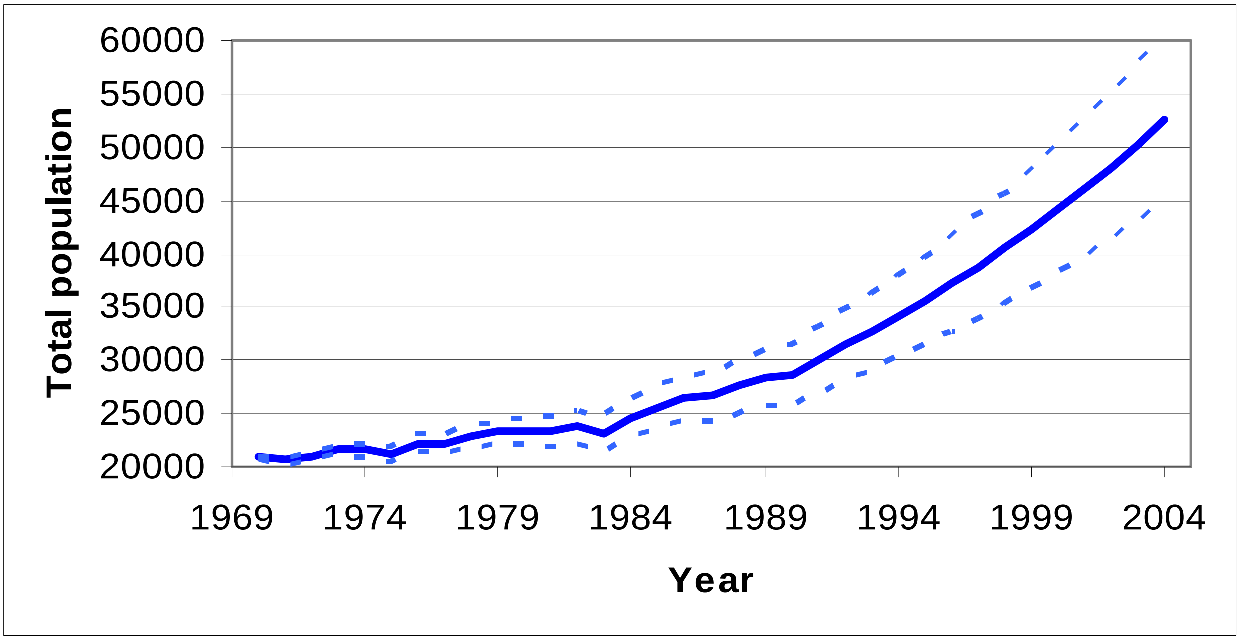


Figure 3. Estimated changes in total non-Sable Island grey seal population.