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Estimated Grey Seal Diets near Sable Island Derived from Fecal Samples: 1991 to 2010

Estimation des régimes alimentaires des phoques gris près de l'île de Sable d'après les échantillons de fèces : 1991 à 2010

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ABSTRACT

Fecal samples collected seasonally at Sable Island were used to estimate the species composition of the diet of grey seals during the period 1991-1998 and in winter, 2010. Sand lance dominated the diet in all seasons and years. Sand lance was recovered in an average of 77.6 % (CV 20.7%) of scats indicating that most individuals in the population consumed this species. Both the occurrence (30.9%) and percentage of the diet (wet weight) comprising Atlantic cod were highly variable, with CVs of 53% and 104%, respectively, among seasons and years. Number correction factors were applied to attempt to reduce the bias associated with complete digestion of otoliths. Percentage of cod in the diet varied from 0 to 21.7 %, but showed no trend over time or significant differences among seasons. Cod averaged 7.1 % (7.4 SD) of the diet.

RÉSUMÉ

Des échantillons de fèces recueillis au fil des saisons à l'île de Sable ont été utilisés pour estimer la composition du régime alimentaire des phoques gris pendant la période s'étendant de 1991 à 1998 et à l'hiver 2010. Les phoques gris se sont nourris principalement de lançon, et ce, peu importe les saisons ou les années. Le lançon paraissait dans 77,6 % (CV 20,7 %) des fèces, en moyenne, ce qui indique que la plupart des individus composant la population se nourrissaient de cette espèce. D'une saison à l'autre et d'une année à l'autre, l'occurrence (30,9 %) et le pourcentage de morue (poids humide) dans le régime alimentaire variaient énormément, comportant des CV de 53 % et de 104 % respectivement. Divers facteurs de correction ont été appliqués pour tenter d'atténuer les biais associés à la digestion complète d'otolithes. Le pourcentage de morue dans le régime variait de 0 à 21,7 %, mais ne présentait aucune tendance au fil du temps ni de différences significatives entre les saisons. En moyenne, le régime alimentaire se composait de morue dans une proportion de 7,1 % (écart-type de 7,4).

INTRODUCTION

This paper documents the time series of estimates of the prey species composition in the diet of grey seal (*Halicheorus grypus*) foraging near Sable Island, with a focus on Atlantic cod (*Gadus morhua*). These data are used as inputs to models which attempt to estimate the magnitude of grey seal predation mortality on cod on the Scotian Shelf (e.g., Trzcinski et al. 2006). With the exception of the 2010 sample, these data have been previously published (Bowen and Harrison 1994, 2007) and used to estimate the proportion of cod in the diet of grey seals and the size distribution of cod consumed (Mohn and Bowen 1996) or the size distribution alone (Trzcinski et al. 2006).

Estimating diet from feaces (scats) is based on the identification of prey structures that are resistant to digestion. Sagittal otoliths are most commonly used, but other structures such as bones, scales, and lenses also provide a means of prey identification (Fitch and Brownell 1968; Pierce and Boyle 1991; Pierce et al. 1993). Where cephalopods are eaten, beaks can be used for prey identification (*e.g.*, Clarke 1986). Recovered otoliths and cephalopod beaks can be used to estimate both the number and size of the prey consumed. Feces are commonly used for this purpose because they are inexpensive to collect, a high proportion of samples contain identifiable prey, and estimates of diet from fecal data are less affected by differential rates of digestion than are estimates from stomachs (Hammond and Prime 1990).

Despite their widespread use, estimates of species composition and the size of prey consumed derived from recovered otoliths and cephalopod beaks may be seriously biased (e.g., Murie and Lavigne 1985; Harvey 1989; Pierce et al. 1991). One difficulty is that otoliths and cephalopod beaks erode during digestion, such that the size and number of prey consumed may be underestimated and in some cases prey identification is not possible. A further complication is that the degree of erosion is species specific and is often a function of prey size within species. Otoliths from some species (*e.g.*, Atlantic salmon, *Salmo salar*) are quickly digested and thus are rarely found in stomach or fecal contents (Boyle et al. 1990). Differential passage and rates of digestion among prey species may also bias stomach content analyses in favor of species with large and robust hard parts (e.g., Hammond and Prime 1990).

A growing number of studies have attempted to experimentally measure *in vivo* the reduction in the size of otoliths that occurs during digestion and to apply correction factors to estimates of diet composition (e.g., review in Bowen and Iverson 2010). A further correction for the complete digestion of ingested otoliths is also required (Jobling 1987) as studies have shown that as few as 10% of the otoliths of species with small, fragile otoliths are recovered in scats whereas about 90% of otoliths of species with large, robust otoliths can be recovered (Bowen 2000).

During the 1990s, when the Sable Island grey seal data were collected and initially analyzed to reconstruct the diet, it was common practice to attempt to correct for the partial erosion of otoliths in fecal. This was and continues to be done in one of two ways: the measure-all otoliths approach and the measure non-eroded otoliths approach. In the first approach, the size of otoliths that have been eroded, as judged by changes in surface topography relative to reference material, are corrected by applying otolith digestion coefficients (e.g., Hammond and Prime 1990). The second approach uses the observation that some otoliths show little evidence of erosion, presumably because they are more robust or were passed from the stomach more rapidly, and therefore are assumed to represent the size of prey eaten. Unmeasured otoliths are then prorated on the basis of the measured sample. Given the limited number of studies at the time, otoliths digestion coefficients were not available for many of the species eaten by grey seals and so the second approach was used to estimate the proportion of cod and other species in the diet. As estimates of number correction factors (NCFs) to account for complete digestion of otoliths come from the same studies in which partial-erosion correction factors were derived, the same problem existed of not having appropriate NCFs to apply (Bowen 2000).

In the past decade, the situation has changed and additional prey species have been experimentally fed to several pinniped species, including grey seals. Here we apply NCFs to the time series of previously published samples and to samples collected in January 2010 to provide better estimates of the proportion of prey species actually consumed by grey seals.

METHODS

The methods used to extract, identify and measure otoliths recovered from fecal samples are given in Bowen and Harrison (1994, 2007) and follow practices commonly used elsewhere. Once otoliths were measured, the sizes of prey eaten are estimated from species-specific regressions relating otolith size to fish length and mass. The estimates of prey mass are then used to determine the proportion of the reconstructed diet comprising cod and other species.

We applied the NCFs listed in Table 1 to re-scale the mass of each species in the sample to that consumed. The experimentally estimated values of correction factors for complete digestion range from 1.1 in Atlantic cod to 7.9 in capelin (*Mallotus villous*), indicating that on average about 10% of cod otoliths were completely digested in the stomach whereas about 90% of capelin otoliths were digested. Where available, we used the correction factor developed for the prey species eaten by grey seals. Where no NCF was available for a species, we used values from prey species with otoliths of similar size and robustness based on the otolith catalogues developed by Campana (2004) and Härkönen (1986) and discussions with S. Campana.

RESULTS

The 2010 winter estimate of the diet (with NCFs applied) was similar to that found during the 1990s with sand lance dominating (91.1% of consumption), followed by cod (3.5%), flatfishes (2.3%), and longhorn sculpin (2.5%).

Over the entire time series, sand lance (*Ammodytes dubius*) was recovered in an average of 77.6 % (CV 20.7%) of scats indicating that most individuals in the population consumed this species. Both the number of scats containing cod (30.9%, SD 16.4) and percentage of the diet (wet weight) comprising Atlantic cod were highly variable, with CVs of 53% and 104%, respectively, among seasons and years.

As expected, applying NCFs to the time series resulted in lower estimates of cod in the diet, with an overall average of 7.1% (7.37 SD). This compare to the uncorrected average of 13.5 % (13.07 SD). Over the entire period, from 1991 to 2010, the fraction of cod in the diet varied considerably (CV= 104 %), but without trend (Fig. 1). There was also no significant seasonal variation in the percentage of cod in the diet ($F_{3,20} = 0.93$, $p = 0.44$; Table 2).

DISCUSSION

There is good experimental data showing that correcting estimates of diet for the complete digestion of otoliths is needed to reduce bias (e.g., Tollit et al. 1997, Bowen 2000, Grellier and Hammond 2006). This bias is caused by prey species differences in size and robustness of otoliths that affect the probability that otoliths will survive digestion and be passed into feces where they can be recovered. Although such corrections are justified, there application is still hampered because NCFs have yet to be determined for a number of species consumed by grey seals. Nevertheless, NCFs have been estimates for a sufficient range of species to provide some confidence that corrected estimates more accurately reflect what was consumed. Where NCFs do not exist, we have used information in the size and robustness (length/thickness ratio) of otoliths for species with similar otoliths characteristics. While this is not ideal, it should not lead to significant bias as size and robustness are the characteristics that seems to have the greatest influence on rate of digestion.

The new estimates indicate a much lower average consumption of cod than previously published. These new estimates have direct implications for the level of predation mortality by grey seals on cod (see Trzcinski et al. 2010). Although corrected estimates should provide an more accurate estimate of cod eaten based on the samples analyzed, these estimates may still be subject to bias arising from the difficulty of obtaining a representative sample of grey seal scats from which to estimate the population diet.

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Table 1. Number correction factors (NCF) to account for complete digestion of prey otoliths. Bold italics are assumed values based on otolith size and robustness of similar species from Campana (2004) and Härkönen (1986).

Common Name	Scientific Name	Size (cm)*	NFC	Rounded NCF	Species	Source
Atlantic herring	*Clupea harengus*	20.2–29.3	2.867	2.9	Grey seal	1
Atlantic mackerel	*Scomber scombrus*	26.6–33.0	1.391	1.4		1
Sandeel	*Ammodytes marinus*	13.2–22.4	2.861	2.9		1
Atlantic cod	*Gadus morhua*	15.8–51.7	1.060	1.1		1
Haddock	*Melanogrammus aeglefinus*	13.5–37.9	1.113	1.1		1
European hake	*Merluccius merluccius*	16.5–40.2	1.081	1.1		1
	Merlangius merlangus					
Whiting		10.0–35.0	1.027	1.0		1
All large gadoids	*Limanda limanda*	10.0–51.7	1.069	1.1		
	Platichthys flesus					
Common dab	*Microstomus kitt*	14.8–29.3	1.226	1.2		1
Flounder	*Hippoglossoides*	23.1–32.5	1.418	1.4		1
Lemon sole	*platessoides*	14.9–32.1	1.539	1.5		1
Long rough dab	*Pleuronectes platessa*	14.0–23.9	1.163	1.2		1
	Glyptocephalus cynoglossus					
European plaice		13.8–34.3	1.190	1.2		1
Witch flounder		24.7–32.0	1.037	1.0		1
Flounder–plaice	*Loligo forbesii*	13.8–34.3	1.294	1.3		1
All flatfish		13.8–34.3	1.241	1.2		
Squid		13.5–337.0	1.064	1.1		1
Capelin	*Mallotus villous*	14.3-14.8	7.87	7.9	Steller seal lion	2
Surf Smelt	*Hypomesus pretiosus*	16.7	4.33	4.3	Harbour seal	3
Wolffish	*Anarhichas lupus*			***2.9***		
Sculpin	Cottidae			***2.9***		
Lumpfish	*Cyclopterus lumpus*			***2.9***		
Eel pout	*Lycodes* sp			***1.2***		
Winter flounder	*Psuedopleuronectes americanius*			***1.3***		
Redfish	*Sebastes* sp			***1.1***		
White Hake	*Urophysis tenuis*			***1.1***		
Ocean pout	*Zoarces americanus*			***2.9***		
American Plaice	*Hippogloossides platessoides*			***1.3***		
Yellowtail flounder	*Limanda feruginea*			***1.3***		
Windowpane flounder	*Scophthalmus aquosus*			***1.3***		
Cunner	*Tautagolabrus adspersus*			***2.9***		
Fourline Snakebeeny	*Eumesogrammus praecisus*			***1.3***		
Butterfish	*Perprilus triacanthus*					
Silver hake	*Merluccius bilinearis*			***1.1***		
Pollock	*Pollachius virens*			***1.1***		

[1] Grellier and Hammond 2006; [2] Tollit et al. 2007; [3] Cottrell et al. 1996

Table 2. Seasonal estimates of percent cod in the diet, 1991-2010.

Season	n	Mean	SD
fall	7	8.2	8.0
spring	6	10.5	9.6
summer	3	5.7	4.4
winter	8	4.1	5.5

Table 3. Time series of estimates of percent cod (wet weight) in the diet of grey seals based on scats (n) collected on Sable Island.

Year	Season	n	Percent
1991	fall	47	15.3
1991	summer	50	9.8
1992	spring	42	0.4
1992	summer	53	6.3
1992	winter	88	1.1
1993	fall	13	0
1993	spring	30	0.7
1993	summer	28	1.1
1993	winter	39	0.3
1994	fall	22	7.3
1994	spring	59	17.5
1994	winter	45	15.4
1995	fall	71	12.1
1995	spring	77	17.9
1995	winter	33	9.4
1996	fall	87	2.5
1996	spring	102	4.6
1996	winter	48	1.5
1997	fall	59	5.1
1997	spring	99	21.7
1997	winter	70	0.4
1998	winter	32	1.2
2010	winter	110	3.5

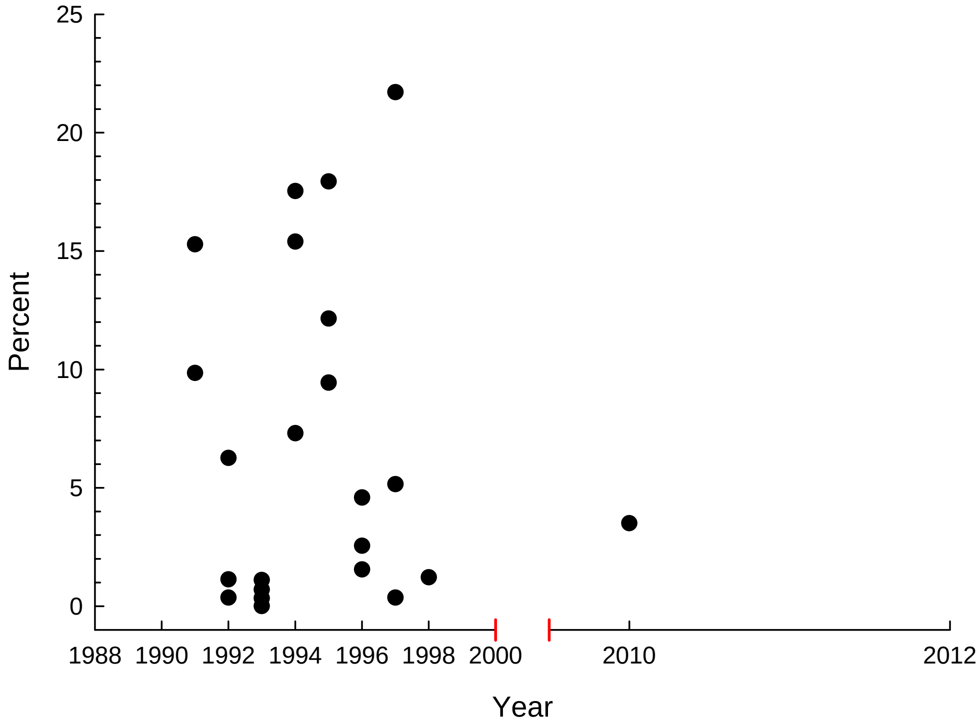

Figure 1. Time series of estimates of the percent cod in the diet of grey seals derived from scats collected on Sable Island.