Diet of South American fur seals at the Falkland Islands

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South American fur seals (SAFS) (Arctophoca australis3) are one of the most widely distributed otariids breeding on both the Atlantic and Pacific sides of South America, from Uruguay to Peru (Campagna 2008). Breeding colonies are, however, patchily distributed and geographically isolated, separated by hundreds to thousands of kilometers (Túnez et al. 2008). Two SAFS subspecies are typically recognized, but their validity is debated (reviewed in Oliveira and Brownell, in press). Specifically, the mainland subspecies (A. australis gracilis) (Argentina, Chile, and Uruguay) is separated from SAFS breeding at the Falkland Islands (A. australis australis) on the basis of skull morphometry (King 1954, Rice 1998, Brunner 2004, Campagna 2008). In addition to these subspecies, recent studies reveal genetic and morphometric differences between the Peruvian (A. australis unnamed) and Uruguayan populations of SAFS (Túnez et al. 2007, Oliveira et al. 2008, Berta and Churchill 2012, Committee on Taxonomy 2012). Genetic and morphometric discontinuities characterize distinct populations of SAFS that may constitute biologically relevant conservation and management units (Túnez et al. 2007, Oliveira et al. 2008). A prerequisite for effective SAFS conservation is the ability to identify the appropriate focus of management effort. This requires information on potential threats to distinct populations and their current conservation status.

1Editor's Note: The Falkland Islands is an Overseas Territory of the United Kingdom but is also claimed by Argentina as Islas Malvinas. The UN designation for the country is Falkland Islands (Malvinas).

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3The Taxonomy Committee of the Society for Marine Mammalogy are currently reconsidering the use of Arctophoca and it is likely the species name will again be Arctocephalus australis.
The Falkland Islands subspecies is one of the least studied SAFS populations. Despite the SAFS species-level classification of "Least Concern" (Campagna 2008), data for the Falkland Island subspecies is both incomplete and outdated. SAFS appear to have been almost extirpated from the Falkland Islands by 1822 through unregulated and indiscriminate harvesting (Laws 1953 and references therein). The last archipelago-wide population census at the Falkland Islands was undertaken between 1965 and 1966, when 14,000 animals were estimated (Strange 1983). Partial surveys in 1984 estimated 18,000–20,000 animals (Strange 1992). Although the current population size is unknown, SAFS have not recolonized their former breeding range that included Beauchène Island, historically one of the archipelagos’ largest breeding colonies (Laws 1953, Lewis Smith and Prince 1985).

The foraging ecology of SAFS at the Falkland Islands has also remained largely unstudied, with one notable exception (see Thompson et al. 2003). This is surprising given the rapid development of intensive commercial fisheries around the Falkland Islands and hydrocarbon exploration (Agnew 2002, Winter et al. 2010). There are no quantitative studies on SAFS diet at the Falkland Islands, despite the potential effects of fisheries on upper trophic level predators such as fur seals and the fact that fishery interactions constitute a dominant threat to pinniped populations worldwide (Trites et al. 2006, Kovacs et al. 2012). Anecdotal observations of SAFS scats at the Falkland Islands have described lobster krill (Mundia gregaria) as the main prey, with cephalopod and fish hard parts also occurring (Strange 1983, 1992). In other parts of their breeding range, SAFS also take a wide variety of prey. In Uruguay for example, where the largest number of SAFS breed, dominant prey items include anchoveta (Engraulis anchoita), cutlassfish (Trichiurus lepturus), weakfish (Cynoscion guatucupa), and cephalopods (Naya et al. 2002).

In this study, we present the first quantitative information on SAFS diet at the Falkland Islands. Scats were collected from Bird Island (52º9’0”S, 60º54’0”W, southwest Falkland Islands) and Steeple Jason Island (51º2’0”S, 61º11’0”W, northwest Falkland Islands) (Fig. 1). Bird Island is one of between 9 and 11 SAFS breeding colonies at the Falkland Islands (Strange 1992). To minimize disturbance scats were collected away from the breeding rookery in areas frequented by adult males and juveniles. Steeple Jason Island is a haul-out site frequented by adult males and juveniles. We assumed scats collected at Bird Island and Steeple Jason Island were from animals of comparable age/sex classes.

To assess diet, whole scats were collected into individual plastic bags and stored at -18°C. Scats were thawed prior to sorting and soaked for 12 h in a 1:10 mixture of detergent and warm water to facilitate the separation of prey remains (Staniland et al. 2004). Scats were then washed through tiered sieves of decreasing mesh size (1.5 mm, 0.5 mm, and 0.25 mm in mesh diameter). The remaining material was transferred from sieves into a black sorting tray and prey hard parts collected (e.g., fish scales, vertebrae, and eye lenses). Otoliths were measured and cataloged, whereas cephalopod beaks were measured and stored in 75% ethanol. The number of prey in individual scats was estimated by the highest number of recovered otoliths (left or right) or squid beaks (upper or lower). Otoliths and cephalopod beaks were used to identify prey to the lowest taxonomic group possible by comparison with reference collections held at the Falkland Islands Fisheries Department and using identification guides (Xavier and Cherel 2009). Patagonotothen fish were identified to genus because of the inherent difficulty in distinguishing otolith morphology between species (particularly juvenile Patagonotothen).
Published regression equations derived from whole fresh samples were used to estimate prey size from otolith length and lower cephalopod beak rostral length (Clausen and Huin 2002, Clausen and Pütz 2003, Clausen et al. 2005). Regression equations were not available for all prey species. However we were able to estimate the length and mass of main prey species (i.e., those occurring in 10% or more of scats). Previous studies emphasize the need for correction factors to account for digestion when estimating prey length from scats (e.g., Tollit et al. 2007). Species-specific correction factors were not available for this study. However, Reid (1995) used correction factors of 1.1 or 1.2 depending on the degree of otolith medial relief visible. Following Staniland (2002), we assigned each otolith to one of three groups on the basis of erosion. These groups were: (1) good = low level of erosion (characterized by intact margins and medial relief); (2) fair = erosion evident including smoothing around margins, but otoliths retained key characteristics; and (3) poor = otoliths heavily eroded. Otoliths in group 3 were not measured. A correction factor of 1.1 or 1.2 was applied to group 1 and group 2, respectively. Regression equations for Patagonotothen spp. were based on those calculated for P. ramsayi (rock cod), the most abundant Patagonotothen on the southern Patagonian shelf (Clausen et al. 2005, Brickle et al. 2006, Winter et al. 2010).

Figure 1. The Falkland Islands subspecies of South American fur seals (Arctophoca australis australis) are known to breed at nine sites at the Falkland Islands, but have not recolonized their former breeding range that included Beauchène Island. Breeding colonies are currently unconfirmed at a further two islands. Scats were collected from Bird Island (breeding colony) and Steeple Jason Island (haul-out site).
To evaluate the relative contribution of prey species to the overall diet of SAFS, we calculated the percent frequency of occurrence (FO%) and the split-sample frequency of occurrence (SSFO). The FO% indicates the proportion of scats that contain a particular prey type. The FO% was calculated by dividing the number of scats in which a prey species occurred, by the total number of scats that contained identifiable prey remains (Lance et al. 2001). SSFO is the proportion of the overall diet made up of any single prey type (Olesiuk 1993). Unlike FO%, the SSFO proportions sum to 100%. The assumptions of the SSFO are that each scat represents a complete sample of all prey consumed in the most recent meal and that all prey were consumed in equal quantity (Olesiuk 1993, Joy et al. 2006). The most effective means of quantifying diet contribution is by reconstructing biomass (Tollit et al. 2007). Consequently, variable biomass reconstruction (VBR) was also calculated for the main prey species (Laake et al. 2002, Joy et al. 2006). The VBR was calculated as

$$\sum_{i=1}^{n} \frac{n_i \bar{w}_i}{C}$$

where $n_i$ is the number of species $i$ and $\bar{w}_i$ is the average weight of species $i$ (Joy et al. 2006).

Chi-squared analysis was used to test for differences in the importance of prey between Bird Island and Steeple Jason Island.

A total of 210 SAFS scats were collected, 131 from Bird Island in October 2010 and 79 from Steeple Jason Island in October 2011. We were unable to visit both sites in the same year due to operational constraints. Thirty scats (14%) did not contain prey hard parts and were excluded from further analysis. Fish occurred in 93.3% of scats, cephalopods in 40.6% of scats and crustaceans in 3.9% of scats. Although characterized as a generalist predator, SAFS diet at the Falkland Islands was dominated by relatively few prey species that are typically abundant on the continental shelf (Table 1). This implies that nonbreeding animals predominantly foraged on the continental shelf in October, as previously reported for lactating SAFS during the austral spring (Thompson et al. 2003).

Falkland herring (Sprattus fuesgensis) was the most frequently occurring prey item, recovered in 78% and 57% of scats from Bird Island and Steeple Jason Island, respectively (Table 1). Falkland herring was also the most important prey item in terms of biomass (Table 1). Interestingly, the highest abundance of Falkland herring occurs in September and October when fish congregate to spawn in the northwest and southwest of the Falkland Islands (Agnew 2002, Clausen et al. 2005). Although we did not collect data on prey distribution, the prevalence of Falkland herring in the diet of SAFS in October could coincide with spawning aggregations of this species. Consequently, the prevalence of Falkland herring in the diet of SAFS may be short-lived and reflect opportunistic foraging on seasonally abundant prey.

Patagonian longfin squid (Loligo gahi) and Patagonotothen spp. also occurred frequently in SAFS scats (Table 1). These species, together with Falkland herring, form the dominant dietary component of many other upper-trophic level marine predators breeding at the Falkland Islands (Thompson 1993, Thompson et al. 1998, Clausen et al. 2005). For example, Falkland herring accounts for 99% of Gentoo penguin (Pygoscelis papua) diet (by reconstituted mass) at some sites (Clausen et al. 2005). In addition, the estimated length of Patagonian longfin squid consumed by SAFS was similar to that reported in the diet of southern sea lions (Otaria byronia) (mean ± SE, 13.9 ± 2.3 cm and 13.0 ± 3.0 cm, respectively), and the average length of Falkland herring consumed by SAFS overlapped with the length most frequently consumed by Gentoo penguins (18.2 ± 1.8 cm and 15–17.5 cm, respectively) (Thompson et al. 1998, Clausen et al. 2005) (Fig. 2). Therefore, our results indicate some degree
of trophic overlap between SAFS and other upper-trophic level marine predators at the Falkland Islands, at least in October. Trophic overlap is probably mediated by interspecies differences in foraging behavior (e.g., time of day, dive depth) and/or spatial partitioning of foraging areas (e.g., Masello et al. 2010). However, commercial fisheries at the Falkland Islands may have important consequences for competitive interactions (e.g., Gómez-Campos et al. 2011).

The second most frequently occurring fish in SAFS diet was *Patagonotothen* spp. Rock cod (the most abundant *Patagonotothen*) and Patagonian longfin squid are commercially important species to the region’s fisheries. The rock cod fishery was established in 2007 and is now the largest fin-fish fishery by biomass at the Falkland Islands (Winter et al. 2010). Patagonian longfin squid is one of two major squid fisheries (Falkland Islands Government 2012). SAFS are rarely reported as bycatch in commercial fisheries at the Falkland Islands, implying operational (direct) interactions between fishing gear and SAFS are limited. However, the occurrence of *Patagonotothen* spp. and Patagonian longfin squid in SAFS diet suggests resource competition exists between commercial fisheries. The paucity of our data prevents a suitable comparison. Nevertheless, it is interesting to note the estimated length of Patagonian longfin squid consumed by SAFS in October was similar to the length of commercially caught squid in 2010 (80% of the commercial catch was 10–16 cm squid) (Falkland Islands Government 2012). In addition, the length of *Patagonotothen* spp. consumed by SAFS in October (19.6 ± 4.2 cm) overlapped with the length of commercially caught rock cod (rock cod of <20 cm in length accounted for 20% of

### Table 1. Prey species recovered from the scats of South American fur seals (*Arctophoca australis australis*) at the Falkland Islands, presented as a simple percent frequency of occurrence (FO%) and split-sample frequency of occurrence (SSFO). Variable biomass reconstruction (VBR) was also calculated for the three main prey species and is presented in parentheses within the SSFO columns. Scats were collected from Bird Island in 2010 and Steeple Jason Island in 2011.

<table>
<thead>
<tr>
<th>Prey</th>
<th>Bird Island SSFO (VBR)</th>
<th>Steeple Jason Island SSFO (VBR)</th>
<th>Bird Island FO%</th>
<th>Steeple Jason Island FO%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Falkland mullet (<em>Eleginops maclovinus</em>)</td>
<td>0.7</td>
<td>0.5</td>
<td>1.8</td>
<td>1.4</td>
</tr>
<tr>
<td>Myctophid (<em>Gymnoscopelus nicholsi</em>)</td>
<td>0.8</td>
<td>0.0</td>
<td>2.7</td>
<td>0.0</td>
</tr>
<tr>
<td>Hoki (<em>Macruronus magellanicus</em>)</td>
<td>0.3</td>
<td>0.7</td>
<td>0.9</td>
<td>1.4</td>
</tr>
<tr>
<td>Common hake (<em>Merluccius hubsi</em>)</td>
<td>0.0</td>
<td>0.7</td>
<td>0.0</td>
<td>1.4</td>
</tr>
<tr>
<td>Southern blue whiting</td>
<td>0.3</td>
<td>1.4</td>
<td>0.9</td>
<td>1.4</td>
</tr>
<tr>
<td><em>Patagonotothen</em> spp.</td>
<td>9.3 (7.8)</td>
<td>26.0 (41.0)</td>
<td>22.5</td>
<td>39.1</td>
</tr>
<tr>
<td>Red cod (<em>Salilota australis</em>)</td>
<td>0.2</td>
<td>0.0</td>
<td>0.9</td>
<td>0.0</td>
</tr>
<tr>
<td>Falkland herring (<em>Sprattus fuguensis</em>)</td>
<td>40.4 (55.0)</td>
<td>40.5 (55.1)</td>
<td>78.4</td>
<td>56.5</td>
</tr>
<tr>
<td>Otoliths unknown, eroded and broken</td>
<td>19.7</td>
<td>16.6</td>
<td>48.6</td>
<td>31.9</td>
</tr>
<tr>
<td>Argentine shortfin squid (<em>Illex argentinus</em>)</td>
<td>0.9</td>
<td>0.0</td>
<td>1.8</td>
<td>0.0</td>
</tr>
<tr>
<td>Patagonian squid (<em>Loligo gahi</em>)</td>
<td>21.1 (37.2)</td>
<td>6.2 (3.9)</td>
<td>46.8</td>
<td>13</td>
</tr>
<tr>
<td><em>Monoteuthis ingens</em></td>
<td>1.6</td>
<td>4.1</td>
<td>6.3</td>
<td>8.7</td>
</tr>
<tr>
<td>Cephalopod unknown</td>
<td>2.9</td>
<td>1.8</td>
<td>9.9</td>
<td>5.8</td>
</tr>
<tr>
<td>Crustacean</td>
<td>1.8</td>
<td>1.6</td>
<td>4.5</td>
<td>2.9</td>
</tr>
<tr>
<td>Fish</td>
<td>69.0</td>
<td>85.0</td>
<td>91.9</td>
<td>95.7</td>
</tr>
<tr>
<td>Cephalopod</td>
<td>29.0</td>
<td>13.0</td>
<td>51.4</td>
<td>23.2</td>
</tr>
<tr>
<td>Crustacean</td>
<td>2.0</td>
<td>2.0</td>
<td>4.5</td>
<td>2.9</td>
</tr>
</tbody>
</table>
the total commercial catch in 2011) (Falkland Islands Government 2012). More detailed dietary studies are required in order to resolve the extent of competition between fisheries and SAFS for shared resources.

Crustaceans occurred infrequently in SAFS scats collected in October (Table 1). These results were surprising given lobster krill is thought to be the main prey of SAFS at the Falkland Islands and are abundant in October (Strange 1992, Clausen et al. 2005, Laptikhovsky 2009). Our findings may have been influenced by the inherent biases associated with using scats to quantify fur seal diet. For example, differential digestion of prey species, varying passage rates, and bias toward prey consumed at the end of the foraging trip, affects the accuracy of diet reconstruction (Dellinger and Trillmich 1988, Gales and Cheal 1992, Tollit et al. 1997, Staniland 2002, Baylis and Nichols 2009). However, near shore prey such as lobster krill are more likely to be over-represented in scats. Furthermore, Antarctic fur seal (A. gazella) feeding trials found that digestion did not influence the recovery of Euphausia superba carapaces from scats (Staniland 2002). This implies if lobster krill were consumed by SAFS, their carapaces should have been reliably recovered from scats.

The small proportion of scats that contained crustaceans in our study may reflect fish and squid being more abundant or preferred SAFS prey in October. Although available throughout the year, lobster krill abundance is greatest in January–March

Figure 2. Estimated length frequency distribution of Patagonian longfin squid (Loligo gahi), Falkland herring (Sprattus fugensis), and Patagonotothen spp. consumed by South American fur seals (Arctophoca australis australis) at the Falkland Islands.
when post larval lobster krill aggregate in dense shoals (Falkland Islands Fisheries Department, unpublished data). Intuitively, sampling over a longer temporal scale would reveal seasonal variation in the diet of SAFS related to seasonal changes in abundance, distribution, and composition of prey, as reported for many other fur seal species including SAFS breeding in Uruguay (Naya et al. 2002).

Significant differences in the occurrence of prey species were also found between scats collected at Bird Island and Steeple Jason Island. Most notably, Patagonian longfin squid occurred more frequently in scats from Bird Island, whereas Patagonotothen spp. occurred more frequently in scats from Steeple Jason Island (SSFO: \( \chi^2 = 10.4, P < 0.01 \) and \( \chi^2 = 7.3, P < 0.01 \), respectively) (Table 1). Given scats were collected from Bird Island in 2010 and Steeple Jason Island in 2011, differences in SAFS diet between sites could reflect interannual differences in prey availability. For example, differences in the occurrence of Patagonian longfin squid between sites coincides with a 48% decline in the annual commercial catch of this species in 2011 (Falkland Islands Government 2012). This implies 2011 was a year of comparatively low squid recruitment and abundance compared with 2010.

Differences in the proximity of Bird Island and Steeple Jason Island to the continental slope (ca. 26 km and 63 km, respectively) may also influence SAFS diet, as reported for other fur seal species (e.g., Reid et al. 2006, Baylis and Nichols 2009, Call and Ream 2012). For example, oceanic myctophid fish (Cherel et al. 2002) were absent from Steeple Jason Island scats but present in scats collected at Bird Island, that is closer to the continental slope and oceanic waters. However, this hypothesis assumes that, like male northern (Callorhinus ursinus) (Sterling and Ream 2004) and Antarctic fur seals (Staniland and Robinson 2008), nonbreeding SAFS exhibit central place foraging tendencies and foraged in colony specific areas. Unfortunately we did not track the movements of SAFS during our study.

Although a snapshot, our study is the first to quantify SAFS diet at the Falkland Islands. Results indicate the potential for trophic overlap between commercial fisheries and other upper trophic level marine predators breeding at the Falkland Islands. Considering the rock cod fishery is a relatively new fishery (established in 2007) and that fisheries can be pervasive drivers of change in marine ecosystems (Lewison et al. 2012), a better understanding of SAFS ecology is warranted. Information on population size, population genetics and more detailed studies on foraging ecology are required to elucidate the conservation status and management requirements of the Falkland Islands’ subspecies and to establish a suitable baseline with which to measure change.

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Literature Cited


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