The relevance of fish in the summer diet of the Antarctic fur seal (Arctocephalus gazella) at Hope Bay, Antarctic Peninsula and Stranger Point, South Shetland Islands

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Research Article

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Abstract

The fish incidence, particularly notothenioids and myctophids, in the diet of non-breeding male *Arctocephalus gazella* in the western Antarctic Peninsula (AP) region is scarcely known. We made a comparative diet analysis on 158 faecal samples collected in summer 2005 at Hope Bay (HB), AP and at Stranger Point (SP), South Shetland Islands (SSI). The occurrence of Antarctic krill *Euphausia superba* and fish as prey was similar at HB, whereas krill was predominant at SP. For each fish species identified based on the otoliths found, their relative importance in the diet was evaluated using the IRI index. Notothenioid fish prevailed at HB: *Pleuragramma antarctica* was the most important prey followed by *Chaenodraco wilsoni*. Contrarily, myctophids predominated at SP: *Gymnoscelus nicholsi* and *Electrona antarctica* were the dominant prey. Both benthopelagic and pelagic fish species were represented at HB, while the latter were more important at SP; we suggest that seals from SP are foraging in pelagic strata, while at HB their habitat includes benthic and pelagic environments. Demersal nototheniid species were scarcely represented and only at HB, which might be related to a preference of fur seals on the more abundant pelagic prey there. At SP, the absence of demersal nototheniid otoliths in the faeces could be linked to the historical finfish fisheries that took place in the SSI area. On fish species consumption, there was a higher diversity at SP in comparison with HB but a low overlap between these sites. Our findings are compared with studies from localities of the AP and the Scotia Arc.

Introduction

Apex predators are key species of the ecosystem; in Antarctic marine communities, which have shorter food webs relative to other marine systems (Knox 1970), they can have pronounced effects often exerting an influence at several trophic levels (Estes et al. 2004; Reid et al. 2006). Understanding of the trophic relationships between predators and their prey allows to elucidate their function in the trophic chain and the subjacent factors influencing more or less diversified diets (Osman et al. 2004). In this context, marine predators can be effective samplers of prey populations; the analysis of the indigestible parts of the prey they consume, (e.g., fish otoliths, crustacean carapaces, cephalopod beaks) provides insights about their population structure and dynamics. This information is also used to address a broad range of important ecosystems concerned topics, from fisheries management to environmental change (Begg et al. 2005; Goebel et al. 2007; Klemmedson et al. 2020, Lowther et al. 2020).

The Antarctic fur seal *Arctocephalus gazella* (Peters 1875) has a widespread distribution in the Southern Ocean (Fischer and Hureau 1988), their breeding colonies occur mainly on islands south of the Antarctic Convergence, such as South Georgia, South Orkney, South Shetland, Heard and Kerguelen islands, with the exception of Marion, Crozet and Macquarie islands, which lie north of it (Reeves et al. 1992). Commercial sealing nearly wiped out this pinniped in the 18th and 19th centuries, but today it has recovered to an estimated population in excess of 6 million individuals (SCAR-EGS 2008; Daneri et al. 2019). The Antarctic fur seal is considered an important biological indicator by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) Ecosystem Monitoring Program (Agnew 1997). The information on their diet and feeding behaviour provides insights into the abundance and
distribution of commercially exploited species such as krill, as well as of poorly sampled species, like mesopelagic fishes (Reid et al. 2006; Klemmedson et al. 2020).

Studies of the feeding habits of this top predator have shown that, at least in the Atlantic sector of the Southern Ocean, the Antarctic krill *Euphausia superba* (Dana 1950) comprises the most abundant prey item, followed by various fish taxa and to a lesser extent, cephalopods. However, there are substantial differences in the relative proportions of the prey taxa, according to the age and sex of the seals, as well as between seasons and different localities (Casaux et al. 2003b; Daneri et al. 2005; Reid et al. 2006; Hofmeyr et al. 2010).

At the South Shetland Islands and the insular zones along the west Antarctic Peninsula, the fish component in the diet of *A. gazella* is dominated by the myctophids *Gymnoscelus nicholsi* (Gilbert 1911) and *Electrona antarctica* (Gunther 1878) and secondarily by notothenioid species, whereas at the tip of the Antarctic Peninsula there is a prevalence as prey of notothenioids over myctophids (Casaux et al. 1998; Daneri et al. 2008; Harrington et al. 2017), being the nototheniid *Pleuragramma antarctica* (Boulenger 1902) and the channichthyid *Chionodraco spp.* the most important fish prey (Casaux et al. 2003b; Reid et al. 2006; Daneri et al. 2009).

Historically, the fishing industry of finfish in the Antarctic began in the Atlantic sector in the 1960s, just as decades of sealing and whaling were ending (Kock 1992). In the southern Scotia Sea region (FAO Statistical Subarea 48.1) at the South Shetland Islands, heavy finfinning was carried out mainly in the northern coasts of Elephant Island and also in the north of Livingston and King George Island / Isla 25 de Mayo in the period 1977–1980, but catches from Joinville-D’Urville Islands, in the tip of the Antarctic Peninsula, were also reported (CCAMLR 1986). While the myctophids were not commercially exploited, the population of some notothenioid species, such as the mackerel icefish *Champsocephalus gunnari* (Lonnberg 1905), the humped rock cod *Gobionotothen gibberifrons* (Longberg 1905) and the marbled notothenia *Notothenia rossii* (Fischer 1885) were seriously depleted (Kock and Jones 2012; Marschoff et al. 2012; Barrera-Oro et al. 2017). The first two species were reported as prey of the Antarctic fur seal at the South Shetland Islands and at other islands of the Scotia Arc (Reid et al. 1995; Daneri et al. 1996; North et al. 1996; Casaux et al. 2004, 2015; Reid et al 2006), while *N. rossii* was registered as prey at South Georgia (Bonner 1968; North et al. 1983). It has been suggested that the limited occurrence of this and other shelf fish species in the diet of fur seals at the South Shetland Islands could be the consequence of the impact of the commercial fishery on notothenioid populations (Reid et al. 2006). In order to promote the recovery of exploited species CCAMLR closed the Subarea 48.1 since the 1990/1991 season to any finfinning (Barrera-Oro et al. 2000; CCAMLR 2017, 2019) and results from the most recent studies indicate that it cannot be reinstated (Barrera-Oro et al. 2017).

The purpose of this study is to examine, by means of scat analysis, the diet and feeding habits of non-breeding male Antarctic fur seals from Hope Bay, Antarctic Peninsula and Stranger Point, South Shetland Islands, with emphasis on its fish component. As both localities are in the same western Antarctic Peninsula region, but only the second was affected by the historical commercial finfish fishery, we also
discuss the possible incidence of this anthropogenic activity in *Arctocephalus gazella*’s dietary composition.

**Materials And Methods**

A total of 52 faeces of non-breeding male Antarctic fur seals was taken at the vicinity of Hope Bay, Antarctic Peninsula (63°24’S; 56°59’W). In this study, we also include samples from Stranger Point, King George Island/Isla 25 de Mayo, South Shetland Islands (62°14’S; 58°40’W) which were previously analyzed in Harrington et al. (2017). At both locations, the faeces were collected during January and February 2005 from the same sex-age group. Hope Bay is situated at Trinity Peninsula/Peninsula Trinidad on the northernmost point of the Antarctic continent; Stranger point is located in the southernmost point of Isla 25 de Mayo/King George Island within the Antarctic Specially Protected Area (ASPA) n°132 (Fig. 1).

Each scat was individually bagged and stored frozen at -20°C until processing. Once in the laboratory, samples were washed through a series of sieves of different mesh sizes (2.5–0.5 mm). Hard prey remains such as fish sagittal otoliths, cephalopod mandibles and crustacean carapaces were separated for identification and measurement. Prey remains were identified to the lowest possible taxonomic level using identification guides (Clarke 1986; Hecht 1987; Williams and McEldowney 1990; Xavier and Cherel 2021). The proportional frequency of occurrence (F%) of the main prey items (e.g., krill, fish, cephalopods) was calculated as the number of scats containing a prey taxon divided by the total number of samples containing prey remains. When otoliths and mandibles were not present, other hard remains such as fish bones and cephalopod eye lenses, which specific identification is not possible, were recorded. A chi-squared test was performed in order to detect geographical differences in the frequency of occurrence of the main taxa preyed on by the fur seals.

Sagittal otoliths were identified by comparison with reference collections and appropriate guides (Hecht 1987; Williams and McEldowney 1990; Reid 1996) and classified according to their degree of erosion into three different categories: 1) Good – little or no erosion; 2) Fair – some signs of smoothing on the edges; 3) Poor – heavily eroded with rounded margins. Otolith lengths were measured with a digital caliper to the nearest 0.01 mm and a correction factor was applied to account the erosion in the digestive process (10% for group 1 and 20% for group 2) after Reid (1995). Markedly eroded or broken items, which often were impossible to identify, were discarded. Fish standard length and mass were estimated using regression equations published in Hecht (1987) and in Williams and McEldowney (1990). For each fish species identified the relative importance in the diet was evaluated in terms of F% frequency of occurrence, N% numerical abundance and W% weight composition. All three measures were combined to estimate the index of relative importance (IRI) (Pinkas et al. 1971); for an easier interpretation, this index was expressed on a percent basis (IRI%) (Cortes 1997). A Kruskal Wallis test was used to evaluate differences in the estimated standard length of the fish species common to both locations.
Cephalopod beaks were identified after Xavier and Cherel (2021); lower beaks were used to relate the lower rostral length (mm) to dorsal cephalopod mantle length (mm) using allometric equations (Rodhouse et al. 1992).

Finally, Shannon’s diversity index (Shannon and Weaver 1963) and Colwell and Futuyma index (Colwell and Futuyma 1971) were calculated in order to compare the diversity of the fish prey taxa and the potential niche similarity between the seals of the different sampling sites. Shannon-Wiener index has a minimum value of 0, when there is no diversity, and increases as the richness and the evenness of the community do so. Colwell and Futuyma index takes a minimum value of 0 when species share no resource states, and its maximum of 1 when the proportional distributions of the two species among the resource states are the same.

**Results**

The Antarctic krill *Euphausia superba* was the most frequent prey item at both study sites, with an occurrence of 75% at Hope Bay and 83% at Stranger Point (Table 1). Fish were present in 73% and 33.2% of scats respectively. Of lesser importance were cephalopods, 7.7% and 4.7%; and penguins, which only occurred at Stranger Point in 3.8% of samples. There were significant differences in the frequency of occurrence of these four prey taxa between the two sampling locations ($X^2_2 = 12.53, p < 0.01$).

<table>
<thead>
<tr>
<th>Prey taxon</th>
<th>Hope Bay (n = 52)</th>
<th>Stranger Point (n = 106)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Krill</td>
<td>75.0</td>
<td>83.0</td>
</tr>
<tr>
<td>Fish</td>
<td>73.1</td>
<td>34.9</td>
</tr>
<tr>
<td>Cephalopods</td>
<td>7.7</td>
<td>4.7</td>
</tr>
<tr>
<td>Penguins</td>
<td>0.0</td>
<td>3.8</td>
</tr>
</tbody>
</table>

Fish were represented in the diet by a total of 514 otoliths (n = 397 at Hope Bay, n = 117 at Stranger Point) at a rate of 12 and 3.34 otoliths per sample containing prey remains respectively. Considering both localities combined, ten species belonging to four families were represented in the scats. However, their relative contribution to the diet of seals varied geographically. Notothenioid species were dominant at Hope Bay; *P. antarctica* was the most frequent and abundant, followed by the channichthyid *Chaenodraco wilsoni* (Regan 1914). These species were also the main contributors in terms of biomass. Conversely, myctophids predominated at Stranger Point, with *E. antarctica* as the most frequent, followed
by *G. nicholsi* and *P. antarctica*. The two myctophid species were the most abundant at this location, but *G. nicholsi* was dominant in terms of biomass. The index of relative importance showed that *P. antarctica* was the most important fish species preyed upon by fur seals at Hope Bay, while *G. nicholsi* and *E. antarctica* were equally important at Stranger Point (Table 2).

Table 2
Composition of fish otoliths recovered from the scats of non-breeding male fur seals *Arctocephalus gazella* at Hope Bay, Antarctic Peninsula and Stranger Point, South Shetland Islands in summer 2005, expressed as percentage of frequency of occurrence (F%), percentage of the total number (N%), percentage of the total wet weight (W%) and percentage of index of relative importance (IRI%). Sample size in parenthesis.

<table>
<thead>
<tr>
<th>Fish prey taxon</th>
<th>Hope bay</th>
<th>Stranger Point</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F%</td>
<td>N%</td>
</tr>
<tr>
<td>No id.</td>
<td>2.9</td>
<td>0.3</td>
</tr>
<tr>
<td>Myctophidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Electrona antarctica</em></td>
<td>55.9</td>
<td>32.5</td>
</tr>
<tr>
<td><em>Gymnoscopelus nicholsi</em></td>
<td>32.4</td>
<td>33.3</td>
</tr>
<tr>
<td><em>Gymnoscopelus braueri</em></td>
<td>5.9</td>
<td>1.7</td>
</tr>
<tr>
<td><em>Protomyctophum tenisoni</em></td>
<td>5.9</td>
<td>1.7</td>
</tr>
<tr>
<td>Channichthyidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Chaenodraco wilsoni</em></td>
<td>34.3</td>
<td>17.9</td>
</tr>
<tr>
<td><em>Chionodraco myersi</em></td>
<td>17.1</td>
<td>5.8</td>
</tr>
<tr>
<td><em>Channichthyidae sp.</em></td>
<td>22.9</td>
<td>8.3</td>
</tr>
<tr>
<td>Nototheniidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Pleuragramma antarctica</em></td>
<td>82.9</td>
<td>62.5</td>
</tr>
<tr>
<td><em>Trematomus/Pagothenia</em></td>
<td>8.6</td>
<td>5.3</td>
</tr>
<tr>
<td>Paralepididae</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Notolepis coatsi</em></td>
<td>8.8</td>
<td>6.0</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

The estimated standard length of the fish consumed ranged from 48.4 mm (*E. antarctica*) to 267 mm (*C. wilsoni*) (Table 3). Within species, only *P antarctica* was present in the scats collected at both sampling sites; the estimated size frequency distribution of individuals of this species discriminated by locality is shown in Fig. 2. There were no significant differences between localities in the sizes of *P. antarctica*
specimens preyed upon by fur seals (Kruskal Wallis $p = 0.25$); modal size class was 140–150 mm in both cases.

Table 3
Estimated standard length (mm) of the fish represented by otoliths in scats of non-breeding male fur seals (Arctocephalus gazella) at Hope Bay, Antarctic Peninsula and Stranger Point, South Shetland Islands in summer 2005. Sample size in parenthesis.

<table>
<thead>
<tr>
<th>Fish taxon</th>
<th>Standard length (mm)</th>
<th>Hope Bay (n = 52)</th>
<th>Stranger Point (n = 106)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Range</td>
<td>Mean ± SD</td>
</tr>
<tr>
<td>Myctophidae</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrona antarctica</td>
<td>79.4 ± 4.8</td>
<td>48.4–107.1</td>
<td></td>
</tr>
<tr>
<td>Gymnoscopelus nicholsi</td>
<td>147.6 ± 10.6</td>
<td>126.5–172.5</td>
<td></td>
</tr>
<tr>
<td>Channichthyidae</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chaenodraco wilsoni</td>
<td>201.4 ± 22.4</td>
<td>124.4–267</td>
<td></td>
</tr>
<tr>
<td>Nototheniidae</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pleuragramma antarctica</td>
<td>152.3 ± 27.6</td>
<td>81.9–216.1</td>
<td>145.1 ± 13.5</td>
</tr>
</tbody>
</table>

Among Cephalopods, octopods of the genus Adelieledone were the only taxa identified in faeces from Hope Bay, represented by 9 beaks (5 superior, 4 inferior). The average lower beak measurement was 2.6 mm, representing specimens of 39.6 mm and 51.2 g average mantle length and mass, respectively. Cephalopod identification was not possible in Stranger Point samples, 3 scats contained eye lenses, but no beaks.

The value of Shannon’s diversity index was 0.74 for Hope Bay and 1.48 for Stranger Point. Colwell and Futuyma index was 0.23.

**Discussion**

In agreement with previous studies carried out at the western Antarctic Peninsula area (Daneri and Carlini 1999; Casaux et al. 2003b; Reid et al. 2006; Harrington et al. 2017; Descalzo et al. 2021) krill and fish were the main taxa preyed on by A. gazella. Our results showed variability on the frequency of occurrence of the main prey taxa consumed by non-breeding male Antarctic fur seals at the sampled locations; krill and fish had a similar frequency of occurrence at Hope Bay, whereas krill was the dominant prey item at Stranger Point. The presence of cephalopods was relatively low in both sites; penguin remains were only found at Stranger Point.
Overall, the fish prey diversity was similar to that reported for other localities of the Scotia Arc and the Antarctic Peninsula (Daneri and Carlini 1999; Casaux et al. 2003a, 2003b; Osman 2004; Ciaputa and Sicinski 2006; Reid et al. 2006; Garcia-Garin et al. 2020). The fur seal diets showed a considerable difference in the fish species composition and their index of relative importance between our sampling sites. At Hope Bay the Antarctic silverfish had the highest IRI%, followed by *C. wilsoni*. At Stranger Point instead, *G. nicholsi* and *E. antarctica* were the most important prey target, followed by *P. antarctica*.

Sexual maturity is attained at lengths of 160–180 mm in *G. nicholsi*, 74 mm in *E. antarctica*, 125–140 mm in *P. antarctica*, and 230 mm in *C. wilsoni* (Gon and Heemstra 1990; Burns et al. 1998). The total fish lengths estimated in this work showed that *A. gazella* preyed upon mature stages of *P. antarctica* and *E. antarctica* and immature stages of *G. nicholsi* and *C. wilsoni*. Similar fish ontogenetic stages were represented in the diets of fur seals from different colonies of the South Shetland Islands and the Antarctic Peninsula (Casaux et al. 2003a, 2003b; Osman et al. 2004; Descalzo et al. 2021). *P. antarctica* inhabits pelagic waters over and near the bottom of the Antarctic continental shelf (Gon and Heemstra 1990; Pinkerton 2017). *C. wilsoni* is a bentho-pelagic species, found in shallow waters; pelagic juveniles inhabit nearshore surface waters (Iwawmi and Kock 1990; Gon and Heemstra 1990). *E. antarctica* is mesopelagic, bounded on the north by the Antarctic Polar Front and in the south by the Antarctic continental shelf (Greely et al. 1999). *G. nicholsi* is present in waters around South Georgia and central Scotia Sea, juveniles are found in open ocean and are mesopelagic (Gon and Heemstra 1990; Klemmedson et al. 2020). In summary, and in agreement with literature data, all the fish species represented in the diet of Antarctic fur seals in this study are permanent or temporary pelagic species that were likely preyed on in the water column. It is known that these fish taxa are krill feeding species, commonly associated with krill swarms (Williams 1985; Fischer and Hureau 1988; Williams and McEldowney 1990).

At Hope Bay, the cephalopods were represented by benthic octopods of the genus *Adelieledone*. These species live on the continental shelf, feeding on amphipods and polychaetes (Allock et al. 2003; Piatkowski et al. 2003; Buring et al. 2019). Even though we were not able to identify the cephalopods consumed at Stranger Point, previous studies from this site have shown that *A. gazella* feeds on subadult squids that inhabit surface waters, such as *Slozarsykovia circumantarctica* (formerly known as *Brachioteuthis picta*) and *Psychroteuthis glacialis* (Daneri et al. 1999; Harrington et al. 2017)

The value of Colwell and Futuyma index points towards a low overlap in fish resource utilization between sites. Shannon-Weiner species diversity index was higher at Stranger Point in comparison with Hope Bay, indicating a major diversity in fish prey consumption at the first location.

In the Antarctic Peninsula, the only sites from which information on the diet of *A. gazella* is available are Hope Bay (Casaux et al. 2003b) and Danco Coast (Casaux et al. 2003a), on the tip and the west coast of the Antarctic Peninsula respectively. At Hope Bay, krill and fish were equally important during the 1999/2000 summer season (%F = 55). In contrast, at Danco Coast, fish was in average the dominant component during the 1998 and 2000 seasons (%F = 92) followed by krill (%F = 74). Hence, our findings...
at Hope Bay in summer of 2005 agree with previous literature data. The differences observed when comparing with Stranger Point, where krill was dominant, could be related to a dissimilar prey availability within the seal's foraging areas at different localities. The absence of recent studies in the Peninsula prevents further analysis.

Our study was carried out in coincidence with an El Niño event which occurred during the winter 2004-summer 2004/2005. Multiple authors speculated that in years when krill is less common in the diet of seals, like those of El Niño events, the incidence of other prey items, such as squid and penguins, become more important (Reid 1996; McCafferty et al. 1998; Daneri et al. 2008). As an example, during the summer of 1998 Daneri et al. (2008) found that fish was the major item consumed by male fur seals at King George Island, along with higher frequency of squid and penguins and a decrease in the occurrence of krill. As mentioned above, similar changes on the diet of fur seals have been observed in Danco Coast during the same season (Casaux et al. 2003a). This variation in the diet composition of the seals coincided with one of the strongest El Niño ENSO events of the twentieth century (McPhaden 1999).

Nevertheless, our results do not show variation to other studies in the area; which could be explained by the short duration and low intensity of the El Niño event that occurred in 2004–2005 (Harrington et al. 2017).

Particularly for the fish component and in agreement with our results, Casaux et al. (2003b) found that at Hope Bay, P. antarctica was the dominant species (%F = 39, %W = 87) followed by C. wilsoni (%F = 9). At Danco Coast, Chionodraco rastrosimus, C. wilsoni and P. antarctica constituted, in average, the bulk of the diet during the 1998 and 2000 seasons (%W = 25, 24 and 23 respectively). E. antarctica was, in average, the most frequent fish prey, along with P. antarctica (%F = 62 and 48) (Casaux et al. 2003a). At South Shetland Islands, there are no records of N. rossii and only a few of G. gibberifrons in the diet of A. gazella (Daneri 1996; Casaux et al. 1998; Casaux et al. 2004), even when they represent energetically important prey (Barrera-Oro 2002). Recent data on the status of these fish species in the Archipelago indicates a slow but continuous increase in the abundance of N. rossii, and a further decline in recruitment of G. gibberifrons (Kock et al. 2007a; Kock and Jones 2012; Marschoff et al. 2012; Barrera-Oro et al. 2017; Arana et al. 2020; Hollyman et al. 2021).

Interestingly, at the South Georgia Islands, remains of juvenile N. rossii were commonly found in fur seal scats collected during the period 1957–1963, that is to say, well before the onset of the big extractions of finfish from the ecosystem (Bonner 1968). On the contrary, during the impact of the commercial finfish fishery from the late 1960s up to the mid-1980s (Kock 1992), N. rossii and G gibberifrons were almost absent as prey (1 and 3 otoliths found respectively) along with a dominance of C. gunnari in the fur seals diet in summer (North et al. 1983). In agreement with the suggestion by North et al. (1983), it is possible that the predominantly benthic habit of the two nototheniid species and their reduction in abundance at both areas during the intense industrial fishery period, made them less suitable prey for fur seals, which in turn, choose pelagic resources that are more abundant and have a higher energy return (Barrera-Oro 2002; Casaux et al. 2015). Nevertheless, G. gibberifrons was abundant in the diets examined during the winter seasons of 1983, 1992 and 1993 (Reid et al. 1995; North et al. 1996). A similar pattern was observed at
the South Orkney Islands, during the summer of 1995, 2000 and 2001, a decade after the end of the heavy fishery activities in this area (1978–1985). During the three seasons demersal fish dominated the diet, being *G. gibberifrons* the species that most contributed (Casaux et al. 2015). *A. gazella* is an opportunistic feeder, changes in its diet are likely to reflect the local prey availability; it is probable that in seasons of scarce pelagic prey demersal species represent an alternative food intake (Casaux et al. 2003b).

It is worth to note that, at the South Shetlands, *N. rossii* and *G. gibberifrons* have been also absent or scarcely represented in the diet of another high predator of the food web, such as Antarctic shag *Phalacrocorax bransfieldensis* (Casaux and Barrera-Oro 2006). These birds inhabit the Antarctic Peninsula and the South Shetland Islands, constituting inshore demersal notothenioid fish their main prey (Casaux and Barrera-Oro 1993; 2006). In contrast, at Danco Coast, *G. gibberifrons* shows a high occurrence in both, the diet of shags and in trammel net catches (Casaux et al. 2002; Casaux and Barrera-Oro 2006, 2016), reflecting its higher availability in areas far from the main historical fishing grounds (Kock 1992; Casaux and Barrera-Oro 2006; Marschoff et al. 2012). The geographical distribution of *N. rossii* barely reaches the northern end of Antarctic Peninsula (DeWitt et al. 1990) explaining their low frequency in the shags diet. In our study, the absence of *G. gibberifrons*’ otoliths in the faeces from Hope Bay might be related to a preference of fur seals on their more common pelagic prey - krill and fish – which were available in the area during the sampling season. Notwithstanding, it is worth mentioning that, judging from the cephalopod prey identified (octopods), seals also foraged on benthic habitats.

The variability in fish consumption by *A. gazella* we found between sites was also reported by Casaux et al. (2003b) and Reid et al. (2006) when comparing dietary data among colonies of the Atlantic sector of the Southern Ocean. In both studies, it was observed that the contribution of notothenioid species tends to increase to the south, in the Antarctic Peninsula, whereas myctophids were dominant in the diet of seals from the South Orkney and South Shetland Islands. In these last two locations, the high predominance of myctophids over demersal notothenioids as Antarctic fur seals’ prey is likely linked with an historical anthropogenic effect – commercial fishery- on the second fish group. On the other hand, the Antarctic Peninsula is surrounded on its north and west side by broad continental shelf of about 200 km wide and 430 m average depth (Ducklow et al. 2007). On the contrary, the southern side of the South Shetland Islands runs along a pronounced slope, which makes the continental shelf practically inexistent (Acosta et al. 1989). The Archipelago is separated from the Antarctic Peninsula by the deep waters of the Bransfield Strait (1100–2000 m) (Kock et al. 2000). Considering these differences, we also suggest that seals from Stranger Point are foraging in pelagic strata on the nearby of the Archipelago while in Hope Bay their range of foraging habitats is broader, including benthic and pelagic environments.

**Declarations**

**Author Contribution Statement:** GD and EBO conceived and designed research. Sample collection was performed by JN and GD. AH, AN and AC analyzed the samples. MD analyzed the data. MD, GD and EBO wrote the manuscript. All authors read and approved the manuscript.
Conflict of interest: The procedures carried out during this work were in accordance with the ethical standards of the Argentine Antarctic Institute and the Scientific Committee on Antarctic Research (SCAR) Code of Conduct (CoC). All applicable international, national, and/or institutional guidelines for the care and use of animals were applied conform to the Code of Ethics of Animal Experimentation in Antarctica. All authors declare no conflict of interest.

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Figures
Figure 1

The studied areas at Hope Bay, Antarctic Peninsula and Stranger Point, King George Island/Isla 25 de Mayo, South Shetland Islands.
Figure 2

Estimated standard length frequency distribution for *Pleuragramma antarctica*, preyed on by Antarctic fur seals *Arctocephalus gazella* at Hope Bay, Antarctic Peninsula and Stranger Point, South Shetland Islands, in summer 2005.