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New Zealand (NZ) sea lions (*Phocarctos hookeri*) are slowly recolonising the Otago coast, South Island, New Zealand. The increase in their numbers may lead to resource competition with other marine predators and fisheries. We determined the diet of female NZ sea lions at Otago during autumn. In total, 571 scats and 110 regurgitations were collected on Otago Peninsula during 2008 and 2009. Barracouta (*Thyrsites atun*) and jack mackerel (*Trachurus* sp.) were the two main prey species and accounted for 26% and 31% of the reconstituted biomass, respectively. This was consistent between two years. Only five other species contributed $> 5\%$ of the diet by biomass in either year. Prey species are all found on the narrow continental shelf surrounding Otago Peninsula. The main prey species of Otago NZ sea lions may be of higher energy content than prey in the Auckland Islands (remnant breeding area). Resource overlap with other marine predators and fisheries appears to occur around Otago Peninsula. A marine trophic model of the area off Otago Peninsula would help understanding potential competition between marine predators and fisheries in this area.

Keywords: pinniped; prey species; foraging; competition; recolonisation; feeding; Otago Peninsula; Hooker's sea lion; New Zealand sea lion; *Phocarctos hookeri*

Introduction

Investigating the diet of animals allows an understanding of their needs in term of prey availability and quality (Capitani et al. 2004; McKenzie & Wynne 2008; Herreman et al. 2009; Chilvers et al. 2010). Firstly, prey species vary geographically, have different handling times and risks, and do not all have the same energy content (Rosen & Trites 2000; Bowen et al. 2002; Meynier, Morel, Mackenzie et al. 2008). Secondly, large marine predators can compete for resources with fisheries (Bjørge et al. 2002; Alonzo et al. 2003; Wilkinson et al. 2003; Huckstadt & Krautz 2004). Knowing the diet of marine mammals can consequently improve our understanding of their habitat needs and help manage their interactions with fisheries.

New Zealand (NZ) sea lions, *Phocarctos hookeri* (Gray 1844), were extirpated from the New Zealand mainland by the 1830s but they have now started recolonising the Otago coast, on the east coast of the South Island of New Zealand, for approximately 50 years (Wilson 1979; Childerhouse & Gales 1998; McConkey, Heinrich et al. 2002). However, consistent breeding only started in 1994 on Otago Peninsula (45°50′S, 172°00″E; McConkey, McConnell et al. 2002). Up to 2010, 45 pups had been born there (Augé 2010). A population of large marine predators is consequently increasing in number and may compete with other marine predators

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and fisheries. Resource competition can significantly affect established populations of smaller and less competitive species when a larger species that was previously absent re-establishes in an area (Herreman et al. 2009; Richard et al. 2010). Otago Peninsula is a breeding area for the endangered yellow-eyed penguin (*Megadyptes antipodes*) (Seddon et al. 1989) and for the New Zealand fur seal (*Arctocephalus fosteri*) (minimum estimate of 20,000 fur seals [Lalas 2008]). The recolonisation of the area by NZ sea lions may affect these populations.

In this paper, we determined the diet of female NZ sea lions based at Otago Peninsula, southeast South Island, New Zealand, during autumn using undigested prey remains in scats and regurgitations. The identification of undigested remains of prey (bones, body parts, feathers etc.) in scats and regurgitations is commonly used to investigate the diet of carnivores, including pinnipeds, as it is non-invasive, low-cost, and samples can easily be collected on land (McLellan & Hovey 1995; Capitani et al. 2004; Ruhe et al. 2008; Paralikidis et al. 2010). By identifying remains in these samples, the prey species, number of prey species and sizes of prey can be determined, hence revealing the diet of the animals. Typically, the identification is only conducted on otoliths for fish, and on beaks for cephalopods (McKenzie & Wynne 2008) but the digestion of otoliths is species-dependant and this overestimates the amount of larger fish (Browne et al. 2002). Along with otoliths, the identification of other species-specific remains increases the accuracy of the method by detecting more prey items, including from species that were not present or under-represented in the reconstructed diet using otoliths only (Browne et al. 2002; Tollit et al. 2003; Tollit et al. 2007; Trites & Calkins 2008). While some studies have only used scat samples, there is a large bias against larger fish and cephalopods in this case and the combination of scats and regurgitations appears to represent the diet of pinnipeds more reliably (Lalas 1997). It is possible to estimate length and mass of prey from the size of remains whenever allometric relationships are available. In case several different bones from the same species are found in a sample, these prey size estimates can be used to determine from how many different prey they came from. Along with direct counts of parts when only single remains per species were found, this enables the estimation of the minimum number of prey of each species that were taken. Biomass reconstruction calculated from the mass estimates of prey provides a more accurate assessment of diet than frequencies of occurrence in samples or numerical abundances of prey when looking at energy intake and resource overlap based on available biomass (Tollit et al. 2007).

Potential competition between fisheries and NZ sea lions around the main remnant breeding areas of NZ sea lions in the Auckland Islands (50°40′S, 166°10″E) is of concern as fisheries may affect the resource availability of prey species of sea lions (Childerhouse et al. 2001; Meynier et al. 2009; Meynier et al. 2010; Robertson & Chilvers 2011). It is, therefore, important to determine the likelihood of this situation around Otago Peninsula as the population grows. This will allow precautionary management decisions to ensure the establishment of new breeding colonies on the New Zealand mainland as this is the main step to remove the species from its ‘nationally critical’ conservation status (Department of Conservation 2009; Baker et al. 2010). The diet of male NZ sea lions was previously investigated on Otago Peninsula (Lalas 1997). However, sexual segregation in diet is often found in pinniped species (Beck, Iverson et al. 2007; Meynier, Morel, Chilvers et al. 2008; Trites & Calkins 2008; Breed et al. 2009). Consequently, the investigation of the diet of the female component of the Otago population was essential.

Material and methods

Scats and regurgitations of female NZ sea lions were collected from 23 March to 28 May 2008 and 2009 at Victory Beach and Papanui Inlet (45°50′S, 170°43″E) on Otago Peninsula. This area was the main site used by all Otago-born female NZ sea lions aged two years and over in 2008 ($n = 14$) during this study period, and was where all lactating females nursed their pups (Augé 2010). Consequently, the entire population of females from Otago Peninsula was sampled. When a female sea lion was found, any fresh scat or regurgitation nearby was collected in a zip-lock plastic bag (Minigrip Redline, Kennesaw, USA). The study area was searched at least twice daily and females' locations and identities (each female could be individually identified, see Augé [2010]) were recorded. Occasionally, males were found in a part of the area, in which case samples were not collected and all scats or regurgitations found in this part were covered with soil or vegetation so they were not re-sampled later. Regurgitation samples were kept chilled after collection, and later stored in a -20 °C freezer within 1–5 days of collection and until further analyses to avoid putrefaction of flesh often present. Scat samples were soaked in water with liquid detergent (laundry soap) in zip-lock plastic bags for up to a week to allow the soft part of the scats to break down. The undigested remains in scats were recovered by washing the contents of the bags with water through a sieve of mesh size 0.6 mm. All remains collected were stored in fresh water in small bottles and kept in a fridge until further analysis. Regurgitations were placed in large containers in water with detergent the day before identification process, and sieved with the same mesh size as the scats before identification. All scat and regurgitation samples from each female during one year were gathered and organised by date so that each sample could be attributed to a foraging trip (i.e. period at sea) based on presence–absence of the females in the study area. This limited the bias of repetitive sampling of the same prey in multiple scats or regurgitations. Foraging trip was defined as the sampling unit in the analyses.

All remains found after sieving were checked for possible identification. Those non-identifiable remains (either broken, too eroded or unknown) were discarded. The identification of the undigested remains was completed using the reference drawings in Furlani et al. (2007) for otoliths, in Leach (1997) for fish jaw bones, in Lu and Ickeringill (2003) and Lalas (2009) for beaks of cephalopods, and the private collection held by Chris Lalas for all remains of species not described in these references (this collection was used in Lalas [1997], Fea et al. [1999] and Mattern et al. [2009]). Cephalopods were mainly identified from beaks, but we also used undigested body parts (e.g., radula or arms) to assess the occurrence of this group. Otoliths and jaw bones were mainly used to determine fish species, although other parts contributed to more identifications than these in some species (e.g. lateral scutes of jack mackerel [*Trachurus* sp.], green bones of green-bone [*Odax pullus*], caudal peduncle and teeth of barracouta [*Thyrsites atun*], denticles of rough skate [*Raja nasuta*] and spines of spiny dogfish [*Squalus acanthias*]). The occurrence of crustaceans corresponded to the recovery of exoskeletal remains. Species of birds were identified from feathers and feet.

For remains with a set number in each prey but no allometric equation available or remains that were broken or too eroded to be measured, but were still identifiable, it was possible to determine the correspondent minimal number of prey ingested during the trip by identifying the side (left or right) of the structure whenever possible. Owing to the large amount of feathers often ingested during seabird predation, if a definite occurrence was detected during a foraging trip, the sole presence of a few feathers in the samples of the following trip was attributed to the previous occurrence. This allowed the determination of the minimal numerical abundance of each prey taken during each foraging trip. When allometric equations were available, the estimated fork length for fish and wet mass for all prey were calculated based on the remains. In this case, if all structures of the same species gave approximately similar sizes and there was no replication of the same structure, they were attributed to the same prey item. Allometric equations were from Leach et al. (1996) for barracouta, Leach, Davidson & Horwood (1997) for blue cod (*Parapercis colias*), Leach et al. (2001) for red cod (*Pseudophycis bachus*), Leach, Davidson, Samson et al. (1997) for wrasses, Labridae spp., Lalas (2009) for Maori octopus (*Macroctopus maorum*), and equations obtained from diagnostic structures in Furlani et al. (2007) or the reference collection held by Chris Lalas, for all other species.

The percentage of sampled foraging trips during which each prey species was identified (percentage of occurrence) and the minimal number of individuals of each prey species (numerical abundance) were determined. All numbers calculated for these two values are given as minimal numbers. The diet was described by calculating the percentage that a particular species contributed to the overall total reconstituted biomass of prey taken during each study season (percentage of reconstituted biomass).

Results

Totals of 166 and 405 scats and 42 and 68 regurgitations were collected, respectively in 2008 and 2009. At least one scat or regurgitation was collected for 104 foraging trips in 2008 and 154 foraging trips in 2009. We identified 386 prey in 2008, and 551 prey in 2009, from 38 different species including 27 fish, 2 cephalopods, 4 crustaceans, 3 seabirds and 2 salps. Twenty of the prey species were found during both years. Pieces of bryozoans were also detected during 21 foraging trips. Reconstituted biomasses added up to totals of 243 kg in 2008 and of 401 kg in 2009.

Only nine species were taken during more than 10% of the sampled foraging trips in any one year, and 22 species were represented by fewer than 10 individual prey items in the diet (Table 1). Barracouta and jack mackerel were taken during 40–60% of the foraging trips while all other species were found in less than 25% of the trips. Fourteen species were identified in the samples of only one individual (seven species during a single foraging trip).

Mean sizes of the prey species of female NZ sea lions at Otago are presented in Table 2. The largest prey species taken by female NZ sea lions at Otago consisted of yellow-eyed penguin (*Megadyptes antipodes*) (5.4 kg), and trumpeter (*Latris lineate*) (4.1 kg). Neither was found in the top five prey species of the diet, which made up 74.0% and 81.4% of the reconstituted biomass during 2008 and 2009. All other prey were less than 2.5 kg. All of the top five prey species in the diet were relatively large prey (range of mean masses 0.5–1.6 kg). During both study years, jack mackerel and barracouta were the main prey species, adding up to 51.0% and 62.5% of the total reconstituted biomass, in 2008 and 2009 respectively. Only four other species made up more than 5% of the female diet during any one year (Table 1).

From Table 1, the inter-annual difference in diet at the population level can be assessed. Percentages of trips and of reconstituted biomass can be compared between years. The numerical abundance cannot be directly compared, as the amount of sampled foraging trips differed between years. There was no difference in the percentages of reconstituted biomass made up by the prey species in the diet of female NZ sea lions between years. Consequently, the diet at the population level appeared similar in 2008 and 2009. This similarity, however, relied in a large part on the high proportions made by barracouta and jack mackerel in the diet as there was a difference between years for prey species of lower importance in the diet. The third to sixth prey species in order of importance in the diet, constituting more than 5% of the diet of the population in any one year, varied. Species making up less than 5% also varied between years, especially in numerical abundance, as they had small sizes (Table 2).

Table 1 Diet of the female population of New Zealand sea lions in autumns 2008 and 2009 on Otago Peninsula, New Zealand. Species ranked by biomass in the diet for the two years combined.

Common name	Species	Percentage of occurrence		Numerical abundance		Percentage of biomass	
		2008	2009	2008	2009	2008	2009
Barracouta	*Thyrsites atun*	43.3	58.4	49	110	24.8	33.4
Jack mackerel	*Trachurus* sp.	57.7	57.1	52	95	26.2	29.1
Arrow squid	*Nototodarus sloanii*	20.2	13.6	68	27	15.2	3.7
Red cod	*Pseudophycis bachus*	3.8	22.7	4	50	1.3	9.8
Maori octopus	*Macroctopus maorum*	12.5	9.1	13	15	6.5	5.4
Yellow-eyed penguin	*Megadyptes antipodes*	2.9	1.9	3	2	6.8	2.8
Wrasses	*Labridae, two* spp.	21.2	16.2	24	38	3.5	3.4
Greenbone	*Odax pullus*	11.5	9.7	12	16	3.6	2.9
Blue cod	*Parapercis colias*	24.0	16.2	31	37	2.8	2.0
Little penguin	*Eudyptula minor*	1.9	3.2	2	6	1.2	2.3
Ling	*Genypterus blacodes*	3.8	–	4	–	3.3	–
Trumpeter[1]	*Latris lineata*	–	0.6	–	2	–	2.1
Rough skate[1]	*Raja nasuta*	1.9	–	2	–	1.9	–
Yellow-eyed mullet	*Aldrichetta forsteri*	2.9	3.9	5	16	0.3	0.6
Spiny dogfish	*Squalus acanthias*	4.8	3.9	5	5	0.4	0.3
Catfish	*Crapatalus* sp.	1.9	1.3	4	3	0.5	0.2
Estuary stargazer	*Leptoscopus macropypus*	4.8	11.7	8	23	0.2	0.3
Spotted shag[1]	*Stictocarbo punctatus*	1.0	0.6	1	1	0.6	<0.1
Blue moki[1]	*Latridopsis ciliaris*	–	0.6	–	2	–	0.3
Rock cod	*Lotella rhacinus*	1.9	3.2	2	5	0.1	0.2
Witch	*Arnoglossus scapha*	1.0	4.5	1	20	<0.1	0.2
Lemon sole	*Pelotretis flavilatus*	1.9	1.3	2	2	0.2	0.1
Marblefish[1]	*Aplodactylus arctidens*	1.0	–	1	–	0.3	–
Paddle crab	*Ovalipes catharus*	3.8	5.2	4	10	0.1	0.1
Tarahiki[1]	*Nemadactylus macropterus*	–	0.6	–	1	–	0.2
Opalfish	*Hemerocoetes* sp.	–	1.9	–	4	–	0.2
Sprat	*Sprattus* sp.	6.7	–	75	–	0.2	–
Pigfish[1]	*Congiopodus leucopaecilus*	–	1.9	–	3	–	0.2
Lobster[1]	*Jasus edwardsii*	–	0.6	–	1	–	0.1
Common roughy[1]	*Paratrachichthys trailli*	–	3.9	–	24	–	0.1
Ahuru[1]	*Auchenoceros punctatus*	–	1.9	–	27	–	0.1
Flounder[1]	*Rhombosolea* sp.	1.0	–	1	–	<0.1	–
Camouflage crab[1]	*Notomithrax* sp.	–	0.6	–	1	–	<0.1
Garfish[1]	*Hyporhamphus ihi*	–	0.6	–	1	–	<0.1
Salp	*Two* spp.	6.7	1.3	14	5	<0.1	<0.1
Mantis shrimp[1]	*Squilla armata*	1.0	–	1	–	<0.1	–

Note: [1]Species taken by a single individual female sea lion.

Table 2 Mean sizes (including masses used to calculate the reconstituted masses) of prey species found in the diet of female New Zealand sea lions on Otago Peninsula, New Zealnd in autumns 2008 and 2009.

	Fork length for fish (cm) [1]			Mass (g) [2]				
Species	Mean ± se	Max.	Min.	Mean ± se	Max.	Min.	*n*	Mass (g) from references[3]
Ahuru	10.0 ± 3.9	18.8	5.5	8 ± 10	34	8	15	
Arrow squid	29.5 ± 3.3	36.8	22.5	543 ± 218	1218	214	54	
Barracouta	61.3 ± 13.3	87.3	38.1	1263 ± 728	3208	250	72	
Blue cod	23.3 ± 5.6	41.1	15.8	21 ± 177	506	51	16	
Blue moki								600
Camouflage crab				80			1	
Catfish	28.5 ± 10.0	32.0	18.7	125 ± 56	215	61	4	
Common roughy	3.4 ± 1.3	6.7	1.8	17 ± 12	51	8	14	
Estuary stargazer	16.6 ± 3.8	25.9	9.9	56 ± 39	161	25	19	
Flounder	17.7			120			1	
Garfish	25.1			36			1	
Greenbone	35.3 ± 8.2	49.0	23.3	734 ± 604	1869	100	12	
Jack mackerel	42.4 ± 6.3	50.1	26.5	1225 ± 232	1605	789	29	
Lemon sole	22.6 ± 15.4	38.8	8.1	225 ± 128	638	105	4	
Ling								2000
Little blue penguin								1100
Lobster								500
Mantis shrimp								10
Marblefish	32.8			778			1	
Maori octopus	14.4 ± 3.9	21.0	6.3	1441 ± 1013	3783	133	17	
Opalfish	35.5 ± 13.0	51.7	21.5	177 ± 124	399	46	4	
Paddle crab				57 ± 31	161	18	19	
Pigfish								200
Red cod	38.4 ± 8.9	49.3	25.5	781 ± 583	2437	64	36	
Rock cod	23.7 ± 5.1	29.2	25.5	162 ± 94	285	117	7	
Rough skate	69.5			2284			1	
Salp				< 1				
Spiny dogfish	39.7			217			1	
Spotted shag								1200
Wrasses	20.4 ± 8.1	33.2	5.8	356 ± 250	1093	31	44	
Sprat	8.6 ± 1.0	12.5	7.0	5 ± 3	20	3	61	
Tarahiki	34.0			714			1	
Trumpeter	63.7	65.2	62.3	4145	4430	3860	2	
Witch	17.3 ± 5.1	28.0	10.7	49 ± 51	173	9	14	
Yellow-eyed mullet	20.5 ± 3.8	28.7	18.8	155 ± 98	313	62	5	
Yellow-eyed penguin								5400

Notes: [1]For squid and octopus, this is the mantle length; [2]obtained from the undigested remains of this study; [3]obtained from references Ayling & Cox (1982), Robertson & Heather (1999), Paul (2000) and Paulin et al. (2001).

Discussion

Prey species of female NZ sea lions around Otago Peninsula

This first study of the diet of female NZ sea lions based on Otago Peninsula showed that barracouta and jack mackerel were the most consumed prey and likely represent critical prey species for female NZ sea lions during autumn at least. Only two other species (arrow squid and red cod) were taken in significant amounts by the female population of NZ sea lions at Otago (representing approximately 10% and over of reconstituted biomass during any one year; see Table 1). Barracouta and jack mackerel are pelagic but can be found near the seafloor from 0 to 200 m depth within the continental shelf (Ayling & Cox 1982). Both are schooling fish during the day but barracouta disperse at night, when they may be feeding at the bottom (O'Driscoll & McClatchie 1998). Arrow squid diurnally migrate in the water column from the bottom to surface waters over the continental shelf (Paul 2000). Red cod are demersal and abundant in any type of habitat from sand to rock at depths up to 150 m (Beentjes et al. 2002). The pieces of bryozoans found in several samples indicated that several females foraged in the bryozoan thickets found off Otago Peninsula (50–100 m deep, around 8–15 km offshore [Batson & Probert 2000]), at least during some foraging trips. No species predominantly living at more than 200 m depth (i.e. on the continental slope or beyond) were recorded in the prey remains from female NZ sea lions at Otago in autumn. This corroborates the results of a satellite tracking study on some of the Otago female NZ sea lions during autumns 2008 and 2009 as foraging mostly occurred in coastal waters and on the continental shelf in the area of bryozoan thickets (Augé et al. 2011).

Diets of any animal populations vary to accommodate usual seasonal variations in food resources (McLellan & Hovey 1995; Fea et al. 1999; Womble & Sigler 2006; McKenzie & Wynne 2008). Female NZ sea lions at Otago may also change prey species or the percentages that each species makes in their diet during the year. Lalas (1997) found significant differences in the diet of male NZ sea lions at Otago between seasons, with some prey species being taken only during specific months. Jack mackerel, one of the two main prey species in the diet of female NZ sea lions in autumn, is likely a migratory species and unusual off Otago outside summer and autumn (Lalas 1997; O'Driscoll & McClatchie 1998). Jack mackerel was absent from scats and regurgitations collected in winter at the beginning of July 2009 (H. Anderson, unpubl. data). This reinforces that this food resource is likely only available during summer and autumn and a seasonal variation in diet probably occurs.

It will be necessary to conduct a year-round diet study of female NZ sea lions at Otago over several years to determine the extent of dietary variations. However, in autumn 2010, the constant presence of several highly mobile juvenile and sub-adult males in the area where females were found prevented sample collection to investigate female diet from remains in scats and regurgitations. The increase in number of the breeding group of NZ sea lions at Otago Peninsula may make it harder to obtain samples from females only. Outside summer, female NZ sea lions in established breeding colonies typically disperse and become less gregarious (Augé et al. 2009) and this may still allow female diet studies using undigested remains. Investigation of the diet of female NZ sea lions could also be conducted by using more invasive methods such as fatty acid analyses of blubber or milk samples (Iverson et al. 1997; Iverson et al. 2004; Beck, Rea et al. 2007; Meynier, Morel, Chilvers et al. 2008; Cooper et al. 2009).

Female NZ sea lions based on Otago Peninsula were previously reported as feeding on yellow-eyed penguins and this raised concerns for the viability of particular local populations of this endangered seabird species (Lalas et al. 2007). We found that only two Otago-born New Zealand female sea lions preyed on seabirds, including yellow-eyed penguins, during each year. These two females were not mother and daughter and their respective daughters never fed on seabirds. The predation by NZ sea lions on yellow-eyed penguins consequently appears potentially to be an individually learnt behaviour that is not transmitted through generations.

Comparison with sub-Antarctic data

At Enderby Island, in the Auckland Islands, the diet of NZ sea lions by mass (based on the digested stomach content of by-caught adult females and juveniles of both sexes with no significant differences between all) was principally composed of octopus (27.8%), arrow squid (20.8%), hoki (*Macruronus novaezelandiae*) and hake (*Merluccius australis*) (together 19.2%), opalfish (*Hemerocoetes* sp.) (4.7%) and red cod (4.3%) (Meynier et al. 2009) during a similar season as our study (end of summer and autumn). This was consistent with the species found in faecal samples analysed by Childerhouse et al. (2001). The diet of NZ sea lions consequently differed between the Auckland Islands populations and Otago Peninsula females on the mainland of New Zealand. Jack mackerel and barracouta were taken only in negligible numbers at the Auckland Islands (Childerhouse et al. 2001; Meynier et al. 2009).

While the two main prey species of the Otago females (barracouta and jack mackerel, on average 57% of the diet) have energy content of 6.1 $kJ.g^{-1}$ and 7.6 $kJ.g^{-1}$, respectively (Pickston et al. 1982; Vlieg 1984), the two main prey species (octopus and squid, 49% of the diet) at the Auckland Islands have lower energy content on average ± sd (3.8 ± 0.4 $kJ.g^{-1}$ and 6.3 ± 0.6 $kJ.g^{-1}$, respectively) (Meynier, Morel, Mackenzie et al. 2008; Meynier et al. 2009). Cephalopods were part of the prey range of the Otago females but constituted only 20.2% and 13.6% of their diet each autumn (2008 and 2009, respectively). Consequently, the food resources at the Auckland Islands seem to be of lower quality than the food resources available to female NZ sea lions at Otago at least during autumn, potentially supporting the hypothesis that the Auckland Islands are marginal marine habitat for this species (Chilvers et al. 2006; Meynier et al. 2009). However, more studies on energy content of prey throughout the year and specifically off Otago Peninsula will be needed to confirm this.

Resource overlap with other marine predators

Male NZ sea lions are found at Otago most of the year, except during the breeding season (December and January) when many migrate to the breeding colonies in the Aucklands and Campbell Islands (McConkey, Heinrich et al. 2002; Robertson et al. 2006). The best estimate of the number of male NZ sea lions using Otago Peninsula is currently 75 (S. McConkey, New Zealand Sea Lion Trust, pers. comm.). Male NZ sea lions at Otago had a similar prey range as females during autumn, at least for the main prey species in the reconstituted biomass (Table 3), although they foraged on some deeper water species than females. Nevertheless, because male diet was investigated more than 10 years prior to this study, a concurrent comparative investigation of Otago male and female NZ sea lion diets during the same period is needed to determine the overlap. In many pinnipeds, males and females forage in different areas and/or have segregated diets (Koen et al. 2000; Beck, Iverson et al. 2007; Trites & Calkins 2008), including potentially NZ sea lions at the Auckland Islands (Meynier, Morel, Chilvers et al. 2008; Geschke & Chilvers 2009).

Southern elephant seals (*Mirounga leonine*), leopard seals (*Hydrurga leptonyx*), orcas (*Orcinus orca*), and several species of dolphins are only occasionally sighted at Otago (J. Fyfe, DOC Coastal Otago ranger, pers. comm.). Consequently, the only other large marine mammal that potentially competes for food resources with female NZ sea lions at Otago is the New Zealand fur seal. Fur seals breed in large numbers on Otago Peninsula (between 20,000 and 30,000 fur seals [Lalas 2008]). Their main prey varies

Table 3 Comparison of the top 10 prey species by percentage of biomass in the diet of male and female New Zealand sea lions at Otago Peninsula, New Zealand.

Females during autumn[1]		Males during autumn[2]		Males year-round[2]	
Prey species	% biomass	Prey species	% biomass	Prey species	% biomass
Barracouta	30	Jack mackerel	30	Barracouta	25
Jack mackerel	28	Barracouta	23	Maori octopus	14
Arrow squid	8	Maori octopus	16	Jack mackerel	13
Red cod	7	Ling	9	Skate	10
Maori octopus	6	Rough skate	7	Flounder	9
Yellow-eyed penguin	4	Red cod	3	Paddle crab	4
Wrasse	3	Greenbone	2	Ling	4
Greenbone	3	Flounder	1	Greenbone	4
Blue cod	2	Wrasse	1	Red cod	4
Little blue penguin	2	Paddle crab	<0.1	Brill	2
Total	93	Total	92	Total	90

Notes: [1]Present study (mean across the two study years); [2]Lalas (1997).

between arrow squid in summer and autumn, and barracouta, jack mackerel and octopus in winter and spring (Carey 1992; Fea et al. 1999). Red cod is taken during the entire year (Fea et al. 1999). Although resource overlap between fur seals and sea lions appeared limited during autumn, both predators may target similar species during half the year, and red cod all year. All diet studies on New Zealand fur seals were, however, conducted more than 10 years prior to this study. To assess possible competition between these two species, concurrent diet studies could be conducted.

The other marine predators inhabiting the Otago Pensinula are seabirds that all tend to forage near Otago Peninsula (McClatchie et al. 1989; Moore 1999). Yellow-eyed penguins nesting on Otago Peninsula feed mainly on blue cod (18.3% of reconstituted biomass), opalfish (28.6%), arrow squid (14.4%), and red cod (7.4% [Moore & Wakelin 1997]). Three of these species constituted a significant part of the diet of female NZ sea lions, indicating some resource overlap but penguins feed on smaller prey than sea lions (Moore & Wakelin 1997). Jack mackerel was not part of the diet of yellow-eyed penguins, and barracouta was rarely consumed (Moore & Wakelin 1997). Most other seabird species feed predominantly on small fish, krill and invertebrate larvae (McClatchie et al. 1989).

Resource overlap with recreational fisheries

Both recreational and commercial fisheries occur along the Otago coast. While commercial fishing is well documented by the Ministry of Fisheries, data on species and quantities taken by recreational fishermen are sparse. Only one survey conducted in 1991 enabled the evaluation of this fishery (Teirney & Kilner 2002). The main species taken by recreational fishermen at Otago that overlapped with the prey range of female NZ sea lions were blue cod (48% of the total number of prey caught by fishermen), barracouta (10%), spiny dogfish (7%), wrasse (3%), red cod (2%) and greenbone (2%). Consequently, there is a resource overlap in targeted species between female NZ sea lions and recreational fisheries and potential competition around Otago Peninsula. However, there is no estimate of biomass taken by recreational fishermen. This only survey of recreational fishing activities at Otago was also conducted almost 20 years prior to this study (Teirney & Kilner 2002). Recreational fishing could be monitored in order to detect the trend in increase or decrease in catch of particular species, and potential consequences for the marine life foraging in the coastal area off Otago Peninsula and adjacent coastlines, including sea lions.

Resource overlap with commercial fisheries

Barracouta and jack mackerel have been in the top five New Zealand commercially targeted fish species by weight managed in the Quota Management System (QMS, see Clark [1993]) at least since 2005 (Ministry of Fisheries 2010). Except for wrasse and octopus (not taken in commercial fishing activities) and seabirds, all top 15 species in the diet of female NZ sea lions at Otago in autumn are commercially targeted around Otago Peninsula and managed in the QMS (Ministry of Fisheries 2010). There is consequently a resource overlap between NZ sea lions and commercial fisheries, including with three of the main New Zealand fisheries (arrow squid, barracouta and jack mackerel, all occurring in the marine areas around Otago Peninsula [Ministry of Fisheries 2010]).

Marine food resources at Otago may have been altered while the NZ sea lion was absent from the mainland owing to fishing activities by early Māori and predominantly by large-scale commercial fishing since the 1970s. Fur seals have reached large numbers at Otago following recolonisation, but the populations now seems to have stabilised (Lalas 2008). Whether this is because of the carrying capacity of the marine habitat or of the terrestrial habitat is not understood (Bradshaw et al. 2002). In order to determine potential competition between NZ sea lions and fishing activities around Otago Peninsula, it will be necessary to gain detailed data including primary production, available biomass of prey species and their distribution and migration, and masses taken out by sea lions, other marine predators and fisheries to integrate them into a complex marine trophic model.

Conclusion

In autumn, the female NZ sea lions foraging around Otago Peninsula fed predominantly on barracouta and jack mackerel, but also to a lesser extent on a wide range of cephalopods, other bony fish, seabirds, cartilaginous fish, crustaceans and salps. All prey species were found in coastal waters or on the continental shelf, hence highlighting that they foraged exclusively in this area. There appears to be a large resource overlap between female NZ sea lions and other resident marine predators of Otago Peninsula and recreational and commercial fisheries that could lead to resource competition as the population of sea lions grows. More research is needed into marine production around Otago Peninsula to evaluate this possibility. Comparison between the diet of female NZ sea lions at Otago and the diet of NZ sea lions foraging around the Auckland Islands indicated that prey quality may be higher at Otago. Year-round diet studies of male and female NZ sea lions at both sites are needed to confirm this.

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