

Dietary analysis of regurgitates and stomach samples from free-living Australian sea lions

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Abstract. Dietary remains recovered from Australian sea lion (*Neophoca cinerea*) digestive tracts and regurgitate samples from Seal Bay (Kangaroo Island, South Australia) were used to identify prey species consumed. Four of eight digestive tracts collected (50%) contained prey items located only in the stomach. On the basis of biomass reconstruction of cephalopod prey remains, octopus contributed 40% of the biomass in the samples, giant cuttlefish (*Sepia apama*) contributed 30% and ommastrephid squids contributed 14% biomass. The remains of several fish species were found in the samples: leatherjacket (Monacanthidae), flathead (*Platycephalus* sp.), swallowtail (*Centroberyx lineatus*), common bullseye (*Pempheris multiradiata*), southern school whiting (*Sillago flindersi*) and yellowtail mackerel (*Trachurus novaezelandiae*). Southern rock lobster (*Jasus edwardsii*) and swimming crab (*Ovalipes australiensis*) carapace fragments, little penguin (*Eudyptula minor*) feathers and bones and shark egg cases (oviparous species and Scyliorhinidae sp.) were also identified.

Introduction

Australian sea lions (*Neophoca cinerea*) are distributed from Kangaroo Island, South Australia, to the Houtman Abrolhos Islands in Western Australia (Gales *et al.* 1994). This species is the only endemic and least numerous seal species in Australia, with a total population estimated between 9794 and 12000 individuals (Gales *et al.* 1994; Goldsworthy *et al.* 2003). The six largest breeding colonies for this species are located in South Australia, of which the colony at Seal Bay (35°41'S, 136°53'E), Kangaroo Island, is the fourth largest, with an estimated 233 (95% confidence interval 219–247) pups produced in the 2003 breeding season (McIntosh *et al.* 2006).

The ocean south of Kangaroo Island has been classified in global standards as moderately productive owing to the occurrence of highly seasonal cold-water upwelling zones (Ward *et al.* 2004). South Australia supports high densities (15800 pups) of New Zealand fur seals (*Arctocephalus forsteri*) (Shaughnessy *et al.* 2005) and up to 80% of the total Australian sea lion pup production (1994 pups) (Goldsworthy *et al.* 2003; McKenzie *et al.* 2005). In addition to its aseasonal breeding cycle, the Australian sea lion has an active gestation period of 14 months, a breeding season of 5–9 months and a lactation period of at least 15 months (Higgins 1993; Higgins and Gass 1993; Gales *et al.* 1997). To support this protracted breeding strategy, this species is likely to exploit locally productive regions with reliable food sources including seasonally and continuously available prey items.

Limited stomach content and faecal analyses have identified a wide variety of prey in the diet of the Australian sea

lion, including teleost fish, squid, cuttlefish, octopus, sharks (including Port Jackson sharks), rock lobster, other small crustaceans and penguins (Marlow 1975; Gales and Cheal 1992). Adult female Australian sea lions at Seal Bay dive continuously while at sea to a mean depth of 41.5–83.1 m, with 35% of their time spent in the deepest 20% of their dives (Costa and Gales 2003). On the basis of these findings, Australian sea lions have been described as opportunistic, benthic foragers (Richardson and Gales 1987; Gales and Cheal 1992; Ling 1992; Costa and Gales 2003).

The analysis of hard parts in faecal samples is an ineffective method for assessing the diets of Australian sea lions. Gales and Cheal (1992) found that Australian sea lion scats contained few hard parts to enable diagnosis of prey. Feeding trials of captive Australian sea lions have shown that fewer than 2% of otoliths are recovered after passing through the digestive tract and the recovery rate of cephalopod beaks in scats was highly variable and biased towards smaller prey (Richardson and Gales 1987; Gales and Cheal 1992). This is possibly due to the presence of gastroliths (stomach stones), which may grind and destroy hard parts, or cause retention of hard parts in the stomach (Needham 1997). In otariids, cephalopod hard parts are often retained in stomach samples in greater proportions than smaller hard parts from fish, biasing diet studies using these sample types towards cephalopod taxa (Gales *et al.* 1993; Lallas 1997).

This study aimed to analyse regurgitates and digestive tracts from Australian sea lions at Seal Bay to identify key prey taxa in their diet, based on hard parts found in the samples. The presence and size of gastroliths were also investigated.

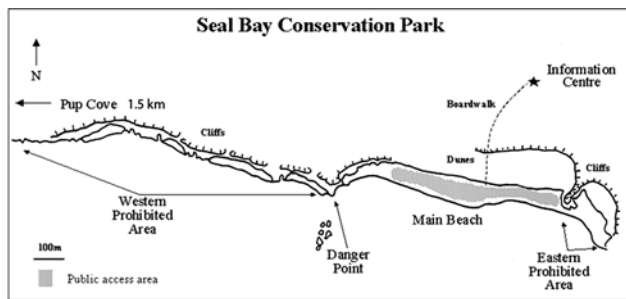


Fig. 1. Map of Seal Bay Conservation Park, Kangaroo Island, South Australia, showing colony survey areas.

Methods

This study was conducted in the Australian sea lion colony at Seal Bay Conservation Park, Kangaroo Island, South Australia (Fig. 1). Samples were collected during colony surveys from August 2002 to March 2005 in the main beach area of the colony and the western area of the colony. The eastern area of the colony is a prohibited area and was not surveyed. Each survey took a day to complete and was conducted on foot. All surveys began at the western extent of the colony with 1–3 surveyors moving through the colony to the eastern end of the main beach. During the breeding seasons (December 2002–August 2003 and June 2004–December 2004), surveys were conducted 4–7 days per week. Outside the breeding seasons, surveys were conducted one day per month as part of the monthly colony count. In total, 324 surveys were conducted over the study period.

During colony surveys, all sea lions were observed and dead individuals were easily located. All dead sea lions found during surveys were sexed, the cohort (adult or juvenile) recorded and the standard length (nose to tail), auxiliary girth and mass (when possible) measured before digestive tracts were removed for sampling. Adult sea lions were identified from juveniles by their body size and reproductive organ development.

Regurgitates were collected opportunistically after sea lions were observed to regurgitate or when regurgitates were found fresh and

undisturbed in the vicinity of a sea lion. Only fresh regurgitates were collected to maximise the number of prey items, because prey items are likely to dry out and break apart or to be scattered with time (Tate 1981).

Regurgitates and digestive tracts were contained individually, labelled and frozen at -20°C or stored in 70% ethanol on site before being sorted and analysed. Prey remains were sorted by rinsing hard parts through 0.5-mm and 1.0-mm sieves. Otoliths, fish bones, penguin bones and feathers, crustacean carapaces and eye lenses were stored dry, shark egg cases and cephalopod beaks were stored in 70% ethanol. Gastroliths were cleaned and dried before weighing, then stored separately from other hard parts. Rock type was identified by Dr John Webb (Department of Earth Sciences, La Trobe University, Bundoora, Victoria) and gastroliths were weighed individually to report total and mean weight for each stomach.

All prey remains were identified to the lowest taxonomic group by comparison with reference collections (shark egg cases: Dr Kate Rodda, SARDI, Port Lincoln, South Australia; crustacean carapaces: Dr Gary Poore, Melbourne Museum, Victoria) and with cephalopod beak and fish otolith atlases (Smale *et al.* 1995; Lu and Ickeringill 2002). Prey items were then sorted and counted to obtain a minimum number of individual prey items for each taxon.

Prey taxa may be biased towards cephalopods in stomachs and regurgitates, so quantitative analyses were conducted only for the cephalopod component of the diet. Well preserved cephalopod beaks were measured using digital callipers (accurate to 0.01 mm) for use in regression equations to estimate prey mass. Upper or lower rostral length was measured for squid beaks and upper or lower hood length was measured for octopus and cuttlefish beaks. The relative importance of each cephalopod prey taxon was assessed using three standardised measures including percentage numerical abundance (percentage of the total cephalopod prey items made up by each cephalopod prey taxon) and percentage frequency of occurrence (percentage of samples containing a given cephalopod prey taxon). However, as the importance of prey taxa in diet studies is best represented by volumetric data (e.g. Hyslop 1980), the most appropriate assessment is based on percentage biomass contribution.

Cephalopod prey mass was estimated using regression equations from relationships between beak measurements and cephalopod mass (Table 1). Several regressions that were used to estimate prey biomass

Table 1. Formulae (Lu and Ickeringill 2002) and mass estimates (g) used to estimate the contribution of each prey type to the total biomass consumed by Australian sea lions in this study

Regression equations are calculated using measures of the hood length (HL) or rostral length (RL) from the upper (U) or lower (L) cephalopod beak

| Prey type | Species used for estimate | Mass regression equation | Mantle length regression equation | <i>n</i> | Mass estimates, lower or upper beaks |
|--|--------------------------------|--|--|----------|--------------------------------------|
| Calamari squid (<i>Sepioteuthis australis</i>) lower beaks | Same species ^C | $= e^{1.71 + 3.34 (\text{LN} \times \text{LRL})}$ | $= -20.78 + (67.89 \times \text{LRL})$ | 3 | 3669.9 |
| Calamari squid upper beaks | Same species ^A | $= e^{2.07 + 2.66 (\text{LN} \times \text{URL})}$ | $= -21.3 + (63.83 \times \text{URL})$ | 3 | 1211.9 |
| Cuttlefish (<i>Sepia</i> sp.) lower beaks | <i>Sepia</i> sp. ^A | $= e^{0.7 + 2.51 (\text{LN} \times \text{LHL})}$ | $= 18.09 + (16.5 \times \text{LHL})$ | 6 | 824.4 |
| Cuttlefish upper beaks | <i>Sepia</i> sp. ^A | $= e^{-2.16 + 2.68 (\text{LN} \times \text{UHL})}$ | $= 13.83 + (6.66 \times \text{UHL})$ | 2 | 237.6 |
| Giant cuttlefish (<i>Sepia apama</i>) lower beaks | Same species ^A | $= e^{-1.59 + 3.29 (\text{LN} \times \text{LHL})}$ | $= -0.26 + (17.06 \times \text{LHL})$ | 13 | 9919.1 |
| Giant cuttlefish upper beaks | Same species ^A | $= e^{-5.78 + 3.6 (\text{LN} \times \text{UHL})}$ | $= -8.4 + (7 \times \text{UHL})$ | 6 | 6225.2 |
| Gould's squid (<i>Nototodarus gouldi</i>) lower beaks | Same species ^B | $= e^{0.8 + 2.86 (\text{LN} \times \text{LRL})}$ | $= 41.88 + (33.99 \times \text{LRL})$ | 6 | 2918.1 |
| Ommastrephidae other lower beaks | <i>N. gouldi</i> ^B | $= e^{0.8 + 2.86 (\text{LN} \times \text{LRL})}$ | $= 41.88 + (33.99 \times \text{LRL})$ | 22 | 879.6 |
| Ommastrephidae other upper beaks | <i>N. gouldi</i> ^B | $= e^{1.02 + 2.67 (\text{LN} \times \text{URL})}$ | $= 55.75 + (29.9 \times \text{URL})$ | 11 | 6514.8 |
| Octopus (<i>Octopus</i> sp.) lower beaks | <i>O. berrima</i> ^A | $= e^{0.75 + 3.23 (\text{LN} \times \text{LHL})}$ | $= -10.08 + (20.05 \times \text{LHL})$ | 9 | 16316.5 |
| Octopus upper beaks | <i>O. berrima</i> ^A | $= e^{-0.44 + 3.53 (\text{LN} \times \text{UHL})}$ | $= -11.58 + (15.99 \times \text{UHL})$ | 24 | 5610.6 |
| Total biomass | | | | | 54327.8 |

^ARegressions based on data that include the range of predicted lengths.

^BRegressions based on data that do not include the lower predicted lengths.

^CRegressions based on data that do not include the upper predicted lengths.

from beak morphometrics were based on data from other species and/or the regressions used did not encompass a small proportion of individuals that had longer or shorter predicted beak lengths. Therefore, biomass reconstructions should be interpreted with caution. The minimum number of cephalopods in each sample was estimated by counting upper and lower beaks. Samples that contained fewer identified beaks than unidentified remains (such as eye lenses or beak fragments) were recorded as containing a minimum number of unidentified individuals.

Biomass estimates were based on the minimum number of individuals per sample, using upper and lower beaks. Percentage biomass was calculated for each prey type by adding the percentage biomass of lower and upper beaks for each prey type (Table 1).

Results

A total of 16 regurgitates and eight digestive tracts were collected during the study period. Of the eight digestive tracts, four contained only gastroliths and four contained gastroliths and prey remains (Table 2); all contained cephalopod beaks, while one also contained crustacean hard parts and one also contained fish hard parts. No hard parts were found in the intestines. Not all regurgitate samples could be attributed to a particular age/sex class of sea lion. Prey items were identified in all 16 regurgitate samples, with 15 samples containing cephalopod taxa and one sample containing crustacean hard parts only. Eight regurgitate samples contained fish hard parts. A total of six cephalopod taxa (Table 3), six fish species, two crustacean species, two types of shark egg cases and one bird species were identified in the samples (Table 4).

In total, 125 individual cephalopod prey items were identified from the 20 samples, of which 105 were measured and used for biomass reconstructions (Table 1). The most important prey (biomass greater than 10%) were octopus, giant cuttlefish and ommastrephid squid, other than Gould's squid (Table 3).

Of the samples containing cephalopods, seven contained one cephalopod taxon only, eight samples included two cephalopod taxa, three samples included three cephalopod taxa and two samples contained four cephalopod taxa. Of the seven samples containing only one cephalopod taxa, three also contained fish hard parts, shark egg cases, little penguin (*Eudyptula minor*) feathers or crustacean carapace fragments. The stomach contents of one juvenile female contained 20 individual octopi (weight range 11.4–98.0 g; average weight = 84 g, s.d. = 162.2; average length = 36.3 mm, s.d. = 25.4); no other prey taxa were identified in this sample.

Two of the most numerically abundant prey were octopus and giant cuttlefish, which also had a high frequency of occurrence (Table 3). The range in size of the octopi consumed was great and that of the giant cuttlefish was smaller (Table 3). The minimum octopus size was estimated as 2.3 g and 11.4 mm, while the largest was estimated as 7859.9 g and 245.4 mm. The minimum giant cuttlefish was estimated as 607.1 g and 198.4 mm, while the largest was estimated as

1775.7 g and 270.2 mm. Other cuttlefish species, which were smaller than giant cuttlefish, contributed minimally to the proportion of the biomass of cephalopods eaten, but their numerical abundance and frequency of occurrence were high (Table 3).

Of the ommastrephids, only the larger individuals could be assigned to species and all were Gould's squid (*Notodarus gouldii*) (Table 3). Other ommastrephids that could not be identified to species represented a larger proportion of the reconstructed biomass and numerical abundance than Gould's squid. The minimum individual size of the other ommastrephids was estimated as 2.9 g and 72.1 mm, while the largest was estimated as 773.6 g and 302.1 mm. Calamari squid (*Sepioteuthis australis*) represented a low proportion of the biomass due to their low numerical abundance despite their large average size (Table 3).

Otoliths and fish eyes or bones were found in seven regurgitates and two stomachs. The presence of spinal processes were used to identify leatherjackets (Monacanthidae) in three samples, but the species and number of individuals consumed could not be determined. Otoliths found in regurgitates were used to identify swallowtail (*Centroberyx lineatus*), common bullseye (*Pempheris multiradiata*), eastern school whiting (*Sillago flindersi*), flathead (*Neoplattycephalus* sp.) and yellowtail mackerel (*Trachurus novaezealandiae*). The sample size for fish otoliths was small (Table 4) and many otoliths were too eroded to reconstitute otolith measures to fish length and size. Little penguin feathers were found in one regurgitate. Southern rock lobster (*Jasus edwardsii*) carapace fragments were found in three regurgitates and one stomach. One swimming crab (*Ovalipes australiensis*) was identified in the stomach of the dead juvenile sea lion. Six shark egg cases were found in three regurgitates. Five of the egg cases were from catsharks (Scyliorhinidae) and the sixth was from an oviparous species.

Gastroliths were found in all eight sea lion stomachs (Table 2) and consisted of metasandstone from the Kanmantoo Group (Drexel and Preiss 1995). Juveniles

Table 2. The number of gastroliths found in the stomachs of eight Australian sea lions at Seal Bay, their weight, and whether the stomach samples contained hard parts of prey. Age–sex categories include adults (A), juveniles (J), females (F) and males (M)

| Age–sex | No. of gastroliths | Total weight (g) | Average weight (g) | s.d. | Hard parts |
|---------|--------------------|------------------|--------------------|------|------------|
| AF | 4 | 333.8 | 83.4 | 37.7 | No |
| AF | 9 | 825.7 | 91.7 | 25.2 | Yes |
| AF | 4 | 257.4 | 64.3 | 29.3 | Yes |
| AF | 2 | 448.8 | 224.4 | 84.7 | Yes |
| AF | 4 | 325.4 | 81.4 | 11.5 | No |
| AF | 2 | 197.3 | 98.7 | 11.4 | No |
| JF | 1 | 15.2 | – | – | Yes |
| JM | 2 | 77.6 | 38.8 | 4.2 | No |

Table 3. Cephalopod prey in the diet of the Australian sea lion

From 20 samples, at least 125 individual cephalopods were identified (n_1) to calculate the percentage numerical abundance (NA) and the percentage frequency of occurrence (FO) of cephalopods identified in Australian sea lion regurgitates and stomachs at Seal Bay. In all, 105 beaks (n) were measured to calculate the percentage biomass contribution (BM)

| Cephalopods | n_1 | NA | FO | n | BM | Prey weight (g) | | Mantle length (mm) | |
|--------------------------|-------|-----|------|------|-----|-----------------|--------|--------------------|------|
| | | | | | | Mean | s.d. | Mean | s.d. |
| Ommastrephidae | | | | | | | | | |
| Gould's squid | 13 | 8 | 10.5 | 6 | 5 | 486.4 | 411.3 | 249.1 | 67.8 |
| Other | 27 | 12 | 10.5 | 33 | 14 | 224.1 | 283.4 | 169.0 | 85.1 |
| Sepiidae | | | | | | | | | |
| Giant cuttlefish | 19 | 25 | 24 | 19 | 30 | 849.7 | 362.1 | 211.7 | 28.6 |
| Other | 17 | 23 | 21 | 8 | 2 | 132.7 | 118.3 | 101.3 | 30.9 |
| Loliginidae | | | | | | | | | |
| Calamari squid | 7 | 6 | 10.5 | 6 | 9 | 813.6 | 621.8 | 280.4 | 70.6 |
| Octopodidae | | | | | | | | | |
| Octopus | 34 | 25 | 21 | 33 | 40 | 664.5 | 1482.8 | 68.4 | 57.9 |
| Unidentified cephalopods | 8 | 1 | 2.5 | n.a. | | | | | |
| Total | 125 | 100 | 100 | 105 | 100 | | | | |

($n = 2$) had smaller gastroliths (average $30.9 \text{ g} \pm 14 \text{ g}$, $n = 3$ gastroliths) than adult females ($n = 6$) (average $95.5 \pm 49.3 \text{ g}$, $n = 25$ gastroliths). Sample sizes were too small to make statistical comparisons.

Discussion

This is the first study to provide quantitative estimates of the percentage biomass and percentage composition of cephalopod prey consumed by Australian sea lions. Although stomach samples have been previously examined (Marlow 1975; Gales and Cheal, 1992; Kemper and Gibbs 1997; S. E. Gibbs, Macquarie University, unpublished data), this is the only study to analyse regurgitates of free-living Australian sea lions.

Quantitative analysis was conducted only on the cephalopod component of the diet as stomach samples and regurgitates are biased towards cephalopod beaks and other large prey items, providing positively biased quantities of cephalopods in the diet (Gales and Cheal 1992; Gales *et al.* 1993; Lalas 1997). For Hooker sea lions (*Phocarctos hookeri*) at Otago Peninsula, New Zealand, regurgitates provided more than one-third of the octopus taxa and most of the crustacean and arrow squid hard parts when compared to prey items identified in scats (Lalas 1997). Regurgitate and stomach content analysis may provide information on cephalopod components of the diet, but provide less information on the fish taxa.

There are inherent biases in any method of diet analysis (Gales *et al.* 1993; Fea and Harcourt 1997; Lake 1997; Hume

Table 4. Prey taxa, excluding cephalopods, of Australian sea lion regurgitates and digestive tracts collected at Seal Bay

The number of samples in which each prey item was identified (in bold) and the total number of individuals identified are also shown

| Prey type | No. of samples | Minimum no. of individuals identified |
|---|----------------|---------------------------------------|
| Birds | | |
| Little penguin (<i>Eudyptula minor</i>) | 1 | 1 |
| Fish hard parts | | |
| Leatherjacket (Monacanthidae sp.) | 3 | 3 |
| Flathead (<i>Neoplatycephalus</i> sp.) | 1 | 1 |
| Swallowtail (<i>Centroberyx lineatus</i>) | 2 | 7 |
| Common bullseye (<i>Pempheris multiradiata</i>) | 1 | 1 |
| Eastern school whiting (<i>Sillago flindersi</i>) | 1 | 1 |
| Yellowtail mackerel (<i>Trachurus novaezelandiae</i>) | 1 | 1 |
| Crustacea | | |
| Southern rock lobster (<i>Jasus edwardsii</i>) | 4 | 4 |
| Swimming crab (<i>Ovalipes australiensis</i>) | 1 | 1 |
| Shark egg cases | | |
| Type 1 (Oviparous species) | 1 | 1 |
| Type 2 (Catshark species: Scyliorhinidae) | 3 | 5 |

et al. 2004) and several problems in particular with analysis of regurgitates and the digestive tracts of dead individuals. Dead individuals found hauled-out are likely to misrepresent the diet of healthy individuals because sickness and poor body condition may influence the type of prey that can be consumed, as has been suggested previously for cetaceans (De Pierrepont *et al.* 2005). Although the stomach contents of dead, beached individuals of South American sea lions (*Otaria flavescens*) were not significantly different from the stomach contents of entangled, healthy individuals (Koen Alonso *et al.* 2000), stomach samples from dead individuals of several other seal species were often found to be empty (Pierce *et al.* 1991; Gales and Cheal 1992). Pierce *et al.* (1991) found that 61% of stomach samples from dead seals were empty, but on examination of the entire digestive tract, 94% of samples contained hard parts from prey items. This was not the case in this study because no hard parts were located in the intestines.

Prey remains in stomach contents and regurgitates may be biased towards prey types in which hard parts remain in the stomach longest (Harwood and Croxall 1988; Pierce *et al.* 1991). Regurgitates also contain other inherent biases for diet analysis, because larger prey items may be over-represented (Gales and Cheal 1992; Gales *et al.* 1993; Needham 1997). The rate of passage of digesta for captive Australian sea lions has been estimated to average 14.9 h (Bodley *et al.* 1999), with large experimental markers (diameter >1.2 mm) being retained for more than 6 days (Richardson and Gales 1987). Because prey remains may be voided while the sea lion is at sea this may lead to an over-representation in regurgitates and stomachs of prey taxa consumed in the last meal before the sea lion hauled out.

Contribution of cephalopods and other prey items to diet composition

The prey items identified in this study were similar to prey items identified in previous diet studies for the Australian sea lion. Gales and Cheal (1992) examined five stomachs and 46 scats from free-ranging Australian sea lions. In the scats, they identified fish remains, octopus, cuttlefish, squid, lobster, amphipods, shrimps, crabs, shark fragments and one feather. Cephalopod remains were found in only 24% of scats and consisted of small octopus beaks and one cuttlefish portion. The stomachs (one was empty) contained large octopus beaks, cuttlefish beaks and a shark egg case. Gales and Cheal (1992) also examined regurgitates from one male and one female during feeding trials of captive Australian sea lions; the regurgitate from the female contained 26 octopus upper jaws, representing 93% minimum recovery of octopus that the sea lion had been fed for that week of trials.

The current study of free-living Australian sea lion regurgitates identified a greater number of taxa in the diet, with 94% of regurgitates containing cephalopod beaks and 50% containing fish hard parts. Half the stomach samples con-

tained cephalopod beaks, with one also containing fish remains, and one also containing crustacean remains. In total, six cephalopod taxa, six fish species, two crustacean species, two shark taxa and one bird species were identified (Tables 3, 4). A greater number of prey items could be identified using regurgitate and stomach samples because hard parts are retained in the stomach and are less eroded than the smaller hard parts egested in scats (Gales and Cheal 1992).

Octopus species were the most numerous cephalopod taxa, making up the greatest proportion of biomass contribution (40%) but the giant cuttlefish represented the greatest frequency of occurrence (24%) (Table 3). There is some evidence of monospecific consumption of cephalopods, with seven of the samples containing only one cephalopod prey taxon, either octopus, cuttlefish or ommastrephid. This may indicate feeding on aggregated patches of cephalopods or targeting of specific prey by individual sea lions. Three of the seven samples contained prey items other than cephalopods, suggesting that individual sea lions are also opportunistic foragers.

The cephalopods identified in this study are generally restricted to the benthos of the continental shelf, but also include taxa that live in the open ocean. The continental slope (200 m depth) is located ~200 km to the south of Kangaroo Island. Adult female Australian sea lions forage on the shelf to maximum dive depths of 60–105 m (Costa and Gales 2003). Octopus, cuttlefish, Gould's squid and calamari squid live on the benthos of the shelf (Stranks 1996; Uozumi 1998; Pecl 2001; Triantifillos *et al.* 2004; Jackson *et al.* 2005). Ommastrephids (other than Gould's squid) are generally fast-swimming species of the open ocean (Dunning and Wormuth 1998; O'Dor *et al.* 2002).

Some cephalopod species identified in the diet samples of the Australian sea lion are non-migratory and constantly available, such as the calamari squid that has genetically isolated populations, indicating minimal movement of larvae or adults (Triantifillos *et al.* 2004). However, the diet samples also contained highly dispersive prey such as the giant cuttlefish of the southern coast, which consists of one genetic population (Triantifillos *et al.* 2004). In South Australia, the giant cuttlefish aggregates every year from May to August to spawn. The semelparous life history (Arnould 1977; Wells 1977) makes such cephalopods likely to be seasonally abundant and a predictable food source for the Australian sea lion. Squid, the least numerous cephalopod in the Australian sea lion samples, may be a less predictable food source for the Australian sea lion because both growth and spawning events vary according to their environment (see Jackson and McGrath-Steer 2005 for a review).

The non-cephalopod prey items (Table 4) consisted of predominantly benthic species (81%) that dwell over the continental shelf in a variety of habitats. Southern rock lobster are found from the intertidal zone to depths of 200 m on rocky reefs (Edgar 1997) and have a high level of site fidelity

(Gardner *et al.* 2003; McGarvey 2003; Linnane *et al.* 2005). Swimming crabs are subtidal, dwelling on soft sandy bottoms (Jones and Morgan 1994). Most catsharks found in southern Australian waters are benthic dwellers, living from nearshore waters to deep offshore waters (Last and Stevens 1994). Sharks and their egg cases are known to be eaten by Australian sea lions (Marlow 1975; Gales and Cheal 1992). It was determined from the external appearance of the egg cases in this study that the catshark egg cases were consumed after laying, while the oviparous egg case was presumably consumed from eating the body of the gravid shark. Little penguins share many habitats with Australian sea lions and have been found in the diet of fur seals on Kangaroo Island (Page *et al.* 2005). Most teleost fish prey identified in this study dwell on reef and other benthic habitats (Table 4). Leatherjackets, flathead, eastern school whiting (to 80 m depth) and common bullseye are benthic and dwell on the reefs and weed beds of the shelf (May and Maxwell 1986; McKay 1992; Hindell *et al.* 2000; Jordan 2001, Shepherd and Brook 2003). Swallowtail are benthopelagic, dwelling near the rocky reefs of the shelf and slope (15–280 m deep) (May and Maxwell 1986) and yellowtail mackerel are pelagic fish (to 150 m deep), that also school coastally (Paxton *et al.* 1989).

Gastroliths

The gastroliths found in the stomach samples were all of the same rock-type, and most likely the same place of origin. Comparison with the rocks sourced from Seal Bay (Pebble Beach, Western Prohibited Area) shows that this rock type is found at this location. The role of gastroliths in the stomachs of otariids is unknown. They may aid the process of digestion (Needham 1997) but have alternatively been discussed as providers of buoyancy control to marine tetrapods that use fore-flippers for underwater propulsion (Taylor 1993). They are commonly found in penguins and otariid seals, but not in odobenids, phocids or cetaceans (Taylor 1993).

Potential dietary overlap with sympatric fur seals

In South Australia, Australian sea lions and New Zealand fur seals breed in sympatry. The eastern extent of the Australian sea lion range also overlaps with that of the Australian fur seal, with small numbers of itinerant males hauling out on Kangaroo Island (Shaughnessy and Dennis 2001). The level of competitive overlap between the diet of the Australian sea lion and the sympatric fur seals is unknown.

On Kangaroo Island, male Australian fur seals primarily utilised demersal and benthic fish species (96% biomass of total diet), male New Zealand fur seals predominantly consumed birds (37% biomass of total diet) and female New Zealand fur seals predominantly consumed cephalopods (55% biomass of total diet) (Page *et al.* 2005). Most prey items of Australian sea lions identified in this study overlapped with the prey items of the sympatric fur seals on Kangaroo Island.

Octopus provided the greatest percentage biomass contribution (40%) in the Australian sea lion samples of this study, but contributed little to the cephalopod biomass of the fur seal diets (adult female New Zealand fur seal 4%; adult male New Zealand fur seal 5%; adult male Australian fur seal 28%). Neither shark egg cases nor rock lobster have been identified in the diet of the New Zealand nor Australian fur seals (Page *et al.* 2005). Despite some identified differences in identified prey items for the three species, the sample size (20) for this study is too small to examine competitive overlap between these sympatric species.

Recommendations for future diet studies

Further research is required to examine seasonal diet variation for the Australian sea lion throughout its range and for the different sexes and age groups. Given that Australian sea lions occur in sympatry over most of their range with New Zealand fur seals and, to a lesser extent, Australian fur seals, it is important to assess how these species partition their prey resources. Determining the calorific content of prey species of Australian sea lions would provide a greater understanding of the foraging behaviour of Australian sea lions and the energetic contribution of prey species to sea lion diet.

Australian sea lion scats contain relatively few hard parts for analysis, and regurgitates and stomach contents are very likely to underestimate fish consumption (Lalas 1997); molecular analysis of prey remains from scats will therefore provide the most representative method of identifying the prey taxa in this species. Both nuclear and mitochondrial DNA may be extracted from seal scats to provide information on the individual seal, prey items and gut bacteria through PCR (polymerase chain reaction) (Reed *et al.* 1997). Because hard parts from prey items may not be ingested, or may dissolve in the gut, analysis of prey DNA will allow identification of a greater number of prey taxa and will avoid the inaccurate identification of prey taxa due to damaged hard parts (Symondson 2002). Reference DNA sequences of prey items must first be determined in order to apply this method of diet analysis, which has been used successfully for marine predators (Farrell *et al.* 2000; Jarman *et al.* 2002; Deagle *et al.* 2005).

Potential overlap with fisheries in the Kangaroo Island region

This study has shown that the diet of the Australian sea lion from Seal Bay includes commercially targeted species such as southern rock lobster, southern school whiting and flathead. Yellowtail mackerel are of moderate commercial value as game fish and baitfish, whereas leatherjackets are of only minor commercial value. The extent to which the prey of Australian sea lions overlaps with the species taken by commercial fishers in the Kangaroo Island region is unknown and requires further study.

Sharks contribute to the diet of the Australian sea lion. There have been reports of Australian sea lions robbing nets set for shark by the gill-net sector of the South East Scalefish and Shark Fishery, and also becoming entangled in the monofilament gill-net (Robinson and Dennis 1988; Shaughnessy 1999). Monofilament gill-net is the most common entanglement material observed on Australian sea lions at Seal Bay, indicating that sea lions interact frequently with this fishery (Page *et al.* 2004).

Conclusion

Regurgitate and stomach samples from Australian sea lions at Seal Bay contained hard parts consisting predominantly of benthic taxa. This supports previous evidence that this species forages primarily on neritic, benthic prey, many of which are non-migratory. For the cephalopod component of the Australian sea lion diet, octopus and giant cuttlefish made up the greatest biomass of prey taxa. Although the Australian sea lion feeds off seasonally available prey such as semelparous cephalopods, it also exploits prey species that are available throughout the year, such as rock lobster and many of the fish species. Further studies are required to analyse the seasonal variation in the diet of adults and juveniles of both sexes of Australian sea lions, in order to determine the potential for interactions with sympatric fur seal species and commercial fisheries.

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