# S5 File. Diet Matrix Sources and Notes

**Table A Literature Sources for diet data.**

| Model Group        | Study Type                                    | Confidence | Diet References                                   |
|--------------------|-----------------------------------------------|------------|--------------------------------------------------|
| Killer Whale       | Predation observations                       | Low        | Pitman and Durban [1], Pitman and Ensor [2]     |
| Leopard Seal       | Scat contents, predation observations, diet model | Low        | Casaux et al. [3], Forcada et al. [4], Boveng et al. [5] |
| Weddell Seal       | Scat contents                                 | Low        | Casaux et al. [6]                                |
| Crabreater Seal    | Stable isotope                                | Low        | Hückstädt et al. [7]                             |
| Antarctic Fur Seal | Scat contents, stable isotope                 | Low        | Casaux et al. [8], Polito and Goebel [9]         |
| S Elephant Seal    | Stable isotope                                | Low        | Hückstädt et al. [10]                            |
| Sperm Whale        | Standardized diet from gut contents           | Low        | Pauly et al. [11], Hückstädt et al. [10]         |
| Blue Whale         | Standardized diet from gut contents           | Low        | Pauly et al. [11], Hückstädt et al. [10]         |
| Fin Whale          | Standardized diet from gut contents, gut contents | Low        | Pauly et al. [11], Armstrong and Siegfried [13], Santor et al. [14] |
| Minke Whales       | Standardized diet from gut contents, gut contents, consumption model, predation observations | Low        | Pauly et al. [11], Kawamura [12], Armstrong and Siegfried [13] |
| Humpback Whale     | Gut contents, standardized diet from gut contents | Low        | Kawamura (1978), Pauly et al. (1998)             |
| Emperor Penguin    | Gut contents, standardized diet from gut contents | Low        | Klages [15], Cherel and Kooyman [16]             |
| Gentoo Penguin     | Gut contents, and stable isotope analysis     | Low        | Miller et al. [17], Polito et al. [18]           |
| Chinstrap Penguin  | Gut content and stable isotope, gut contents  | Low        | Polito et al. [18], Lynnes et al. [19]           |
| Adélie Penguin     | Gut contents                                 | Low        | Lynnes et al. [19]                               |
| Macaroni Penguin   | DNA analysis of scat                          | Low        | Deagle et al. [20]                               |
| Flying Birds       | Literature synthesis, behavioral              | Low        | Ainley et al. [21], Ainley et al. [22], Malzof and Quintana [23] |
|                | Study type                                      | Confidence | Literature sources                                                                 |
|----------------|------------------------------------------------|------------|-------------------------------------------------------------------------------------|
| Cephalopods    | Literature synthesis, gut contents, fatty acid analysis | Low        | Rodhouse and Nigmatullin [24], Phillips et al. [25], Kozlov [26]                    |
| Myctophids (Off shelf) | Gut contents                                       | Low        | Pusch et al. [27], Pakhomov et al. [28]                                             |
| On-shelf fish  | Literature synthesis, gut contents                | Low        | La Mesa et al. [29], Barrera-Oro [30]                                              |
| N. rossii      | Gut contents                                      | Low        | Casaux and Barrera-Oro [31], Jones et al. [32]                                      |
| C. gunnari     | Gut contents                                      | Low        | Main et al. [33], Flores et al. [34], Jones et al. [32]                             |
| G. gibberifrons| Literature synthesis, gut contents                | Low        | Barrera-Oro [30], Casaux and Barrera-Oro [31], Flores et al. [34], Jones et al. [32], Jones et al. [35] |
| Salps          | Gut contents                                      | Low        | Pakhomov et al. [36], Perissinotto and A. Pakhomov [37]                             |
| Benthic Invertebrates | Model diet                                     | Low        | Jarre-Teichmann et al. [38], Ballerini et al. [39]                                 |
| Large Krill (≥ 24 months) | Model diet, fatty acid analysis, gut contents | Low        | Ballerini et al. [39], Atkinson et al. [40], Atkinson and Snýder [41], Perissinotto et al. [42] |
| Small Krill (> 24 months) | Feeding experiments, gut content       | Low        | Meyer et al. [43], Meyer et al. [44], Töbe et al. [45], Ross et al. [46]            |
| Other Euphausiids | Model diet, prey field observations, stable isotope analysis | Low        | Ballerini et al. [39], Hopkins [47], Marrari et al. [48], Donnelly et al. [49], Pers. Comm, J. Walsh, November 2018, unpublished stable isotope data |
| Microzooplankton | Model diet, grazing experiements                 | Low        | Ballerini et al. [39], Froneman and Perissinotto [50], Froneman et al. [51]         |
| Mesozooplankton | Model diet, gut contents, grazing experiments     | Low        | Ballerini et al. [39], Hopkins [47], Pasternak and Schnack-Schiel [52], Swadling et al. [53] |
| Macrozooplankton | Model diet, gut contents, predation experiments  | Low        | Ballerini et al. [39], Pakhomov and Froneman [54], Oresland and Ward [55], Pakhomov and Perissinotto [56] |

The study type column provides a gross description of the field methods used to collect diet data. The confidence column relates to the confidence in the percentages of prey items reported in each study being precise for all predators of that model group in the region. Many of the diet studies referenced have small, spatially constrained sample sizes relative to their respective populations and therefore the percentage of mass in the diet was uncertain.

No detailed, regionally specific diet studies exist for the cetacean species included in the model. Killer whale (Orcinus orca) is a species that is composed of several ecotypes distinguished, *inter alia*, by diet [1, 2]. At least two distinct ecotypes of killer whale occur in the
WAP. Ecotype A, which feeds on minke whales (*Balaenoptera bonaerensis* and *B. acutorostrata*) and to a lesser extent elephant seals (*Mirounga leonina*), and the more abundant Ecotype B, which feeds on pack ice seals and penguins [1, 2]. Fish-eating killer whales may also occur in the region [2]. The diet presented in our model reflects what whales in the region have been observed eating and is skewed to favor the more abundant Ecotype B. The diets of blue whale (*Balaenoptera musculus*), fin whale (*Balaenoptera physalus*), minke whales (*Balaenoptera bonaerensis* and *B. acutorostrata*) and humpback whale (*Megaptera novaeangliae*) are based on generalized diets presented in Pauly et al (1998). However, the WAP diets are adapted to recognize the importance of krill and other euphausiids as the main planktonic prey items [12-14].

Published diet studies do not adequately describe the percentages of prey items consumed by two pinniped species. A diet study of leopard seal (*Hydrurga leptonyx*) in the region [3] describes a high percentage of krill and a variety of fish in this predator’s diet. Observations from elsewhere in the study region indicate that consumption of Antarctic fur seal (*Arctocephalus gazella*) pups by leopard seals is a significant source of pup mortality [4, 5, 57]. The diet used in the Ecopath model includes consumption of Antarctic fur seals. Three diet studies have been conducted on southern elephant seals in the region, and all three agree that fishes and cephalopods are dietary staples [10, 58, 59]. However, the studies do not assign proportion of diet to cephalopods or fishes. In the current study, the diet of southern elephant seal is described as favoring cephalopods, with a significant portion of the diet coming from both myctophids and on-shelf fishes.

The seabird functional group represents a diverse group (see S1). There is wide variation in the reported diets of seabirds, though all species feed primarily in the near-surface marine
environment [21-23]. The diet reflects a synthesis of the literature to create a representative diet for this group.

The multispecies groups for cephalopods and on-shelf fish represent diverse species and diets. Cephalopods are known to be opportunistic foragers [24] and important consumers of myctophids and mesopelagic fishes [24, 26], though percentages of diet composition could not be found in the literature. The diet for cephalopods is split between euphausiid and fish groups. All modelled fish groups include krill as significant portions of their diets [27-31, 33, 34]. *Electrona antarctica* serves as the example diet for myctophids as it is the best documented and most abundant myctophid in the region [27, 39].

The diet of Antarctic krill (*Euphausia superba*) varies both by season [40, 42] and life stage [43, 44]. The diets of large and small krill presented here take that variability into account and attempt to reflect an average annual diet for each krill group.

Ballerini et al. [39] re-create monthly diets for non-krill zooplankton based on published and previously non-published data. The diets for other euphausiids, microzooplankton, mesozooplankton, and macrozooplankton are derived from the average diets used by Ballerini et al. (2014). The diet for the other euphausiid group was adjusted to include more microzooplankton based on stable isotope analyses which indicate that other euphausiids occupy a higher trophic level than krill [J. Walsh, Pers. Comm, August 2016]

We assume that the benthic invertebrate group largely consumes detritus that has reached the seafloor. This is consistent with other Antarctic food web models [38, 39, 60]

The initial diet matrix compiled from the literature is provided below. This diet matrix was incrementally adjusted to bring the model into balance.
| Model Group          | Prey                                                                 |
|----------------------|----------------------------------------------------------------------|
| Killer Whale         | 1% Leopard Seals, 45% Weddell Seals, 35% Crabeaters Seals, 1%        |
|                      | Elephant Seals, 1% Blue Whales, 1% Fin Whales, 5% Minke Whales,      |
|                      | 1% Humpback Whales, <1% Emperor Penguins, 3% Gentoo Penguins, 3%      |
|                      | Chinstrap Penguins, <1% Adélie Penguins, 1% Myctophid fish, 1%       |
|                      | On-shelf Fish, <1% N. rossii, 1% G. gibberifrons                     |
| Leopard Seal         | 1% Antarctic Fur Seals, 6% Gentoo Penguins, 5% Chinstrap Penguins,    |
|                      | 1% Cephalopods, 2% Myctophids, 2% G. gibberifrons, 83% Large Krill   |
| Weddell Seal         | 5.5% Cephalopods, 5.5% Myctophids, 86.5% On-shelf Fish, 1.5% G.     |
|                      | gibberifrons, 1% Benthic Invertebrates                               |
| Crabeater Seal       | 1% Cephalopods, 10% Myctophids, 1% On-shelf Fish, 88% Large Krill    |
| Antarctic Fur Seal   | 1% Gentoo Penguins, 1% Chinstrap Penguins, <1% Adélie Penguins,      |
|                      | <1% Macaroni Penguins, 2% Cephalopods, 20% Myctophids, 35% On-shelf |
|                      | Fish, 40% Large Krill                                               |
| S Elephant Seal      | 60% Cephalopods, 20% Myctophids, 10% On-shelf fish, 5% N. rossii,    |
|                      | 5% G. gibberifrons                                                  |
| Sperm Whale          | 70% Cephalopods, 10% Myctophids, 15% On-shelf Fish, 5% Benthic       |
|                      | Invertebrates                                                       |
| Blue Whale           | 70% Large Krill, 10% Other Euphausiids, 20% Macrozooplankton        |
| Fin Whale            | 1% Myctophids, 1% On-shelf Fish, 70% Large Krill, 10% Other          |
|                      | Euphausiids, 5% Mesozooplankton, 13% Macrozooplankton               |
| Minke Whales         | 4% Myctophids, 4% On-shelf fish, 70% Large Krill, 20% Other          |
|                      | euphausiids, 2% Macrozooplankton                                     |
| Humpback Whale       | 1% Cephalopods, 10% Myctophids, 10% On-shelf Fish, 70% Large Krill,  |
|                      | 4% Mesozooplankton, 5% Macrozooplankton                             |
| Emperor Penguin      | 10% Cephalopods, 38% On-shelf Fish, 52% Large Krill                 |
| Gentoo Penguin       | 15% Myctophids, 15% On-shelf-fish, 70% Large Krill                  |
| Chinstrap Penguin    | 5% Myctophids, 4% On-shelf Fish, 90% Large Krill, 1%                |
|                      | Macrozooplankton                                                   |
| Adélie Penguin       | 1% Myctophids, <1% C. gunnari, <1% G. gibberifrons, 97% Large        |
|                      | Krill, 1% Macrozooplankton                                          |
| Macaroni Penguin     | 1% Cephalopods, 9% Myctophids, 12% On-shelf Fish, 35% Large Krill,   |
|                      | 35% Other Euphausiids, 8% Mesozooplankton                            |
| Flying Birds         | 30% Cephalopods, 15% Myctophids, 14% On-shelf Fish, 35% Large Krill, |
|                      | 5% Mesozooplankton, 1% Macrozooplanklon                              |
| Cephalopods          | 12% Myctophids, 12% On-shelf Fish, 21% Benthic invertebrates, 25%    |
|                      | Large Krill, 15% Other Euphausiids, 15% Macrozooplankton            |
| Myctophids           | 40% Large Krill, 20% Other Euphausiids, 20% Mesozooplankton, 20%    |
|                      | Macrozooplankton                                                   |
On-shelf Fish

|                  | % Cephalopods | % Myctophids | % C. gunnari | % Salps | % Benthic Invertebrates | % Large Krill | % Other Euphausiids | % Mesozooplankton | % Macrozooplankton |
|------------------|---------------|--------------|--------------|--------|------------------------|---------------|-------------------|------------------|------------------|
| N. rossii        | 10% Myctophids, 5% Salps, 5% Benthic Invertebrates, 50% Large Krill, 20% Other Euphausiids, 10% Ice algae |                  |              |        |                        |                |                   |                  |                  |
| C. gunnari       | 5% Myctophids, 80% Large Krill, 5% Other Euphausiids, 10% Macrozooplankton |                  |              |        |                        |                |                   |                  |                  |
| G. gibberifrons  | 1% Cephalopods, 1% Myctophids, 1% Salps, 40% Benthic invertebrates, 25% Large Krill, 2% Macrozooplankton, 30% Ice algae |                  |              |        |                        |                |                   |                  |                  |
| Salps            | 5% Small Krill, 30% Microzooplankton, 5% Mesozooplankton, 30% Small phytoplankton, 30% Large Phytoplankton |                  |              |        |                        |                |                   |                  |                  |
| Benthic invertebrates | 100% Detritus |                  |              |        |                        |                |                   |                  |                  |
| Large Krill (≥24 months) | 25% Mesozooplankton, 50% Large phytoplankton, 10% Ice Algae, 15% Detritus |                  |              |        |                        |                |                   |                  |                  |
| Small Krill (< 24 months) | 15% Microzooplankton, 25% Small phytoplankton, 25% Large phytoplankton, 25% Ice Algae, 10% Detritus |                  |              |        |                        |                |                   |                  |                  |
| Other Euphausiids | 30% Mesozooplankton, 50% Large phytoplankton, 20% Detritus |                  |              |        |                        |                |                   |                  |                  |
| Microzooplankton | 60% Small phytoplankton, 25% Large phytoplankton, 15% Detritus |                  |              |        |                        |                |                   |                  |                  |
| Mesozooplankton  | 3% Microzooplankton, 24% Small phytoplankton, 66% Large phytoplankton, 7% Detritus |                  |              |        |                        |                |                   |                  |                  |
| Macrozooplankton | 3% Large Krill, 2% Small Krill, 10% Other euphausiids, 70% Mesozooplankton, 5% Small phytoplankton, 10% Large phytoplankton |                  |              |        |                        |                |                   |                  |                  |

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