A Ross Sea MPA: Preservation for science
A ROSS SEA MPA:
PRESERVATION FOR SCIENCE [1]

**Summary**

If we are to understand the indirect effects of climate change on the Southern Ocean and its foodwebs, a network of no-take zones and marine reserves of sufficient scale needs to be established in which other influences are kept to a minimum. The Ross Sea, as defined below, is the last open-ocean, cold-water, continental shelf (neritic) ecosystem remaining on Earth whose foodweb has yet to be seriously and irretrievably altered by direct human activities. Therefore, because it has been little affected by direct human activity, as detailed in this paper, the Ross Sea should be preserved for scientific research realities and potential, as well as for its profound ecosystem values. Besides a better understanding of the capabilities of living organisms to cope with or adapt to climate change, lost will be a unique evolutionary site containing the radiations of a tribe of seals, 100+ species of notothenioid fishes and several invertebrate groups.

A recent analysis ranked the Ross Sea as the least affected area within the entire World Ocean, judging from impacts measured during the last 10 years. Within a longer historical perspective, though, the continental slope (pelagic) foodweb, like the remainder of the Southern Ocean, saw its blue whales (*Balaenoptera musculus*) removed by the 1960s, and no evidence of recovery is apparent. Evidence shows that the neritic portion has a cetacean fauna, principally minke (*bonaerensis*) and killer whales (*Orcinus orca*), much like it was before the whaling era. While Weddell seals (*Leptonychotes weddelli*) were slaughtered en masse to feed sled dogs at bases in southern McMurdo Sound until the early 1980s, a slight reduction in population size in that area is considered local. The fishing, currently for Antarctic toothfish (*Dissostichus mawsoni*), has just begun.

Without protection from relatively recently initiated industrial fishing and whaling, the Ross Sea neritic food web is sure to exhibit trophic cascades, as well documented elsewhere in the World Ocean, as stocks of top-trophic, long-lived, slow-to-mature, and slow to reproduce minke whales and Antarctic toothfish are depleted, although irreversible changes to the ecosystem have not yet occurred.

**1. Overview**

Effective research on the effects of climate change to the Southern Ocean and its foodwebs requires a network of marine protected areas in which other anthropogenic influences are kept to a minimum. [2] The Ross Sea, as defined below, is the last open-ocean, cold-water, continental shelf (neritic) ecosystem remaining on Earth whose foodweb has yet to be seriously and irretrievably altered by direct human activities [3, 4; see 5, 6, for a discussion of such ecosystems]. Therefore, because it has been little affected by direct anthropogenic influences, as detailed within this paper, the Ross Sea should be preserved for scientific research [7].

The Ross Sea is divided into two components, the continental shelf (neritic) and the continental slope (pelagic). The former has as its principle, mid-trophic “forage species”, ice or crystal krill (*Euphausia crystallorophias*) and the Antarctic silverfish (*Pleuragramma antarcticum*) [8]. It, therefore, differs from the Ross Sea continental slope foodweb, dominated by *E. superba*, which was damaged in the past by the mass removal of whales (see below).

Without protection from further industrial fishing and whaling, the Ross Sea neritic food web is expected to exhibit trophic cascades that are sure to occur as stocks of top-trophic, long-lived, slow-to-mature, and slow to reproduce minke whales (*Balaenoptera bonaerensis*) and Antarctic toothfish (*Dissostichus mawsoni*) are depleted [9-13]. If these cascades are allowed to happen, the Ross Sea’s trophic structure would no longer provide an example of how Earth’s cold-water, neritic food webs once functioned, nor would it remain a laboratory in which the effects of climate change could be investigated without other factors confusing or masking climate effects. Dealing with the latter is problematic for the remainder of the Southern Ocean.

Support for the near-pristine nature of the Ross Sea was recently shown in a study concluding that it is the area of the World Ocean least impacted by recent anthropogenic influence [14]. This study divided the ocean
into 232 parts and assessed the importance of 17 different factors in altering ecosystem function. Based on averaging impacts, and considering cumulative effects, the Ross Sea received a score of 0.1 compared to the highest scores, which ranged 17.0-19.5 (North Sea, certain equatorial reefs, etc). Impacting factors included pollution of different sorts, artisanal fishing, alien species invasion, climate change (warming, acidification, UV), and others. In regard to commercial fishing, five types were included, but just for the five years from 1999 to 2003; apparently recent whaling was not included. Some pollution associated with coastal bases in McMurdo Sound and Terra Nova Bay is seen to be highly localized [15]. This paper summarizes historical and current sealing, fishing, and whaling data within the Ross Sea area, and concludes that its continental shelf foodweb is currently in a state much as it has been over past millenia.

2. Working Definition of the Ross Sea

The Ross Sea - about the size of southern Europe - is defined, following the 3000 m boundary identified by Davey [16], as the waters overlying the continental shelf and slope extending in a wavering line from Cape Adare, Victoria Land, to Cape Colbeck, Marie Byrd Land (Fig. 1). Not included are waters around the Balleny Islands (66°55' S, 163°20' E) [17], which are the summits of deep-rising sea mounts, 200 km to the northwest of Cape Adare [18]. Ross Sea Surface Water (RSSW) is distinctive and, until recent glacial melting upstream, was the most saline surface water in the Southern Ocean region. At the Ross Sea (Antarctic) Slope Front, Circumpolar Deep Water is upwelled and constrains RSSW to the south [19]. The central portion of the Ross Sea, from Ice Shelf front northward, due initially to incessant winds and subsequently to warming, becomes increasingly clear of sea ice as the season progresses, October through January. This is the Ross Sea Polynya and post polynya [20, 21].

Figure 1. The Ross Sea showing locations mentioned in the text. The shelf-break, defined as the 800 m isobath, is shown by a dashed line; banks are shown by narrow, solid lines; sea ice is shown as marbled shading in a distribution typical of early December. Discovery Inlet, an embayment in the Ross Ice Shelf that was similar to Bay of Whales, is no longer a feature, having been the product of iceberg calving in the early years of the 20th century. The Balleny Islands are well to the northwest, beyond the boundaries of this map.

3. Summaries of Sealing, Fishing and Whaling

A. Sealing

Major, industrial sealing did not affect the Ross Sea. No evidence exists that fur seals (Arctocephalus spp.), the main target species of early sealers, ever bred in any numbers, if at all, in the vicinity. No specimens have ever been found along Ross Sea shores, and no reports exist noting their presence at sea in the vicinity. The closest, and virtually only location where Antarctic fur seals (A. gazella) could have bred and still reach the Ross Sea in any numbers would have been the very steep-sided Balleny Islands (next closest, Macquarie Island, 54°S, 159°E). These emerged sea mounts are surrounded by sea ice for most of the year, and the Antarctic fur seal is not a “pack ice associated species” [25]. No evidence exists that fur seals ever occurred on the Balleny Islands despite the inspection made by sealer John Balleny, who happened upon them while
looking for new colonies to exploit in 1839, and inspections by subsequent early explorers, e.g. members of James Clark Ross’s party attempted to wade ashore [22, 26].

In the case of the southern elephant seal (Mirounga leonina), as late as the early 1980s after sub-Antarctic breeding populations recovered from decimation [27], low numbers of subadult males hauled out for molt in a number of locations during late summer, e.g. Ross Island and Victoria Land coast [28], as well on offshore rocks at the Balleny Islands [26]. No longer do they occur in the Ross Sea as the source population on Macquarie Island seriously decreased once again in the 1980s [27], and thus the likely density-dependent foraging range of that population appears to have contracted. Assuming that a recent analysis concerning Antarctic southern elephant seal rookeries is correct [29], the decrease was due to the depletion of their fish prey in sub-Antarctic Macquarie’s surrounding waters and shelves [30].

The early expeditions killed, for human and dog food, an unknown number of Weddell seals (Leptonychotes weddellii) in southern McMurdo Sound, but by the 1950s the population was thought to have recovered [31]. The New Zealand Antarctic Programme then began to kill 50-100 annually, eventually totaling about 2000, in the same area from 1957 to 1985 in order to feed sled dogs; the U.S. program killed a small (unknown) number during the first few years of this period [31]. The population, in the late 1950s prior to initiation of the kill, numbered close to 3000 individuals [32]. Since the end of the seal take, the population of seals in southern McMurdo Sound recovered only slightly, stabilizing around 2000, owing to an ocean regime shift in the mid-1970s and changes of sea ice or the foodweb that seem to have precluded additional recovery [33].

Therefore, at the large scale, the Ross Sea shelf is missing several dozen elephant seals and several hundred Weddell seals from the summer foodweb. A minimum of 10,000 Weddell seals currently breed along the Victoria Land coast and outlying islands; unknown numbers occur in Bay of Whales and along Cape Colbeck [33]. There are a few hundred thousand seals of three species present, as well as non-breeding Weddell seals, in the Ross Sea total; mostly they are associated with the marginal ice zone of the eastern and western Ross Sea and the continental slope (See Appendix I) [2, 34].

B. INDUSTRIAL FISHING

The world’s continental shelves have largely been depleted of fish, especially demersal species [4, 5, 11]. This is true even in the Antarctic [35]. Recent documentation has shown a strong correlation between decreasing populations of fish-eating penguins and pinnipeds and the over-exploitation and depletion of fish stocks on the insular shelves and slopes of low-latitude Antarctic islands, including the Antarctic Peninsula [29]. Among the data amassed from FAO and CCAMLR, none indicate that industrial fishing had ever occurred in the Ross Sea [35], until the last 12 years [10].

In a process reminiscent of “fishing down the food web” [37], led by New Zealand, CCAMLR initiated a program whereby the toothfish biomass will be reduced by 50% from pre-exploitation levels within 35 years [10]. In 1996, an “experimental” fishery began when New Zealand vessels extracted 1 mt, growing to 745 mt by 1999 (data from CCAMLR) [3, 4]. Some portion of this catch was from sea mounts north of the Ross Sea. In 2000 no longer an experimental fishery, vessels from other countries joined, along with illegal vessels. Once CCAMLR raised the allowable catch from ~2500 mt to ~4000 mt in 2002, vessels from more than 10 countries were attracted and the catch began to meet the quota. CCAMLR believes that as of 2007, based on the legal take, a 15% reduction in pre-fished biomass has already been achieved [10]. Although the catch-per-unit effort has not shown any signs of depletion — the fishery has been concentrated at 2000m along the Ross Sea slope, fishing for the largest fish — it is no longer possible to catch adult fish in the southernmost reach of the shelf, McMurdo Sound, judging from a record that spans 35 years; therefore the stock appears to have contracted [38].

C. WHALING

While the extraction of whales, especially blue whales (Balaenoptera musculus intermedia), from the continental slope of the Ross Sea was important, little whaling was thought to have been carried out on the shelf itself [3, 4], where only minke whales, killer whales (Orcinus orca) and Arnoux’s beaked whales
(Berardius arnuxii) are known to occur now, and as will be argued, in the past [39]. Some people have questioned how whales could have avoided the Ross Sea neritic system, as being contrary to the literature. However, a closer look at the available information indicates that very few blue, fin and certainly no humpback whales occurred over the shelf in the past or at present, unlike adjacent waters, and in fact very few individuals of these species, if any, were ever taken from Ross Sea neritic waters (as opposed to waters of the continental slope). The subsequent industrial whaling for minke whales during the 1970s-80s was largely confined to waters north and west of the Ross Sea, but nevertheless the population has recovered [40] since cessation of whaling in the 1980s. Unlike the great whales, the Antarctic minke was never decimated to the point of near extinction, thus challenging chances for recovery.

Two factors confuse the role of whaling in the potential alteration of the Ross Sea neritic ecosystem. First, the whales separated the Southern Ocean into parts, such as Ross Sea, Amundsen Sea, etc, with these designations applying to any Antarctic waters lying in the general vicinity of these areas [23]. Therefore, based on the definition of the Ross Sea above, any historical reports that nebulously refer to “the Ross Sea” need to be reviewed carefully [41]. Second, a perception of whaling in the Ross Sea exists because of the “Bay of Whales”, named by Ernest Shackleton [42], who appears to have encountered a large concentration of killer whales (Orcinus orca) at the time. In fact, the Ross Sea is the major area where the diminutive ecotype-C (fish eating) killer whale is found [43], and characteristically they occur in large groups sometimes 50-100 or more, especially where fast ice is breaking up thus to expose yet-to-be-harassed fish [22, p. 244]. Such a density of animals is quite uncharacteristic of foraging baleen whales [44].

Ross [22] visited this area in 1841 and 1842 and, though he wrote extensively of the whales seen during his two voyages to the Ross Sea, especially where large numbers were encountered, he made no mention of whales during the several days he explored the Barrier front. Other subsequent visitors to the Bay of Whales, as well as the factory ship James Clark Ross, which tied up here for weeks at a time during the 1923 and 1924 whaling seasons, encountered no whales nor any in nearby Discovery Inlet (Fig. 1) [23, 24, 34, 46]. Regarding southern right whales (Eubalaena australis) and sperm whales (Physeter macrocephalus), Ross [22] is the only person to have ever seen right whales in the Ross Sea sector, and in fact well north of the Ross Sea, at latitude 63° 20’S, 174° 30’E at the north edge of the ice pack. Ross also reported sperm whales in a few instances, in each case well north of the Ross Sea (waters of the outer slope and deeper) [47]. The IWC database indicates that 8 were taken in the region during the 1920s (Table 3) [48].

The early history of “Ross Sea” whaling is summarized in Appendix 2, which gives an idea of the abundance, species composition and distribution of the whaled species. In the first year, the effort was entirely contained in the central portion of the Ross Sea slope (all blues, a very few fin whales), with the single factory ship stationed from time to time at the Ross Ice Shelf [49]. In the next two years, almost all of the effort occurred in the vicinity of Possession Island (Fig. 1), at the extreme western end of the Ross Sea shelf break (almost all blues, a few fins). In the next three years, with two, then three, factory ships added (Appendix 3), the effort shifted farther west to the waters off Adélie Land (Balleny Islands), but still in the Ross Sea “sector” (blues, fins, humpbacks Megaptera novaeangliae and an occasional sei whale B. borealis). A final attempt was made in 1929-30 to enter the Ross Sea for whales but only a few blues were taken. In the 1950s, factory ships twice attempted to whale in the Ross Sea, south of the ringing ice field, but quickly departed taking few, if any, whales [23, 50]. Therefore, the picture is clear, especially as supported by additional analyses [51]: the current neritic fauna of minke, killer and Arnoux’s beaked whales that is present now is what whaler’s encountered in the past; the whales found blue and fin whales on the Ross Sea slope.

Finally, IWC surveys for minke whales (done in open water) indicate them to be abundant in the eastern and western Ross Sea, along the edge of the pack ice, as well as along the slope; few have been found in the south-central Ross Sea (along the Ross Barrier) [34, 53, 54]. On the basis of existing documentation, many more would be within the pack ice of the polynya’s marginal ice zone [55]. It is highly likely that minke whales increased their numbers and expanded into the slope habitat [53] when blue whales were removed in the 1920s. Given density-dependent factors they would not be expected to have increased over the shelf. If and when blue whales recover, we might expect them again to frequent slope waters and for minke whales to decrease there.

4. **Conclusions**
The foodweb of the Ross Sea continental shelf up until the past 10 years appears to have been largely untouched directly by humans. There are fewer elephant seals, formerly rare in the Ross Sea, and fewer Weddell seals in McMurdo Sound. The cetacean fauna appears to be much as it has been since James Clark Ross first sailed into these waters in the mid-19th century [55]. It is possible that the large take of minke whales, especially in pelagic waters north and west of the Ross Sea (IWC area V, VI), during the 1970s - early 1980s may have facilitated, along with climate-driven changes in Ross Sea polynyas, the increase of Adélie penguins (Pygoscelis adeliae) in the Ross Sea at that time. With cessation of industrial whaling, the penguin increase leveled off. Recent research shows that the penguins and these whales are direct trophic competitors [56] This would seem to be, therefore, the major anthropogenic influence so far in altering the Ross Sea neritic foodweb: more penguins in response, partially, to fewer whales on the penguins’ wintering grounds.

The unique ecology and relatively undisturbed state of the Ross Sea make it a priority area for protection as part of a comprehensive and representative network. Implementing strong measures on biotic resource extraction in the Ross Sea will be essential to enabling sustainable fisheries in the South Pacific sector of the Southern Ocean as well as future analysis of climate change effects to the biota undertaken without the confusion of having to consider complicating factors. Moreover, the Ross Sea is a unique evolutionary site involving the radiations of a tribe of seals, 100+ species of notothenioid fishes and several invertebrate groups. In the case of the fish, and unlike elsewhere in the world, the Eocene fauna has been completely replaced by a modern fauna dominated by a single group – the notothenioids. There is no other locality in the marine realm with a similar situation; understanding how this group responds to and adapts to rapid climate change has no precedent elsewhere.

Comprehensive protection for the Ross Sea would deliver a wide range of ecosystem benefits that further key values of the Antarctic Treaty, the Environmental Protocol and CCAMLR. Such a living laboratory would provide a tangible example of how the Antarctic Treaty is living up to its aspiration of the Antarctic as a natural reserve, devoted to *peace and science*. 
Appendix I
A summary of population estimates of marine mammals in the Ross Sea made on the basis of several cruises during the late 1970s [34]

<table>
<thead>
<tr>
<th>Marine Mammal</th>
<th>Estimated Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weddell seal <em>Leptonychotes weddellii</em></td>
<td>31,990</td>
</tr>
<tr>
<td>Leopard seal <em>Hydrurga leptonyx</em></td>
<td>7,990</td>
</tr>
<tr>
<td>Crabeater seal <em>Lobodon carcinophagus</em></td>
<td>203,700</td>
</tr>
<tr>
<td>Ross seal <em>Ommatophoca rossii</em></td>
<td>5,050</td>
</tr>
<tr>
<td>Elephant seal <em>Mirounga leonina</em></td>
<td>40</td>
</tr>
<tr>
<td>Minke whale <em>Balaenoptera bonaerensis</em></td>
<td>14,280</td>
</tr>
<tr>
<td>Killer whale <em>Orcinus orca</em></td>
<td>3,440</td>
</tr>
</tbody>
</table>

Appendix II
Summary of information from Tønnesen & Johnsen ([23] (their table 25 and text) with annotations. All numbers, except as noted, for the last total listed and for any whales taken in Balleny area, are of blue whales (see Appendix 3 for those)

<table>
<thead>
<tr>
<th>Season</th>
<th>Whales</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1923-24</td>
<td>221</td>
<td>Ross Sea, factory ship stationed at Discovery Inlet; whaling along slope (of total 10 fin)</td>
</tr>
<tr>
<td>1924-25</td>
<td>427</td>
<td>Ross Sea, factory ship at Possession Is area, slope; short time at Discovery Inlet; whaling along slope (of total 19 fin)</td>
</tr>
<tr>
<td>1925-26</td>
<td>531</td>
<td>Almost entirely Possession Is area, slope [24]</td>
</tr>
<tr>
<td>1926-27</td>
<td>1117</td>
<td>Possession Is (Ross Sea slope) and Balleny Is area</td>
</tr>
<tr>
<td>1927-28</td>
<td>2012</td>
<td>Same logistical area as previous season.</td>
</tr>
<tr>
<td>1928-29</td>
<td>1742</td>
<td>Most whales from Balleny area, outside of ice belt</td>
</tr>
<tr>
<td>1929-30</td>
<td>61</td>
<td>All from Ross Sea, i.e. inside of ice belt [24], along slope; any others from Balleny area</td>
</tr>
<tr>
<td>Total</td>
<td>6111</td>
<td>Number expressly from Ross Sea slope: 1,240 + unknown numbers taken in 1926-27 and 1927-28 (when most were from Balleny area)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>Whales</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1929-31</td>
<td>5223</td>
<td>NE of Balleny Is; no operation inside of pack ice, i.e. in the Ross Sea</td>
</tr>
<tr>
<td>1923-31</td>
<td>18,238</td>
<td>Total for Ross sector including outside Ross Sea proper [24] unlisted above</td>
</tr>
</tbody>
</table>
### Appendix III

Whales taken during historical times from the Ross Sea sector of the Southern Ocean; information contained in the IWC data base, courtesy T. Branch; cf. Appendix 2 for specifics of locations within this sector.

<table>
<thead>
<tr>
<th>Year</th>
<th>Floating factory</th>
<th>Blue</th>
<th>Fin</th>
<th>Sperm</th>
<th>Humpback</th>
<th>Sei</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1923</td>
<td>JC Ross</td>
<td>211</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>221</td>
</tr>
<tr>
<td>1924</td>
<td>JC Ross</td>
<td>408</td>
<td>19</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>427</td>
</tr>
<tr>
<td>1925</td>
<td>JC Ross</td>
<td>523</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>531</td>
</tr>
<tr>
<td>1926</td>
<td>CA Larsen</td>
<td>405</td>
<td>45</td>
<td>0</td>
<td>82</td>
<td>0</td>
<td>532</td>
</tr>
<tr>
<td></td>
<td>NT Nielsen-Alonso</td>
<td>426</td>
<td>27</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>453</td>
</tr>
<tr>
<td></td>
<td>JC Ross</td>
<td>237</td>
<td>17</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>254</td>
</tr>
<tr>
<td>1927</td>
<td>CA Larsen</td>
<td>785</td>
<td>43</td>
<td>0</td>
<td>9</td>
<td>0</td>
<td>837</td>
</tr>
<tr>
<td></td>
<td>NT Nielsen-Alonso</td>
<td>733</td>
<td>22</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>755</td>
</tr>
<tr>
<td></td>
<td>JC Ross</td>
<td>564</td>
<td>45</td>
<td>0</td>
<td>7</td>
<td>0</td>
<td>616</td>
</tr>
<tr>
<td>1928</td>
<td>CA Larsen</td>
<td>644</td>
<td>23</td>
<td>2</td>
<td>13</td>
<td>0</td>
<td>682</td>
</tr>
<tr>
<td></td>
<td>CALarsen</td>
<td>111</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>113</td>
</tr>
<tr>
<td></td>
<td>NT Nielsen-Alonso</td>
<td>710</td>
<td>18</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>732</td>
</tr>
<tr>
<td></td>
<td>JC Ross</td>
<td>530</td>
<td>15</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>545</td>
</tr>
<tr>
<td>1929</td>
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<td>733</td>
<td>192</td>
<td>1</td>
<td>166</td>
<td>0</td>
<td>1092</td>
</tr>
<tr>
<td></td>
<td>Kosmos</td>
<td>995</td>
<td>464</td>
<td>2</td>
<td>356</td>
<td>0</td>
<td>1817</td>
</tr>
<tr>
<td></td>
<td>Kosmos</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>NT Nielsen-Alonso</td>
<td>509</td>
<td>128</td>
<td>2</td>
<td>105</td>
<td>0</td>
<td>744</td>
</tr>
<tr>
<td>1930</td>
<td>NT Nielsen-Alonso</td>
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<td>0</td>
<td>0</td>
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<td>1</td>
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<tr>
<td></td>
<td>JC Ross</td>
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<td>68</td>
<td>1</td>
<td>24</td>
<td>0</td>
<td>435</td>
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<tr>
<td></td>
<td>JC Ross</td>
<td>0</td>
<td>12</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Southern Princess</td>
<td>459</td>
<td>294</td>
<td>0</td>
<td>121</td>
<td>0</td>
<td>874</td>
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<tr>
<td>Totals</td>
<td></td>
<td>9330</td>
<td>1451</td>
<td>8</td>
<td>890</td>
<td>1</td>
<td>11680</td>
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</table>
Footnotes and References

1. Principle author D. Ainley; thanks to T.A. Branch, R.L. Brownell, J. Eastman, P. Penhale and M. Pinkerton for comments that helped immensely to improve this paper.


11. This scenario has been documented countless times elsewhere in the World Ocean (see [5, 6], and there is no logical reason to expect otherwise with respect to the Ross Sea.


18. The Ross Sea is shaped like a right triangle, with the height being the north-south oriented Victoria Land coast and the base being the east-west Ross Ice Shelf (or Barrier). [Actually, to be totally accurate, the Ross Ice Shelf covers a portion of the Ross Sea basin to the south equal in size to the open-water portion in the north]. The mean depth of the exposed shelf is about 500 m, although this varies widely between deep troughs and shallow banks. The shelfbreak has been defined by some to occur at the level of the troughs, about 800 m, rather than the outward crest of its banks, with the slope descending to 3000 m [8]; the tops of the banks at the shelf break can be <200 m deep. Overall, the Ross Sea bathymetry slopes upward from south to north (the banks) owing to the isostatic depression of the continent from the heavy mass of the polar ice cap.


21. Gaining access to this central portion has been the bane of heroic explorers and whaling ships (and ships even now). It was and is best to wait until later in the summer, February or so, when a passage usually opened(s) just to the east of the northern Victoria Land coast (Fig. 1). However, in February, too, the southernmost waters near the Ice Shelf begin to freeze, a fact learned well by early explorers and whalers [22, 23, 24].


32 It initially decreased in size, and then began to increase in a density-dependent response to the kill, followed by a decrease to near 1500 by the mid-1980s when the killing ended. Relative to the Ross Sea population, this decrease was thought to be local (McMurdo Sound), although it is partially sustained by emigration from the greater Ross Sea. Therefore, fluctuation in some sort of density-dependent emigration from outside McMurdo Sound was likely involved at times (Testa, J.W. & Siniff, D.B. 1987. Population dynamics of Weddell seals (Leptonychotes weddelli) in McMurdo Sound, Antarctica. *Ecol. Monogr.* 57: 149-165).


Based on IWC abundance estimates by small geographic areas in the most recent c

Konishi, K., Tamura, T., Zenitani, R.

We can assume that their numbers now, in waters north of the Ross Sea, are much reduced as their range contracted


Amundsen, R. 1912.


Shackleton, E. 1909.

Until recently, even CCAML

Branch, T.A. 2006. Abundance estimates for Antarctic minke whales from three completed circumpolar sets of


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On the basis of all available catch, sightings, strandings, discovery marks and recoveries, and acoustic recording data

of the 648 whale species taken from the Ross Sea on the slope during 1923-24 only 29 were fin whales (B. physalus) and the vast majority were blue whales. In subsequent years, blue whales taken in the region outnumbered fins 10 to 1 (See Appendices 2 and 3).

We refer to the waters south of New Zealand as the Ross Sea. However, waters north of the Ross Sea shelf, being referred to by oceanographers as the Ross Gyre (Jacobs et al. 2002), are quite different and, other than numerous sea mounts, descend to depths of 3000 m or more.[18]


We can assume that their numbers now, in waters north of the Ross Sea, are much reduced as their range contracted upon the population being decimated by whaling farther north. See for instance: Whitehead, H. 2000. Density-


Of the 648 whales taken from the Ross Sea on the slope during 1923-24 only 29 were fin whales (B. physalus) and the vast majority were blue whales. In subsequent years, blue whales taken in the region outnumbered fins 10 to 1 (See Appendices 2 and 3).

Marshall [39], on the factory ship C.A. Larsen, in the final year of the (true) Ross Sea whaling (1929-30) noted, with map to illustrate, that the blue whales were taken on the northward side of an offshore “bank”. In fact, the northern slope of this bank (now known to be several banks running SW to NE; Fig. 1) constitutes the shelf break.

On the basis of all available catch, sightings, strandings, discovery marks and recoveries, and acoustic recording data in the Southern Ocean, it was concluded that “Blue whales were generally associated with waters deeper than continental shelves. Shallow-water records were typically from regions with narrow continental shelves...In the Antarctic, they were most common on deep continental slopes...,” pp. 136-37 in Branch, T.A., Stafford, K.M., Palacios, D.M., Allison, C., et al. 2007. Past and present distribution, densities and movements of blue whales Baleaenoptera musculus in the Southern Hemisphere and northern Indian Ocean. Mammal Rev. 37: 116–175; see also: Tynan, C.T. 1998. Ecological importance of the southern boundary of the Antarctic Circumpolar Current. Nature 392: 708–710; Branch, T.A. 2007. Abundance of Antarctic blue whales south of 60°S from three complete circumpolar sets of surveys. J. Cetacean Res. Manage. 9: 253–262. In addition, recent maps for IWC areas III-VI (40E-150W), 1987-2004 show only three blue whales taken from or seen in the neritic waters of the Ross Sea and few even on the outer shelf, except for a tiny “island” of catches just to east of Ross Island at the western end of the Barrier [52]. This must be a record of catch processing and not capture, as in modern times very few whales of any kind are seen in this locality. The waters there have a food web that does not generate high krill or forage fish densities and certainly not E. superba[6], the other attribute of habitat identified by Branch et al. as being critical to blue whale occurrence in the Southern Ocean. Finally, sighting and capture data for fin and humpback whales [52] show none over the Ross Sea shelf. All of these data, then, are consistent with the story expressed herein: these whales do not and did not occur over the Ross Sea shelf. All of these data, then, are consistent with the story expressed herein: these whales do not and did not occur over the Ross Sea shelf in any numbers (blue), if at all (fin, humpback). In the case of the latter species, the pattern is consistent with that described by others: none in the Ross Sea, shelf or slope, but large numbers off the Adélie Land coast (see Branch, T.A. 2009. Humpback abundance south of 60S from three completed sets of IDR/C/SOWER circumpolar surveys. J. Cetacean Res. Manage., in press).


Based on IWC abundance estimates by small geographic areas in the most recent circumpolar survey (1991-2003), a population of 21,000 minke whales is estimated for the Ross Sea (T.A. Branch, pers. comm.), including the shelf...
and slope (but of course any within the pack ice would not have been surveyed). Therefore, this represents an appreciable population increase from the days of minke whaling of the 1970s-early 1980s (see Appendix 1).