Charles Monnett · Jeffrey S. Gleason

Observations of mortality associated with extended open-water swimming by polar bears in the Alaskan Beaufort Sea

Received: 25 April 2005 / Revised: 20 December 2005 / Accepted: 20 December 2005
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Abstract During aerial surveys in September 1987–2003, a total of 315 live polar bears were observed with 12 (3.8%) animals in open water, defined for purposes of this analysis as marine waters >2 km north of the Alaska Beaufort Sea coastline or associated barrier islands. No polar bear carcasses were observed. During aerial surveys in early September, 2004, 55 polar bears (Ursus maritimus) were seen, 51 were alive and of those 10 (19.9%) were in open water. In addition, four polar bear carcasses were seen floating in open water and had, presumably, drowned. Average distance from land and pack ice edge for live polar bears swimming in open water in 2004 (n = 10) were 8.3 ± 3.0 and 177.4 ± 5.1 km, respectively. We speculate that mortalities due to off-shore swimming during late-ice (or mild ice) years may be an important and unaccounted source of natural mortality given energetic demands placed on individual bears engaged in long-distance swimming. We further suggest that drowning-related deaths of polar bears may increase in the future if the observed trend of regression of pack ice and/or longer open water periods continues. There is evidence that total extent of Arctic sea ice has declined at an annual rate of 3–5% over the past several decades, although these declines are not consistent across the Arctic (Comiso 2003, 2005; Stroeve et al. 2004). Warming trends in the Arctic (Comiso 2003) also appear to be affecting thickness of multiyear ice in the polar basin (Rothrock et al. 1999) and perennial sea ice coverage (declines 9% per decade) (Comiso 2002a, b). Concerns have been raised over apparent declines in the minimum extent of summer ice pack and temporal increases in the open water period, and the potential for impacts on polar bears and their populations (Stirling and Derocher 1993; Stirling 2002; Derocher et al. 2004). Evidence of potential negative effects from reductions in Arctic sea ice comes from long-term monitoring of polar bears in Canada. Mean monthly (April–June) surface air temperatures in western Hudson Bay increased at a rate of 0.2–0.3°C per decade during 1950–1990 (Skinner et al. 1998) and annual ice breaks up 2.5 weeks earlier than 30 years ago (Stirling et al. 1999; Derocher et al. 2004; Gough et al. 2004). Female polar bears in this region are now coming ashore roughly 2 weeks earlier and in poorer condition (Derocher and Stirling 1992; Stirling and Lunn 1997; Stirling et al. 1999). Long-term declines in birth rates and reduced cub weights in conjunction with delayed fall dispersal onto the ice by females and associated young are indicative of negative population effects, at least at a regional scale (Stirling and Derocher 1993; Stirling et al. 1999; Derocher et al. 2004). Though these sublethal effects are now recognized, no mention has been made of potential for lethal effects of reduced sea ice on individual polar bears. The net effect of global climate change on polar bear populations remains largely unknown (but see Stirling et al. 1999; Derocher et al. 2004), but its potential for negative impacts may pose one of the greatest conservation challenges to the management of polar bears (Norris et al. 2002; Hassel 2004).

The primary purpose of the Minerals Management Service (MMS) Bowhead Whale Aerial Survey Project (BWASP) is to monitor the fall migration of bowhead

Introduction

Polar bears (Ursus maritimus) depend on the vast expanses of Arctic sea ice for hunting their primary prey species, ringed (Phoca hispida) and bearded (Erignathus barbatus) seals (Stirling and Derocher 1993; Stirling et al. 1993) and locating potential mates. In some locations, they rely heavily on fat stores to meet energetic demands incurred during the open water fasting period (Ramsay and Stirling 1988; but see Derocher et al. 1993).
whales in the Alaskan Beaufort Sea. However, systematic observations have been made of all marine mammals encountered, including polar bears. Herein, we discuss our observations of polar bears swimming offshore in the Alaskan Beaufort Sea and the circumstances surrounding subsequent observations of dead, and presumably drowned, polar bears.

**Study area**

The BWASP is based on a set of random field transects within established geographic blocks overlapping or near Chukchi and Beaufort Sea lease sale areas offshore of the north Alaskan coast (140°–157°W and south of 72°N, Fig. 1). The study area roughly overlaps a “core area” of polar bear activity (see Amstrup 2000, Amstrup et al. 2000, 2001 for further details). In the Beaufort Sea, landfast ice forms during the fall and may eventually extend up to 50 km offshore by the end of winter (Norton and Weller 1984). The pack ice, which includes multiyear ice averaging 4 m in thickness with pressure ridges up to 50 m thick (Norton and Weller 1984), becomes contiguous with new and fast ice in late fall. From early-November to mid-May, the Beaufort Sea remains almost totally ice covered. In mid-May, a recurring flaw lead can form just seaward of the stable fast ice followed by decreasing ice concentrations and large areas of open water in summer (LaBelle et al. 1983). A detailed description of local weather patterns off the coast of northern Alaska is provided by Brower et al. (1988).

**Methods**

The BWASP survey was conducted from 1987 to 2004 from a de Havilland Twin Otter Series 300 aircraft equipped with two medium-sized bubble windows behind the cabin bulkhead and one on the aft starboard side that afforded complete trackline viewing. Data

![Map of Beaufort Sea and Alaska](image)

Fig. 1 Distribution of polar bears (*Ursus maritimus*) observed during fall annual bowhead whale (*Balaena mysticetus*) aerial surveys in the Beaufort Sea, 1987–2004. Open circles represent live bears that were observed swimming. Closed circles represent dead bears observed in 2004. Numbers within open circles indicate year in which the observation occurred. Circles without numbers represent observations in 2004.
on sightings included date, time, latitude, longitude, altitude, aircraft heading, species, total number, observer, behavior (for all whales and some polar bear sightings), size (adult, cow-calf pair, adult female with cub), habitat (for all whales and some polar bear sightings), sea ice type, sea ice coverage, sea state, visibility, weather, glare and response to aircraft. Surveys were generally flown at a target altitude of 457 m and a groundspeed of roughly 200–250 km/h. Surveys were aborted when cloud ceilings were consistently <305 m or when sea state was consistently greater than Beaufort 4 (Chapman 1977). Survey effort hereafter refers to distance flown in kilometers while on transect, on connect and on search. For a more detailed description of survey methodology (and general findings) refer to Treacy (2002) and Monnet and Treacy (2003).

Data selection and analysis

Analysis was limited to observations during September as nearly all observations of swimming polar bears were made during this month which corresponds to maximum area of open water in the survey region. A caveat of our data is that individual locations represent the latitude-longitude of the aircraft relative to the polar bear at the time of the observation and not the exact location of the animal. However, low sightability dictated that most swimming bears were very near or under the aircraft when their location was registered.

Data on sea ice conditions were obtained from the United States Navy/NOAA Joint Ice Center (NAVY/NOAA 2002) and incorporated into the ArcGIS database. Data on sea ice conditions on or nearest the date bears were observed (range 0–4 days) were used. Distance estimates from land and pack ice edge were generated by selecting on individual points and “connecting” a straight-line from the bear to land and ice, respectively, in ArcGIS.

Data on wind speeds for September 2004 were taken from the research meteorological station at Endicott (Hoeffler Consulting Group 2004) and Barter Island (Kaktovik) weather station (Station Number 700860 99999, National Climatic Data Center, Asheville, NC). The Kaktovik station is located onshore near the village, whereas the Endicott station is more exposed situated approximately 5 km offshore on a causeway.

Distances of observations to land (barrier islands or coastline) were measured in ArcGIS (Environmental Systems Research Institute; ESRI 2001) and only those observations >2 km north of barrier islands and the coast (definition of open water in the context of this paper) were selected. All descriptive statistics and analyses were performed in SPSS Release 10.1 (SPSS, Inc., 2001). Database manipulations were done in Microsoft ACCESS and all spatial analyses employed ArcGIS version 3.2 (ESRI 2001).

Results

Survey effort

Approximately 292,000 km were flown during September (1987–1994). Survey effort (transect + connect + search) varied by year [mean September effort = 16,192 km; range 8,253 (1991)–23,916 (1998)] with effort influenced primarily by local weather conditions. Survey effort and bear sightings are summarized by year in Table 1.

During aerial surveys conducted in 1987–2004, a total of 658 polar bears were observed in all habitats (i.e., land, ice and water). Total number of bears observed during September in all years was 370 and varied annually from 0 to 96 (Table 1).

Development of inclement weather during mid-September, 2004

Surveys were initially flown in the vicinity of Kaktovik on 6–8 September 2004. During that time, light wind conditions (0–10 km/h) were prevailing (Fig. 2). The sea state of nearshore waters where most of the swimming bears were observed was calm. Over the next days, high winds occurred across the study area with light westerly winds switching to strong easterly winds peaking at 54 km/h at Endicott and 46 km/h measured at Kaktovik between 10 and 11 September (Fig. 2). Winds offshore were likely considerably higher because the weather stations are located at relatively sheltered onshore sites. Seas became very rough with wave heights estimated in excess of 2 m. By 14 September, winds had decreased and waves had diminished.

Polar bears in open water

During 1987–2003, a total of 315 live polar bears was observed during September and of those 12 (3.8%) were in open water (Table 2). No dead and floating polar bears were observed. In 2004, a total of 55 polar bears were observed during September. Fifty-one were alive and of those 10 (19.9%) were in open water (Fig. 1). In addition, four polar bear carcasses were seen floating in open water (Table 2), the first such observations over the span of the survey.

Mean distance (± standard error) from land and pack ice edge to the four dead polar bears was 53.6±17.0 and 181.2±25.2 km, respectively (Table 2). Distance from land and pack ice edge for live polar bears swimming in open water in 2004 was 8.3±3.0 and 177.4±5.1 km, respectively. Distance from land and pack ice for all live swimming bears observed from 1987 to 2003 ranged 4.9–75.3 and 22.349 km, respectively.
Table 1 Range of survey dates, number of polar bears (*Ursus maritimus*) observed (total and swimming) and number of flights and kilometers flown as an index to effort during fall bowhead whale (*Balaena mysticetus*) surveys, 1987–2004

<table>
<thead>
<tr>
<th>Year</th>
<th>Survey period*</th>
<th>No. of bears observed&lt;sup&gt;a&lt;/sup&gt;</th>
<th>No. of bears swimming&lt;sup&gt;a&lt;/sup&gt;</th>
<th>No. of flights&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Total distance (km) surveyed&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>1 Sept.–18 Oct.</td>
<td>55 (51)</td>
<td>14 (4)</td>
<td>29</td>
<td>25,865</td>
</tr>
<tr>
<td>2003</td>
<td>1 Sept.–19 Oct.</td>
<td>45 (45)</td>
<td>3</td>
<td>28</td>
<td>17,600</td>
</tr>
<tr>
<td>2002</td>
<td>22 Aug.–7 Oct.</td>
<td>11 (6)</td>
<td>2</td>
<td>27</td>
<td>23,253</td>
</tr>
<tr>
<td>2001</td>
<td>31 Aug.–19 Oct.</td>
<td>6 (0)</td>
<td>0</td>
<td>23</td>
<td>16,996</td>
</tr>
<tr>
<td>2000</td>
<td>1 Sept.–19 Oct.</td>
<td>23 (5)</td>
<td>0</td>
<td>28</td>
<td>21,053</td>
</tr>
<tr>
<td>1999</td>
<td>31 Aug.–23 Oct.</td>
<td>37 (34)</td>
<td>1</td>
<td>36</td>
<td>26,053</td>
</tr>
<tr>
<td>1998</td>
<td>31 Aug.–27 Oct.</td>
<td>114 (96)</td>
<td>0</td>
<td>44</td>
<td>40,813</td>
</tr>
<tr>
<td>1997</td>
<td>31 Aug.–19 Oct.</td>
<td>52 (5)</td>
<td>1</td>
<td>36</td>
<td>28,701</td>
</tr>
<tr>
<td>1996</td>
<td>1 Sept.–10 Oct.</td>
<td>10 (1)</td>
<td>0</td>
<td>34</td>
<td>26,008</td>
</tr>
<tr>
<td>1995</td>
<td>31 Aug.–20 Oct.</td>
<td>5 (5)</td>
<td>5</td>
<td>32</td>
<td>26,276</td>
</tr>
<tr>
<td>1994</td>
<td>31 Aug.–18 Oct.</td>
<td>32 (15)</td>
<td>1</td>
<td>33</td>
<td>29,299</td>
</tr>
<tr>
<td>1993</td>
<td>1 Sept.–28 Oct.</td>
<td>5 (5)</td>
<td>0</td>
<td>41</td>
<td>36,809</td>
</tr>
<tr>
<td>1992</td>
<td>31 Aug.–23 Oct.</td>
<td>209 (57)</td>
<td>0</td>
<td>45</td>
<td>44,815</td>
</tr>
<tr>
<td>1991</td>
<td>31 Aug.–20 Oct.</td>
<td>21 (0)</td>
<td>0</td>
<td>25</td>
<td>18,954</td>
</tr>
<tr>
<td>1990</td>
<td>1 Sept.–20 Oct.</td>
<td>1 (0)</td>
<td>0</td>
<td>30</td>
<td>20,424</td>
</tr>
<tr>
<td>1989</td>
<td>1 Sept.–20 Oct.</td>
<td>6 (0)</td>
<td>0</td>
<td>31</td>
<td>23,175</td>
</tr>
<tr>
<td>1988</td>
<td>1 Sept.–20 Oct.</td>
<td>25 (5)</td>
<td>0</td>
<td>32</td>
<td>28,598</td>
</tr>
<tr>
<td>1987</td>
<td>1 Sept.–31 Oct.</td>
<td>0 (0)</td>
<td>0</td>
<td>41</td>
<td>34,836</td>
</tr>
</tbody>
</table>

<sup>a</sup>Includes all dates for aerial surveys in which the plane left the airport in Deadhorse, AK regardless of whether or not transects were actually flown. In some instances, transects could not be flown due to inclement weather in the study area on a given date.

<sup>b</sup>Includes all polar bears observed regardless of location, e.g., on land or ice, and is uncorrected for effort. Numbers in parentheses were bears seen during September.

<sup>c</sup>Includes only those polar bears observed swimming ≥2 km from shore. Numbers in parentheses in 2004 were bears confirmed as dead via circling. Swimming in open water was only observed during September.

<sup>d</sup>Total distance flown includes all kilometers flown from the time of departure from the airport in Deadhorse, AK until the plane returns back at the airport. Though it provides a rough estimate of effort it overestimates distance actually “scoarched”.

*Represents some larger groups (≥5 bears) that were resighted in the proximity of villages, usually with concentrations of bears attracted to bowhead whale carcasses, i.e., bone piles.

Discussion

To our knowledge, we report here the first observations of polar bears floating dead offshore and presumed drowned while making apparent long-distance movements in open water. Polar bears are considered strong swimmers, but they have rarely been observed swimming far from ice or land. Ørnsby (1969) observed a polar bear in open water estimated to be 160 km from land, and Burns et al. (1981) commented that the eventual fate of this bear was unknown. Ferguson et al. (2000) documented only 0.04% (3 of 6,943) of polar bear telemetry observations were classified as occurring in "open water".

Our observations suggest that polar bears swimming in open water near Kaktovik drowned during a period of high winds and correspondingly rough sea conditions between 10 and 13 September 2004. No other deleterious environmental conditions were present that might have led to the deaths of those polar bears. The only human-related activity in the near-shore marine environment in the eastern Alaskan Beaufort Sea during the relevant time period

![Fig. 2 Time series from data on hourly wind speeds (km/h) from the Endicott (solid line; MMS Contract # 31067, Minerals Management Service, Anchorage, AK) and Barter Island (Kaktovik) weather stations (dashed line; Station Number 700860 99999, National Climatic Data Center, Asheville, NC) during September 2004](image-url)
Table 2. Dates (number in parentheses indicates multiple bears for a given observation event) of polar bears (*Ursus maritimus*) observed, distance from land, distance to pack ice edge and date in which pack ice edge was estimated during fall annual bowhead whale (*Balaena mysticetus*) surveys in the Beaufort Sea, 1987–2004

<table>
<thead>
<tr>
<th>Year</th>
<th>Date observed</th>
<th>Distance from land (km)</th>
<th>Distance to ice (km)</th>
<th>Date ice estimated</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>6 Sept.</td>
<td>2.1</td>
<td>185</td>
<td>6 Sept.</td>
</tr>
<tr>
<td></td>
<td>6 Sept.</td>
<td>4.3</td>
<td>188</td>
<td>6 Sept.</td>
</tr>
<tr>
<td></td>
<td>6 Sept. (2)</td>
<td>11.4</td>
<td>195</td>
<td>6 Sept.</td>
</tr>
<tr>
<td></td>
<td>6 Sept.</td>
<td>33.2</td>
<td>188</td>
<td>6 Sept.</td>
</tr>
<tr>
<td></td>
<td>7 Sept.</td>
<td>3.6</td>
<td>187</td>
<td>6 Sept.</td>
</tr>
<tr>
<td></td>
<td>14 Sept. (3)</td>
<td>2.6</td>
<td>160</td>
<td>13 Sept.</td>
</tr>
<tr>
<td></td>
<td>14 Sept.</td>
<td>39.9*</td>
<td>158</td>
<td>13 Sept.</td>
</tr>
<tr>
<td></td>
<td>16 Sept.</td>
<td>8.9</td>
<td>156</td>
<td>13 Sept.</td>
</tr>
<tr>
<td></td>
<td>16 Sept.</td>
<td>30.6*</td>
<td>170</td>
<td>13 Sept.</td>
</tr>
<tr>
<td></td>
<td>18 Sept.</td>
<td>33.9*</td>
<td>255</td>
<td>20 Sept.</td>
</tr>
<tr>
<td></td>
<td>22 Sept.</td>
<td>104.5*</td>
<td>142</td>
<td>20 Sept.</td>
</tr>
<tr>
<td></td>
<td>16 Sept.</td>
<td>75.3</td>
<td>305</td>
<td>15 Sept.</td>
</tr>
<tr>
<td>2002</td>
<td>10 Sept.</td>
<td>24.2</td>
<td>83</td>
<td>9 Sept.</td>
</tr>
<tr>
<td></td>
<td>13 Sept.</td>
<td>5.7</td>
<td>244</td>
<td>13 Sept.</td>
</tr>
<tr>
<td>1999</td>
<td>7 Sept.</td>
<td>16</td>
<td>53</td>
<td>6 Sept.</td>
</tr>
<tr>
<td>1997</td>
<td>26 Sept.</td>
<td>6.4</td>
<td>349</td>
<td>22 Sept.</td>
</tr>
<tr>
<td>1995</td>
<td>19 Sept. (3)</td>
<td>19.2</td>
<td>246</td>
<td>19 Sept.</td>
</tr>
<tr>
<td>1995</td>
<td>19 Sept. (2)</td>
<td>32.5</td>
<td>50</td>
<td>19 Sept.</td>
</tr>
<tr>
<td>1993</td>
<td>11 Sept.</td>
<td>4.9</td>
<td>65</td>
<td>12 Sept.</td>
</tr>
</tbody>
</table>

Only years having observations are reported.

*Indicates dead bears observed floating offshore during aerial surveys.

was limited subsistence whaling which was also hampered by weather conditions during the range of dates above.

Only a small total number of bears was seen on > 14,000 km of transect surveyed in 2004, thus limiting our ability to provide accurate estimates of polar bear mortality and associated confidence intervals (see McDonald et al. 1999; Evans et al. 2003). If, however, data are simply spatially extrapolated, bear deaths during a period of high winds in 2004 may have been significant. Our observations obtained from 34 north-south transects provide coverage of approximately 11% of the 630 km wide study area assuming a maximum sighting distance for swimming/floating polar bears of 1 km from the aircraft (coverage = 630 km/34 transects x 2 km wide transect) = 10.8% of study area. Limiting data to bears on transect and not considering bears seen on connect and search segments, four swimming polar bears were encountered in addition to three dead bears. If these bears accurately reflect 11% of bears present under these conditions, then 36 bears may have been swimming in open water on 6 and 7 September, and 27 bears may have died as a result of the high offshore winds. These extrapolations suggest that survival rate of bears swimming in open water during this period was low (9/36 = 25%).

We believe that the increased risk of swimming in open water is not likely to result simply from long-distance swimming as polar bears are considered strong swimmers (Oritsland 1969; Burns et al. 1981). Long-distance swims may impose higher metabolic costs than standing or walking on ice even under favorable weather conditions. High mortality in 2004 was more likely related to extreme and metabolically demanding conditions, such as high sea states associated with stormy weather. As previously discussed, there is some indication that such conditions may become more common in the future (Serreze et al. 2000; Serreze and Barry 2005). In general, for a given wind speed and direction, wave height (sea state) increases as a function of open water surface area (discussed as sightability of whales in Clarke et al. 1993; see also Moore 2000). Therefore, polar bears swimming in open water will presumably encounter increased wave heights compared to swimming under conditions of ≥50% ice cover for the same wind speed and direction. Open water conditions where ice is virtually absent in August and September are expected to increase if Arctic air temperatures continue to rise (Stroeven et al. 2004), and thus swimming polar bears would be more at risk of encountering unfavorable conditions (i.e., high sea states and increased winds). Presumably, in the future, more time and energy will be allocated to swimming due to increased distances among ice floes, abandoning sea ice for land when ice concentration falls below 50% (Sterling et al. 1999), or during routine travels searching for suitable substrates in which to hunt seals (Derrocher et al. 2004).

Our count of dead polar bears related to the 2004 windstorm almost certainly represents an underestimate of the actual number of polar bears affected. Swimming and floating polar bears are difficult to see from the survey's standard 457 m altitude even under ideal conditions. Also, some bears that drowned may have sunk or drifted outside the study area.

Other bears may have suffered sublethal effects and later succumbed due to exhaustion or inspiration of sea
water as a result of swimming long distances in rough seas. Fatigued polar bears occasionally swim ashore along the coastline of the Alaskan Beaufort Sea (R. Shideler, in litt.) and Hudson Bay (L. Stirling, personal communication) during times when open water is at its maximum extent. After reaching land, these bears may sometimes take up to several days to recover. In one extreme case in 2002 (R. Shideler, in litt.) an adult male bear swam ashore in Prudhoe Bay. Initially, the bear was lethargic, shivering and appeared to be dehydrated because it drank considerable fresh water from nearby pools. After a few hours, managers attempted to haze the bear away from human activities using Karelian bear dogs and noisemakers, but the bear was generally unresponsive. The bear remained near where it came ashore for approximately 2.5 days. Such observations are indicative of the physical stress and high metabolic demands associated with long-distance swimming in cold water. Though estimates of metabolic costs associated with swimming are unavailable, it is likely that energetic costs for this activity far exceed those for walking (Hurst et al. 1982).

Although a number of published papers have discussed implications of climate change on polar bears (e.g., Stirling and Derocher 1993; Stirling et al. 1999; Norris et al. 2002; Stirling 2002; Derocher et al. 2004), to date, mortality due to swimming has not been identified as an associated risk. Evaluations of future population dynamics and the significance of sources of human-related and natural mortality in polar bears may need to consider this previously unidentified source of natural mortality which may be significant in some years (e.g., mild-ice or late-ice) and may become important in the future if Arctic pack ice continues to regress. Such risk might increase if land-based bears are forced to swim in search of ice if the open water period continues to increase in fall. presumably, changes in sea ice would not affect all sex/age classes of polar bears randomly or uniformly. Lone females and females with cubs may be more prone to deaths during long-distance travel in open water (Derocher et al. 2004, p 166). If this scenario is realistic, there are rather serious population-level implications since additional losses to females above those expected under current "take" agreements (Brower et al. 2002, p 365) could ultimately lead to long-term population declines (Taylor et al. 1987).

Polar bears swimming offshore in the Beaufort Sea risk contact with oil, if spilled and strikes by ships (see Stirling 1988, 1990). Our observations of higher numbers of swimming polar bears in open water than previously supposed should be considered by analysts and managers relative to marine transportation, ice-breaking, oil and gas development and other potential activities in open water. Minimizing and discouraging anthropogenic effects that encourage polar bears to remain or aggregate onshore as annual shorefast ice melts and pack ice recedes could ultimately reduce the risk of drowning.

Acknowledgements We thank Steve Treacy who was research manager for most of the project's duration (1987-2003). We thank Cleve Cowles who has been project supporter since its inception. We thank the numerous personnel from the Minerals Management Service and other agencies who participated in BWASP as team leaders, observers, data recorders or in other capacities during this project. We greatly appreciate the services, knowledge and skills provided by staff, and pilots of ERA, Inc. who participated in many activities, as well as support from the Department of Interior, Office of Aircraft Services, Anchorage. Project data collection and field analysis programs used throughout were designed by John Bennett, John Dunlap and Tom Murrell. Matt Heller assisted with data management and figure preparation. Warren Horowitz managed contracts that provided weather from the Endicott Weather Station. We also acknowledge the National Ice Center for providing data on sea ice conditions. We thank Craig Perham and Susanne Miller for sharing data on observations of bears on land along the Beaufort Sea coastline. We thank Ian Stirling and Richard Shideler for sharing observations of polar bears suffering from fatigue upon coming ashore following open-water swimming. This paper benefited greatly from reviews by, and discussions with, Andrew Derocher, Lisa Rotterman, Richard Shideler, Ian Stirling and Cleveland Cowles. This paper was improved by useful comments from Rolf Gradinger and three anonymous reviewers. Funding for BWASP surveys was provided by the U.S. Minerals Management Service, Alaska Outer Continental Shelf Region. The findings and conclusions in this paper are those of the authors and do not necessarily represent the views of the funding agency. Any mention of trade names is coincidental and does not represent endorsement by the government.

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