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INTRODUCTION

The Bristol Bay region supports a great abundance of fish and wildlife. Beluga whales (Delphinapterus leucas) occur in this area throughout the year. They occur most commonly in Kvichak and Nushagak bays, and are especially numerous in the months of April through August (Frost et. al. 1984, Frost and Lowry 1990).

Kvichak and Nushagak bays also support large runs of anadromous fishes, especially red salmon (Oncorhynchus nerka) which are a major food for the belugas in this region. Because of possible impacts of belugas on the salmon fishery, the whales in this area have been studied at intervals since the 1950s (Brooks 1955, Fish and Vania 1971, Frost et al. 1984). Studies conducted in the 1980s produced relatively detailed information on beluga abundance, distribution, and movements in this region (Frost et al. 1983, 1985). An aerial survey conducted on 29 June 1983 resulted in an estimate of approximately 1,100 belugas in Kvichak and Nushagak bays (Frost et al. 1984). Frost and Lowry (1990) estimated the abundance of belugas in Bristol Bay in the early 1980s as 1,000-1,500, and stated that "(t)here is good reason to think that the Bristol Bay stock is stable at or near its historical size."

Belugas spend much of their time below the surface where they cannot be seen from the air. Therefore, aerial survey counts must be corrected to estimate the actual number of animals that are present, not just the number that are at the surface. Some investigators have proposed correction factors for beluga surveys based on observations of breathing and diving cycles (Sergeant 1973), comparisons of simultaneous aerial and boat counts (Frost et al. 1983), and their impressions of sightability of different age classes (Brodie 1971). Data from radio-tagged belugas can be used to estimate the proportion of time spent at and below the surface (Frost et al. 1983, 1985). This information can then be used to correct the actual survey counts for submerged belugas.

The National Oceanic and Atmospheric Administration has provided funds to the Alaska and Inuvialuit Beluga Whale Committee (AIBWC) to conduct studies of beluga whales in Alaska. Part of the AIBWC research program consists of aerial surveys to estimate the abundance and trends of beluga stocks. This report describes the results of AIBWC surveys flown in Bristol Bay during 1993 and 1994.

METHODS

Aerial surveys were flown during 28 June-2 July 1993, 17-18 July 1993, and 5-8 July 1994. The survey aircraft was a high-wing,
twin engine Aero Commander Shrike chartered from Commander Northwest.

The survey was designed to cover all coastal and offshore waters of Kvichak and Nushagak bays (Figures 1 and 2). The standard survey track followed the coast about 4,000 feet offshore from approximately Johnston Hill (southeast Kvichak Bay) to Nichols Spit (southwest Nushagak Bay). Coastal surveys included the lower Kvichak River (upstream as far as the Branch (Alagnak) River), the lower Naknek River, the Nushagak River to above the Wood River, the Little Muklung River, the Snake River, and the Igushik River. Offshore surveys were flown along east-west transects at 2 nm intervals from 58°40'N to 58°58'N latitude in Nushagak Bay and 58°40'N to 58°52'N latitude in Kvichak Bay. Navigation was done by reference to landmarks and with a Global Positioning System (GPS) that was linked to a computer data entry program. Survey altitude was usually 1000 feet, and airspeed was 120 knots.

The flight crew included the pilot (Tom Blaesing), a data recorder in the right front seat (Debbie Blaesing or Sandy Kennedy) and two observers seated behind the pilot on the left and right sides of the aircraft (Lloyd Lowry and Kathy Frost). Observers were the same for all surveys. All belugas visible along the survey track were counted. When large groups were encountered, two or more counts were made. In those situations the aircraft circled after passing by the group and flew past again on a line oriented to provide one observer the best view of the entire group (i.e., minimum glare and no whales in the blind area under the plane). Multiple counts were noted in comments, and the highest count for that group was used in analysis of the data. A computerized data logging system was used to record the time and position from the GPS at the beginning and end of every transect, at 60 second intervals along the transect, and at every beluga sighting. Weather, sighting conditions, and other relevant information were also recorded. Each observer also kept a written record of the time and number of whales sighted, which was used to check the computer database.

RESULTS

Aerial surveys were conducted on eight days during June-July 1993 (Table 1). For three of these (28 June and 1, 2 July), weather was foggy or windy along part of the survey route and total counts were not obtained. For the other five days, survey conditions were judged to be good to excellent and all survey areas were counted. Counts on these five days ranged from 269-443, with a mean of 354 (s.d. = 68.05) (Table 1). Most belugas (200-300) were found in Nushagak Bay, particularly the upper Nushagak near Grassy
Island and the mouths of the Little Muklung and Wood rivers (Figure 3). A small group of belugas was always present in the Igushik River, and belugas were sometimes seen in the Snake River.

In the Kvichak, belugas were most often sighted near the mouth of the Kvichak River, in Halfmoon Bay, and along the west side. Very few belugas were seen on offshore transects. Almost all of those were very near shore and would also have been counted during coastal transects.

During July 1994, surveys were flown on four days (Table 2). The first of these (5 July) was a reconnaissance flight in windy weather, with poor sighting conditions, and the counts were not used. The other three surveys were conducted under good to excellent conditions for sighting belugas. Two complete coastal surveys were conducted on 7 July, one in the morning and one in the afternoon. Total counts on good survey days ranged from 265-503, with a mean of 357 (s.d. = 104.94) (Table 2). Belugas were seen in both Kvichak and Nushagak bays (Figure 4). The largest groups were seen in the upper Nushagak near Grassy Island and the mouths of the Little Muklung and Wood rivers, and along the west side of Kvichak Bay. Offshore transect lines were surveyed on only one day in 1994 and no belugas were seen.

**DISCUSSION**

The distribution of beluga whales in Nushagak and Kvichak bays during late June and July 1993-1994 was generally similar to that observed in 1982-1983 (Frost et al. 1984). All concentration areas identified in 1982-1983 were also used in 1993-1994. However, during 1993 and 1994 most belugas in Nushagak Bay (several hundred animals) were seen in the upper Nushagak between Grassy Island and the mouths of the Little Muklung and Wood rivers. This is in contrast to 1982-1983 when groups in this area usually numbered fewer than 50. In late June and July 1982-1983, the largest concentrations in Nushagak Bay occurred near the mudflats off the mouth of the Snake River and between the Snake River mouth and Clarks Point. Fried et al. (1979) also reported large concentrations of belugas near the Snake River mouth in late June 1979.

Small groups of belugas were seen in the Igushik and Snake rivers during the early 1980s and the 1993-1994 surveys. During 1982-1983, counts in the Igushik during late June ranged from 7-20; in mid-July and August no belugas were seen in the Igushik (Frost et al. 1984). Counts during June-July 1993-1994 were somewhat higher, ranging from 6-42 but usually numbering more than 20.

Frost et al. (1984) reported that belugas in Kvichak Bay were present either along the west side (especially in Halfmoon Bay) or
near the mouth of the Kvichak River (Salmon Flats). They were not seen on the east side near the Naknek River after about mid-June. Distribution was similar during 1993-1994 surveys of the Kvichak. Usual counts for the Kvichak in 1993-1994 were about 100, with the exception of 6 July 1994 when 234 belugas were counted there.

Maximum and mean counts of belugas were similar for Bristol Bay as a whole during 1993 and 1994, and somewhat higher than counts made in 1983 (Table 3). However, the numbers reported in Table 3 do not take into account the number of belugas that were underwater and could not be counted during surveys. To estimate the total number of belugas present, it is necessary to multiply actual counts by a correction factor to account for animals that were underwater and could not be seen to be counted. Because survey aircraft and methodology were not the same, sighting corrections factors were different for 1983 and 1993-1994. Appropriate correction factors were 3.17 for 1983 and 2.62 for 1993 and 1994 (Frost and Lowry 1995). Because surveys were flown at 1,000 ft altitude, it was not possible to see small, dark-colored neonates and young calves. For this reason, corrected counts were multiplied by an additional correction factor of 1.18 to account for these small, dark animals (Frost et al. 1984, Brodie 1971).

The corrected totals in Table 4 provide our best estimates of the number of belugas present in Bristol Bay during June-July 1983, 1993, and 1994. These estimates indicate that beluga numbers were stable or increasing during this period and that approximately 1250-1550 belugas use Bristol Bay during the summer months.

Frost et al. (1983, 1984, 1985) used a mean correction factor of 2.75 for 1983 Bristol Bay beluga surveys, which is lower than the 3.17 used in this study. That is partly because they assumed a value for t of 10.4 seconds, which has been revised in this paper to 7.5 seconds based on additional data and analysis. Also, for calculating the correction factor they used data from two radiotagged animals, an adult female and a 1-2 year old calf. Frost and Lowry (1995) recommended that radiotag-based correction factors from adult animals only should be used to expand survey counts if separate corrections are made for missed calves and yearlings. That approach, however, is conservative since 2 and 3-year-olds probably would very likely also have larger correction factors than adults. Furthermore, they are also small and dark colored, and therefore less likely to be counted during surveys.

There are a number of assumptions involved in estimating population size based on aerial survey counts corrected as described above. Some of those include: 1) all whales in the population are within the area covered by the survey; 2) whales are counted only when they are actually at the surface; 3) all whales older than yearlings are counted if they surface within the
transect while the aircraft is passing; 4) no animals are double
counted during a pass of the aircraft; and 5) the diving behavior
of animals being counted is similar to that of the radiotagged
animals. We are currently unable to evaluate all of these
assumptions, but we think the available data can and should be
used to expand aerial counts and produce more realistic population
estimates.

ACKNOWLEDGEMENTS

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Bristol Bay have benefited greatly from information provided to us
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reproduction, and behavior of the white whale (Delphinapterus
leucas) with reference to the Cumberland Sound, Baffin


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of white whale (Delphinapterus leucas) predation upon sockeye
salmon (Onchorhynchus nerka) smolts in Nushagak Bay and
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Table 1. Counts of beluga whales in Bristol Bay, 28 June through 18 July 1993. Counts were done by Lloyd Lowry and Kathy Frost (ADF&G) for the Alaska and Inuvialuit Beluga Whale Committee. NS means not surveyed.

<table>
<thead>
<tr>
<th>Area</th>
<th>6/28/93</th>
<th>6/29/93</th>
<th>6/30/93</th>
<th>7/01/93</th>
<th>7/02/93</th>
<th>7/03/93</th>
<th>7/17/93</th>
<th>7/18/93</th>
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<td>Nearshore Kvichak</td>
<td>12</td>
<td>113</td>
<td>82</td>
<td>46</td>
<td>107</td>
<td>80</td>
<td>82</td>
<td>99</td>
</tr>
<tr>
<td>Offshore Kvichak</td>
<td>NS</td>
<td>0</td>
<td>5**</td>
<td>NS</td>
<td>52**</td>
<td>31**</td>
<td>NS</td>
<td>88**</td>
</tr>
<tr>
<td>TOTAL KVICHAK</td>
<td>12</td>
<td>113</td>
<td>82</td>
<td>46</td>
<td>107</td>
<td>80</td>
<td>82</td>
<td>99</td>
</tr>
<tr>
<td>Etolin Point</td>
<td>8</td>
<td>6</td>
<td>8</td>
<td>0</td>
<td>NS</td>
<td>0</td>
<td>45</td>
<td>16</td>
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<tr>
<td>Upper Nushagak</td>
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<td>135</td>
<td>274</td>
<td>29</td>
<td>NS</td>
<td>130</td>
<td>310</td>
<td>244</td>
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<td>16</td>
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<td>22</td>
<td>NS</td>
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<td>0</td>
<td>0</td>
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<td>Igushik River</td>
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<td>26</td>
<td>21</td>
<td>30</td>
<td>NS</td>
<td>42</td>
<td>6</td>
<td>4</td>
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<td>NS</td>
<td>NS</td>
<td>7**</td>
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<td>188</td>
<td>325</td>
<td>81</td>
<td>--</td>
<td>189</td>
<td>316</td>
<td>248</td>
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<td>TOTAL ALL AREAS</td>
<td>58</td>
<td>307</td>
<td>387</td>
<td>127</td>
<td>--</td>
<td>269</td>
<td>443</td>
<td>363</td>
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</tbody>
</table>

* at least 4 were duplicates of coastal counts and are not included in total
** all probably duplicates of coastal counts and not included in totals
Table 2. Counts of beluga whales in Bristol Bay, 5-8 July 1994. Counts were done by Lloyd Lowry and Kathy Frost (ADF&G) for the Alaska and Inuvialuit Beluga Whale Committee. NS means not surveyed.

<table>
<thead>
<tr>
<th>Area</th>
<th>7/05/94</th>
<th>7/06/94</th>
<th>7/07/94</th>
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<th>7/08/94</th>
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<td>Nearshore Kvichak</td>
<td>47</td>
<td>234</td>
<td>124</td>
<td>109</td>
<td>95</td>
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<tr>
<td>Offshore Kvichak</td>
<td>NS</td>
<td>1</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>TOTAL KVICHAK</td>
<td>47</td>
<td>235</td>
<td>124</td>
<td>109</td>
<td>95</td>
</tr>
<tr>
<td>Etolin Point</td>
<td>0</td>
<td>0</td>
<td>31</td>
<td>36</td>
<td>7</td>
</tr>
<tr>
<td>Upper Nushagak</td>
<td>33</td>
<td>180</td>
<td>156</td>
<td>41</td>
<td>179</td>
</tr>
<tr>
<td>Snake River</td>
<td>9</td>
<td>68</td>
<td>74</td>
<td>46</td>
<td>7</td>
</tr>
<tr>
<td>Igushik River</td>
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<td>20</td>
<td>6</td>
<td>33</td>
<td>12</td>
</tr>
<tr>
<td>Offshore Nushagak</td>
<td>NS</td>
<td>0</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>TOTAL NUSHAGAK</td>
<td>58</td>
<td>268</td>
<td>236</td>
<td>120</td>
<td>198</td>
</tr>
<tr>
<td>TOTAL ALL AREAS</td>
<td>105</td>
<td>503</td>
<td>360</td>
<td>265</td>
<td>300</td>
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Table 3. Comparison of beluga whale counts in Bristol Bay in 1983, 1993, and 1994. Maximum counts shown for Nushagak and Kvichak bays are the highest single day count for each of those areas, while the total maximum count is the highest single day count for the entire Bristol Bay survey area. Maximum total counts also include Etolin Point.

<table>
<thead>
<tr>
<th></th>
<th>Nushagak Bay</th>
<th>Kvichak Bay</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>max</td>
<td>mean</td>
<td>range</td>
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<tr>
<td>1983 (2 counts)</td>
<td>134</td>
<td>130</td>
<td>126-134</td>
</tr>
<tr>
<td>1993 (5 counts)</td>
<td>316</td>
<td>254</td>
<td>202-316</td>
</tr>
<tr>
<td>1994 (4 counts)</td>
<td>268</td>
<td>205</td>
<td>120-268</td>
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Table 4. Minimum population estimates for beluga whales in Bristol Bay, based on the maximum number of whales counted in 1983, 1993, and 1994. Figures shown in parentheses are based on the upper and lower limits of correction factors for adult whales calculate by Frost and Lowry (1995), and do not represent confidence intervals.

<table>
<thead>
<tr>
<th>Survey Date</th>
<th>belugas counted</th>
<th>CF</th>
<th>Corrected Number</th>
<th>Neo + Yrl CF</th>
<th>Total Belugas</th>
</tr>
</thead>
<tbody>
<tr>
<td>29 June 1983</td>
<td>334</td>
<td>3.17 (3.08-3.33)</td>
<td>1059 (1029-1112)</td>
<td>0.18 (185-200)</td>
<td>1250 (1214-1312)</td>
</tr>
<tr>
<td>17 July 1993</td>
<td>443</td>
<td>2.62 (2.57-2.73)</td>
<td>1161 (1139-1209)</td>
<td>0.18 (205-218)</td>
<td>1370 (1344-1427)</td>
</tr>
<tr>
<td>6 July 1994</td>
<td>503</td>
<td>2.62 (2.57-2.73)</td>
<td>1318 (1293-1373)</td>
<td>0.18 (233-247)</td>
<td>1555 (1526-1620)</td>
</tr>
</tbody>
</table>
Figure 1. Transect lines flown during aerial surveys of beluga whales in Bristol Bay, Alaska, 28 June-18 July 1993.
Figure 2. Transect lines flown during aerial surveys of beluga whales in Bristol Bay, Alaska, 5-8 July 1994.
Figure 3. Sightings of beluga whales made during aerial surveys of beluga whales in Bristol Bay, Alaska, 28 June-18 July 1993.
Figure 4. Sightings of beluga whales made during aerial surveys of beluga whales in Bristol Bay, Alaska, 5-8 July 1994.