Population trend, 1978–2004, of Bering-Chukchi-Beaufort bowhead whales (*Balaena mysticetus*)

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ABSTRACT

Ice-based surveys have been used to obtain most estimates of abundance and trend for the Bering-Chukchi-Beaufort (BCB) stock of bowhead whales (*Balaena mysticetus*). Climate change has raised concerns that such surveys may not be practical in the future. Aerial photography surveys from which abundance can be estimated do not require an ice-based platform for collecting data and provided independent abundance estimates for 1985 and 2004. These estimates, based on captures and recaptures of photographically identified bowheads, were added to the estimates from ice-based surveys between 1978 and 2001 in order to estimate 1978–2004 population trend. The generalized least-squares estimate of annual rate of increase for this bowhead population is 3.5% with a 95% confidence interval of 2.2% to 4.8%.

KEYWORDS: POPULATION TREND; ABUNDANCE ESTIMATE; SURVEY-SHORE-BASED; SURVEY-AERIAL-PHOTOGRAPHY; BOWHEAD WHALE; ARCTIC; BEAUFORT SEA

INTRODUCTION

Ice-based surveys conducted near Barrow, Alaska during the spring migration of bowheads from the Bering Sea to the Beaufort Sea produced the abundance estimates shown in Table 4 of Zeh and Punt (2005) for the years 1978, 1980–83, 1985–88, 1993 and 2001. Their CVs and correlation matrix are shown in that table. George *et al*. (2004) fit an exponential growth model to these data using generalized least squares. They obtained an estimated annual rate of increase (ROI) during those years of 3.4% with a 95% confidence interval (CI) of 1.7% to 5%.

Aerial photography surveys were conducted near Barrow during the spring migrations of 1984–86, 2003 and 2004. In addition, in 1984–86 summer and autumn surveys were conducted in the Beaufort Sea, providing a large collection of bowhead photographs for 1984–86. Most of the 2005 photographs came from an early spring survey in the northern Bering Sea, though there was a brief September 2005 survey near Barrow prior to the main fall migration of bowheads returning to the Bering Sea. Koski *et al*. (2010) document these surveys and give abundance estimates for 1985 and 2004 in their Table 4. The 1985 and 2004 abundance estimates of Koski *et al*. (2010) are independent and are also uncorrelated with the estimates described in the previous paragraph.

Conducting the ice-based surveys requires stationing observers on the sea ice for at least 6 weeks in spring under cold and dangerous conditions. In addition, there are concerns that climate warming and unstable shore-fast ice might prevent successful completion of future ice-based surveys. Thus, it is important to determine whether photographic data collected in two consecutive years and analyzed using capture-recapture methods could provide adequately precise abundance estimates to justify replacing ice-based with photographic surveys (Koski et al., 2010).

METHODS

Survey methods and data processing as well as abundance estimation methods are described by George *et al*. (2004), Zeh and Punt (2005), and Koski *et al*. (2010). The abundance estimates in Koski *et al*. (2010) are based on photographically identified bowheads, with the first photograph of a whale during the years from which the estimate is being computed constituting a capture and a recapture occurring in any subsequent year in which the same whale is photographed. The 1984–86 estimate and the 2003–05 estimate with bootstrap CV from Table 4 of Koski *et al*. (2010) were added to the Table 4 estimates of Zeh and Punt (2005) to form an augmented table. The 1984–86 estimate (6,129 with CV 0.1695) was assigned to 1985, and the 2003–05 estimate (12,631 with CV 0.2442) was assigned to 2004. As already noted, each of the Koski *et al*. (2010) estimates has zero correlation with any other estimate in the augmented table. ROI was computed as described by George *et al*. (2004) using the data in the augmented table.

RESULTS

The abundance estimates from the augmented table with their standard errors (SE) are shown in Figure 1. The open circles are the estimates from the ice-based surveys and the filled circles the estimates from the aerial photography surveys. The vertical line through each estimate extends from one SE below it to one SE above it. The 1985 estimates have been offset slightly to show that the estimate from the photography surveys is more precise. The ROI obtained for 1978–2004 from these data was 3.5% with 95% CI 2.2% to 4.8%.

DISCUSSION

The 1978–2004 ROI of 3.5% is almost the same as the 1978–2001 ROI of 3.4% obtained by George *et al*. (2004) from ice-based survey data. However, the addition of the two estimates obtained by Koski *et al*. (2010) from the photography survey data improved precision. There is no suggestion in Figure 1 that any adjustment to the photography survey estimates is needed to make them comparable to the ice-based survey estimates.

In terms of CVs, the 1985 photography survey estimate is more precise than the 2004 photography survey estimate. It is also more precise than any of the ice-based survey estimates except those for 1988, 1993 and 2001 (Zeh and Punt, 2005). As noted by Koski *et al*. (2010), those three surveys had more comprehensive acoustic monitoring of whales that passed too far offshore to be seen than the earlier surveys, leading to improved precision. The years with no data for estimating the proportion of whales that passed beyond viewing range (1978, 1980, 1983 and 1987) had abundance estimates with the highest CVs (Zeh and Punt, 2005). Too few hours of watch under acceptable visibility conditions when whales were passing may also have contributed to less precise abundance estimates, e.g. 2001 compared to 1993 (George *et al*., 2004).

The 2004 photography survey estimate is less precise than the 1985 photography survey estimate because comprehensive summer and autumn photography surveys were conducted in the Beaufort Sea in 1984–86 but not in 2003–05. These provided more initial captures and recaptures for the 1985 estimate than there were for the 2004 estimate, leading to better precision. Four of the ice-based survey estimates have CVs less than the CV of the 2004 photography estimate and the remaining seven ice-based survey estimates have larger CVs than that estimate. If weather and ice conditions permit adequate watch under acceptable visibility conditions, then adequate acoustic monitoring can produce an ice-based survey estimate more precise than the 2004 photography survey estimate. However, it is notable that in about five of the 16 years in which an ice-based survey was attempted between 1978 and 2001, weather and ice conditions did not permit adequate watch to estimate abundance (George *et al*., 2004). In two of those five years, successful photography surveys were conducted. In fact, conditions that interfere with conducting an ice-based survey (closed shore leads, water-generated fog, etc.) may actually be favourable for conducting aerial photography. If more precise estimates than the 2004 photography survey estimate are considered necessary, precision of future photography survey estimates can be improved by conducting more than one photography survey in a given year.

Koski *et al*. (2010) also showed that abundance estimates based on two years of photography surveys had CVs within the range of those given by Zeh and Punt (2005) for abundance estimates from ice-based survey data. The estimates of Zeh and Punt (2005) are currently used by the IWC SC for giving management advice on the bowhead harvest. It can be concluded that abundance estimates obtained from photography surveys in two or three years are also adequate for management under the Aboriginal Whaling Management Procedure.

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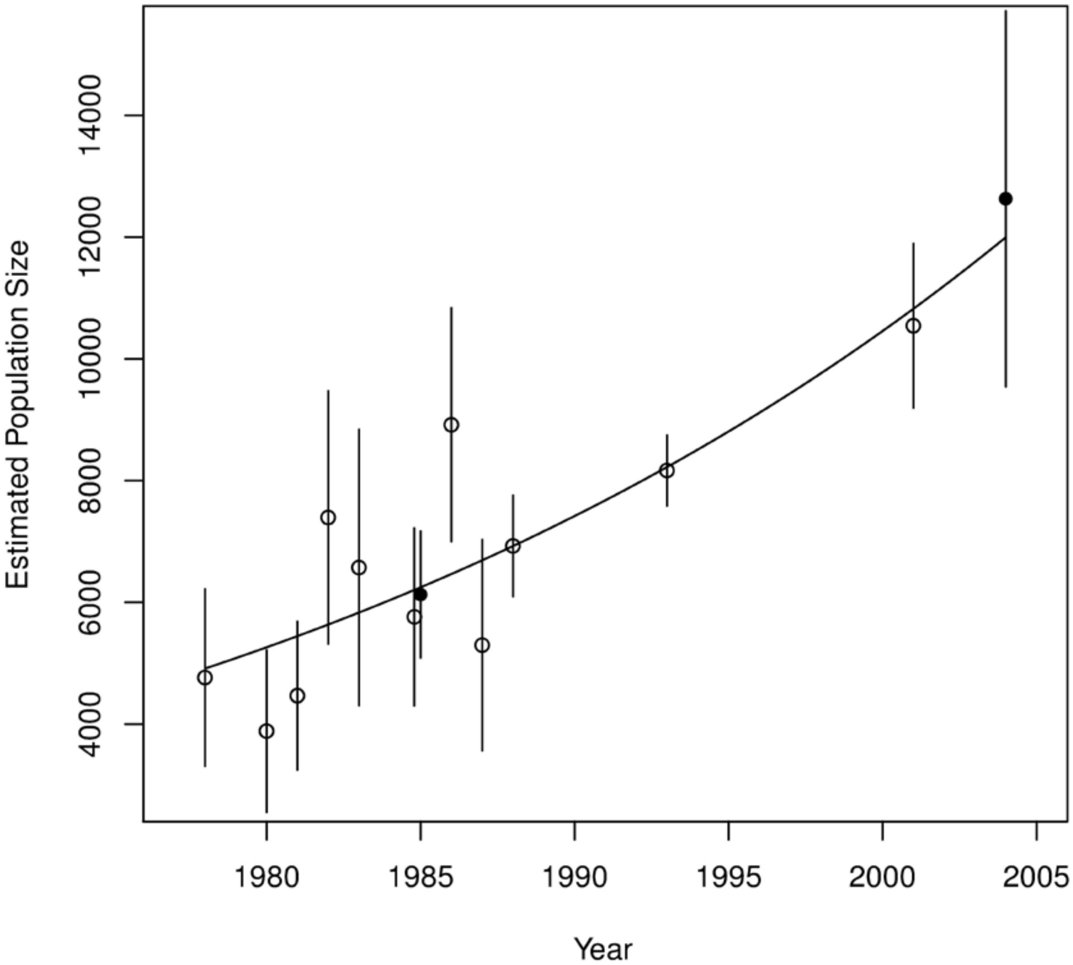

Figure 1. Abundance estimates with standard errors (SE). Open circles are estimates from ice-based surveys and filled circles estimates from aerial photography surveys. The vertical line through each estimate extends from one SE below it to one SE above it. The 1985 estimates have been offset slightly to show that the estimate from the photography surveys is more precise.