SC/56/BRG33

Preliminary investigation of stock structure of B-C-B bowhead whales based on analyses of biological parameters

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ABSTRACT

The possibility of more than one stock mixing within B-C-B stock of bowhead whales was examined using biological parameters such as conception date, body length distribution of mature whales, migration period and mean cycle of $\delta^{13}C$ oscillation in baleen. Heterogeneity was found in some of the parameters but statistical tests were not conducted due to the small sample size. To elucidate the stock structure of B-C-B bowhead whales, further research and samples are needed.

KEYWORDS: BOWHEAD WHALE; STOCK IDENTITY; BIOLOGICAL PARAMETERS

INTRODUCTION

The comprehensive assessment of the bowhead whale conducted in 1991 identified five stocks of bowhead whales including the B-C-B stock (IWC, 1992). Since then, the Committee addressed the issue of stock identity of the B-C-B stock on several occasions (DeMaster *et al*., 2000). However, those discussions were based on very limited data and no comprehensive analyses on stock identity within the B-C-B have been presented. Despite the limited availability of data and comparative analyses, the Committee recommended a single B-C-B stock scenario for management in 2002, which is the only stock scenario being considered by the Aboriginal Whaling Management Procedure (AWMP).

Accurate elucidation of the stock structure of the large whales requires not only genetic data but also non-genetic data (Donovan, 1991; Fujise *et al*., 2001; Perrin, 2001; Rugh *et al*., 2003, Pastene, 2003). For example, the stock structure of the North Pacific common minke whale has been examined by genetic data (Goto *et al*., 2000), conception date (Kato, 1992), body length at physical maturity (Zenitani *et al*., 2000), scars on the skin (Fujise *et al*., 2001) and pollutant (Fujise *et al*., 2000). Some heterogeneity was found in these parameters and two stocks, the Okhotsk Sea-Western Pacific stock (the 'O' stock) and the Sea of Japan-Yellow sea-East China Sea stock (the 'J' stock) were identified. A review of the studies on stock identity was conducted by Pastene *et al*. (2000).

Pastene *et al*. (this meeting) have suggested the possibility of more than one stock mixing within the B-C-B bowhead whale stock as a result of genetic analysis of samples from the Alaskan aboriginal whaling. If more than one stock exists and mixing occurs in the Bering-Chukchi-Beaufort Sea, their breeding area and breeding period might differ resulting in differences of conception dates. Further, if the migration period and course differs for each stock, distribution and migration route in the feeding season may differ between them. Growth rate may also differ between each stock as the result of difference of nutritional condition. Variation of $\delta^{13}C$ value in the baleen was thought to result from different nutritional condition (Schell *et al.*, 1989) and differences in the cycle of $\delta^{13}C$ oscillation in each individual would be the result of difference of migration pattern, feeding record or heretic growth rate of baleen.

In this paper, we attempt to examine the stock structure of B-C-B bowhead whales by using biological data such as conception date, growth curve, body length distribution of mature whales, migration period and cycle of $\delta^{13}C$ oscillation in baleen, which were derived from data and samples of whales taken in the aboriginal whaling off the Alaska mainland.

MATERIALS AND METHODS

Data used in this study

Following the guidelines on data availability agreed by the Scientific Committee of the IWC, the following biological data from bowhead whales caught in aboriginal whaling in 1973-2003 was provided by data owners:

Archive 1: Basic data for the animals caught (date and position of catch, sex, body length).
Archive 3: Date on which whales were seen during aerial survey/ photogrammetry work; dates on which whales were caught at Barrow.
Archive 6: Corpora counts.
Archive 7: Baleen measurements for age determination.
Archive 8: Aspartic acid measurements for age determination.
Archive 16: Data for fetuses and reproductive females.

Data used in this study is shown in Table 1. All year and area are combined due to the small sample size.

Method to estimate the conception date

Conception date was estimated from the date of catch and body length of fetus using the formula of Huggett and Widdas (1951). Body length at birth was assumed as 4.3m (Philo *et al.*, 1992).

Method to estimate age

Age was estimated from D/L ratio for aspartic acid of eye lens nucleus by the formula of George *et al.* (1999).

$$Age = \frac{\ln\left\{\frac{1+D/L}{1-D/L}\right\} - \ln\left\{\frac{1+(D/L)_0}{1-(D/L)_0}\right\}}{2k_{Asp}}$$

D/L: D/L ratio for aspartic acid of eye lens
$(D/L)_0$: D/L ratio at birth 0.0285 (George *et al.* 1999)
k_{Asp}: Rate of racemization 1.18×10^{-3} (George *et al.* 1999)

Determination of sexual maturity

Male

Following O'Hara *et al.* (2002), body length of less than 12.5m were identified as immature, 12.5m to 13.0m were identified as maturing and greater than 13.0m were identified as mature.

Female

Whales with one or more corpora lutea or albicantia were identified as mature and whales with fetus record were also identified as mature. Whales with no corpora lutea or albicantia in each ovary were identified as immature. For the whales with no corpora counts or fetus record, body length of greater than 14.0m were identified as mature and less than 14.0m were identified as immature (Nerini *et al*., 1984).

Method to examine stock structure

If all whales in the sample belonged to a single stock, the distribution of the plot of each biological parameter must become a normal distribution with a single median, despite the occurrence of some individual variation. If whales from another stock with differences in biological parameters were mixed in the samples, the distribution of the plots would deviate from a normal distribution. So, we checked the distribution of the plot of each parameter to examine the possibility of mixing of more than one stock.

RESULT

Conception date

Catch date and body length of fetus are plotted in Fig. 1. In spring, body length of fetus shows two modes of 0-100cm and greater than 350cm. The former was assumed to have conceived in the latest breeding season and the latter was assumed to have conceived in the previous breeding season. So, they were plotted separately. From the regression curve and formula of Huggett and Widdas (1951), fetus growth was shown as follows.

$$T=BL/1.017+42$$

T: date from conception

BL: body length of fetus

Estimated conception date of each whale is shown in Fig. 2. Breeding season was assumed from late December to early April with a peak in mid February. Some whales such as 88G1, 92B8, 83KK1 and 02S3 deviated from the normal distribution but too small sample size did not allow use of statistical tests.

Growth curve

Estimated age and body length are plotted in Fig. 3. A precise growth curve was not obtained due to the small sample size and large individual variation. Individual variation was greater in female than in male. The coarse accuracy of age determination (George *et al*., 1999) would also prevent obtaining an accurate growth curve.

Body length distribution of mature whales

Body length distribution of female bowhead whales, whose maturity status was identified by corpora counts or fetus record, is plotted in Fig. 4. Body length of the smallest mature whale was 13.0m and largest immature whale was 14.2m.

Body length distribution of male and female whales, whose maturity status was identified by corpora counts, fetus record or body length are plotted in Fig. 5. Two peaks of 14-15m and 16-17m were observed in body length distribution of mature female whales. This could represent mixing of more than one stock, or considering the longevity of bowhead whales, the larger peak might be physically mature whales.

Migration period

Spring migration season observed at Barrow is plotted in Fig. 6 with sighting record in Anadyrskiy Gulf in April to June obtained from Melinikov *et al*. (1998). The last day of whale sighting at Barrow differs from 5/24 to 6/15 but is concentrated around early June. Melinikov *et al*. (1998; 2002) showed that many bowhead whale are distributed near the Sireniki area in the Gulf of Anadyr in late May, which contradicts the single stock scenario of almost all whales migrating to the Beaufort Sea in summer.

Cycle of $\delta^{13}C$ oscillation in baleen

73 mean cycles of δ^{13}C oscillation in baleen was obtained from 123 records in Archive 7. Mean cycle of δ^{13}C oscillation becomes lower as the number of oscillations increase and invariable at more than 5 oscillations (Fig. 7). Distribution of mean cycles of δ^{13}C oscillation in each oscillation number is plotted in Fig. 8. Two peaks of short (20-40cm) and long (40-60cm) cycles were found in oscillation number one and two. This might be the result of differences of migration pattern, feeding record or heretic growth rate of baleen, which leads to the possibility of more than one stock of bowhead whales included in these samples.

DISCUSSION

Conception date, growth curve, body length distribution of mature whales, migration season and cycle of δ^{13}C oscillation, which were considered as indicator of stock structure, were examined in this paper. Age at sexual maturity and accumulation rate of corpora are also an effective indicator of stock structure, but we did not examine them due to the small sample size. Rooney *et al.* (2002) reported a morphological variant of bowhead whale 'ingutuk', but we could not identify them from the database.

Mark recapture, Photo ID, distribution, density of distribution, migration pattern, body length at physical maturity, fat index, body color, body proportion, sound, diet, pollutant loads, parasites and presence of scars on the skin are also useful to identify stock structure (Rugh *et al*., 2003), but no data was obtained.

In this study, we were unable to derive definitive conclusions about the stock structure of B-C-B bowhead whales caught around the Alaska mainland. The main cause for this is the small number of samples and scarcity of data. Too small sample sizes prevented the use of statistical tests on data used in this study. Rate of investigation for each parameter is plotted in Fig. 9. Samples such as reproductive organ were not collected with sufficient frequency to allow detailed data analysis. Increased sample size may reveal heterogeneity in biological parameters in B-C-B bowhead whales, as was the case with heterogeneity found in the genetic study (Pastene *et al*., this meeting).

Bowhead whales are distributed year-round in the Chukchi peninsula and concentrated in Anadyrskiy Gulf at late May (Melinikov *et al*., 1998; 2002). Some bowhead whales were reported in the Bering Sea in summer (Dalheim *et al*., 1980; Bogoslovskaya et al., 1982). Two or more peaks were observed in spring migration to the Beaufort Sea by the sighting survey conducted at Barrow (Braham *et al*. 1979). This information suggests the possibility of more than one stock of bowhead whale distributed in the Bering-Chukchi-Beaufort Sea region.

More data collection and research is required on all whales caught by aboriginal whaling. Additional research, such as satellite telemetry, sighting surveys in all distribution areas in summer, examination of variation of sea ice conditions, biopsy sampling and research at the breeding area would be useful to accumulate knowledge about the stock structure of B-C-B bowhead whales.

CONCLUSION

Some heterogeneity was found in some parameters but the small sample size prevents confirmation. To elucidate the stock structure of B-C-B bowhead whales, analysis of biological parameters is required together with genetic studies. It is possible that catch quotas calculated using the single stock scenario for

B-C-B bowhead whales assumed by the Scientific Committee could threaten other mixed and depleted small stocks. We recommend further research be conducted on bowhead whales caught in aboriginal whaling and that research be conducted in the Bering Sea and Chukchi Sea in both the summer feeding season and winter breeding season.

ACKNOWLEDGMENTS

We would like to thank all researchers and hunters to investigate whales and to collect samples in hard environment. We also thank to Dr T. Smith to arrange data request. Dr Geof Givens allowed us to use data of migration period (Archive 3). Dr Judy Zeh, Dr Cheryl Rosa and Susan Lubetkin allowed us to use data of stable isotope (Archive 7). Dr. John C. George provided useful comments and allowed us to use data of basic data (Archive 1), corpora counts (Archive 6), baleen measurements (Archive 7), aspartic acid measurements (Archive 8) and data for fetuses and reproductive females (Archive 16). We thank to Dr Hiroshi Hatanaka and Dr Luis A. Pastene of the Institute of Cetacean Research, for providing useful comments. Dan Goodman kindly reviewed and corrected English.

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Table 1. Sample size used in the analysis of biological parameters.

	Body length		Body length of fetus	Number of corpora		Aspartic acid racemization		$\delta^{13}C$ oscillation[*1]		
	M	F		Full	Part	M	F	M	F	Uk
Gambell	20	27	2	2	1	1	2		4	
Savoonga	20	32	2	2	1	1	1			
Wales	2	5								
Kivalina	4	3								
Point Hope	44	41		2		2	1	3	1	1
Wainwright	36	42	2	7		2	3	4	1	
Barrow	199	209	18	53	10	32	33	24	21	1
Nuiqsut	20	16	1		1				1	
Kaktovik	34	30	3	6	1	2	2	6	5	
Unknown									1	
Total	379	405	28	72	14	40	42	37	34	2

[*1]Baleen plates which has more than one $\delta^{13}C$ oscillation were used.

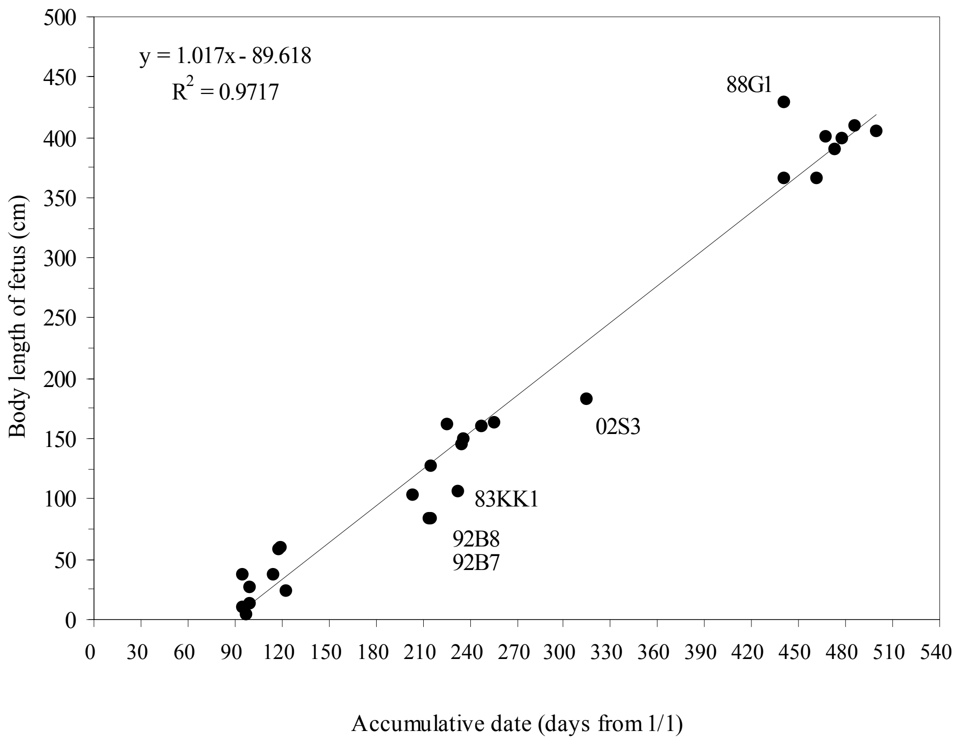


Fig. 1. Fetul growth curve of bowhead whale. Large fetus (more than 350cm) caught in spring were plotted separately (see text). Legends in figure shows whale ID.

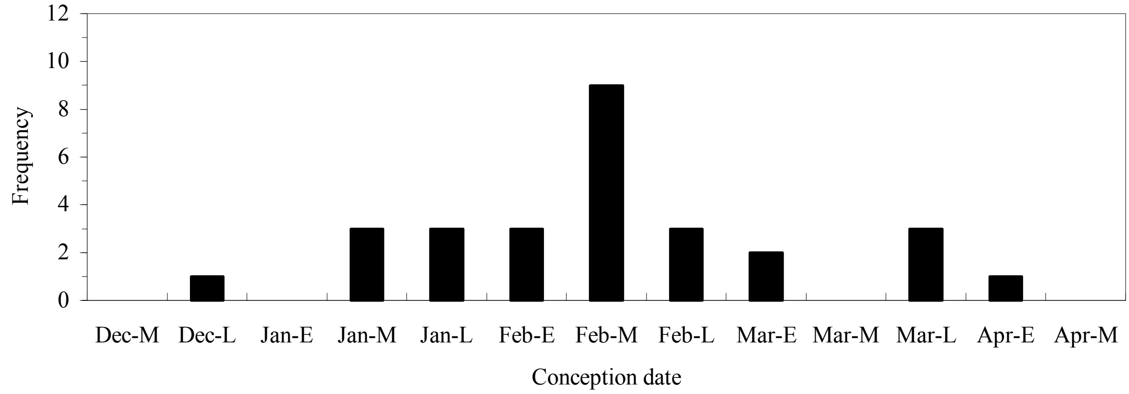
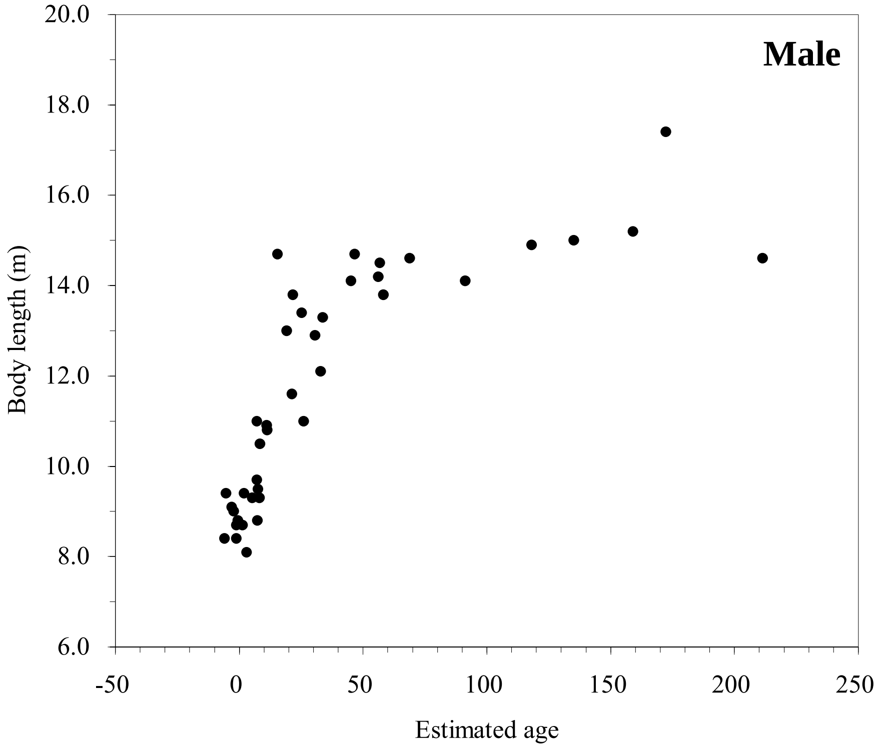


Fig. 2. Estimated conception date of Bowhead whales.



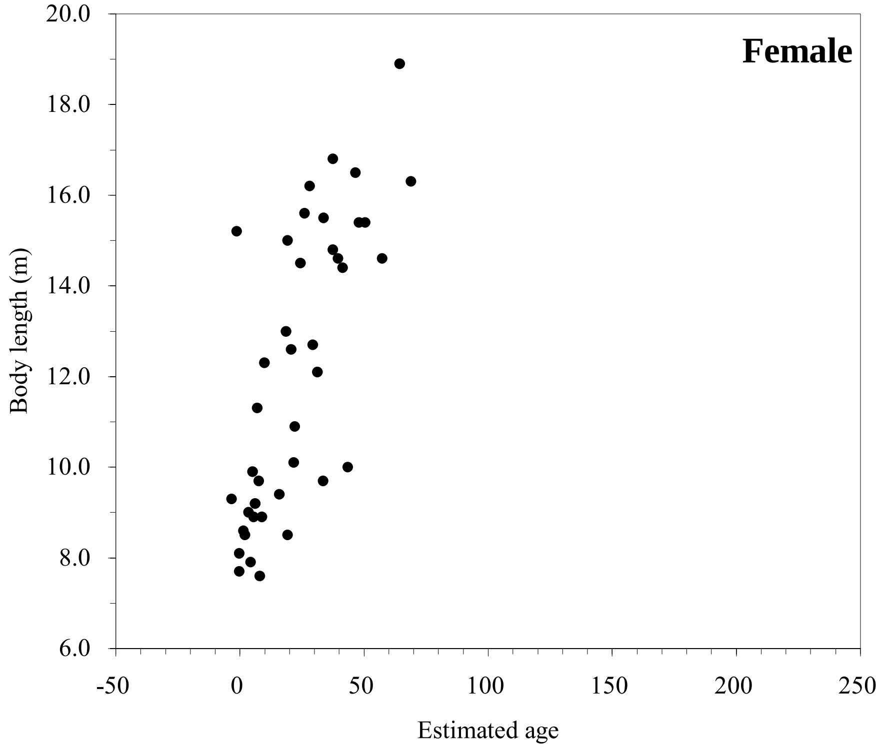


Fig. 3. Estimated age and body length of male(upper) and female (lower) Bowhead whales.

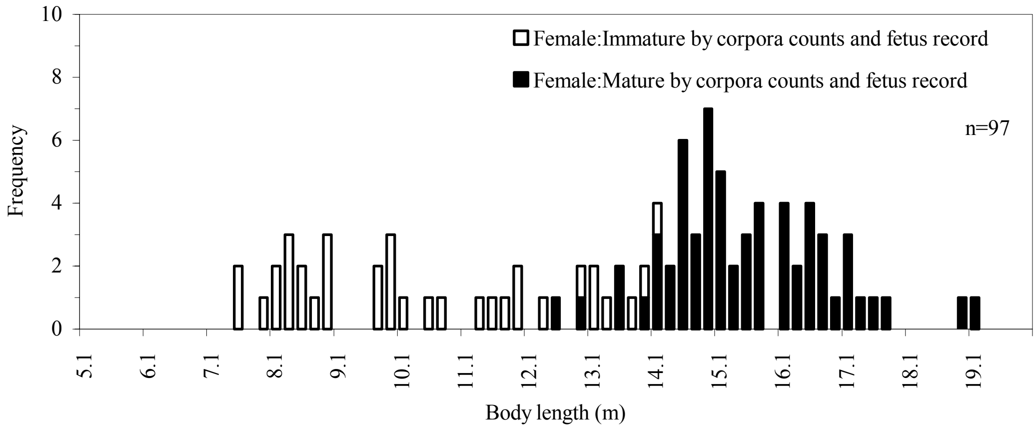
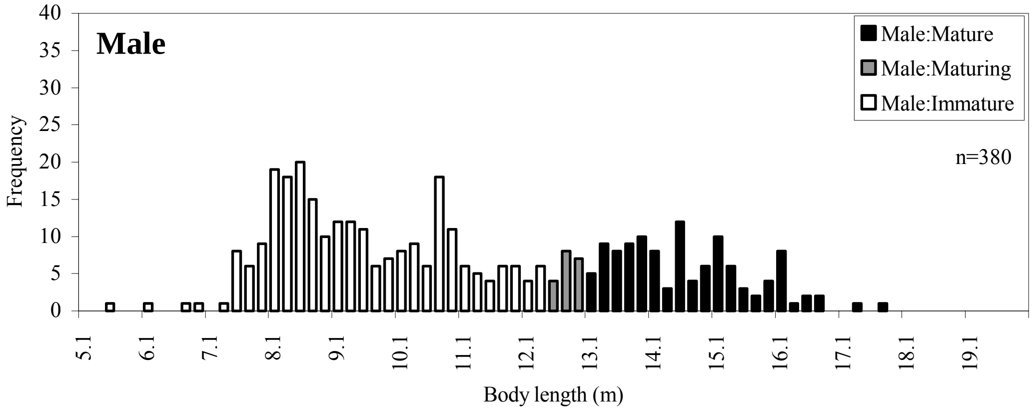


Fig. 4. Body length distribution and maturity status of Bowhead whales.
Maturity status was identified by corpora counts and fetus record.



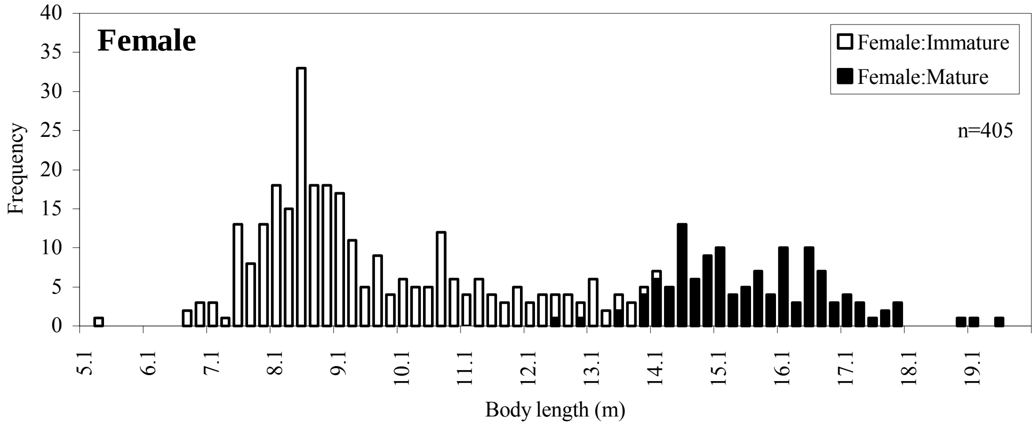
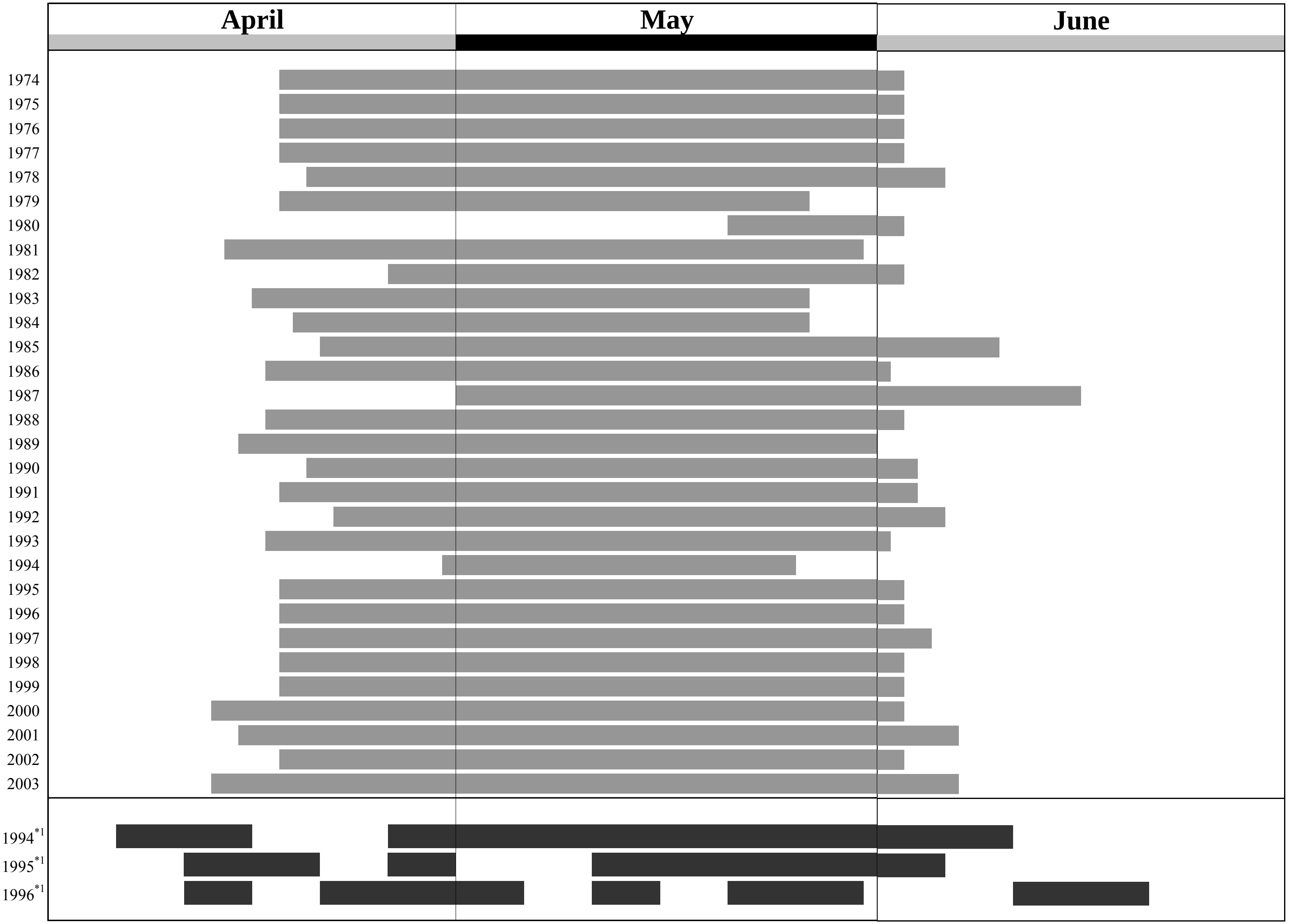


Fig. 5. Body length distribution and maturity status of Bowhead whales.
Maturity status was identified by corpora counts, fetus record or body length.



*1 : Sighting of bowhead whales in Sireniki area (Anadyrskiy Gulf) extracted from Melinikov et al. (1998).

Fig. 6. Migration season of Bowhead whales investigated at Barrow and sightings in Sireniki area.

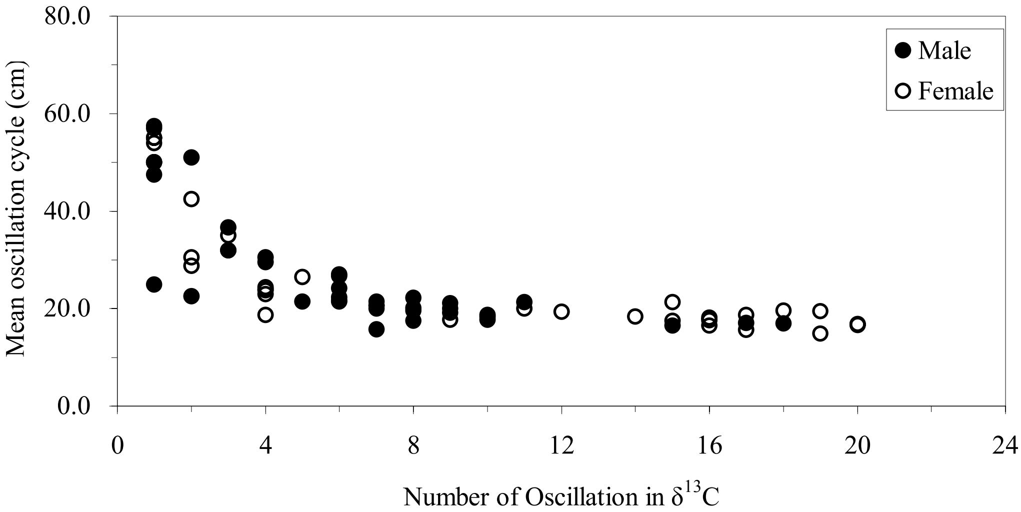


Fig. 7. Number of oscillation and mean cycle of $\delta^{13}C$ in baleen of Bowhead whales.

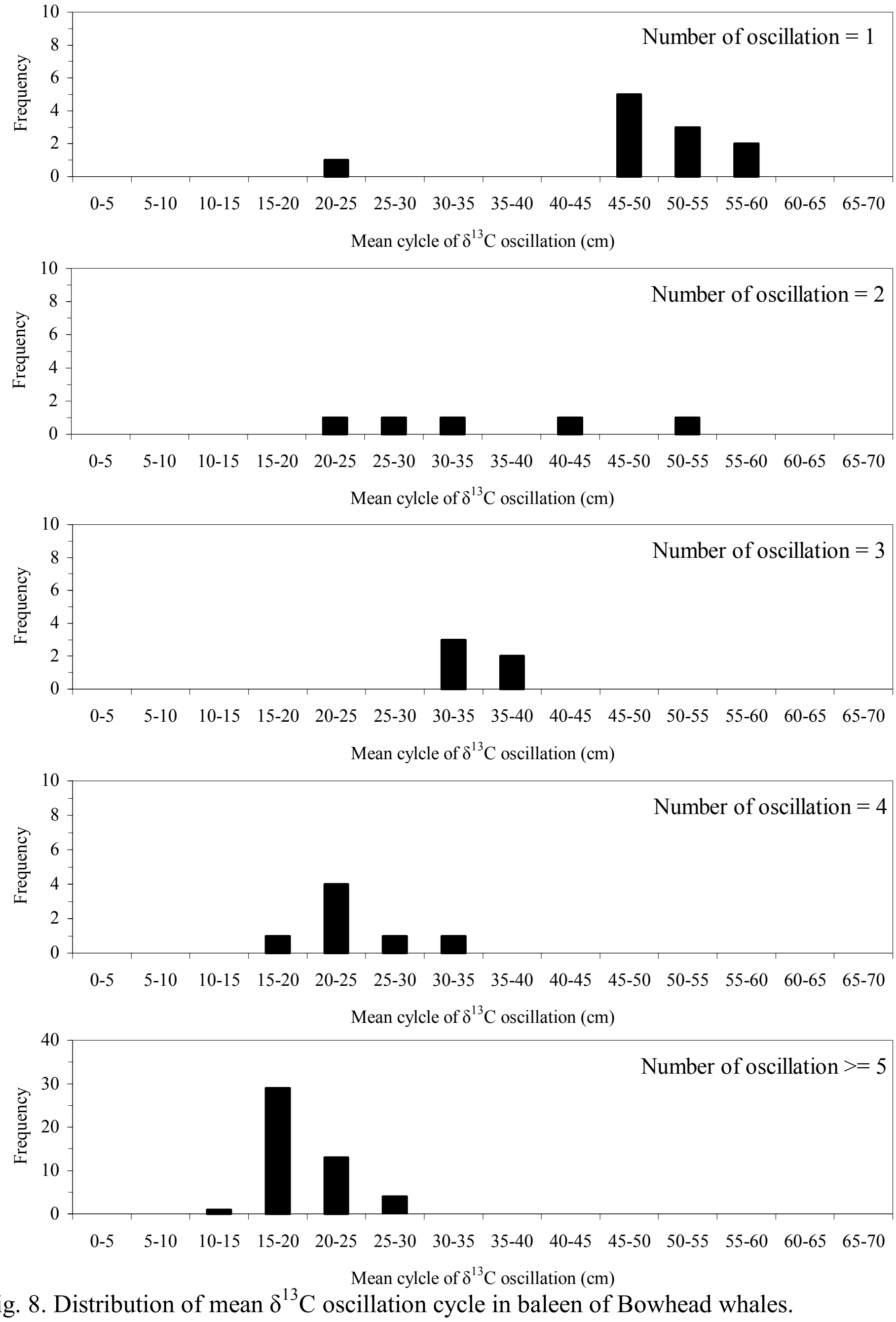


Fig. 8. Distribution of mean $\delta^{13}C$ oscillation cycle in baleen of Bowhead whales.

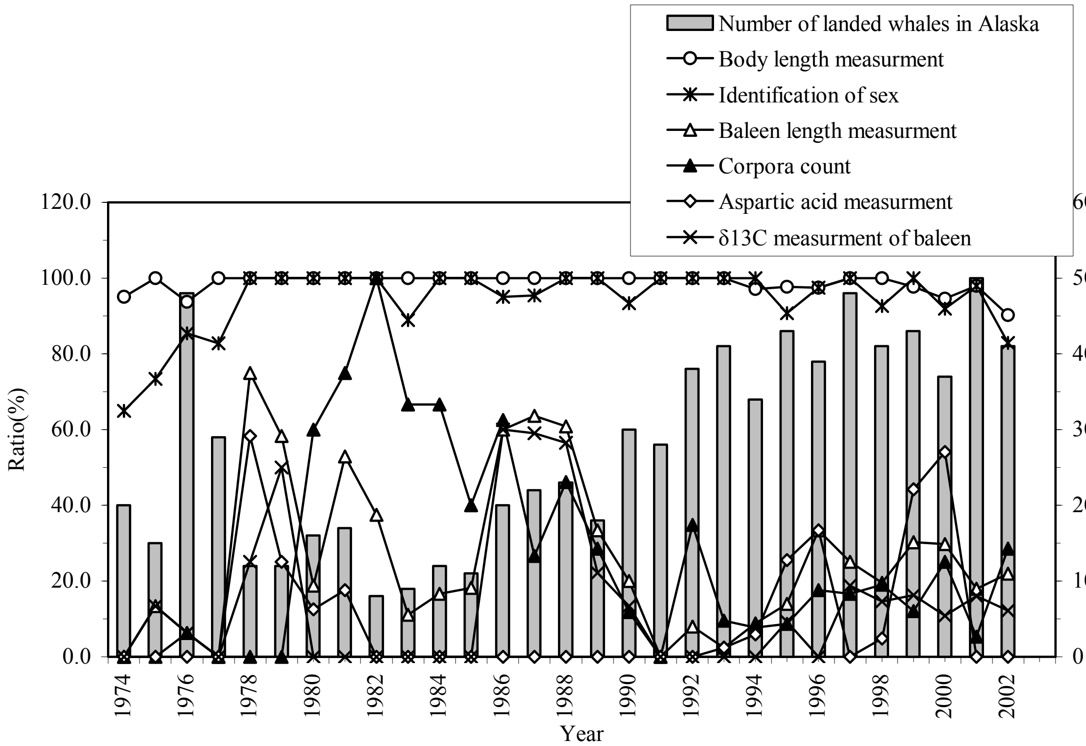


Fig. 9. Catch history and rate of investigation in each parameter. Data of landed whale from 1974 to 1993 are from Suydam *et al* . (1995), data from 1994 to 2002 are recompiled from the annual report of the Scientific Committee.