Birth-Intervals and Sex Composition of Western Gray Whales Summering off Sakhalin Island, Russia

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INTRODUCTION

Determining the birth-interval at which reproductive females produce calves is an indispensable component of studies on the population biology of large whales. In theory, shorter birth-intervals will result in a faster rate of population increase. Therefore, estimating this reproductive parameter is particularly important for modeling exercises designed to project the potential growth of a given population and, in the case of endangered populations, their ability to recover from a depleted state (e.g. Cooke *et al*., 2008). While a number of inherent biases exist with respect to determination of birth-intervals for baleen whales (Barlow and Clapham, 1997), dedicated sampling efforts and long-term field studies of known individuals have provided significant insight regarding this variable for a number of large whale populations. Knowing the ratio of males to females, including the primary, secondary, and tertiary sex ratio in a population is also essential to demographic assessments. In general, sex ratio information for baleen whale populations is patchy and, as true for birth-interval data, subject to a broad range of sampling bias.

Despite the aforementioned limitations, valuable information on the birth-interval and sex ratio of eastern Pacific gray whales (*Eschrichtius robustus*) has been published (e.g. Rice and Wolman, 1971; Rice, 1983; Jones, 1990). These studies, drawing upon biological samples collected from stranded or hunted individuals and photo-identification data from free-ranging whales, indicate that the typical birth-interval for the eastern gray whale is two-years, with a gestation period of about 418 days and lactation period of 6-8 months (Rice and Wolman, 1971; Rice, 1983). The fetal sex ratio for eastern gray whales has been estimated to be 1:1 (Rice, 1983).

The western Pacific gray whale population is critically endangered, numbering only about 130 individuals, and its ability to recover from near extinction is questionable (Cooke *et al*., 2008; Weller *et al*., 2008). Given the small size of the population and a relatively short period of study, fewer data exist regarding the birth-interval and sex ratio of western gray whales compared to the available information on eastern gray whales. This paper presents preliminary analysis of birth-intervals and sex composition of western gray whales summering off northeastern Sakhalin Island, Russia. Calving data were examined to determine the range of birth-interval values, the relative frequencies of different birth-intervals, and if calving intervals for individual females were stable or variable. In addition, determining the sex of calves and non-calves observed during the 12-year study allowed sex composition of the population to be assessed, including an examination of the proportion of male vs. female calves born to individual females.

METHODS AND MATERIALS

From 1997 to 2007, following an opportunistic effort in 1994 and a pilot study in 1995, western gray whale photo-identification surveys were carried out annually during summer months off the northeastern coast of Sakhalin Island, Russia, in the nearshore waters proximate to Piltun Lagoon. Further information about the study area and a detailed description of the photo-identification data collection and analysis protocols can be found in Weller *et al.* (1999). From 1994 to 2007, 337 photo-identification surveys were conducted, resulting in 5,167 sightings of 169 individual whales. In tandem with the photo-identification program, biopsy sampling for genetic research was also conducted (see Lang *et al*., 2008).

The term *calf*, as used herein, refers to 6-8 month old whales observed on the Sakhalin feeding ground for the first time in the year of their birth (*n* = 71). In general, calves were first identified while still closely bonded with their mother. In a few cases (*n* = 11), however, already weaned calves (i.e. independent of their mother) were photo-identified and, for seven of these calves, biopsy sampled. *Birth-interval* is defined as the period of time, in years, between the births of successive calves. This definition of both calf and birth-interval assume that the peak date of conception (5 December), gestation period (418 days) and estimated mean date of birth (about 10 January) for eastern gray whales (Rice and Wolman, 1971; Rice 1983) are similar for western gray whales.

RESULTS

Calving and Birth-Intervals

Seventy-one calves were visually identified on the Sakhalin Island feeding ground between 1995 and 2007. Eleven of these calves were weaned from their respective mothers prior to their first sighting. Of these 11, seven have been biopsy sampled - resulting in three of them being genetically linked to a known female (i.e. mother) in the study population. Thus, based on visual and/or genetic evidence, a total of 63 calves were linked to 24 reproductive females (Table 1).

Annual occurrence and calving patterns of the 24 known reproductive females are presented in Table 1. The number of calves recorded on an annual basis ranged between 2 and 11 (Table 2). The number of calves observed with a given mother between 1995 and 2007 ranged from 1 to 5 and 39 birth-intervals for 20 (83.3%) of the 24 reproductive females were documented (Tables 1 and 3). The number of intervals available to be calculated per female ranged from 0 (for females that were sighted with only a single calf) to 4 (for females that were observed with five calves). Of the observed birth-intervals, 51.3% (*n* = 20) were two years, 33.3% (*n* = 13) three years, 10.3% (*n* = 4) four years and the remainder represented by one interval of five years and one of six years.

For the subset of 12 females in which more than one birth-interval could be calculated, the interval remained stable for six (50.0%), decreased for five (41.7%) and increased for one (8.3%). This assessment was not possible for 12 females that had either one or zero observed intervals. In general, most females appeared to be maintaining stable intervals of 2 years (*n* = 5) or 3 years (*n* = 1) or have experienced a shortening of the birth-interval (*n* = 5; Table 1).

Sex Ratio

For all individuals of known sex (*n* = 142) identified between 1995 and 2007, a male-biased sex ratio of 58.5% male and 41.5% female has been documented. When the subset of whales sampled as calves (*n* = 62) was examined, 66.1% were male and 33.9% female. The sex ratio of calves as a function of year, presented in Table 2, was also biased. That is, in 9 (75.0%) of 12 years there was a male bias in the calf sample. In comparison, in only 2 (16.7%) years was there a female bias and in only 1 (8.3%) year was there an even sex ratio.

The sex ratio of calves born to the 18 reproductive females that produced at least two calves of known sex during the study varied (Table 3). Ten (55.6%) of these 18 females had a male calf bias, including five individuals that produced only male offspring. In comparison, three females (16.7%) had a female calf bias, including two individuals that produced only female offspring. Finally, five females (27.8%) had an unbiased (i.e. equal) male to female calf ratio.

DISCUSSION

Birth-Intervals

A variety of biological and observational data suggest that the typical birth-interval for eastern gray whales is normally two-years (Rice and Wolman, 1971). Reilly (1992) examined all available data on eastern gray whale pregnancy (0.47-0.48) and ovulation (0.52) rates, ovarian condition, and gestation period and found overall support for a two-year minimum cycle. Jones (1990) collected photographic records on 55 females with calves in Laguna San Ignacio between 1977 and 1982 and determined that calving intervals were predominantly on a two-year cycle. Although a number of inherent biases exist in the estimation of birth-intervals, the data derived from a number of sources are similar to the overall pattern observed for western gray whales as described herein. That is, two-year birth-intervals account for 50% of the intervals observed to date in the western population.

A recent western gray whale population assessment by Cooke *et al.* (2008), using the same 1994-2007 photo-identification data presented here, reported a slightly more optimistic projection of population recovery then had previously been reported (Reeves *et al*., 2005). This revised projection is thought to be mainly because the modal calving interval has shortened (implying a higher reproductive rate) from 3 years for data up to 2002 to 2 years post-2002 (Cooke *et al*., 2008). Variation in the inter-birth interval, including shortening and lengthening of such, are likely to be influenced by the health and nutritive condition of a female, both of which are linked with habitat and environmental variables (Perryman *et al*., 2002a, 2002b). Further analysis of the current data set will examine the inter-birth interval for western gray whales relative to assessments of body condition (see Bradford *et al*., 2008), environmental conditions (e.g. sea ice dynamics) and anthropogenic disturbance.

Sex Ratio

Rice (1983) reported the fetal sex ratio for eastern gray whales off central California as 1:1. Data on fetal sex ratio, if determined by qualified observers, is perhaps the least biased source of information with regard to the determination of the primary sex ratio in a population. That said, it is also true that estimates of fetal sex ratio can be substantially biased if unqualified observers collect the data. Thus, while a number of fetal sex ratio estimates exist in the literature, caution needs to be used in their interpretation. Estimates of secondary and tertiary sex ratio are also problematic. In many cases, these estimates suffer from inherent bias. This is especially true for species like gray whales that demonstrate age and sex class structure during some or all phases of their life cycle. For example, Rice (1990) noted that of 701 eastern gray whales killed on their summer feeding ground off Chukotka, Russia, only 29.8% were male. This female bias, found on a shallow water feeding ground contrasts will the male bias (58% male and 42% female) recorded for western gray whales, on a similar shallow water feeding ground off Sakhalin Island.

There is some suggestion that a male bias in the western gray whale population has persisted for about 100 years. Andrews (1914) recorded a 63.4% (n = 92) male to 36.6% (n = 53) female ratio for 145 western gray whales killed off the coast of Korea between 1909 and 1912. Mizue (1951), added additional records to those of Andrews (1914), and reported a 68.3% male to 31.7% female ratio for 545 western gray whales killed in the early 20th century off the coast of Korea. The male bias found by Andrews (1914) is particularly interesting in that much of the hunt from which his data were collected occurred during December and early January which, based upon the behavior of the eastern population, is expected to be predominately composed of pregnant female whales.

The pronounced male bias found in calves born during the current study remains unexplained. Rice and Wolman (1971) examined 55 near term fetuses (30 male and 25 female) and found no significant difference in body length, suggesting that a difference in gestational energy investment for male versus female calves is unlikely to play a role in the bias reported here. Body condition has been demonstrated to influence calf production (Perryman *et al*., 2002a, 2002b), but it has yet to be determined if health and body condition of reproductive females influences the sex of their offspring. In mammals, including humans, endocrine disruptors have been shown to affect the sex ratio of offspring (Navara and Nelson, 2009). Finally, it may be the case that neonatal mortality at birth or on the first northbound migration to the Sakhalin feeding area is higher for female calves than male calves. This hypothesis, however, is counter to the 62.5% male bias in neonatal stranding reported for the eastern population (Rice, 1990).

In summary, the data presented herein point to similarities and differences in birth-intervals and sex ratios between the eastern and western gray whale populations. A more detailed and comprehensive analysis of the current data on western gray whales is underway. When this analysis is complete, it is hoped that further insight will be gained regarding the population biology of both western and eastern gray whales.

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Table 1. Annual occurrence and calving patterns for known reproductive females. Years in which the female was sighted on the Sakhalin Island feeding ground with a calf are denoted by a "C", while years in which the female was sighted without a calf are indicated by a "1". Years in which the female was not sighted on the Sakhalin Island feeding ground are coded with a "0". Shaded rows represent the sample of birth-intervals analyzed.

Female	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
A	0	-	1	**C**	1	1	1	**C**	0	0	0	0	0
B	1	-	1	1	1	1	**C**	0	**C**	1	**C**	1	**C**
C	1	-	1	1	0	1	1	0	**C**	1	**C**	0	**C**
D	1	-	1	**C**	1	1	**C**	1	1	**C**	1	1	**C**
E	0	-	1	1	1	1	1	**C**	0	1	1	**C**	1
F	0	-	1	**C**	1	1	1	**C**	1	**C**	1	1	1
G	**C**	-	1	**C**	1	1	**C**	0	**C**	1	**C**	1	0
H	**C**	-	**C**	1	1	**C**	1	1	**C**	1	0	1	**C**
I	0	-	1	1	0	0	0	**C**	0	**C**	1	0	0
J	1	-	1	1	1	0	1	0	**C**	0	0	1	0
K	0	-	**C**	0	0	0	0	0	0	0	0	0	0
L	1	-	1	1	1	1	1	1	**C**	1	1	**C**	1
M	0	-	1	**C**	1	1	**C**	1	1	1	1	0	1
N	1	-	1	1	**C**	0	1	1	1	**C**	1	1	**C**
O	0	-	1	1	**C**	0	0	**C**	0	**C**	1	**C**	1
P	1	-	0	0	1	1	1	**C**	1	**C**	0	**C**	0
Q	0	-	0	**C**	1	1	**C**	1	**C**	1	1	1	0
R	0	-	1	**C**	0	1	1	1	0	0	1	0	1
S	0	-	0	0	1	1	1	1	**C**	1	**C**	1	**C**
T	0	-	0	0	1	1	1	1	**C**	1	**C**	1	**C**
U	0	-	0	0	1	**C**	1	0	**C**	1	1	0	0
V	0	-	0	0	0	1	**C**	1	0	0	1	1	**C**
W	0	-	0	0	0	0	1	1	1	1	1	1	**C**
X	0	-	1	1	1	0	1	**C**	1	**C**	0	0	0

Table 2. Sex ratio of calves as a function of year.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Total Calves	2	NA	2	8	3	3	6	9	11	8	6	4	9
Male	2	NA	2	3	1	3	2	6	8	3	4	1	6
Female	0	NA	0	2	0	0	4	3	3	3	1	2	3
Unknown	0	NA	0	3	2	0	0	0	0	2	1	1	0
% Male	100	NA	100	60	100	100	33	67	73	50	80	33	67
% Female	0	NA	0	40	0	0	67	33	27	50	20	67	33

Table 3. Sex ratio of calves born to known reproductive females.

Female	Total Calves	Male	Female	Unknown	% Male	% Female
A	2	1		1	100	0
B	4	2	2		50	50
C	3	2	1		67	33
D	4	2	2		50	50
E	2		2		0	100
F	3	3			100	0
G	5	5			100	0
H	5	3	2		60	40
I	2	2			100	0
J	1	1			100	0
K	1	1			100	0
L	2	1	1		50	50
M	2		2		0	100
N	3	2	1		67	33
O	4		1	3	0	100
P	3	1	2		33	67
Q	3	2	1		67	33
R	1			1	?	?
S	3	2	1		67	33
T	3	3			100	0
U	2	2			100	0
V	2	1	1		50	50
W	1		1		0	100
X	2	1	1		50	50