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What do we know about whales and ecosystem in the western North Pacific Ocean? Part 3: summary of results on biological parameters in baleen whale species

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ABSTRACT

Three baleen whale species, sei, Bryde's and common minke whales were surveyed during the former Japanese scientific whaling programs in the western North Pacific Ocean conducted from 1994 to 2019. This paper summarizes some life history-related biological parameters estimated for the three species, based on data and samples collected during the research programs. These biological parameters are important as input data for models aimed at studying the population dynamics of the species. Results therefore will contribute to the management of these whale species in the western North Pacific.

INTRODUCTION

Three baleen whale species, sei (*Balaenoptera borealis*), Bryde's (*B. edeni brydei*) and common minke (*B. acuto-rostrata scammoni*) whales were surveyed by former Japanese scientific whaling program in the western North Pacific conducted by the Institute of Cetacean Research (ICR). The target species for the Japanese Whale Research Program under Special Permit in the North Pacific (JARPN) (1994–1999) was the common minke whales (GOJ, 1994). The second phase of this program (JARPNII) (2000–2016) targeted Bryde's, common minke and sei whales. The latter was added as a target species in 2002 (GOJ, 2000; 2002).

After the completion of the JARPNII, the New Scientific Whale Research Program in the western North Pacific (NEWREP-NP) commenced in 2017 and lasted until 2019 (GOJ, 2017). The target species were sei and common minke whales. Figure 1 shows the baleen whale species targeted by the former Japanese scientific whaling programs in the western North Pacific.

During these research programs, systematic biological sampling was conducted on the whales taken. These included earplugs for age determination, testes and ovaries for determination of sexual maturity and estimation of reproductive history, fetus for reproductive studies and body length for growth studies. Some life history-related biological parameters, which are important as input data

for population dynamics models, were estimated for the three whale species based on data and samples collected during the research programs.

This paper summarizes the results of biological parameter estimations in sei, Bryde's and common minke whales in the western North Pacific. It follows more detailed analyses presented previously in Bando (2017; 2018), Bando and Maeda (2020) and Maeda *et al.* (2017).

SUMMARY OF BIOLOGICAL PARAMETERS IN THREE BALEEN WHALE SPECIES

Laboratory and analytical procedures to estimate biological parameters in baleen whales were explained in previous articles (Bando, 2017; 2018; Bando and Maeda, 2020; Maeda *et al.*, 2017). Details of these approaches are not repeated here for brevity. The results of biological parameter estimations for the three species in the western North Pacific are presented in this section.

Earplug age readability

In many baleen whale species, ages are estimated by counting the number of growth layers accumulated in the earplugs which are formed in the external auditory meatus (Lockyer, 1984a). During the scientific whaling programs, earplug age readability had improved compared to the reading based on earplug collected from past commercial whaling. This was due to careful sampling



Figure 1. Baleen whale species targeted by the former Japanese scientific whaling programs in the western North Pacific: sei whale (upper left); Bryde's whale (upper right); and common minke whale (lower).

of earplugs by experienced researchers and introduction of a new gelatinized extraction method during the scientific whaling programs (Bando, 2021; Bando and Maeda, 2020; Maeda, *et al.*, 2013).

Sei whales

Bando and Maeda (2020) reported earplug age readability of immature sei whales as 55.9% and 48.9% for males and females, respectively. Readability in sexually mature animals was higher. The values were 72.5% and 67.4% for males and females, respectively.

Bryde's whales

Similar readability values were reported for Bryde's whales. They were 43.8% and 40.8% for immature males and females, respectively, and 74.0% and 76.4% for mature males and females, respectively (Bando, 2021).

Common minke whales

In the case of common minke whale, the readability was somewhat lower. They were 35.4% and 34.7% for immature males and females, respectively, and 49.2% and 59.0% for mature males and females, respectively (Maeda *et al.*, 2016).

Growth curve

The growth curve of each whale species was estimated by

fitting the von Bertalanffy growth model to body length and age.

Sei whales

The growth curve of sei whales was estimated as $L_t = 14.14(1 - e^{-0.174(t+6.650)})$ for males, and $L_t = 15.17(1 - e^{-0.150(t+7.407)})$ for females (Bando and Maeda, 2020).

Bryde's whales

The asymptotic length of Bryde's whales was slightly smaller than that of sei whale. The growth curve was estimated as $L_t = 12.65(1 - e^{-0.189(t+5.250)})$ for males, and $L_t = 13.30(1 - e^{-0.170(t+4.929)})$ for females (Bando, 2021).

Common minke whales

The asymptotic length of common minke whales was much smaller than the other two species. The growth curve was estimated as $L_t = 7.49(1 - e^{-0.41(t+0.90)})$ for males, and $L_t = 8.66(1 - e^{-0.11(t+7.60)})$ for females (Maeda, 2012).

In the three whale species, the asymptotic length was greater in females than in males.

Maximum life span

Sei whales

Bando and Maeda (2020) reported the maximum age of sei whales (estimated from earplug reading) as 54 years for males and 43 years for females.

Bryde's whales

Bando (2021) reported the maximum age of Bryde's whales as 51 and 56 years for males and females, respectively.

Common minke whales

Maeda *et al.* (2016) reported maximum age of male and female common minke whales as 49 and 41 years, respectively.

Age at sexual maturity

There are several methods to estimate age at sexual maturity of baleen whales (Lockyer, 1984b). Age at 50% sexual maturity ($tm_{50\%}$) is estimated by calculating the ratio of immature and mature whales in each age. Age at first ovulation (t_{mov}) is estimated by mean age of whales with one corpus luteum and no corpus albicans in both ovaries. It is generally known that the transition phase in earplugs of large baleen whales indicates sexual maturity (Lockyer, 1972; Masaki, 1979; Kato, 1983; Ohsumi, 1986) and age at sexual maturity (t_{mp}) is estimated by mean age of whales when the transition phase is formed.

Sei whales

Bando and Maeda (2020) estimated $tm_{50\%}$ of sei whales as 6.7 (SE=0.29) years for males and 6.9 (SE=0.27) years for females, respectively. t_{mov} was estimated as 8.6 (SD=3.14) years (Bando, 2017).

Bryde's whales

For Bryde's whales, $tm_{50\%}$ were estimated as 7.72 (SE=0.49) and 8.56 (SE=0.39) years for males and females, respectively (Bando, 2021). t_{mov} was estimated as 10.1 (SD=1.13) years (Bando, 2017).

Common minke whales

t_{mp} was estimated as 7.68 (SD=1.81) years for males and 7.82 (SD=1.58) years for females (Maeda *et al.*, 2017). t_{mov} was estimated as 8.75 (SD=1.5) years (Maeda *et al.*, 2017).

Body length at sexual maturity

Body length at 50% sexual maturity ($Lm_{50\%}$) and first ovulation (L_{mov}) are estimated in the same manner as the age at 50% sexual maturity ($tm_{50\%}$) and age at first ovulation (t_{mov}). $Lm_{50\%}$ is estimated by calculating the ratio of immature and mature whales in each body length class. L_{mov} is estimated by mean body length of whales with one corpus luteum and no corpus albicans in both ovaries.

Sei whales

$Lm_{50\%}$ of sei whales was estimated as 12.72 m (SE=0.12) for males and 13.31 m (SE=0.12) for females (Bando and Maeda, 2020). L_{mov} was estimated as 13.70 m (SD=0.47) (Bando, 2017).

Bryde's whales

$Lm_{50\%}$ of Bryde's whales was slightly smaller than that of sei whale, 11.41 m (SE=0.25) for males and 11.75 m (SE=0.23) for females (Bando, 2021). L_{mov} was estimated as 12.13 m (SD=0.62) (Bando, 2017).

Common minke whales

There are no available estimates of $Lm_{50\%}$ and L_{mov} for common minke whales. Common minke whales are known to segregate in the western North Pacific by sex and sexual maturity status (Zenitani *et al.*, 2000a; 2000b). This fact will bias the estimate of length at sexual maturity.

Pregnancy rate

Pregnancy rates are usually calculated as the proportion of pregnant females among captured mature females. However, in some cases, this value may differ from the true pregnancy rate due to biases such as segregation and the effect of mother and calf pair's occurrence.

Sei and Bryde's whales

Most sei and Bryde's whales are thought to give birth every two or more years. Females accompanied by calf are considered to have a low pregnancy rate because they were pregnant in the previous year. If females with calf were excluded from samples, pregnancy rate may be overestimated. Bando (2017) estimated pregnancy rate of sei and Bryde's whales with correction of the effect of mother and calf pair (which were not targeted for sampling in most years) as 0.650 and 0.491, respectively.

Common minke whales

Pregnancy rates of common minke whale have not been estimated due to the small number of mature female samples. Most of the mature females distribute outside of the research area (Hatanaka and Miyashita, 1997; Wada, 1989).

Conception Date

In baleen whales, growth of fetus after the early stage of development is considered to be linear with time, and methods for estimating conception date from foetal length and date of capture has been developed (Huggett and Widdas, 1951; Kato and Miyashita, 1991; Lockyer, 1984b).

Table 1
Summary of biological parameters of three baleen whale species in the western North Pacific.

	Sei whale		Bryde's whale		Common minke whale	
	Male	Female	Male	Female	Male	Female
Age reading						
Earplug readability	Immature	48.9% (n=174)	43.8% (n=105)	40.8% (n=120)	35.4% (n=548)	34.7% (n=501)
	Mature	67.4% (n=562)	74.0% (n=208)	76.4% (n=296)	49.2% (n=1,340)	59.0% (n=183)
	Total	68.4% (n=618)	63.9% (n=313)	66.1% (n=416)	45.2% (n=1,888)	41.2% (n=684)
Growth						
Growth curve	$L_t = 14.14(1 - e^{-0.174(t+6.650)})$	$L_t = 15.17(1 - e^{-0.150(t+7.407)})$	$L_t = 12.65(1 - e^{-0.189(t+5.250)})$	$L_t = 13.30(1 - e^{-0.170(t+4.929)})$	$L_t = 7.49(1 - e^{-0.41(t+0.90)})$	$L_t = 8.66(1 - e^{-0.11(t+7.60)})$
Maximum life span	54 years	43 years	51 years	56 years	49 years	41 years
Sexual maturity						
Age at sexual maturity	<i>tmov</i>	8.6 years	7.72 years	10.1 years	—	8.75 years
	<i>tm50%</i>	6.7 years	6.9 years	8.56 years	—	—
	<i>tmp</i>	—	—	—	7.68 years	7.82 years
Body length at sexual maturity	<i>Lmov</i>	13.70 m	11.41 m	12.13 m	—	—
	<i>Lm50%</i>	12.72 m	13.31 m	11.75 m	—	—
Reproductive characteristics						
Pregnancy rate	Peak from December to February	0.650	Year round with peak from October to May	0.491	Peak from autumn to winter (J-stock)	—
Conception date	—	—	—	—	One peak in winter (O-stock)	—
Annual ovulation rate	0.519	0.744/year	0.533	0.526/year	—	—
Foetal sex ratio	—	0.481	—	0.467	—	—
Litter size	—	1.007	—	1.011	—	—
References	Bando (2017) Bando and Maeda (2020)	Bando (2017); (2018); (2021)	Bando (2017); (2018); (2021)	Bando (2017); (2018); (2021)	Bando <i>et al.</i> (2010) Goto <i>et al.</i> (2021) Maeda (2012) Maeda <i>et al.</i> (2016); (2017)	—

Sei and Bryde's whales

Bando (2017) calculated conception dates based on the analysis of fetuses from 414 sei and 177 Bryde's whales. He reported that the conception season of sei whales lasts from November to March, with a peak from December to February, and that of Bryde's whales is year-round, with a moderate peak from October to May.

Common minke whales

As for minke whales, two biological stocks are known to exist in the western North Pacific, the J and O stocks (see reviews in Goto *et al.*, 2017; 2021). Both stocks are reported to have different conception seasons, the O-stock from November to June with a single winter peak, and the J-stock from August to March with a peak from autumn to winter (Bando *et al.*, 2010, Goto *et al.*, 2021).

Annual ovulation rate

Annual ovulation rate was estimated from regression of age and number of corpora in the ovaries.

Sei and Bryde's whales

Annual ovulation rate was estimated as 0.744/year for sei whales and 0.526/year for Bryde's whales, respectively (Bando and Maeda, 2020; Bando, 2021).

Common minke whales

There is no estimate available for common minke whales.

Foetal sex ratio

Sei and Bryde's whales

Bando (2017) reported foetal sex ratio (male ratio) of sei whales as 51.9% ($n=418$) and that of Bryde's whales as 53.3% ($n=169$). No significant difference from parity was detected for sei and Bryde's whales.

Common minke whales

There are no estimates available for common minke whales.

Litter size

In baleen whale species, the number of fetuses is usually one. However, multiple fetuses (twins in most cases) are observed occasionally (Kimura, 1957; Lockyer, 1984b).

Sei and Bryde's whales

Litter sizes were estimated as 1.007 for sei whales ($n=420$), and 1.011 for Bryde's whale ($n=177$) (Bando, 2017).

Common minke whales

There are no estimates available for common minke whales.

Table 1 summarizes the estimates of life history-related biological parameters in sei, Bryde's and common minke whales in the western North Pacific.

CONCLUDING REMARKS

Several biological parameters of three baleen whale species were estimated from the samples collected by scientific whaling programs conducted by the ICR. During these surveys, a wide range of whale samples, from young to old, were collected by random sampling method which led to a more accurate estimation of biological parameters than that estimated from past commercial whaling data. Some biological parameters respond to changes in their environment such as food availability or fecundity, which will affect the status of whale stocks. Biological parameters are also important as input data for models aimed at studying the population dynamics of the species. The estimated biological parameters will contribute to the management of these whale species in the western North Pacific Ocean.

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