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Status of J stock minke whales (*Balaenoptera acutorostrata*)

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The status of J stock minke whales (*Balaenoptera acutorostrata*) was assessed using potential biological removal (PBR) and mortality data. Using the estimated abundance of minke whales in this area (6260; CV = 0.212), the minimum population estimate of the stock was estimated as 5247. The PBR for J stock minke whales was calculated as 52.5 individuals using the minimum population estimate (5247), one-half of the maximum theoretical net productivity rate (0.02) and the recovery factor (0.5). The estimated mean annual level of anthropogenic mortality was 270.4 individuals. Thus, the status of this stock was considered as strategic. However, fortunately, the abundance of this population in the East Sea from 2000 to 2008 showed an increasing trend (rate of increase 0.0488; annual rate of increase 5.0%) although it is not statistically significant ($P > 0.05$). The primary sources of anthropogenic mortality were bycatch (set nets, pots and gill nets) and illegal catch. Because of the status of this population, it is urgently necessary to reduce the amount of bycatch and illegal catch of minke whales. Further study needs to use population health and viability analysis for investigating the long-term survival of this population more clearly.

Keywords: status; minke whale; potential biological removal (PBR); abundance; mortality; bycatch

Introduction

Minke whales (*Balaenoptera acutorostrata*) are widely distributed in most of oceans in the world (Jefferson et al. 1993). It is thought that there are probably two stocks of minke whales in the western North Pacific Ocean such as the J stock (East Sea-Yellow Sea-East China Sea stock) and the O stock (Okhotsk Sea-West Pacific stock) (IWC 1983). Minke whales of the J stock are known to migrate northward in the summer season for feeding and southward in the winter season for breeding (Gong 1988). Also, they tend to occur frequently in the continental shelves along the shore based on the analysis of the occurrence pattern of minke whales in the East Sea of Korea (Cho et al. 2003). Minke whales are considered as the most abundant baleen whale in Korean waters, and the abundance of this stock was estimated as 7600 individuals (CV = 0.4) based on a previous report (IWC 1984). Also, several studies were conducted on stock structure (Park et al. 2004), abundance (Gong 1988; Sohn et al. 2001), bycatch (Kim 1999; Kim et al. 200; Kim 2008; Song et al. 2010) and age structure (Na 2005) of minke whales in this area.

On the other hand, this stock was seriously affected by extensive commercial whaling until the moratorium on commercial whaling in 1986. The total recorded catch from 1962 to 1986 was 13,734 whales (Kim 1999), with a peak of 1033 in 1973, and the declining catch-per-unit-effort led to the conclusion the population was depleted and it being declared a protected stock by the IWC scientific committee in 1983. Also, this stock was depleted by human-induced mortality such as bycatch in this area after the moratorium. According to several reports, approximately 200 individuals of minke whales per year were bycaught in Korean and Japanese waters (Tobayama et al. 1992; Kim 1999; Kim et al. 2004; Kim 2008). Furthermore, according to the simulation, this stock was predicted to decrease and probably be extinct within the next few decades at this rate (Baker et al. 2000).

Cetaceans in Korean waters including minke whale have been protected for more than 24 years since the declaration of a commercial whaling moratorium in 1986. However, there was little effort to assess their status in this area after the moratorium in 1986 except for finless porpoise in the Yellow Sea (Park 2006). Therefore, it was difficult to assess the status of minke whales, and to investigate the efficacy of the moratorium in spite of extensive protection. Generally, management of cetaceans is based on exact information on the trend in abundance and status of cetacean stocks (Punt and Donovan 2007). Therefore, it needs to assess the status of minke whales for the effective conservation and management of this population.

Potential biological removal (PBR), which is the maximum allowable annual removal, has been generally used to assess the status of marine mammal stocks

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under the Marine Mammal Protection Act (MMPA) in the USA (Wade 1998; Read and Wade 2000). In a review of sustainability indices for exploited populations, Milner-Gulland and Akçakaya (2001) found that PBR-type calculations performed well in all tests considered, and described it as highly promising in terms of its ability to reduce the risk of extinction to acceptably low levels. The PBR concept is widely used internationally to guide conservation of marine mammals (e.g. Gales 1995; Taylor et al. 2000; Marsh et al. 2004; Thompson et al. 2007; Underwood et al. 2008), and has been used by the European Union (ASCOBANS 2000) and by New Zealand (Slooten and Dawson 2008) to evaluate bycatch of cetaceans. Japan's National Research Institute of Far Seas Fisheries has proposed a PBR-type method to set quotas on Dall's porpoises (*Phocoenoides dalli*) hunted in Japan, and a simulation study on how to apply this method is described in Okamura et al. (2008). The PBR concept has also been adopted for use in evaluating the sustainability of bush-meat hunting in tropical forests (Parry et al. 2009) and is being widely used to evaluate the sustainability of fisheries bycatch of seabirds (e.g. Dillingham and Fletcher 2008; Barbraud et al. 2009; Zydelis et al. 2009). According to Wade (1998), the PBR is calculated from the product of the minimum population estimate of the stock (N_{min}), one-half of the maximum theoretical or estimated net productivity of the stock (R_{max}) and a recovery factor (F_r) (0.1–1.0). The status of marine mammal stock can be estimated by comparing PBR and mortality levels. If the level of mortality of this stock is greater than the PBR, the status of this stock will be considered as strategic and it needs to reduce level of mortality. However, if the level of mortality of this stock is lower than the PBR, the status of this stock will be considered as non-strategic and specific action is not required.

The objective of this study is to assess the status of J stock minke whales using PBR data and mortality data. This information can be used as fundamental data for the effective conservation and management of this population.

Material and methods

To estimate the status of J stock minke whales, abundance (Kitakado et al. 2010) and mortality (Baker et al. 2007; Lukoschek et al. 2009) data of this stock were used. Also, to investigatethe trend in abundance of minke whales in Korean waters, abundance data of minke whales in the East Sea of Korea from 2000 to 2008 were used (An et al. 2010).

N_{min} was calculated from the following equation using abundance estimate and coefficient of variation (CV) of abundance estimate (Wade 1998).

$$N_{min} = N / \exp\left(0.842 * \left(ln\left(1 + CV(N)^2\right)\right)^{1/2}\right)$$

PBR was calculated from the following equation using abundance data of minke whales (Wade 1998).

$$PBR = N_{min} \times 1/2R_{max} \times F_r$$

N_{min} = the minimum population estimate of the stock

$1/2R_{max}$ = one-half of the maximum theoretical or estimated net productivity of the stock

F_r = a recovery factor (0.1–1.0).

And then I compared the PBR level with the mortality level of minke whales to determine whether the level of mortality of this stock is greater or less than the level of PBR. Finally, I determined the status of minke whales in Korean waters from this comparison. Also, I estimated the rate of increase (r) or trend in abundance using an exponential growth model ($N_t = N_0e^{rt}$; r is rate of increase and N is abundance).

Results

PBR (potential biological removal)

Using the estimated abundance of minke whales in this area (6,60; CV = 0.212) (Figure 1 and Table 1), the

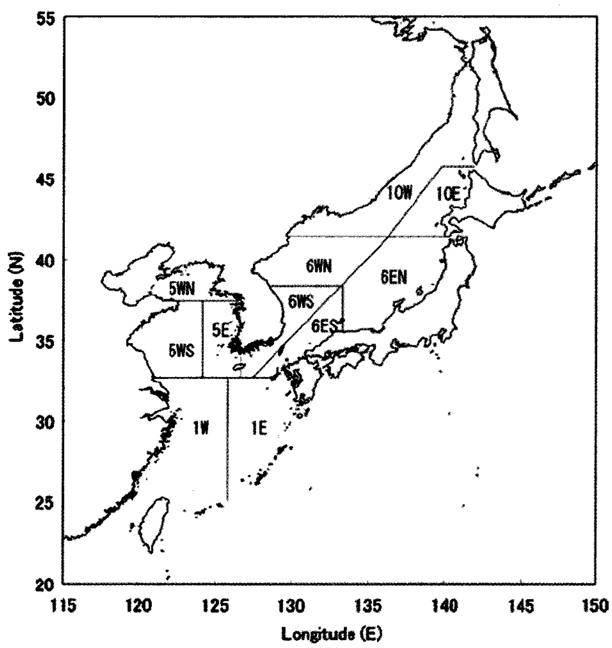

Figure 1. Definition of sub-areas and survey blocks for J stock minke whales.

Table 1. N is uncorrected abundance, CV[N] is the coefficient of variation of N, $g(0)$ is the estimated probability of detection on the trackline, N(cor) is the abundance after correction with $g(0)$, and CV(cor) is the coefficient of variation of N(cor). The CVs were combined using standard formulas for combining variances of a product (i.e. $N \times 1/g(0)$) and combining variances of a sum (e.g. for total abundance), assuming all estimates are independent. Estimates of N, CV[N], and $g(0)$ are from Kitakado et al. (2010). Estimates of N(cor), CV(cor), and total abundance were calculated in this study.

Subarea	Year	N	CV[N]	$g(0)$	CV[$g(0)$]	N(cor)	CV(cor)
5E	2008	680	0.372	0.798	0.168	852	0.408
6WS	2002	391	0.614	0.798	0.168	490	0.637
6ES	NA						
6EN	2004	727	0.372	0.798	0.120	911	0.408
10W	2006	2,855	0.327	0.856	0.120	3335	0.348
10E	2007	575	0.327	0.856		672	0.348
Total abundance						6260	0.212

minimum population of this stock was estimated as 5247 individuals based on Wade (1998). I used the values of maximum theoretical net productivity rate and recovery factor as 0.04 and 0.5, respectively (Barlow et al. 1995; Wade 1998). The PBR for minke whales in this area was calculated as 52.5 individuals using the minimum population estimate (5247), one-half the maximum theoretical net productivity rate (0.02) and the recovery factor (0.5) (Table 2).

Mortality

Minke whales experienced several anthropogenic mortalities including bycatch, ship strike and illegal catch in Korean waters (Figures 2 and 3). However, most anthropogenic mortalities were associated with fishing activities such as set net, pot and gill net. Baker et al. (2007) estimated 827 minke whales were killed for the 5-year period 1999–2003, for an annual kill of 165.4. Lukoschek et al. (2009) conservatively estimated 105 J stock whales were killed per year in Japanese waters for the years 2002–2004. Therefore, the mean annual level of anthropogenic mortality of this stock was estimated as 270.4 individuals based on the data of Baker et al. (2007) and Lukoschek et al. (2009).

Status

Mortalities of minke whales (270.4) in this area exceeded their estimated PBR level (52.5) (Table 2). Thus, the status of this stock was considered as strategic based on Wade (1998). However, fortunately, the abundance of this population in the East Sea showed an increasing trend from 2000 to 2008 using the data of An et al. (2010) although it is not statistically significant ($P > 0.05$) (Figure 4). The rate of increase and annual rate of increase (%) was estimated as 0.0488 and 5.0%, respectively. There is an urgent need to reduce the level of anthropogenic mortality such as bycatch. The primary sources of anthropogenic mortality were bycatch (especially set nets, pots and gill nets) and illegal catch.

Discussion

Although minke whales in Korean waters have been protected for more than 24 years after a commercial

Table 2. Minimum population estimate (N_{min}), maximum net productivity rate (R_{max}), recovery factor (F_r), potential biological removal (PBR), average annual mortality, primary source of mortality, trend in relative abundance and status of minke whale stock (J stock).

N_{min}	R_{max}	F_r	PBR	Average annual mortality	Trend[a]	Status	Source of mortality
5247	0.04	0.5	52.5	270.4	+ (Positive)	Strategic	Bycatch (set nets, pots and gill nets) and illegal catch

[a] Trend in abundance of minke whales in the East Sea of Korea from 2000 to 2008.

Figure 2. A picture of bycaught minke whale in Korean waters (photo by Cetacean Research Institute, Republic of Korea).

Figure 3. A picture of illegally caught minke whale in Korean waters (photo by Pohang Coast Guard, Republic of Korea).

whaling moratorium in 1986 by the International Whaling Commission (IWC), there was little effort to assess their status in this area after the moratorium and the efficacy of the moratorium. Our study suggests that the moratorium in 1986 has probably been unsuccessful in protecting this population because of high bycatch and illegal catch. Because of the status of this population, it is necessary to reduce the amount of bycatch and illegal catch of minke whales for the effective conservation and management of this population.

On the other hand, Park (2006) showed that the moratorium in 1986 has been probably effective in protecting and conserving finless porpoises in the Yellow Sea although they also experienced anthropogenic mortality such as bycatch. According to his report, finless porpoises in the Yellow Sea are increasing and recovering after more than 24 years protection. Furthermore, he suggests that it is possible to remove finless porpoises in the Yellow Sea from the list of endangered species in the CITES based on his result.

Several anthropogenic mortalities including bycatch, ship strike and illegal catch affected the survival of minke whales in Korean waters. Among these threats, bycatch was the primary source of mortality for the J stock population, especially set net, pot and gill net (Kim 1999; Kim et al. 2004; Kim 2008; Song et al. 2010). On the other hand, the effect of ship strike and illegal catch on the survival of this population was less than that of bycatch. Although the effect of ship strikes and illegal catch was not so great, ship strike and illegal catch can pose significant potential threats

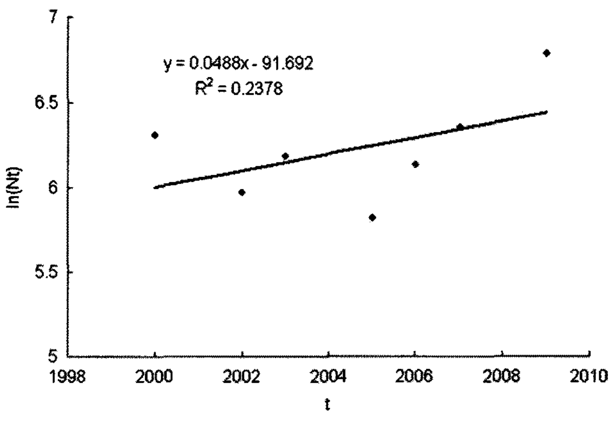

Figure 4. Trend in abundance of minke whales in the East Sea.

to the survival of this population. Therefore, it is necessary to be concerned about these threats as well as bycatch.

A number of studies have reported the amount of bycatch of minke whales in Korean waters (Kim 1999; Kim et al. 2004; Kim 2008). According to these reports, the average number of bycatch was estimated at 93.7 individuals per year between 1996 and 2002 (Kim et al. 2004), and 83.0 individuals per year between 2002 and 2006 (Kim 2008). On the other hand, unfortunately, this population was predicted to decrease and also probably be extinct within the next few decades in view of the range of bycatch in recent years in Korean and Japanese waters (100–150 individuals per year), according to the simulation models (Baker et al. 2000). Thus, it is probably necessary to reduce the amount of bycatch of minke whales in this area for the effective conservation and management of this population.

There were several mitigation measures to reduce bycatch of cetaceans including acoustic alarm attachments, time-area closures and gear modifications (Kraus et al. 1997; Murray et al. 2000). According to the review conducted by Cox et al. (2007), attachment of acoustic alarms (pinger) successfully reduced bycatch of dolphins and porpoises among these mitigation measures (Kraus et al. 1997; Trippel et al. 1999; Gearin et al. 2000; Bordino et al. 2002; Barlow and Cameron 2003). Although there was some progress in reporting the extent of bycatch of minke whales in this area (Kim 1999; Kim et al. 2004; Kim 2008), there was little progress in investigating the efficacy of several mitigation measures on reducing bycatch until now. Thus, it is necessary to investigate the efficacy of several mitigation measures on this population in this area in the future.

However, more accurate data are needed to investigate the status of J stock minke whales because the data on abundance including $g(0)$ and anthropogenic mortality including illegal catch are not enough at present. Actually, several studies reported that there was a high number of illegal, unreported or unregulated catches for this stock (Baker et al. 2006, 2007; Lukoschek et al. 2009). Also, the default value of R_{max} was used to estimate PBR for minke whales in this area because the data on R_{max} were insufficient. Thus, it is necessary to obtain more exact information on abundance, anthropogenic mortality and R_{max} in the future for the accurate estimation of the status of J stock minke whales.

Baker et al. (2000) used simulation models to predict that the population will decline towards extinction. In addition to this study, further study is needed to examine population health and viability for investigating the long-term survival of this population more clearly.

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