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A New Abundance Estimate for the Finless Porpoise *Neophocaena asiaeorientalis* on the West Coast of Korea: An Indication of Population Decline

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Abstract

The west coast of Korea is the largest habitat for finless porpoises, with approximately 36,000 individuals reported in 2005 (Park et al., 2007). To date, there have been no subsequent finless porpoise population estimates. However, in recent bycatches, finless porpoises accounted for the highest proportion of all cetaceans and have been reported to be most frequently caught on the west coast of Korea (Kim et al., 2013). The present study, conducted in 2011, enumerated finless porpoises inhabiting the west coast of Korea using a line transect survey in offshore and inshore regions to assess variations in their abundance. In offshore regions we found the population density of finless porpoises to be 0.122 ind./km^2, whereas it was 0.565 ind./km^2 in 2004. In inshore regions, the population density of finless porpoises was 0.151 ind./km^2, whereas it was 0.638 ind./km^2 in 2005. Therefore, we estimate that the population densities of finless porpoises in both offshore and inshore regions of the west coast of Korea decreased by approximately 70% between 2004/2005 and 2011. It is imperative to mitigate the bycatch of finless porpoises and protective action is urgently needed in the near inshore regions.

Key words: Finless porpoise, *Neophocaena asiaeorientalis*, Abundance, West coast of Korea

Introduction

The finless porpoise *Neophocaena asiaeorientalis* is a small porpoise that inhabits the west, south, and southeast coasts of Korea as well as inshore regions of Japan and the eastern and northern inshore regions of China (Jefferson et al., 2003). The finless porpoise belongs to the Odontoceti family, which is characterized by its lack of a dorsal fin. Recent studies have shown that finless porpoises that populate northern China, Korea, and Japan are a separate species from those inhabiting the region between the coasts of Southern China and Persia (Wang et al., 2008).

In a study of finless porpoises conducted via research vessels from 2000 to 2010, Sohn et al. (2012) reported that porpoises were distributed throughout the west and south coasts of Korea, as well as along the south coast of the East Sea of Korea. Park et al. (2007) also used research vessels to estimate the abundance of finless porpoises on the west coast of Korea, and arrived at an estimate of approximately 36,000 individuals, which was then reported as the largest finless porpoise population. In Japan, Yoshida et al. (1998) conducted an aircraft-operated line transect survey to determine the abundance of finless porpoises inhabiting the west coast of Kyushu. Similarly, Miyashita et al. (1994) investigated the abundance of finless porpoises in eastern Japan, while Kasuya and Kureah (1979) assessed the abundance of finless porpoises in the Japanese Inland Sea. Together, these studies indicated that approximately 10,000 finless porpoises inhabited Japanese

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waters. However, Kasuya et al. (2002) compared these assessments with a line transect survey conducted in 2000 and found a large decline in finless porpoise numbers. However, Kasuya et al.'s results were not derived from a continuous survey, but from separate surveys using different methods.

The bycatch of cetacean species occurs frequently in Korea, and Kim et al. (2013) reported that the finless porpoise is the most frequently bycaught species, particularly along the west coast of Korea. The abundance of finless porpoises has been assessed on the west coast of Korea, but no surveys have been conducted since 2005 (Park et al., 2007). Notably, no studies have been carried out to determine the influence of the mass bycatch of finless porpoises on their abundance along the west coast of Korea.

We assessed the abundance of finless porpoises in the offshore and inshore regions of the west coast of Korea using line transect surveys. We used the same platform and method of study as previous surveys in order to derive accurate estimates of changes in population density and the impact of bycatch.

Materials and Methods

In 2011, we conducted two line-transect surveys for finless porpoises in the offshore and inshore regions (divided by longitude 126° E) of the west coast of Korea. The offshore survey was carried out for 40 days, from April 21 to May 31, using the research vessel Tamgu-3 (360 G/T, stern trawl type) of the National Fisheries Research and Development Institute (NFRDI). The vessel traversed the west coast of Korea between latitude 33°00′ - 37°18′ N and longitude 123°24′ - 126°00′ E, heading northward in the inshore regions and southward in the offshore regions. The speed of the research vessel was maintained at 10-12 knots across a total perimeter of 1,966.75 km and the research area was 98,626.06 km^2 (Table. 1). In a separate study, Kim et al. (2014) reported the seabird distribution on the Yellow Sea based on data collected during this survey cruise.

We installed a barrel on the foremast of the research vessel at a height of 11.5 m above the sea surface. This barrel served as the main observation platform. We used a second location on the top bridge, 8 m from the surface, as an auxiliary observation platform. Visual observations were conducted by eight NFRDI researchers. The line transect survey was performed from 30 min after sunrise until 30 min before sunset, and observations were made with rotations every two hours to limit concentration difficulties and exhaustion. An observer who recognized a finless porpoise set the foremast to 0° to determine the angle and distance between the foremast and the porpoise, and notified the researcher on the auxiliary observation platform to record the observation.

The inshore survey was performed from July 5 - 20, 2011 by the NFRDI R/V *Tamgu-2* (280 G/T) between latitude 35°12′ - 37°20′ N and longitude 125°61′ - 126°00′. The survey was conducted along a survey line designed to move southward over 16 days, assessing a total perimeter of 586.19 km and a survey area of 7,223.16 km^2.

The main observation point was on the upper deck, 4 m above the ocean surface and the auxiliary observation desk was located on the bridge. Visual observation was conducted by four researchers with previous sighting experience. The survey was intended to start 30 minutes after sunrise. However, owing to heavy fog in the morning, the survey began only when the fog had cleared enough to allow accurate sightings and continued until 30 minutes before sunset. Three observers operated from the main observation deck and the other observer recorded any complications due to obstacles or weather that affected the survey, as well as the location, vessel speed, and wave height when finless porpoises were sighted.

The abundance of finless porpoises was assessed by the method of Buckland et al. (1993).

Abundance (N) follows Equation (1) below:

$$N = \frac{n \times f(0) \times \bar{s} \times A}{2 \times L} \quad (1)$$

Here, n = primary sighting, f(0) = probability density function from 0 distance, $\bar{s}\bar{s}$ = group size, A = survey area (km^2), and L = total length of survey effort (km).

This study defined n/L as the detection rate and 1/f(0) as the effective search width (ESW), in which the expected number of finless porpoises detected would be the same as for the actual surveys. The detection probability at distance 0, g(0), should be determined based on sightings from independent observations; however, because independent observations were not made, g(0) was assumed to be 1.

Detection probability modeling is dependent on the perpendicular distance for each line transect survey. We used three types of models (uniform, half-normal and hazard-rate) with three adjustments (cosine, simple polynomial, hermite polynomial; Buckland et al., 2001) and selected the most suitable model based on Akaike's information criterion (Akaike, 1985). Modeling and estimation of parameters, statistics, density, and abundance were performed using the computer program DISTANCE Ver. 6.0 (Thomas et al., 2009). Dispersion increases with the influence of far outliers. Therefore, up to 5% of the primary observations from the farthest distance were truncated for analysis, as shown in Table 2 (Buckland et al., 2001).

We compared the results of surveys conducted offshore in 2004 and inshore in 2005 with measurements of finless porpoise abundance from 2011 (Park et al., 2007). The offshore survey in 2004 was performed using the same research vessel and methods as the offshore survey performed in 2011, and the inshore survey in 2005 was also conducted using the Tamgu-18 (69 G/T) of the NFRDI.

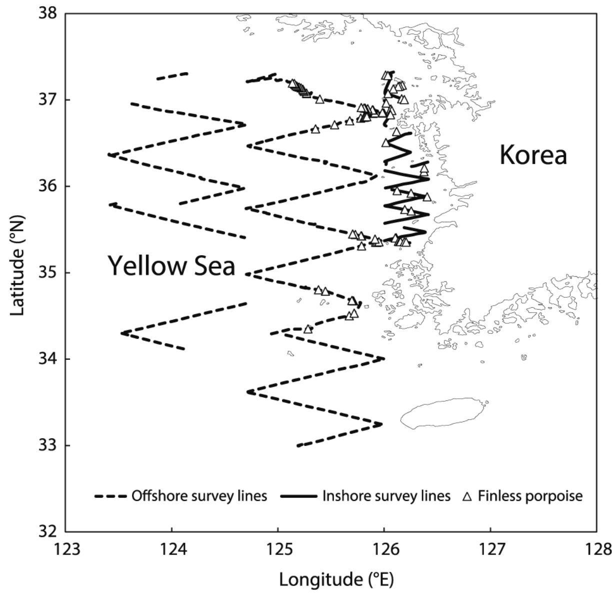

Fig. 1. Completed survey lines and the sighting location (triangles) of finless, *Neophocaena asiaeorientalis*, on the west coast of Korea in 2011.

Results

Sightings and cluster size

Survey details and finless porpoise sightings from the two surveys conducted in 2011 are summarized in Table 1. During the offshore survey, a total of 57 finless porpoises were sighted from a combination of primary and secondary efforts, and the discovery rate was 0.046/km. The average perpendicular distance from an observed finless porpoise to the research vessel was 346.27 m, and the farthest perpendicular distance was 2,037 m. In the inshore survey, a total of 42 individuals were discovered from a combination of primary and secondary efforts, and the discovery rate was 0.107 /km. The average perpendicular distance from an observed finless porpoise to the research vessel was 328.65 m, and the farthest perpendicular distance was 1,111 m (Fig. 1).

Outlier sightings at a far distance from the line transect impose a large variance on the estimation model. Buckland et al. (2001) therefore recommend truncating 5 - 10% of the data from the farthest distance of discovery for analysis. Therefore, we excluded 5% of the observations made from the farthest distances (Table 2). After removing 5% of these data there remained 23 offshore primary sightings at a discovery rate (coefficient of variation) of 0.019 (0.46) /km. There were 24 inshore primary sightings and the discovery rate (coefficient of variation) was 0.041 (0.32) /km, which was approximately twice that of the offshore primary survey.

The mean cluster sizes of the finless porpoises were 1.32 (0.11) and 2.04 (0.20) in the offshore and inshore regions, respectively. However, the cluster size reported in this study used regression results based on the detection function estimated from the models of each type of survey, with the estimated expected cluster size being 1.24 (0.07) in the offshore and 2.16 (0.16) in the inshore regions (Table 2).

Abundance

The frequency distribution according to the perpendicular distance of the offshore survey samples is shown in Fig. 2a and that of the inshore survey sample is shown in Fig. 2b. Frequency distributions were divided into six to seven sections according to the number of samples and distance. The frequency of discovery was highest near the survey line with a declining trend with respect to distance, which represented a typical frequency distribution for distance sampling.

The AIC values of the half-normal model, uniform model, and hazard-rate model that were applied to each survey sample are shown in Table 3. In the offshore survey, the AIC value of the hazard-rate model had the lowest estimated value (432.79), and in the inshore survey, the AIC value of the uniform model had the lowest estimated value (292.41). Therefore, we selected the hazard-rate model for the offshore survey

Table 1. Summary of the survey and sightings (including both primary and secondary sightings for the finless porpoise, *Neophocaena asiaeorientalis*, on the west coast of Korea. The standard deviation is provided in parentheses. The encounter rate is in clusters for each km.

Survey	Survey area (km^2)	Survey distance (km)	Observations (Primary)	Perpendicular distance (m)		Sighting rate (n/km)
				Mean	Max.	
Offshore	98,626.06	1,966.75	57 (40)	346.27 (321.50)	2,037	0.046
Inshore	7,223.16	586.19	42 (25)	328.65 (204.15)	1,111	0.107

Table 2. Sighting data after the truncation of 5% of the primary observations and the estimated expected cluster size. The coefficient of variation is shown in parentheses. R = correlation coefficient, p = p-value from a t-test of the regression estimates of log cluster-size against the detection function

Survey	Sightings (5% truncated)	Sighting rate (n/km)	Mean cluster size	Estimated expected cluster size
Offshore	38	0.019 (0.46)	1.32 (0.11)	1.24 (0.07)
Inshore	24	0.041 (0.32)	2.04 (0.20)	2.16 (0.16)

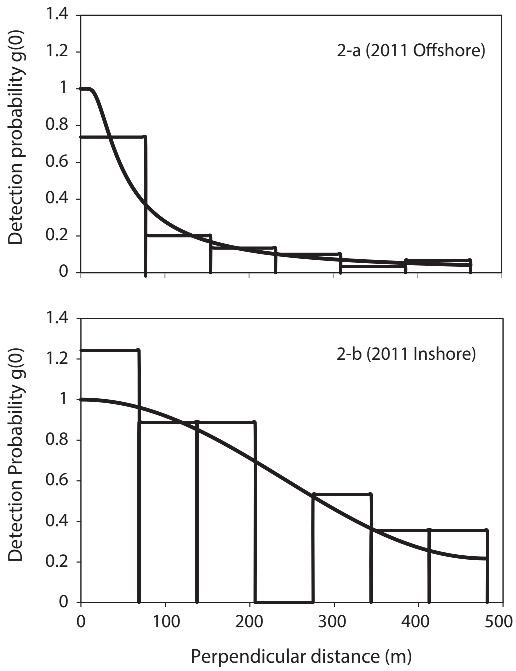

Fig. 2. Histogram of the perpendicular distance and fitted detection function for the best Akaike's information criterion (AIC) selected model of the offshore survey in 2011 (2-a) and the inshore survey in 2011 (2-b).

and the uniform model for the inshore survey. The variations in discovery rates estimated for each of the surveys according to each model are shown in Fig. 2. The discovery rate during the offshore survey declined rapidly with distance, whereas there was a more gradual change during the inshore survey. The estimated ESW value was 98.28 m for the offshore survey and more than twice that for the inshore survey (228.45 m) (Table 3).

The f(0) [probability detection function from distance at 0 (PDF) = $\frac{1}{\mathrm{ESW}}$] and detection rate (P) within the detection distance are shown in Table 3. The f(0) estimated for the offshore survey had the highest value of 0.010 and that for the inshore survey was 0.003. The f(0) was 6.71 for the 2005 survey, 4.20 for the 2006 survey, 2.56 for the 2000 survey, and 2.53 for the 2002 survey. The P value was 0.608 for the inshore survey, which was higher than that for the offshore survey (0.212).

The density, abundance, and coefficients of variation estimated using the models selected for each survey are shown in Table 4. In the offshore survey, the density was 0.122 /km^2 (95% CI: 0.042-0.359) and the coefficient of variation was 0.577. The abundance of finless porpoises was estimated to be 12,052 (95% CI: 4,099-35,437) in the offshore region. The density in the inshore survey was 0.151 /km^2 (95% CI: 0.072-0.316), which was higher than that in the offshore survey, and the coefficient of variation was 0.379, which was lower than that of the offshore survey. The abundance of finless porpoises in the inshore regions was estimated to be 1,092 (95% CI: 523-2,281).

Discussion

The survey distance and results of the 2004 offshore and 2005 inshore surveys, as well as the survey distance and results of the 2011 surveys, are shown in Table 5. The survey area, survey distance, and discovery rate of the 2004 offshore survey were all greater than those of the 2011 inshore survey. The discovery rate (0.214 pod/km) in the offshore survey was

Table 3. Parameter estimates of each model used to fit the perpendicular distance data for finless porpoise, *Neophocaena asiaeorientalis*, sightings. AIC = Akaike information criterion, GOF = goodness of fit, ESW = effective strip width. f(0) = probability density function at zero. P = detection probability

Survey	Model	AIC	GOF	ESW(m)	f(0)	P
Offshore	Half-normal	438.10	0.266	151.26	0.007	0.327
	Uniform	439.85	0.198	157.58	0.006	0.340
	Hazard-rate	432.79	0.859	98.28	0.010	0.212
Inshore	Half-normal	292.95	0.345	294.76	0.003	0.613
	Uniform	292.41	0.364	292.76	0.003	0.608
	Hazard-rate	293.38	0.283	228.45	0.004	0.475

Table 4. Estimates of finless porpoise, *Neophocaena asiaeorientalis*, numbers along the west coast in 2011. D = individuals/km^2. N = abundance, CV = coefficient variance, CI = confidence interval

Survey	Parameter	Estimate	CV	95% CI	
				Lower	Upper
Offshore	D	0.122	0.577	0.042	0.359
	N	12,052		4,099	35,437
Inshore	D	0.151	0.379	0.072	0.316
	N	1,092		523	2,281

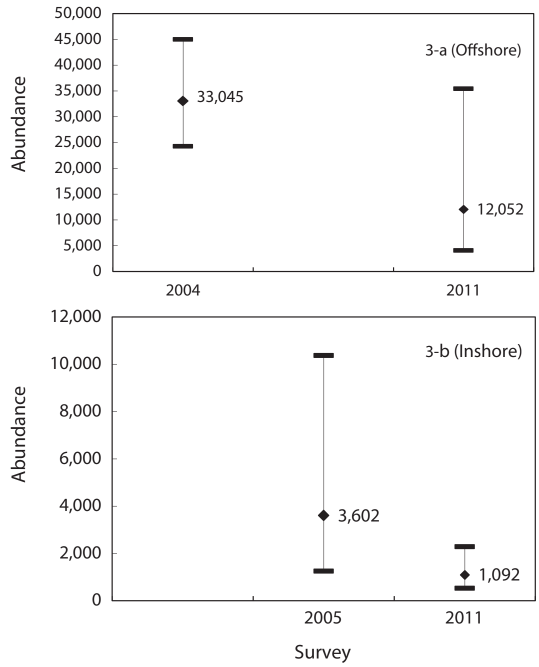

Fig 3. Comparison of the abundance estimates of finless porpoise, *Neophocaena asiaeorientalis*, in 2004 and 2005 (Park et al., 2007) with the estimates in 2011.

11-fold higher than that in the 2011 inshore survey (0.019 pod/km). The finless porpoise density offshore in 2004 was 0.565 ind./km^2, but this value had decreased by 78% in 2011 to 0.122 ind./km^2. The inshore survey area and distance were higher in the 2011 survey than in the 2005 survey, but the discovery rate in 2005 was 0.060 pod/km, which was higher than the discovery rate of 0.041 pod/km in 2011. The finless porpoise density in the inshore region was 0.638 ind./km^2 in 2005, whereas in 2011 this value was 0.151 ind./km^2, a decrease of 76%. Therefore, finless porpoise density declined by approximately 70% in the offshore and inshore regions of the west coast of Korea between 2004 and 2011.

By extrapolating the estimated densities over each survey area, we estimated the number of finless porpoises in offshore regions to be 33,045 in 2004 and 12,052 in 2011. In inshore regions we estimated the number of finless porpoises to be 3,602 in 2005 and 1,092 in 2011 (Fig. 3).

Based on our results, we estimated that the abundance of finless porpoises along the west coast of Korea declined by more than 70% from 2004 to 2011. The extent of the decline was similar in offshore and inshore regions (78% offshore and 76% inshore). However, considering that the area surveyed offshore in 2011 was smaller than that surveyed in 2004, and that the area surveyed inshore was larger in 2011 than 2005, the ratios of reduction for the offshore and inshore regions are similar.

The capture of all cetacean species, including the finless porpoise, is banned in Korea. However, bycatch of cetacean species related to stranding and fishing gear occurs frequently in the inshore regions. To address this issue, Korea enacted the "Notice of conservation and management of cetacean resources" in January 2011 to systematically regulate bycaught and stranded cetacean species. Before enactment of the notice, several incidents involving bycatch activities and the stranding of small cetacean species, including the finless porpoise, in the inshore regions were left unrecorded. However, since the stable implementation of the notice, reports from inshore regions have been collected systematically. Through this system, Kim et al. (2013) counted a total of 2,107 finless porpoises bycaught in Korean inshore regions in 2012 and found that most of the bycatching took place along the western coast of Korea.

Kasuya et al. (2002) reported a decline in the abundance of finless porpoises in the Inland Sea due to bycatching using fishing gear, a decline in available food due to the fishery industry, deterioration of habitat, and the influx of chemicals and organic compounds into the sea. Similar issues are likely to affect the western coast of Korea, but the primary impact on finless porpoise numbers is thought to be bycatch. In 2012, 2,000 finless porpoises were identified in bycatch, which accounted for 5.5% of the estimated finless porpoise population in 2004 and 2005. Reilly and Barlow (1986) estimated the rate of population increase for cetaceans to be approximately 4%, but rate of death due to bycatching is exceeding the rate of increase. Furthermore, bycatch deaths among finless porpoises off the west coast of Korea accounted for 15.2% of the total population in 2011. The large decline (over 70%) in the abundance of finless porpoises along the west coast of Korea during the 6 years between surveys is most likely due to either a decline in the reported 4% rate of increase in the finless porpoise population or a higher net mortality due to bycatch than that reported in 2000.

Table 5. Summary of survey results and density comparisons between 2004-2005 and 2011 on the west coast of Korea

Survey	Year	Survey area (km^2)	survey effort (km)	Sighting rate (pod/km)	Density (ind./km^2)	Decline level (%)
Offshore	2004	116,870.5	3,331.2	0.214	0.565	
	2011	98,626.06	1,966.75	0.019	0.122	78
Inshore	2005	5,642.2	446.7	0.060	0.638	
	2011	7,223.2	586.2	0.041	0.151	76

Bycatch reports have increased since the implementation of the effective management system, but it is assumed that there are still bycatch activities that do not get reported for two main reasons. First, each finless porpoise caught in a fishing net costs approximately $100 (100,000 Wons). Therefore, the dead porpoise can be discarded because it has no significant value. Second, the bycatch of finless porpoises is usually reported only in large harbors, with deaths in smaller ports seldom reported (Kim et al., 2013). Therefore, it is likely that the impact of the bycatch of finless porpoises on its population is underestimated.

Park et al. (2007) reported that finless porpoise population density is higher inshore compared with offshore, which is consistent with the results of the present study. This observation indicates that the finless porpoise is more widely distributed in inshore than offshore regions. However, the finless porpoise is more likely to inhabit more inshore regions than our results suggest because a large number of finless porpoises were discovered near the shore or around islands not designated as survey lines during the surveys. These findings were categorized as secondary sightings and accordingly the number of finless porpoise pods discovered, including those reported in Table 1, were 57 and 42 in the offshore and inshore regions, respectively, although the primary sightings used in the analysis were less than half of these numbers. It is therefore likely that we underestimated finless porpoise population numbers. To cover shallow waters and nearshore areas, future studies should adopt other survey platforms, such as airplanes, that are better-suited for assessing these regions.

In order to conserve the finless porpoise, it is essential to reduce bycatch. Protective action is urgently required in the near inshore regions. Failure to reduce the bycatch of finless porpoises will lead to their continued decline and possibly to the local extinction of the finless porpoise along the west coast of Korea.

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