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Finless porpoise bycatch in Ariake Sound and Tachibana Bay, Japan

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ABSTRACT: Bycatch of narrow-ridged finless porpoises *Neophocaena asiaeorientalis* in gillnets was estimated for the Ariake Sound/Tachibana Bay population in Japan using interview-based surveys. In 2007 and 2008, the minimum number (actual number reported by all interviewees) of bycatch was 31 to 35 individuals (ind.) yr^{-1}. The number of interviewees was 131 to 136 in each year. The bycatch estimate was 238 (95% CI 123 to 353) to 270 (95% CI 148 to 391) ind. yr^{-1}. The estimate exceeded the potential biological removal level of this population, 27 ind., which was calculated on the basis of a published abundance estimate. The bycatch estimate accounted for 8% of the abundance. The bycatch rate was 0.237 ind. $gillnetter^{-1}$ yr^{-1} in 2007 and 0.257 ind. $gillnetter^{-1}$ yr^{-1} in 2008. Additional analysis of information on bycatch in the bottom-set gillnet fisheries collected from 1987 to 1992 suggested an increase in bycatch during fall and winter seasons, the possible existence of a calving ground, and age–sex related habitat use patterns. Neonates were found in a restricted area, whereas nursing calves and possible calves were seen in a wide range of waters, implying outward movement of mother–calf pairs from a calving ground. Neither neonates nor nursing calves were captured in waters deeper than 30 m.

KEY WORDS: Narrow-ridged finless porpoise · *Neophocaena asiaeorientalis* · Gillnets · Habitat use · Ariake Sound/Tachibana Bay population · Japan

INTRODUCTION

Declines in large marine vertebrates such as sea turtles, seabirds and marine mammals have focused attention on the ecological impacts of bycatch in global fisheries (Lewison et al. 2004). The global bycatch of cetaceans is estimated to be >300 000 animals per year (Read et al. 2006). Bycatch has been implicated as being an important factor in the decline of freshwater and coastal species such as baiji *Lipotes vexillifer* and vaquita *Phocoena sinus* (D'Agrosa et al. 2000, Turvey et al. 2007).

Indo-Pacific finless porpoises *Neophocaena phocaenoides* and narrow-ridged finless porpoises *N. asiaeorientalis* are distributed in shallow coastal waters and some rivers in the Indo-Pacific region (Reeves & Wang 2012, Wang & Reeves 2012). *N. phocaenoides* occurs along a narrow strip of coastal waters from the Persian Gulf eastwards to the Indo-Malay region and to Java and Indonesia and northwards to the Taiwan Strait and central Chinese waters. *N. asiaeorientalis* inhabits the temperate coastal waters of northern China, Korea and Japan and the Yangtze River. Both species are affected by bycatch, vessel strikes, habitat loss and degradation and are considered vulnerable species (Reeves et al. 1997, Kasuya et al. 2002, Jefferson et al. 2008, Reeves & Wang 2012, Wang & Reeves 2012). In Japanese waters, incidental catch takes place in all 5 recognized populations of *N. asiaeorientalis* (Yoshida et al. 2001, Kasuya et al. 2002; see also Marine Mammals Information Database, National Museum of Nature and Science, Tokyo, available at http://svrsh1.kahaku.go.jp/marmam/index_e.html; and stranding records from the Institute of Cetacean Research, Tokyo, available at www.icrwhale.org/zasho.html). The southernmost population of the porpoises

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in Japan inhabits the waters of Ariake Sound and Tachibana Bay (see Fig. 1). This population, whose size in 1993/1994 was estimated at 3093 individuals (Yoshida et al. 1997), suffers mortalities in bottom-set and drift gillnets (M. Shirakihara et al. 1993, 2008). To clarify the magnitude of bycatch in gillnet fisheries for this population, we conducted interview-based surveys among fishermen in 2007 and 2008. An interview-based survey is one approach to assess the incidental capture of marine megafauna (Van Waerebeek et al. 1997, D'Agrosa et al. 2000, López et al. 2003, Moore et al. 2010, Mancini et al. 2012). Additionally, to infer the habitat use patterns of the porpoises, we analyzed data on the spatial distribution of individuals accidentally captured from 1987 to 1992.

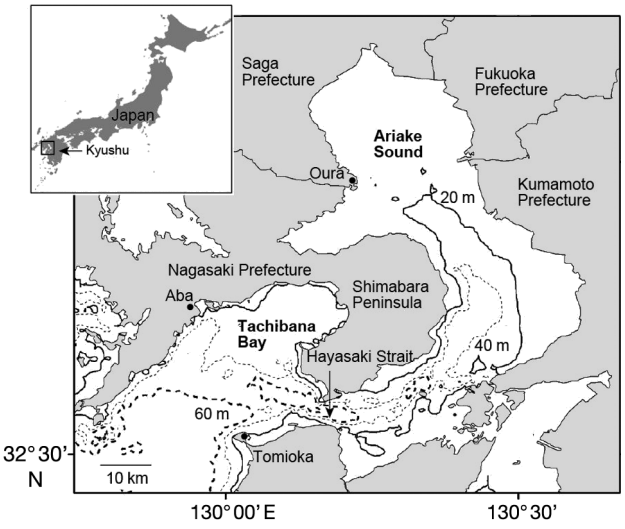

Fig. 1. Study area. The interview-based surveys were conducted at fishing ports in Kumamoto, Nagasaki, Saga and Fukuoka, from Aba to Tomioka in 2007 and 2008. Data on the characteristics of the fisheries involved in the porpoise bycatch were collected along the coast of Nagasaki and Saga, from Aba to Oura in 1987 to 1992

MATERIALS AND METHODS

Bycatch estimation from interview-based surveys in 2007 and 2008

Ariake Sound and Tachibana Bay are located in western Kyushu, Japan (Fig. 1). The Sound is divided into 3 areas on the basis of bio-geographic features (Sato & Takita 2001): the inner area, the central area and the mouth including Hayasaki Strait. Tachibana Bay is a transition area between the sound and the open sea. Hundreds of fishermen work in the sound and the bay using bottom-set and drift gillnets. The fisheries are legal, and are conducted with permission of the prefectural governors. Fishermen are well acquainted with *Neophocaena asiaeorientalis*, and can distinguish them from other small cetaceans (K. Shirakihara et al. 1992).

Interviews were conducted during 10 d in October 2007 in Kumamoto and Nagasaki prefectures and during 12 d in October and November 2008 in Kumamoto, Nagasaki, Saga and Fukuoka. The following questions were asked: (1) Have you captured the porpoises unintentionally over the past 1 yr? (2) If so, how many? The number of gillnetters working from each fishing port was obtained from the fisheries cooperative association offices or interviewees. Data were divided into 3 prefecture categories: Kumamoto, Nagasaki and Saga/Fukuoka. Bycatch in numbers in a prefecture category i, $\hat{B}_i$, was estimated by:

$$\hat{B}_i = \bar{b}_i \times N_i \quad (1)$$

where $\bar{b}$ is the mean number of bycaught individuals per interviewed gillnetter during the past year and N is the number of gillnetters. Variance of $\bar{b}$ was adjusted using finite population correction. Variance of the bycatch estimate was given by:

$$V(\hat{B}_i) = \left[\sum_j (b_{ij} - \bar{b}_i)^2 / (n_i - 1) / n_i^2\right] \times N_i^2 \times [(N_i - n_i) / (N_i - n_i)] \quad (2)$$

where j is an interviewed gillnetter and n is the number of interviewed gillnetters. Bycatch in the past year and its variance were estimated according to:

$$\hat{B} = \sum_{i=1}^{3} \hat{B}_i \quad (3)$$

$$V(\hat{B}) = \sum_{i=1}^{3} V(\hat{B}_i) \quad (4)$$

The 95% confidence interval (CI) was given by:

$$\hat{B} \pm 1.96\sqrt{V(\hat{B})} \quad (5)$$

Impact of bycatch on the population

To assess the impact of bycatch on this population, the potential biological removal (PBR) (Wade 1998), was calculated. The PBR was calculated according to $N_{min} \times 1/2\ R_{max} \times F_r$, where N_{min} is the minimum population estimate, R_{max} is the maximum net productivity rate and F_r is a recovery factor. Following Wade (1998), N_{min} was the lower 20th percentile of a log-normally distributed abundance estimate, R_{max} was 0.04 (default value for cetaceans) and F_r was 0.5 (default value).

Bycatch data collected in 1987 to 1992

Data on the characteristics of the fisheries involved in the bycatch along the coast of Nagasaki and Saga (Fig. 1) were collected during a survey for the studies of life history and food habits of the porpoises in 1987 to 1992. Entangled individuals were provided by fishermen as biological specimens (M. Shirakihara et al. 1993, 2008). The data included the type of gear used, net length/height, mesh size, distance from shore and depth at the location of net setting, the time of net setting and retrieving, target fish species, fish species caught, months when the net was used and months when the fishermen sighted the porpoises. Porpoises were categorized as follows: neonate, aged 0 yr, with invisible or very thin postnatal dentine and milk in the stomach; nursing calf, 0 yr < age ≤1 yr, with milk in the stomach; and possible calf, aged < 1 yr, an individual for which milk could not be verified in the stomach. Other specimens were categorized as immature individuals ≥1 yr old, sexually mature females and sexually mature males. Age and sexual maturity followed M. Shirakihara et al. (1993). The location of net setting (i.e. location of bycatch) was mapped as the homeport of the fishermen.

RESULTS

Estimates of bycatch for 2007 and 2008

We visited 102 fishing ports in Kumamoto, Nagasaki, Saga and Fukuoka, from Aba to Tomioka (Fig. 1). A total of 868 fishermen worked in the survey areas in 2007 and 2008. Approximately 15% of them (131 in 2007 and 136 in 2008) were interviewed. A total of 42 (19 in 2007 and 23 in 2008) reported porpoise *Neophocaena asiaeorientalis* bycatch. The number of entangled individuals per fisherman per year ranged from 0 to 5. Incidental capture was mainly reported in the central area and the mouth of Ariake Sound and in the eastern area of Tachibana Bay (Fig. 2). Total bycatch reported by the interviewees was 31 ind. in 2007 and 35 in 2008 (Table 1). Bycatch estimates for the entire gillnetter fleet were 238 ind. (95% CI: 123 to 353) in 2007 and 270 ind. (95% CI: 148 to 391) in 2008. Bycatch estimates by prefecture

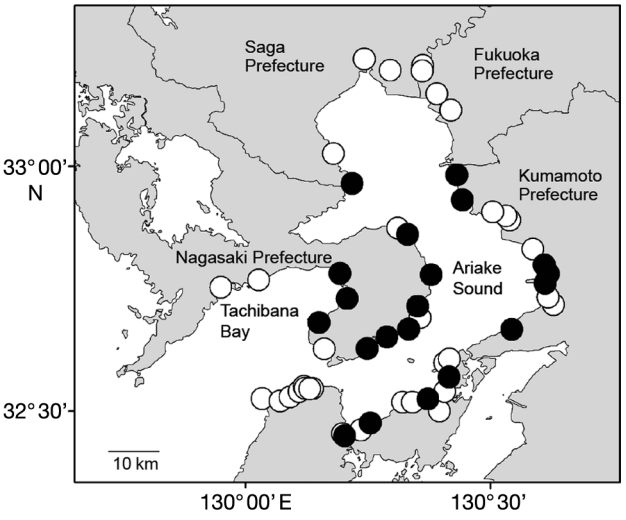

Fig. 2. Locations of the fishing ports where interview surveys were conducted in 2007 and 2008. White and black circles show the fishing ports where bycatch of *Neophocaena asiaeorientalis* was not reported and reported, respectively

Table 1. Estimation of number of bycaught individuals of *Neophocaena asiaeorientalis* in Ariake Sound and Tachibana Bay, Japan. K: Kumamoto Prefecture; N: Nagasaki Prefecture; S/F: Saga and Fukuoka Prefectures

	2007				2008				2007/2008			
	K	N	S/F[a]	All	K	N	S/F	All	K	N	S/F	All
Total bycatch reported by the interviewees	26	5	–	31	13	12	10	35	39	17	10	66
Total no. of interviewed gillnetters	85	46	–	131	76	34	26	136	161	80	26	267
Total no. of gillnetters	260	274	334	868	260	274	334	868	260	274	334	868
Bycatch estimate	79.5	29.7	128[a]	238	44.5	96.7	128	270	63.0	58.2	128	250
Bycatch estimate CV(%)	24.2	39.0	41.8[a]	24.5	31.1	27.2	41.8	22.8	14.4	20.8	41.8	22.3
Mean (SE) annual no. of bycaught ind. per gillnetter	0.306 (0.0741)	0.109 (0.0424)	– –	0.237 (0.0564)	0.171 (0.0533)	0.353 (0.0960)	0.385 (0.161)	0.257 (0.0498)	0.242 (0.0348)	0.213 (0.0442)	0.385 (0.161)	0.247 (0.0339)

[a]An estimate of number of bycaught individuals in S/F in 2008 was used in the estimation of the total number of bycaught individuals in 2007 and in both years

categories were follows: Kumamoto, 80 ind. (95% CI: 41 to 118) in 2007 and 45 ind. (95% CI: 17 to 72) in 2008; Nagasaki, 30 ind. (95% CI: 6 to 53) in 2007 and 97 ind. (95% CI: 43 to 150) in 2008; and Saga-Fukuoka, 128 ind. (95% CI: 18 to 239) in 2008.

Mean annual number of bycaught individuals per gillnetter was 0.247 and did not differ significantly among the 3 prefecture categories (Kruskal-Wallis: df = 2, χ^2 = 5.32, p = 0.0699). Thus, a fisherman caught 1 porpoise every 4 yr on average.

Table 2. Gillnet operations accompanied by bycatch of *Neophocaena asiaeorientalis*

	Bottom-set gillnet					Drift gillnet				
	n	Mean	SD	Min.	Max.	n	Mean	SD	Min.	Max.
Net length (m)	32	770	480	100	1880	5	450	270	150	750
Net height (m)	34	2.7	1.3	1	6	6	6.3	3.1	1.5	10
Mesh size (cm)	25	11	2.7	5.5	17	6	14	2.9	8	16
Soak time (h)[a]	34	19	15	0.5	51	9	2.4	2.6	1	9
No. of months[b]	38	7.2	3.2	2	12	6	5.0	2.3	2	9
Distance from shore (km)[c]	11	0.6	0.5	0.1	1.5	8	2	1.3	0.4	4
Depth (m)[c]	10	5.6	3.8	1.5	15	8	10	6.1	5	24

[a]Time from setting to retrieving the net
[b]Number of months in which the net was used
[c]In the inner part of Ariake Sound, where water depth is <20 m (see Fig. 1)

PBR

The PBR value of this population was calculated as 27 ind. The bycatch estimates, 238 ind. (95% CI: 123 to 353) in 2007 and 270 ind. (95% CI: 148 to 391) in 2008, exceeded the PBR, even when only the minimum number is considered (total bycatch reported by the interviewees).

Gear descriptions and spatial distribution of the bycaught individuals from 1987 to 1992

Analysis of the data obtained in 1987 to 1992 revealed that 20% of the bottom-set gillnet users used their nets throughout the year. In contrast, drift gillnet fisheries were mainly active in spring and fall. A total of 67 entangled porpoises was collected: 49 were captured in bottom-set gillnets, 12 in drift gillnets, 5 in small-set nets, and 1 in a net of unknown type. Immature individuals <1 yr old accounted for about half of the specimens. Bastard halibut *Paralichthys olivaceus*, right-eye flounder (Pleuronectidae), red seabream *Pagrus major* and swimming crab *Portunus trituberculatus* were the main targets of the bottom-set gillnet fishery. Japanese seabass *Lateolabrax japonicus* was the main target species of the drift gillnets. Table 2 shows net dimensions, soaking time and duration of use of the nets in which the porpoises were bycaught. Entanglements occurred in nets of various sizes. Mean soak time of bottom-set gillnets was more than half a day, whereas the drift gillnets were used for a few hours. Differences in net length, net height, mesh size and soak time of bottom-set gillnets were not detected between seasons (Kruskal-Wallis: $p > 0.05$).

Bottom-set gillnetters sighted the porpoises during almost all seasons, with a small peak in fall (Fig. 3A).

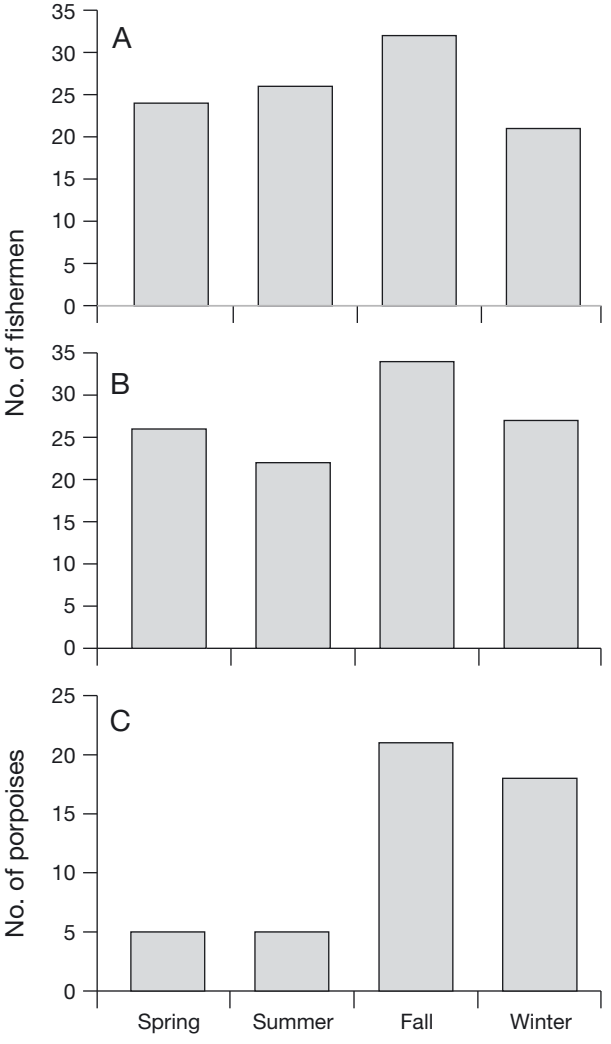

Fig. 3. Number of fishermen by season that (A) sighted *Neophocaena asiaeorientalis* at sea and (B) used bottom-set gillnets, and (C) the number of bycaught individuals by season in bottom-set gillnets in 1987 to 1992

The number of bottom-set gillnetters was also slightly higher in fall (Fig. 3B). Porpoise entanglement in bottom-set gillnets occurred mainly in fall and winter (Fig. 3C). Locations of bycatch in bottom-set gillnets are shown in Fig. 4. Neonates were taken in the inner and central areas of Ariake Sound, whereas nursing calves and possible calves were captured in wide areas including the mouth of the sound and in Tachibana Bay. No sexually mature males were caught in the inner area of Ariake Sound. All individuals were captured in waters ≤5 km from shore and ≤60 m in depth (Fig. 5). Most individuals were captured in waters ≤2 km from shore. All neonates and nursing calves were captured in waters ≤30 m. Three-fourths (9 of 12) of the possible calves, most of which were smaller than 110 cm in body length were also found in waters ≤30 m. In contrast, about half the total (6 of 13) immature individuals ≥1 yr and sexually mature males were caught in waters >30 m deep. Among sexually mature females, a lactating female was found in >30 m and 2 pregnant and simultaneously lactating females were caught in waters ≤30 m deep.

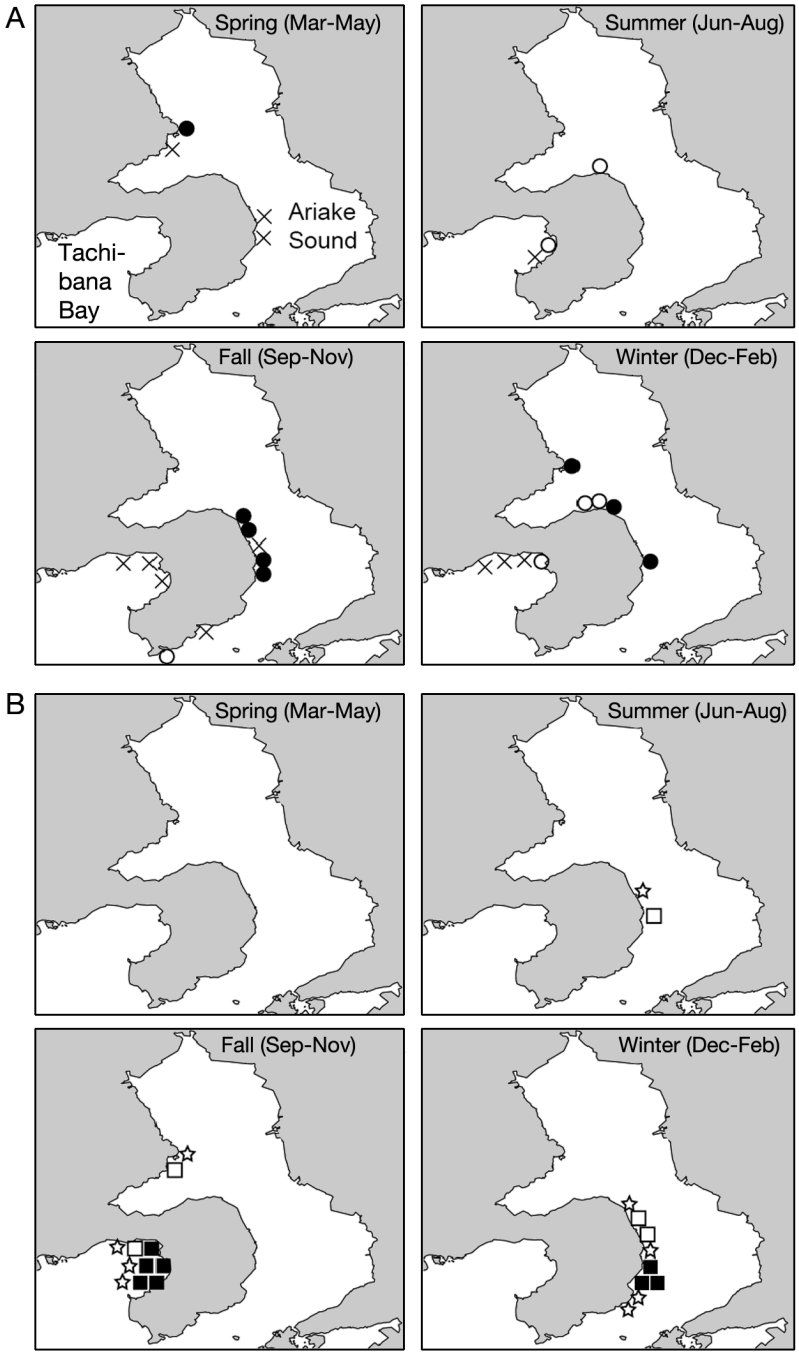

Fig. 4. Locations of *Neophocaena asiaeorientalis* bycatch in bottom-set gillnets in 1987 to 1992. (A) ●, neonate; ○, nursing calf; ×, possible calf. (B) ☆, immature individual ≥1 yr; □, sexually mature female; ■, sexually mature male

A total of 12 individuals were accidentally captured in drift gillnets: 1 nursing calf, 2 possible calves, 7 immature individuals ≥1 yr and 2 sexually mature males. Immature individuals ≥1 yr accounted for 58% of the total, while neonate and sexually mature females were not captured in drift gillnets. Two sexually mature males were captured in central Ariake Sound and Tachibana Bay (Fig. 6). The distance from shore and depth at the location of the drift gillnet setting were greater than those for the bottom-set gillnet in the inner part of Ariake Sound (Table 2).

DISCUSSION

This study is the first attempt to estimate the accidental catch of *Neophocaena asiaeorientalis* in gillnet fisheries in the waters of Ariake Sound and Tachibana Bay, Japan. We used an interview survey as a feasible method of gathering bycatch data because fishermen are able to recognize the porpoises and distinguish them from other small cetaceans. We believe that the minimum numbers of bycatch reported (31 ind. in 2007 and 35 ind. in 2008) are credible. A total of 42 people reported bycatch occurrence in the pres-

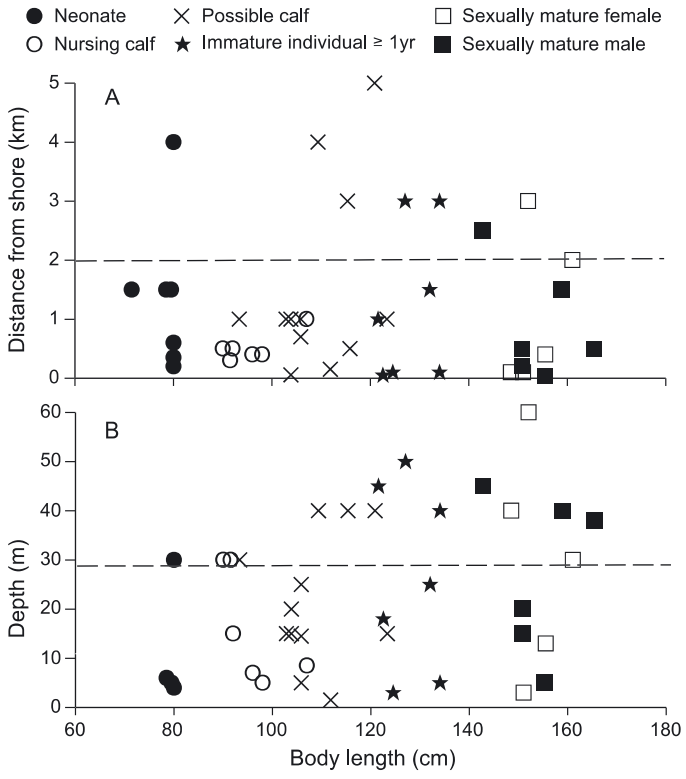

Fig. 5. (A) Distance from shore and (B) depth of locations where *Neophocaena asiaeorientalis* were bycaught in 1987 to 1992

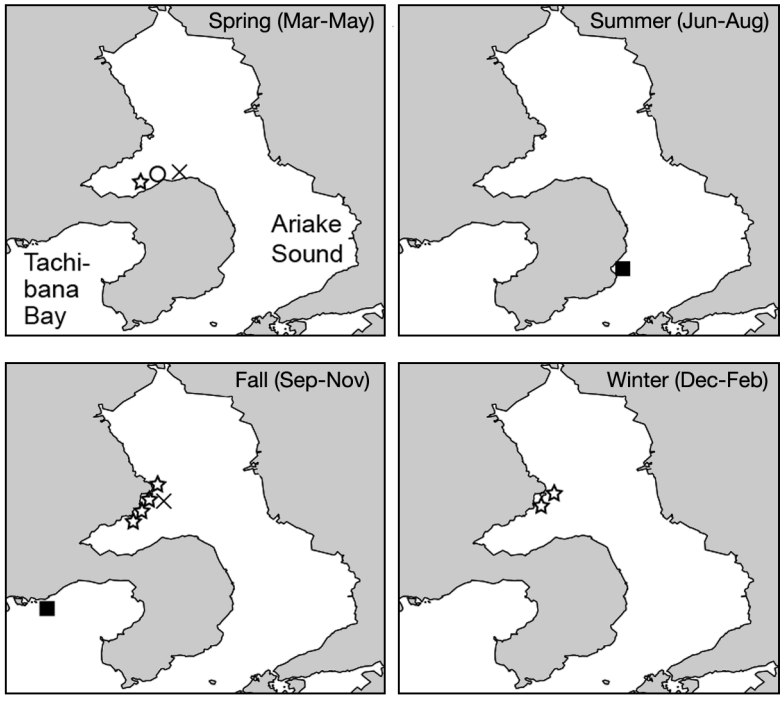

Fig. 6. Locations where bycaught individuals of *Neophocaena asiaeorientalis* in drift gillnets were reported in 1987 to 1992. Symbols as in Fig. 4

ent study. To receive answers from fishermen without disturbing their work, we reduced the number of questions and answer choices. Most fishermen replied earnestly to our questions. However, there may be memory-related errors. The fishermen we interviewed may not represent all fishermen in the areas, because we interviewed fishermen who happened to be at a fishing port when we visited. Individual fishermen used gillnets in flexible and different ways. Some used their nets to obtain marine products for private use, others for commercial purposes. If the fishermen we interviewed were biased as to being more active (or less active) workers, bycatch estimates could be overestimated (or underestimated). The bycatch estimate (238 ind., 95% CI 123 to 353 in 2007; and 270 ind., 95% CI 148 to 391 in 2008) greatly exceeded the PBR for this population (27 ind.) and accounted for about 8% of the published abundance for this population (Yoshida et al. 1997). Although this abundance was determined by aerial sighting surveys using a Cessna about 20 yr ago, no significant difference was detected between this estimate and the latest one obtained in 2000 (K. Shirakihara unpubl. data). Even if the detection probability at zero distance $g(0)$ is estimated to be 0.65 (an estimate from helicopter sighting surveys by Jefferson et al. 2002) instead of 1, the modified PBR would still only be 42 ind. Thus, bycatch estimates would still be > 5 times higher than the modified PBR. The minimum bycatch (31 to 35 ind.) is close to the modified PBR. Incidental takes of porpoises also occurred in set nets, trawl nets and floating nets for *Porphyra* culture (M. Shirakihara et al. 1993, M. Shirakihara unpubl. data). The impacts of these fisheries on the porpoise population are unknown and require further research, but bycatch mitigation measures are required for conservation of the population.

The porpoises were mainly accidentally captured in bottom-set gillnets from fall to winter, though fishing efforts did not seem to change considerably between seasons. This trend is consistent with previous findings. Mizue et al. (1965) reported that porpoises were landed at a fish market from fall through winter in Tachibana Bay. Many porpoises were captured in small set nets in fall. Bycatch during these sea-

sons may be related to changes in density or behaviors. Seasonal changes in density of the genus *Neophocaena* have been described in various waters (Kasuya & Kureha 1979, Jefferson et al. 2002, Taguchi et al. 2007, Akamatsu et al. 2008, 2010, Kondo et al. 2010, Kimura et al. 2012). The peak of the calving season in the Ariake Sound/Tachibana Bay population has been determined to occur in fall and winter (M. Shirakihara et al. 2008). Breeding is also likely to occur at that time, as the gestation period of the species is estimated to last 11 mo (Kasuya & Kureha 1979). During these seasons the ratio of the numbers of fishes in stomach contents of the porpoises in the Ariake Sound/Tachibana Bay population was larger than that in spring and summer seasons (M. Shirakihara et al. 2008). Behaviors such as reproduction or foraging may be related to the increase in bycatch in fall and winter. It has been hypothesized that porpoises approach the coast to chase fishes and are accidentally captured in small set nets (Mizue et al. 1965).

In specimens provided by fishermen, the number of lactating females was less than the number of neonate and nursing calves. Though some fishermen captured 2 porpoises simultaneously in a net and brought them to shore, there may be other cases of larger individuals abandoned at sea.

Analysis of the spatial distribution and age of entangled porpoises suggests the possibility of a calving ground and of age-sex-related habitat-use patterns, as described in other Phocoenoides (Yoshioka et al. 1990, Amano & Kuramochi 1992, Sonntag et al. 1999). Entanglement of neonates occurred in relatively limited areas of Ariake Sound. Observations of nursing calves and possible calves in wider areas may be related to the movements of mother–calf pairs, as suggested by Kasuya & Kureha (1979). No neonate was captured in drift gillnet sets in deeper waters or in places that are distant from the shore in the inner area of Ariake Sound. This observation indicates the existence of a calving ground, though the sample size was small. Mother–calf pairs seemed to prefer shallow waters ≤30 m and may move from Ariake Sound to Tachibana Bay through the near-shore waters along the coast of the Shimabara Peninsula where the isobathic line of 30 m is close to the land (Fig. 1).

To determine the habitat-use patterns of porpoises, the bycatch numbers of lactating females, the age–sex composition of bycaught individuals and the total numbers of bycatch, a systematic method for the collection of porpoise bycatch is needed for Ariake Sound and Tachibana Bay.

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