Bycatch of the Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) in gillnet fisheries off Amakusa-Shimoshima Island, Japan

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ABSTRACT

A year-round resident population of the Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) inhabits the waters off Amakusa-Shimoshima Island (32°25′N, 130°05′E), in Japan. The effect of bycatch in gillnet fisheries on the Amakusa population was examined. Population size in 2007 and 2008 was estimated at 230 individuals (CV = 2.5%) and 216 individuals (CV = 2.1%), respectively, based on a mark-recapture technique. The magnitude of bycatch was evaluated by analysing interview surveys (263 gillnetters) during these two years. Minimum numbers of dolphin bycatch were 12 individuals in 2007 and 14 individuals in 2008. Most of the dolphins, which were captured by bottom-set gillnets, were considered to be Indo-Pacific bottlenose dolphins for the following reasons: (1) two individuals were identified based on DNA analysis; (2) only *Tursiops* sp. and finless porpoises were found in the sighting survey by ferry boats, and fishermen can distinguish between the two; and (3) the seasonal and spatial distribution of bycatch corresponded well to habitat use patterns of the Amakusa population. If the US potential biological removal (PBR) approach is used it estimates two individuals per year, which is much lower than the minimum bycatch numbers of 12–14 individuals per year (5.2–6.5% of abundance estimates). Reducing bycatch mortality caused by bottom-set gillnets is essential for the effective conservation of Indo-Pacific bottlenose dolphins in Amakusa, Japan.

KEYWORDS: GILLNETS; INCIDENTAL CATCHES; INDO-PACIFIC BOTTLENOSE DOLPHIN; ASIA; ABUNDANCE ESTIMATE; MARK-RECAPTURE

INTRODUCTION

Bycatch is a serious and widespread threat to cetacean populations (Reeves *et al.*, 2003). Globally, it is estimated that hundreds of thousands of cetaceans may be incidentally captured on an annual basis, primarily in gillnets (Read *et al.*, 2006). Mortality in gillnets can be a serious threat to the survival of local populations of coastal dolphins (D'Agrosa *et al.*, 2000; Dawson *et al.*, 2001; Rojas-Bracho *et al.*, 2006; Slooten *et al.*, 2006). The Indo-Pacific bottlenose dolphin (*Tursiops aduncus*), which is distributed in coastal waters of the Indian and western Pacific oceans including Japanese waters (Jefferson *et al.*, 2008; Mori and Yoshioka, 2009), is also bycaught in gillnet fisheries (Amir *et al.*, 2002; Natoli *et al.*, 2008; Stensland *et al.*, 2006). Although bycatch of this species has been confirmed in Japanese waters[a,b], no studies have been conducted that evaluate the effect of bycatch at the population level.

A year-round resident population of Indo-Pacific bottlenose dolphins, with an abundance estimate of about 220 individuals in 1995–1997, inhabits the waters off the northern coast of the Amakusa-Shimoshima Island (Shirakihara *et al.*, 2002). It is one of the known isolated resident populations in Japanese coastal waters (Hayano *et al.*, 2004; Morisaka *et al.*, 2005).

At least three individuals from this population were bycaught in gillnets between 1995 and 2004 (Shirakihara *et al.*, 2003; Minoru Shimizu, pers. comm.). In 2006 and 2007, bycatches were confirmed off the northern coast of the island. In 2006, two individuals were incidentally captured in one month; one was captured in a bottom-set gillnet, and the other (identification #134) sank into the sea, with the remaining anterior insertion of fluke entangled in a fishing rope. In 2007, a calf was found entwined in something resembling a fishing line. The animal may have died subsequently because the mother was found unaccompanied the next year. An examination of the magnitude of bycatch is needed for the effective conservation of this small population.

The goal of this study was to examine the possible effects on the Amakusa population of Indo-Pacific bottlenose dolphins of bycatch in gillnet fisheries.

METHODS

Study area and dolphins

The study area included waters surrounding the Amakusa-Shimoshima Island in the central part of western Kyushu, Japan (Fig. 1). The island is surrounded by Tachibana Bay, Ariake Sound, Yatsushiro Sound and the open sea (Amakusa-nada). Ariake and Yatsushiro sounds are highly productive estuaries that are separated by the Uto Peninsula and three islands (Amakusa-Shimoshima, Amakusa-Kamishima and Oyano). Tachibana Bay is a junction between Ariake Sound and Amakusa-nada.

The Amakusa population of Indo-Pacific bottlenose dolphins now consists of a northern and southern community (Miki Shirakihara, unpublished data) – the southern community (found off the southern coast of Amakusa-Shimoshima Island) developed from the movement of

[a] *Stranding records from the Institute of Cetacean Research, Tokyo (http://www.icrwhale.org/zasho.htm)*
[b] *Marine Mammals Information Database from the National Museum of Nature and Science, Tokyo (http://svrsh1.kahaku.go.jp/m/mm/)*

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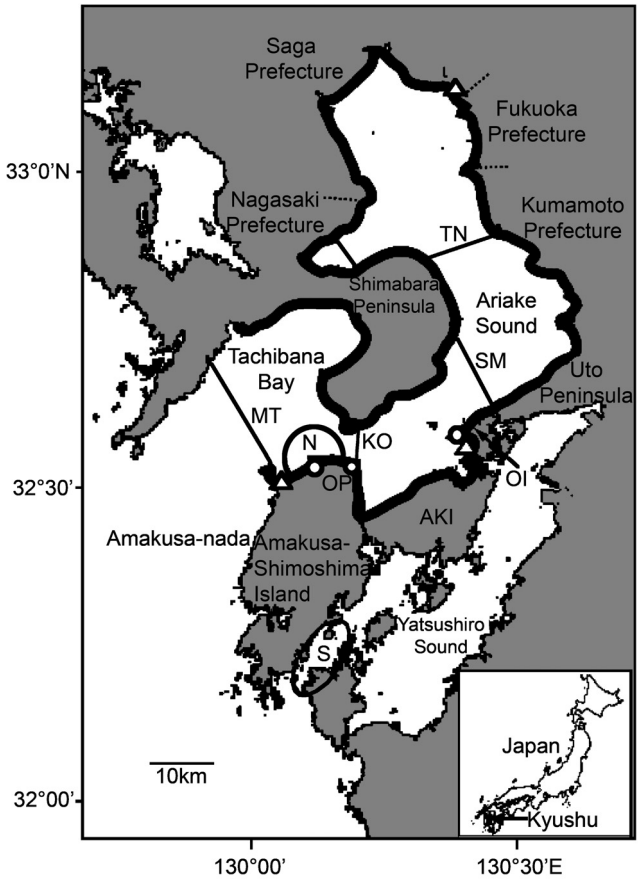

Fig. 1. Map of the study area. N shows the range of the theodolite tracking survey, which is considered the stable daytime habitat for the northern community (Ken Inoue, pers. comm.). S is the area where the southern community dolphins were observed during the daytime. TN, SM, KO, and MT are ferry routes. White circles and triangles show the areas where bycatch and stranding of the species, respectively, were reported. The bold black line along the coast is the area where interviews were conducted. The dotted line is the prefectural boundary. AKI, OI and OP are Amakusa-Kamishima Island, Oyano Island, and Oniike Port, respectively.

individuals from the northern community found off the northern coast (Shirakihara *et al.*, 2002).

No systematic boat-based surveys covering all four waters in which they may have been seen (Tachibana Bay, Ariake Sound, Yatsushiro Sound and Amakusa-nada) have been conducted. However, a number of surveys indicate that areas N and S (Fig. 1) are stable daytime habitats for the dolphins. In theodolite tracking surveys, groups in the northern community remained in area N and those in the southern community remained in area S (Ken Inoue and Masato Nishiyama, pers. comm.). In area N, dolphin groups, maximum group size >100 (Shirakihara *et al.*, 2002), were found on all the 93 survey days between 1996 and 1998. When the survey was able to be carried out from sunrise to sunset, the group was able to be tracked for a long time: mean of 8.5 hours (n = 54 days; Ken Inoue, pers. comm.).

In addition, sighting surveys were carried out from ferry boats. These were conducted in all seasons of the year between summer 1988 and spring 1992. The finless porpoise (*Neophocaena phocaenoides*) was the only cetacean species spotted on ferry routes TN and SM (Table 1, Fig. 1), whereas groups of *Tursiops* sp. were found on route KO and on the southern part of route MT (Shirakihara *et al.*, 1994; Miki Shirakihara unpublished data).

Table 1

Summary of sighting surveys using ferry boats reported in Shirakihara *et al.* (1994) and Shirakihara (unpublished data).

Route[a]	Distance (km)[b]	No. of GNP[c]	No. of GT[d]
TN	2,450	652	0
SM	957	197	0
KO	526	21	4[e]
MT	464	4	1
Total	4,397	874	5

[a]For abbreviations, see Fig. 1. [b]When Beaufort scale ≤1. [c]Number of groups of *N. phocaenoides*. [d]Number of groups of *Tursiops* sp. [e]Including a group which was spotted when the boat was in Oniike Port.

In aerial sighting surveys in Ariake Sound, Tachibana Bay and the northern part of Yatsushiro Sound, only groups of finless porpoise were sighted, except for one group of an unknown species of dolphin in waters off the northern coast of Amakusa-Shimoshima Island (Yoshida *et al.*, 1997). The group may have been Indo-Pacific bottlenose dolphins, based on sighting location. Furthermore, area N is an active dolphin-watching site, where many boats gather from different ports (Matsuda *et al.*, 2011), suggesting the high encounter rate of *T. aduncus* in this area. Dolphin-watching boats also are found in area S.

Gillnetter interview surveys were conducted to clarify the occurrence of bycatch of the Amakusa population dolphins in coastal gillnets. Stranding and bycatch of the species have been confirmed in Ariake Sound and Tachibana Bay (Shirakihara *et al.*, 2003; Minoru Shimizu, pers. comm.; Akira Takemura, pers. comm., Fig. 1), but there were no reports for Yatsushiro Sound or Amakusa-nada. Therefore, the surveys were conducted in towns and villages along Ariake Sound and Tachibana Bay (Fig. 1).

Abundance estimation

For the northern community, abundance was estimated using mark-recapture techniques. Photo-identification surveys were carried out for eight days each during the summers of 2007 and 2008. The summer season was selected because the dolphin groups stayed longer in area N during the summer than during the other seasons (Ken Inoue, pers. comm.). The dolphins commonly form a large group in area N. Before the survey, dolphin groups were searched for from land. Mean group size estimated from the land was 50 individuals (n = 14, SD = 26.2). The group was approached by small boat and the left side of the dorsal fin was photographed using a *Canon* digital camera with a 100–300mm zoom lens. Occasionally, other groups were seen in the distance. The team attempted to approach them and randomly photograph as many individuals as possible. A photographic survey conducted for 2–3 hours was regarded as one sampling occasion for the abundance estimation.

Images were compared with the photo-identification catalogue. Number, shape and position of notches on the trailing or leading edge of the dorsal fin were used as natural marks for identification (Würsig and Jefferson, 1990). As in Shirakihara *et al.*(2002), high-quality, unobscured images almost parallel with the photographic frame were selected

for abundance estimation. The Mth model in the program CAPTURE (Otis *et al.*, 1978; Rexstad and Burnham, 1992) was used to estimate the number of identifiable individuals (*NI*). The ratio of identifiable individuals (*p)* among the population was estimated using the ratio estimator (Cochran, 1977); $\Sigma a_i/\Sigma b_i$, where a_i is the number of identified individuals in the photograph *i*, and b_i is the total number of individuals photographed in *i*. The abundance estimate (*N*) was calculated as *NI/p*.

For the southern community, photo-identification surveys were conducted in area S for two days (several hours per day) each during the summers of 2007 and 2008. Searching for dolphin groups occurred from the Kagoshima University research vessel *Azuma* (8.5t), in shallow waters along the coast. When a group was sighted, a 5m fibre-reinforced plastic boat was launched with 10hp outboard engine and dorsal fins were photographed. Almost all individuals in the southern community were recognisable. For calves that had no clear notches on the dorsal fin, mothers were identified based on synchronised behaviour. We believe that these intensive surveys can be considered a census.

Total population size was estimated from the sum of the abundance estimate of the northern community and that of the southern community.

Bycatch data collection and analysis

Interviews were conducted for 10 days in October 2007 and 12 days in October and November 2008. Interviewed gillnetters were those we met by chance at fishing ports or Fisheries Cooperative Association offices near the ports. Approximately 60 associations and more than 100 fishing ports are scattered throughout the survey area. Questions on the survey included:

(1) the number of bycaught dolphins during the past year;

(2) the season of the year in which the bycatch occurred;

(3) the depth at which the net was placed (capture depth) if known; and

(4) the occurrence of interactions with dolphins that negatively affected fishing, such as depredation, the behaviour of toothed whales to remove or damage fish captured in fishing gear (Read, 2008), during the past year.

Interviewees were also asked about any finless porpoise bycatches (several gillnetters had also caught porpoises). Fishermen in Ariake Sound and Tachibana Bay recognise the finless porpoise and use different names for them 'nami(e)noi(u)o' and other dolphins 'iruka' and thus the possibility that finless porpoise bycatch was reported as dolphin bycatch is believed unlikely. Information on the total number of gillnetters in each fishing port was provided by interviewees or association staff.

As bycatches were only reported for limited areas (see 'Results' and Fig. 3a), the estimate of the total number of bycaught animals (B) was only calculated for those waters with bycatch reports, not the whole area i.e. *post hoc* stratification was applied based on ports. The annual estimate B was given by (BR/NIG)NG, where BR is the total reported bycatch in numbers, NIG is the total number of interviewed gillnetters in the fishing ports from which bycatch was reported, and NG is the total number of gillnetters in the ports. The 95% confidence interval of bycatch was calculated from the mean bycatch per interviewed gillnetter, BR/NIG (using t-distribution).

Evaluation of effect

There are a number of approaches to evaluating the effect of bycatches on a population. These depend on a number of issues especially conservation objectives and how to deal with uncertainty. For illustrative purposes for this paper we have chosen to use the potential biological removal (PBR) level approach used in the USA (Wade, 1998). The PBR level, which estimates an upper limit of allowable human-induced mortality, is given by $N_{MIN} \cdot 1/2R_{MAX} \cdot F_R$, where N_{MIN} is the minimum population estimate, R_{MAX} is the maximum net productivity rate, and F_R is a recovery factor ($0.1 \leq F_R \leq 1$). Following Wade (1998), these three values were given as follows: N_{MIN} = lower 20th percentile of a log-normally distributed *N*, R_{MAX} = 0.04 (default value for cetaceans), and F_R = 0.5 (default value).

RESULTS

Photo-identification surveys

For the northern community, more than 5,000 pictures were taken during 16 surveys over the two study years. The total number of identified individuals that had notable notches on their dorsal fins was 153 in 2007 and 140 in 2008. The cumulative number of identified individuals reached 140–150 and remained almost constant during each survey period in 2007 and 2008 (Fig. 2), suggesting that most of the identifiable dolphins were photographed. For the southern community, about 2,000 pictures were taken during four surveys.

Estimates of abundance

Dolphin abundance in the northern community was estimated at 205 (CV = 2.8%) in 2007 and 193 (CV = 2.3%) in 2008 (Table 2). Dolphin abundance in the southern community was 25 in 2007 and 23 in 2008. The abundance of the Amakusa population was considered to be 230 (CV = 2.5%) in 2007 and 216 (CV = 2.1%) in 2008.

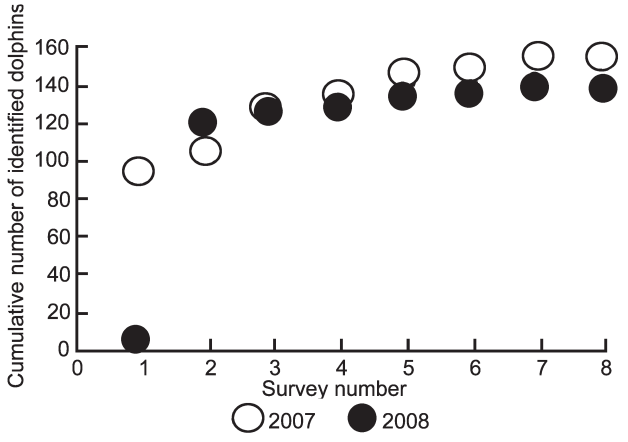

Fig. 2. Cumulative number of identified dolphins from photo-identification surveys for the northern community of the Amakusa population of Indo-Pacific bottlenose dolphins.

Table 2

Results of abundance estimation and bycatch of the Amakusa population of Indo-Pacific bottlenose dolphins, Japan.

	2007	2008
Abundance estimates of the northern community		
Number of identifiable individuals (*NI*)	160	144
Its CV (%)	2.40	1.88
Ratios of identified individuals (*p*)	0.78	0.75
Abundance estimate (*N*)	204.61	192.61
Its CV (%)	2.76	2.30
Abundance of the southern community	**25**	**23**
Abundance estimate of the Amakusa population	**229.61**	**215.61**
Its CV (%)	2.46	2.05
Minimum bycatch		
Number of interviewees in all areas	127	136
Number of interviewees who reported bycatch	8	9
Number of bycatch reported in the port on the northern coast of ASI[a]	5	5
Number of bycatch reported in the ports of other areas	7	9
Total number of bycatch reported (BR)	12	14
Bycatch estimation		
Number of interviewees in the ports bycatch reported (NIG)	41	32
A total number of gillnetters in the ports bycatch reported (NG)	58	69
Mean number of bycatch per gillnetter (BR/NIG)	0.29	0.44
Its standard error	0.06	0.13
Bycatch estimates (B)	16.98	30.19
Its CV (%)	19.81	29.26

[a]Amakusa-Shimoshima Island.

Bycatch

Species of bycaught individuals

We concluded that most of the bycaught animals were Indo-Pacific bottlenose dolphins based on the following reasons:

(1) two dolphins incidentally captured in October and November in 2007 were identified as Indo-Pacific bottlenose dolphins based on DNA analysis (Azusa Hayano, pers. comm.). The DNA samples were collected from flukes discarded by a gillnetter at a fishing port;

(2) gillnetters distinguish finless porpoises from other dolphins;

(3) no cetacean species except the finless porpoise and *Tursiops* sp. was sighted in the sighting surveys by ferry boats (see Methods);

(4) Seasonal and spatial bycatch distribution corresponded well to habitat use patterns of the northern community, which included the use of area N, stable daytime habitat, throughout the year and reduced use from autumn to spring (Ken Inoue, pers. comm.) – reported bycatch except in the ports on the northern coast of Amakusa-Shimoshima Island increased from autumn to spring (Table 3).

Estimates of bycatch

The exact bycatch location (location of net operation) was difficult to determine from the interview surveys. Coastal gillnet fisheries operate based on each association's fishery rights and by permission, and the fishing grounds generally are limited to waters near the ports. We therefore assumed that bycatches occurred near to the interview location of the reporting gillnetters.

The total number of gillnetters in the survey area was 868. Approximately 15% of the gillnetters (127 in 2007 and 136 in 2008) were interviewed about dolphin bycatch. No gillnetters refused to reply to our interviews, except those who were actively working. At least 42 gillnetters were interviewed in both years.

A total of 17 gillnetters (eight in 2007 and nine in 2008) reported dolphin bycatches (Table 2). Two gillnetters captured dolphins consecutively in two years: one gillnetter captured one individual the first year and two individuals the following year, and the other gillnetter captured one individual each year. The number of bycaught individuals per gillnetter per year ranged from zero to five. Among eight fishermen who reported bycatch in 2007, two gillnetters caught two individuals and one caught three individuals. In 2008, one fisherman reported two individuals and another person reported five. All were captured in bottom-set gillnets except for one, which was caught in a trap net. Five live dolphins were returned to the sea. The latter dolphins were included for bycatch estimation as information on their survival is lacking. Thus the minimum number of bycaught dolphins (sum of reported bycatch in numbers) was 12 individuals in 2007 and 14 individuals in 2008. Highest levels of bycatch were reported for the ports on northern coast of Amakusa-Shimoshima Island. Bycatch in these areas accounted for 42% in 2007 and 36% in 2008 of the total number bycaught.

The number of interviewees in the ports where bycatch was reported was 41 in 2007 and 32 in 2008 (Table 2). Bycatch estimates were 17 (95% CI 10–24) in 2007 and 30 (95% CI 12–48) in 2008.

Bycatches were reported throughout the year in the ports on the northern coast of Amakusa-Shimoshima Island at depths from 10–30m. Bycatches from other areas were reported from autumn to spring (Table 3) with little depth information. However, gillnetters in the Shimabara Peninsula (Fig. 1), who normally fixed nets at a depth of about 80m, reported previous dolphin bycatch. Bycatch may also occur at deeper locations in other areas.

About half of all gillnetters reported depredation: 21 out of 41 in 2007 and 15 out of 32 in 2008. Depredation occurred in the middle and southern parts of Ariake Sound and Tachibana Bay (Fig. 3b).

Evaluation of effect

From the information available, the PBR level was estimated to be two individuals. The bycatch rate was 5.2% in 2007 and 6.5% in 2008.

DISCUSSION

The objective of the study was to present an initial evaluation of the magnitude of bycatch (using estimates of the minimum number) and to evaluate possible population-level effects using the PBR approach. The estimated annual bycatch (12–14 individuals) was substantially greater than the PBR level of two individuals for this population. Even without the PBR approach, the high annual rates (up to 6.5%) is well above the level of 1% that generally raises concerns about sustainability for small cetacean populations (IWC, 1995). It is clear that the survival of the Amakusa population will be in doubt if such a high bycatch rate persists.

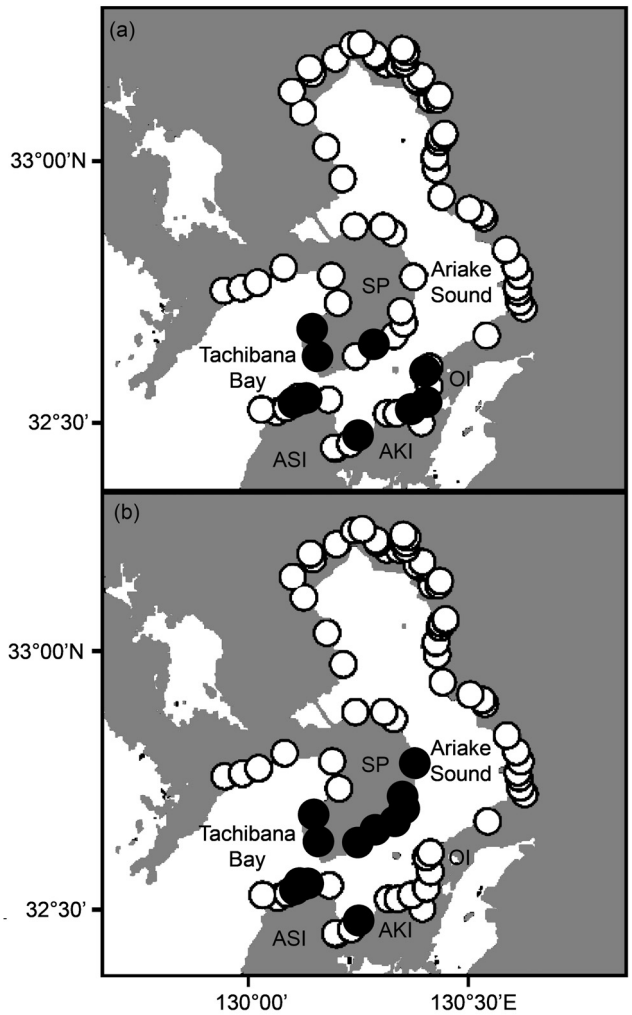

Fig. 3. Locations of the fishing ports where fishermen were interviewed. Black circles show the fishing ports where bycatch (a) and depredation (b) were reported. ASI, Amakusa-Shimoshima Island; AKI, Amakusa-Kamishima Island; OI, Oyano Island; SP, Shimabara Peninsula.

Table 3

Number of bycatch of Amakusa population of Indo-Pacific bottlenose dolphins by season and capture depth.

	PNASI[a]	OP[b]	Total
Season[c]			
Winter–Spring	–	2	2
Spring	1	5	6
Summer	3	–	3
Autumn	2	4	6
Autumn–Winter	4	1	5
Winter	–	2	2
Total	10	14	24
Depth (m)			
10	3	1	4
10–15	–	1	1
17–18	2	1	3
20	2	–	2
30	1	–	1
Total	8	3	11

[a]Ports of the northern coast of Amakusa-Shimoshima Island. [b]Other ports. [c]Spring = March–May; Summer = June–August; Autumn = September–November; Winter = December–February.

It is important to examine possible causes of uncertainty in our estimates. One of the potential biases in the interview surveys was species identification. For example, strandings of other small toothed whales, excluding the finless porpoise and the Indo-Pacific bottlenose dolphin were reported in Ariake Sound and Tachibana Bay; *Tursiops* sp., *Stenella longirostris*, *Grampus griseus*, *Delphinus* sp. and *Steno bredanensis* between 1984 and 2010 (Ishikawa, 1994)[a,b]. Given the absence of these species in the ferry boat surveys (Table 1), we believe that the bycatch of other dolphins in the regions was infrequent. In fact, even if all non-identified bycatches were assumed to be other species, the known Indo-Pacific bottlenose dolphin bycatch in 2007 was two genetically confirmed bycaught individuals and a bycaught calf.

The lack of an observed drastic decline in abundance from the mid-1990s to the present suggests that bycatch frequency may have increased recently or even that these two years for some reason had unusually high levels. During the interview survey, some fishermen noted a recent increase in depredation. In Ariake Sound and Tachibana Bay, the total commercial catch of fish and of Mugilidae, important prey for Amakusa Indo-Pacific bottlenose dolphins (Yamazaki *et al.*, 2008), decreased (Fig. 4). If the fishermen's observations are true, a decrease in local food resources may be one of the factors responsible for the increase in depredation and an increase in the frequency of approaching a net may cause an increased risk of bycatch.

It is clear that bycatch mitigation should be implemented immediately for this population at the same time as better evaluating the levels of the threat.

The use of acoustic deterrents is a bycatch mitigation measure that has been adopted for some species in some areas, notably the harbour porpoise (Read, 2008). Although, acoustic deterrent devices (pingers) have been shown to reduce the number of individuals caught in gillnets in certain species and areas (e.g. Kraus *et al.* (1997), it is essential that a proper evaluation of the efficacy of this approach be undertaken for Amakusa Indo-Pacific bottlenose dolphins in this region before widespread use can be recommended and a number of issues must be considered in such an evaluation. Depredation is already reported by many gillnetters and although evasive behaviour of the dolphins might be seen at first (Leeney *et al.*, 2007), they may later learn to associate the pingers with the presence of a gillnet that contains fish (Cox *et al.*, 2003). The habitat use patterns of the dolphins are also important. Many individuals remain for long periods in area N, a stable daytime habitat (Fig. 1); resting in shallower waters has been frequently observed (Ken Inoue, pers. comm.). Fisheries including gillnets is an important occupation in area N, with local statistics for the Kumamoto prefecture, showing over 200 fishing boats in the northern coast of Amakusa-Shimoshima Island. The use of pingers on a large number of vessels may increase noise pollution and alter behaviour and distribution, as suggested by Carlström *et al*. (2009).

Modification of net material is another method of changing animal behaviour to reduce the risk of bycatch (Read, 2008) that might be considered. This method has resulted in the reduction of harbour porpoise bycatch (Larsen *et al.*, 2007; Trippel *et al.*, 2003).

Another alternative to be evaluated is that of targeted geographical and temporal closure (Read, 2008). Gillnetters

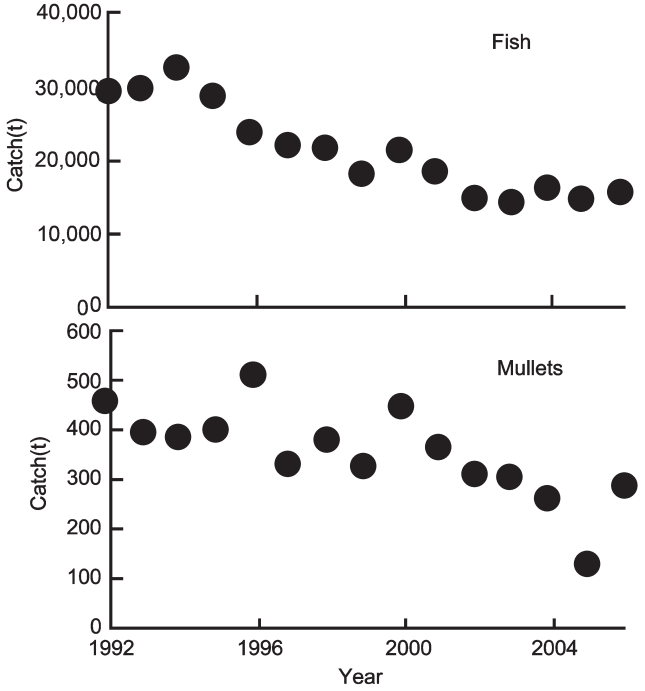

Fig. 4. Commercial catch of fish and mullets in Ariake Sound and Tachibana Bay in four prefectures surrounding Ariake Sound and Tachibana Bay

in the bycatch area (southern part of Ariake Sound and Tachibana Bay) do not use the same gear every day. They commonly use bottom-set gillnets for a limited period around neap tides because the current is too fast to set the nets. Some gillnetters use different fishing gear for the seasonal capture of more expensive fishes. Some gillnetters set the net for personal consumption. The fact that a wide variety of gear types is used by local fishermen suggests that there is some flexibility in fishing operations which may enable the fishing community to continue to fish profitably even if bottom-set gillnets were banned from certain areas. Of course, changes in fishing gear must be evaluated to ensure that they do not cause additional unforeseen problems to cetaceans and other components of the ecosystem.

Finally, good conservation requires consideration of all potential threats to populations. Besides interaction with fisheries, the dolphins are exposed to dolphin-watching tourism year around. It has been reported that the maximum number of the boats surrounding the dolphin groups can reach 16 and such operations can change dolphin behaviour (Matsuda *et al.*, 2011).

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