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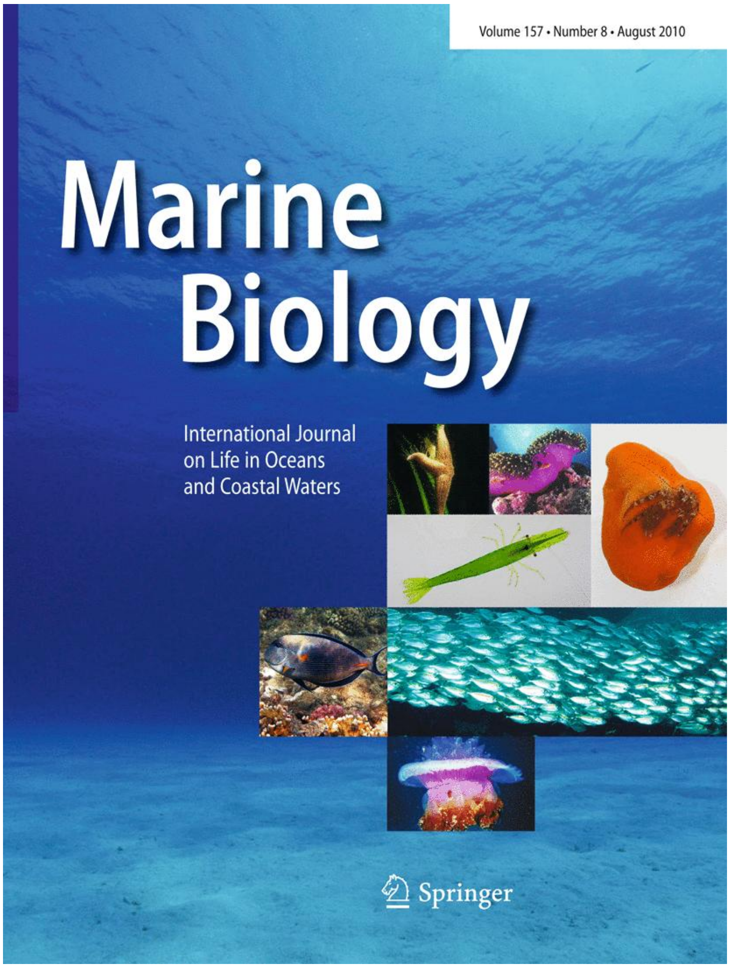

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ORIGINAL PAPER

Seasonal and diurnal presence of finless porpoises at a corridor to the ocean from their habitat

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Abstract A number of local populations of finless porpoises (*Neophocaena phocaenoides*) are widely distributed throughout the warm coastal waters of Asia. The Omura Bay population, consisting of approximately 300 individuals, is the smallest of five populations inhabiting Japanese waters. It is a relatively new population that established after the global warming that took place approximately 9000 years ago. To observe whether these porpoises appear in the major corridor to the ocean from Omura Bay, we used acoustic monitoring to record occurrences of finless porpoises from November 2007 to May 2009. A stereo acoustic event recorder recorded the intensity and the sound source direction of biosonar signals, providing independent traces of sound sources corresponding to each detected animal. A total of 226 individuals were detected over the 1.5-year monitoring period, of which 76% occurred at night and 73% occurred during March and April. We compared the presence of porpoises to the Japanese anchovy catch in Omura Bay and the Hario Strait over the same period. Results suggested that possible reductions in anchovy resources in the bay could attract porpoises to the outside of their normal habitat. In total, 70% of the porpoise recordings took place when the tidal current was moving out of Omura Bay. Porpoises might follow the prey that are transported out of the bay due to the strong outbound current. The finless porpoises confined to the bay might extend their swimming area if prey is available.

Introduction

Finless porpoises (*Neophocaena phocaenoides*) are widely distributed throughout Asian coastal waters from the eastern Persian Gulf to Senday Bay in northern Japan (Reeves 2007). This species is divided into many subpopulations (Jefferson 2002). For example, morphological and genetic evidence has indicated five independent populations of this species in Japanese waters (Yoshida et al. 2001, Yoshida et al. 2002). The Seto Inland Sea population was estimated as 7,472 individuals (Shirakihara et al. 2007), and the smallest population of finless porpoise in Japan inhabits Omura Bay (Fig. 1), Nagasaki prefecture (32.58°N, 129.52°E). The mechanisms governing the wide dispersal distribution and colonization to local waters of this species are still unknown.

Omura Bay is an ellipsoidal semi-enclosed sea located in the western Kyusyu Island, Japan. The bay is 26 km in length from south to north and 11 km in width from east to west (Matsuoka 2005). The area was land approximately 9000 years ago. However, as a result of global warming, seawater entered the area through the Hario Strait, forming

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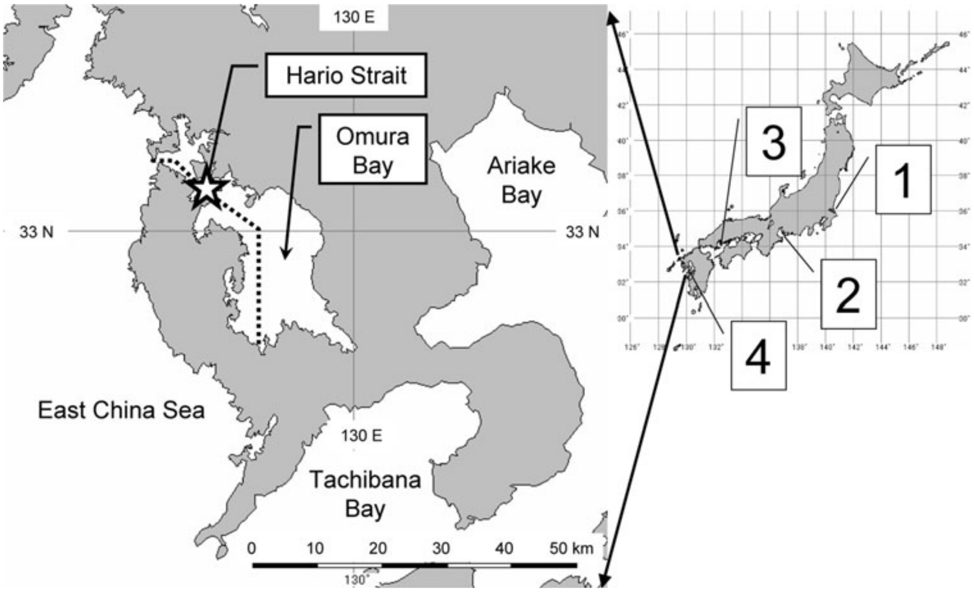

Fig. 1 The smallest population of finless porpoises inhabiting Japanese waters is in Omura Bay, which is connected to the East China Sea via the Hario Strait. The four other Japanese populations of this species are found in Sendai Bay–Tokyo Bay (*1*), the Ise–Mikawa Bays (*2*), Inland Sea–Hibiki Nada (*3*), and Ariake Sound–Tachibana Bay (*4*; Yoshida et al. 2002). The acoustic monitoring station in the Hario Strait is indicated by a star. The *dotted line* is the path of a visual survey conducted by a boat

the bay approximately 7000 years ago (Matsuoka 2005). Thus, the finless porpoise population in the bay is fairly new.

Yoshida et al. (1998) reported a population size of 187 finless porpoises in Omura Bay (0.6 individuals/km^2, CV = 20%, survey conducted in 1993–1994). Approximately 300 individuals were estimated from an aerial survey in 2004, and no obvious decline in the population size has been observed (Fisheries Agency of Japan and Fisheries Research Agency 2008, 0.9 individuals/km^2, CV = 30%). Crews of powerboats report finless porpoise sightings offshore as well as inshore in Omura Bay (Shirakihara et al. 1994); however, only one sighting of a finless porpoise in the adjacent ocean outside Omura Bay has been recorded. A questionnaire of local fisheries operations confirmed several sightings inside of the bay but very few in the East China Sea (Shirakihara et al. 1992). These observations indicate a relatively high-density distribution of finless porpoises in the bay and very low density in waters outside of the bay.

The Hario Strait is the major corridor for seawater and marine organisms between Omura Bay and the East China Sea. It is a narrow channel 20 m in depth. Tidal current through the strait moves at a maximum of 8.5 knots (Tide Table 2008, Japan Coast Guard) and supplies seawater twice a day to Omura Bay. Species such as Japanese anchovy (*Engraulis japonica*) migrate seasonally between Omura Bay and the East China Sea (Azeta 1981). This species leaves the bay to avoid water temperatures below 10°C in the winter and moves back into Omura Bay from March to May for hatching after the water temperature getting higher. The Hario Strait is an ideal point from which to observe the possible migration of finless porpoises to the ocean in conjunction with simultaneous monitoring of anchovy catches.

Shirakihara et al. (2008) reported numerous prey species collected in the stomachs of stranded finless porpoises in Omura Bay, including fish (Gobiidae, Apogonidae, *Konosirus punctatus*, *E. japonica*, and *Hypoatherina valenciennesi*), cephalopods (Loliginidae and *Todarodes pacificus*), and crustaceans (shrimp and Isopoda). According to the fisheries statistics, 95 fish species were recognized in fisheries catches from the bay from 1973 to 1974 (Nagasaki University 1976). However, the dominant fisheries catch in Omura Bay has been *E. japonica*. In 2006, Japanese anchovy accounted for 1,229 tons of catch out of a total catch of 3,365 tons in this area (Fisheries Statistics of Nagasaki Prefecture). The second most popular catch was sea cucumber, which accounted for 317 tons. Fisheries catches inside Omura Bay and the Hario Strait provide an index of local prey available to finless porpoises.

We monitored the presence of finless porpoises at the strait using a passive acoustic method and compared our results with the fisheries catches in the focal area over 1.5 years. Passive acoustic detection by stationed platform is a well-established method for detecting finless porpoises (Kimura et al. 2009) from their frequent vocalizations (Akamatsu et al. 2007).

Methods

Study site and fisheries catch

The presence of finless porpoises in the Hario Strait, Nagasaki, Japan, was monitored acoustically from November

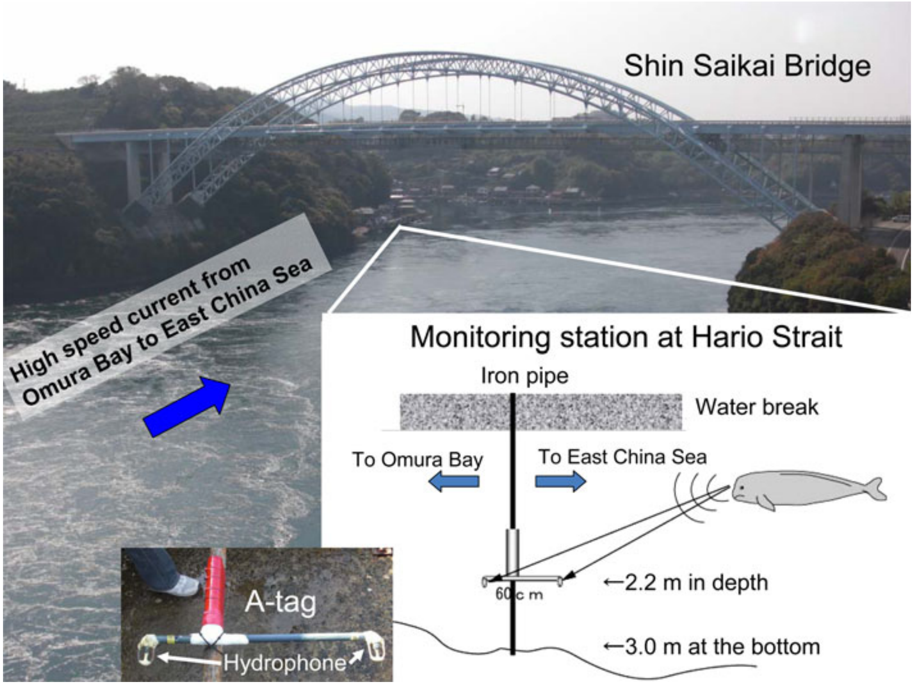

Fig. 2 Overview of the Hario Strait from the Omura Bay side looking out in the direction of the East China Sea direction. The monitoring station was at the southern bank of the strait. The acoustic monitoring system (A-tag) was fixed on an iron pipe and lowered 2.2 m below the surface. In this image, the tidal current is running out of Omura Bay

2007 to May 2009. Biosonar sounds from the porpoises were recorded at the south side of the Hario Strait (33.03′13″ N, 129.45′10″ E) using an acoustic data logger (A-tag; Marine Micro Technology, Saitama, Japan), which is the stereo acoustic event recorder for detection of ultrasonic pulses. An iron pipe was fixed vertically to the water break, and the A-tag was deployed at a depth of 2.2 m (Fig. 2). The primary hydrophone was nearer Omura Bay. When it received an ultrasonic pulse, the primary hydrophone provided a reference time for measuring the time arrival difference between two hydrophones. The positive bearing angle of the sound source recorded by the A-tag corresponded to the sound coming from the Omura Bay side. This means that the primary hydrophone was triggered first. The A-tag was retrieved every month to download the data and to remove any biological fouling from the system and the iron pipe.

The width of the strait is 260 m at the deployment point 100 m west of the Shin-Saikai Bridge; this is the narrowest part of the strait (Fig. 2). The Sasebo Coast Guard Office of the Japan Coast Guard provided current conditions, including the times of changes in direction and the maximum speed of the current. Water temperature was continuously monitored in the Hario Strait nearby the study site with a data logging system (Compact EM, JFE ALEC Co. Ltd., Kobe, Hyougo, Japan) courtesy of the Nakata Laboratory of Nagasaki University.

The daily fisheries catch of Japanese anchovies in the Hario Strait was recorded by a fisheries broker (Takeshita Suisan Co. Ltd., Saikai, Nagasaki, Japan) and Segawa Fisheries Cooperative Association (Saikai, Nagasaki, Japan). The anchovies are used as live bait for skipjack pole and line fishing. Six draft nets (beach seines) were operated year round except during the summer, when the anchovy entered Omura Bay. The broker kept all anchovies caught in a large blue cage capable of holding 600 kg of fish. Daily catch was recorded as the number of blue cages filled per net per day. Two draft nets were operated each day and changed alternately. The sampling locations were identical throughout the year, as was the sampling effort, which provided a useful index of the density of the anchovy in the Hario Strait.

In addition, a round net fishery inside Omura Bay provided an estimate of the anchovy density in the bay. From October 1 to March 31, small round net fisheries targeting Japanese anchovy are permitted by the Nagasaki Prefecture government. In practice, anchovy were caught from October to January, corresponding to the high-density season for anchovy in the bay (Azeta 1981). The Sasebo City Fisheries Cooperative (Sasebo, Nagasaki, Japan), which is in charge of fisheries in the area, provided fisheries statistics. No other round net fishing is conducted in Omura Bay.

We also conducted a standard visual survey of finless porpoises inside and outside of Omura Bay. A small research boat (Kanokoyuri, 7.62 m in length, Kujyukushima Aquarium) was operated five times (October 11 and December 18 in 2007; March 5, June 10, and September 10 in 2008). An identical cruise line was used for each survey, as indicated by the dotted line in Fig. 1. The boat traveled from the port of Sasebo through Hario Strait, then southeast into Omura Bay. At the cross-point on the 33°N line, the boat headed to the southern end of the bay. The total distance traveled one way was 38 km, 12 km (32%) of which, including the Hario Strait, were outside of Omura Bay. A visual survey for finless porpoises was conducted on every trip with only occasional disruptions due to windy conditions. Two observers visually surveyed 90° sectors in front of the boat in alternating 30-min shifts. At least four observers were on board at all times. Group size and distance were recorded, and direction of the animal from the boat was based on the clock system, referring to the bow direction as zero o'clock.

Passive acoustic logging system

The acoustic data logger consisted of two ultrasonic hydrophones (MHP 140ST; Marine Micro Technology, Saitama, Japan) with a passive bandpass filter circuit (–3 dB with a range of 55–235 kHz), a high-gain amplifier (+60 dB), a CPU (PIC18F6620; Microchip, Detroit, MI, USA), flash memory (128 MB), and two off-the-shelf alkaline UM-1 batteries housed in a waterproof aluminum case. The logger was sensitive to the biosonar clicks of finless porpoises, which have a dominant frequency of approximately 128 kHz (Kamminga 1988). The A-tag was the pulse event recorder; it sensed the incoming sound pressure and recorded the difference in time of arrival between the two hydrophones every 2.0 ms. If no pulse was received on both hydrophones during 2.0 ms time bin, the acoustic data logger skipped recording and started measurements again in the next time bin. The average inter-pulse interval between successive biosonar pulses of finless porpoises was 60 ms under free-ranging conditions (Akamatsu et al. 2007). The 2-ms resolution of the time bin in the present system was good enough to measure the inter-pulse interval of the clicks produced by finless porpoises, except for the high clicking rate that appeared at the end of the approach phase of biosonar signals. To conserve memory capacity, we only recorded sound pressure that was above a preset detection threshold level of 144.7 dB peak-to-peak re 1 μPa. This high threshold also helped eliminate background noise due to contamination of biological pulse noises. When a pulse having sound pressure over the detection threshold level triggered either of hydrophones, the loop counter of the sound-arrival time difference started, and it continued until the second hydrophone was triggered. The time arrival difference was measured separately from the sound pressure. Therefore, the time difference could be measured even after the sound pressure measurement started in the next 2.0 ms time bin. An incoming pulse above the preset threshold level triggered measurement of the delay time between two hydrophones with 1.08 μs resolution. The baseline length was the distance between two hydrophones, i.e. 600 mm, which corresponds to the maximum time difference for a sound arrival of 400 μs in water. Given a resolution of 1.08 μs, the time arrival difference was digitized within ±370 counts of the loop counter. When the first pulse above the detection trigger was detected at the beginning of the 2.0-ms time bin of each measurement, the loop counter started to measure the time difference at 1.08-μs resolution until the trigger was detected at the other hydrophone. The sound-arrival time difference was stored at the triggering of the second hydrophone. The sound intensity of the first and second triggering were also stored at the same time. The detection distance of the porpoises was calculated as 100 m assuming spherical sound propagation and a peak-to-peak source level of 185.6 dB, referring to 1 μPa (Li et al. 2006). This covers 38% of the width of the strait.

Off-line noise reduction

Despite the use of a high-detection threshold level, the system picked up substantial noise contamination. Thus, we used custom software to reduce the background noise and extract the biosonar sound. In the first step, surface reflections and isolated pulses were reduced. A surface reflection is received a few milliseconds after the direct path signal in a shallow water system such as the Hario Strait. Any pulses detected within 2.5 ms of the previous pulse were considered surface reflections and therefore eliminated. Sources of biological noise include crustaceans such as shellfish and snapping shrimp produce single-snap pulses. The sounds were received 1.1–2.2 times in a second; i.e., each pulse is unrelated to other pulses that are produced independently by individual animals. Therefore, pulses with no other pulse sounds within 150 ms were considered isolated and were excluded. The inter-pulse interval of the biosonar is the time separation between successive pulses in a click train. The inter-pulse intervals of the biosonar sounds produced by finless porpoises in the wild range up to 150 ms (Akamatsu et al. 2007). If no other pulse sounds are detected within 150 ms of a single pulse, the sound is unlikely to be the biosonar signal of a finless porpoise. Pulse trains with irregular inter-pulse intervals were discarded. The inter-pulse intervals of biological sonar sounds change gradually, whereas those of noise created by waves, bubbles, and snapping shrimp are irregular. Regularity was defined as successive inter-pulse intervals that changed between 50 and 200%.

For the second step, two criteria were used for screening typical click trains used for biosonar from false detection of train like sounds. The beginning and end of a click train was defined as the separation between successive pulse intervals longer than 200 ms (Akamatsu et al. 2007). A series of clicks of 6–100 pulses was considered a possible click train. Fewer than six pulses could be created by a group of independent marine organisms. Whereas ship noises due to cavitation from propellers are continuous and are composed of many pulses, the biosonar signals of porpoises are not received as continuous pulses by a stationary acoustic monitoring system because of the directional beam pattern and the movement of the animal. Thus, a pulse train with more than 100 pulses was considered noise from a ship passing through the Hario Strait. CV of the inter-pulse interval in a click train was used for the screening as well. Click trains with a CV >0.3 were not included in the analysis in order to exclude random noise trains allowed by the previous filters.

This two-step screening still allows for the false positive detections so that potential biosonar signals would not be missed. Thus, some background noise remained. For the final examination, the first author checked each click train visually and discarded potential background noise. Two or more possible click trains detected in a short time were judged as biosonar signals. If a porpoise swam near the system, several click trains could be received from that individual because of the frequent sound production of finless porpoises (Akamatsu et al. 2007). We need to note that detections of multiple click trains do not mean the presence of multiple individuals. A continuous long train produced by an animal could be recorded as two or more click trains due to the directional beam pattern of the biosonar. Freshwater finless porpoises have known to roll their bodies and shake their heads to scan the beam axis (Akamatsu et al. 2010). When multiple click trains were recorded within a very short time, the number of independent sound source direction was counted as described in the next session. For an additional screening criterion of a biosonar sound, a click train with an average inter-pulse interval of 70 ms or less was considered. This is the typical inter-pulse interval for finless porpoise clicks.

Determination of the number of animals and swimming directions

Finless porpoises rarely stop producing click trains for more than 200 s (Akamatsu et al. 2007). This means that a single finless porpoise will likely produce two or more click trains in a 3-min period (180 s). Thus, two pulse trains detected within 3 min were considered to be produced by a single animal. This may cause an overestimation of the number of animals passing by the system when an animal moves back and forth near the system with more than 3-min separation.

It must be noted that the number of received click trains does not equal the number of animals or group size. Independent sound source direction was used to count the number of animals. The bearing angle of the sound source recorded by the stereo hydrophone of the A-tag was used to identify the swimming direction of the porpoises (Fig. 3). The primary hydrophone was always directed toward Omura Bay. Sound from the Omura Bay side was recorded as a positive bearing angle, and sound from the East China Sea side was characterized as a negative bearing angle. Therefore, a decreasing bearing angle of the sound source indicated that the animal was swimming toward the ocean. In the case of a single-click train, it was not possible to identify swimming direction if the duration of the click train was less than 1 s, which is not enough time to detect a change in the bearing angle of the sound source.

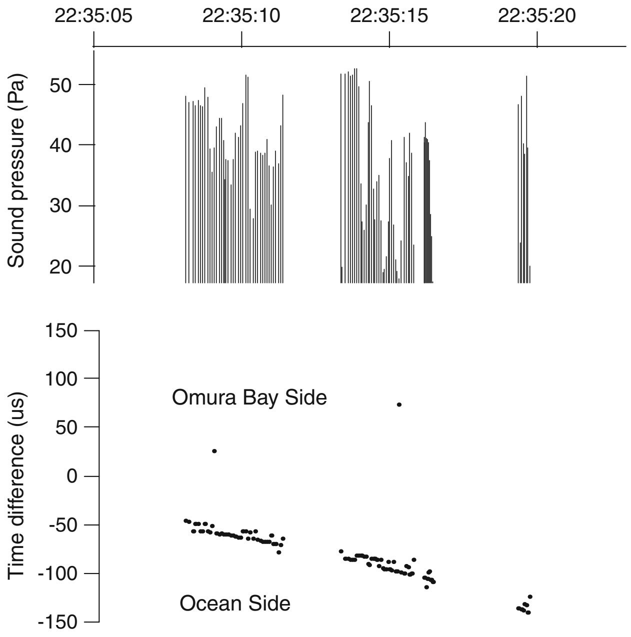

Fig. 3 Recorded echolocation signals of a finless porpoise passing by the fixed acoustic monitoring system. Three click trains were detected (*top*), and the bearing angle of the sound source was decreasing, which means the porpoise was swimming toward the ocean

Results

From November 21, 2007, to May 31, 2009, 226 porpoises were detected acoustically, of which 73% were observed from March to April (Fig. 4, bottom). Porpoises were occasionally detected during other seasons. In Omura Bay, the fisheries catches of Japanese anchovy were high from October to January (Fig. 4, top). Although round net fisheries are permitted in Omura Bay from October to the end of March, no catches were conducted in February or March of 2008 or 2009. In the Hario Strait, Japanese anchovy fishing was attempted throughout the year with the exception of August and September, which is the low-catch season. The total catch was high in January and April of both years (Fig. 4, second inset). The water temperature measured in the Hario Strait was approximately 10°C in February, with a minimum of 9.8°C, and reached 13°C at the end of March.

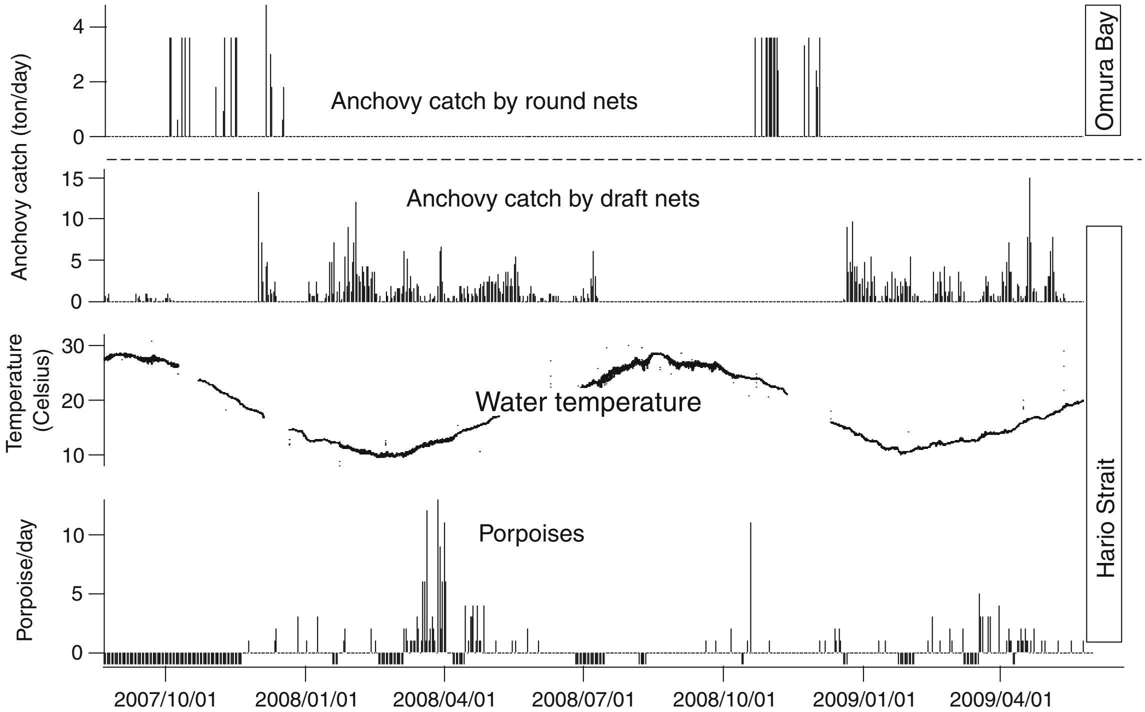

Fig. 4 Seasonal change in fisheries capture, water temperature, and number of porpoises detected. The total catch of Japanese anchovy per day inside Omura Bay (*top*) and the Hario Strait (*second row*) showed seasonal highlights. The water temperature in the Hario Strait dropped below 10°C only in February. Detections of porpoises in the Hario Strait were most common in March and early April. Negative black bars indicate the period without passive acoustic monitoring of porpoises due to system maintenance

During the visual surveys inside and outside of Omura Bay, a total of 15 porpoises were detected over five round trips along the cruise line from 2007 to 2008 (Fig. 5). In March 2007, seven porpoises were found in the northern part of Omura Bay. In contrast, porpoises were scattered in June and December. No animals were observed in October 2007 or September 2008. The porpoises were in groups of one to three. Group size was defined as the number of animals sighted in the same location within 300 m of the boat, which was the reliable visible range for finless porpoises. All of the porpoises were sighted inside of the bay. Relatively high-density area in the northern part of Omura Bay was suggested by the visual observation.

The finless porpoises did not show a bias toward swimming in either direction (Fig. 6). We could determine the swimming detections of porpoises for 25% when multiple click trains or a long-duration click train were recorded (Fig. 6 both sides). We were not able to determine the swimming direction for 75% of the porpoises detected (indicated by NA in Fig. 6 center) because only a single-click train was recorded.

Comparing the acoustic detection of porpoises with tidal current direction, 70% of detections occurred when the tidal current was moving out of Omura Bay to the ocean (components indicated by black bars in Fig. 6). Porpoises appeared in Hario Strait mostly when the tidal current was running toward the ocean. When swimming directions of animals were detected acoustically using the change in sound source–bearing angle of multiple click trains (both

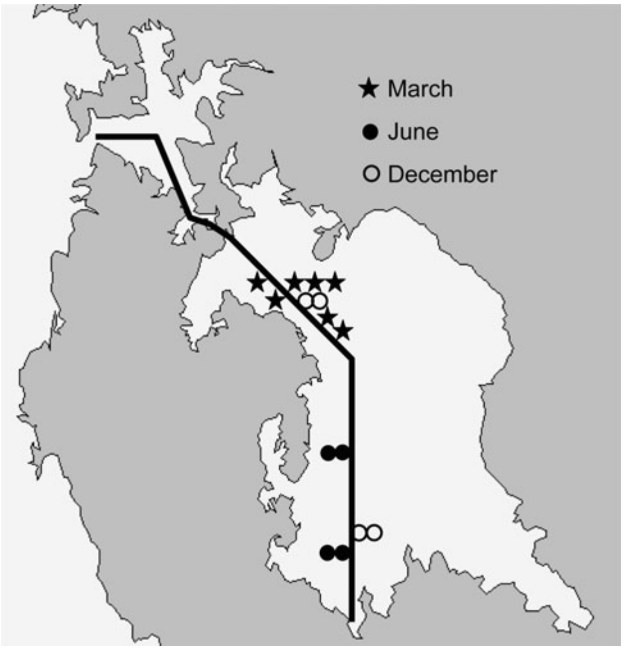

Fig. 5 Locations of visually observed finless porpoises. Each individual is shown as a *circle* or a *star*. No porpoises were detected outside of Omura Bay

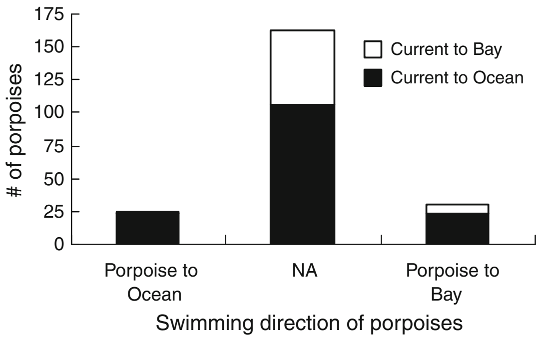

Fig. 6 Swimming direction and direction of the tide when the animal was detected by the A-tag. The direction of movement could not be identified for 75% of the animals, who made only a single-click train or did not move much during the production of multiple click trains that means the animal remained same direction from the A-tag. Porpoises appeared in the Hario Strait as the tidal current moved out of Omura Bay as indicated by the *black bars*

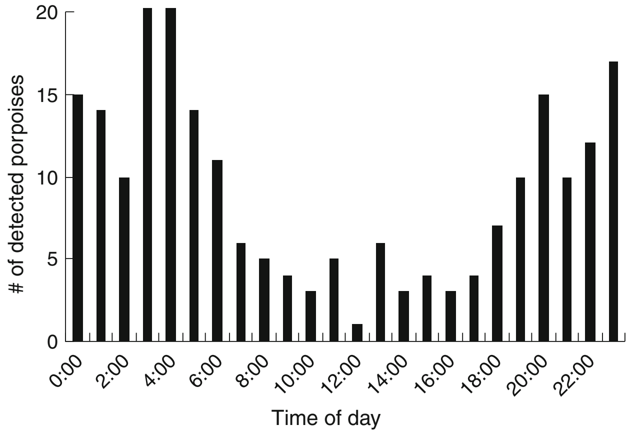

Fig. 7 Diurnal presence of porpoises in the Hario Strait. Total number of finless porpoises detected for each 1-h time interval over the 1.5-year observation period

sides of Fig. 6), 84% of detections of porpoises associated with the current went toward the ocean. This indicates that porpoises using sonar extensively were associated with the ocean-going tide.

Of the porpoise detections, 76% occurred at night between 6 p.m. and 6 a.m. (Fig. 7). Data for the total number of porpoises in each 1-h time interval indicate that the porpoises frequently appeared between 4 and 6 a.m. Only 24% animals were detected between 6 a.m. and 6 p.m. over the 1.5-year observation period.

Discussion

All sightings of finless porpoises occurred in Omura Bay even though 32% of the cruise line was outside. This is consistent with the study by Shirakihara et al. (1994), who reported many visual observations made by the crew of a powerboat inside the bay but only one sighting outside of the bay. However, the data of the present study showed the presence of finless porpoises in the Hario Strait during the spring. This suggests that finless porpoises in a semi-enclosed water system occasionally move out of their habitat. Another possibility is that they came from ocean and moved temporarily in the strait. The second possibility was not supported by the present data, which showed the porpoises mostly presented when the current moved oceanward.

Although fixed acoustic monitoring is a powerful method for detecting odontocetes (Koschinski et al. 2003, Kimura et al. 2009), the system has several limitations. The width of the strait at the location of the recording system was 260 m. This means that our system with a detection distance of 100 m could have missed more than half of the strait. The detection threshold level of the A-tag was 144.7 dBp-p, such that the maximum signal-to-noise ratio was 40.9 dB, assuming a source level of 185.6 dB (Li et al. 2006). Even though the porpoises produced high-intensity clicks, the directionality of the biosonar beam affects the detection performance of the A-tag. Harbor porpoises, which belong to the same family as finless porpoises, produce a directional sonar beam with a 16° width (–3 dB; Au et al. 1999). Thus, porpoises may not always direct their sounds toward the hydrophone. The sound pressure level 90° off the axis was 162 dB (Akamatsu et al. 2005). In this case, the signal-to-noise ratio was 17 dB, which provided a 9-m detection distance.

Another limitation to a fixed monitoring system is the potential for double counting. If an animal moved back and forth near the system over an interval greater than 3 min, our method counted it as two individuals. Therefore, the total number of animals detected may not reflect the total number of animals in the Hario Strait. In addition, we used only one station. Therefore, migration through the Hario Strait and possible movement toward the East China Sea cannot be fully proven. Despite these limitations, our long-term observation of the number and swimming direction of finless porpoises provides new insights into this small population.

In February, the water temperature dropped below 10°C, as shown in Fig. 4. This corresponded to when the anchovies moved out of the bay (Azeta 1981). The surface water temperature of Omura Bay tended to be 2–3°C lower than the water temperature of the East China Sea during the winter. The anchovies avoided the colder waters in the bay before February and were caught by draft nets at the Hario Strait in January. They were also caught as they moved into Omura Bay for hatching in the spring, thus explaining the double peak profile of the anchovy capture in the Hario Strait in January and April (Fig. 4, second inset). During autumn, Japanese anchovies were caught within Omura

Bay. Fishermen were aware of this migration pattern and used different types of fishing gear accordingly, such as draft nets during the winter in Hario Strait and round nets during the autumn in Omura Bay. This also suggests an annual decline in the Japanese anchovy population in Omura Bay in February. In March, porpoises appeared in the Hario Strait. In the same season, even the limited number of data from the visual observations in the present study suggested an accumulation of porpoises in the northern part of Omura Bay (Fig. 5). In spring, anchovies enter the northern end of the bay through the Hario Strait, which may attract the finless porpoise, although the Japanese anchovy is not the only prey species (Shirakihara et al. 1994) of this opportunistic feeder.

Among the detections assigned with swimming direction, 84% of detections occurred when the tidal current went out to the ocean. It was necessary to record multiple successive click trains or a long-duration click train to identify the swimming direction of the porpoises. This required extensive use of sonar within the Hario Strait. The tidal current speed reaches up to 8.5 knots (4.4 m/s) in the Hario Strait, which is too fast for the Japanese anchovy to swim against. An anchovy can swim 0.2 to 0.8 m/s (Aoki and Tsuruta 1989). Anchovies close to the northern end of Omura Bay could be transported into the Hario Strait with the strong tidal current, which was going back to the ocean (Fig. 2). Because of the lack of available anchovies in February, finless porpoises might concentrate at the northern end of Omura Bay, close to the mouth of the Hario Strait. That is, the 70% of finless porpoises found in the Hario Strait when the current was moving toward the East China Sea (Fig. 6) may have been harvesting anchovies brought by the influx of water into the strait. Even for finless porpoises, swimming against the tidal current seems difficult with their average swimming speed of 1.3 m/s. Therefore, the porpoises present in the Hario Strait as the tidal current went toward the ocean were considered to have come from Omura Bay.

Serial net samplings of the waters off of southern Kyushu revealed that the Japanese anchovy tends to spawn between 00:00 and 01:00 (Matuoka et al. 1998). The swimming speed of the captive Japanese anchovy was 0.5 m/s from 8:50 to 9:10 in the morning and 0.8 m/s from 20:00 to 22:00 at night (Aoki and Tsuruta 1989). The active movement associated with spawning happens in darkness. Most of the finless porpoises appeared in the Hario Strait during the night between 18:00 and 6:00 (Fig. 7). Tsuruta (1992) reported that Japanese anchovies spawn in water temperatures above 14°C in Sagami Bay, Japan. In the present study, the water temperature rose from 10 to 13°C in March of 2008 and many porpoises were observed in the strait during this season. The inbound anchovies in Omura Bay were considered to be at the pre-spawning stage. Finless porpoises could be harvesting active pre-spawning anchovies during the night using extensive sensing effort by their biosonar. However, further research is necessary to determine whether this accounts for the diurnal pattern of finless porpoises seen in our study. We need to note that the observable distance was less than half the width of the strait. This means that diurnal patterns could reflect the swimming distance of porpoises from the shore. Monitoring stations at the both sides of the strait will be appropriate for future monitoring.

The supply of prey species within the Hario Strait may be one of the factors responsible for the seasonal presence of finless porpoises. That is, rather than providing a year-round habitat, the Hario Strait may be a prey ground for porpoises in the spring. The finless porpoise population in Omura Bay seems to be confined, and mtDNA shows that these animals are distinct from those of the Ariake-Tachibana population approximately 60 km from the bay (Yoshida et al. 2001, 2002). Finless porpoises inhabit shallow waters but are able to swim up to 90 km in a day (Akamatsu et al. 2002). The maximum depth of the Hario Strait is 20 m, and the coastal waters off Kyusyu Island outside of Omura Bay compose part of the continental shelf of the East China Sea. There is no obvious physical barrier outside of Omura Bay. The occasional migration of finless porpoises induced by prey migration may enable the colonization of new habitat, which may explain the establishment of the Omura Bay population less than 9000 years ago. The low genetic diversity among finless porpoises in Omura Bay (Yoshida et al. 2001, 2002) suggests a founder event. Another example of a founder event in this species might have occurred in the upper stream of the Yangtze River (Zheng et al. 2005). Although finless porpoises tend to be confined to local areas, the availability of prey could trigger the occasional migration of founder individuals, thereby expanding their habitats across Asian coasts.

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