A note on cetaceans off Kiribati and Tuvalu from a research cruise in October 2010

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ABSTRACT

This paper summarises the results of a sighting survey conducted around the Gilbert Islands (Kiribati) and Tuvalu Islands (Tuvalu) in the central Pacific Ocean between 3 and 17 October 2010. This was the first systematic collection of cetacean sighting data in this region. The main objective of the survey was to investigate the occurrence and distribution of cetaceans around Kiribati and Tuvalu. In addition biopsy samples were obtained to investigate the species identity of Bryde's-whale-like baleen whales through genetic analyses and to assess feeding ecology of cetaceans in the survey area through the examination of fatty acids. The survey was carried out using a sighting survey vessel, which covered a total of 1,012 n.miles (≈1,875km). A total of 24 schools (640 individuals) of cetaceans was sighted: three schools (five individuals) of Bryde's-whale-like baleen whales, one school (nine individuals) of sperm whales (*Physeter macrocephalus*), one school (six individuals) of killer whales (*Orcinus orca*), one school (14 individuals) of short finned pilot whales (*Globicephala macrorhynchus*), one school (two individuals) of false killer whales (*Pseudorca crassidens*), eight schools (483 individuals) of spinner dolphins (*Stenella longirostris*), and one school (70 individuals) of striped dolphins (*Stenella coeruleoalba*). Mitochondrial DNA (mtDNA) analyses based on the biopsy samples identified two of the Bryde's-whale-like whales sighted, as of the putative species *Balaenoptera brydei*. Compositions of fatty acids of Bryde's and killer whales are presented. The survey provided new information on the distribution and fatty-acid composition of cetaceans around Kiribati and Tuvalu.

KEYWORDS: BRYDE'S WHALE; DISTRIBUTION; FEEDING ECOLOGY; TAXONOMY; TROPICAL PACIFIC

INTRODUCTION

There is only sporadic information on cetaceans around the waters of Kiribati and Tuvalu (Fig. 1) in the central Pacific (see Miller, 2007 for review). In the waters of Kiribati, the sighting records were mainly from around the Line and Phoenix Islands; there is little information for the Gilbert Islands.

Limited sightings of large whales were reported from surveys in the area conducted by Japanese Scouting Vessels (JSV) from 1964 to 1990 (Miyashita *et al.*, 1995). Within the four 5° squares relevant to the present survey (0°–5°N, 170°E–175°E; 0–5°S, 170°E–175°E; 0°S–5°S, 175°E–180°; and 5°S–10°S, 175°E–180°), effort was limited to the months of March (2 squares with 100–200 n.miles total effort[5], 2 squares with between 3,000–5,000 n.miles total effort), October (2 squares with no effort, 1 square with 100–300 n.miles effort and 1 square with 2,000–3,000 n.miles total effort) and November (2 squares with 100–300 n.miles total effort and 2 squares with 500–1,000 n.miles total effort). For November the authors reported sightings of blue whales (*Balaenoptera musculus*), Bryde's whale-like baleen whales and sperm whales (*Physeter macrocephalus*) – sperm whales were also reported in March. No large whales were sighted in October in that period. Moreover, sightings of small cetaceans were not reported in Miyashita *et al.* (1995).

This note provides information on a dedicated survey carried in the waters of Kiribati and Tuvalu from 3 to 17 October 2010. Where possible, biopsy samples were collected with the objective of undertaking genetic (for taxonomy) and fatty acid (for feeding ecology) analyses.

The taxonomy of the Bryde's whale-like baleen whales is still unresolved (e.g. IWC, In press). Past genetic analysis (e.g. Wada *et al.*, 2003) suggested the existence of three species: the larger ordinary Bryde's whale (*B. brydei*), Eden's whale *(B. edeni*) and Omura's whale *(B. omurai*). The International Whaling Commission (IWC) treats all these taxa as *B. edeni* (IWC, 2001), but recognises that more than one species exists and has recommended a review of the 'species complex'. *B. brydei* and *B. edeni* present three ridges on the dorsal surface of the head typical of Bryde's whales but *B. omurai* does not. *B. brydei* has been reported from all oceans, *B. edeni* has been reported from the Pacific (e.g. Australia, Bangladesh, China, Indonesia, Japan, Myanmar and the Philippines), while Omura's whale is known only from the Solomon Islands and waters around Japan (Reilly *et al.*, 2008). Some consider the Bryde's and Eden's whale to be subspecies of *B. edeni* (Kato and Perrin, 2009; Society for Marine Mammalogy Taxonomy Committee, 2011). Given the uncertainty, particular emphasis was given to obtaining biopsy samples from Bryde's whale-like individuals on this cruise.

MATERIALS AND METHODS

Research area and survey protocol

The research was conducted within the Exclusive Economic Zones (EEZ) of Kiribati and Tuvalu. Planned survey

[5]Total effort refers to the sum of n.miles steamed over the total period 1964-90.

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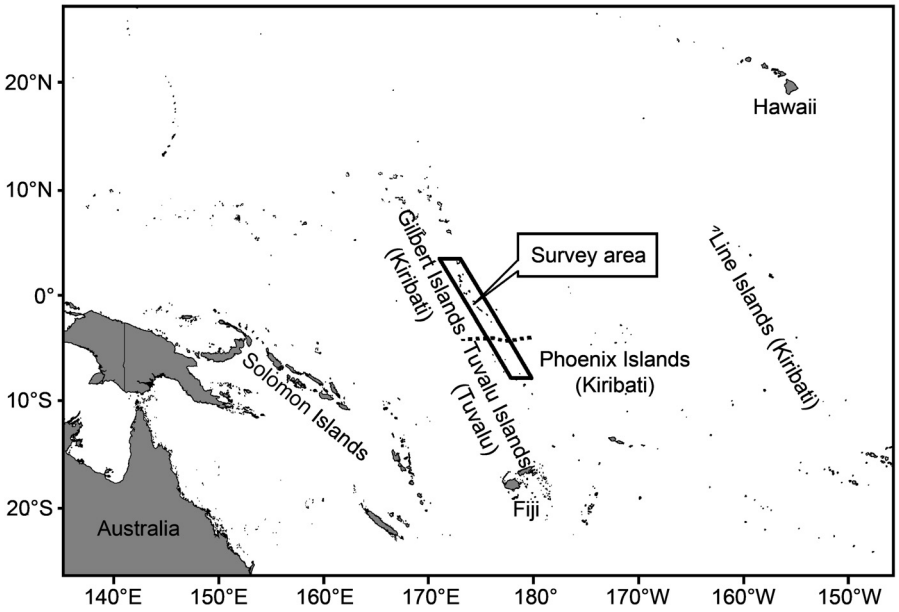

Fig. 1. Area of the cetacean sighting survey carried out in the waters of Kiribati and Tuvalu from 3 to 17 October 2010. Black thick line represents planned survey tracklines.

tracklines (Fig. 1) were set around the Gilbert Islands (the westernmost of the three main island groups of the nation of Kiribati) and the northern part of the Tuvalu Islands (Tuvalu). Research was scheduled for 16 days, from 3 to 17 October 2010.

The survey vessel was the *Kaiko-maru* (KM; 860.25GT); the barrel and front bridge heights are 19.5m and 9m above the water surface, respectively. One of us (HM) acted as the cruise leader while another (IT) acted as a researcher during the survey.

The survey was conducted daily from one hour after sunrise to one hour before sunset in local time. The vessel covered a predetermined trackline at a speed of 10.5knots (19.5km/h). 'On effort' observations were only conducted when visibility was greater than 2 n.miles (3.7km) and wind speed was lower than 20 knots (10.3m/s), i.e. Beaufort 5 or less. When on-effort, two observers were in the top barrel and five observers, including the captain and the researchers, were at the front bridge. No observers worked during off-effort. For each sighting, the distance from the vessel to the whales was estimated using 7×50 binoculars with reticule and the sighting angle with reference to the course of the vessel was estimated using an angle board installed in each observation booth. The survey was conducted in closing mode (all cetacean schools found were approached close enough to confirm species identity, number of individuals in the school and approximate body length of individuals). These data along with sighting positions were recorded. The cruise leader confirmed the species identity while experienced observers in the top barrel made visual estimates of number and body length of individuals. Cetacean groups recorded during on effort and off effort are considered primary and secondary sightings, respectively.

Biopsy sampling

Biopsy sampling was carried out on an opportunistic basis when the sighted schools were approached for confirming species identity and school size. It was carried out from the bow of the vessel with a compound crossbow. Biopsy samples were preserved at –20ºC until analysis.

Genetic analysis

Total DNA was extracted from 0.05g of skin using a standard protocol (Sambrook *et al.*, 1989). Sequencing analysis of the mtDNA control region (about 300bp) was conducted as described in Kanda *et al.* (2007). Sequences of the two Kiribati Bryde's whale-like baleen whales were aligned to 54 haplotypes (unique sequences) identified in a set of Wada *et al.*'s (2003) *B. brydei* from the western North Pacific, western South Pacific (Fiji), eastern South Pacific (Peru) and eastern Indian Ocean (Java), mostly used in Kanda *et al.* (2007); a sequence from Wada *et al.*'s (2003) *B. edeni* collected from coastal waters off Kochi, Japan; a sequence from Wada *et al.*'s (2003)'s *B. omurai* caught from off the Solomon Islands; and a sequence from a North Atlantic sei whale. The genealogy of the mtDNA sequences was estimated using the Neighbor Joining method (Saitou and Nei, 1987) as implemented in the program PHYLIP (Felsenstein, 1993). Genetic distances among sequences were estimated using the program DNADIST of PHYLIP, based on Kimura's 2-parameter model (Kimura, 1980). A transition-transversion ratio of 5:1 was used.

Fatty acids analysis

Analyses were conducted at the Japan Food Research Laboratories (Tokyo, Japan), according to the 'JOCS Standard Methods for the Analysis of Fats, Oils and Related Materials' (Japan Oil Chemists' Society (JOCS), 2009). The blubber samples from biopsies were converted to fatty acid methyl esters by treatment with 1.5ml of 0.5 mol/L NaOH in methanol solution at 100ºC for nine minutes. The fatty acid compositions (%) were then analysed with a gas chromatography mass spectrometer (GC-1700 system; Shimadzu Co., Japan) equipped with a DB-23 capillary column (J&W Scientific, USA). Relative standard deviations in components above 5% were within 2%.

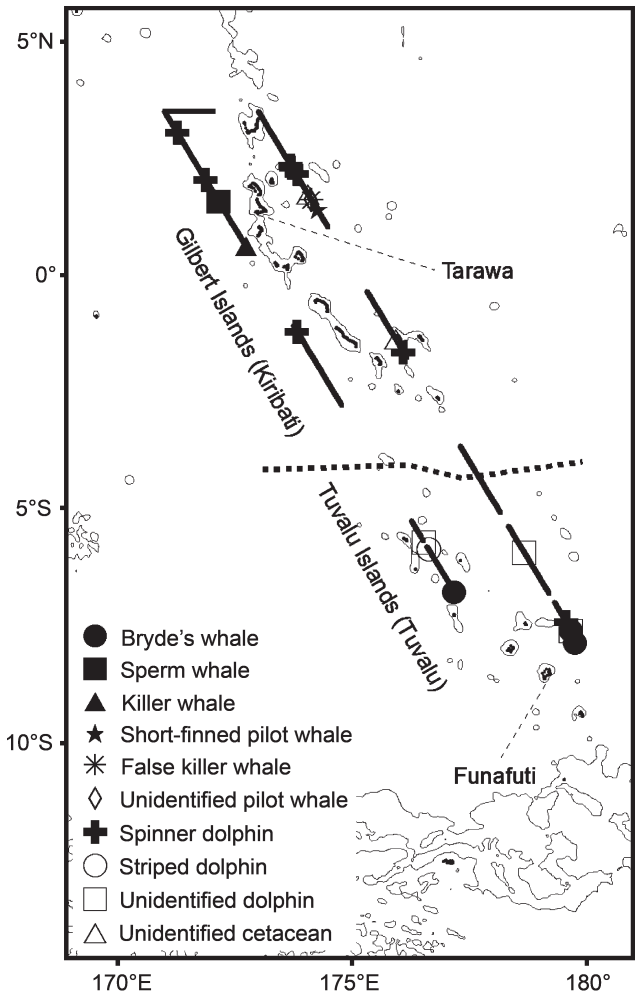

Fig. 2. Sighting positions of cetaceans. Black lines represent surveyed tracklines while grey thin lines represent 3,000m isobaths.

RESULTS

Sighting effort

Fig. 2 shows the tracklines covered by the vessel. The vessel covered 1,012.2 n.miles (1,874.6km) of the planned 1,823.2 n.miles (3,376.8km) on effort (solid black line in Fig. 2) in 95:03 survey hours i.e. about 56%. The survey was conducted under relatively adverse conditions, especially for small cetaceans because strong easterly wind prevailed with a mean of 15.3 knots±2.7SD (7.9m/s±1.4SD), i.e. Beaufort 4. A total of 61% of the total surveyed distance was covered under wind speed more than or equal to 15 knots. Mean surface temperature during the survey period was 27.9ºC±0.7 SD.

Sightings

A total of 24/640 (groups/individuals) of seven identified (although see below for discussion of Bryde's whales) species of cetacean was sighted during the survey (Table 1 and Fig. 2). There was one sighting of pilot whales unidentified to species, five sightings of unidentified small cetaceans and two sightings of unidentified cetaceans. Insufficient sightings were made to develop robust abundance estimates, even for the limited survey area considered.

Biopsy sampling

Two biopsy samples were obtained from two Bryde's-whale-like baleen whales (sample #: KIRI-BR01 and KIRI-BR02) and one from a killer whale (sample #: KIRI-KR01) (Table 2).[6]

[6]Unfortunately no further work can be done on the biopsy samples obtained in this survey other than that reported here as they were lost during the tsunami in Japan on 11 March 2011.

Table 1

Summary of sightings.

Species	Primary sighting		Secondary sighting		Total	
	Group	Individual	Group	Individual	Group	Individual
Bryde's whale	3	5	–	–	3	5
Sperm whale	1	9	–	–	1	9
Killer whale	1	6	–	–	1	6
Short finned pilot whale	1	14	–	–	1	14
False killer whale	1	2	–	–	1	2
Unidentifed pilot whale	1	3	–	–	1	3
Spinner dolphin	7	383	1	100	8	483
Striped dolphin	1	70	–	–	1	70
Unidentifed dolphin	3	29	2	17	5	46
Unidentifed cetacean	2	2	–	–	2	2
Total	21	523	3	117	24	640

Table 2

List of biopsy samples collected during the survey.

Date	Time	Latitude	Longitude	SST (ºC)	Estimated body length (m)	Sample no.
Bryde's whale						
13 Oct	10:31h	7–36.69°S	179–40.21°E	28.8	11.3	KIRI-BR01
14 Oct	07:00h	6–48.17°S	177–10.84°E	28.5	12.8	KIRI-BR02
Killer whale						
16 Oct	07:51h	0–36.53°N	172–44.03	27.2	6	KIRI-KR01

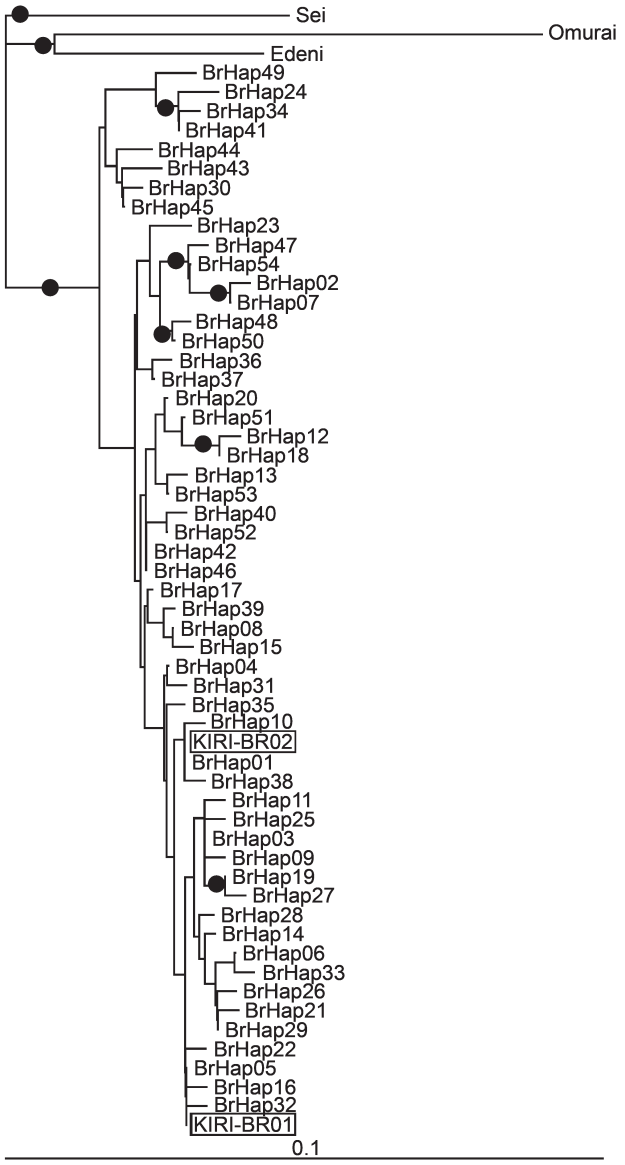

Fig. 3. Tree of mtDNA haplotypes based on neighbour-joining method. The two Kiribati Bryde's whale-like baleen whales (KIRI-BR01 and KIRI-BR02) are shown in squares. These two sequences clustered with 54 haplotypes of the Wada *et al.*'s (2003) *B. brydei* (BrHap##). Terminology of these haplotypes are the same as in Kanda *et al*. (2007). Sequences of the Wada *et al*.'s (2003) *B. edeni* and *B. omurai* and a sequence of a sei whale (*B. borealis*) were used for reference purposes. Clades supported by over 50% in 1,000 bootstrap simulations are indicated by a dot.

Identity of Bryde's-whale-like whales

Fig. 3 shows the neighbour-joining-based genealogy estimated from the mtDNA haplotypes in this study. The two Kiribati Bryde's whale-like sequences (KIRI-BR01 and KIRI-BR02) clustered with the haplotypes of Wada *et al.*'s (2003) *B. brydei*. This was supported by a high bootstrap value.

Fatty acid compositions of Bryde's and killer whales

Table 3 shows the results of the fatty acid analyses in the blubber of one Bryde's whale (KIRI-BR02) and one killer (KIRI-KR01) whale sampled in the survey. It also shows values for Bryde's whales in the western North Pacific (Yasunaga and Fujise, 2004) and killer whales in the eastern North Pacific (Herman *et al.*, 2005).

The ratios of ∑n–3 and ∑PUFA in KIRI-BR02 were higher than that in Bryde's whales from the western North Pacific, while those of oleic acid were in reverse ratio. The ratio of palmitoleic acid (18:1) in KIRI-KR01 was higher than those of the resident and the transient killer whales in the eastern North Pacific, while the ratios of ∑n–3 and ∑PUFA (poly unsaturated fatty acids) were in reverse ratio.

DISCUSSION

Identity of Bryde's-whale-like baleen whales around Kiribati and Tuvalu

The five Bryde's-whale-like baleen whales observed during this survey were visually identified as either Bryde's or Eden's whales not Omura's whales (e.g. three ridges at the top of the head). The genetic analyses confirmed that the two individuals biopsy sampled were Wada *et al.*'s (2003) *B. brydei*, suggesting that it is this species that is found in the waters of Kiribati and Tuvalu, although the sample size is small and the survey period short.

Omura's whales have been observed to the south of the Solomon Islands (around 10ºS and 157ºE) (see Wada *et al.*, 2003) and Yamada (2009) considered that area as the eastern limit of their distribution range. The results of this survey suggest that the range of Omura's whales does not extend to the waters of Kiribati and Tuvalu.

Distribution and environmental factors

Seven species of cetaceans (Bryde's, sperm, killer, short-finned pilot and false killer whales and spinner and striped dolphins) were confirmed in the waters of Kiribati and Tuvalu. These species are commonly distributed in the tropical Pacific such as the Pacific Islands (Miller, 2007), Hawaii (Barlow, 2006), and the eastern tropical Pacific (Wade and Gerrodette, 1993). Compared to the list of Miller (2007), this survey added the confirmed the presence of Bryde's whales, false killer whales and striped dolphins. However, the present survey did not see the following species reported by Miller (2007) for this area: pantropical spotted (*S. attenuata*), Fraser's (*Lagenodelphis hosei*), rough-toothed (*Steno bredanensis*), bottlenose (*Tursiops* spp.) dolphins and Southern bottlenose whale (*Hyperoodon planifrons*) in Kiribati and bottlenose dolphins (*Tursiops* spp.) in Tuvalu. It should be noted that most of the sighting information for Kiribati listed in Miller (2007) was outside and to the east of the present survey area, i.e. around the Line and Phoenix Islands (Fig. 1).

DNA samples obtained from locally consumed individuals on the Gilbert Islands (Baker *et al.*, 2013) indicated that the following four species may be found there: *Mesoplodon* sp. representing either a new species or a subspecies of beaked whale, the dense-beaked whale (*M. densirostris*), Cuvier's beaked whale (*Ziphius cavirostris*) and the pygmy sperm whale (*Kogia breviceps*). It was also reported that melon-head whales (*Peponocephala electra*) were locally consumed in certain islands in Kiribati (Robards and Reeves, 2011). None of these species were seen during this survey. In the past, blue whales were also sighted by JSV (Miyashita *et al.*, 1995). Combining these results, 19 species of cetaceans are potentially found in the waters of Kiribati and Tuvalu. The species diversity is thus similar to Hawaiian waters (24 species; Barlow, 2006) and in the Eastern tropical

Table 3

Compositions of fatty acids (%) in killer and Bryde's whales. ∑SCMU: sum of all short-chain mono-unsaturated fatty acid (C≤16); ∑LCMU: sum of all long-chain mono-unsaturated fatty acids (C>16); ∑PUFA: sum of all poly-unsaturated fatty acids.

	Bryde's whale		Killer whale		
Fatty acids (%)	BR02	WN Pacific*	KR01	EN Pacific (resident)**	EN Pacific (transient)**
12:0	–	0.2	1.4	–	–
14:0	3.4	4.7	6.6	–	–
14:1	0.4	0.6	1.8	4.1	5
15:0	0.6	0.6	0.8	–	–
16:0	14.3	18.7	11.9	5.42	5.5
16:1	10.2	11.4	21.7	21.61	25.18
16:2	0.1	0.1	–	–	–
17:0	0.8	1.1	0.5	–	–
17:1	1	0.9	2	–	–
18:0	4.1	4.4	1.6	0.94	0.93
18:1	31.6	35.3	42.4	27.26	24.45
18:2n-6	1.5	0.9	0.7	–	–
18:3n-3	0.5	0.3	–	–	–
18:4n-3	0.3	0.3	–	–	–
20:0	0.3	0.3	–	–	–
20:1	5.2	1.9	1.3	–	–
20:2n-6	0.3	0.1	–	–	–
20:3n-6	0.2	0.1	–	–	–
20:4n-6	1	0.9	0.4	–	–
20:4n-3	0.8	0.4	–	–	–
20:5n-3	2	1.8	0.1	–	–
21:5	–	0.1	–	–	–
22:0	–	0.1	–	–	–
22:1	1.9	0.6	–	–	–
22:4n-6	0.3	0.3	–	–	–
22:5n-6	0.8	0.7	–	–	–
22:5n-3	2.1	1.4	0.1	–	–
22:6n-3	11.6	8.2	0.4	0.74	0.32
24:1	0.3	0.5	–	0.27	0.1
Unknown	4.4	3.8	6.3	–	–
Σ n-3	17.3	12.3	0.6	3.57	2.14
Σ saturated	23.5	30.2	22.8	14.5	16.68
Σ SCMU	10.6	12.1	23.5	31.8	39.4
Σ LCMU	40	39.1	45.7	46.99	39.38
Σ PUFA	21.4	15.3	1.7	6.74	4.84

*Yasunaga and Fujse (2004).**Herman *et al.* (2005).

Pacific (17 species; Wade and Gerrodette, 1993). Survey coverage of this study was limited both in time (October 2010) and space (around the islands of Kiribati and Tuvalu (within about 45 n.miles (83.34km) from the coastline). For a full understanding of the species diversity of cetaceans in the waters of Kiribati and Tuvalu, spatial and seasonal coverage should be expanded in future surveys.

Our sightings tended to be concentrated in the northern and southern parts of the survey area where water depth is relatively shallow compared to the middle of the survey area. The relationship between water depth, prey distribution and cetacean distribution warrants further consideration when more data throughout the year become available.

Fatty acids of Bryde's and killer whales

Clearly nothing can be concluded on the basis of two samples and further work is needed. The ratios of ∑n–3 and ∑PUFA in an individual of Bryde's whale (KIRI-BR02) in this study were higher than reported for Bryde's whales in the western North Pacific which mainly fed on both fish (Japanese anchovy) and plankton (krill) (Yasunaga and Fujise, 2004); ∑n–3 and ∑PUFA occur in high concentrations in fish (Roche, 1999). This result suggests that main prey of the Bryde's whale examined is fish.

The fatty acid composition of an individual killer whale (KIRI-KR01) in this study was different from those of two ecotypes of killer whales in the eastern North Pacific. The resident and transient whales in the eastern North Pacific fed on fishes, such as salmon, and small mammals, such as belugas and harbor seals, respectively (Herman *et al.*, 2005). Palmitoleic acid was abundant in KIRI-KR01. Palmitoleic acid occurs in high concentrations in baleen whales (Yasunaga and Fujise, 2004). Therefore, the result suggests that this killer whale may have fed on baleen whales.

Role of cetaceans in the ecosystem

Ecosystem models for ecosystem-based fisheries management (mainly focused upon tunas) have been developed for the western and central Pacific including the waters of Kiribati and Tuvalu (e.g. Allain *et al.*, 2007; Senina *et al.*, 2008). Although cetaceans may play important roles in the ecosystem they were not considered in these models, primarily due to the absence of data. Distribution, abundance and feeding data are fundamental input data to ecosystem models. While the data obtained in this study are a useful start, it is clear that further data collection is vital to develop more broadly applicable ecosystem models for management.

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