

A note on radionuclide ^{137}Cs and ^{40}K concentrations in Dall's porpoises, *Phocoenoides dalli*, in coastal waters of Japan¹

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ABSTRACT

Concentrations of artificial radionuclide ^{137}Cs and natural radionuclide ^{40}K in Dall's porpoise, *Phocoenoides dalli*, from the Pacific coast of northern Japan in 1996 are presented. Concentrations of ^{137}Cs in muscle tissue from two male Dall's porpoises were 0.153 ± 0.011 and 0.234 ± 0.016 Bq kg⁻¹ wet weight, and those of ^{40}K were 104.0 ± 0.3 and 107.8 ± 0.9 Bq kg⁻¹ wet weight, respectively. Concentration factors (CF, concentration in animal/concentration in sea water) for the two porpoises are 59 and 90 for ^{137}Cs , respectively. These concentrations and CF values are within published ranges for marine fish in coastal waters. The CFs obtained in this study suggest that the trophic position of Dall's porpoises is similar to that of the large piscivorous fish in the marine community in coastal waters of Japan.

KEYWORDS: DALL'S PORPOISE; RADIOACTIVITY; NORTH PACIFIC OCEAN

INTRODUCTION

The long-lived artificial radionuclide ^{137}Cs is of great interest and importance as an indicator of radioactive pollution in the marine environment. Its major source is the atmospheric deposition of debris from nuclear explosions that occurred between 1954 and 1962, and in 1980. The nuclear accident at the Chernobyl nuclear power station in 1986 has renewed interest in this radionuclide. For a number of years, the dynamics and fate of radionuclides in the ecosystem has been a subject of major interest to applied ecologists and health physicists, and much work on marine organisms has been completed (Baptist and Price, 1962; Hiyama and Shimizu, 1964; Pentreath, 1973; Suzuki *et al.*, 1973; Morgan *et al.*, 1993; Rowan and Rasmussen, 1994). However, it is only recently that transmission mechanisms in the marine community have been demonstrated (Kasamatsu and Ishikawa, 1997; Kasamatsu, 1999a; b). Although a number of measurements of ^{137}Cs levels in marine organisms have been made, little information is available for marine mammals. Marine mammals are consumers of production at most trophic levels and bioconcentration (or bioaccumulation) of contaminants is generally thought to be high for certain contaminants (e.g. heavy metals, organochlorines – Honda *et al.*, 1983; Tanabe, 1985; Subranainan *et al.*, 1986; Reijnders *et al.*, 1999). Information on the concentrations of radionuclides in top predators is necessary to quantify their bioaccumulation through the marine food chain. The Dall's porpoise (*Phocoenoides dalli*) is one of the most abundant cetaceans (more than one million individuals) in the northern part of the North Pacific (Buckland *et al.*, 1994; Miyashita, 1994) and is taken by Japanese coastal fisheries for human consumption (Bjørge *et al.*, 1994; Anonymous, 1997a; Ohizumi, 1998). This paper reports the level of ^{137}Cs in two Dall's porpoises caught off the Pacific coast of northern Japan, along with levels of the naturally occurring radionuclide ^{40}K .

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MATERIALS AND METHOD

Two male Dall's porpoises (total length 203 and 225cm) were taken in the hand harpoon fisheries off Hamanaka on the Pacific coast of Hokkaido on 23-24 October 1996 (Fig.1). Sea water samples (80-200 litres of surface sea water) were also collected in 1996 off the Pacific coast of northern Japan including Hamanaka and Sea of Japan (Fig. 1). Muscle samples (*ca* 5kg) from each animal were frozen and transferred to the Japan Chemical Analysis Center where the major part of the analysis was carried out. After being dried at 105°C, individual samples were ashed at 450°C for 24 hours. Levels of ^{137}Cs and ^{40}K were determined using Gamma-Spectrometry (measurement duration 20 hours). Results are expressed as Bq kg⁻¹ wet weight for ^{137}Cs and ^{40}K . ^{137}Cs concentration of a 50 litre sea water sample was also measured. Caesium was adsorbed onto ammonium molybdophosphate precipitate under acidic conditions and ^{137}Cs was separated using a cation exchange resin column, fixed as caesium chloroplatinate and measured by Gamma-Spectrometry (duration 20 hours).

^{40}K in muscle was measured at the same time as ^{137}Cs by Gamma-Spectrometry. ^{40}K in sea water was not measured.

RESULTS AND DISCUSSION

Table 1 shows the ^{137}Cs and ^{40}K concentrations and the ^{137}Cs concentration factors (CF, concentration in animal/concentration in sea water) in the muscles of the Dall's porpoises. Table 2 shows the ^{137}Cs concentrations in sea water off northern Japan. The ^{137}Cs concentrations in the muscles of the Dall's porpoises were 0.153 ± 0.011 and 0.234 ± 0.016 Bq kg⁻¹ wet weight, and the respective CFs were 59 and 90. Concentrations of ^{40}K were 104.0 ± 0.3 and 107.8 ± 0.9 Bq kg⁻¹ wet weight, respectively.

Radiocaesium originating from weapons fallout is readily soluble and thus available to marine mammals via concentration and transfer through the food chain. Dall's porpoises feed mainly on pelagic fish and squid (Wilke *et al.*,

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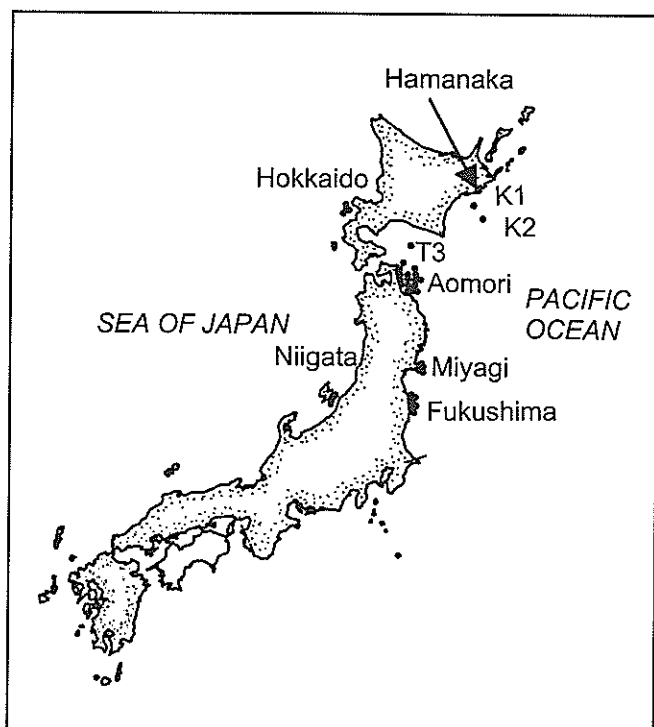


Fig. 1. Sampling areas and sites.

Table 1

Total length, ^{137}Cs and ^{40}K concentrations in muscle tissue (units $\text{Bq}\cdot\text{kg}^{-1}$ wet weight \pm one sigma, the measurement error), and concentration factors CF (based on the mean ^{137}Cs concentration of sea water from Table 2) of ^{137}Cs in Dall's porpoises taken off the Pacific coast of Hokkaido, Japan.

Total length (cm)	Sex	Concentration in muscle		CF ^{137}Cs
		^{137}Cs	^{40}K	
225	Male	0.153 \pm 0.011	104.0 \pm 0.3	59
204	Male	0.234 \pm 0.016	107.8 \pm 0.9	90

Table 2

^{137}Cs concentrations in surface sea waters off northern Japan. n=number of measurements. The spatial and temporal variations of ^{137}Cs concentrations in sea waters were the result of the spatial and temporal variations of the different water masses (or currents) (Inatomi, 1997; Kasamatsu and Inatomi, 1998).

Area	^{137}Cs	n	Sampling month
Sea of Japan (off Hokkaido)	2.9 \pm 0.4	4	Jun. 1996
Sea of Japan (off Niigata)	2.9 \pm 0.1	4	Jun. 1996
Pacific (off Hamanaka)	1.6 \pm 0.1	2	May 1996
Pacific (off Hamanaka)	2.0 \pm 0.4	2	Oct. 1996
Pacific (off Hamanaka, K1,K2)	1.8	1	May 1996
Pacific (off Hamanaka, K1,K2)	2.4	1	Oct. 1996
Pacific (off south Hokkaido T3)	1.7	1	May 1996
Pacific (off south Hokkaido T3)	2.8	1	Oct. 1996
Pacific (off Aomori)	2.6 \pm 0.3	16	May 1996
Pacific (off Aomori)	2.6 \pm 0.4	16	Oct. 1996
Pacific (off Miyagi)	2.7 \pm 0.1	4	May 1996
Pacific (off Fukushima)	2.7 \pm 0.1	8	May 1996
Mean	2.6 \pm 0.3	56	May-Oct. 1996

1953; Wilke and Nicholshon, 1958; Ohizumi, 1998). Mizue *et al.* (1966), Kuramochi *et al.* (1993), Walker (1996), Ohizumi (1998) and Fiscus and Jones (1999) have reported that Dall's porpoises in the northwestern North Pacific and Okhotsk Sea feed mainly on mesopelagic squid (Gonatidae) and fish (e.g. lanternfishes, Myctophidae; Japanese pilchard *Sardinops melanostictus*). These prey items suggest that Dall's porpoises occupy a high trophic position in the marine community.

Kasamatsu and Ishikawa (1997) and Kasamatsu (1999a) suggested that the CF of ^{137}Cs could be used as an *in-situ* tool to evaluate trophic levels in the marine community. For example, the magnitude of the ^{137}Cs CFs for the two Dall's porpoises in the present study are in accord with feeding studies of stomach contents (Ohizumi, 1998). Fig. 2 illustrates the ^{137}Cs levels for various trophic levels and shows that bioaccumulation of this radionuclide occurs (Kasamatsu and Ishikawa, 1997). The CFs reported here suggest that the trophic position of Dall's porpoises is similar to that of large piscivorous fish (Fig. 2). Ohizumi (1998) examined and discussed the food habits of Dall's porpoises taken off northern Japan based on both stomach contents and the $\delta^{15}\text{N}$ (another indicator of trophic levels) of both prey and Dall's porpoises. The $\delta^{15}\text{N}$ levels (9.8-13.4‰) in the Dall's porpoises presented by Ohizumi are similar to those in piscivorous fish (11-15‰, Kasamatsu *et al.*, 1998). This is also in accord with the trophic position suggested by ^{137}Cs CF value for Dall's porpoises reported here.

There is no comparable information on ^{137}Cs levels for Dall's porpoise from other areas. However, information on ^{137}Cs and ^{40}K concentrations of the harbour porpoises, *Phocoena phocoena*, collected in the open North Atlantic, Celtic Sea, Irish Sea and North Sea is available (Rogan and Berrow, 1996; Berrow *et al.*, 1998). Levels of ^{137}Cs were generally between 2-4 (range 0.9-45.0) $\text{Bq}\cdot\text{kg}^{-1}$ (wet weight) during the late 1980s and early 1990s, except for samples from the Irish Sea, where the discharge of low-level radioactive effluents from the Sellafield nuclear plant occurs (Berrow *et al.*, 1998). These levels are 10-20 times higher than those observed in Dall's porpoises off Japan. However, it is to be expected that ^{137}Cs concentrations would be greater in these harbour porpoises since sea water concentrations in the Irish Sea and Scottish waters are substantially higher than those off Japan (McDonald *et al.*, 1991; Kershaw and Baxter, 1995; Anonymous, 1997b; Berrow *et al.*, 1998; Kasamatsu and Inatomi, 1998).

The CFs for the Dall's porpoises in this study are substantially lower than those in Irish and Celtic Seas (CFs 300-600) but similar to those in the North Sea (CFs 100) if the ^{137}Cs concentrations in sea water are taken into account (see Table 3). It should be noted that the ^{137}Cs concentrations in waters of the Irish Sea and the North Sea have decreased substantially since the late 1980s, due to a decrease in discharges from Sellafield (Kershaw and Baxter, 1995). This suggests that equilibrium cannot be assumed between marine organisms and sea water in these waters whereas it can be assumed in the coastal waters of Japan (Kasamatsu and Ishikawa, 1997; Kasamatsu and Inatomi, 1998). Consequently it is difficult to compare the bioaccumulation by marine organisms from the coastal waters of Japan and the UK.

The levels of ^{40}K in Dall's porpoises in Japanese coastal waters are identical to those in harbour porpoises from Irish waters and the North Sea (Rogan and Berrow, 1996; Berrow *et al.*, 1998). Calmet *et al.* (1992) presented the levels of ^{210}Pb , ^{137}Cs and ^{40}K concentrations in spotted, spinner and common dolphins (*Stella attenuata*, *S. longirostris* and

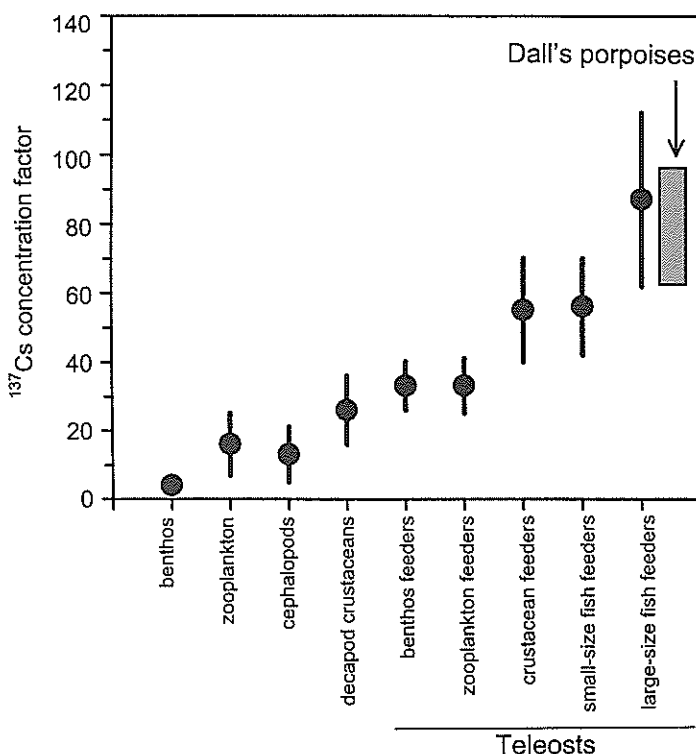


Fig. 2. Concentration factors of ¹³⁷Cs and trophic levels of Dall's porpoises and other marine organisms (modified from Kasamatsu and Ishikawa, 1997).

Delphinus delphis) caught in the tuna purse-seine fishery in the eastern tropical Pacific Ocean between 1977 and 1983. The ¹³⁷Cs CF values (CF 30-100) were similar to those obtained in the present study for Dall's porpoises (CF 60-90), while levels of ⁴⁰K in the three species (391-451 Bq kg⁻¹) were higher than those observed in the Dall's porpoises (04-108 Bq kg⁻¹) in the coastal waters of Japan.

Table 3
Concentrations of ¹³⁷Cs in sea water.

Area	Year	mBq l ⁻¹	Reference
Coastal UK	1989	mainly 20-60	McDonald <i>et al.</i> , 1991
Irish Sea	1993	50	Berrow <i>et al.</i> , 1998
Atlantic seaboard	1993	3.7	Berrow <i>et al.</i> , 1998
Celtic Sea	1993	5.4	Berrow <i>et al.</i> , 1998
North Sea	1993	10-20	Berrow <i>et al.</i> , 1998
Coastal Japan	1996	1.7-2.9	Kasamatsu and Inatomi, 1998

A note of caution should be raised with respect to comparisons of CF values, particularly with low sample sizes. Environmental sources of variability mean that CF values for individuals of the same species can vary greatly, even from similar locations. Additionally, comparisons between species can be problematic, given different feeding ecology. However, the CF values here are in broad accord with those for other cetaceans.

With respect to the bioconcentration of ¹³⁷Cs compared with that of other contaminants in porpoises or dolphins, the ¹³⁷Cs CF values (60-90) observed in the Dall's porpoises are substantially lower than those for metals (Hg or Cd, CF=10⁵-10⁶; Honda, 1990) and organochlorines (PCB, DDT, CF=10⁷; Tanabe *et al.*, 1984) found in striped dolphins (*Stenella coeruleoalba*).

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