Impact of the human activities on cetaceans in the South West Pacific Ocean by measuring ^{137}Cs, ^{40}K and ^{210}Pb

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Introduction

Radionuclides occur naturally in the environment but recently some artificial radionuclides have been introduced. One of the most widespread is the ^{137}Cs isotope. Its major sources come from the atmospheric deposition of debris from atmospheric nuclear explosions that occurred in the 50 and 60's and in the northern hemisphere from nuclear accidents in particular Tchernobyl power station accident that took place in 1986.

The analyses of long-lived artificial radionuclide ^{137}Cs is used as an indicator of radioactive pollution in the marine environment. Along time after the nuclear weapons test were stopped, this radionuclide can be traced in tissues of living organisms.

Many data are available on ^{137}Cs concentrations in pelagic fish, especially tuna species (Suzuki *et al.*, 1973; Young *et al.*, 1975). Some measurements were realized on marine invertebrates (Kasamatsu and Ishiwaka, 1997) but little information is available on marine mammals. Osterberg (1964) and Samuel *et al.* (1970) gave concentrations on mysticetes and Calmet *et al.* (1992) Berrow *et al.* (1998) and Kasatmatsu *et al.* (1999) did measurements on odoncetes. The diet of these two groupes of marine mammals come from different trophic level. Most of the mysticetes feed on plankton whereas the odontocetes or toothed cetacea feed on fish, squid and shrimps.

Recently some studies (Kasatmatsu and Ishiwara, 1997; Watson *et al.*, 1999) examined the mechanisms of transmission of the radionuclides in the marine community showing that in fish the ^{137}Cs concentration increased with rising trophic level and that the biomagnification factor (Cs predator/ Cs prey) equals 2.0.

In marine mammals the bioconcentration is thought to be high. Measurements of radionuclides are necessary on the mammals from the top of the food chain in order to quantify this bioconcentration.

This paper will present results of data analysis of ^{137}Cs, ^{40}K and ^{210}Pb realized on four cetaceans stranded in 1997 on the coast of New Caledonia marine mammals.

Materials and methods

New Caledonia is situated in the South West of the Pacific Ocean between 18° and 23° latitude South and 158° to 170° longitude East. In 1997, four marine mammals stranded on the coast of the island: two pilot whales (*Globicephala macrorhynchus*) and two pygmy sperm whales (*Kogia breviceps*). The conditions of the cadavers varied from fresh to good for stranded animals dead for a few days prior to sampling. During post-mortem examination, morphological data were noted and stomach contents were collected for diet analyses. Skin samples were taken for genetic analyses and teeth were extracted to determine the age by counting the growth layer groups (GLG) (Lockyer, 1995). Then carcasses were dissected and samples of muscle, blubber and liver were taken in order to measure the concentrations of heavy metals and radionuclides ^{137}Cs, ^{40}K and ^{210}Pb. These tissues were weighted to get the wet weight. They were then freeze-dried and finely grounded. Direct measurements of ^{137}Cs, ^{40}K and ^{210}Pb were carried out by gamma spectrometry on the respectively energy rays, 0.661 MeV 1.460 MeV and 0.046 MeV. The counting time ranged between 50,000 and 80,000 seconds.

Concentrations were expressed in $Bq.kg^{-1}$ wet weight and the Cs concentration factor (CFs) was defined as the ratio concentration in the animal on the concentration in the sea water. As the sea water concentration hasn't been measured around New Caledonia, the value of 1.3 $mBq.l^{-1}$ recommended for the SW Pacific by IAEA technical document (1995) was used to calculate the CFs.

Results

The total length of each animal, its sex, the concentrations of ^{137}Cs, ^{40}K and ^{210}Pb and the Cs concentration factors (CFs), are presented in Table 1 for the different tissues of the two marine mammals species sampled.

The ^{40}K concentrations were greater than the ^{137}Cs concentration in the four animals sampled. For the pygmy sperm whales the concentration of ^{137}Cs were higher in the muscle than in the liver than in the blubber. All the measurements done in the blubber were at the detection limits. The ^{40}K concentrations followed the same pattern. For the short-finned pilot whales the concentrations of ^{137}Cs measured in the liver of the two individuals were in the same order of magnitude than those measured in the pygmy sperm whales. Concerning the female it is interesting to note that the concentration found in its muscle was equal to the value measured in its liver whereas for the ^{40}K the concentration was higher in the muscle than in the liver.

The concentrations of ^{210}Pb measured in the muscles and the blubber were very small compared to those found in the liver. In all the measurements, the highest concentrations of ^{210}Pb appear in the liver.

Species	Sex	Length (m)	Tissue	210 Pb (mBq.kg⁻¹)	Cs 137 (mBq.kg⁻¹)	K 40 (mBq.kg⁻¹)	Cs CF
Globicephala	M	5.4	Liver	39±5	0.09±0.02	91±9	70
macrorhynchus	F	3.5	Muscle	<5	0.08±0.03	132±14	62
			Liver	53±12	<0.08	72±10	<62
	M	3.1	Liver	24±6	<0.11	81±11	<82
			Blubber	<1	<0.04	26±4	<30
Kogia breviceps			Muscle	<6	0.26±0.04	171±17	200
	F	3.0	Liver	10±3	0.08±0.03	84±9	62
			Blubber	<7	<0.05	28±5	<38
			Muscle	<6	0.16±0.03	110±11	123

Table 1
Total length, radionuclide concentrations and Cs concentration factors in different tissues of *Kogia breviceps* and *Globicephala macrorhynchus.*

The analyses of stomach contents showed that pygmy sperm whales feed mainly on squid and crustaceans whereas the pilot whales feed mainly on mesopelagic fish and squid. The list of the species identified in the stomach are presented in Table 2. These prey suggested that these marine mammals occupied a high position in the marine community.

The result of the teeth study showed that the two females were old. The male of Kogia was a young animal.

The concentration factors for ^{137}Cs have been calculated using the value for the sea water recommended by IAEA (1995) given as 1.3 mBq.l^{-1} for the South West Pacific in 1995. They are presented on Figure 1. For the pygmy sperm whales the CF ranged from 123 to 200. For the female short finned pilot whales it reached 62.

Discussion

There is no published information on ^{137}Cs levels in short-finned pilot whales or pygmy sperm whales but there are information on harbour porpoises (*Phocoena phoceona*) in North Atlantic, Dall's

Species	Sex	Stomach contents
Globicephala macrorhynchus	M	Fishes : *Bathyclupea malayana* (Bathyclupeidae) *Antigonia sp.* (Caproidae) *Synagrops sp.* (Acropomatidae) *Diaphus sp.* (Myctophydae) *Cubiceps sp.* (Nomeidae) *Chlorophthalmus sp.* (Chlorophthalmidae) Cephalopods : *Stenoteuthis sp.* (Ommastrephidae) 3 unidentified species (Ommastrephidae) *Moroteuthis sp.* (Onychoteuthidae) *Lycoteuthis sp.*? (Lycoteuthidae) *Histioteuthis sp.* (Histioteuthidae) 5 unidentified species (Histioteuthidae)
Globicephala macrorhynchus	F	Stomach empty
Kogia breviceps	M	Shrimps : *Pasiphea sp.* (Pasiphaeidae), *Gnathophausia ingens* Dohrn, 1870 (Mysidacea) *Meningodora sp.* (Oplophoridae). Cephalopods : Taonius sp. (Cranchidae) Octopoteuthidae Histioteuthidae Enoploteuthidae
Kogia breviceps	F	Shrimps : *Pasiphea sp.* (Pasiphaeidae), *Gnathophausia ingens* Dohrn, 1870 (Mysidacea) *Meningodora sp.* (Oplophoridae). Cephalopods : *Histioteuthis sp.* (Histioteuthidae) *Enoploteuthis sp.* ? (Enoploteuthidae) 2 unidentified species

Table 2
Prey identified from the stomach contents.

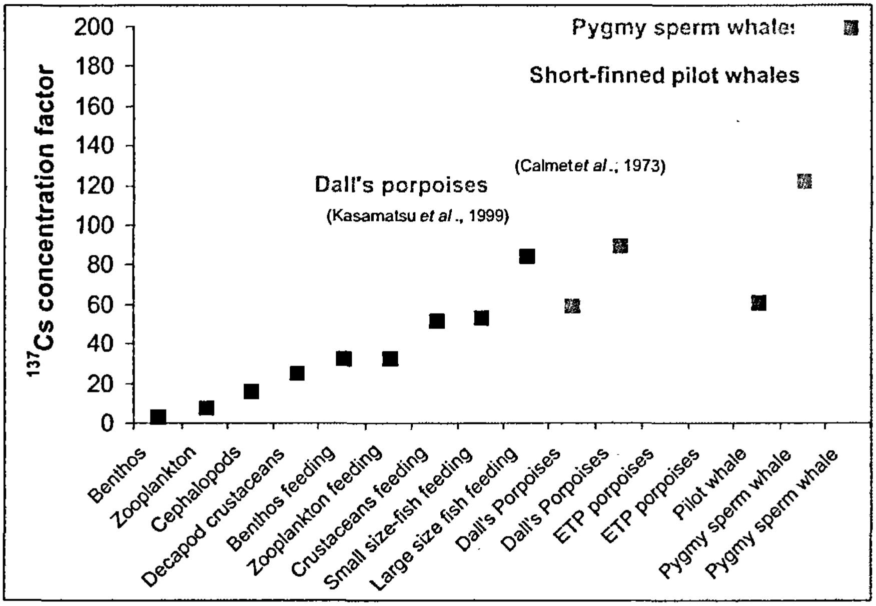

Figure 1
Caesium concentration factor in cetaceans in ETP (Eastern Tropical Pacific), from Kasamatsu and Ishiwaga (1997).

porpoises (*Phocenoides dalli*) in Japan and three species of dolphins in the Eastern Tropical Pacific (*Stenella longirostris, S. attenuata, Delphinus delphis*) (Calmet *et al.*, 1992; Berrow *et al.*, 1998; Watson *et al.*, 1999; Kasamatsu *et al.*, 1999). These information are summarized in Table 3.

The ^{137}Cs concentrations observed in New Caledonia are lower than those measured in the North Atlantic on harbour porpoises and especially when compared to the measurements carried out in the Irish sea. The measurements on the pygmy sperm whales are consistent to the results found by Kasamatsu *et al.* (1999) in Japan on Dall's porpoises and slightly lower to the ones found in dolphins from eastern tropical Pacific (Calmet *et al.*, 1992).

Our sampling is too small to discuss the possible relation between ^{137}Cs concentration and size or age of the animal. Nevertheless we can suggest that the very low ^{137}Cs concentration in the muscle of the female pilot whale could be due to its particular physiologic preg-

Species	Locations	Cs-137 Bq.kg^{-1}	K-40 Bq.kg^{-1}	CFs	Authors
Harbour porpoises	Ireland Sea	5.3-45.0	54 - 99.7	300 - 400	Berrow *et al.*, 1998
	Atlantic seaboard	<1.0-3.4	85.4 - 108.7	500 - 600	
	Celtic sea	<1.0-2.4	66.8- 125.9	300 - 400	
	North Sea	2.2-2.7	90.3 - 106.5	100 - 200	
Dall porpoise	Japan	0.153 - 0.234	104.0 - 107.8	59-90	Kasamatsu *et al.*, 1999
Eastern tropical porpoise	Eastern Tropical Pacific	0.37 - 0.62	125 - 144	30 - 100	Calmet *et al.*, 1992
Common porpoise	Irish sea, UK	37.6	85.0		Kershaw, pers. com.
	Coastal waters of Wales, UK	6.69	97.5		
Short finned pilot whale	New Caledonia	0.08	132	62	Present study
Pygmy sperm whale	New Caledonia	0.16-0.26	110-171	123 - 200	

Table 3
^{137}Cs and ^{40}K concentrations measured in the muscle of marine cetaceans species (Bq.kg^{-1} wet weight).

nancy conditions. Samuels *et al.* (1970) showed that juvenile harp seals had higher concentration than the adults. They suggested that a significant quantity of ^{137}Cs could be transferred to the calf by lactation, like for humans. It is also probable that radionuclides may be transferred during pregnancy. Unfortunately it has not been possible to carry out measurements on the fetus for technical reasons.

The predominance of ^{137}Cs in muscle compared to the other tissues have been shown by Osterberg *et al.* (1964) and Samuels *et al.* (1970) in their studies of the distribution of radionuclides within the body of baleen whales and pinnipeds. This was confirmed for pinnipeds and toothed whales by Calmet *et al.* (1992) and Watson *et al.* (1999).

The values of ^{40}K in short-finned pilot whales and pygmy sperm whales are in the same order of magnitude of the concentrations measured in the other studies.

In all the measurements, there is a higher concentration of ^{210}Pb in the liver than in the muscle. This data shows that liver appears to be a privileged organ for the accumulation of trace metals. Similar results have been found by Calmet *et al.* (1992) in dolphins.

The caesium concentration factor calculated for the stranded cetaceans are in the same order of magnitude as for those found in dolphin in the eastern tropical Pacific (30 to 100) and in the Dall's

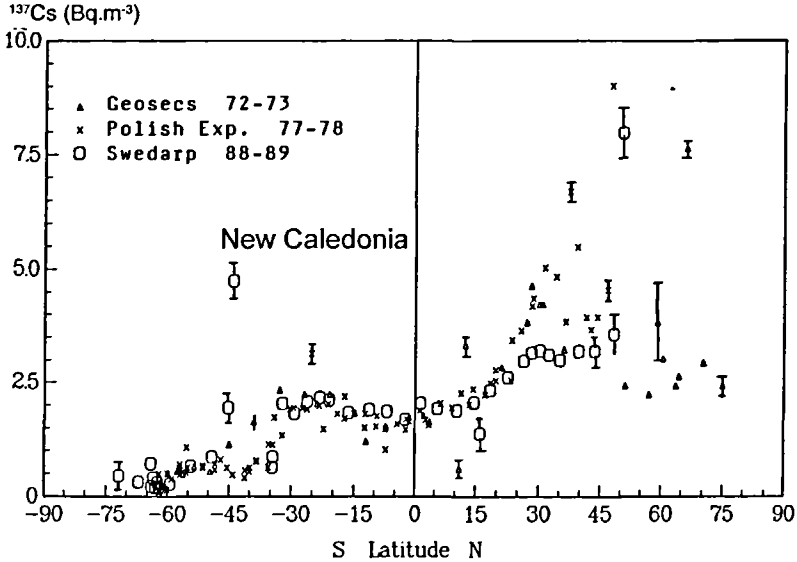

Figure 2
Caesium-137 activity concentrations (Bq.m^{-3}) in surface waters from the North and the South Atlantic in 17972/73 (GEOSECS expedition), 1977/78 (Polish expedition) and 1988/89 (SWEDARP expedition). Extracted from Holm *et al.* (1991).

porpoises in Japan (59 and 90). Kasamatsu and Ishiwaga (1997) wrote that ^{137}Cs falls to earth in a readily soluble form and is transferred up the food chain. Therefore this radionuclide is available to marine mammals via concentration phenomena. Pygmy sperm whales feed on squid and shrimps and short finned pilot whales feed on fish and squid. These two species occupy a high trophic level. The weak concentration factor for the ^{137}Cs in the female short finned pilot whales could be explained by its physiological state as the animal was pregnant. Hence a great part of the ^{137}Cs could have been transferred to the foetus.

Conclusions

The ^{137}Cs concentrations measured in the four stranded marine mammals are low compared to the measurements realised elsewhere. We could hypothesis that this is due to the variation of the radioactivity concentrations in different parts of the ocean, reflecting latitudinal impacts (Young *et al.*, 1975) as shown on the Figure 2 (Holm *et al.*, 1991) due to the difference in the nuclear past between the two hemispheres (lower fallout in the southern hemisphere than in the northern hemisphere).

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