

New observations and a review of killer whale (*Orcinus orca*) sightings in Papua New Guinea waters

Ingrid N. Visser¹ and Frank J. Bonoccorso²

¹*Orca Research Trust, P.O. Box 1233, Whangarei, New Zealand*

²*National Museum & Art Gallery, P.O. Box 5560, Boroko, NCD, Papua New Guinea*

Abstract

Although typically considered a temperate to cold water species, killer whales (or orca) (*Orcinus orca*) have been reported intermittently in tropical waters. While the IUCN (IUCN, 2000) does not list the species as present in Papua New Guinea waters, the records presented here indicate it is found in the area for at least 10 months of the year. A total of 94 sightings of killer whales in Papua New Guinea waters were compiled. Thirty-seven sightings from April 1987 to July 2002 were recorded with an exact date and location, with a further 57 sightings of unknown date or exact location. Twenty-seven of all records had either photographs or videotape to confirm species identification. The earliest reference to killer whales in this region was from 1956, when they were recorded taking fish off long-lines. Killer whales from Papua New Guinea waters have been observed feeding on four species of elasmobranchs (scalloped-hammerhead shark, *Sphyrna lewini*; grey reef shark, *Carcharhinus amblyrhynchos*; manta ray, *Manta birostris*; and blue-spotted ray *Dasyatis kuhlii*) and four species of fin-fish (yellow-fin tuna, *Thunnus albacares*; big-eye tuna, *Thunnus obesus*; Indo-Pacific sailfish, *Istiophorus platypterus*; and sunfish, *Mola mola*). These are the first records, worldwide, of killer whales feeding on scalloped-hammerhead sharks, grey reef sharks and blue-spotted rays. Killer whales in these waters have been reported in association with two species of cetaceans (sperm whales, *Physeter macrocephalus* and spinner dolphins, *Stenella longirostris*). Photo-identification images were collected for 14 individuals and a catalogue established. Matches were made for two animals—a female sighted approximately 30 n mi and two days apart and a sub-adult male sighted in the same region 16 months apart. Some individual killer whales from these waters have been observed with grey under-flukes, in contrast to white, which is typically described for this species.

Key words: Killer whale, *Orcinus orca*, Papua New Guinea, photo-identification, foraging, elasmobranchs, fin-fish.

Introduction

The status of Papua New Guinea cetaceans is largely unknown. The only systematic study of species, or individuals within a species, was conducted in 2001, targeting sperm whales (*Physeter macrocephalus*) (Bonoccorso, unpublished data). Munday (1994) compiled anecdotal information on cetaceans in the Kimbe Bay area (New Britain Island, Papua New Guinea) for a 'Rapid Ecological Assessment' and noted that *Orcinus orca* had been observed. However, only approximate timings of sightings by month or year were given, and only general locations were stated. In addition, although killer whales were listed as 'uncommon', no quantification was given for this classification (Munday, 1994). Although the IUCN Red Data List (IUCN, 2000) does not list killer whales as present in Papua New Guinean waters, they are known to occur intermittently in the area (Cousteau & Richards, 1989; Munday, 1994).

Therefore, following Aragonés *et al.* (1997), who suggest an order of procedures for cetacean research in developing countries (i.e., interviews followed by actual surveys), a preliminary Kimbe Bay Cetacean Research Project was instigated in April 2002. Over a 13-day period, six species were recorded, including killer whales (Visser, 2002a). Details from that survey, along with other records of the species in Papua New Guinea waters are presented here.

Materials and Methods

Records and anecdotal sightings

For this paper, scientific manuscripts, newspapers, dive magazines, books, unpublished newsletters, the

'Internet', anecdotal sightings, and unpublished data were sourced for details of killer whale sightings. Records were divided into two types, 'complete' and 'data-deficient'. For 'complete' records an exact date and an exact location was known (Table 1, Figure 1), whereas for 'data-deficient' records only a month or year was known, or no date at all, and an exact location may not have been known. Because uncertainty in dates could result in confusion, or replication of sightings without dates, 'data-deficient' records were listed in a separate table (Table 2, Figure 2).

Although species identification may be uncertain when suggested by non-specialists, killer whales are considered one of the easiest species of marine mammal to identify at sea based on their size, postocular white patch, and the large dorsal fins on males (Heyning & Dahlheim, 1988). In addition, many observations recorded here were accompanied by photographs or videotape, or the observer had multiple encounters with the species e.g., M. Benjamin and T. Peluso (Table 1).

Photo-identification

Photo-identification uses photographs to record individual congenital and/or acquired identification marks (Hammond *et al.*, 1990). For killer whales, every individual can be uniquely identified from high-quality photographs (Baird, 2000). The dorsal fin is the main feature photographed because it is exposed above water most often (Bigg, 1982). Some killer whale research projects use photographs of only one side of the dorsal fin, e.g., in the Pacific North West (Ford & Ellis, 1999; Ford *et al.*, 1994) and Norway (T. Similä, pers. comm.). However, wherever possible during this study, both sides of the killer whales were photographed, as pigmentation patterns can differ considerably on each side of an animal (Leatherwood *et al.*, 1984; Visser & Mäkeläinen, 2000) and a record of both sides could improve the chances of subsequent matches. Moreover, this allows photographs from the public (which may be taken of either side of an animal) to be matched (Visser & Mäkeläinen, 2000).

Killer whales can also be photo-identified by their distinctive saddle patches (Baird & Stacey, 1988; Bigg, 1982), eye patches (Visser & Mäkeläinen, 2000), pigmentation patterns on the underside of the tail (Visser, 2000b), malformations (Berghan & Visser, 2000), scars from propellers (Visser, 1999b; Visser & Fertl, 2000) and other scars such as teeth rake marks (Baird, 2000; Visser, 1998). Therefore, photographs (including underwater images) and videotape illustrating any unique features were collected.

To catalogue the killer whales, each animal was assigned a unique consecutive number, preceded by the letters PNG, signifying that it was identified in

Papua New Guinea waters, i.e., PNG1, PNG2, PNG3 etc. This catalogue was compared to the nearest geographic population of killer whales for which an identification catalogue is held, i.e., New Zealand.

Agelosex classification

Photo-identified killer whales were grouped by age and sex, following Bigg (1982) and Bigg *et al.* (1990). These groupings were; 'adult male'; 'sub-adult male'; 'female'; 'juvenile'; 'calf'; and 'unidentified'.

Results

'Complete' and 'data-deficient' sightings

Ninety-four sightings of killer whales in Papua New Guinea waters were compiled. Twenty-seven of all records had either photographs or videotape to confirm species identification. Table 1 lists those sightings where exact date and location were known. Of these 'complete' killer whale sightings ($n=37$), 56.7% come from the Kimbe Bay area (West New Britain Island).

Table 2 lists 'data-deficient' sightings ($n=57$), for which exact dates or precise locations could not be established. To enable future researchers access to data and clarity of the records, all known 'data-deficient' records are listed here. However, it is possible that some records in Table 2 are duplicates, e.g., sighting No. 10 (Table 1) and sighting No. 19 (Table 2) both record killer whales at Bradford Shoal, Kimbe Bay in 1994, and both record foraging on a shark, yet these sightings cannot conclusively be shown to be either the same nor different events.

Sightings by month and year

Records from Table 1 and 2 ('complete' and 'data-deficient') were plotted by month, where known ($n=52$) (Fig. 3). The most sightings were recorded in April ($n=15$), followed by July ($n=8$). There were no sightings recorded for January or February (Fig. 3). For a 15 year period (1987–2002) killer whales have been sighted each year (with the exception of 1989 and 1990—Table 1).

Photo-identification

All killer whales photographed in Papua New Guinea, with high quality images, were identifiable. The Papua New Guinea killer whale photo-identification catalogue is currently comprised of dorsal fin, saddle-patch, and eye-patch surface photographs and side-on, full-body and partial-body underwater photographs (catalogue held by Visser). From these images, 14 unique animals were registered in the catalogue (PNG1–PNG14). Of these, two are adult males, three are females, one is

Table 1. 'Complete' records of sightings of killer whales in Papua New Guinea waters (exact date and location known).

Date & Time	Location/ Latitude & Longitude	Photographs/ Videotape	Number of animals (sex/age)	Foraging behaviour	Other details	Source (<i>p.c.</i> = <i>personal communication</i>)
1 23 April 1987 1600–1730 h	Susan's Reef, Kimbe Bay, West New Britain Island 05°17'36"S/150°08'17"E	Underwater photographs	Approximately 15 (1 adult male, calves)		Spy-hopped and looked at boat. Swimmers entered the water and the killer whales approached within 15 m.	M. Benjamin ¹ <i>p.c.</i>
2 26 June 1988 at sunset	Off Auna Village, Wuvulu Island, Bismark Archipelago 01°44'97"S/142°48'95"E	No photographs	3 (1 adult male, 2 females)		Dorsal fins, silhouetted in the distance.	C. Davis ² & L. Prezelin ³ <i>p.c.</i>
3 27 June 1988 0900–1900 h	Off Auna Village, Wuvulu Island, Bismark Archipelago 01°44'97"S/142°48'95"E	Underwater and surface videotape and underwater photographs	3 (1 adult male, 2 females)	0900 h foraging on a 2.1 m manta ray. 1600 h foraging on three 2–3 m grey reef sharks.	Emerged from deeper, one with a manta ray upside-down and fully intact in its mouth, which was shaken, 'torn to pieces', and eaten. By 1600 h one female and male killer whale remained. Three grey reef sharks were caught and each held alive and upside-down before being eaten. Both the male and female caught a shark. Circled the island three times. Adult male had 'bulge' in front of dorsal fin and grey under-flukes. Snorkelled with them.	C. Davis ² & L. Prezelin ³ & J-M. Cousteau ⁴ <i>p.c.</i>
4 7 July 1988	Less than 1 km off the SW corner of Wuvulu Island, Bismark Archipelago 01°44'97"S/142°48'95"E	No photographs	2			P. Munday ⁵ <i>p.c.</i>
5 19 July 1988	Off Wuvulu Island, Bismark Archipelago 01°44'97"S/142°48'95"E	No photographs	Unknown		Observed by people from the local villages.	P. Munday ⁵ <i>p.c.</i>
6 21 July 1988	Off Wuvulu Island, Bismark Archipelago 01°44'97"S/142°48'95"E	No photographs	Unknown		Observed by people from the local villages.	P. Munday ⁵ <i>p.c.</i>

Table 1. Continued.

Date & Time	Location/ Latitude & Longitude	Photographs/ Videotape	Number of animals (sex/age)	Foraging behaviour	Other details	Source (<i>p.c.</i> = personal communication)
7 30 July 1988	Off Wuvulu Island, Bismark Archipelago 01°44'97"S/142°48'95"E	No photographs	Unknown		A report from local people.	P. Munday ⁵ <i>p.c.</i>
8 9 April 1991 0930 h	2 miles off WPR*, Kimbe Bay, West New Britain Island 05°26'34"S/150°05'22"E	No photographs	3 (2 females, 1 calf)		Approached boat. Encounter terminated after 20 min due to dive schedule.	M. Benjamin ¹ <i>p.c.</i>
9 12 November 1991 0900–1300 h	Restorf Island towards WPR*, Kimbe Bay, West New Britain Island 05°17'30"S/150°06'05"E	Surface videotape	5 (1 adult male, 1 sub-adult male)		Adult male with identification feature (notch) to tip of fin.	D. Eglitis ⁶ <i>p.c.</i>
10 25 May 1994	Bradford Shoals, Kimbe Bay, West New Britain Island 05°09'42"S/150°17'78"E	Underwater photograph at WPR*	3 (1 female, 1 calf, 1 unknown)	Foraging on scalloped- hammerhead shark.	Photograph shows female killer whale (or non-sprouted male) with partially consumed shark draped over snout. Many oceanic sharks in the vicinity.	Skinner (1994) G. Skinner ⁷ <i>p.c.</i>
11 24 July 1994	Off WPR*, Kimbe Bay, West New Britain Island 05°26'34"S/150°05'22"E	Underwater photograph at WPR*	3 (1 adult male, 1 female, 1 calf)		Photograph labelled as 'Tammy's Orcas'.	T. Peluso ⁸ & M. Benjamin ¹ , <i>p.c.</i>
12 3 August 1994 1500–1700 h	Near Restorf Island, Navarai Passage, Kimbe Bay, West New Britain Island 05°19'69"S/150°03'58"E	Digitally enhanced photograph at WPR*	4 (1 adult male, 2 females and 1 calf)	Foraging on Indo-Pacific sailfish which appeared to 'explode' when hit.	With the killer whales for 2 h. A sailfish came up and hid under the boat. The visibility was poor. Photograph labelled incorrectly as September 1994.	Czarny (1994) M. Czarny ⁹ & M. Benjamin ¹ <i>p.c.</i>
13 7 April 1995 1000–1100 h	15 miles out from WPR*, Kimbe Bay, West New Britain Island 05°26'30"S/150°20'34"E	No photographs	1 (adult male)		Attempts made to enter the water with the animal, but it avoided the boat and the divers.	M. Benjamin ¹ <i>p.c.</i>

Table 1. Continued.

Date & Time	Location/ Latitude & Longitude	Photographs/ Videotape	Number of animals (sex/age)	Foraging behaviour	Other details	Source (<i>p.c.</i> = <i>personal communication</i>)
14 10 July 1996	Bradford Shoals, Kimbe Bay, West New Britain Island 05°09'42"S/150°17'80"E	Surface photographs	3		Bow riding.	T. Peluso ⁸ <i>p.c.</i>
15 3 December 1996	Inside First Reef, off WPR*, Kimbe Bay, West New Britain Island 05°26'34"S/150°05'22"E	Surface photographs	3		Close approaches to the boat. Some swimming upside-down.	M. Benjamin ¹ <i>p.c.</i>
16 6 October 1997 1200–1430 h	Christine's Reef, then towards Restorf Island, Kimbe Bay, West New Britain Island 05°18'32"S/150°07'35"E	No photographs	At least 20		Seen in association with approximately 12 sperm whales, including calves. They appeared to be hunting the sperm whales. Squid parts floating in the water. When second boat approached, killer whales split off from sperm whales and left area rapidly. Underwater photographs of the sperm whales at WPR*.	T. Peluso ⁸ , M. Benjamin ¹ & M. Westmorland ¹⁰ <i>p.c.</i>
17 10 July 1998	Bradford Shoals, Kimbe Bay, West New Britain Island 05°09'419"S/150°17'59"E	Underwater videotape	3		Bow riding. One animal had grey-underflukes.	T. Peluso ⁸ <i>p.c.</i>
18 3 October 1998 1030–1330 h	Bradford Shoals, Kimbe Bay, West New Britain Island 05°09'42"S/150°17'76"E	Underwater photographs at WPR*	8 (2 adult males, 2 females, 2 juveniles, 2 calves)		Observed underwater from the 'dolphin-nets' of the boat. Males were separate from main group.	J. Johnson ¹¹ <i>p.c.</i> Johnson (1999)

Table 1. Continued.

Date & Time	Location/ Latitude & Longitude	Photographs/ Videotape	Number of animals (sex/age)	Foraging behaviour	Other details	Source (<i>p.c.</i> = personal communication)
19 1999	Cape Matanalem, New Hanover (Lavongai) Island 02°30'43"S/149°57'63"E		3 (1 adult male, 1 female, 1 young calf)		Female and calf swam directly under the boat, adult male remained at a distance from the boat. Local people report this and other groups to be residents.	H. Mandui & G. Summerhayes ¹² <i>p.c.</i>
20 6 April 1999	Kasikasi, Normanby Island 10°12'43"S/161°03'35"E	No photographs	2		Jumping out of waves in rough surf conditions.	D. Mitchel ¹³ <i>p.c.</i>
21 15 April 1999	Off WPR*, Kimbe Bay, West New Britain Island 05°26'34"S/150°05'22"E	Surface videotape	4-5		Sub-adult male had white patch on right-hand side of dorsal fin.	T. Peluso ⁸ & P. Manz ¹⁴ <i>p.c.</i>
22 24 April 1999	Steffen Strait, SW of Kavieng, New Ireland Island 02°41'67"S/150°38'79"E	No photographs	4 (1 adult male, 1 calf & 2 smaller animals)		Snorkelled for about 10 min with them and got as close as 2 m. They swam away to the east.	E. & D. Amon ¹⁵ <i>p.c.</i>
23 31 December 1999 1200 h	Vakuta Island, Trobriand Islands 08°50'0"S/151°20'0"E	No photographs	6 (1 adult male, 2 females, 3 'smaller' animals)		Followed the group for two hours, as they headed South. On a number of occasions they turned upside down and swam looking up. No distinctive markings were noted on any of the animals.	R. Pearce ¹⁶ <i>p.c.</i>
24 16 April 2000	Off WPR*, Kimbe Bay, West New Britain Island 05°26'34"S/150°05'22"E		5-6		No further details known.	T. Peluso ⁸ <i>p.c.</i>

Table 1. Continued.

Date & Time	Location/ Latitude & Longitude	Photographs/ Videotape	Number of animals (sex/age)	Foraging behaviour	Other details	Source (<i>p.c.</i> = personal communication)
25 8 August 2000	Susan's Reef, Kimbe Bay, West New Britain Island 05°17'36"S/150°08'17"E	Surface videotape	5		Bow riding.	B. Dent ¹⁷ & T. Peluso ⁸ <i>p.c.</i>
26 11 September 2000 1400 h	South of Baudisson Island Steffen Strait, SW of Kavieng, New Ireland Island 02°44'88"S/150°38'97"E	Surface photographs	4 (1 adult male, 2 females, 1 calf)		Male surfaced next to the bow and could be touched.	H. Haddock ¹⁶ <i>p.c.</i>
27 21 December 2000 0800 h	East coast of Kirawina Island, Trobriand Islands 08°38'0"S/151°18'2"E		4-5		Followed them for approximately 2-3 n mi. Passed under the vessel.	R. Pearce ¹⁴ <i>p.c.</i>
28 12 November 2001	Near Restorf Is, Kimbe Bay, West New Britain Island 05°17'30"S/150°06'05"E	Underwater photographs	3 (1 sub-adult male, 1 female, 1 juvenile)		<i>Duckling</i> (WPR* boat), positioned in front of them. Entered the water as they swam past. Animals came within 5-7 m. Sighted sailfish on the surface right after encounter. Flukes of adult male appear very wide.	D. Hall ¹⁸ <i>p.c.</i>
29 9 November 2001 Early afternoon	Between Restorf Island and Big MaluMalu Island, Kimbe Bay, West New Britain Island 05°15'90"S/150°38'97"E		3-4, then an additional 1 sighted later		No further details known.	M. Prior ¹⁷ <i>p.c.</i>
30 8 December 2001 1400 h	Between Katavia and Kirawina Island, Trobriand Islands 08°38'0"S/151°18'2"E		Unknown		Could not approach close enough to establish numbers.	R. Pearce ¹⁴ <i>p.c.</i>
31 19 December 2001	East coast of Kirawina Island, Trobriand Islands 08°38'0"S/151°18'2"E	Surface photographs	5		Heading south. Approached divers underwater. Adult male let small boat approach.	R. Pearce ¹⁴ <i>p.c.</i>

Table 1. Continued.

Date & Time	Location/ Latitude & Longitude	Photographs/ Videotape	Number of animals (sex/age)	Foraging behaviour	Other details	Source (<i>p.c.</i> = <i>personal communication</i>)
32 20 March 2002 1000–1030 h	Katavia Island, Trobriand Islands 08°38'0"S/151°18'2"E	Surface photographs	5 (1 sub-adult male)		Animals following edge of reef approximately 1 n mi offshore in a northerly direction.	Visser ¹⁹ unpublished data
33 13 April 2002 1154–1326 h	South of Cape Heussener, Kimbe Bay, West New Britain Island 05°01'51"S/150°11'69"E	Surface photographs	6 (1 adult male, 1 calf)	Foraging on a scalloped-hammerhead shark.	Adult male and one unidentified animal were only sighted once. At 1157 h a female (or 'non-sprouted' male) was sighted with a scalloped-hammerhead shark upside-down, alive, in its mouth. Female with notch in trailing edge of fin.	Visser (2002a)
34 15 April 2002 1320–1400 h	North of Kimbe Village, West New Britain Island 05°29'37"S/150°08'74"E	Surface photographs	5 (1 female, 1 calf)		Heading south towards Bob's Knob Reef. Dispersed animals, difficult to approach. At 1440 h, approximately 50 spinner dolphins were observed high-speed porpoising from the area where the killer whales were last observed. Female with notch in trailing edge of fin. Heading east towards Hoskins airport.	T. Peluso ⁸ & M. Benjamin ¹ <i>p.c.</i> Visser ¹⁹ unpublished data
35 16 April 2002 0400 h	Hanging Gardens Reef, Kimbe Bay, West New Britain Island 05°25'63"S/150°06'12"E	No photographs	3			S. Kalin ²⁰ <i>p.c.</i>
36 8 May 2002 1600 h	Madang Bay 05°11'49"S/145°48'71"E		4		Heading towards Pig Island. Avoided boat.	L. Collins ²¹ <i>p.c.</i>

Table 1. Continued.

Date & Time	Location/ Latitude & Longitude	Photographs/ Videotape	Number of animals (sex/age)	Foraging behaviour	Other details	Source (<i>p.c.</i> = <i>personal communication</i>)
37 11 July 2002	Between Restorf Island and Cape Heussener, Kimbe Bay, West New Britain Island 05°09'72"S/150°06'45"E	No photographs	3		Seen by police, on boat heading to WPR*.	J. Loga ²² <i>p.c.</i>

People cited in Table 1 and/or Table 2:

WPR* Walindi Plantation Resort, Kimbe Bay, West New Britain Province 05°26.341'S: 150°05.223'E. ¹Max Benjamin, Walindi Plantation Resort, P.O. Box 4, Kimbe Bay, West New Britain Province, Papua New Guinea. ²Chuck Davis, Tidal Flats Video Productions, 1215 Surf Avenue, Pacific Grove, CA 93950, United States of America. ³Louis Prezelin, 1281 Ferlo Road, Santa Barbara, CA 93103, United States of America. ⁴Jean-Michael Cousteau, Ocean Futures Society, 325 Chapala Street, Santa Barbara, CA 93101, United States of America. ⁵Phillip Munday, School of Marine Biology and Aquaculture, James Cook University, Townsville, QLD 4811, Australia. ⁶Dale Eglitis, *c/-Walindi Plantation Resort*, P.O. Box 4, Kimbe Bay, West New Britain Province, Papua New Guinea. ⁷Geoff Skinner, 55 Two Bays Crescent, Mt. Martha, Victoria, 3934, Australia. ⁸Tammy Peluso, Walindi Photography, Walindi Plantation Resort, P.O. Box 4, Kimbe Bay, West New Britain Province, Papua New Guinea. ⁹Michael Czarny, 36 Selwyn Avenue, Elwood, Victoria, 3184, Australia. ¹⁰Michele Westmorland, 14128—11th Drive SE, Mill Creek, WA 98012, United States of America. ¹¹Jim Johnson, 1156 Lake Moogerah Rd, Kalbar, Queensland, 4309, Australia. ¹²Herman Mandui, PNG National Museum, Port Moresby & Glen R. Summerhayes, Archaeology and Natural History Research School of Pacific and Asian Studies, Australian National University, Canberra ACT, Australia. ¹³David K Mitchell, Conservation International, P.O. Box 804, Alotau, Milne Bay Province, Papua New Guinea. ¹⁴Peter Manz, *c/-Walindi Plantation Resort*, P.O. Box 4, Kimbe Bay, West New Britain Province, Papua New Guinea. ¹⁵Edith & Dietmar Amon, Lissenung Island Resort, P.O. Box 536, Kavieng, New Ireland Province, Papua New Guinea. ¹⁶Rod Pearce, P.O. Box 320, Lae, Papua New Guinea. ¹⁷Brian Dent, *c/-Tammy Peluso*, P.O. Box 4, Kimbe Bay, West New Britain Province, Papua New Guinea. ¹⁸Holly Haddock, Lissenung Island Resort, P.O. Box 536, Kavieng, New Ireland Province, Papua New Guinea. ¹⁹Maclaren Prior, P.O. Box 767, Kimbe Bay, West New Britain Province, Papua New Guinea. ²⁰David Hall, 257 Ohayo Mountain Road, Woodstock, New York 12498, United States of America. ²¹Ingrid N. Visser, Orca Research Trust, P.O. Box 1233, Whangarei, New Zealand. ²²Sebastian Kalu, *c/-Walindi Plantation Resort*, P.O. Box 4, Kimbe Bay, West New Britain Province, Papua New Guinea. ²³Lorraine Collins, Blue Sea Charters, P.O. Box 494, Madang, Papua New Guinea. ²⁴Joe Loga *c/-Walindi Plantation Resort*, P.O. Box 4, Kimbe Bay, West New Britain Province, Papua New Guinea. ²⁵Andrew Wright, P.O. Box 240, Apia, Samoa. ²⁶Carl Roessler, Sea Images, Inc. P.O. Box 33668, Las Vegas, Nevada 89133, United States of America. ²⁷Tim Rowland, Jais Aben Resort, Aquaventures PNG Ltd, P.O. Box 166, Madang, Papua New Guinea. ²⁸Bill Gleeson, 205 Fern street, West Hartford, CT 06119, United States of America. ²⁹Jeff Kinch, Conservation International, P.O. Box 804, Alotau, Milne Bay Province, Papua New Guinea. ³⁰Jens Lindstrom, University of Upsala, (via Frank Bonaccorso). ³¹Mathew Johnson via Mick Zaletel, *M.V. FeBritia, c/-Walindi Plantation Resort*, P.O. Box 4, Kimbe Bay, West New Britain Province, Papua New Guinea. ³²Bernie Leahy, *c/-Blue Sea Charters*, P.O. Box 494, Madang, Papua New Guinea. ³³Max Letban *c/-Divinal Primary School*, P.O. Box 33, Alotau, Milne Bay Province, Papua New Guinea. ³⁴Bebega Disilale *c/-East Cape Primary School*, Alotau, Milne Bay Province, Papua New Guinea. ³⁵Craig De Wit, Dolphin Enterprises Ltd, P.O. Box 1335, Port Moresby, Papua New Guinea. ³⁶Shane Ritchie, *c/-Walindi Plantation Resort*, P.O. Box 4, Kimbe Bay, West New Britain Province, Papua New Guinea. ³⁷Kevin Baldwin via John Miller *c/-Dive Centre*, Waterfront, Port Moresby, Papua New Guinea. ³⁸Rob van der Loos, Chertan web site, <http://www.chertan.com>. ³⁹Mark Heighes *c/-MY Evening Star* 'Dive Komodo', Labuan Bajo, Flores, Indonesia.

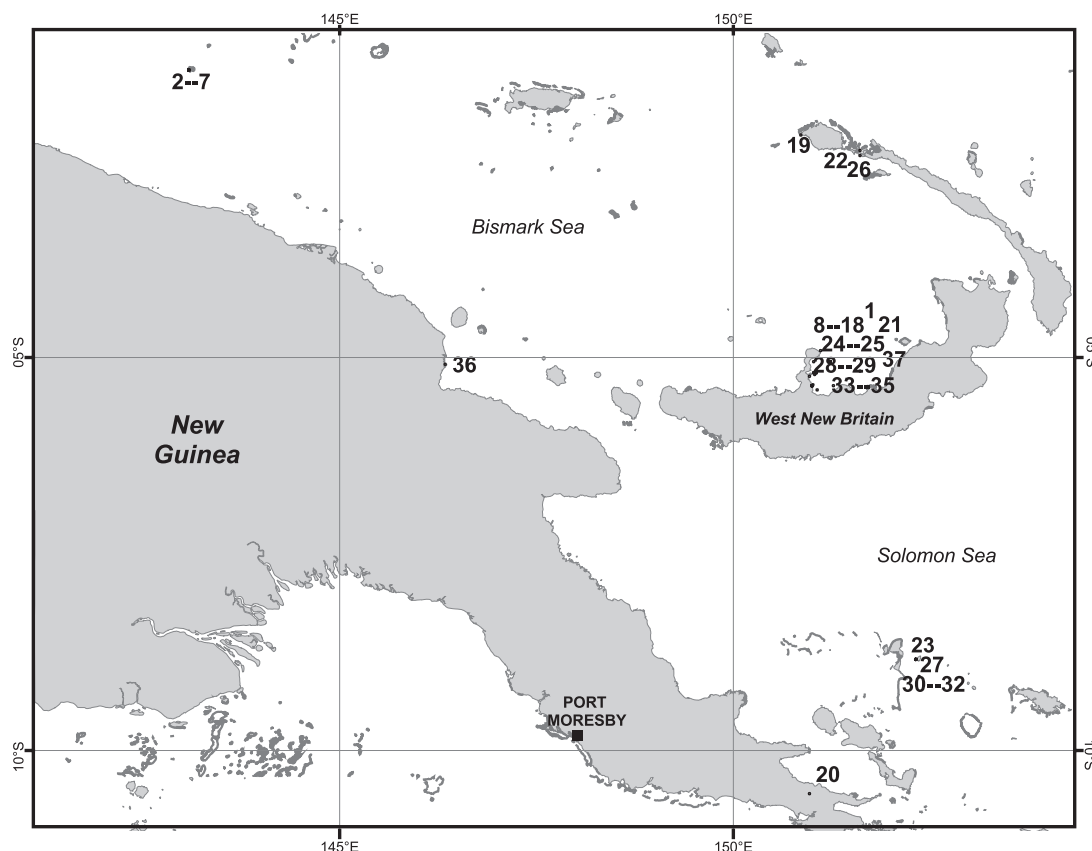


Figure 1. Approximate locations of "Complete" records of killer whale sightings in Papua New Guinea waters (extracted from Table 1).

a sub-adult male, one is a juvenile, two are calves and five are unclassified into any age or sex grouping.

Matches were made for two animals. One, a female with a calf was sighted (13 April 2002) and photographed (Fig. 4), east of Cape Huessener, Kimbe Bay ($05^{\circ}01'51''\text{S}/150^{\circ}11'69''\text{E}$, sighting No. 33, Table 1) and photographed again two days later, to the north of Kimbe Village, ($05^{\circ}29'37''\text{S}/150^{\circ}08'74''\text{E}$, sighting No. 34, Table 1). These locations are approximately 30 n mi apart. A sub-adult male with a distinctive white mark on the right-side of the top of the dorsal fin was photographed in the Kimbe Bay region approximately 16 months apart; however, exact date and location for the resighting were not available (sighting No. 21, Table 1 and sighting No. 34, Table 2).

Two individuals were observed (one in a photograph, and the other in a videotape—sighting No. 3 and No. 17, Table 1, respectively) to have light grey under-flukes (Visser, 2002b) in comparison to the

typical white under-flukes described as diagnostic for the species (Heyning & Dahlheim, 1988).

Group size and composition

Group size varied from one to approximately 20 individuals, with the group sizes of three ($n=15$), of two ($n=11$), of one ($n=9$), and of five ($n=6$) reported most often. Calves were noted 16 times (Tables 1 and 2). Adult males were not recorded in all groups (Tables 1 and 2) and four sub-adult males were noted (Tables 1 and 2).

Foraging behaviour and interactions with other cetaceans

Killer whales in Papua New Guinea waters have been observed foraging on four species of elasmobranchs: four records of scalloped-hammerhead shark (*Sphyrna lewini*) (sightings No. 10 and No. 33 Table 1, and sightings No. 19 and 20 Table 2); three records of grey reef shark (*Carcharhinus amblyrhynchos*) (sighting No. 3, Table 1); two

Table 2. 'Data-deficient' records of sightings of killer whales in Papua New Guinea waters (exact date or location not known).

Date & Time	Location/ Latitude & Longitude	Photographs/ Videotape	Number of animals (sex/age)	Foraging behaviour	Other details	Source
1 1956-1958	Eastern latitudes near New Guinea, New Britain, and Dolak	Not stated	Not stated	Reports of killer whales taking fish off long-lines (target species were tuna).	No further details stated.	Iwashita <i>et al.</i> , 1963
2 1956-1958 During July to December	Eastern latitudes near New Guinea, New Britain, and Dolak	Not stated	Not stated	Reports of killer whales taking fish off long-lines (target species were tuna).	No further details stated.	Iwashita <i>et al.</i> , 1963
3 September 1956	Neighbourhood of 15°S to the south of New Guinea Island 15°15'87"S/154°18'57"E	Not stated	Not stated	Reports of killer whales taking tuna off long-lines. (Various species of tuna mentioned, but none identified specifically).	"The southern limit of the appearance of <i>Orcinus</i> moved to the neighbourhood of 15°S to the south of New Guinea in September 1956".	Iwashita <i>et al.</i> , 1963
4 December 1958	Neighbourhood of 19°S to the south of New Guinea Island 19°00'0"S/154°32'58"E	Not stated	Not stated	Reports of killer whales taking tuna off long-lines. (Various species of tuna mentioned, but none identified specifically).	No further details stated.	Iwashita <i>et al.</i> , 1963
5 Prior to 1964	Around New Guinea and New Britain Islands 07°23'99"S/150°51'359"E	Not stated	Not stated	Taking yellow-fin tuna and big-eye long-lines.	No further details stated.	Sivasubramaniam (1964)
6 Prior to 1972	NW coast of New Guinea Island	Not stated	Not stated			Dawbin, (1972)
7 1980	South of Micronesia and north of Irian Jaya and Papua New Guinea	Not stated	Not stated	Taking yellow-fin tuna and big-eye tuna from long-lines.	"In Papua New Guinea waters the most frequent sightings reported are those from off the coast of north-west New Guinea". "10.2% of tunas hauled were mauled by sharks and killer whales".	(Wright, 1980)

Table 2. Continued.

Date & Time	Location/ Latitude & Longitude	Photographs/ Videotape	Number of animals (sex/age)	Foraging behaviour	Other details	Source
8 1982	1 km off the south coast of Lovangai Island (New Hanover) Trobriand Islands 08°37'41"S/151°12'92"E	No photographs	2 (1 female, 1 calf)		Passed under the boat.	A. Wright ²³ <i>p.c.</i>
9 Approximately 1985	1 km west of Susan's Reef, Kimbe Bay, West New Britain Island 05°17'36"S/150°08'17"E	Underwater photographs	1 (adult male)		On a trip with Bob Halstead, aboard <i>Melanesian Explorer</i> . Spent 1 h with them from approximately 1600 h. Snorkelled with a mother and calf who made close approaches (3 m) underwater. Killer whales visit every year, and the sharks leave.	C. Roessler ²⁴ <i>p.c.</i>
10 April 1987	1 km west of Susan's Reef, Kimbe Bay, West New Britain Island 05°17'36"S/150°08'17"E	Underwater photographs	Approximately 15 (1 adult male, 1 calf)			M. Benjamin ¹ <i>p.c.</i>
11 Unknown, but prior to June 1988	Wuvulu Atoll 01°44'97"S/142°48'95"E	Not stated			Wuvulu residents, quoted in Cousteau & Richards (1989)	M. Benjamin ¹ <i>p.c.</i>
12 April 1989	Near Port Moresby 09°28'06"S/147°08'30"E		'Large group'		Sighted two days in a row (see record No. 13, this table).	M. Benjamin ¹ <i>p.c.</i>
13 April 1989	Near Port Moresby 09°28'06"S/147°08'30"E		'Large group'		Second sighting of what was presumed the same animals (see record No. 12, this table).	M. Benjamin ¹ <i>p.c.</i>
14 April 1991 (during Easter)	Approximately four miles north of WPR*, Kimbe Bay, West New Britain Island 05°22'86"S/150°06'90"E		3		No further details stated.	M. Benjamin ¹ <i>p.c.</i>
15 1991	Bagabag Island, Madang Province 04°47'36"S/146°10'52"E		Not stated		One or more pods each year.	T. Rowland ²⁵ <i>p.c.</i>
16 November 1992	Kavieng, New Ireland Province 02°34'73"S/150°53'11"E		'Several'		No further details stated.	M. Benjamin ¹ <i>p.c.</i>
17 1992	Bagabag Island, Madang Province 04°47'36"S/146°10'52"E		Not stated		One or more pods each year.	T. Rowland ²⁵ <i>p.c.</i>

Table 2. Continued.

Date & Time	Location/ Latitude & Longitude	Photographs/ Videotape	Number of animals (sex/age)	Foraging behaviour	Other details	Source
18 1993	Bagabag Island, Madang Province 04°47'36"S/146°10'52"E		Not stated		One or more pods each year.	T. Rowland ²⁵ p.c.
19 May 1994	Bradford Shoals, Kimbe Bay, West New Britain Island 05°09'42"S/150°17'76"E	Underwater video	2 (1 calf)	Foraging on a hammerhead shark.	Snorkellers entered the water.	Anonymous, (1995)
20 Prior to end of 1994	Kimbe Bay area, West New Britain Island 05°14'12"S/150°10'18"E	Not stated	Individuals or small pods (<4)	Foraging on a scalloped- hammerhead shark.	“Uncommon. Are occasionally seen within Kimbe Bay. Killer whales were seen on three occasions in 1994. At Bradford Shoal they have been filmed eating a scalloped-hammerhead shark.”	Mundy (1994)
21 1994	Bagabag Island, Madang Province 04°47'36"S/146°10'52"E		Not stated		One or more pods each year.	T. Rowland ²⁵ p.c.
22 1995	Bagabag Island, Madang Province 04°47'36"S/146°10'52"E		Not stated		One or more pods each year.	T. Rowland ²⁵ p.c.
23 November 1996	Near Inglis reef, Kimbe Bay, West New Britain Island 05°14'12"S/150°10'18"E	No photographs	2		No further details stated.	M. Benjamin ¹ p.c.
24 December 1996	Western end of New Britain Island 05°38'95"S/148°15'81"E		8		Observed from boat <i>MV FeBrena</i> .	M. Benjamin ¹ p.c.
25 Early December 1996 0830–1030 h	WPR*, Kimbe Bay, West New Britain Island 05°14'12"S/150°10'18"E	No photographs	6 (1 adult male)		Followed to Restorf Island.	M. Benjamin ¹ p.c.

Table 2. Continued.

Date & Time	Location/ Latitude & Longitude	Photographs/ Videotape	Number of animals (sex/age)	Foraging behaviour	Other details	Source
26 Prior to 1996	East Cape, Milne Bay 10°14'64"S/150°53'35"E	Surface photograph, page 143	1 (adult male)	Foraging on a sunfish.	Snorkelled with the killer whale while it was eating. It brought the dead sunfish towards the surface then let it drop. When the sunfish had almost sunk from sight, the killer whale dived for it, brought it back to the surface and dropped again. He did this several times before swimming away. "Orca are seen regularly at this site."	Halstead (1996)
27 March 1997	Witu Islands, West New Britain Province 04°41'57"S/149°25'76"E	Underwater photographs	Not stated	Foraging on a blue-spotted ray.	Observed from boat <i>MV FeBrena</i> .	Gleeson (1997) B. Gleeson ²⁶ & M. Benjamin ¹ p.c. Anderson (1998)
28 Prior to April 1998	Lama Shoal, Witu Islands, West New Britain Province 04°43'10"S/149°32'88"E	No photographs	3		Observed from boat <i>Star Dancer</i> . Entered water with the animals.	
29 April 1988	Panasagusu Islands Calvados chain 10°58'30"S/152°37'73"E		2		On the surface, just outside the lagoon along the reef. Tide had just changed.	J. Kinch ²⁷
30 November 1999	Mwatata Beach, Kiriwina Island, Milne Bay Province 08°33'29"S/151°11'74"E		Approximately 10		The group appeared at mid-day, following the contour of the reef northward.	J. Lindstrom ³⁰ p.c.
31 1999	NW Nuakata Island, Milne Bay Province 10°15'42"S/150°59'62"E	No photographs	2		Two killer whales came close in to the dinghy. Cut the engine and they swam off.	D. Mitchell ²⁸ p.c.
32 1999	Nuakata Island, Milne Bay Province 10°17'30"S/150°59'25"E	No photographs	1		Came alongside the vessel then swam off again.	D. Mitchell ²⁸ p.c.

Table 2. Continued.

Date & Time	Location/ Latitude & Longitude	Photographs/ Videotape	Number of animals (sex/age)	Foraging behaviour	Other details	Source
33 Prior to May 2000	Goshen Strait, East Cape, New Guinea, to Cape Ventenant, Normanby Island 10°12'43"S/150°03'35"E	Not stated			'Frequently sighted.'	D. Mitchell ²⁸ <i>p.c.</i>
34 August 2000	Restorf Island, Kimbe Bay, West New Britain Island 05°17'30"S/150°06'05"E	Surface photographs	6 (1 sub-adult male)		Sub-adult male had white patch on right-hand side of dorsal fin.	M. Johnson ³¹ <i>p.c.</i>
35 December 2000	Rai Coast, Saidor, Madang Province 05°36'02"S/146°26'31"E	No photographs	4-5		Seen killer whales several times moving along the coast. In boat one day and was surrounded by about 4 or 5 of them. One spy-hopped.	B. Leahy ³² <i>p.c.</i>
36 2000	Chamiso Channel, New Hanover Island 02°40'07"S/150°27'89"E				Boat <i>MV FeBrina</i> observed a killer whale give birth, the calf swimming with its umbilical cord still attached. Killer whale sightings are common at least 2-3 times a year.	<i>Via E. & D.</i> Anom ¹³ <i>p.c.</i>
37 March 2001	South Killerton Island, Milne Bay 10°21'23"S/150°39'51"E	No photographs	2 (1 'big', 1 'small')		Coming into the bay with the current. Seen from an outrigger canoe.	M. Leiban ³³ <i>p.c.</i>
38 November 2001	Between WPR* and Restorf Island, Kimbe Bay, West New Britain Island 05°21'82"S/150°27'89"E	No photographs	3		Close into shore 100 spinner dolphins high-speed porpoising in a north eastern direction away from killer whales	M. Prior ¹⁶ & T. Peluso ⁸ <i>p.c.</i>
39 2001	Between Egum atoll & Woodlark/Madau Island, Milne Bay Province 09°06'30"S/152°07'94"	No photographs	2		Animals were heading towards Gawa. Seen from a local trading boat <i>Hwi</i> .	M. Leiban ³³ <i>p.c.</i>

Table 2. Continued.

Date & Time	Location/ Latitude & Longitude	Photographs/ Videotape	Number of animals (sex/age)	Foraging behaviour	Other details	Source
40 2002	Between Boiaboia Waga Island and East Cape, Milne Bay 10°12'98"S/150°53'88"E	No photographs	1		Seas were rough (wind from the SE sector), saw the animal in the lee of the islands.	B. Disilale ³⁴ p.c.
41 'Some years ago'	Manum Island, North of Madang 04°03.715'S/145°06.515'E	No photographs	5 (1 adult male, 1 calf)		With them for over 1 h.	C. de Wit ³⁵ p.c.
42 March (year unknown, prior to 2002)	East Cape, Milne Bay 10°13'97"S/150°52'83"E	No photographs	1		Came from the direction of Cape Vogel, found in deep water.	B. Disilale ³⁴ p.c.
43 April (year unknown, prior to 2002)	East Cape, Milne Bay 10°13'97"S/150°52'83"E	No photographs	2		Came from the direction of Cape Vogel.	B. Disilale ³⁴ p.c.
44 Unknown	Raven Channel, between East Cape & Nuakata Island, Milne Bay 10°15'00"S/150°56'05"E	No photographs	1		Heading towards Normanby Island, following the current.	B. Disilale ³⁴ p.c.
45 Unknown	Star Reefs, Lusancay Islands, Trobriand Islands 08°19'51"S/148°56'99"E	Underwater videotape		Foraging on a manta ray.	Observed from boat <i>MV FeBrita</i> .	T. Peluso ⁸ p.c.
46 Unknown	Bagabag Island, Madang Province 04°49'93"S/146°19'49"E		1 (adult male)		This adult male is thought to be the same male sighted at Stettin Bay (record No. 47, this table). Distance between is a minimum of 350 km.	S. Ritchie ³⁶ p.c.
47 Unknown	Stettin Bay, Kimbe Bay, West New Britain Island 05°23'71"S/150°08'28"E		1 (adult male)		This adult male is thought to be the same male sighted at Bagabag Island (record No. 46, this table). Distance between is a minimum of 350 km.	S. Ritchie ³⁶ p.c.

Table 2. Continued.

Date & Time	Location/ Latitude & Longitude	Photographs/ Videotape	Number of animals (sex/age)	Foraging behaviour	Other details	Source
48 Unknown	Kimbe Bay, West New Britain Island 05°22'63"S/150°10'14"E		2 (1 calf)		Killer whale with a dead calf observed underwater.	T. Peluso ⁸ <i>p.c.</i>
49 Unknown	'Pinnacles' 15 miles south east of Port Moresby 09°42'92"S/147°24'05"E	Surface photographs	'Family group' (1 adult male)		Killer whales were travelling in a south easterly direction along the coast. Approached boat and interacted with snorkellers. Departed when scuba used. Male spy-hopped next to boat. Observed from boat <i>Tiata</i> .	K. Baldwin ³⁷ <i>p.c.</i>
50 Unknown	Planet Channel, New Hanover Island 02°39'98"S/150°29'47"E	Not stated	Not stated	Foraging on a shark (species unknown).		<i>Via E. & D.</i> Anom ¹³ <i>p.c.</i>
51 Unknown	Big Fish Reef, NE of New Hanover Island 02°21'63"/150°22'87"E	Not stated	Not stated		Observed from boat <i>Tiata</i> .	<i>Via E. & D.</i> Anom ¹³ <i>p.c.</i>
52 Unknown	Ward Hunt Strait, Cape Vogel, Milne Bay Province 09°37'32"S/150°05'45"E	No photographs			Occasionally seen.	D. Mitchell ²⁸ <i>p.c.</i>
53 Unknown	Wahoo Point, Milne Bay 10°27'31"S/150°46'58"E	Not stated	Not stated		No further details given.	R. van der Loos ³⁸ <i>p.c.</i>
54 Unknown	Wahoo Point, Milne Bay 10°27'31"S/150°46'58"E	Not stated	Not stated		No further details given.	R. van der Loos ³⁸ <i>p.c.</i>
55 Unknown	Between Basalisk Point & East Cape, north side of Milne Bay 10°23'40"S/150°59'28"E	Surface videotape				M. Heighes ³⁹ <i>p.c.</i>
56 Unknown	Marshal Bennett Group, Trobriand Islands 08°51'14"S/151°54'86"E					M. Heighes ³⁹ <i>p.c.</i>
57 Unknown	Egum Atoll, Trobriand Islands 09°24'09"S/151°53'90"E					M. Heighes ³⁹ <i>p.c.</i>

See Table 1 for footnotes.

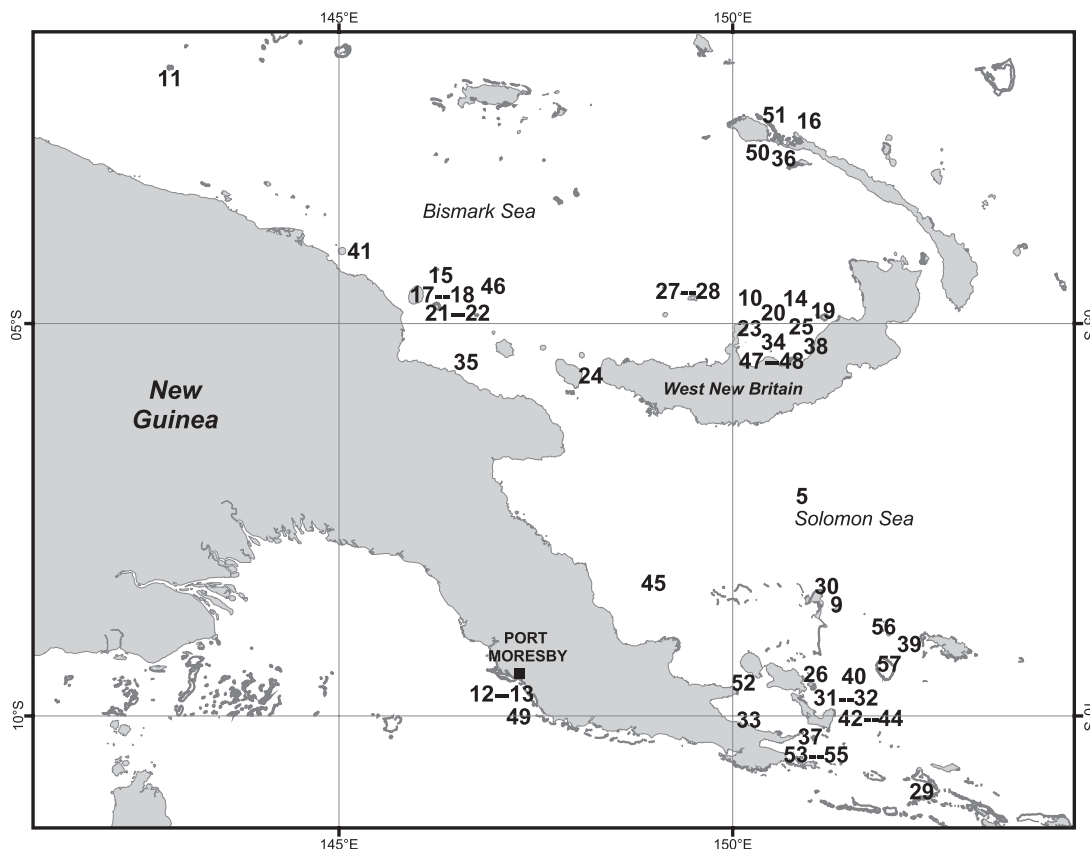


Figure 2. Approximate locations of "Data-deficient" records of killer whale sightings in Papua New Guinea waters (extracted from Table 2).

records of manta ray (*Manta birostris*) (sighting No. 3 Table 1, sighting No. 45, Table 2), and one record of blue-spotted ray (*Aetobatus narinari*) (sighting No. 27, Table 2).

The earliest records of killer whales in Papua New Guinea waters describe the animals removing fish (tuna of various species) from long-lines (Iwashita *et al.*, 1963; Sivasubramaniam, 1964). An additional two species of fin-fish have been identified as free-swimming prey; Indo-Pacific sailfish, *Istiophorus platypterus* (sighting No. 12, Table 1) and sunfish, *Mola mola* (sighting No. 26, Table 2).

During the interaction between an estimated 20 killer whales and 12 sperm whales (*Physeter macrocephalus*) (sighting No. 16, Table 1), anecdotal information suggested that the killer whales could have harassed the sperm whales in an attempt to attack them. Subsequent to the two species separating into their conspecific groups, the sperm whales were observed for approximately 20 min, and their behaviour did not appear to change from when first

encountered. Divers entered the water and were able to take underwater photographs. The killer whales were observed for approximately 20 min as they traveled at high speed in a tight group in a north east direction, until contact was lost (T. Peluso, pers. comm.).

During two other killer whale encounters, spinner dolphins (*Stenella longirostris*) were sighted porpoising at high speed. In encounter sighting No. 38 (Table 2), a group of three killer whales were observed off Restorf Island. After following them for a short period, a group of approximately 100 spinner dolphins were observed to move away from the vicinity, porpoising at high speed. The killer whales were not observed to follow the dolphins and were not resighted. In the second encounter (sighting No. 34, Table 1), a group of approximately 50 spinner dolphins were observed to porpoise at high speed away from an area where killer whales were last sighted surfacing approximately 30 min earlier.

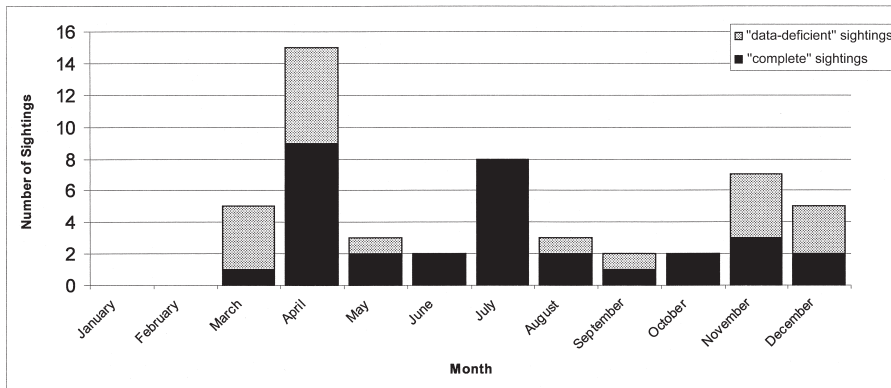


Figure 3. Killer whale sightings in Papua New Guinea, plotted by month where known ($n=52$). Data extracted from Tables 1 and 2.



Figure 4. Female killer whale and calf (catalogue numbers PNG4 & PNG5 respectively). Photographed off Cape Huessener, Kimbe Bay, West New Britain Island, Papua New Guinea, 15 April 2002. The eye-patch of the calf is clearly visible, as is a notch at the anterior base of female's dorsal fin. Both animals show the typical black and white pigmentation pattern of killer whales from this area. Photo: I. N. Visser.

Discussion

Although typically considered a temperate to cold water species, killer whales have been reported from tropical areas around the world (e.g., Dahlheim *et al.*, 1982). Sightings in tropical Oceania, Indo-Pacific and South-east Asia, although not common, are widespread (Table 3). In addition to those sightings listed in Table 3 there are the records from Papua New Guinea presented here (Tables 1 and 2). From these it is apparent that killer whales are not uncommon in Papua New Guinea waters. The people living around the coastline occasionally sight them (Table 1 and 2) and call them in Pidgin English *black white bigpla dolphin* (black and white big-fellow dolphin). The people living in the

southern islands call them *Ulaulasi* in the Tawala language. It is of note that local Papua New Guinea people have names for this species, in that they are familiar enough with them to warrant a specific name (i.e., they do not just classify them as a 'general' dolphin). This is not the case in New Zealand, where although the killer whales are very coastal in their habits (Visser, 1999a; Visser, 2000b) the local Maori people have no names, nor myths or legends about them (Best, 1982a; Best, 1982b; Grace, 1907; Orbell, 1995). The vernacular name 'orca' is used in Papua New Guinea, having been introduced by the expatriate community, which is primarily from Australia and New Zealand.

Table 3. Sightings of killer whales in tropical Oceania, Indo-Pacific and South-east Asia, (for Papua New Guinea sightings see Tables 1 and 2).

Location	Source
Borneo	Beasley (1997); Rudolph (1997)
Federated States of Yap	Reeves (1999); B. Acker (<i>pers. comm.</i>)
Indonesia	Barnes (1991); Hembree (1980); Rudolph (1997); Sivasubramaniam (1964)
New Guinea	Iwashita (1963)
Malaysia	Corkeren (1995)
Naru	Eldredge (1991)
New Caledonia	Das (1993); Garrigue and Greaves (2001)
Palau	Iwashita (1963)
Solomon Islands	Newbert (1995); Shimada (1995)
Thailand	Andersen (1999); Chantrapornsyl (1996)
Tonga	I. N. Visser (unpublished data)

Although there were only 52 sightings in Papua New Guinea waters, for which the month was known (Fig. 3), it appears that killer whales can be found between March and December, inclusive. Iwashita *et al.* (1963) commented that killer whales will stay in the same region (which included Papua New Guinea waters) for at least three months, and based on predation from long-lines, they tend to remain in tropical waters throughout the year.

Apparent peaks in sightings (or lack of sightings) recorded here may be due to observer bias, and/or data collection bias (e.g., weather conditions may not be conducive to cetacean sightings during the 'wet' season of December–February). Observer bias is likely to be a factor contributing to the high number of sightings in April e.g., a survey conducted during this month (Visser, 2002). It is also likely to be a contributing factor to the high number of sightings from the Kimbe Bay area (56.7% of 'confirmed' sightings). This area is one of the few places in Papua New Guinea where, for many years dive boats have made daily trips more than five nautical miles from base (M. Benjamin, *pers. comm.*).

Because there are only two matches within the catalogue, and both are within the same area of Kimbe Bay, it is not possible to suggest any patterns of movement. The two killer whales with grey under-flukes were not the same animal (Visser, unpublished data), and they were observed in different locations (one off Wuvulu Island, and the other at Kimbe Bay). Therefore, it is possible that more killer whales in Papua New Guinea waters may have grey under-flukes, and this may be an indicative pigmentation feature for this population (Visser, 2002b). Further collection of photographs and comparison with catalogues from adjacent areas is encouraged.

Although the primary food source for this population of killer whales is unknown, elasmobranchs form at least part of their prey, with the

first documentation worldwide of killer whales feeding on scalloped-hammerhead sharks, grey reef sharks and blue-spotted rays (Fertl *et al.*, 1996).

There are records of killer whales feeding on rays (*albeit*, different species) from Brazil, the Galápagos Islands, and New Zealand (Fertl *et al.*, 1996; Visser, 1999a), and although a population of killer whales off New Zealand has been recorded eating a wide range of elasmobranchs ($n=8$ species) (Visser, 1999a; Visser, 2000a; Visser *et al.*, 2000) they have not been recorded foraging on grey reef sharks, scalloped-hammerhead sharks, or manta rays. However, grey reef sharks are not found in the temperate waters of the area and scalloped-hammerhead sharks and manta rays are not common, perhaps contributing to these species not recorded as prey for New Zealand killer whales. The only other records of killer whales feeding on manta rays are from the Galápagos Islands (Fertl *et al.*, 1996).

It is noteworthy that where detailed observations were made, all elasmobranchs were held upside-down (Table 1). In some instances the prey were still alive while being carried or when subsequently dropped. New Zealand killer whales have been observed 'flipping' live rays dorsoventrally (Visser, 2000b) and in all instances off New Zealand, where electric rays (*Torpedo fairchildii*) were observed as prey, they were held dorsoventrally (Visser, unpublished data). Elasmobranchs can be a high-risk prey (e.g., the death of a killer whale was attributed to a sting-ray spine (Duignan *et al.*, 2000) and defences such as teeth and electrical charges are also potentially lethal). It is possible, given that elasmobranchs can be induced to exhibit 'tonic immobility' (an unlearned response characterised by a state of immobility, which may last from less than a min to several h) (Henningson, 1994), that

the killer whales invert them dorsoventrally to render them defenceless. However, this should be interpreted with caution, as a lack of response from the prey may be the result of injury, and the position the prey is held by the killer whales may be a consequence of prey shape.

Killer whales have been reported taking fish off long-lines in many areas of the world (e.g., Visser, 2000a) and although tuna have been reported as prey off Papua New Guinea, this seems to be predominately associated with removing them from long-lines (e.g., Iwashita, 1963; Sivasubramaniam, 1964; Visser, 2000a). Killer whales take swordfish (*Xiphias gladius*) from long-lines in Brazilian waters (della Rosa, 1995; Secchi & Vaske, 1998), but the instance reported here, of the killer whales foraging on Indo-Pacific sailfish, is the first for this prey species, and also as a free-swimming prey. Two other records exist for killer whales foraging on sunfish, both from the South Pacific—one off New Zealand (Visser, 2001) and one off the Great Barrier Reef, Australia (Gladstone, 1988).

Jefferson *et al.* (1991) recorded interactions between killer whales and other marine mammals and divided killer whale interactions with other marine mammals into two types; predatory and non-predatory. They reported most attacks on large whales (e.g., sperm whales) were by groups of one to five killer whales, which is well below the group size associated with the sperm whales in sighting No. 16 (Table 1). Although neither predatory behaviour nor avoidance behaviour was observed, acoustic harassment by either species cannot be ruled-out, as no hydrophone recordings were made.

Jefferson *et al.* (1991) did not list any predatory interactions between killer whales and spinner dolphins and listed only one record of non-predatory behaviour where a single killer whale, which had escaped captivity, was seen associating with spinner dolphins off Hawaii (Pryor, 1973). The group size (of both prey and predator), for the two events involving killer whales and spinner dolphins in Papua New Guinea waters (sighting No. 34, Table 1 and sighting No. 38, Table 2), could have influenced the responses of the animals. Group sizes of the killer whales recorded in these interactions were five and three respectively. Although Jefferson *et al.* (1991) recorded instances of harassment of prey by small groups of killer whales (≤ 5), they suggested that attacks on large herds of dolphins (≥ 10 prey) are most common by groups of 6–10 killer whales.

Based on Jefferson *et al.* (1991) we classify the three events presented here (involving killer whales, sperm whales, and spinner dolphins) as non-predatory because there was no apparent attempts at predation by the killer whales (again, acoustic harassment cannot be ruled-out).

It is generally accepted that marine mammals form an important part of the diet of some killer whale populations (Baird, 1994; Baird, 2000; Baird & Dill, 1995; Barrett-Lennard *et al.*, 1996; Ford & Ellis, 1999; Visser, 1999c). Although they have not been recorded as prey in Papua New Guinea, it is unlikely that the dolphins would flee the vicinity of killer whales if they were not potential prey. Flight responses are considered to be 'expensive' in terms of energy expenditure (Ydenberg, 1986), but they are an effective predator avoidance strategy. It is likely, as marine mammal research expands in Papua New Guinea, cetaceans will be reported as prey for killer whales in these waters.

Aragones *et al.* (1997) suggested that preliminary investigations for cetaceans in developing countries could collect anecdotal information and use platforms of opportunity, because resources are often limited for starting such a project. This protocol was followed, and the results presented in a preliminary cetacean survey of Kimbe Bay (Visser, 2002) and herein, suggesting that a research project, targeting killer whales, is not only feasible, but due to the lack of robust information about the species in this area, urgent. Due to the time constraints for platforms of opportunity, such as scuba-diving boats, and the lack of precise data from anecdotal information, we believe that a dedicated vessel, with trained observers, would be most successful. Such a dedicated, long-term project would provide scientific information to assist government and non-government organisations in protecting these animals in Papua New Guinea, where their status is unknown.

Acknowledgments

M. & C. Benjamin of Walindi Plantation Resort hosted the Kimbe Bay Preliminary Cetacean Survey and provided logistical support (including vessels, crew and fuel), without their kind support this study would not have been possible. T. Peluso assisted extensively with data collection, and logistics. Many people provided access to unpublished reports of orca in Papua New Guinea, and their response is gratefully acknowledged. D. Eglitis, A. Dutton, S. Ritchie, the crew of *Fe Brina* and the 'dive crew' at Walindi were helpful beyond words. J. Grove and W. Zender of Zegrahm Expeditions allowed research to be conducted during their Papua New Guinea Expedition. Thanks to B. Nickel who compiled the maps, J. Berghan, P. Munday, J. McDowell, T. Jefferson, S. Imberti and C. Guinet provided helpful comments and reviewed the manuscript.

Literature Cited

Andersen, M. & Kinze, C. C. (1999) Annotated checklist and identification key to the whales, dolphins and

- porpoises (order Cetacea) of Thailand and adjacent waters. *Natural History Bulletin of Siam Society* **47**, 27–62.
- Anonymous. (1995). Walindi & FeBrina Newsletter. Unpublished Report. Walindi Plantation Resort, P.O. Box 4, Kimbe Bay, WNB, Papua New Guinea. Kimbe.
- Aragones, L. V., Jefferson, T. A. & Marsh, H. (1997) Marine mammal survey techniques applicable in developing countries. *Asian Marine Biology* **14**, 15–39.
- Baird, R. W. (1994) Foraging behaviour and ecology of transient killer whales (*Orcinus orca*). Ph.D. Dissertation. Simon Fraser University, Burnaby, British Columbia, Canada.
- Baird, R. W. (2000) The killer whale. Foraging specializations and group hunting. In: *Cetacean Societies: Field Studies of Dolphins and Whales*, J. Mann, R. C. Connor, P. L. Tyack, and H. Whitehead, (eds.), pp. 127–153. University of Chicago Press, Chicago.
- Baird, R. W. & Dill, L. M. (1995) Occurrence and behaviour of transient killer whales: Seasonal and pod-specific variability, foraging behaviour, and prey handling. *Canadian Journal of Zoology* **73**, 1300–1311.
- Baird, R. W. & Stacey, P. J. (1988) Variation in saddle patch pigmentation in populations of killer whales (*Orcinus orca*) from British Columbia, Alaska, and Washington State. *Canadian Journal of Zoology* **66**, 2582–2585.
- Barnes, R. H. (1991) Indigenous whaling and porpoise hunting in Indonesia. United Nations Environment Program Marine Mammal Technical Report. UNEP Report Number 3: 99–106.
- Barrett-Lennard, L. G., Ford, J. K. B. & Heise, K. A. (1996) The mixed blessing of echolocation: differences in sonar use by fish-eating and mammal-eating killer whales. *Animal Behavior* **51**, 553–565.
- Beasley, I. & Jefferson, T. A. (1997) Marine Mammals of Borneo: A preliminary checklist. *Sarawak Museum Journal* **LI**, (No. 72 (New Series)), 193–216.
- Berghman, J. & Visser, I. N. (2000) Vertebral column malformations in New Zealand delphinids with a review of cases world-wide. *Aquatic Mammals* **26**, 17–25.
- Best, E. (1982a) *Maori Religion and Mythology. Volume I*. Government Printer, Dominion Museum Bulletin # 11, Wellington.
- Best, E. (1982b) *Maori Religion & Mythology. Volume II*. Government Printer, Dominion Museum Bulletin No. 11, Wellington.
- Bigg, M. (1982) An assessment of killer whale (*Orcinus orca*) stocks off Vancouver Island, British Columbia. *Report of the International Whaling Commission* **32**, 655–666.
- Bigg, M. A., Olesiuk, P. F., Ellis, G. M., Ford, J. K. B. & Balcomb, K. C. (1990) Social organization and genealogy of resident killer whales (*Orcinus orca*) in coastal waters of British Columbia and Washington State. *Report of the International Whaling Commission Special Issue* **12**, 383–405.
- Chantrapornsil, S., Andulyanukosol, K. & Kittiwathana-wong, K. (1996) Records of cetaceans in Thailand. *Phuket Marine Biological Research Bulletin* **61**, 39–63.
- Corkeren, P. (1995) Report on the trip to the eastern Malaysian states of Sarawak and Sabah, and to Negara Brunei Darussalam—April, May 1995. Unpublished report.
- Cousteau, J.-M. & Richards, M. (1989) *Cousteau's Papua New Guinea Journey*. Harry N. Abrams, Incorporated, New York.
- Czarny, M. (1994). A fax to Irv . . . from Walindi. *Dive Log Australia*. **September**, 6.
- Dahlheim, M. E., Leatherwood, S. & Perrin, W. F. (1982) Distribution of killer whales in the warm temperate and tropical eastern Pacific. *Report of the International Whaling Commission* **32**, 647–653.
- dalla Rosa, L. (1995) Interactions with the longline fishery and information on the feeding habits of the killer whale, *Orcinus orca* Linnaeus 1758 (Cetacea, Delphinidae), in south and southeast Brazil. Masters Thesis. University of Rio Grande, Rio Grande.
- Das, J. P. (1993) Estimation préliminaire concernant la présence de mammifères marines en Nouvelle-Calédonie. Unpublished Report. 3 pp.
- Dawbin, W. H. (1972). Dolphins and whales. *Encyclopaedia of Papua and New Guinea*, P. Ryan, (ed.), Melbourne University Press, in association with the University of Papua New Guinea, Melbourne, 270–276.
- Duignan, P. J., Hunter, J. E. B., Visser, I. N., Jones, G. W. & Nutman, A. (2000) Stingray spines: A potential cause of killer whale mortality in New Zealand. *Aquatic Mammals* **26**, 143–147.
- Eldredge, L. G. (1991) Annotated checklist of the marine mammals of Micronesia. *Micronesica* **24**, 217–230.
- Fertl, D., Acevedo-Gutierrez, A. & Darby, F. L. (1996) A report of killer whales (*Orcinus orca*) feeding on a carcharhinid shark in Costa Rica. *Marine Mammal Science* **12**, 606–611.
- Ford, J. K. B. & Ellis, G. (1999) *Transients: Mammal-hunting killer whales*. University of British Columbia Press, Vancouver.
- Ford, J. K. B., Ellis, G. M. & Balcomb, K. C. (1994) *Killer whales: The natural history and genealogy of Orcinus orca in British Columbia and Washington State*. University of British Columbia Press, Vancouver.
- Garrigue, C. & Greaves, J. (2001). Cetacean records for the New Caledonian area (Southwest Pacific Ocean). *Micronesica* **34**, 27–33.
- Gladstone, W. (1988) Killer whale feeding observed underwater. *Journal of Mammalogy* **69**, 629–630.
- Gleeson, B. (1997). Explore the Bismark Sea. *Skin Diver* **June**, 106–108.
- Grace, A. (1907) *Folktales of the Maori*. Gordon & Gotch, Wellington. p. 257.
- Halstead, B. (1996). *The Dive Sites of Papua New Guinea – Comprehensive Coverage of Diving and Snorkelling*. New Holland (Publishers) Ltd., London.
- Hammond, P. S., Mizroch, S. A. & Donovan, G. P. (1990) Individual recognition and the estimation of cetacean population parameters. International Whaling Commission. Cambridge, United Kingdom. p. 440.
- Hembree, E. D. (1980) Biological aspects of the cetacean fishery at Lamalera, Lembata. Unpublished Final Report to WWF. World Wide Fund for Nature, Switzerland.

- Henningson, A. D. (1994) Tonic immobility in 12 elasmobranchs: Use as an aid in captive husbandry. *Zoo Biology* **13**, 325–332.
- Heyning, J. E. & Dahlheim, M. E. (1988) *Orcinus orca*. *Mammalian Species* **304**, 1–9.
- IUCN. (2000) Hilton-Taylor, C. (compiler). 2000 IUCN Red List of Threatened Species. International Union for the Conservation of Nature, Gland, Switzerland and Cambridge, United Kingdom. xviii+61 pp.
- Iwashita, M., Motoo, I. & Yukinobu, I. (1963) On the distribution of *Orcinus* in the Northern and Southern Pacific equatorial waters as observed from reports on *Orcinus* predation. Original title (Japanese): Shachi no shokugai Hokoku ni yoru Taiheiyo Nan-Boku Sekido Kaiiki no shachi no bunpu ni tsuite. *Tokai Daigaku Suisan Kenkyusho Hokoku. Fisheries and Marine Service (Canada) Translation Series No. 3751 (1976)* **1**, 24–30.
- Jefferson, T. A., Stacey, P. J. & Baird, R. W. (1991) A review of killer whale interactions with other marine mammals: Predation to co-existence. *Mammal Review* **21**, 151–180.
- Johnson, J. (1999). Close encounters of the Walindi kind. *Sportdiving Magazine* **74**, 44–48.
- Leatherwood, S., Balcomb, K. C., Matkin, C. O. & Ellis, G. (1984) Killer whales (*Orcinus orca*) of southern Alaska. Results of field research 1984, preliminary report. Report No. 84-175, pp. 59. H.S.W.R.I. Technical Report, San Diego, CA. Available from Hubbs-Sea World Research Institute, 6295 Sea Harbor Drive, Orlando, FL 32821–8043 USA.
- Munday, P. (1994) Kimbe Bay Rapid Ecological Assessment. Volume 7: Marine Mammals. Unpublished report to The Nature Conservancy, in association with Mahonia na Dari Conservation and Research Centre, P.O. Box 697, Kimbe, West New Britain, Papua New Guinea.
- Newbert, C. (1995) Just when we thought things could not get any better. . . . Unpublished Newsletter. Rainbow Sea Tours, Florida, United States of America. (<http://www.rstours.com>). **7**, 1–13.
- Orbell, M. (1995) *The illustrated encyclopaedia of Maori myth and legend*. Canterbury University Press, Christchurch.
- Pryor, K. (1973) Behaviour and learning in porpoises and whales. *Naturwissenschaften* **60**, 412–420.
- Reeves, R. R., Leatherwood, S., Stone, G. S. & Eldredge, L. G. (1999) Marine mammals in the area served by the South Pacific Regional Environment Programme (SPREP). South Pacific Regional Environment Programme and United Nations Environment Programme.
- Rudolph, P., Smeenk, C. & Leatherwood, S. (1997) Preliminary checklist of Cetacea in the Indonesian archipelago and adjacent waters. *Zoologische Verhandlungen Leiden* **312**, 1–48.
- Secchi, E. R. & Vaske, T. J. (1998) Killer whale (*Orcinus orca*) sightings and depredation on tuna and swordfish longline catches in southern Brazil. *Aquatic Mammals* **24**, 117–122.
- Shimada, H. & Pastene, L. A. (1995) Report of a sighting survey off the Solomon Islands with comments on Bryde's whale distribution. *Report of the International Whaling Commission* **45**, 413–418.
- Sivasubramaniam, K. (1964) Predation of tuna longline catches in the Indian Ocean, by killer-whales and sharks. *Bulletin of Fisheries Research Station, Ceylon* **17**, 221–236.
- Skinner, G. (1994). Orcas at Walindi. *Dive log Australia*. **July**.
- Tomich, P. Q. (1969) *Mammals in Hawaii*. Bishop Museum Press, Honolulu, Hawaii, Honolulu.
- Visser, I. N. (1998) Prolific body scars and collapsing dorsal fins on killer whales in New Zealand waters. *Aquatic Mammals* **24**, 71–81.
- Visser, I. N. (1999a) Benthic foraging on stingrays by killer whales (*Orcinus orca*) in New Zealand waters. *Marine Mammal Science* **15**, 220–227.
- Visser, I. N. (1999b) Propeller scars and known migration of two orca (*Orcinus orca*) in New Zealand waters. *New Zealand Journal of Marine and Freshwater Research* **33**, 635–642.
- Visser, I. N. (1999c) A summary of interactions between orca (*Orcinus orca*) and other cetaceans in New Zealand waters. *New Zealand Journal of Natural Science* **24**, 101–112.
- Visser, I. N. (2000a) Killer whale (*Orcinus orca*) interactions with longlines fisheries in New Zealand waters. *Aquatic Mammals* **26**, 241–252.
- Visser, I. N. (2000b) Orca (*Orcinus orca*) in New Zealand waters. Ph.D. Dissertation. University of Auckland, Auckland.
- Visser, I. N. (2001) Foraging behaviour and diet of (*Orcinus orca*) in New Zealand waters. *Proceedings of the 14th biennial conference on the biology of marine mammals*, Vancouver, Canada. November 28–December 3, 2001.
- Visser, I. N. (2002a) Kimbe Bay Preliminary Cetacean Survey Report. Unpublished report submitted to Walindi Plantation Resort and Mahonia na Dari Conservation and Research Centre, P.O. Box 4, Kimbe, West New Britain, Papua New Guinea
- Visser, I. N. (2002b) Pigmentation as an indicative feature for populations of killer whales. *Proceedings of the Orca Symposium*, Niort, France. 23–28 September, 2002.
- Visser, I. N., Fertl, D., Berghan, J. & van Meurs, R. (2000) Killer whale (*Orcinus orca*) predation on a shortfin mako shark (*Isurus oxyrinchus*), in New Zealand waters. *Aquatic Mammals* **26**, 229–231.
- Visser, I. N. & Fertl, D. C. (2000) Stranding, resighting and boat strike of a killer whale (*Orcinus orca*) off New Zealand. *Aquatic Mammals* **26**, 232–240.
- Visser, I. N. & Mäkeläinen, P. (2000) Variation in eye patch shape of killer whales (*Orcinus orca*) in New Zealand waters. *Marine Mammal Science* **16**, 459–469.
- Wright, A. (1980). An investigation of Japanese longline tuna fishing operations in the region of Papua New Guinea. Research Bulletin. G. Yamamoto, (ed.), Papua New Guinea Government (Department of Primary Industry). Port Moresby (Papua New Guinea), pp 49.
- Ydenberg, R. C. (1986) The economics of fleeing from predators. *Advances in the study of behaviour* **16**, 229–249.