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MARINE MAMMAL SCIENCE, 16(2):459–469 (April 2000)

VARIATION IN EYE-PATCH SHAPE OF KILLER WHALES (*ORCINUS ORCA*) IN NEW ZEALAND WATERS

Individual killer whales can be recognized by variations in shape, size, and scarring of the dorsal fin and in a lightly pigmented area behind the dorsal fin called the "saddle patch" (Bigg 1982). By photographing these distinctive marks some populations have been closely monitored and individuals followed over periods of years (von Ziegesar *et al.* 1986, Baird 1994, Ford *et al.* 1994). In addition to using dorsal fin and saddle-patch photos, some researchers have used eye-patch photos to supplement identification (Guinet 1991; Baird 1994; Visser, unpublished data). However, no published catalogs include eye-patch photographs.

There is very limited literature on variation in eye patches between and within killer whale populations around the world. Although a few papers mention the eye patch in passing (Jehl *et al.* 1980, Heyning and Dahlheim 1988), details are limited to those described by Carl (1945) (who was the first to publish and draw notice to the individual variation in eye patches), Evans and Yablokov (1978), and Evans *et al.* (1982). Evans *et al.* (1982) collected photographs of eye patches from eight regions around the world. Although the eye patch has not commonly been considered a valuable tool in photo-identification, we present findings that show it is unique to each individual and has high variation. We present photographic evidence to show eye patches remain consistent over time and give a basic measurement technique for comparison of eye-patch size within and between populations.

The observations reported here were collected as part of a long-term study (ongoing since December 1992) of the killer whale population around New Zealand. To date (December 1998) 117 individuals have been photo-identified (Visser 1999), using methods developed by Bigg *et al.* (1987). The photographic catalog (Visser, unpublished data) consists of images showing congenital and acquired characteristics of individual dorsal fins, saddle patches and eye patches.

Although each eye patch is distinctly different, the photographs were assembled into categories in which similarly shaped patches were grouped and labeled alphabetically (Fig. 1). Descriptive names were given to each category, *e.g.,* "Smooth," "Hooked," and "Bumps." Generally we found little variation in the shape of the posterior portion of the New Zealand eye patches, therefore patches were assigned to categories based on the shape of the anterior portion of the patch. However, three eye patches had distinctive variations in the posterior portion and were placed in a category described as "Rear Variation" (Fig. 1), regardless of the anterior shape. When both eye patches from an individual were photographed, each was considered independently, based on the assumption that there may be asymmetry of pigmentation patterns (Leatherwood *et al.* 1984).

Orientation of the eye patch was determined following Evans *et al.* (1982); an imaginary line was drawn through the long axis of the eye patch and was extended until it intersected the outline of the animal's body. This allows the angle of the eye patch to be determined in relation to the rest of the animal; it is a relative measurement only (Fig. 2).

Variation in the size of eye patches was quantified from photographs, using a ratio measurement. This measurement compares the distance from the front of the blowhole to the anterior base of the dorsal fin, with the length of the eye patch (Fig. 3).

A blind test was set up to ascertain if eye-patch photos could be used to identify individual killer whales independently and just as consistently as dorsal-fin photos. Photographs which were unfamiliar to the senior author, from the Center for Whale Research (CWR) (Friday Harbor, Washington State, U.S.A.), were used. Left-dorsal-fin, right-dorsal-fin, left-eye-patch, and right-eye-patch photographs were compared. These photos were also used to establish the long-term stability of eye patches. The blind test resulted in a minimum of 89% successful identifications using any one of the four features, *i.e.*, left or right eye-patch or saddle-patch photographs. The remaining 11% of unmatched images were either out of focus, from an oblique angle, or part of the dorsal fin or eye patch was obscured. The eye patch of an adult female killer whale (L11) photographed in 1976 (K. Balcomb) was consistent over 15 yr, as a photograph taken in 1991 (D. Ellifrit) clearly shows the distinctive leading edge and a small "dip" in the upper edge (Fig. 4).

In New Zealand, 98 eye-patch photographs were collected from 68 different animals. The distribution of eye patches in each of the nine categories is given in Table 1. The most common type of eye patch was the "Hook" variety (n = 33, 33.67%) with "Hook and Bump" shapes the next most common (n =

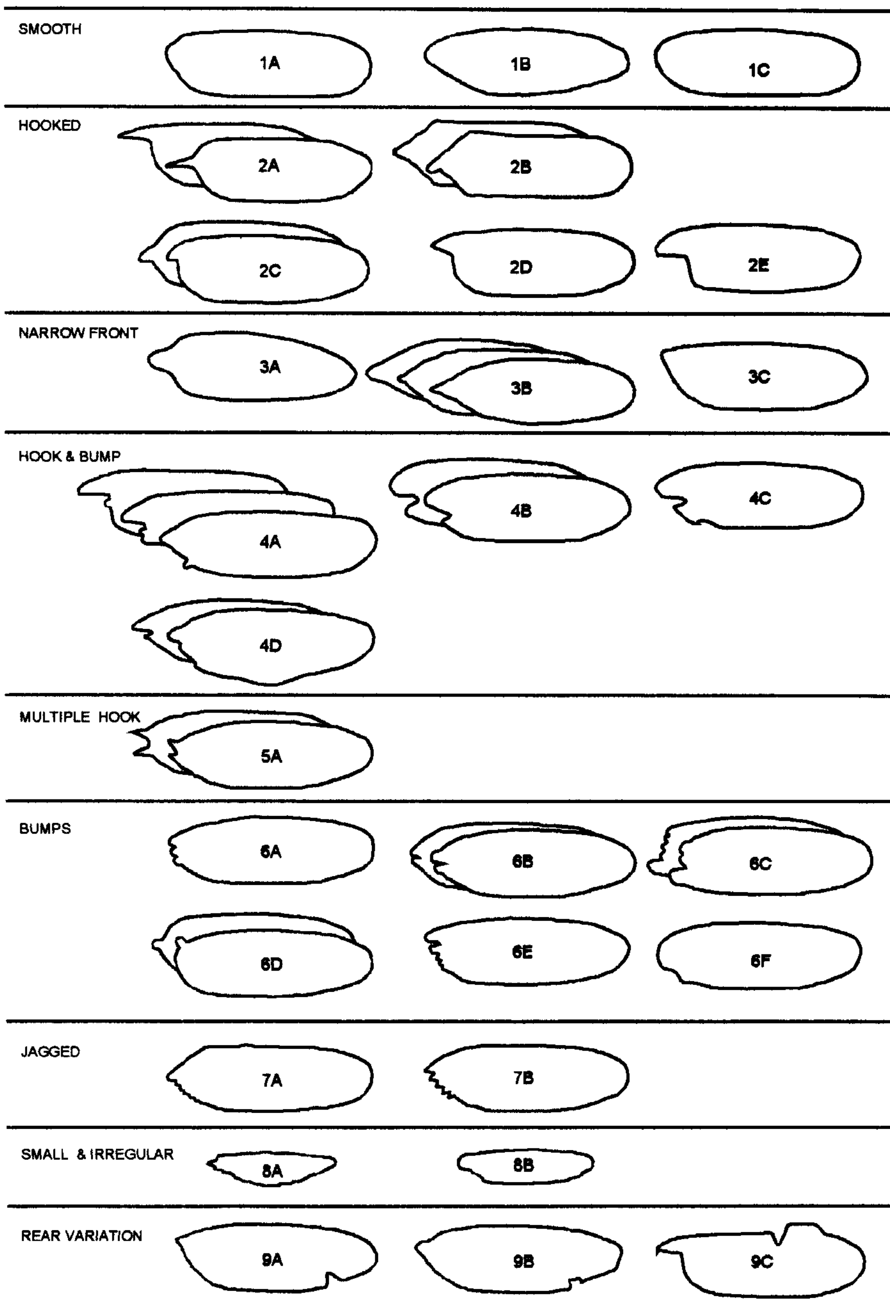

Figure 1. Variation in killer whale eye-patch shape in New Zealand waters.

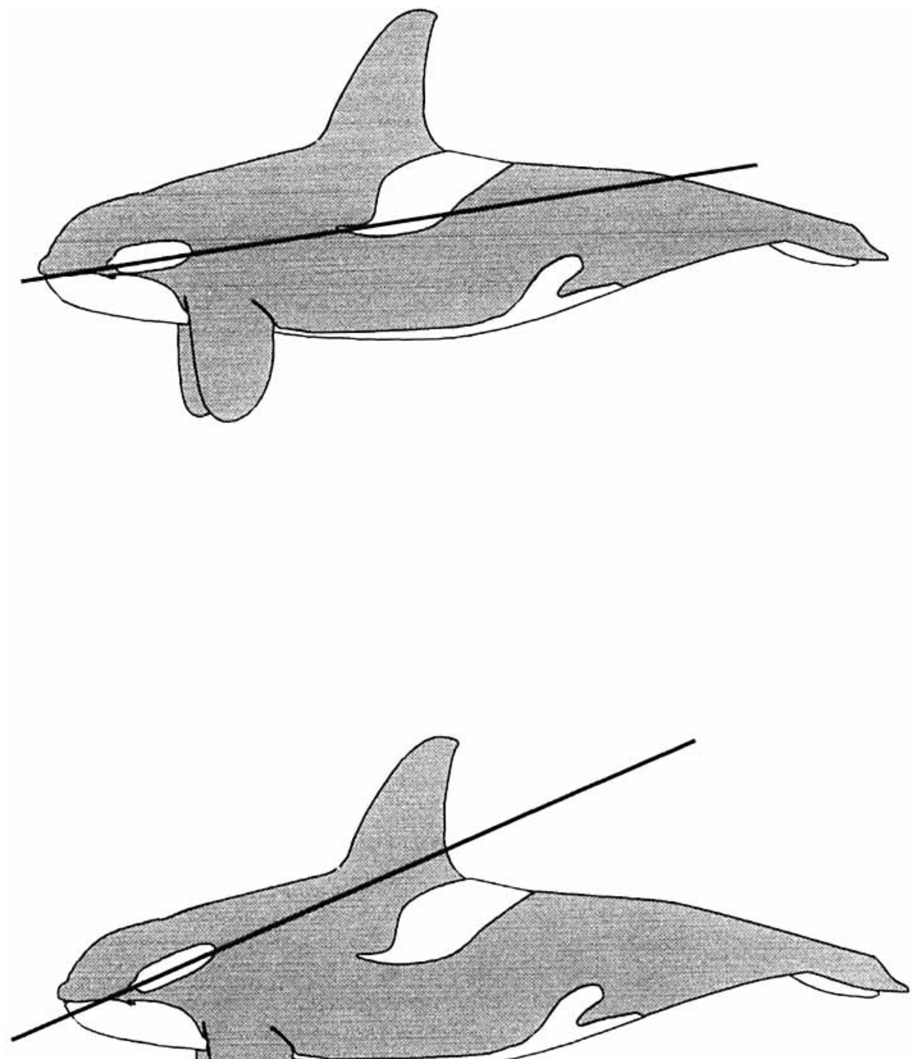

Figure 2. Orientation of eye patch (after Evans *et al.* 1982). "Parallel" orientation above; "angular" orientation below (drawing by P. Mäkeläinen).

20, 20.41%). The least frequent patch types were the "Multiple Hook" (n = 3, 3.06 %) and the "Small and Irregular," (n = 2, 2.04%). For 29 animals, both left and right eye-patches were photographed. Fifteen of these had similar eye-patches and 14 were asymmetric (Table 2).

With regard to the angular orientation of the eye patch, all New Zealand animals (with the exception of two from a 1955 stranding; Baker 1983, Rob-

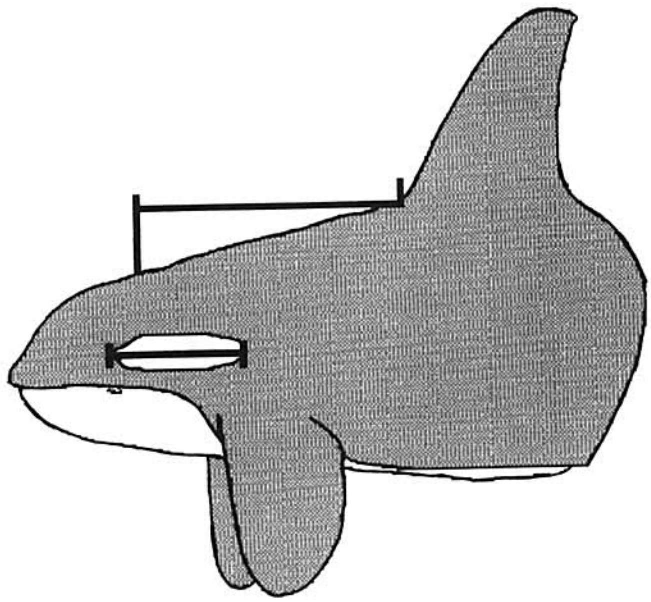

Figure 3. Ratio measurement of eye patch (drawing by P. Mäkeläinen).

son 1984) had what we termed a 'parallel' orientation, where the imaginary line drawn through the long axis of the eye patch intersected the outline of the body at the posterior end of the tail stock (Fig. 2). The two specimens from the 1955 stranding had eye patches with an "angular" orientation, where the line intersecting the eye-patch exited in front of the dorsal fin (Fig. 2, 5).

Ninety-eight percent of the eye patches fell between 2:3 and 3:7 in their size ratio. The exceptions were from two of the 17 whales that stranded in 1955, Category 8 ("Small and Irregular"). These animals had exceptionally small eye patches (Fig. 5), resulting in a ratio of 7:2 (compare Fig. 5 with Fig. 6). No other reports of killer whales with such small eye patches have been published.

Bigg (1982) stated that calves and young individuals often have few other unique features apart from scars. Baird and Stacey (1988) did not include

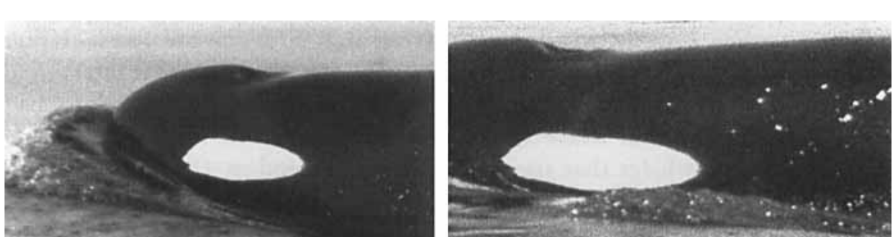

Figure 4. Eye-patch photographs showing consistency over time. Left eye patches of same female (L11) from Washington: (a) 1976 (photo K. Balcomb), (b) 1991 (photo D. Ellifrit).

Table 1. Distribution of eye patch shapes of New Zealand killer whales, by category.

Category		Number of patches	Percent
1A–1C	smooth	5	5.10
2A–2E	hooked	33	33.67
3A–3C	narrow front	14	14.29
4A–4D	hook & bump	20	20.41
5A	multiple hook	3	3.06
6A–6F	bumps	14	14.29
7A–7B	jagged	4	4.08
8A–8B	small & irregular	2	2.04
9A–9C	rear variation	3	3.06
	Total	98	100

calves in their cataloging of saddle-patch variations, due to the patches being indistinct. However, calves have very obvious eye patches compared to saddle patches, even though they may be yellowish in color. Photographs of eye patches may help with identification of the calf in subsequent encounters (Matkin *et al.* 1994). A young animal often lifts the head clear of the water, allowing eye-patch photos to be obtained (Fig. 6). In the eastern North Pacific researchers have been collecting eye-patch photos of calves less than two years old, as they have found that they are more developed than the saddle patch.[1]

Eye-patch photographs may also help when comparing historical archives. In New Zealand, a female killer whale stranded in 1993. Photographs of the stranded animal were taken at night and do not show the fin or saddle patch clearly. However, due to the contrast of white against the black body color, the eye patch is highly visible. In 1996, 1997, and 1998 this animal was resighted, photographed, and identification was confirmed, based on matching the eye patches.

Jehl *et al.* (1980) commented that the eye patch (in particular, angular orientation) in conjunction with the "bipartite cape," may be used to designate three different populations in the waters adjacent to the Antarctic. However, they showed only one example. Evans *et al.* (1982) found two main population differences when considering the angular orientation of the eye patch. Killer whales near the ice edge of the Antarctic had an imaginary line that intersected the dorsal fin, or base of the dorsal fin, and those found farther offshore had an "angular" orientation where the line intersected behind the fin, similar to those seen in the whales that stranded in New Zealand in 1955 (Fig. 5).

There are conflicting reports in the literature with regard to the symmetry of pigmentation in killer whales. Evans *et al.* (1982) stated that most of the main color-pattern components are symmetrical, an exception being the saddle

[1] Personal communication from Robin Baird, Biology Department, Dalhousie University, Halifax, NS B3H 4J1, Canada, June 1999.

Table 2. Differences between left and right eye patches of same animal (n = 29). Categories relate to Figure 1. Although eye patches may be symmetrical with respect to category, each is unique in details.

Killer whale NZ#	Category			
	Left		Right	
NZ3	jagged	B	bumps	B
NZ4	narrow front	A	jagged	A
NZ6	jagged	B	jagged	B
NZ7	bumps	C	hook & bump	A
NZ9	hook & bump	B	hooked	B
NZ15	bumps	D	hook & bump	A
NZ20	bumps	C	hooked	C
NZ23	smooth	C	smooth	C
NZ24	bumps	B	hook & bump	B
NZ25	hooked	E	hooked	E
NZ26	hooked	A	hooked	A
NZ27	hooked	A	hooked	A
NZ28	narrow front	B	narrow front	B
NZ39	hooked	C	hooked	C
NZ47	narrow front	B	narrow front	B
NZ87	hooked	A	hooked	A
NZ88	hook & bump	A	hooked	E
NZ89	narrow front	A	narrow front	A
NZ91	hooked	A	hooked	A
NZ92	hook & bump	B	hook & bump	B
NZ93	hook & bump	D	hooked	A
NZ95	hooked	B	hooked	B
NZ101	hook & bump	D	hooked	D
NZ105	multiple hook	A	narrow front	A
NZ107	hooked	A	hooked	A
NZ109	rear variation	B	hooked	A
NZ110	hook & bump	D	bumps	D
NZ111	multiple hook	A	hooked	A
NZ112	hooked	D	hooked	D

patch. However Leatherwood *et al.* (1984) suggested that there is an asymmetry of pigmentation patterns. Our findings show that eye patches may be either the same on both sides (n = 15) or different (n = 14). Asymmetry of pigmentation has also been reported for fin whales, *Balaenoptera physalus* (Agler *et al.* 1990). Although killer whale eye patches may be similar in shape on both sides, each is unique and should be considered as such when being used for photo-identification purposes. If possible, photographs should be taken of both eye patches, or one side compared consistently for analysis.

The killer whale is not the only species of cetacean with lighter pigmentation in the postocular area. Long-finned pilot whales (*Globicephala melas*) (Oliver 1924, Aguayo 1975) and short-finned pilot whales (*Globicephala macrorhynchus*) (Yonekura *et al.* 1980) have been recorded with a "postocular blaze"

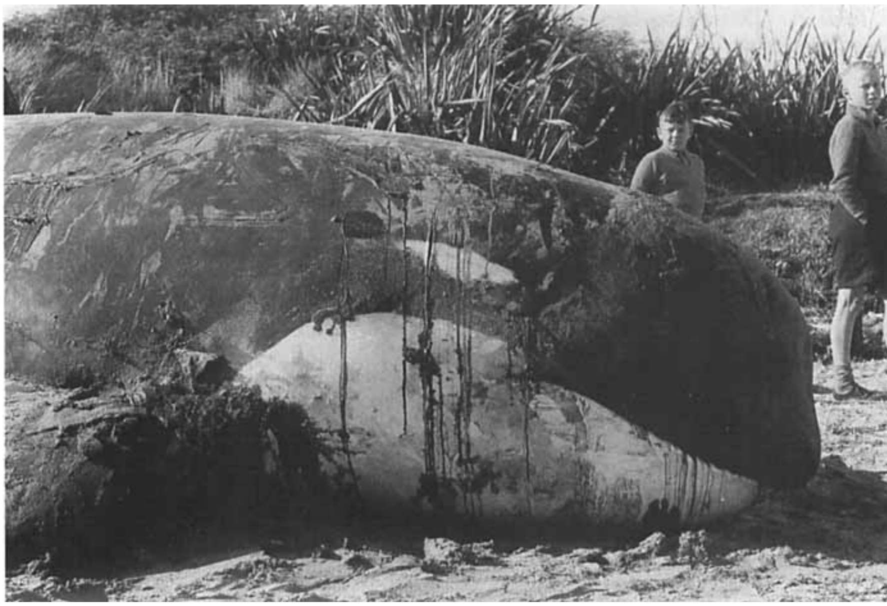

Figure 5. "Small and irregular" eye patch (photo courtesy Museum of New Zealand).

which varies from animal to animal (Mitchell 1970). Some bottlenose dolphins (*Tursiops truncatus*) seen in New Zealand waters have a "brush stroke" of pigmentation starting in or near the postocular position (Visser, unpublished data). We believe that collecting photographs of these distinguishing features may also be useful in the individual identification of other cetacean species.

As each killer whale eye patch is as unique and individualistic as saddle patches and fin shapes, it is possible to distinguish between individual killer whales using only eye patches. They appear to remain unchanged over long periods of time and may aid in matching an animal that has new marks or scars on its fin or saddle patch. Using eye patches may also provide flexibility in identification procedures in situations where obtaining standard left-side dorsal fin photos is difficult, for instance if lighting is bad or when animals are traveling close to shore with their left sides facing shorewards. In focal-animal behavioral studies, knowing both the left and right sides of an animal is advantageous, particularly when observations are being made from the shore or some other platform that cannot be maneuvered.

Eye-patch photographs are already collected and included in some unpublished catalogs, but we have found no formalized suggestions in the literature to use them in this manner. Although it is important to recognize the disadvantages of departing from a standardized identification protocol which helps facilitate comparisons between study areas, we propose that where funding and other logistics allow, subsequent published catalogs include eye patches as a useful supplementary identification tool.

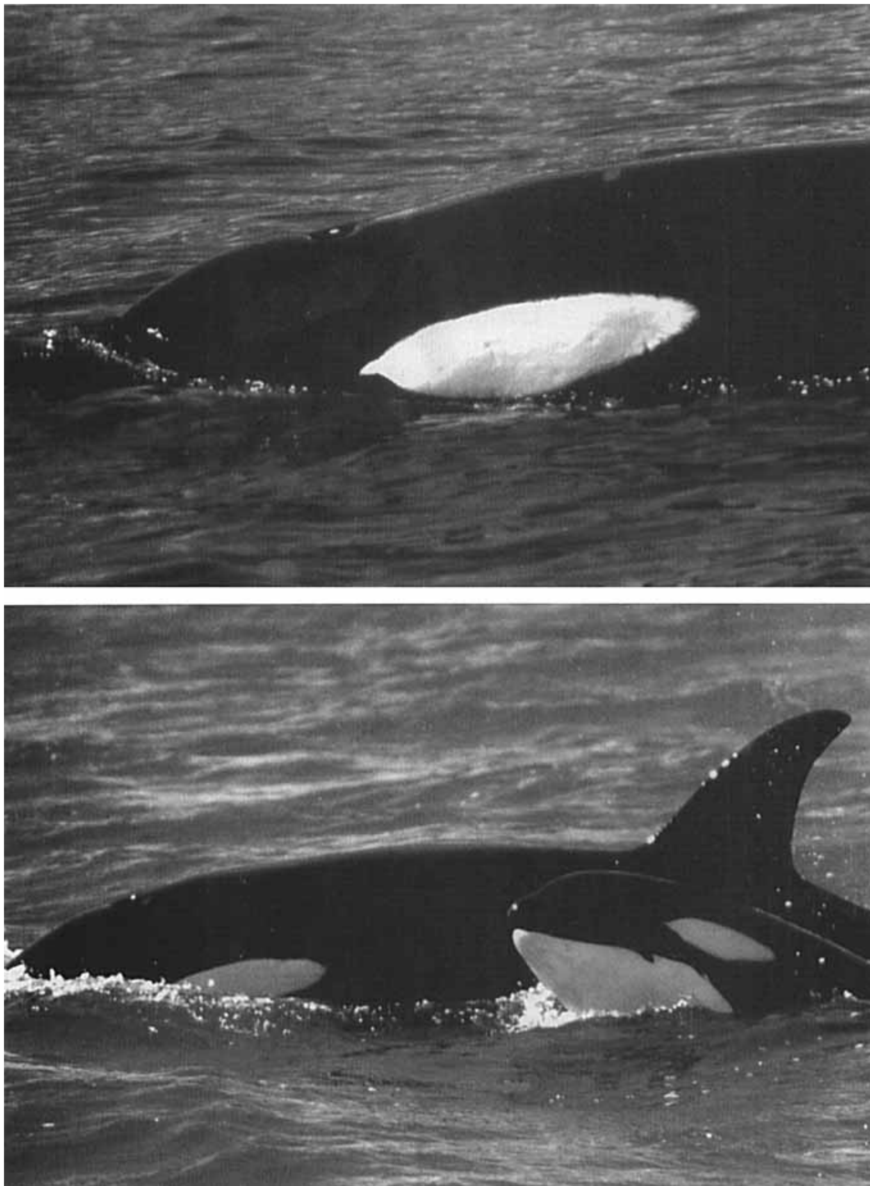

Figure 6. "Typical" eye patch (photos by I. Visser).

ACKNOWLEDGMENTS

This manuscript has been improved by extremely helpful comments from J. Berghan, J. Craig, W. E. Evans, D. Fertl, H. Pietiäinen, R. Baird, K. Mäkeläinen, T. Similä, S. Yin, J. Doherty, D. Pace, W. F. Perrin, and D. Mayson. J. Ford and an anonymous reviewer offered constructive contributions to the paper and suggested the blind test. D. Fertl, D. Bain, R. Baird, and T. Pusser helped source references. The

Center for Whale Research (A. van Ginneken, K. Balcomb, K. Balcomb Bartock, C. Emmons, D. Ellifrit, A. U. and C. Rice) provided IV with access to their extensive photograph collection and research facilities. R. Cooper and G. Wallace printed all the CWR eye-patch photos. Funding has been received from Golden Bay Cement, Kodak NZ, Yamaha, New Zealand Lotteries Grant Board, Aqualung New Zealand, Safety at Sea, Dive Log, Humminbird, Cetacean Society International, WDSC, Lion Foundation, and PADI NZ. Private grants from K. McIntyre, R. Jacks, W. Inman, C. McLachlan, and O. Clemens supported IV's research. A permit to conduct this research was issued by the New Zealand Department of Conservation.

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Received 6 January 1998. Accepted 2 July 1999.

MARINE MAMMAL SCIENCE, 16(2):469–481 (April 2000)

PINNIPED BRAIN SIZES

Except for a few scattered estimates in the literature (see Table 1), brain sizes in most pinniped species are unknown. A knowledge of pinniped brain sizes is useful for two reasons. First, comparative and allometric studies require a good estimate of (body) size. Brain size is often a better estimator than other measures (Sacher and Staffeldt 1974, Gittleman 1986*b*) because it is less variable intraspecifically (Economos 1980, Pagel and Harvey 1988). Body weight in particular is highly variable in large species and changes with season, reproductive condition, and physical condition, among other factors (Gittleman 1986*b*). Estimates of size in pinnipeds are especially problematic. Body weight is highly variable due to blubber mass varying both seasonally and individually (McLaren 1993; see also Table 2). Estimates derived from body length tend to be more uniform,[1] but depend on how the measurement was taken, some-

[1] Unpublished data and personal communication from Michael M. Bryden, University of Sydney, Sydney, NSW 2006, Australia, July 1999.