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THE USE OF NATURAL MARKINGS IN STUDIES OF LONG-FINNED PILOT WHALES (*GLOBICEPHALA MELAS*)

MARIE AUGER-MÉTHÉ
HAL WHITEHEAD
Department of Biology, Dalhousie University,
1355 Oxford Street, Halifax, Nova Scotia, B3H 4J1, Canada
E-mail: maugerme@dal.ca

ABSTRACT

Photo-identification using natural markings has been used for pilot whale (*Globicephala melas*) studies. However, none of these studies investigated the reliability of the marks used. To identify which mark types are reliable and which could improve the method, fifteen mark types, and their distribution within the population, were described. The rates of gain and loss of each mark type were calculated and the variability in visibility was investigated. Although the mark types associated with the current photo-identification method, the notch and the protruding piece, appear to be permanent, they allowed us to identify only 33% of our sample. The prevalence of all but two mark types is independent of the identifiability of a photograph. One of these is already used in the current photo-identification method. This independence indicates that the proportion of the population that is currently identifiable does not differ from the rest of the population in its susceptibility to factors causing marks, such as predation, and thus appears to be representative of the whole population. Using saddle patches in combination with the current photo-identification method would double the percentage of the identifiable individuals. However, due to limitations of matching software, the current method is easier to use.

Key words: Photo-identification, pilot whale, *Globicephala melas*, natural mark, mark rate

Identifying individuals allows field biologists to estimate population parameters and produce models of social structure (Hammond *et al*. 1990). Photo-identification (photo-id) is a method of using photographs of natural markings, such as scars and pigmentation patterns, to identify individuals. Using natural marks to identify individuals has many advantages. For example, photo-id is noninvasive and inexpensive, two qualities that may account for its extensive use in cetacean studies (Hammond *et al*. 1990).

However, the use of natural marks for identifying individuals, especially in mark-recaptures studies, has several disadvantages. For example, natural marks on different individuals are sometimes indistinguishable from one another (Hammond 1986), which can result in grouping distinct individuals under the same identification number. In addition, marks can be unevenly distributed within a population, allowing the identification of only some of its individuals (Gowans and Whitehead 2001). For instance, scars can result from behavioral acts or diseases, and the use of these marks potentially limits a study to individuals who are not representative of the complete population. Furthermore, natural marks can change with time and the individuals who are recognized by those marks can become unidentifiable. In mark-recapture studies, this can result in an overestimate of the population size (Hammond 1986). Finally, if marks are not visible in poor-quality photographs, part of the population could be unidentifiable when using such photographs. Because of these challenges, it is important to investigate the characteristics of different marks in relation to identification probabilities when using natural markings in a study.

Photo-id has been used in studies of long-finned pilot whales (*Globicephala melas*; formerly *G. melaena*) (Weilgart and Whitehead 1990; Cañadas and Sagarminaga 2000; Ottensmeyer and Whitehead 2003); however, all of these studies relied wholly on the markings of the dorsal fin, and none investigated the reliability of the marks used. In addition, the photo-id methods used allowed the identification of only 33.6% of the population (Ottensmeyer and Whitehead 2003). This percentage is low compared to other species. For example, 66% of bottlenose whales (*Hyperoodon ampulatus*) (Gowans and Whitehead 2001) and 82% of sperm whales (*Physeter macrocephalus*) (Dufault and Whitehead 1995) are identifiable. Such low mark rates reduce sample sizes and thereby limit the power of statistical analyses. Finally, no study has investigated whether the individuals identifiable with the method used are representative of the population.

The overall goal of this paper is to identify whether the mark types currently used in studies of long-finned pilot whales are reliable and which other mark types could improve the method. To do so, we categorize and describe the mark types found on long-finned pilot whales, describe the distribution of marks within the population, calculate the rates of gain and loss of each mark type, and investigate the variability in visibility of the mark types in photographs of the best quality.

Methods

Field Methods

Photographs were taken from whale-watch boats based in either Bay St. Lawrence (47°02′N 60°29′W) or Pleasant Bay (46°49′N 60°47′W), Nova Scotia, Canada, in July and August 1998, 1999, 2000, 2003, and 2004. The whales were approached at a range of 30–50 m. The approach represented the beginning of an encounter, which was described by Ottensmeyer and Whitehead (2003) as a spatio-temporal unit used to delineate whale groups. A total of approximately 28,250 photographs were taken, about 18,000 of which were taken during the summer of 2004.

The photographs from 1998 to 2003 were taken on black and white Ilford HP5 400 ASA film using a Canon EOS Elan IIe or Canon Rebel G equipped with a 300-mm autofocus lens. The photographs from 2004 were digital color images, of 2,048 × 1,360 pixels, taken with a Canon EOS-10D, equipped with a 200-mm autofocus lens. Photographs of the dorsal fin and the surrounding body area of individuals close to the boat were taken. We attempted to photograph individuals without bias related to identification probability (*e.g.*, presence of distinctive marks) or the number of pictures previously taken of an individual.

Photographic Analysis

A quality value was assigned to each individual in each photograph using the method of Ottensmeyer and Whitehead (2003). The quality value was determined using the following five criteria: the focus of the subject, the size of the subject relative to that of the frame, the percentage of the fin visible, the orientation of the fin in relation to the frame, and the exposure of the subject. Quality values ranged from one to five (hereafter written as Q1 to Q5), Q1 being the lowest.

As in Ottensmeyer and Whitehead (2003), only fins having at least three mark points in photographs of $Q > 2$ were considered marked and thus adequate for matching. To fulfill the three-mark-points condition, a fin required a notch with several internal corners, multiple simple notches, or a combination of both. From the photographs taken of the marked individuals in an encounter, the best photograph was matched against the catalogue. The matching process was done using Finscan software[1] (Araabi *et al*. 2000), which uses only the dorsal fin outlines. Only photographs from a common encounter could be used to match the left to the right side of a dorsal fin. From now on, "3MP-identifiable" will refer to the individuals fulfilling the three-mark-points condition.

Objective 1: Description of Mark Types

In order to describe the mark types, 100 encounters from 2004 were selected. One Q5 photograph was randomly sampled from each encounter. For each photograph the distance from the anterior point of the dorsal fin to its tip was measured in millimeter, and whether the individual would be considered 3MP-identifiable or not was recorded. For each mark, the longest axis was measured. The size of the mark was represented as a proportion of the fin by dividing the longest axis measure of each mark by the dorsal fin measure. The shape of the mark, its location on the body, its color, and whether the mark was completely visible were also recorded.

Each mark was assigned to a mark type. These mark types were based on those described by Gowans and Whitehead (2001) for northern bottlenose whales (*Hyperoodon ampullatus*) and two additional mark types: the saddle patch, previously described for long-finned pilot whales (Sergeant and Fisher 1957; Sergeant 1962*a*); and the fetal folds, described for bottlenose dolphins (*Tursiops truncatus*) (transverse birth bands in Kastelein *et al*. 1990). All marks corresponding to no previously described mark types were placed into a temporary mark type "other" until the marks were compiled. These "other" marks were compared to one another and "new" types were created.

Objective 2: Mark Distribution

Using the results of the previous objective, we determined the average number of marks and the average number of mark types per photograph. Then we determined the prevalence of each mark type (proportion of photographs containing the specific mark) in the entire sample, as well as in the 3MP-identifiable and 3MP-unidentifiable

[1] Finscan was created by the Texas A & M Marine Mammal Rescard Program and was provided by Dr. Gail Hillman.

photographs. We also performed a χ^2 test for each mark type to assess whether the presence or absence of mark types in photographs was independent of whether the photograph was 3MP-identifiable or not.

Objective 3: Gain and Loss Rates

All individuals having a Q5 photograph of the same side of their body in at least two different years were chosen. Only one body side per individual was used. If several photographs were suitable for a given year, one was selected randomly. All scanned photographs of a given individual were viewed simultaneously. The presence or absence of each mark in each photograph was noted. When the area of the body where the mark should have been found was obscured, the mark was recorded as "not seen."

For each mark type, the rate of gain was calculated by dividing the total number of marks gained for that type by the total whale years:

$$\textit{Rate of gain} = \frac{\textit{No. gained}}{\textit{total whale years}}$$

where the total whale years was the summation of the number of years between the earliest and latest years of each chosen individual.

The rate of loss was estimated by dividing the total number of marks lost by the whale years of available marks:

$$\textit{Rate of loss} = \frac{\textit{No. lost}}{\textit{whale years of available marks}}$$

where the whale years of available marks refers to the summation of the number of years between the earliest presence of a mark noted and either its latest presence or its earliest absence noted. For the rate of loss, only marks for which the area of the body was observed in consecutive years were included.

Objective 4: Mark Visibility Variations

For ten individuals, two Q5 photographs from the same year and body side were chosen at random. These photographs were inserted into the photograph sample used for the previous objective. This allowed us to examine variability in the visibility of marks while blind to whether photographs were from the same or different years. For each mark type, the number of marks seen in both photographs from the same-year pairs and the number seen in only one photograph from the pairs were tabulated.

Results

Mark-Type Description

Fifteen mark types were described (Fig. 1, Table 1). Three "new" types were given names based upon descriptions in the literature: the postorbital eye blaze (Sergeant 1962*a*), the black spot (Similä and Lindblom 1993), and the squid mark (Bloch *et al.* 1993*a*). We created two other "new" types based on multiple occurrences of marks

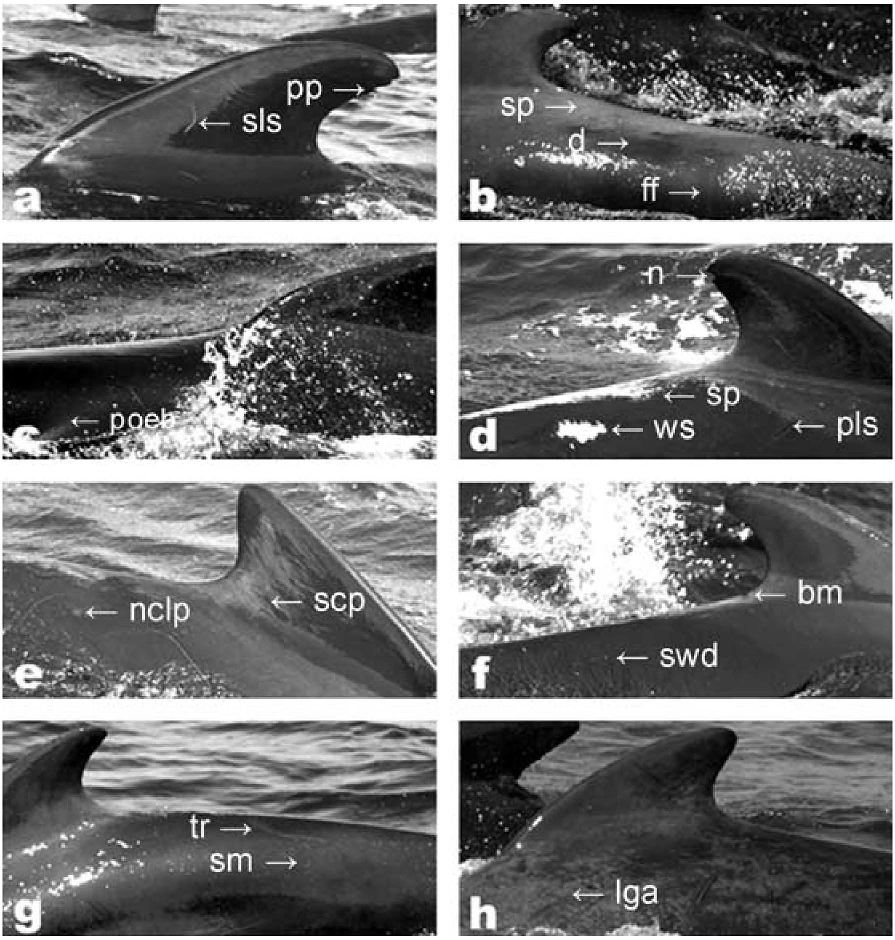

Figure 1. The fifteen described mark types: (a) sls—small linear scrape, pp—protruding piece; (b) sp—saddle patch, ff—fetal fold; (c) poeb—postorbital eye blaze; (d) ws—white scar, sp—saddle patch, pls—parallel linear scrape, n—notch, (e) nclp—noncircular light patch, scp—scratch patch; (f) swd—small white dot, bm—black mark; (g) tr—tooth rakes, sm—squid marks; and (h) example of a mark falling in the miscellaneous type (lga—light gray area). Photograph b is of a calf, note the diatoms (d).

with the same characteristics: the protruding piece and the scratch patch. Moreover, we created a miscellaneous type, which included all marks from the "other" temporary mark type excluded from the newly described types.

The mark types were grouped into four broad classes: dorsal fin outline, linear, patch, and pigmentation (Fig. 1, Table 1). The two mark types associated with the dorsal fin outline were the protruding piece and the notch, the latter being most often observed on the trailing edge. Light color bands characterized the three types in the pigmentation class: the postorbital eye blaze, the fetal folds, and the saddle patch. The saddle patch, which was found on some adults and on the only calf in the

Table 1. Mark-type description.

Mark type	Color	Description	Shape	Body location	Length[a] x	Length[a] SD
Dorsal fin outline						
Notch	—	Indentation in dorsal fin	Irregular	Dorsal fin	0.04	0.05
				Trailing edge (114)		
				Leading edge (5)		
Piece protruding	Skin (2)	Piece of skin protruding	Triangular	Dorsal fin (next to a N)	0.06	<0.01
Pigmentation						
Fetal folds	Gray (1)	Transverse bands on flank of calf	Band	Back	>0.29[b]	—
Postorbital eye blaze	Gray (2), white (1)	Behind the eye	Thick band	Front	>0.10[b]	0.01
Saddle patch	Gray (11), white (19), cream (26)	Pigmentation:	Thick band	Back (posterior to dorsal fin)	0.49	0.26
		sparse (20), dense (9), medium (27)				
Linear						
Parallel linear scrape	Gray (171), black (26), skin (15), white (10), cream (2)	—	2 parallel lines	All body parts	0.13	0.19

Table 1. Continued.

Mark type	Color	Description	Shape	Body location	Length[a]	
					x	*SD*
Single linear scrape	Gray (470), skin (34), white (30), black (22), cream (8)	—	Single line	All body parts	0.08	0.08
Tooth rake	Gray (107), black (36), skin (17), white (16), cream (4)	—	More than 2 parallel lines	All body parts	0.16	0.14
Patch						
Black mark	Black (1)	Mark in the SP	Irregular	Back	0.02	—
Noncircular light patch	Gray (125), cream (6), white (3)	—	Irregular	All body parts	0.04	0.04
White scar	White (17), gray (1)	—	Irregular	All body parts (8 next to a N)	0.04	0.05
Scratch patch	Gray (9)	Area of scratches	Irregular	Dorsal fin (8), back (1)	0.29	0.14
Small white dot	Gray (487), white (48), skin (25), cream (19)	—	Circular	All body parts	0.01	<0.01
Squid mark	Gray (1)	—	Ring	Back	0.04	—
Miscellaneous	—	All other marks	—	—	0.19	0.38

[a]Size is expressed as a ratio of the mark length of completely visible mark to the transverse measurement of the dorsal fin.
[b]No completely visible mark available.

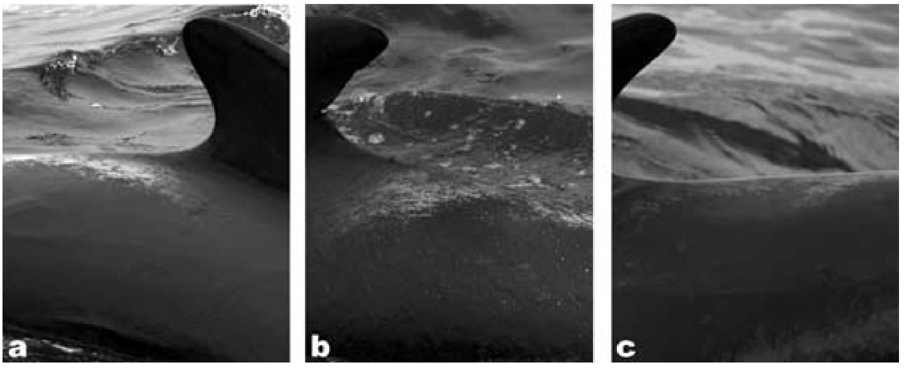

Figure 2. The three levels of saddle patch pigmentation densities: (a) dense, (b) medium, and (c) sparse.

sample (Fig. 1b), was the longest mark type, was found in three colors: gray, white, and cream, and was divided into three pigmentation levels: sparse, medium, and dense (Fig. 2). The calf also had a brown film of diatoms, which was not attributed to a type. The three types of linear marks, the single linear scrape, the parallel linear scrapes, and the tooth rake, were similar in their color range, shape, location, and size. The six mark types from the patches were either irregular, circular, or ring shaped. Forty percent of the white scar marks were next to a notch, and the black spot was found in the pigmented area of the saddle patch. Finally, the body of one individual from the sample, which had many small white dots, was mostly light gray (Fig. 1h). This gray area, which was not described in the literature and unique in the sample, is an example of a mark that was placed in the miscellaneous type.

Mark Distribution

A total of 1,935 marks were found in the sample of 100 Q5 photographs, resulting in an average number of marks per photograph of 19. On average, 5.4 different mark types were found per photograph and all photographs contained at least one mark. Thirty-three percent of the sample photographs were 3MP-identifiable. The prevalence in the population of six mark types, including the saddle patch and the notch, exceeded 33% (Table 2). In addition, the saddle patch, as well as four other types, was in more than 50% 3MP-unidentifiable. With two exceptions, notches and white scars, there was no significant difference in the probability of finding a mark type in 3MP-identifiable and 3MP-unidentifiable photographs (χ^2 test: $P > 0.05$).

Gain and Loss Rates

Thirteen of the fifteen mark types described above were present in the gain/loss sample, which comprised seventy-four individuals seen in 165 whale years (Table 3). The four mark types for which no losses were recorded were the notch, the protruding piece, the white scar, and the saddle patch. Although the rate of loss of the notches was zero, four notches of the sample seemed to have disappeared (Fig. 3). These were not included in the rate of loss calculations as the pairs of photographs showing the

Table 2. The total number of marks (*n*) of each mark type, their prevalence in the population, the 3MP-unidentifiable and the 3MP-identifiable photographs, as well as the results of the χ^2 test for independence of the presence of a mark type and the 3MP-identifiability of an individual (if sample size was sufficiently large for the test to be valid).

		Proportion of photographs containing a type			
Mark Type	*n*	All photographs	3MP unidentifiable	3MP identifiable	χ^2 test *P* value
Dorsal fin outline					
Notch	119	0.60	0.40	1.00	0.000
Piece protruding	2	0.02	0.00	0.06	—
Pigmentation					
Fetal folds	1	0.01	0.01	0.00	—
Postorbital eye blaze	2	0.02	0.03	0.00	—
Saddle patch	56	0.56	0.51	0.67	0.132
Linear					
Parallel linear scrape	224	0.76	0.75	0.79	0.647
Single linear scrape	564	0.93	0.94	0.91	0.565
Tooth rake	181	0.70	0.66	0.79	0.178
Patch					
Black spot	1	0.01	0.01	0.00	—
Noncircular light patch	134	0.54	0.48	0.67	0.074
White scar	18	0.12	0.07	0.21	0.047
Scratch patch	9	0.09	0.10	0.06	0.471
Small white dot	581	0.70	0.72	0.67	0.610
Squid mark	1	0.01	0.01	0.00	—
Miscellaneous	42	0.29	0.25	0.36	0.255

loss of the notches were not in consecutive years. Using marks seen in nonconsecutive years might result in an overestimate of the rate of loss. All mark types showed gains with time.

Mark Visibility Variations

Ten mark types were observed in the same-year pairs sample (Table 4). Five types, including the notch, the protruding piece, and the saddle patch, were always seen in both photographs from the pairs. Two types, the noncircular light patch and the small white dot, were mostly seen in only one photograph of the pairs.

Discussion

Mark-Type Descriptions and Causes

Notch and Protruding Piece

The notches of the pilot whales in this study, those examined from Newfoundland drive fisheries (Sergeant 1962*b*), and those of other cetaceans (Würsig and Würsig 1977; Bigg 1982), were mainly found on the trailing edge of the dorsal fin (Table 4). The trailing edge appears to be particularly vulnerable to abrasion and tattering

Table 3. The rate of gain and loss of each mark type.

	Rate of loss (per mark per year)	Whale years of available marks	Rate of gain[a] per (individual per year)
Dorsal fin outline			
Notch	0.0000	128	0.0848
Protruding pieces	0.0000	7	0.0182
Pigmentation			
Fetal folds	—	—	—
Postorbital blaze	—	—	—
Saddle patch	0.0000	21	0.0061
Linear			
Parallel linear scrape	0.7073	41	0.4606
Single linear scrape	0.9145	152	1.4000
Tooth rake	0.9024	41	0.5212
Patches			
Black mark	—	—	—
Noncircular light patch	0.8871	62	0.7697
White scar	0.0000	7	0.0121
Scratch patch	1.0000	1	0.0181
Small white dot	0.8537	246	2.8727
Squid mark	—	—	0.0061
Miscellaneous	0.4000	5	0.0303

[a]The total whale years was 165.

(Würsig and Jefferson 1990), probably partly due to the reduction of the thickness of the dorsal fin toward the trailing edge. The ragging of fin edges is believed to result from injuries (Bigg *et al*. 1987), perhaps occurring during intraspecific fighting (letter from Norris to Sergeant: Sergeant 1962*b*).

It has been suggested that the tissue of the dorsal fin of bottlenose dolphins does not regenerate (Würsig and Würsig 1977). Bigg (1982) confirmed the permanency of notches by surgically removing two pieces from a killer whale's dorsal fin. The marks remained unchanged for at least 7 y. However, he cautioned that notches can elongate on growing fins and can become shallower with time. In our study, although the rate of loss for the notch was zero, four notches seemed to have been lost. Three of these notches were very small, suggesting that small notches may have the capacity to regenerate or that they had changed to such an extent that they became undetectable. However, most of the photographs in which the notches appeared to have been lost were taken at an angle or contained glare, which might have decreased the visibility of the marks.

Only two protruding pieces were found in our sample. Both were next to a notch, and appeared to be residual flesh resulting from the formation of the notch. Although not described in the literature, they are present in the photographic catalogue of resident killer whales (Ford *et al*. 2000); all were next to notches.

Fetal Folds

Fetal folds, also known as vertical creases, transverse birth bands, and fetal bands, were previously observed on a long-finned pilot whale fetus (plate II: Sergeant 1962*a*).

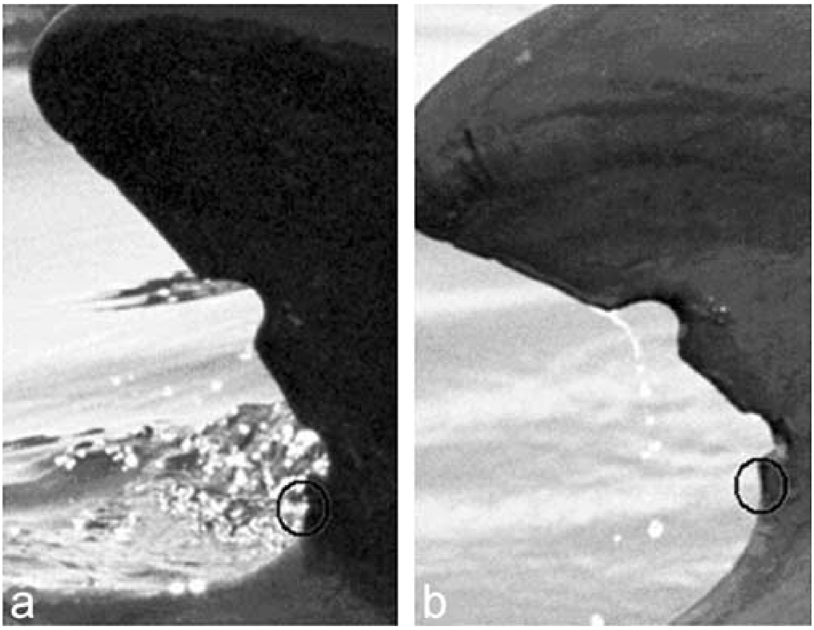

Figure 3. Possible loss of a notch on an individual observed in nonconsecutive years: (a) 1998 photography when the mark was present and (b) 2000 photography when the mark was absent. Note that the notch could also be glare.

A histological study on bottlenose dolphins showed that the light color of such bands results from the thicker than normal white *stratum spinosum* layer in the epidermis, which shields the black dermal papillae (Kastelein *et al*. 1990). Fetal folds are thought to disappear within the first year of a dolphin life (Slooten and Dawson 1988, Table 2, Kastelein *et al*. 1990; Herzing 1997; Grellier *et al*. 2003) and thus are not useful for long-term photo-id. However, they help to distinguish young calves from older age classes (Herzing 1997; Wilson *et al.* 1999; Grellier *et al*. 2003).

Postorbital Eye Blaze and Saddle Patch

The postorbital eye blaze and the saddle patch are both characterized as bands of light pigmentation (Table 1). Although only two partially visible postorbital eye blazes were found in this sample, they were similar to blazes extending behind the eye previously described in the literature (Hector 1877; Sergeant 1962*a*).

As described by Sergeant (1962*a*), the saddle patch of long-finned pilot whales was found behind the dorsal fin (Table 1). Both females and males in eastern Canadian waters were found to posses the saddle patch (Sergeant and Fisher 1957), and the occurrence of saddle patches on long-finned pilot whales from the Faroe Islands did not differ significantly between the sexes (Bloch *et al*. 1993*b*). However, males had both the saddle patch and the postorbital eye blaze in combination significantly more often than females. The occurrences of these marks were not independent of one another in Bloch *et al*.'s (1993*b*) sample. The inheritance of saddle patches patterns has been suggested for killer whales because its shape is more

Table 4. Marks observed in ten pairs of photographs, each of which had Q5 photographs from the same individual in a given year.

	Presence frequency in photographs of the same-year pair		
Mark type	Only in one photograph	In both photographs	Total
Dorsal fin outline			
Notch	0	26	26
Protruding piece	0	2	2
Pigmentation			
Fetal folds	—	—	0
Postorbital blaze	—	—	0
Saddle patch	0	4	4
Linear			
Parallel linear scrape	4	11	15
Single linear scrape	13	42	55
Tooth rake	5	15	20
Patches			
Black mark	—	—	0
Noncircular light patch	23	8	31
White scar	0	2	2
Scratch patch	—	—	0
Small white dot	91	46	137
Squid mark	—	—	0
Miscellaneous	0	2	2

similar among closely related groups (Baird and Stacey 1988). Similarly, several characteristics of the saddle patch of the short-finned pilot whales off Japan appear to vary between schools (Miyashita and Kasuya 1990). If the probability of an individual having a saddle patch is not independent of its group or of its sex, the individuals identified using the saddle patch may not be representative of the entire population.

Results from both the Newfoundland (Sergeant and Fisher 1957; Sergeant 1962*a*) and Faroe Islands (Bloch *et al.* 1993*b*) drive fisheries indicated that the saddle patch is absent on small whales. Furthermore, both the saddle patch and the postorbital eye blaze increased in frequency with age and body length, particularly the saddle patch (Bloch *et al.* 1993*b*). Bloch *et al.* (1993*b*) suggested that the pale skin color of calves and juveniles prevents one from distinguishing the postorbital eye blaze and the saddle patch. However, the only calf in our sample displayed a saddle patch (Fig. 1b), although its poor contrast with the calf's light gray skin made it less conspicuous. Newborn killer whales do not have saddle patches (Bigg 1982), and the saddle patches of calves are less distinct than those of adults (Baird and Stacey 1988). Although the visibility of saddle patches in killer whales changes with age, the shape of the saddle patch does not change once it appears (Bigg 1982).

White Scar and Black Mark

As their names suggest, white scars and black marks were mainly defined by their respective colors. They were both irregularly shaped and each was associated with another mark type. White scars were often found next to a notch (Table 1) and were more prevalent on 3MP-identifiable animals, suggesting that white scars are often related to notches. The only black mark found in the sample was a dark area in a saddle patch. This is consistent with the description of the permanent single black scars found on the saddle patch of killer whales (Similä and Lindblom 1993).

Tooth Rake

It has been suggested that tooth rakes result from male conspecific fighting; all adult males examined for scars in the Faroe Islands' drive fisheries possessed tooth rakes (Bloch 1992). However, at least 50% of the juveniles from both genders and 57% of adult females of the same study also possessed tooth rakes. This suggests that juveniles and females are either involved in aggressive behaviors, as it is the case for bottlenose dolphin (Scott *et al*. 2005), or that the marks result from other causes, such as nonaggressive social behavior or interspecific interactions.

Single Linear Scrape, Parallel Linear Scrapes, and Scratch Patch

The single and parallel linear scrapes, as well as scratch patches are likely caused by abrasion. McBride and Kritzler (1951) indicated that captive dolphins rub their bodies against various objects. Linear scrapes were thought to result from contact with small animals or inanimate objects (Greenwood *et al*. 1974). However, as all the linear mark types, including the tooth rake, were similar in most of the characteristics considered in the study, it is likely that linear scrapes result from the same causes as tooth rakes. Scratch patches appear to be an area of intersecting single linear scrapes and are probably linked to this type.

Squid Mark

The only squid mark found in this sample was a ring-shaped mark (Table 1). This corresponds to the squid marks from the Faroe Islands' pilot whales (plate IV: Bloch *et al*. 1993*a*). The squid mark ring consists of a single row of depressed dots (Jensen 1916). Squid marks can easily be confused with lamprey marks, which were described as circles filled with depressed dots containing a hole in the center (Pike 1951). Sergeant (1962*b*) confirmed that the marks found on long-finned pilot whales were from squid suckers, as they only affected the epidermis and no depressed dots or tongue marks were found in the middle of the ring.

Small White Dot and Noncircular Light Patch

Diseases likely cause small white dots. As Greenwood *et al*. (1974) noted, circular marks are usually caused by parasites. The individual who had, in addition to many small white dots, a large light gray area on its body (Fig. 1h) could have been suffering from an advanced stage of a disease such as dermatologic erysipelas (Dunn 1990).

Similarly, noncircular light patches are possibly caused by parasites. However, because only eight of the thirty-one noncircular light patches were seen in both photographs of the same-year pairs (Table 4), many of them may be artifacts caused by the conditions in which the pictures were taken and should not be considered a mark. It is possible that discrepancies in quality assessment have influenced the results of the study, especially for mark types seen in only one photograph of the same-year pairs (Table 4). For example, there may be more marks in the population than the ones we detected.

Diatoms

A film of diatoms was visible on the skin of the only calf of this sample. Diatom patches may change at a rapid rate (Gowans 1999). This feature was not considered a mark type because they are not a characteristic of the skin but rather attached microscopic algae that do not alter the skin beneath it (Greenwood *et al*. 1974).

USE OF MARK TYPES FOR PHOTO-ID

The mark types currently used for photo-id of long-finned pilot whales are the notch and protruding piece. Both appeared to be permanent (Table 3), although a few small notches may have disappeared. Although protruding pieces were not prevalent in the population (2%), notches were (60%). However, not all of the notches were large or complex enough for reliable photo-id merely on the basis of one notch. In agreement with Ottensmeyer and Whitehead's (2003) results, which found that 33.6% of the individuals fulfill the three-mark-points condition, only 33% of the sample was assessed as 3MP-identifiable. This represents about half of the photographs with notches. Our analysis indicated that the prevalence of mark types not used in the current photo-id method is independent of 3MP-identifiability, with white scars being the only exception (Table 2). As explained above, white scars are generally next to a notch and likely caused concurrently. The independence of the other types from the current photo-id method suggests that the proportion of the population that is currently identifiable does not differ greatly from the rest of the population in its susceptibility to diseases and predation, in its inter- and intraspecific interactions, and in other factors that could cause marks. Thus, the individuals deemed 3MP-identifiable using notches and protruding pieces appear to be reasonably representative of the rest of the population in these respects.

Although only 33% of the sample was assessed as 3MP-identifiable, all pilot whales were marked by at least one mark type and had, on average, nineteen marks of about five types. However, only two mark types other than the ones currently used for photo-id were permanent, the white scar and the saddle patch (Table 3). The white scar is not prevalent in the population (12%) and is less prevalent in the 3MP-unidentifiable photographs (7%). Thus, incorporating the white scar into the photo-id method would not significantly improve its utility.

Although the saddle patch is less prevalent in the population than the notch, it is often visible in the 3MP-unidentifiable photographs (51%). The saddle patch, like the notch and protruding piece, is always seen in both pictures from the same-year pair, which indicates that it is consistently visible, at least in pictures of the highest quality. In addition, the saddle patch is the longest mark type, and thus conspicuous. Furthermore, the pigmentation pattern within the saddle patch has many reference points and therefore can be considered intricate (Fig. 1e), which would decrease the chance of duplication (Pennycuick 1978).

The addition of the saddle patch to the current photo-id method would double the percentage of identifiable individuals (from 33% to 67%). In addition, the division of this mark type into pigmentation categories (Fig. 2), which has been done for other species (*e.g.*, blue whales, *Balaenoptera musculus*, Sears *et al*. 1990), would improve the efficiency of the photo-id process. As mentioned above, the saddle patch might not be visible on young whales, and may be both genetically inherited and gender dependent. Thus, its use in the photo-id technique may not fully represent the population. Unfortunately, no software allowing the use of the saddle patch for the photo-id of long-finned pilot whales is available. Consequently, until such software is developed, and we know how the occurrence of a saddle patch depends on sex and social group membership, it may be more practical to continue using just notches and protruding pieces for photo-id. However, as gaining a mark can make an individual unidentifiable, the rates of gain of these two mark types (Table 3) should be taken into account when using them for photo-id.

Other Uses of Natural Markings

In addition to aiding in identification, natural marks can serve to indicate characteristics of the population such as disease prevalence (Thompson and Hammond 1992; Wilson *et al.* 2000), predation pressure (Heithaus 2001), and intraspecific interactions (MacLeod 1998; Scott *et al.* 2005). For such analyses, mark types independent of the current photo-id method (all but the notch, the protruding piece, and the white scar) could be investigated in photographs of individuals identified with the current photo-id method; these individuals would be expected to be reasonably representative of the whole population.

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