A new classification method to simplify blue whale photo-identification technique

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ABSTRACT

Individual identification of blue whales is based on unique pigmentation patterns. Historically photo-identification has been based on the pigmentation patterns observed on a large portion of the animal's flanks. The new classification method presented here is based primarily on seven dorsal fin shapes and secondarily on five pigmentation patterns selected from a minor portion of the flank adjacent to the dorsal fin. This classification is then applied to a blue whale catalogue that comprises 621 individuals photo-identified in the waters adjacent to the Baja California Peninsula in Mexico. The classification system adequately divides the number of individuals per dorsal fin category and pigmentation patterns. It has been useful not only for reducing time and for matching photographs more efficiently but also has facilitated the finding of intra-catalogue photographic recaptures or photo-recaptures and has enhanced the efficiency of the field work. This new classification method should be considered by other blue whale researchers and for future inter-catalogue comparisons.

KEYWORDS: TECHNIQUE; PHOTO-ID; BLUE WHALE

INTRODUCTION

Since the cessation of whaling, knowledge of the biology of free-ranging species through identification photographs of individuals has been substantial. The photo-identification technique, applied to the blue whale, *Balaenoptera musculus* (Sears *et al.*, 1990) has proven to be useful to investigate movement patterns (Calambokidis *et al.*, 2009; Calambokidis *et al.*, 1990; Gendron, 2002), and in the estimation of population abundance and survival rates through mark-recapture models (Calambokidis and Barlow, 2004; Ramp *et al.*, 2006; Ugalde de la Cruz, 2008).

Blue whales are currently considered endangered under the IUCN Red List of threatened species and three subspecies are recognised worldwide although the intra-specific taxonomy of the Northeastern Pacific blue whales is ambiguous (Reilly *et al.*, 2008). The abundance estimates based on capture-recapture method for the northeastern Pacific range are around 2,000 blue whales (Calambokidis and Barlow, 2004). Evidence from photographic recaptures shows some of these whales move to the Gulf of California (Calambokidis *et al.*, 1990). This region serves as a nursing and feeding area for approximately 300 blue whales during winter-spring season (Gendron, 2002). At the Laboratory of Cetacean and Chelonian Ecology based in CICIMAR-IPN, an identification catalogue of blue whale photographs has been built which encompasses a data series of 25 years. The main objective is to monitor the blue whales that visit this area for long term conservation purposes. Identification photographs and biological samples are collected to develop a comprehensive individual sighting history to serve as the basis of several current research projects.

Standard photo-identification technique consists in taking photographs at a perpendicular angle to a large portion of the left and right flanks of the animal including the dorsal fin and comparing them with individual photographs that have been classified into several pigmentation patterns (Sears *et al.*, 1990). The photos are usually taken during the last respiration when the whale is preparing for a deep dive. Depending on whale behaviour and maritime conditions when photographic attempts are made, it may not always be possible to obtain a photo of a large portion of the flank in one frame. In Sears' classification, photographs of whales that showed only small portions of the flank are problematic to classify.

Since no computer-assisted matching program has yet been developed for blue whales, comparing identification photographs by hand can become a laborious task, especially when the number of individuals is large. This paper proposes a new classification method for blue whale photo-identification that simplifies the photograph comparison by hand.

METHOD

The Baja California blue whale catalogue (Baja CA Catalogue) maintained at CICIMAR includes photographs obtained in coastal and offshore waters adjacent to the Baja California Peninsula. Most of the effort has been conducted in the southwestern region of the Gulf of California (Fig. 1). The photographs were taken between 1985 and 2009 and comprise 621 individuals (unpublished data). This work has been accomplished with the collaboration of the Mingan Island Cetacean Study (2003; 2004; 2006; 2009), Cascadia Research Collective (2001; 2004; 2006), Universidad Autónoma de Baja California Sur, as well as with the help of other researchers and naturalist-guides with opportunistic photographs taken in the study area.

Initially, a 35mm reflex EOS Canon camera coupled with a 70–300 telephoto lens, with black and white film was used. Since 2005, photographs have been taken using colour digital EOS (10D, 20D and 30D) Canon cameras with a 100–300 telephoto lens. The quality of each photograph in the catalogue has been rated from one (excellent) to 4 (bad)

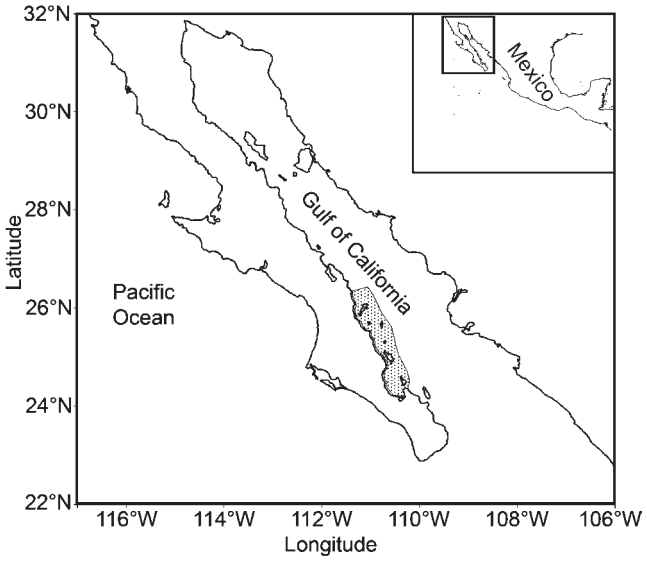

Fig. 1. Study area around the Baja California Peninsula where blue whales were photographed. Shaded area denotes the southwestern region of the Gulf of California where most of the effort has been conducted.

according to the focus, camera angle, and exposure. Quality 4 photographs contain features that are useful to identify the individual; however, for population parameter estimations they are not taken into account (Hammond, 1986; Hammond *et al.*, 1990).

Distinct pigmentation patterns observed on blue whales do not change with time therefore all individuals can be photo-identified (Sears *et al.*, 1990), including calves born during the winter season (Gendron, 2002). Of the 621 individuals contained in the Baja CA Catalogue, 57.2% of them possess photographs of both flanks, while 23.8% and 19.0% have only one flank, the right and left, respectively. Until 2009, 92 calves have been photo-identified and 40% of them have been re-sighted from 1 to 15 years later. This catalogue was initially classified by following the method of Sears *et al.* (1990). Over the years, changes were made to simplify the comparison of whale photographs which led to this new classification method.

Description of the classification

The only criterion needed is that photographs of the flank must contain the dorsal fin with, preferably, a sufficient area of adjacent pigmentation (see Fig. 2). The method is centred primarily on seven categories based on dorsal fin shapes (Fig. 3). A further category includes undefined dorsal fins for photographs in which the angle may bias the dorsal fin classification. In these cases, the photographs are temporally classified as undefined, until a better photograph of this particular individual is obtained. Furthermore, photographs included in each dorsal fin category are secondarily classified into five pigmentation patterns that progressively change from light to dark (Fig. 4). Photographs showing insufficient areas of pigmentation around the dorsal fin or taken with poor light exposure may not be categorised and are classified temporally under undefined pigmentation patterns.

New photographs are assigned to dorsal fin and pigmentation categories in accordance with the opinions of two persons that keep the catalogue up to date. In order to test how subjective this new photograph classification is, a set of 70 photographs (10 of each dorsal fin category including all pigmentation categories) of qualities 1 to 3 were chosen from the Baja CA Catalogue and then classified independently by four observers with little to extensive experience in blue whale photo-identification. The results were then compared with the category previously assigned in the Baja CA Catalogue. Furthermore, to test how consistent the categorisation is over time, duplicates of five individuals, first photographed as calves and then years later, were included and mixed in the set of photographs selected. A chi-squared test ($p < 0.05$) was used to verify if all dorsal and pigmentation categories were assigned in concordance with the Baja CA Catalogue. As significant differences were found, a subdivision of the test was made to verify which category failed to distinguish from the others by removing the category that contributes with a relatively larger amount to the previous calculated chi-square (Zar, 1996).

RESULTS

The classification applied to the Baja CA Catalogue of blue whale photographs showed that the seven dorsal fin types were not equally represented but they formed a suitable division of it (Table 1). The falcate dorsal fin was the most abundant type comprising 33.5% of the individuals compared to the mutilated dorsal fin that corresponds to 4.3%. Only 2.9% of the individuals were classified in the undefined dorsal fin category.

As for the pigmentation patterns, the most commonly observed was the light mottled with a frequency of 36.5% while the least common was the dark pattern (12.6%; Table 1). Only 6% of all individuals were included in the undefined category, mostly due to the poor light exposure.

There were significant differences in the selection of categories made by the observers and the ones assigned in the Baja CA Catalogue (χ^2 =18.6, degrees of freedom (df) = 6, p = 0.0049). Notably, the most ambiguous category was the falcate-triangular dorsal fin with only 45% of matches with the Baja CA Catalogue (Table 2). This ambiguity was associated with the contiguous categories of triangular and

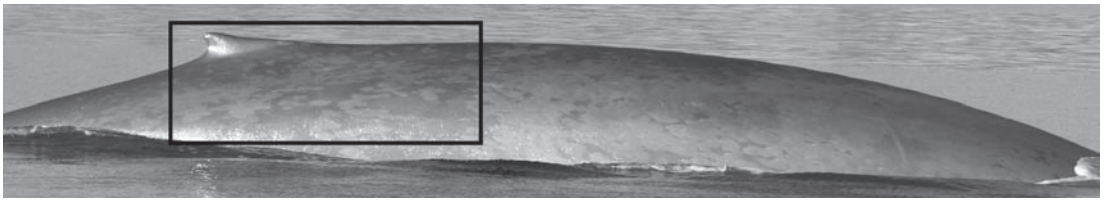

Fig. 2. Example of a blue whale identification photograph included in the Baja California blue whale catalogue. The area delimited by the box indicates the minimum body area needed for photograph comparisons.

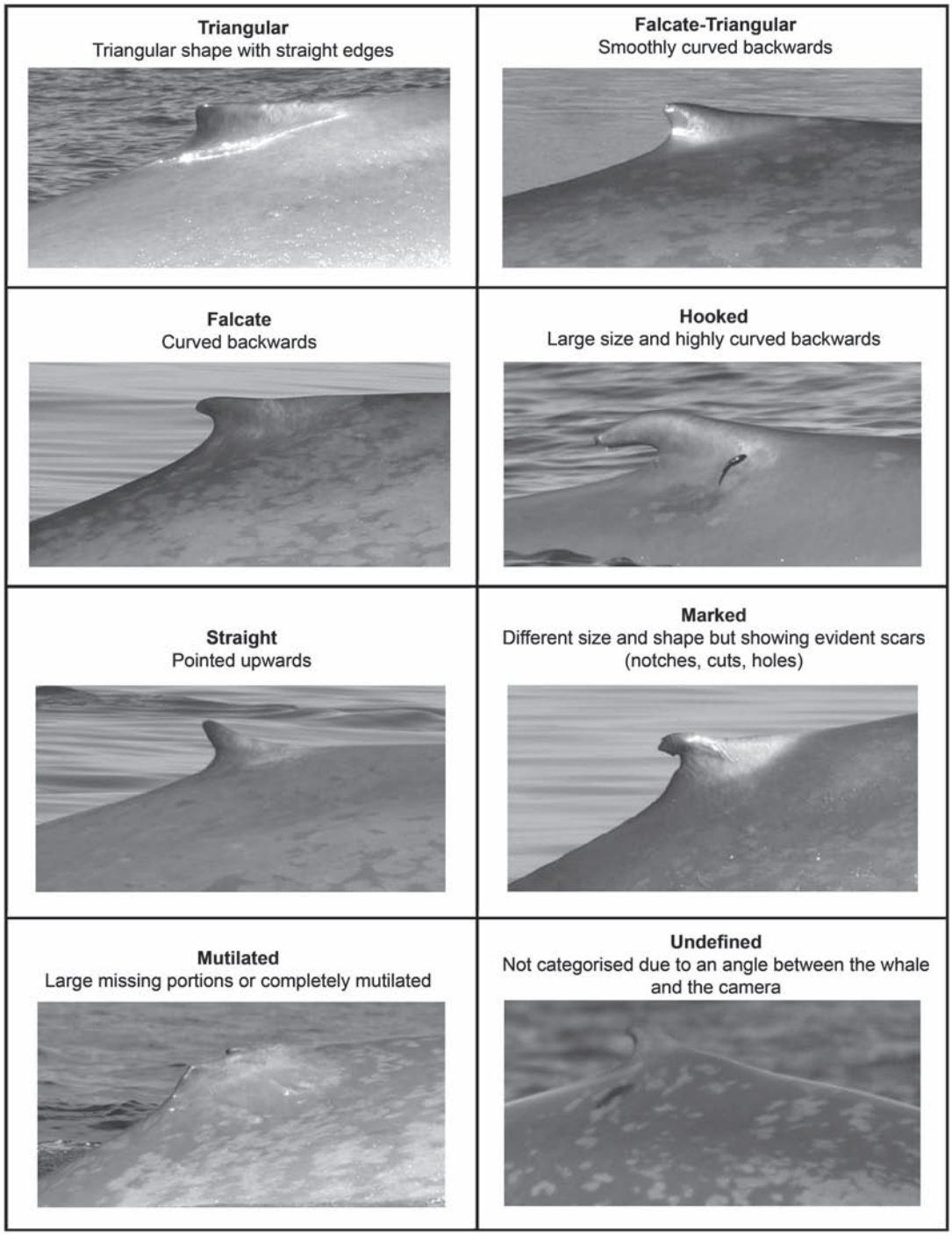

Fig. 3. Description and photographs of eight dorsal fin categories used as the first classification step in the blue whale photo-identification method.

Table 1

Number of individual blue whales classified per dorsal fin and pigmentation categories included in the Baja California blue whale catalogue.

	Dorsal fin categories								
Pigmentation patterns	Triangular	Falcate-triangular	Falcate	Hooked	Straight	Marked	Mutilated	Undefined	Total (%)
Light	6	14	25	21	8	4	2	3	13.4
Light-mottled	15	34	80	36	25	19	10	8	36.5
Striped	8	11	26	14	10	6	3	2	12.9
Balanced	8	22	34	17	12	15	6	2	18.7
Dark	5	11	33	11	8	8	1	1	12.5
Undefined	5	6	10	7	1	1	5	2	6.0
Total (%)	7.6	15.8	33.5	17.1	10.3	8.5	4.3	2.9	100

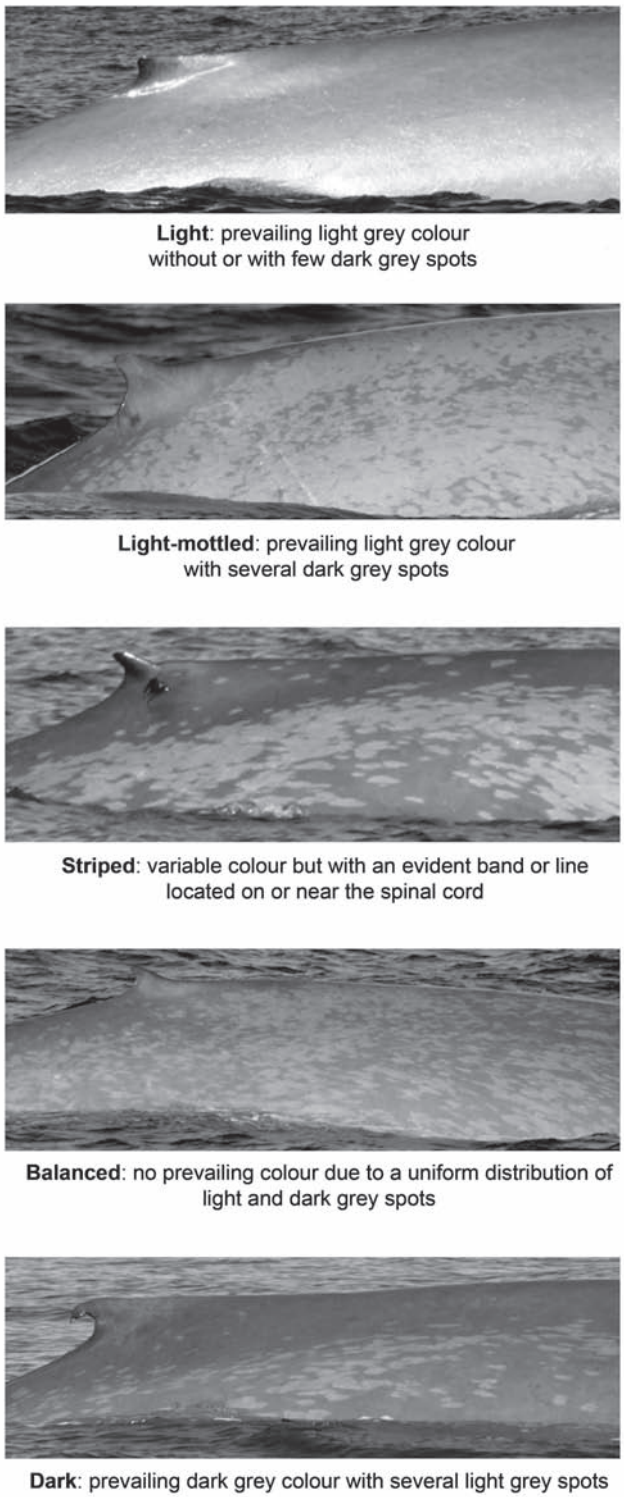

Fig. 4. Description and photographs of the five pigmentation patterns used as a second classification step in the blue whale photo-identification method.

falcate dorsal fins. The falcate-triangular category contributed largely to the chi-square calculated. After removing this category no significant difference between the other six categories was found ($\chi^2 = 6.5$, df = 5, $p = 0.26$). These categories ranged between 70 and 100% of matches with those assigned in the Baja CA Catalogue. As expected, the mutilated dorsal fin was the least ambiguous category. Ambiguities observed for the other categories were also associated with the contiguous dorsal fin shapes.

For the pigmentation patterns the range of matches between observers and the catalogue assignments was over 75% for all categories (Table 3), however a small but significant difference was observed ($\chi^2 = 10.1$, df = 4, $p = 0.038$). The most ambiguous categories were the light mottled and the balanced pigmentation patterns. They contributed similarly to the chi-square calculated. The subdivision of the test revealed that only the combined effect of these two categories leads to significant differences, contrasting the results when only one of those categories was removed ($\chi^2 = 5.6$ and 6.1, df = 3, $p = 0.133$ and $p = 0.107$, respectively). Likewise, the ambiguity was mostly related to the adjacent pigmentation patterns (Table 3).

Consistency in dorsal fin and pigmentation categorisation over time showed a similar trend, with 65% matches in dorsal fin assignment between observers and the catalogue. Ambiguities were observed between falcate-triangular and falcate dorsal fin shapes (20%) and between falcate and hooked shapes (15%). For the pigmentation pattern there were 85% of matches and ambiguousness was mostly found between light and light-mottled categories.

DISCUSSION

The potential of this new classification method is founded in the combination of the dorsal fin shape and pigmentation patterns categories. By separating the photographs in 48 combinations (including the undefined categories), the number of photographs to compare is greatly reduced.

Similar to other classification systems, the proposed dorsal fin shape and pigmentation categories are not exclusively distinct, as for the mutilated or marked dorsal fins, but are centred on shapes and pigmentation that change progressively. This characteristic has lead to a degree of uncertainty in the categorisation, which was particularly noted for the falcate-triangular dorsal fin and the light mottled and balance pigmentation patterns.

These results were obtained by comparing the category selections made by observers with different experience in blue whale photo-id work. Including observers with less experience reflected a situation for new research groups starting to work on blue whales, in order to test this classification method from a broad perspective. Our experience with this method has found that, with time, classification becomes less ambiguous.

In the process of photo-identification, the categories that most represent the dorsal fin and the pigmentation observed in the photograph are first compared. To assure that a match has not been omitted, the comparison is extended first with the adjacent pigmentation categories and then with the adjacent dorsal fin category in addition to the undefined categories. This process avoids comparing photographs that share combinations that have a very low probability of a photographic match (i.e. light with dark, or triangular with hooked).

Categorisation of individual dorsal fin and pigmentation over time, such as those that were first photo-identified as calf and recaptured at later age, also showed the same ambiguities with contiguous categories as found for the other whales photographs. There was no modification of dorsal fins or change noted in the pigmentation pattern over time.

Table 2

Percentage of matches between dorsal fin categories elections made by the observers compared to the Baja California Catalogue (Baja CA Catalogue) classification of 70 blue whales photographs and the second elections for the photographs unmatched.

Dorsal fin category (Baja CA Catalogue)	Matches (%)	Second elections unmatched photographs (%)	
Triangle	72.0	Straight (20.0)	Falcate-triangular (8.0)
Falcate-triangular	45.0	Falcate (35.0)	Triangular (20.0)
Falcate	77.5	Hooked (15.0)	Falcate-triangular (7.5)
Hooked	82.5	Falcate (15.0)	Straight (2.5)
Straight	95.0	Falcate (2.5)	Falcate-triangular (2.5)
Marked	87.5	Mutilated (12.5)	
Mutilated	100.0		

Table 3

Percent of matches between pigmentation categories elections made by the observers compared to the Baja California Catalogue (Baja CA Catalogue) classification of 70 blue whales photographs and the second elections for the photographs unmatched.

Pigmentation category (Baja CA Catalogue)	Matches (%)	Second elections unmatched photographs (%)		
Light	93.0	Light-mottled (7.0)		
Light-mottled	77.0	Light (18.0)	Striped (2.5)	Balanced (2.5)
Striped	85.0	Light-mottled (7.5)	Balanced (5.0)	Dark (2.5)
Balanced	76.5	Dark (11.0)	Striped (8.5)	Light-mottled (4.0)
Dark	89.0	Balanced (8.0)	Striped (3.0)	

Here the different category selections may also have been caused by the quality of the photograph that served as recaptures.

Since the exact age of these individuals at their first sighting as calves is known, the blue whale photo-identification technique constitutes a powerful tool in the long term sighting history data set. This contrasts with most other species of whales in which not all individuals can be photo-identified due to a lack of colour pattern or scars (Agler *et al.*, 1990; Rugh, 1990) or due to the fact that the calves show changes in the pigmentation patterns over the years (Carlson *et al.*, 1990) or their behaviour prevents photographing the body part used in the photo-identification technique (Arnbom, 1987).

There are, however, two factors in the blue whale photo-identification technique that can cause misidentification or negatively influence the photo-identification process. The first is the acquisition of marks on the dorsal fin or in the worse cases its mutilation. Therefore, during the comparison of marked or mutilated dorsal fin photographs, if no photo-recapture is found, the comparison with the other dorsal fin categories will be required to assure that the mark or mutilation has not been recently acquired. During the study period, only four whales presented conspicuous changes in their dorsal fin; one was mutilated and the three others showed new marks.

The other factor that might interfere with the certainty of the uniqueness of individual pigmentation patterns is the effect of skin desquamation (Sears *et al.*, 1990). This is a natural phenomenon in cetaceans (Geraci *et al.*, 1986) and sloughed skin is observed and may be sampled from most individual blue whales (Gendron and Mesnick, 2001). However, it is observed more frequently on the flanks of lactating females than non-lactating females or males (χ^2 = 59.84; $p < 0.05$; Ugalde de la Cruz, 2005). This characteristic may be related to physiological factors that take place during pregnancy and lactation (Perryman and Lynn, 2002; Randall *et al.*, 2002). It is probable that some lactating females may be misidentified during the photo-identification process due to large areas of desquamation on their flanks obstructing the pigmentation patterns normally visible. Although this problem is not observed in all lactating females, a special emphasis is recommended in those cases, since the estimation of population reproductive parameters relies on females (Barlow and Clapham, 1997). Likewise, this new classification method based on dorsal fin identification may improve the matching comparison of these females.

Although 68% of the blue whale individuals in the catalogue are now represented in digital images, the difference in the image quality of black and white and colour digital photographs has not been evaluated in the identification process. While good black and white pictures are normally easy to match, the coloured digital images may be improved with software. The efficiency in matching digital photographs may be biased upwards especially since 2005 when digital cameras began to be used. Still only a low percent of the individuals in black and white photographs (4.2%) and digital images (1.6%) are contained in the undefined pigmentation category.

Overall, this method has been useful not only for reducing comparison time and thus allowing more efficient matching, but also in facilitating the finding of intra-catalogue photographic recaptures or photo-recaptures, a major bias when abundance estimations are performed (Hammond *et al.*, 1990). At sea, it has improved survey efficiency by allowing rapid identification of individuals. Depending on the type of photo-identification survey, recognition of individuals may be required to avoid spending unnecessary time photographing the same individual or duplicating skin-blubber biopsy samples within and between seasons. To achieve this objective, a catalogue of previously biopsied individuals classified into these dorsal and pigmentation

categories allow us to accomplish rapid comparison of a newly photographed whale (digital camera viewing) with those included in the field catalogue.

The results of the classification experiment appear to suggest that it may be convenient to remove the falcate-triangular dorsal fin category in order to group all falcate shapes together. However, grouping them in one category would increase the number of photographs considerably. On the other hand, leaving these two categories separate, there are still 77.5% and 45% probability of finding a match within the falcate and triangular falcate categories respectively (see Table 2) with less time consumed for the comparison. As for the light mottled or balanced pigmentation categories, we believe grouping them with the contiguous pigmentation categories will not change substantially the process of photographic comparison, since these are secondary classifications adjacent to each other in every dorsal fin category.

Finally, we encourage other blue whale researchers to test this classification method based on dorsal fin shapes and pigmentation patterns. If it proves as useful as it has been for us, this method will improve large comparison photographs between catalogues.

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