Aquatic Mammals 2022, *48*(5), 456-461, DOI 10.1578/AM.48.5.2022.456

Short Note

The Camera Does Not Lie: Superimposed Dorsal Fins Introducing Error in Cetacean Photo-Identification

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Photo-identification is a commonly used non-invasive technique in cetacean research which can be utilized to identify individuals and, consequently, acquire a variety of life history and demographic information such as group composition, site fidelity, movement patterns, and abundance estimates (Würsig & Jefferson, 1990). Many dolphin species acquire nicks and notches along the trailing edge of the dorsal fin (primary marks) as a result of interaction with conspecifics (Scott et al., 2005; Auger-Méthé & Whitehead, 2007; Kügler & Orbach, 2014). Coupled with scars and other lesions on the dorsal fin and body (secondary marks) as well as natural body pigmentation (Vetters Bichell et al., 2018), these marks make each individual uniquely identifiable. Tissue loss is permanent—that is, nicks and notches might change their shape or size due to additional injuries but regeneration of the tissue has never been recorded (Scott et al., 1990).

The application of photo-identification is rapidly advancing. The development of digital photography (Markowitz et al., 2003) has allowed for easier collection of higher quality data, and recent improvements in automatic image recognition and neural networks assist researchers in the matching process (Thompson et al., 2021). However, the application of photo-identification should still be approached with great caution as misidentification errors are common due to a variance in image quality, individual distinctiveness, and robustness of applied data handling protocols (Urian et al., 2015). In light of this, some research groups require a minimum of three experienced researchers to confirm a match in the photo-identification process (Urian et al., 2015). In addition, a number of situation-specific causes can lead to misidentification of animals in particular images, such as misinterpreting physical obstacles in the field of view like waves, water droplets, and shade or clustered animals as relevant parts of the pattern used to identify an individual. Herein, we look at the possible errors in the matching procedure stemming from images showing several individuals surfacing in tight formation, using the common bottlenose dolphin (*Tursiops truncatus*) as an example.

Commonly, a photograph of a group of bottlenose dolphins surfacing will show different parts of their bodies that may overlap to a varying extent, depending on the timing of the photo and the orientation of the photographer in relation to the dolphins, as well as the timing of the surfacing of any one individual in the group. Even though a perfect alignment of dorsal fins belonging to several individuals that may introduce matching errors is not probable, a recent note by Quick et al. (2017) shows it is an objective possibility. The authors presented several explanations to address a single anomalous image documenting the sudden appearance of nicks on an otherwise unmarked individual. The authors considered circumstances that might result in an anomaly: real-life alterations (tissue alteration, temporary obstruction), human error (erroneous identification), and technical issues (JPEG compression, dead pixels). While these may all be plausible explanations in such occurrences, the authors did not consider the possibility that the image is showing two overlapping dorsal fins rather than just one. The original image provided by the authors (Supplementary Figure 1A in Quick et al., 2017; see Figure 1) appears to show two individuals surfacing next to each other and, at first glance as correctly stated by the authors, the second dolphin cannot be responsible for the visible alterations in the trailing edge of the fin. However, upon closer examination, three visible tell-tale signs that a third individual is present in the image become apparent: (1) a disproportionately long back of the dolphin with the anomalous fin, (2) a clear area of contrast between its body and the body of the "cryptic" dolphin visible about halfway to the tail,

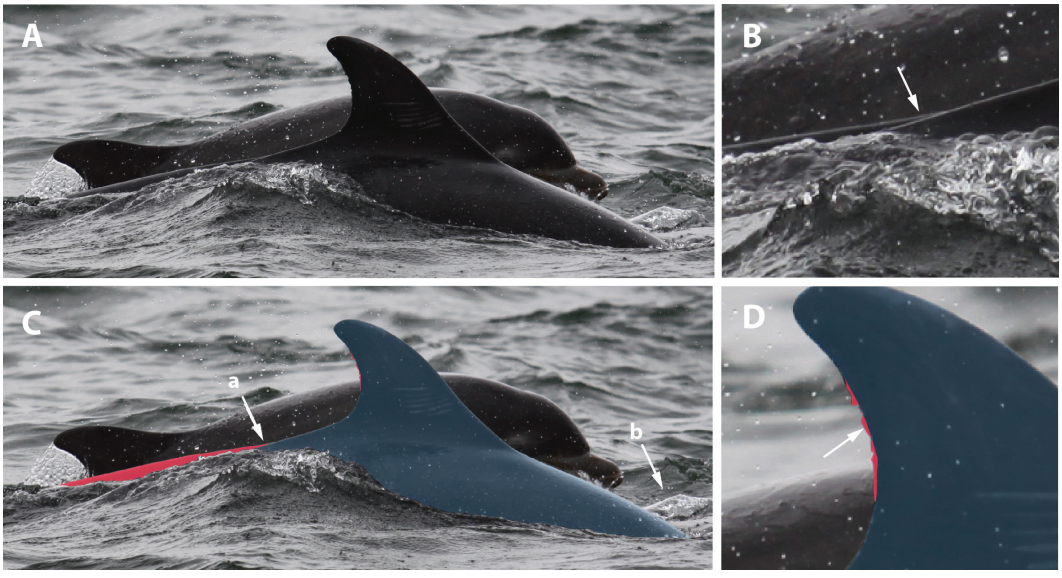

Figure 1. (A) Cropped photograph of individual 1121 reproduced from Quick et al. (2017) showing the supposed non-permanent nick; (B) crop of image A showing the area on the back of the dolphin (white arrow); (C) copy of image A with the third dolphin marked in red and white arrows showing (a) an overlap with individual 1121 and (b) splash created by third dolphin; and (D) crop of image C showing the dorsal fins of the third dolphin (marked in red; white arrow) and individual 1121 (blue).

and (3) a splash located in front of the dolphin visible in the image that cannot be explained by the surfacing of the two obvious animals in the image (Figure 1). The anomalous fin appears ordinary and without apparent indication that a foreign body, splash, or image processing flaw is to blame for the discrepancy. Taking into consideration that a third cryptic dolphin is present in the picture, the simplest solution to the problem is that the image in fact shows two superimposed dolphin fins. The authors state images of all dolphins present in the encounter are available, and it should be an easy task to match the "new" nicks (Figure 1D) to one of the other individuals; however, to date, we were unable to gain access to these data to confirm this.

The Blue World Institute (BWI) photo-identification database from the Adriatic Sea, Croatia, presently comprises more than 500,000 photographs of bottlenose dolphins (Pleslić et al., 2019, 2021; Miočić-Stošić et al., 2020) taken in the past 26 years following data collection protocols described in Pleslić et al. (2013). It features examples of superposition of two almost perfectly aligned dorsal fins, one of which persisted within the catalogue of individuals for several years before the mistake was spotted. An image of a composite dorsal fin was extracted from a sighting, cropped, and included in the catalogue as a distinct individual (Figure 2). The matching was done by a junior researcher in what was, at the time, a relatively new study area (Vis Archipelago, Central Eastern Adriatic Sea) in its third research season and with less than 80 sightings in total. Subsequent validation by another researcher was done using cropped images only, making it difficult to spot the mistake as data indicating that there was another dolphin in the image was missing. In the end, the error was spotted based on fairly pronounced secondary markings (i.e., tooth rakes). It must be noted there were confounding circumstances making it more difficult to spot the mistake: at the time, catalogue images were cropped to show the fin only, and the composite fin was less marked than the two fins from which it was made up. This led to it being consistently compared to poorly marked individuals or those that later became fairly/highly marked (fin distinctiveness categories following Pleslić et al., 2013). In addition, catalogue images were sorted based on randomly attributed names which means the two existing individuals and the false positive dolphin were never aligned in sequence when reviewing the catalogue, which could make it easier to spot the mistake.

It is apparent that superimposed images are difficult to detect even when using fair and high-quality images that are well lit (Figure 3). Lighting conditions likely play a major role in successfully differentiating composite fins, and backlit images are most likely to go undetected as demonstrated in Figure 2D through F. Low light conditions substantially decrease or eliminate even prominent secondary markings such as tooth rakes, lesions,

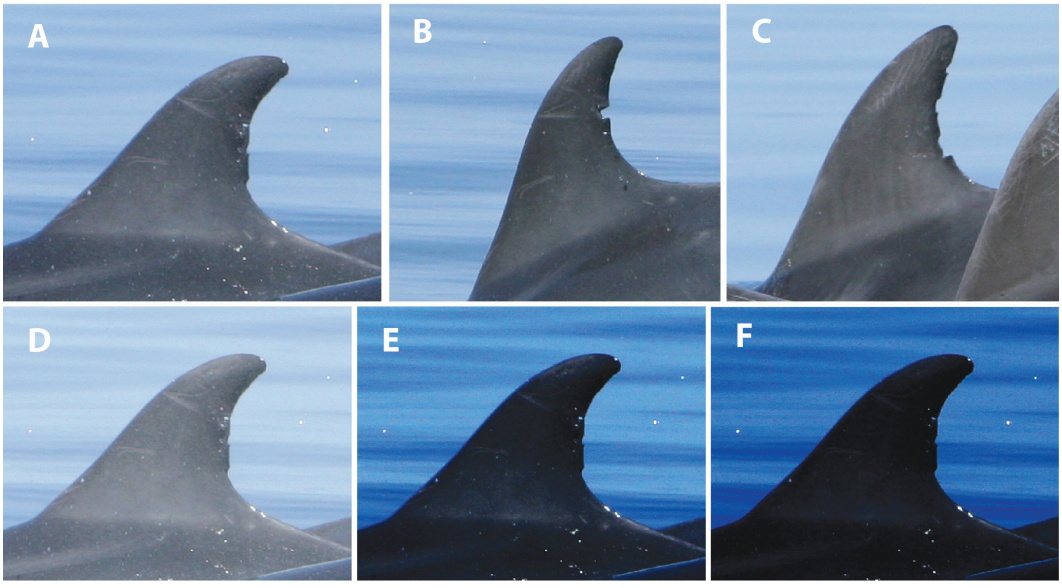

Figure 2. Photographs of two individuals, "Dujka" and "Gruje." The first image in the top row (A) shows the superimposed fins of both individuals with no enhancements, followed by images of individual dolphins taken in the same sighting (B & C). The bottom row shows image A adjusted with three different gamma correction levels (D, E & F) to simulate different lighting conditions.

and pigmentation, leaving nicks and notches as the only identifiable features in addition to the general fin shape. Other obstructions and artefacts can also have a large impact on the ability of the matcher to spot superposition. For example, water droplets may mask contrasting areas of overlap between the fins—also present in the provided example. Low visibility of secondary marks in less-than-optimal lighting conditions may be alleviated to some extent by using images stored in RAW format as they contain more information than commonly used JPEGs (Mizroch, 2007).

As demonstrated here, superimposed fins may introduce error that is likely to persist for a significant period until it is eventually corrected, if at all; however, due to a specific set of conditions that need to be met for such an error to arise, it is likely they contribute only to a small percentage of the total misidentifications that are present in any photo-identification dataset, of which false negatives due to temporal changes in distinctiveness may be most frequent. The example described herein is the only known composite individual featuring superposition that was overlooked in the matching procedure and included in the BWI catalogue, currently containing images of more than 1,100 individuals taken in the respective study area. Nevertheless, photo-identification relies on making matches with (near) 100% certainty (Urian et al., 2015), and any sources of error should be minimised or eliminated if possible. This issue is likely to affect photo-identification studies of other cetacean species, and the frequency of errors may be linked to surfacing behaviour and gregariousness of different species, owing to increased possibility of overlap in large groups swimming in tight formation.

The relative implications of superposition for analyses based on photo-identification data are likely to be case specific and related to the size of the study area as well as the size of the resident population and the available dataset. These are inherently one-off events as it is highly unlikely that the exact same appearance of the composite dorsal fin will be replicated by superposition in subsequent sightings. The false positive individual will therefore persist in the database as a single data point, or it may be misidentified as an existing individual and merged with its capture history. Both situations can lead to overestimation of abundance as false positives add to the total number of capture histories or captures in the dataset. However, due to the presumed low number of false positives caused by superposition, these are only likely to significantly affect estimates based on small datasets and in areas with few resident animals.

The possibility of capturing superimposed fins has several important implications that should be considered when designing a photo-identification study. Using experienced researchers to validate

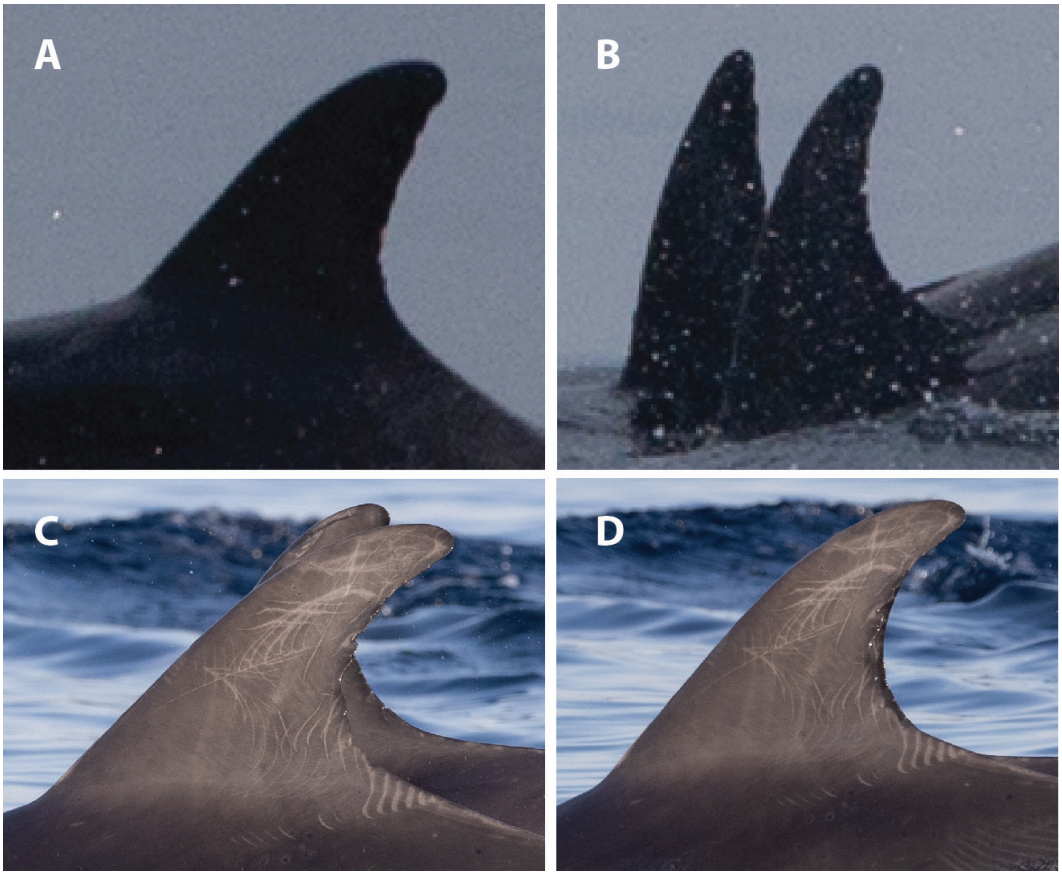

Figure 3. (A) Photographs showing superimposed fins on a poor-quality image followed by an image taken in sequence (B) showing two dolphins, "Neptun" and "V_1801"; (C) high-quality photograph of two dolphins, "Rosa" and "V_2071," followed by an image taken in sequence showing their superimposed fins (D).

data preprocessed by others does not guarantee the error will be spotted, as elucidated by provided examples. Therefore, we are proposing the following recommendations to be integrated into the workflow and protocols for photo-identification data management:

- Ensuring more than one researcher is well-acquainted with individuals from a particular study area is a prerequisite for double-checking the validity of initial matching. Relying on the expertise of otherwise experienced researchers who have never matched the individuals in question may not be enough to spot superimposed fins.

- Adequate temporal spread of research effort is key in monitoring the community and developing good specific knowledge on individuals appearing in the study area. Building a database with multiple sightings of each individual will increase the chances of spotting erroneous designations due to superposition.

- The importance of non-permanent, secondary markings such as tooth rakes should not be underestimated as they are the primary source of information for detecting merged fins. Validation using cropped images showing only the dorsal fin is strongly discouraged due to the loss of important data—not only for detecting superimposed fins but for the matching procedure itself. All visible body parts may show secondary marks that can be used to confirm the identity of the animal, especially in poorly marked individuals with indistinct nicks and notches. In addition, evidence of the presence of additional individuals may be apparent in cropped-out portions of the image.

- Taking sequential photographs of a single surfacing event aids in easier elimination of superimposed fins as it allows for reviewing the surfacing event in more than one photo and following the movement of a particular individual during the event.

- Archiving images in RAW file format allows image manipulation which can be crucial for the identification process in low-light photographs that may require corrections to elucidate identifying features.

- Sightings where only one image of a particular individual is taken should be scrutinized in great detail, unless the image shows a well-known and easily recognisable dolphin.

- Superimposed fins are unlikely to be elucidated by currently available matching software focusing on the trailing edge pattern, and it is imperative that automated matches are confirmed by more than one experienced researcher.

In conclusion, tissue loss on the trailing edge of the dorsal fin of cetaceans remains a permanent feature according to all available data. The problem of identifying superimposed fins is best summarized by paraphrasing a well-known quote: "If it looks like a fin, is shaped like a fin, and has the same nicks as a regular fin, then it probably is a fin . . . or fins."

Acknowledgments

We are grateful to all our colleagues from the Blue World Institute of Marine Research and Conservation for their committed work on the Adriatic Dolphin Project, collecting and analysing data that contributed to this short communication. We thank the anonymous reviewers and the editor for their insightful comments and suggestions which helped improve this manuscript.

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