The effectiveness of individual facial features of bottlenose dolphins as a supplementary tool to conventional fin-based photo-identification

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Abstract

It is important to identify individuals within a population in order to inform the understanding of the biology, ecology, behaviour, and population dynamics of an entire species. Current methods of identifying cetaceans rely on nicks and marks on the thin membrane of the dorsal fin. This has a significant amount of error and issues with the identification of calves prevent generational analyses. This study investigated the reliability of facial identification as a supplement to fin-based identification, using a holistic measure of *Tursiops truncatus* faces. A combination of incidental and collected images were used to perform matching trials with experienced and inexperienced biologists using the Cardigan Bay population. Facial features were found to be reliable for identification, matching scores were significantly higher than would be expected by random matching. The life stage of the individual and time between images was not found to have an impact on matching ability. This would allow a greater ratio of identified individuals within a population, especially calves. Images of a lower quality reduce the reliability of identification, and it is yet to be proven that facial features are consistent. This form of identification can be used as a supplement to current identification methods and can reduce the errors within fin-based identification.

1. Introduction

Long-term studies of populations allow a greater understanding of the ecological and evolutionary processes affecting the demographic and evolutionary structure of a species (Clutton-brock & Sheldon, 2010). Many important ecological processes can affect the demographic and biological structure of a species, influencing change and survival of populations (Wells & Scott, 1990; Clutton-brock & Sheldon, 2010); these processes habitually occur long-term, only becoming clear over multiple years or decades and cannot be understood with a single study over hours or days (Clutton-brock & Sheldon, 2010). Identifying the individuals within a population can increase the understanding of the biology, ecology, and behaviour of a population, and therefore the entire species (Bain, 1990; Defran et al., 1990; Wells & Scott, 1990). Following a population long-term through linkages between generations can allow a greater understanding of reproduction, selection, and recruitment rates, therefore displaying and quantifying the social structure of the individual population (Defran, et al., 1990). The age structure of a specific population can be found, this allows for linkages between life history and understanding of survival and mortality rates, which can then be extrapolated to survival rates and used to form lifetime fitness measurements for the species. This is also highly relevant to understanding how best to conserve and manage a species (Genov et al., 2018); improving the understanding of ecological patterns and ecosystem function is critical for preventing extinctions, loss of biodiversity and disruption of ecosystem services. (Block et al., 2011).

Marine mammals can be used as “focal species”, indicating any changes in the ecosystem and acting as “flagships” for conservation efforts; following these species is a relatively simple means of understanding complex environments and communities (Zacharias & Roff, 2001). However, there are logistical and financial challenges involved in identification of marine mammals (Hastie, 2012). Obtaining individual-level information is complicated by the lifestyle of large marine mammals. Marine mammals are wide-ranging and highly mobile species that spend most of their time submerged (Martin et al., 1971; Hastie, 2012). This creates issues in locating and identifying individuals who can range across whole oceans. Cetaceans have varying levels of confidence in approaching humans and boats, creating bias in the individuals who are identified; this is especially true for animals with young calves who show greater avoidance responses (Wursig & Jefferson, 1990). This can limit sample sizes and result in lower statistical power in measuring populations, especially in the case of high inter-individual variability (Hastie, 2012).

K-selected vertebrates can be identified in a variety of ways (Wells, 2009). Capture and handling was used until recently to identify individuals, such as cetaceans, through tagging or mark-recapture schemes (Hastie, 2012). This has been found to have logistical and legal negatives, requiring disturbance to the animal and expensive equipment that only lasts for a short time-scale (Gope, et al., 2005). Photo identification through the utilisation of natural markings or features has been found to provide the least disturbance to the individual, while being practical and cost efficient (Gope, et al., 2005). These markings can be found across the body and include notches, scars, patches, and pigmentation variations (Gope, et al., 2005: Wursig & Jefferson, 1990). Cetaceans are vulnerable to scarring, with the most identifiable scars occurring on head, back, dorsal fin and tail flukes (Lockyer & Morris, 1990). 166 species of aquatic animals possess biological marks that have been used in identification studies (Emery and Wydoski, 1987; Wursig & Jefferson, 1990). The most widely used and current technique for cetaceans is through the measurement of nicks, scars, scratches, and pigment spots in membranes on the trailing edge of the dorsal fin and flukes; these thin membranes are prone to damage (Wursig & Jefferson, 1990) (Fig. 1). These are often unique and distinct between individuals (Wells, 2009). The long-term tracking of individuals through the repeated identification of natural fin markings can facilitate the understandings of distribution, movement patterns, and migrations of individuals (Defran et al., 1990). Identification studies assume that features are distinct and long-lasting, creating no error in interpretation (Wursig & Jefferson, 1990).

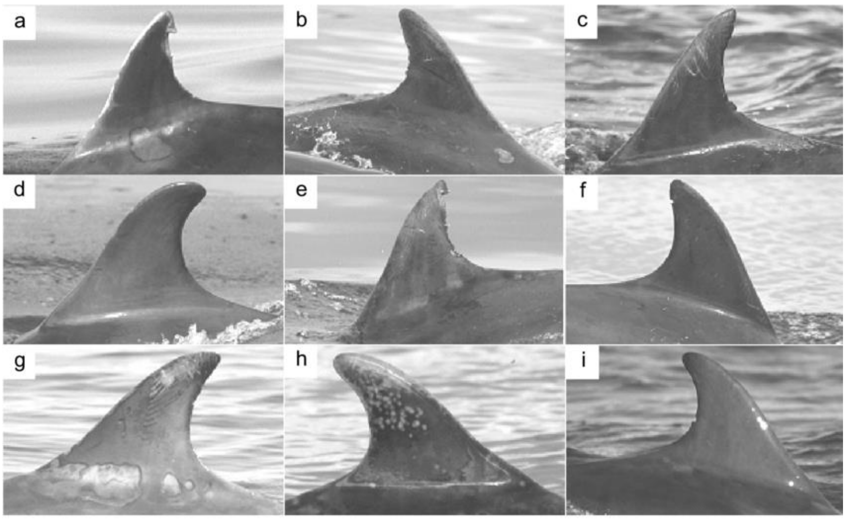


Fig. 1- High quality dorsal fin identification photographs of nine different bottlenose dolphins from NE Scotland (unpublished data from the Lighthouse Field Station, University of Aberdeen & Sea Mammal Research Unit).

Dorsal fin marking studies have significant limitations in interpretation, due to varying distinguishability of markings (Culloch, 2004) (Fig. 1). Natural markings must be distinct enough to eliminate the potential for 'twins' to occur within one population (Wursig & Jefferson, 1990). These markings are often caused through wounds or pigmentation changes following healing of marks. Wounds on *Tursiops truncatus* have been found to last between 5 and 7 months and can leave permanent scar tissue damage and changes in pigmentation of the individual (Lockyer & Morris, 1990). Marks are diminished over long-term studies, and new scars or marks can appear and obscure previous marks (Lockyer & Morris, 1990). The distinguishability of a fin has a controlling impact of the reliability of identification and capture probability (Urian et al., 1990). A fin must be unique enough and have enough markings to allow identification of an individual without error (Urian et al., 1990). The interpretation of different markings on a fin is often subjective to the observer

(Culloch, 2004). This has been shown to inject a large amount of bias to the results of identification studies (Wells & Scott, 1990). Previous studies have found high rates of false positives and negatives within fin-based identification studies (Culloch, 2004; Gunnlaugsson & Sigurionsson, 1980). The error rate of identification has been found to decrease from 0.125 to 0 with a more distinctive fin (Urian et al., 1990). The non-distinctive individuals with unmarked or slightly marked fins are often excluded from population estimates due to this high rate of error and the lack of reliable identification methods (Urian et al., 1990).

Fig. 2- Adult and calf swim together in Sarasota Bay. The calf is identified through the distinguishability of the mother, due to an unmarked fin. (Sarasota Dolphin Research Program. Photo taken under NMFS Permit No. 15543.)

Generally, calves have a lack of distinguishable marks on the dorsal fin (Weigle, 1990; Wursig & Jefferson, 1990). The nicks used for identification are often gained through inter- and intra-species social interactions and over long-time scales on an incidental basis (Wursig & Jefferson, 1990). Calves are generally associated with their mother, not found at random within the population, and will not have had as many interactions to cause scars (Grellier et al., 2003) (Fig.2). Identifying juveniles is vital to fully understand the social and demographic composition of a species (Weigle, 1990; Wells & Scott, 1990). These individuals may be lost post-weaning due to a lack of markings, preventing long-term generational studies and decreasing understanding of reproduction within the species (Wells & Scott, 1990). Identification after recruitment would aid in following the calf post-weaning, allowing cross-generational studies (Grellier et al., 2003). Lineages may be followed, and genetic diversity may be inferred without disturbance inducing methods of genetics (Wells & Scott, 1990).

It is important to reliably identifying a representative sample of individuals within a population. The issues with fin-based identification methods have given a greater importance to the creation of new methods for marine mammal identification. Symmetry is similarly a visual property that is common across animals and has been shown to be detected efficiently by humans (Genov et al., 2018; Tate et al., 2006). Humans have been shown to process and differentiate facial images quicker and more efficiently than images of non-facial objects, by >200ms (Farah et al., 1998), and recognise mammal faces at the same speed as visual processing of human faces (Leopold & Rhodes, 2010). A 30-minute old baby can track a moving face farther than other moving patterns of similar complexity (Farah et al., 1998). It is important for mammals to be able to identify faces within mammalian species as these often contain important visual cues that display social information (Racca et al., 2010; Tate et al., 2006); this is especially important in social mammals, such as *Tursiops truncatus* and humans (Genov et al., 2018). This suggests facial-specific cognitive and neural processing mechanisms within humans; these have strong similarities with the processing systems of other mammals (Tate et al., 2006). Previous studies using visual comparison tasks have found similar discrimination between individuals within other species, including non-mammalian species such as birds and insects (Racca et al., 2010). Holistic processing is the most widely used method of distinguishing facial features; this relies less on part decomposition than taking a single measure of the shape of local features and their spatial arrangement (Farah et al., 1998).The use of a matrix of facial features forming a distinctive and unique ‘face’ of an individual has been widely employed in the identification of terrestrial animals (Tate et al., 2006). Facial features are consistent long-term, and several taxa exhibit unique and distinct faces to allow for identification (Tate et al., 2006).

Previous studies have suggested facial features and holistic processing can be used for the identification of individual *Tursiops truncatus*. Genov et al. (2018) first investigated the feasibility of this method, the matching achieved from facial features was found to be significantly different to what would be expected from random matching, and therefore facial matching was shown to be possible within bottlenose dolphins (Genov, 2018). Distinctive facial features are found to be consistent and reliable within bottlenose dolphins, with adult facial features showing uniformity over 9 years, while juvenile bottlenose dolphins show temporal stability over 32 months (Genov et al., 2018) (Fig. 3). The use of facial identification may be used as an alternative or supplement to fin-based identification, increasing reliability and allowing mark-recapture analyses to include a greater subset of the population.

Fig. 3- Faces of two dolphin calves, showing consistency of facial features over time, as well as differences between the two animals (Genov et al., 2018).

This study aims to analyse the reliability of facial-based identification of individuals; this will eventually be used to compliment a pre-existing catalogue of fin-identified individuals. This catalogue has been formed over 8 years of data collection from 2012 to 2019 in Cardigan Bay on wild *Tursiops truncatus*. The use of facial features to compliment the current ongoing fin-based identification studies will increase reliability of ecological studies. These data will then be used alongside that collected specifically for use in facial recognition studies to build a catalogue of Cardigan Bay dolphin facial features. The reliability of identifying individuals in this way will be tested, to analyse the potential for wide-spread long-term use. If this method of identification is successful it will allow a more reliable method of identifying juveniles or unmarked adults, increasing the representative samples for studying populations. Specific gaps in knowledge will be targeted, and attempts will be made to match unmarked juvenile dolphins to calf pictures from previous years.

2. Methodology

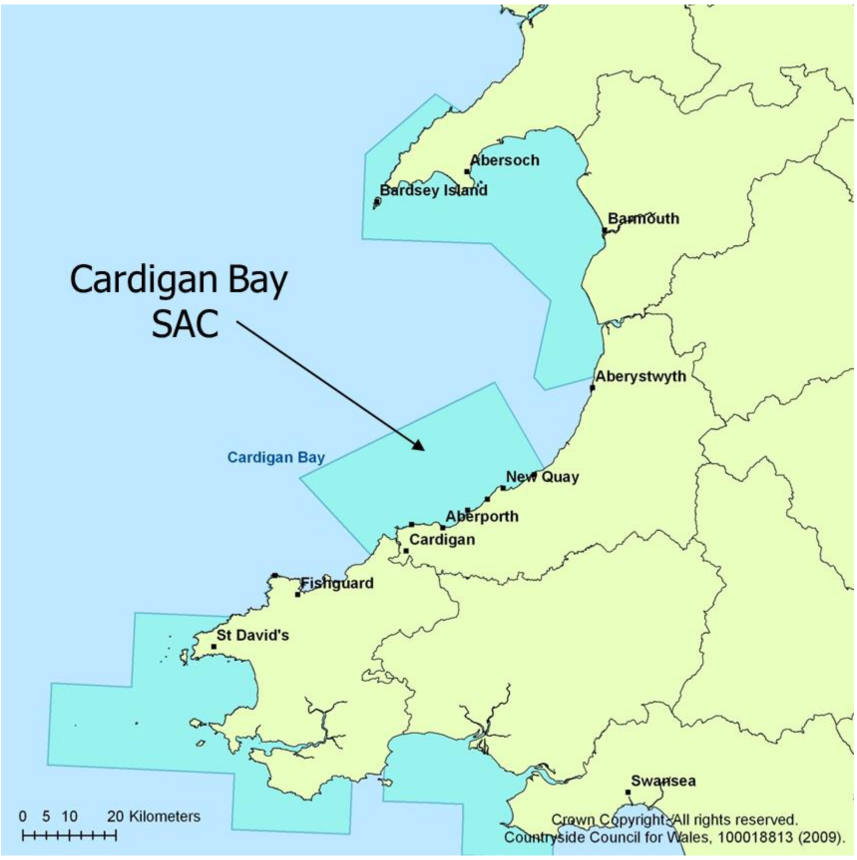


Fig. 4- Map of the Cardigan Bay area, including the SAC protected sites of Cardigan Bay and the wider Cardigan Bay area (top box). (Countryside council for Wales, 2009).

2.1 Study location and species

The Cardigan Bay study area covers >650,000km^2 of Welsh coastal waters and the Irish Sea, with 96km of coastline (Fig. 4). The Bay itself is a large shallow embayment found on the West coast of Wales and is the largest bay in the UK. The Cardigan Bay area is a Special Area of Conservation (SAC), due to the protected status of several cetacean and pinniped species resident to the bay under the annex II of the EU Habitats Directive (Pierpoint et al., 2019). Nine out of 28 cetacean species inhabiting UK coastal waters can be found here, with 8 out of 9 being regular seasonal visitors or residing here (Pierpoint et al., 2009). The *Tursiops truncatus,* or bottlenose dolphin, is one of those species. This area is home to the largest population of dolphins in Europe, with 300 to 500 individuals occupying the area throughout the year and possesses one of two resident bottlenose dolphin populations within the UK (Bristow & Rees, 2001; Pierpoint et al., 2009). 56% of *T. truncatus* within the SWF catalogue have been resighted in the region over 6 years (SeaWatch Foundation, 2019).

The SeaWatch Foundation has been using land and boat-based surveys to study populations of bottlenose dolphins and other cetaceans in this area since 1973 and has collected a database of >70,000 records, comprising of images of individuals and data on all encounters. The collated data on encounters includes biotic and abiotic conditions, such as weather and human encounters. 2,000 people have contributed to one of the largest and longest-running sighting schemes in the world. Dedicated line transects have been performed using boat surveys in the Cardigan Bay SAC since 2001; this was expanded in 2011 to include Northern Cardigan Bay (Fig. 5). There are >400 individuals currently in the fin-based catalogue, with ~50% slightly marked or unmarked.

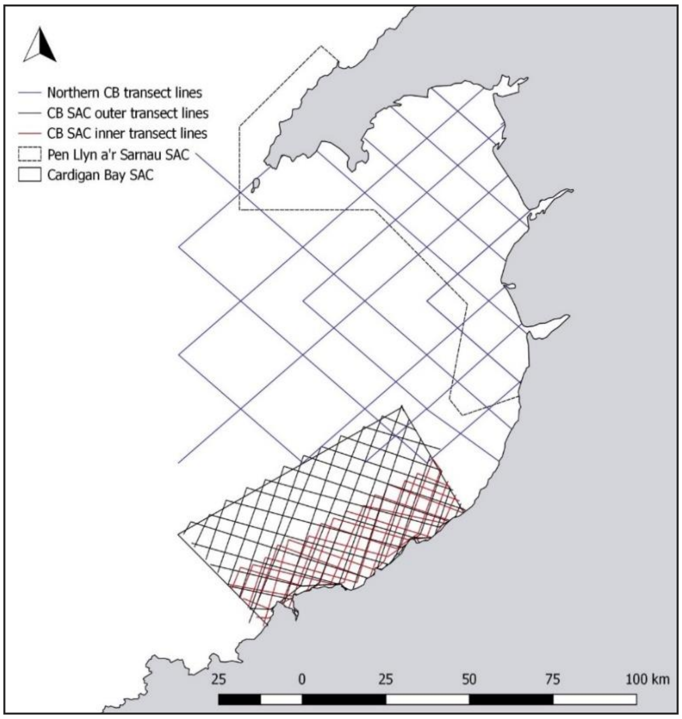


Fig. 5- Maps showing the predetermined transect lines of the Cardigan Bay area. (SeaWatch Foundation, 2019).

This site is known to be frequented by mothers and calves, due to the shallow nature of the bay, reaching 60m at its deepest, and summer tidal fronts in the Irish Sea transporting significant amounts of plankton, fish and squid (SeaWatch Foundation, 2019). Individuals are found to use New Quay for predominantly demersal feeding; observations of live and stranded individuals have shown they consume a wide range of prey with the Bay (Pierpoint et al., 2009). Calves are born all year round, however the maximum concentrations occur between May and September, with a peak in June and July. 71 mothers and 93 calves were sighted in the Cardigan Bay area in 2016 with an average birth rate from 2005 to 2016 of 6.4% of the population using a closed population model (Lohrengel et al., 2017). 65% of female *T. truncatus* resident to North Wales were found to migrate to Cardigan Bay to give birth and raise new-borns, with 50% of those remaining in the bay for >1 year (SeaWatch Foundation, 2019). Currently there are difficulties with tracking juvenile bottlenose dolphins in the population, creating errors in abundance estimates and difficulties with cross-generational studies.

2.3 Data collection

Data were collected through a combination of dedicated line transects and non-line transects carried out from June to August from 2012 to 2019. This represented the highest residence time and the widest range of individuals found within the bay (Pierpoint et al., 2009). Data from the past 8 years were used within this study. This was due to availability of data and ensured the highest quality of photography due to increased quality of digital images and cameras. Data collection methods followed the marine code of conduct to ensure the least disturbance to local populations. Transect lines were chosen randomly. Transects were conducted using two platforms, surveying a narrow strip around the centreline. GPS measurements were used to ensure repeatability of the line transects over seven years of data collection. Environmental data were taken every 15 minutes. Each survey took the date, time, location, species ID, physical description, number of adults, juveniles, distance, behaviour, direction, and environmental factors such as sea state, swell, and wind direction. Vessels travelled at a constant speed during line transect surveys to prevent disturbance to the individual, deviating during encounters for photo identification then returning to as close the previous position as possible. Surveys were performed in the most appropriate weather conditions for photograph identification, with a Beaufort Sea state of ≤3 and visibility of >1.5m. This ensured photographs were of the highest quality and the most representative of facial features.

Two pairs of independent observers ensured the best coverage of the survey area. Photographs were taken by two observers using 35mm digital single lens reflex cameras, with a continuous shooting speed of ≥5 frames/sec. Telephoto lenses were used to ensure the best quality images of the breaching individual. Photographs were only taken of individuals within 40m from the vessel, under NRW licence, to ensure the best representation of features while ensuring the least disturbance to the animal. If individuals were shown to react negatively to the boat presence encounters were terminated.

Any pre-existing images of the facial features fitting the quality requirements for facial based recognition methods were then extracted from the data. This was done by eye, looking at each image individual for a facial picture, and then assessing the quality of the image and suitability for matching. Quality rankings were created based on peer reviewed identification standards for fin-based identification (Rosso et al., 2011), with quality 5 and 6 including close proximity photographs showing the best representation of an individual, and the best resolution of pictures to ensure accuracy (Fig. 6). Quality 4 images were taken at a distance with a full or partial image of the face represented. Images of quality 4 and above were used within the study. Quality 4 photos were initially gathered to act as a contingency quality measure, which was then utilised due to a lack of data.

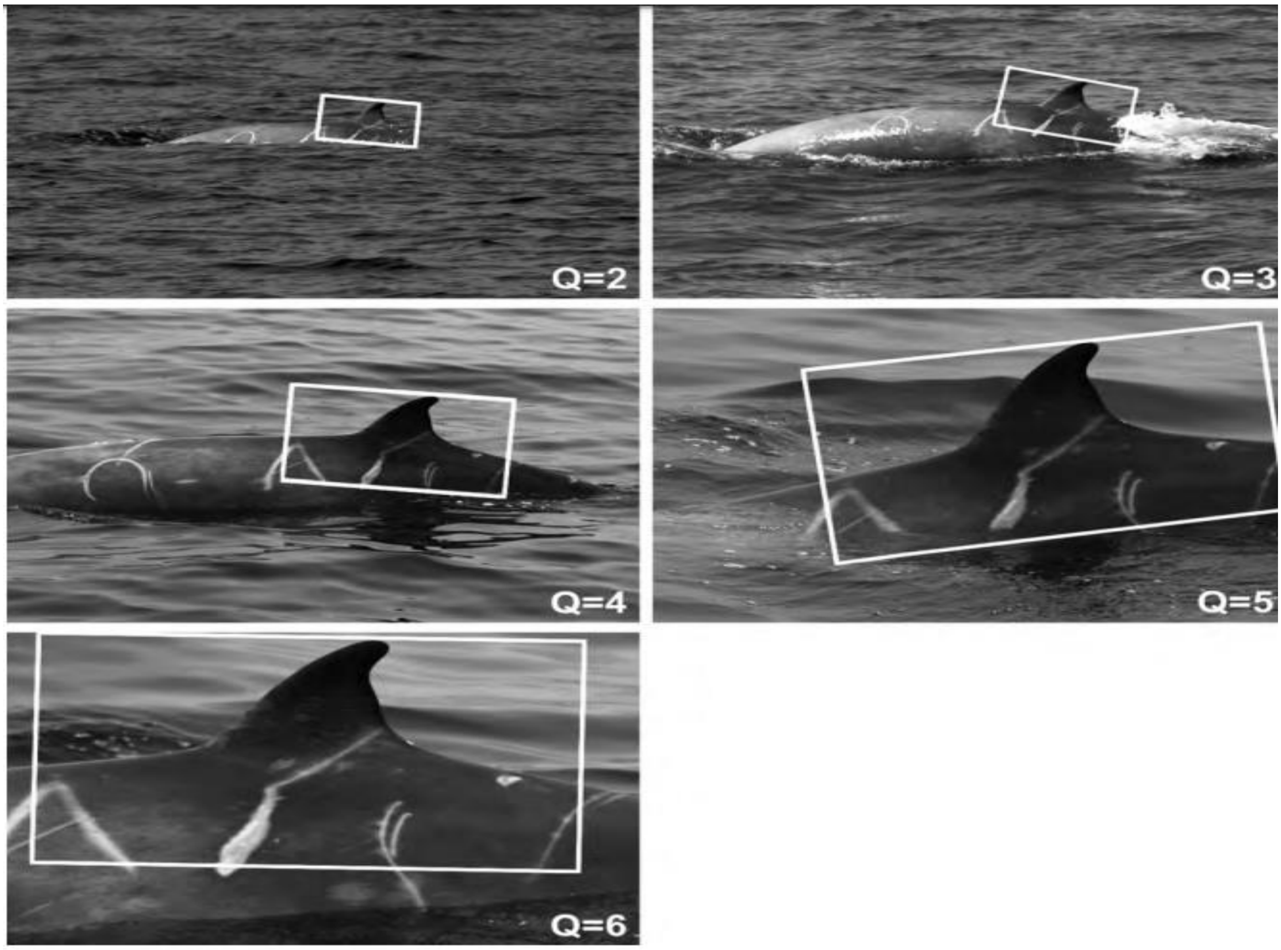


Fig. 6- Example qualities of the same individual in different photos, where Q = 4 distant shot showing the whole area; Q = 5 close, well focused, with good representation of the area; Q = 6 close, well focused, showing the whole area (Rosso et al., 2011)

Photographs of an acceptable quality level were then matched by eye to previous images of known identities, using fin-based identification. 262 images matched the quality requirements for facial matching. Of these, the incidental nature of capturing both an identifiable fin and the full facial structure meant only 42 images were able to be linked to an individual. Twenty-four adults and 3 calves were successfully matched to high quality images. These images were then used to create a face-based identification catalogue to allow further study and a more accurate identification of *T. truncatus* in Cardigan Bay.

2.3 Matching trials

Ten individuals were chosen to be used within the matching trials (Fig. 8). These individuals were selected based on the availability of data. Within the matching trials 3 calves were represented, and 7 adults. This was done in order to analyse the viability of this technique to fill the gaps in knowledge caused by difficulties in identifying calves. Calves were identified by reliable identification of the mother's fin, and only images were used with the calf in close proximity to the mother. Photographs were selected where the full representation of the calves' face was shown. Two folders of 20 images were created. Ten images within folder A had a match to folder B. The other 10 images in each folder had no match; this ensured the correct matches did not occur randomly.

Experienced and inexperienced matchers were used to gain the most accurate measurement of the feasibility of facial based identification. Human performance in facial matching is known to depend primarily on exposure to facial structures and practice in matching (Racca et al., 2010). Six SeaWatch Foundation interns served as inexperienced participants and 12 biologists with experience in fin-based identification methods served as the experienced matchers. Experienced biologists must have been working in the cetacean identification field, or similar disciplines, for a minimum of one year. The number of participants in the study ensured the best replication of the 2018 study into facial identification (Genov, et al. 2018) allowing accurate comparisons into the suitability of this technique for identification studies and expansions on previous studies. A 'holistic' examination of the facial structure was used to identify individuals. This method of identification involves a general overview of the individual's facial features and structures, as opposed to focusing on one area or feature. Participants were told to match the faces of an individual and were not told of how this should be performed, in an attempt to simulate natural matching studies.

2.4 Statistical analysis

Matching trials were scored through a point being awarded for selecting the correct image from folder A, with a maximum of 10 points, and then a separate point was awarded for correctly matching that image with its match in folder B, again with a maximum of 10 points, therefore all scores were out of 20. The results of the matching trials were analysed through a peer-reviewed hierarchical statistical model used to establish the null distribution of scores and comparing actual scores with those predicated by a random probability distribution. The random probability was calculated through a binomial distribution equation (see Genov, et al., 2018).

N is the number of correct images selected in folder A by the participant. In order to analyse the likelihood of selecting the correct photographs from folder A to match to folder B, a binomial process was used to calculate the probability of selecting *n*. The probability was equal to the proportion of correct images in folder A and was calculated using equation 1 within RStudio with *N* being 10 and *Nt* being all possible images, therefore equalling 20.

(1)

```
p.in <- dbinom(0:N,size=N, prob=N/Nt)

p.out <- dbinom(0:N,size=N, prob=1-(N/Nt))
```

N_B was calculated as the probability of selecting all ten correct images from folder A, and therefore has a binomial distribution of 0.5, or 10 out of 20. This was simplified in equation 2.

$$P\ (n/N_B,\ N_A) \sim \text{Binomial}\ (N_B,\ p = N_B/N_A) \qquad (2)$$

K is the number of matches a participant would achieve with *n* correct images from A with its counterpart in folder B. In the case of selecting all 10 correct images from folder A (n=N_B), the probability of getting K matches was solved in equation 3 through Montmort's matching problem (de Montmore, 1713), also known as the hat matching problem.

$$P(k/NB) = 1/k! \sum_{(J=0)}^{(N_B=k)} (-1)^j/j! \qquad (3)$$

However, no researcher chose the correct 10 images from folder A, so *n* was always less than N_B. Equation 4 was used repeatedly to calculate the probability of getting *K* matches from the selected *n* photos, with *n* being 0-9 and $K<n$.

$$P\ (k/N_B,\ n) = (1-k/n) \times P\ (k/N_B,\ n+1) + (k/n) \times P\ (k+1/N_B,\ n+1) \qquad (4)$$

This was used to create the observed frequency distribution for the actual and random distribution of scores.

3. Results

3.1 Matching reliability

Matching of facial features was significantly higher than would be expected in the case of random matching, for both experienced and inexperienced matchers ($P<0.0001$). The expected score for random matching was 5/20. All results were equal to or above the 95% confidence interval of 10/20 that would be expected in the case of random matching. Experienced researchers performed better than those inexperienced in dolphin identification (Fig. 7). 68% of experienced matchers and 44% of all participants scored the median result (Table 1). No experienced or inexperienced participant scored above 95% or below 50%.

Table 1. - Matching results by experienced and inexperienced participants. Median scores and percentages with ranges shown in brackets.

	Experienced	Inexperienced
Median	16 (15-19)	13 (10-14)
Median %	80 (75-95)	63 (50-70)

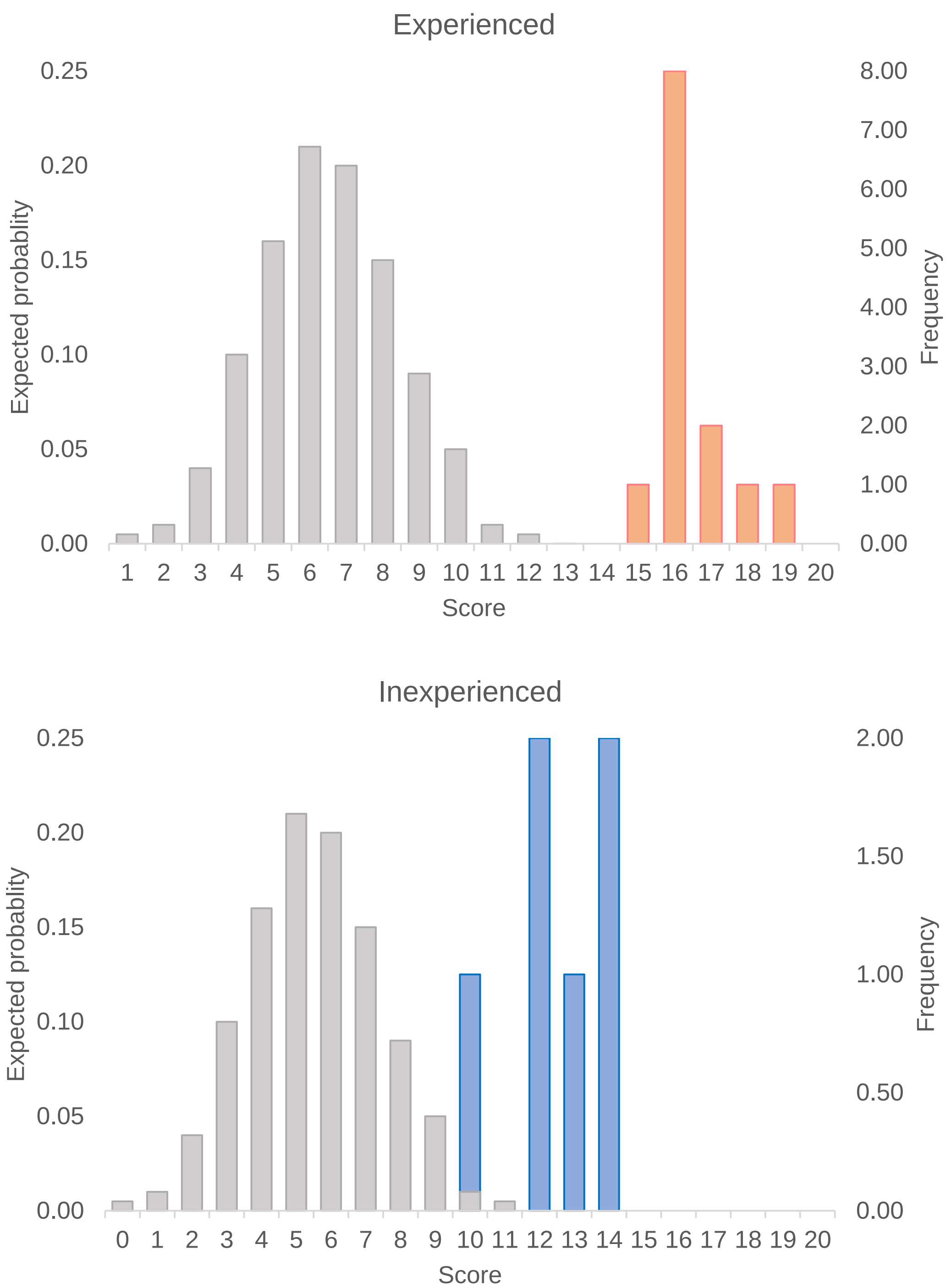
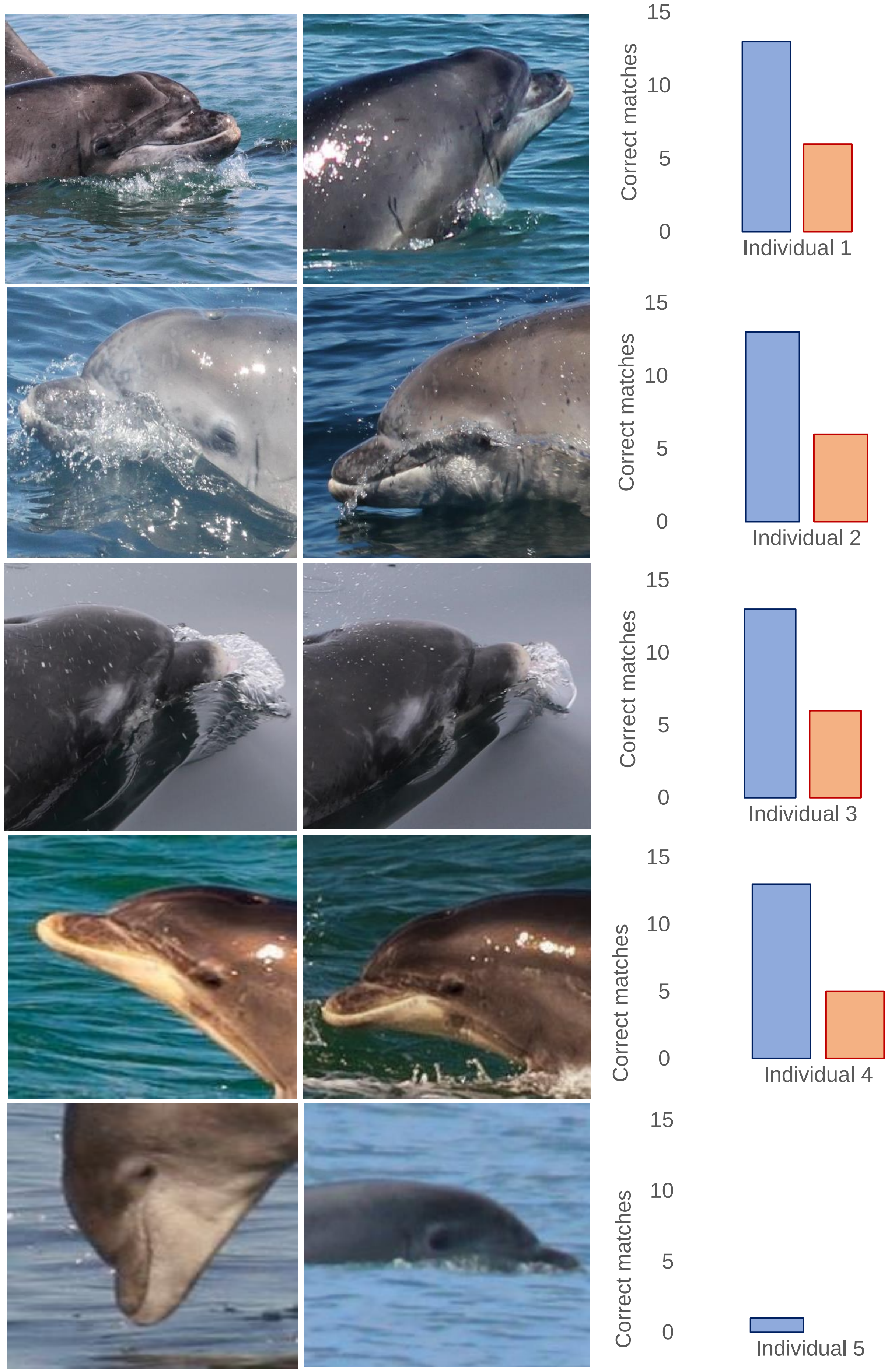


Fig. 7- Experienced and inexperienced participant scores in the matching trials out of 20, compared with the probability distribution expected from random matching (grey).

3.2 Individual impact

The individuals included in the study were found to have an impact on how successful matching was. Only one participant matched images of individual 10 and 5 (Fig. 8).


Correct matches
15
10
5
0
Individual 1
Correct matches
15
10
5
0
Individual 2
Correct matches
15
10
5
0
Individual 3
Correct matches
15
10
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0
Individual 4
Correct matches
15
10
5
0
Individual 5

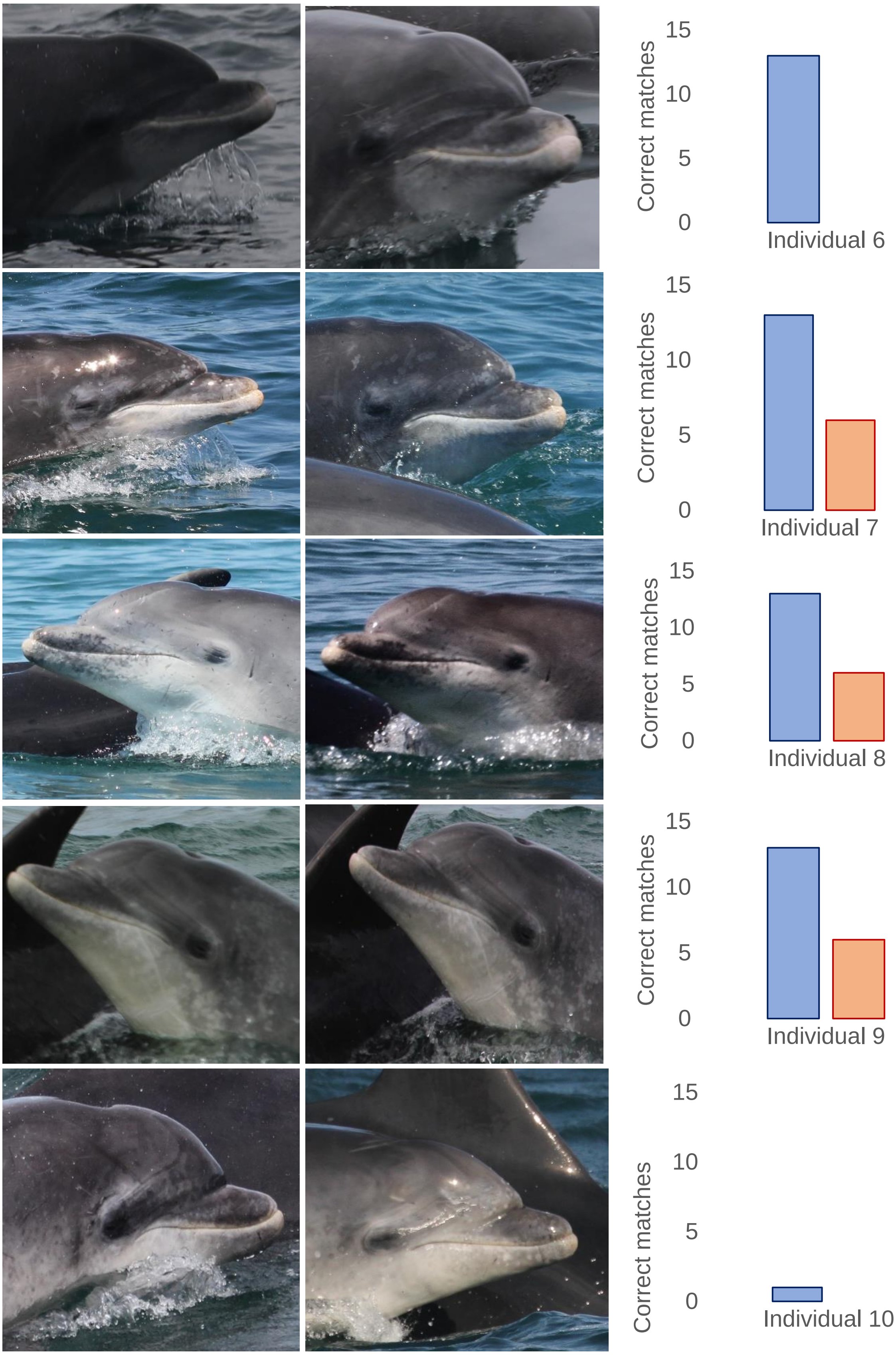

Fig. 8- Individual *T. truncatus* included in the matching trials, with the number of matchers correct of experienced (red) and inexperienced (blue) matchers.

3.3 Quality analysis

The quality of the images had an impact of how successful matching was (Fig. 9). Above quality 5, all matchers achieved the correct matches, regardless of experience level (Fig. 8). Individuals of quality 5 and above had a 100% matching rate with both experienced and inexperienced matchers (Fig. 8). This suggest a quality threshold where experience has little impact of matching. However, below this threshold, experience was an important factor in the success of matching images of varying quality. Individual 6 was correctly matched by all experienced participants and was not matched by any inexperienced participants (Fig. 8). Individuals 5 and 10, who were represented by the lowest quality images with an average quality of 4.5, both had only one correct match each, showing a separate threshold where most participants cannot match the individual, no matter their experience level (Fig. 9).

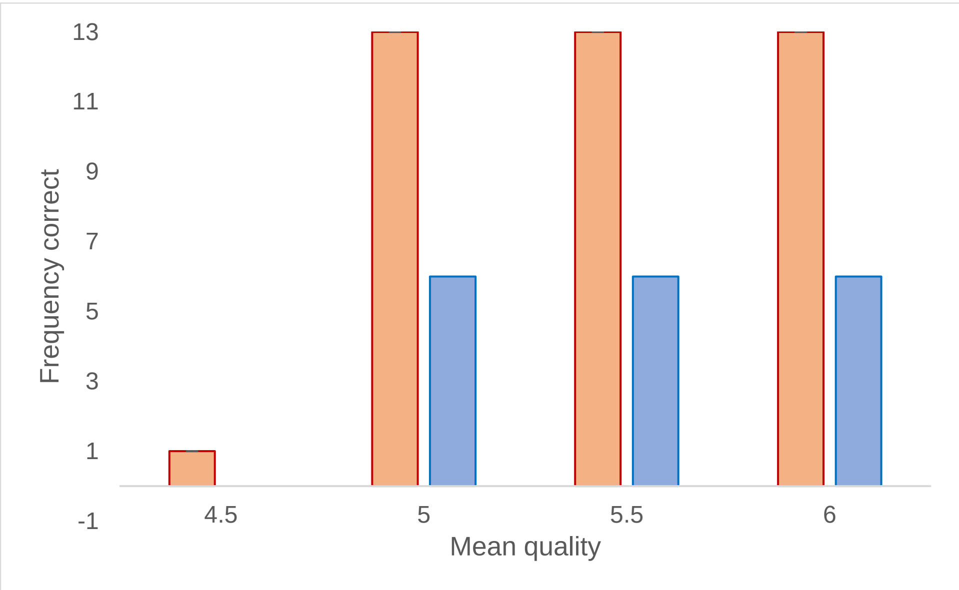

Fig. 9- Frequency of correct matchers achieved in the matching trials for varying quality of the two images for experienced (red) and inexperienced matchers (blue).

3.4 Calf identification

Matching ability was not found to vary significantly with individual life stage (Fig. 10). 3 calves and 7 adults were included in the matching trials. This did not affect the frequency of correct scores. Images used within the matching trial were limited to a maximum of two years between photographs, due to a lack of available data over longer time scales. This was not found to have an impact on matching ability. Facial features appear to be stable and recognisable over a two-year period, for both calves and adults in the population.

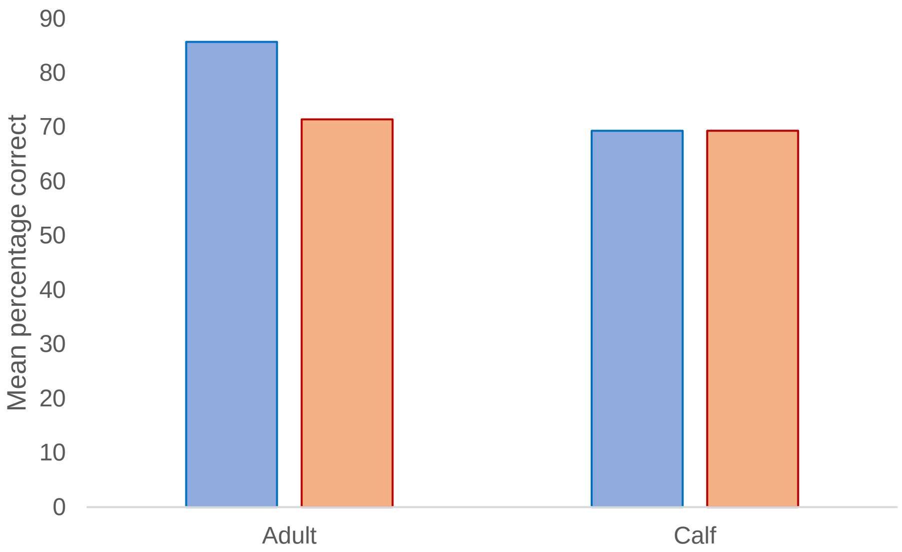

Fig. 10 – Mean percentage matching ability for adults (n=7) and calves (n=3) included in the matching trial for experienced (red) and inexperienced (blue) participants.

4. Discussion

The results reported here support previous theories that facial features can be reliably used to identify individual *Tursiops truncatus* (Genov, et al., 2018). In the case of both experienced and inexperienced matchers, facial identification scores were shown to be higher than random and matchers were able to be distinguished by facial features alone. Calves previously identified through the presence of a mother were able to be distinguished and identified by both experienced and inexperienced matchers. A facial catalogue was established to be utilised in future years as a supplement to fin matching.

The results of the only previous study into facial feature identification in bottlenose dolphins were replicated in this paper; facial feature identification is a reliable method for bottlenose dolphins (Genov, et al., 2018). These features were found to be consistent across angles of the dolphin within the image and time scale of the images (Genov, et al., 2018). This study introduced a greater capacity for error than Genov's study (2018) as the original study only included 10 images of the chosen individuals in folder B, making the correct images easier to match. The inclusion of an extra ten images in folder B, representing unmatched dolphins, increased the chance of randomly selecting incorrect images due to double the choice of images. This increased the non-random nature of matches between the two folders and augmented the reliability of the study.

Bottlenose dolphins are an easily identifiable species, with some studies reporting most populations display >50% of individuals showing identifiable fin characteristics (Wursig & Jefferson, 1990; Wursig & Wursig, 1997); this is significantly higher than other fin identified species such as pilot whales, with <20% showing identifiable characteristics (Wursig & Jefferson, 1990). Bottlenose dolphins have been used as a 'white rat' within cetacean studies since the 1960s, due to the survival of the species in captivity allowing population wide experiments (Wursig & Jefferson, 1990; Clutton-brock & Sheldon, 2010). Large wild communities have also been studied for long time-scales, such as the Sarasota Bay population in Florida, Shark Bay in Australia, and Moray Bay in Scotland, all of whom have been studied extensively for >40 years (Wells et al., 2013).

Fin-based identification has been shown to introduce both positive and negative errors to population studies (Culloch, 2004; Gunnlaugsson & Sigurionsson, 1980). This has been attributed to issues with the stability of fin-marking and the uniqueness of marks (Urian et al., 1990), with marks being scarred over or fading (Lockyer & Morris, 1990); it is common for fins to vary within a short time-scale due to marks healing or becoming scarred over (Lockyer & Morris, 1990).

Matching was performed based on a 'holistic' image of the dolphin's face in both studies into facial identification; this was based on how the human neural systems process faces at the quickest speed (Leopold & Gillian, 2010). In this study individual markings or features were not supposed to be utilised in matching. However, images used in the study were taken a maximum of 2 years apart. The incidental nature of gaining all these within a short time-scale, with some during the same encounter, may have introduced a level of bias to the study around scar markings. Any markings would have likely been visible in both images and may have been utilised by participants to match the individuals. These scars would affect the results and the long-term implications of this study may have been affected as scars fade (Lockyer & Morris, 1990) However, facial features are exposed to little external influences, such as social interactions which may cause scars (Genov et al., 2018). The short time-scale between images meant the stability of facial features was not tested, and variations over time, especially with calves being recruited into the population, may introduce bias into facial identification.

Identification reliability was not affected by the life stage of the individual, with calves being able to be identified at the same rate as adults. This suggests facial identification may be a suitable supplementary method to fin based identification methods in order to increase the reliability of calf identification. The effect of time between images was not found to influence the identification ability of participants within the matching trials. However, due to the incidental nature of image collection and identification of the individual, images were only found a maximum of 2 years apart, with the majority coming from the same year. Previous studies have found a stability of calves of 32 months, and adults of 8-9 years (Genov, et al., 2018).

Identification of calves is vital for long-term studies of populations (Wursig & Wursig, 1979). Following a population through generations will increase comprehension of reproduction, selection, and recruitment rates, therefore displaying and quantifying the social structure of the individual population (Weigle, 1990; Wells & Scott, 1990). Current population models are formed using the adults of the species as a proxy measure, this forms adult-specific assumptions on survival rates for a species (Genov et al., 2018). It is important for research into population ecology and evolutionary biology to gather information on the more vulnerable younger age classes that are susceptible to change to gain the most representative sample of populations (Clutton-brock & Sheldon, 2010). The greater understanding provided by knowledge of life histories and mortality rate over time will increase knowledge of populations (Clutton-brock & Sheldon, 2010; Wells & Scott, 1990). Variations in survival rates and breeding success occur as an individual ages in both short and long-lived species, and fluctuations in age structure instigate variation in mortality and population size (Clutton-brock & Sheldon, 2010). Environmental changes are known to have an impact on the reproduction and survival rates of a species; juveniles and calves of a species are most strongly impacted by these changes and suffer the highest mortality rates during times of stress (Tyne et al., 2016). Understanding the mortality rates of a population can inform long-term conservation methods and future management strategies (Clutton-brock & Sheldon, 2010; Tyne et al., 2016).

Identifying a representative sample of individuals within a population is important in order to reliably model and understand variations within the population (Wursig & Jefferson, 1990; Clutton-brock & Sheldon, 2010). A population with large numbers of recognisable individuals with several years' worth of data allows experiments or statistical analysis that isolate single parameters, which could not occur in populations with large numbers of unidentified individuals (Clutton-brock & Sheldon, 2010). ~50% of *T. truncatus* display unmarked or slightly marked fins that cannot be consistently tracked or used in identification (Wursig & Jefferson, 1990). The use of facial feature identification will reduce this proportion, removing the large amounts of variation and error in population models.

The accuracy and reliability of matching an individual decreased with lower quality images and therefore images must be used of a high quality to ensure an accurate representation of the facial structure. The incidental nature of capturing the facial structure and fin in the same image meant the quality of images varied greatly. Only images of quality 4 and above were included in the matching trials. Quality 4 images were used within this study due to the lack of higher quality images and were initially gathered as a contingency plan and would not have been used in traditional fin-based identification studies. The inclusion of higher quality images would increase the matching scores. Modern cameras with a greater shutter speed may allow for more facial images and the number of high-quality facial images increased in the past three years (Defran, et al., 1990). The use of lower quality images would introduce a large amount of error into identification and would vary how unique and identifiable an individual is (Genov et al., 2018; Defran, et al., 1990).

It can be concluded that facial feature-based identification methods can be used to successfully identify individual *T. truncatus*. The complications of fin-based matching methods can be alleviated through supplementation of potentially stable facial features. This is particularly important for allowing the identification of calves and unmarked individuals within the population. Using facial identification to supplement fin-based identification of younger individuals will increase knowledge of reproduction and life cycles of the population (Clutton-brock & Sheldon, 2010). Creating a more representative subset of a population will increase the capacity for generational analysis and allow a greater understanding of the features affecting a population, including mortality and survivability rates (Clutton-brock & Sheldon, 2010; Wursig & Jefferson, 1990). It may be possible to use images of facial features to identify lineages and sex within the population through variations in facial structure and shape (Genov, et al., 2018). However, it is yet to be found how the aforementioned biases in capture behaviour and distinctiveness of facial features, along with markings and stability of facial features, would affect population models and identification studies. Therefore, it is recommended facial identification is used as a supplementary method to fin-based identification, reducing the impact of false positives and negatives and potentially allowing increased identification of calves.

5. References

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