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# Validation of photo-identification as a mark–recapture method in the spotted eagle ray *Aetobatus narinari*

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The spotted eagle ray *Aetobatus narinari* is characterized by pigmentation patterns that are retained for up to 3·5 years. These pigmentations can be used to identify individuals through photo-identification. Only one study has validated this technique, but no study has estimated the percentage of correct identification of the rays using this technique. In order to carry out demographic research, a reliable photographic identification technique is needed. To achieve this validation for *A. narinari*, a double-mark system was established over 11 months and photographs of the dorsal surface of 191 rays were taken. Three body parts with distinctive natural patterns were analysed (dorsal surface of the cephalic region, dorsal surface of the pectoral fins and dorsal surface of the pelvic fins) in order to determine the body part that could be used to give the highest percentage of correct identification. The dorsal surface of the pectoral fins of *A. narinari* provides the most accurate photo-identification to distinguish individuals (88·2%).



Key words: dorsal surface; double mark; $I_3$S Spot; mark–recapture; microchip; natural marks.

## INTRODUCTION

Evaluating conservation status and applying effective strategies for species conservation requires knowledge of population parameters, such as population size, longevity and growth rates (Caughley & Gunn, 1996). Individual identification of population members, such as when using mark–recapture, is necessary to be able to apply models for estimating population parameters (Wanger *et al.*, 2009).

Both invasive and non-invasive techniques for individual identification exist to mark and later identify individuals. Invasive techniques often employ the use of artificial tags. Applying artificial tags, however, may alter the natural behaviour and

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survivorship of the organism, due to handling (Gauthier-Clerc *et al.*, 2004; Ogutu *et al.*, 2006). Artificial tagging also has some practical difficulties, including the loss of tags or a lack of sightings. Both problems can compromise the reliability of the estimated population parameters (Schwarz & Seber, 1999; Bradshaw *et al.*, 2000).

Non-invasive identification techniques rely on using natural colouration patterns or distinctive natural marks that can be used to recognize individuals (Speed *et al.*, 2007). These characteristics can be useful for population parameter estimation, since there is no risk of loss of these marks (Anderson *et al.*, 2007; Auger-Méthé & Whitehead, 2007). This technique has been used successfully with insects (Caci *et al.*, 2013), fishes (Martin-Smith, 2011; Merz *et al.*, 2012; Barriga *et al.*, 2015), including elasmobranchs (Corcoran & Gruber, 1999; Speed *et al.*, 2007; van Tienhoven *et al.*, 2007), reptiles (Schofield *et al.*, 2008; Sacchi *et al.*, 2010; Moro & Mac Aulay, 2014) and mammals (Auger-Méthé & Whitehead, 2007; Gilkinson *et al.*, 2007; Hiby *et al.*, 2009). In elasmobranchs this method is able to identify individuals with 100% accuracy, *e.g. Rhincodon typus* Smith 1828 (Meekan *et al.*, 2006), *Stegostoma fasciatum* (Hermann 1783) (Dudgeon *et al.*, 2008), *Carcharodon carcharias* (L. 1758) (Domeier & Nasby-Lucas, 2007), *Triaenodon obesus* (Rüppell 1837) (Whitney *et al.*, 2011) and *Manta alfredi* (Krefft 1868) (Marshall *et al.*, 2011).

*Aetobatus narinari* (Euphrasen 1790) is a batoid belonging to the family Myliobatidae and has a dorsal surface covered with white spots that are consistent in size and evenly spaced (Corcoran & Gruber, 1999; White *et al.*, 2010). Little is known about the permanence of the colouration (spots) or if any change is observed from juvenile to adults. Bassos-Hull *et al.* (2014) observed a retained spot pattern for up to 3·5 years. Clarifying the reliability of using patterns of spots as natural tags in *A. narinari* would help to increase demographic knowledge of this pelagic and migratory species in areas where they can be observed year-round (Sellas *et al.*, 2015).

Field information about *A. narinari* is limited, derived mainly from dead specimens obtained from fisheries (Schluessel *et al.*, 2010; Cuevas-Zimbrón *et al.*, 2011; Tagliafico *et al.*, 2012). Length at birth for *A. narinari* has been reported to be between 18·0 and 44·5 cm disc width (McEachran & de Carvalho, 2002; Yokota & Lessa, 2006; Cuevas-Zimbrón *et al.*, 2011). The size at sexual maturity for *Aetobatus* spp. females varies depending on the geographic area (Raje *et al.*, 2007; Schluessel *et al.*, 2010; Tagliafico *et al*., 2012). The smallest size at sexual maturity was 99·8 cm disc width (White & Dharmadi, 2007) and the longest 150·0 cm disc width (Schluessel *et al.*, 2010).

Recently, genetic evidence suggests rays with this dorsal colouration pattern, which were considered a species complex, are now three allopatric species (White, 2014): *A. narinari*, an Atlantic species (Naylor *et al.*, 2012), *Aetobatus ocellatus* (Kuhl 1823), an Indo-West Pacific species (White *et al.*, 2010) and *Aetobatus laticeps* (Gill 1865), an eastern Pacific species (Naylor *et al.*, 2012). There is, however, insufficient molecular or morphological evidence to determine whether the rays in the Mexican tropical Pacific, specifically those at the Chacahua Lagoon, are *A. laticeps*. Based on this, the present study continues to name the Mexican tropical Pacific rays as *A. narinari*.

Photo-identification in *A. narinari* has previously been used to evaluate social structure (Corcoran & Gruber, 1999), while age and growth were studied comparing pigmentation patterns on the dorso-cephalic surface (Bassos-Hull *et al.*, 2014). Bassos-Hull *et al.* (2014) validated the use of pigmentation patterns for individual identification, through photo-identification with numbered nylon-headed dart tags and passive integrated transponder tags. Nevertheless, the study did not evaluate the percentage of the correct identification of the rays and used a low sample size ($n = 19$).

The aim of this work was to validate photo-identification based on pigmentation patterns in *A. narinari* as a reliable individual identification method.

## MATERIALS AND METHODS

### STUDY AREA

The study was conducted at Chacahua Lagoon (15° 58′ and 16° 00′ N; 97° 32′ and 97° 37′ W), inside the Chacahua Lagoon National Park, Oaxaca, Mexico. Chacahua Lagoon is elongate in shape, has an average depth of 2·5 m and a 4·4 km$^2$ surface area. It has a length of >5 km and a width of 2·4 km (González & Rodríguez, 2002). No published field studies exist on *A. narinari* population status, life history or behaviour in the lagoon, but fishermen mention that they have seen mostly female *Aetobatus* spp. in the main lagoon year round and new-born *Aetobatus* spp. in shallow channels, but the use of the lagoon remains unknown.

### PHOTOGRAPHIC SURVEY

Photographs of *A. narinari* were taken in the lagoon from November 2014 to September 2015. Each *A. narinari* was captured using an tangle net with 95 cm mesh, 4 m drop and 100 m length. The net was placed at four sites in the lagoon for a period of 12 h in each location. The net was raised at intervals of at least 1 h to avoid damage to trapped rays. One person carefully untangled each ray and positioned it dorso-ventrally on the foam covered floor of the boat where it was photographed. Three anatomical regions were photographed (dorsal surface of the cephalic region, dorsal surface of the pectoral fins and dorsal surface of the pelvic fins) using a Canon A2200 Power Shot Camera (RAW, JPG, 14·1 mega pixel resolution; www.canon.com). The distance of photo-capture was 1 m between the camera and the ray. Each region was selected for the homogeneity and easy detection of the pigmentation patterns (spots) from a dorsal view. All digital photographs were downloaded, renamed with the number of the tag and month of capture and archived on two different storage media (hard drive and a computer). No digital manipulation was done to any photograph used for the analysis.

### TAGGING

Every *A. narinari* was marked with a double-mark system (Marshall & Pierce, 2012): an aluminium sequentially numbered tag (National wing bands, style 893; www.nationalband.com), placed with a pressure clamp (National wing bands) on the dorsal fin and an intradermic microchip (AVID, www.avidid.com) inserted in the pectoral fin on the right side of the mid-dorsal region. No reaction was conducted to the rays from the intradermic microchip due to its cover of biocompatible crystal and a layer of parylene-like latex. Both marking methods were used to identify individuals at recapture; metallic tags were read by eye and the intradermic microchips were read using an AVID microchip reader.

Handling time for each ray during photographing, tagging and taking morphometric data was *c.* 7 min for a new capture and 5 min for recaptures. No rays died during or immediately after manipulation during the present study. To achieve this, throughout the manipulation time, sea water was continually pumped through both opercula, allowing the ray to continue to breathe. Once the manipulation was complete, the ray was returned to the lagoon, holding it in the water by the operculum and tail for 2 min, moving it back and forth to stimulate water circulation through the opercula. When the ray moved its body, it was released.

 

Fig. 1. Reference points (–O–O–) for the photo-identification trials in the cephalic and pelvic regions in *Aetobatus narinari*.

## PHOTO IDENTIFICATION

The spots of *A. narinari* varied between photographed regions in shape size, number and position. In order to validate the use of pigmentation patterns to photo-identify individuals in the three anatomical regions photographed, three images per individual were used. Interactive individual identification system ($I^3S$ Spot; van Tienhoven *et al.*, 2007) and an algorithm based in AIC (Speed *et al.*, 2007) were used to establish the most appropriate region for individual photographic recognition.

First, the software generated digital files for each anatomical region in both first capture and recapture rays. A methodological limitation of the software, however, was that the maximum number of spots included in a digitized image was 30, whereas the dorsal surface has >30 spots. Hence the dorsal surface was divided into three anatomical regions (dorsal surface of the cephalic region, dorsal surface of the pectoral fins and dorsal surface of the pelvic fins).

The $I^3S$ software digitizes spot patterns and compares the number of spots, shape, size and position within a reference area delimitated by three reference points. Reference points selected on the dorsal surface of the cephalic region were: the origin of the rostral lobe, the right operculum and the left operculum (Fig. 1). For the dorsal surface of the pelvic fins, the dorsal fin origin and the far edges of the right and left pelvic fin were selected (Fig. 1). Finally, for the dorsal surface of the pectoral fins, the middle point between the right and left opercula and the far edges of the right and left portions of the pectoral fin were selected; these far edges were located by drawing an imaginary straight line starting at the union of the pectoral and pelvic fins on both sides of the dorsal surface to the far edges of the pectoral fin (Fig. 2). The reference points were manually selected. Only spots delimited by the defined area between the three reference points were utilized to digitize an image for software comparison.

The software used a two-dimensional linear algorithm to compare photographs. A comparison of two photographs basically comes down to finding corresponding spot pairs in the area delimited by the defined reference points. From these pairs a distance metric is calculated to be able to rank each image in the database. In this case, photographs of first-time captured rays were compared with photographs upon recapture. The software generated an image number, a similarity value and the number of similar spots for each compared image. The similarity value given by the software was higher if the distance between compared points was larger, a lower value was given when a better match between compared points was indicated.

FIG. 2. Reference points (–O–O–) for the photo-identification trials in the dorsal region of the pectoral fins in *Aetobatus narinari*.

The algorithm based on the information criteria of AIC gave three values per photograph: a measure of how well the image adjusted to the AIC model, developed by Speed *et al.* (2007), the AIC weight value, a numeric corroborative value of the similarity with the photograph and the AIC evidence value, concordance between the best ranked photograph in relation to the next ranked photograph.

## RESULTS

*Aetobatus narinari* individuals were captured in all sampling months, but only females were captured in the study area during the sampling period. Of 191 captures, 132 *A. narinari* were catalogued as new individuals (69·1%) and 59 as recaptures (30·9%). The size of the captured rays varied between 58 and 134 cm disc width. The captures were mainly from two parts of the lagoon, as were the recaptures.

An increase in captures was noted from November to December, decreasing from January until September, with a slight increase in April. Most captures occurred in December (18·9%) and fewest in September (3·8%). Recapture rays were recorded from December to September, increasing in number until February. In March the number of recaptures started to decrease with a small rise in April. Most recaptures occurred in February (18·6%), whereas December and September shared a low number of recaptures (3·4%) (Table I). The recapture size varied between 88·6 and 128 disc width.

Five hundred and seventy-six images were digitised, 192 for each of the three anatomical regions. During the sample period each *A. narinari* showed unique spot patterns and distributions for the three photographed anatomical regions. The spot patterns remained constant for the sample period; distinct patterns between captured *A. narinari* were shown. All *A. narinari* ranked in the first position of the list of matches given by the software $I^3S$ were considered as correctly identified.

Table I. Number of captures, recaptures, recapture disc width ($W_D$) range (minimum–maximum) and capture–recapture ratio of *Aetobatus narinari* recorded in the sampling period November 2014 to September 2015

| Sampling month | Captures | Recaptures | Recaptures size range (cm) | Recapture ratio (%) |
|---|---|---|---|---|
| November | 18 | 0 | 0 | 0 |
| December | 25 | 2 | 119–124 | 3·4 |
| January | 19 | 3 | 111–116 | 5·0 |
| February | 13 | 11 | 92·4–123 | 18·6 |
| March | 9 | 7 | 104·9–123 | 11·9 |
| April | 12 | 10 | 93·9–128 | 16·9 |
| May | 9 | 7 | 95–119·5 | 11·9 |
| June | 9 | 7 | 95·4–119·5 | 11·9 |
| July | 7 | 5 | 95–119·5 | 8·5 |
| August | 6 | 5 | 88·6–119·5 | 8·5 |
| September | 5 | 2 | 92·8–121·4 | 3·4 |

After all anatomical regions were matched, the software generated 49 of 59 images as correctly identified for the dorsal region of the pelvic fins (83·1%), 50 of 59 images correctly identified for the cephalic region (84·7%) and 52 of 59 correctly identified for the dorsal region of the pectoral fins (88·2%). Poor quality of the photographs was responsible of misidentification given by the software, the size or sex of the rays did not affect software misidentification. Based on this, the most appropriate region for individual photographic recognition is the dorsal region of the pectoral fins (AIC $w = 0{\cdot}108$; Table II).

Metal tags were detached in 172 rays (90·0%). In *A. narinari* that lost a tag, a scar at the insertion site was observed, a consequence of healing. All *A. narinari* marked with the double-mark system were successfully identified using the AVID identification microchip but only 9·9% retained the metallic tag until the end of the sample period.

## DISCUSSION

Individual recognition of *A. narinari* through photo-identification was validated. Spot patterns on the dorsal region of the pectoral fin is unique to each individual and is easily recognizable through photo-identification, as found by Corcoran & Gruber (1999) and Bassos-Hull *et al.* (2014). The 88·2% correct identification obtained in this study is

Table II. Number of *Aetobatus narinari* correctly identified per sample (*n*/*N*), and percentage, obtained by the $I^3S$ software and the AIC weight (*w*) given for each body region

| | Dorsal | Cephalic | Pelvic |
|---|---|---|---|
| *n* of *N* and % correct identification | 52/59 = 88·2% | 50/59 = 84·7% | 49/59 = 83·1% |
| *w* | 0·108 | 0·311 | 0·339 |

 

close to levels obtained in other photo-identification studies using $I^3S$ as a tool, *e.g.* the common wall lizard *Podarcis muralis* (99%) (Sacchi *et al.*, 2010), *Phyllopteryx taeniolatus* (Lacépède 1804) (90%) (Martin-Smith, 2011), the beetle *Rosalia alpina* (94·8%) (Caci *et al.*, 2013) and *Hatcheria macraei* (Girard 1855) (96%) (Barriga *et al.*, 2015). Therefore *A. narinari* can be added to the list of species that can be correctly identified by photo-identification. Capture of neonates and juveniles is difficult for these species and more information is needed to establish if smaller individuals are more difficult to identify using photo-identification due to possible changes in spot patterns as they grow.

Smaller percentages of successful identification were observed when comparing photographs of spot patterns in the pelvic and cephalic regions (83·1 and 84·7%). Variations in the angle and position at which the photograph was taken could explain this misidentification by the software. Taking photographs on a boat in motion is challenging, often resulting in blur or moved photographs and a device that sets the distance and the movement of the camera would be useful to future studies.

In previous studies, a better identification reliability percentage was obtained using more than one photograph per individual (van Tienhoven *et al.*, 2007; Hiby *et al.*, 2009). For *A. narinari* the high percentages of correct identification using spot patterns in the dorsal region of the pelvic fins and cephalic regions could be used as complementary images to identify each individual, functioning as a double-mark system, as was used in *R. typus* (Meekan *et al.*, 2006), *C. carcharias* (Domeier & Nasby-Lucas, 2007) and *M. alfredi* (Marshall *et al.*, 2011); they used more than one reliability characteristic in species where the pigmentation patterns or scars are only reasonably stable.

No observable change was observed in spot patterns of recaptured rays through time and the spot patterns could be recognized for a period up to 11 months. This is consistent with Bassos-Hull *et al.* (2014), who cited a permanency of 5 days to 3·5 years for pigmentation patterns, as reported for *Carcharias taurus* Rafinesque 1810 (1–4 years) (Barker & Williamson, 2010), *P. taeniolatus* (365 days) (Martin-Smith, 2011) and *H. macraei* (250 days) (Barriga *et al.*, 2015).

The stability of natural marks or pigmentation patterns could be evaluated over time through conventional marks and these should be applied to a portion on the observed rays in order to validate the stability of pigmentation patterns over a standardized period of time (Dudgeon *et al.*, 2008). Nonetheless, the stability of pigmentation patterns was verified in this study by using an alternative marking method (AVID microchips). This method remained stable and was easily and quickly read in 100% of the *A. narinari*.

The study site is an easily accessible body of water where the presence of *A. narinari* is constant throughout the year, allowing for their easy capture. According to Marshall *et al.* (2011), species that are more suited to photo-identification methods are those that have distinctive marks and that can be reached and photographed easily, criteria that are met for *A. narinari* at Chacahua Lagoon.

Despite the fact that the present study was carried out in a closed area such as Chacahua Lagoon, taking underwater photo-identification of the *A. narinari* was not possible because of lagoon characteristics, such as excessive turbidity and the presence of crocodiles. Also, taking pictures of swimming rays from the boat was impossible due to their rapid movements. Nevertheless, the photo-identification collection of the rays taken inside the lagoon could be useful for future comparisons with underwater photo-identification from open waters near the lagoon where better visibility exists.

In summary, this study validates the use of photo-identification for the purpose of individual identification through the comparison of pigmentation patterns shown in the dorsal portion of *A. narinari*. This method of individual photo-identification may be used to establish long-term population monitoring at Chacahua Lagoon based on mark–recapture models. In the future the information provided by the use of this method will help in the correct application of models that provide demographic information for *A. narinari*, fundamental for the knowledge of the species at the lagoon and needed to establish management and conservation strategies in Chacahua Lagoon National Park.

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