



**UNIVERSIDADE FEDERAL DA PARAÍBA  
CENTRO DE CIÊNCIAS AGRÁRIAS  
PROGRAMA DE POS-GRADUAÇÃO EM BIODIVERSIDADE  
CAMPUS II – AREIA-PB**

**YEDDA CHRISTINA BEZERRA BARBOSA DE OLIVEIRA**

**FOTOIDENTIFICAÇÃO DE TARTARUGAS MARINHAS  
UMA FERRAMENTA PARTICIPATIVA DE CONSERVAÇÃO**

Areia, Agosto de 2017

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Dissertação apresentada ao Programa de Pós-Graduação em Biodiversidade, da Universidade Federal da Paraíba, como requisito parcial para obtenção do título de Mestre.

Orientador: Bráulio Almeida Santos

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Areia, Agosto de 2017

*Ficha Catalográfica Elaborada na Seção de Processos Técnicos da  
Biblioteca Setorial do CCA, UFPB, campus II, Areia - PB*

O48f    *Oliveira, Yedda Christina Bezerra Barbosa de.*  
          *Fotoidentificação de tartarugas marinhas: uma ferramenta participativa*  
          *de conservação / Yedda Christina Bezerra Barbosa de Oliveira. – Areia - PB:*  
          *CCA/UFPB, 2017.*  
          62 f. : il.

Dissertação (Mestrado em Biodiversidade) - Centro de Ciências Agrárias.  
Universidade Federal da Paraíba, Areia, 2017.

Bibliografia.

Orientador: Braúlio Almeida Santos.

1. Tartaruga marinha – Fotoidentificação 2. *Eretmochelys imbricata* –  
Conservação marinha 3. *Chelonia mydas* I. Santos, Braúlio Almeida  
(Orientador) II. Título.

UFPB/BSAR

CDU:        598.132.6(043.3)



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**TÍTULO: “FOTOIDENTIFICAÇÃO DE TARTARUGAS MARINHAS: UMA FERRAMENTA PARTICIPATIVA DE CONSERVAÇÃO”**

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*Dedico este Mestrado à minha mãe, irmã e avó pelo incentivo em todas as minhas escolhas.*

## **AGRADECIMENTOS**

A CAPES pela bolsa e suporte financeiro.

Ao PPGBio pela oportunidade de execução deste projeto e aos professores Helder, Luciana e Célia por toda atenção e paciência.

Ao Orione, por plantar a semente do mestrado na minha mente e me apresentar ao Braúlio, que representa a melhor definição de orientador: incentivador, paciente, atencioso e referência como pessoa.

Ao meu co-orientador, Washington, pelas contribuições, principalmente nos ajustes iniciais e fundamentais.

À minha família, pelo apoio em minhas decisões e compreensão nos meus momentos de ausência, e aos familiares que me adotaram na Paraíba, todos essenciais para que eu concluísse mais esta etapa.

Aos meus amigos do PPGBio, especialmente Thamiris, Júnior, Leo, Marcelinho e Wylde, pelos momentos de diversão, apoio e aprendizado.

A todos do EcoLab, em especial a Layla, Tainá, Aiara e Juliano pelo conhecimento compartilhado e boa companhia.

À Thayse, pela contribuição na organização dos dados dos JampaDivers.

Ao Ismar, staffs e mergulhadores da Mar Aberto pelo suporte logístico e interesse pela pesquisa científica.

A toda equipe do Projeto TAMAR de Ubatuba, Arembepe e Noronha que viabilizaram a coleta de dados, especialmente Edu, Mauro e Letícia pela amizade, e Henrique e Armando pela solicitude.

A Barracudas Imagens, pela cortesia de uso das imagens na pesquisa.

A todos meus amigos que contribuíram de alguma forma para que o mestrado se tornasse possível e tranquilo.

A todos os membros da banca pelo interesse e disposição em contribuir com o trabalho.

*“We need to respect the oceans and take care of them as if our lives depended on it. Because they do”.*

Sylvia Earle

## RESUMO

Tartarugas marinhas são espécies guarda-chuva representativas na ecologia e conservação marinha. O conhecimento básico sobre as espécies, desde a sua distribuição à dinâmica e estrutura de populações específicas, é iniciado pelo monitoramento dos indivíduos. Um dos métodos indicados para isso é a fotoidentificação, por ser de baixo custo, de alta acurácia e não-invasivo. A análise das fotografias é realizada a partir das marcas naturais de cada animal, e seu processamento ocorre a olho nu ou computadorizado. A facilidade na coleta de dados também é mais uma vantagem da fotoidentificação sobre os métodos de marcação artificial, o que tem permitido a contribuição de cidadãos cientistas. O presente trabalho buscou criar parâmetros para fotoidentificação de *Chelonia mydas* e *Eretmochelys imbricata*, a partir do programa I<sup>3</sup>S baseando-se nas já utilizadas placas faciais e também testou um novo método de identificação a partir das nadadeiras posteriores. Tendo em vista a sua aplicação em projetos de ciência cidadã, também avaliou-se a qualidade dos dados coletados por mergulhadores voluntários com diferentes perfis. Foram registrados 53 indivíduos, *Chelonia mydas* (n= 47) e *Eretmochelys imbricata* (n= 6), e 4 recapturas de cada espécie, no Arquipélago de Fernando de Noronha para validação da metodologia. Cada registro de ocorrência foi catalogado no banco de dados de forma independente, com fotografias em série dos perfis faciais e das nadadeiras posteriores. Foram testadas a acurácia do programa (1) em reconhecer cada indivíduo e (2) diferenciá-los entre os demais. Ambas regiões corpóreas mostraram-se eficientes para fotoidentificação, sendo o fator espécie de maior influência sobre os escores calculados pelo programa. As nadadeiras posteriores demonstram ser altamente diferenciadas entre os indivíduos de *E. imbricata*, ao contrário de *C. mydas*, em que estão sujeitos a ocorrência de falso-negativo. Entre os 83 registros fornecidos por cidadãos cientistas, 43% foi descartado e apresentou principalmente problemas com ângulo de visão e enquadramento. Nesse sentido, o método proposto pode ajudar a superar problemas de identificação de tartarugas marinhas e representa novas oportunidades de estudo. No entanto, recomenda-se o treinamento sobre os registros para potencializar a qualidade desses dados.

Palavras-chave: *Chelonia mydas*, *Eretmochelys imbricata*, marcação-recaptura, I<sup>3</sup>S, ciência cidadã

## ABSTRACT

Sea turtles are representative umbrella species in marine ecology and conservation. Prior knowledge about the species, from their distribution to population structure and dynamics of them start by individual monitoring. One of the recommended methods is the photo-identification, due to the low cost, high accuracy and non-invasive procedure. Photographic analyses are based on natural marks from animal body, and can be performed by naked eye or computer-assisted. The ease in collecting data is also a further advantage over artificial tags, in which allow the contribution of citizen scientists. Our work aimed to define parameters for the photo-identification of *Chelonia mydas* and *Eretmochelys imbricata* using I<sup>3</sup>S software, based on already used facial scales and the new method from the hind flippers. Focusing on citizen-science projects, we evaluated the quality of the data collected by volunteer divers with different profiles. A total of 53 individuals was captured, *Chelonia mydas* (n = 47) and *Eretmochelys imbricata* (n = 6), and 4 recaptures of each species were registered in Fernando de Noronha Archipelago as method validation. We cataloged the records independently on the database, with a set of facial profiles and hind flipper fingerprints. We tested the accuracy of the program in (1) recognizing each individual and (2) differing them among the population. Our results show that both body regions are efficient for photo-identification, and species is the main effect on the scores calculated by the program. Hind flippers indicate to be highly differentiated in *E. imbricata*, unlike *C. mydas*, in which are prone to the false-negative errors. Among the 83 records provided by citizen scientists, 43% were discarded mainly due to the angle-of-view and framing errors. The proposed method may help to overcome problems in identification of sea turtles and represents new opportunities of study. However, training on records is highly recommended to enhance data quality.

Key words: *Chelonia mydas*, *Eretmochelys imbricata*, mark-recapture method, I<sup>3</sup>S, citizen science

## SUMÁRIO

<b>INTRODUÇÃO GERAL</b> .....	10
TARTARUGAS MARINHAS.....	10
FOTOIDENTIFICAÇÃO.....	13
CIÊNCIA CIDADÃ.....	19
<b>OBJETIVOS</b> .....	22
OBJETIVO GERAL.....	22
OBJETIVOS ESPECÍFICOS.....	22
<b>REFERÊNCIAS</b> .....	23
<b>PHOTO-IDENTIFICATION OF SEA TURTLES FROM HIND FLIPPER AND ITS POTENTIAL USE IN CITIZEN SCIENCE INITIATIVES</b> .....	29
<b>ABSTRACT</b> .....	31
<b>INTRODUCTION</b> .....	32
<b>MATERIALS AND METHODS</b> .....	34
DATA COLLECTION.....	34
QUANTIFYING THE IMAGE SCORES.....	36
STATISTICAL ANALYSIS.....	36
<b>RESULTS</b> .....	37
METHOD VALIDATION.....	37
CITIZEN SCIENTIST DATA.....	38
<b>DISCUSSION</b> .....	39
<b>REFERENCES</b> .....	42
<b>INSTRUCTIONS FOR AUTHORS - SPECIFIC REQUIREMENTS</b> .....	51
<b>CONSIDERAÇÕES FINAIS</b> .....	62

## INTRODUÇÃO GERAL

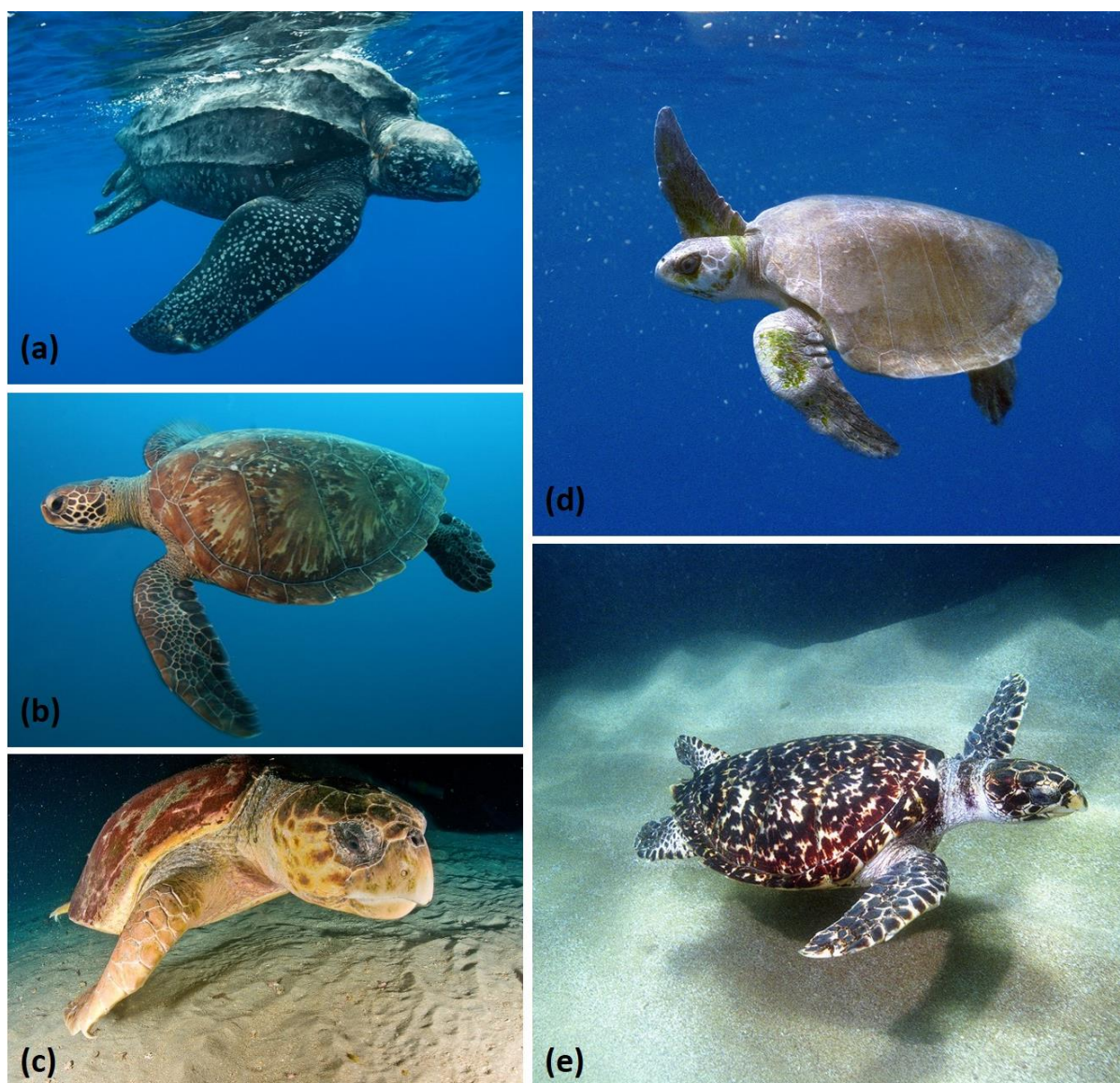
### TARTARUGAS MARINHAS

O registro mais antigo de tartaruga marinha, *Desmatochelys padillai* (CADENA; PARHAM, 2015), é datado no início do Cretáceo (final do Barremiano ou início do Aptidiano) e foi encontrado na Colômbia (CADENA; PARHAM, 2015). Entre as famílias originadas nesse período, somente são existentes Cheloniidae e Dermochelyidae. A primeira inclui *Caretta caretta* (Linnaeus, 1758), *Chelonia mydas* (Linnaeus, 1758), *Eretmochelys imbricata* (Linnaeus, 1766), *Lepidochelys olivacea* (Eschscholtz, 1829), *Lepidochelys kempii* (Garman, 1880) e *Natator depressus* Garman, 1880. Dermochelyidae compreende apenas *Dermochelys coriacea* (Vandelli, 1761), diferenciando-se principalmente pelo revestimento coriáceo da carapaça em relação ao córneo em Cheloniidae (SPOTILA, 2004).

A distribuição global das tartarugas marinhas é tropical e subtropical, com ocorrências pontuais em regiões temperadas, uma vez que o clima é limitante tanto na oferta de recursos como no funcionamento metabólico de regulação térmica desses animais (PIKE, 2013). Entre as sete espécies existentes, cinco delas ocorrem no território brasileiro *C. caretta*, *C. mydas*, *E. imbricata*, *L. olivacea* e *D. coriacea* (MARCOVALDI; MARCOVALDI, 1999) (Fig. 1). Embora haja esforços conservacionistas e cooperações internacionais em virtude da ampla distribuição, todas essas espécies se encontram na Lista Vermelha de Espécies Ameaçadas da União Internacional para a Conservação da Natureza e dos Recursos Naturais (IUCN, 2016) e na Portaria nº 444, de 17/12/2014, do Ministério do Meio Ambiente (BRASIL, 2014) (Tabela 1), tendo como principais ameaças a urbanização de praias onde ocorrem as desovas, captura incidental em atividades pesqueiras e poluição marinha (MARCOVALDI et al., 2006; MARCOVALDI; THOMÉ, 1999; SPOTILA, 2004).

**Tabela 1** Principais características biológicas e ecológicas das espécies (ICMBIO, 2011; LUTZ; MUSICK; JEANETTE, 2003; TAMAR, 2011).

	Status de conservação (IUCN 2016, Brasil 2014)	Distribuição	Habitat	Comprimento curvilíneo da carapaça (máximo registrado)	Peso médio	Dieta	Área reprodutiva no Brasil
<i>C. caretta</i>	Ameaçada, ameaçada	Mares tropicais, subtropicais e temperados	Desenvolvimento inicial em zona oceânica e tardiamente nerítica	136 cm	140 kg	São carnívoras, alimentam-se de caranguejos, moluscos, mexilhões e outros invertebrados	Espírito Santo, Bahia, Sergipe e Rio de Janeiro
<i>C. mydas</i>	Ameaçada, vulnerável	Mares tropicais e subtropicais e, durante a fase juvenil, em regiões temperadas	Desenvolvimento inicial em zona oceânica e tardiamente nerítica	143 cm	160 kg	Onívoras enquanto filhotes, tornando-se basicamente herbívoras a partir da fase juvenil	Ilhas oceânicas de Trindade, Atol das Rocas e Fernando de Noronha
<i>D. coriacea</i>	Vulnerável, criticamente ameaçada	Regiões tropicais, subtropicais e temperadas	Desenvolvimento em zona oceânica	178 cm	400 kg	Zooplâncton gelatinoso	Espirito Santo e Piauí
<i>E. imbricata</i>	Criticamente ameaçada, criticamente ameaçada,	Espécie mais tropical entre as demais, encontrada nos oceanos Atlântico, Índico e Pacífico	Desenvolvimento inicial em zona oceânica e tardiamente nerítica	110 cm	86 kg	Esponjas, anêmonas, lulas e camarões	Bahia, Sergipe, Rio Grande do Norte, Paraíba e Pernambuco
<i>L. olivacea</i>	Vulnerável. Ameaçada	Regiões tropicais e subtropicais, nos oceanos Pacífico e Índico. No Atlântico, ocorrem na América do Sul e na costa oeste da África	Desenvolvimento em zona oceânica	72 cm	42 kg	São carnívora, alimentam-se de peixes, moluscos, crustáceos, eventualmente algas e outros invertebrados	Alagoas, Sergipe, Bahia



**Fig. 1** Espécies encontradas no litoral brasileiro: (a) Tartaruga-de-couro (*D. coriacea*), (b) Tartaruga-verde (*C. mydas*), (c) Tartaruga-cabeçuda (*C. caretta*), Tartaruga-oliva (*L. olivacea*), (e) Tartaruga-de-pente (*E. imbricata*). FONTE: Modificado de TAMAR 2011.

Tartarugas marinhas formam um grupo bastante representativo em ações de conservação marinha em escala global. Resultados como regulamentação de atividades pesqueiras esportes náuticos, ordenamento do turismo, criação de políticas públicas e delimitação de áreas marinhas protegidas podem ser facilitados pelo suporte da sociedade em esforços para a conservação de espécies-bandeira (ECKERT; HEMPHILL, 2005). Além disso, Testudines marinhos são também considerados espécies guarda-chuva e desempenham um papel importante na manutenção de recifes de corais, ciclagem de nutrientes, controle de populações relacionadas à sua dieta, além de possuírem o valor biológico intrínseco de sua existência (SPOTILA, 2004).

Numa revisão global de 30 anos de pesquisa em manejo e conservação de tartarugas marinhas, foram levantados os principais estudos em relação à biologia reprodutiva,

biogeografia, ecologia de populações, ameaças e conservação (HAMANN et al., 2010). Embora as tartarugas estejam entre os animais marinhos mais estudados (HAMANN et al., 2010), ainda há lacunas no conhecimento, uma vez que a concentração dos estudos entre todas as categorias mencionadas está no ambiente terrestre: monitoramento de encalhes (NICOLAU et al., 2016; ORÓS et al., 2016), fêmeas adultas e filhotes durante o período reprodutivo (FUENTES; HAMANN; LIMPUS, 2010; HAYS et al., 2003). Isto é devido a razões logísticas e ao fácil acesso a esses indivíduos que permitem a realização, por exemplo, de trabalhos sobre diferentes temperaturas de incubação dos ovos e o efeito na razão sexual dos filhotes (FUENTES; HAMANN; LIMPUS, 2010; HAYS et al., 2003; WITT et al., 2010), estrutura populacional com base em recapturas em regiões pontuais (ARAUJO et al., 2016a; CHASSAGNEUX et al., 2013; COLMAN et al., 2015; JEAN et al., 2010) e análise de mortalidade a partir de encalhes (NICOLAU et al., 2016; ORÓS et al., 2016). No entanto, há lacunas do conhecimento sobre machos e demais estágios de vida das tartarugas marinhas no ambiente marinho (FUENTES; HAMANN; LIMPUS, 2010; HAMANN et al., 2010). Nesse sentido, foram definidos como prioritários o conhecimento sobre dinâmica de metapopulações e padrões demográficos, biologia e comportamento reprodutivo, fronteiras e conexões entre áreas de alimentação, fatores biogeográficos no oceano e avaliação da efetividade de conservação das populações (HAMANN et al., 2010).

A informação de distribuição e dinâmica de animais marinhos também tem sido aplicada na delimitação de áreas marinhas protegidas (AMPs) (DOHERTY et al., 2017; WITT et al., 2008). Enquanto as unidades de conservação terrestres, muitas vezes, são definidas a partir de remanescentes florestais, as AMPs possuem maior complexidade na sua caracterização decorrente da conexão dos oceanos (EDGAR et al., 2014). Assim, as rotas de migração e uso de área de espécies marinhas podem contribuir para a melhor definição dessas unidades, a partir de indicadores ecológicos que fundamentem a conservação efetiva dos ecossistemas costeiros e marinhos (CIGLIANO et al., 2015; DOHERTY et al., 2017).

## FOTOIDENTIFICAÇÃO

Estudos de populações são conduzidos por meio da quantificação dos dados biológicos (ARAUJO et al., 2016a; COLMAN et al., 2015), o que exige a marcação dos animais para inferir sobre a biologia e ecologia dos grupos (WILSON; MCMAHON, 2006), como uso e fidelidade de hábitat (WILLIAMS et al., 2017), movimentação dos indivíduos (ARAUJO et al., 2016a), estimativas de tamanho, estrutura e dinâmica populacional (COLMAN et al., 2015; MADON et al., 2011). A identificação de um indivíduo no grupo se dá a partir de

técnicas de marcação natural ou artificial. Marcas naturais, como cicatrizes, coloração, padrões de pelagem permitem a identificação por fotografia ou vídeos, enquanto marcadores de DNA microssatélite podem ser extraídos da coleta de fezes ou biópsias. Os marcadores artificiais são dispositivos instalados no corpo do animal, como anilhas, transmissores à rádio e GPS, ou produzidos por tinta, caneta ou queimaduras com nitrogênio líquido. A seleção da técnica de marcação deve ser criteriosa e adequada ao grupo de estudo, até mesmo porque a medida de avaliação pode influenciar no comportamento e, conseqüentemente, na confiabilidade dos dados (WILSON; MCMAHON, 2006). Além da heterogeneidade individual, que é a probabilidade de recaptura intrínseca de cada indivíduo, os diferentes comportamentos após a marcação podem interferir nos resultados da recaptura. A captura com recompensa, quando envolve reforço positivo, como o uso de iscas, por exemplo, pode induzir o aumento de retornos à armadilha (*trap happy*); enquanto a ausência de recompensa tende a promover a sua rejeição (*trap shy*) (WHITE et al., 1982), além de ser estressante ao animal, assemelhando-se à sua predação. Outros fatores a serem considerados são o tempo em que o marcador permanecerá no corpo do animal, levando em consideração o aumento do gasto energético e a probabilidade de sobrevivência, e qual o tamanho amostral suficiente. Essas reflexões levam à escolha da prática mais aceitável realística (WILSON; MCMAHON, 2006).

Uma ferramenta que tem se mostrado eficiente em estudos populacionais é a fotoidentificação, comumente empregada em cetáceos e se diversificou entre vários grupos nos ambientes marinho e terrestre (SPEED; MEEKAN; BRADSHAW, 2007). Os indivíduos são identificados a partir de marcas naturais em seu corpo, como padrão de pintas em tubarões baleia e raias manta (MARSHALL; PIERCE, 2012), placas faciais em tartarugas marinhas da Família Cheloniidae (JEAN et al., 2010; SCHOFIELD et al., 2008), pintas na região superior da cabeça em tartarugas Dermochelyidae (DE ZEEUW et al., 2010) e formato da nadadeiras entre os cetáceos, sendo a nadadeira dorsal geralmente utilizada em golfinhos e a caudal em baleias (FRIDAY et al., 2000). Cicatrizes, calosidades, coloração, entre outras características específicas também são utilizadas como critérios de identificação (MARSHALL; PIERCE, 2012; REISSER et al., 2008; SPEED; MEEKAN; BRADSHAW, 2007). A técnica é empregada *in situ*, sem que seja necessário o manejo dos animais e fornece informações comportamentais adicionais, a exemplo de registros de forrageamento, sítios de refúgio e repouso, identificação de estações de limpeza e interações ecológicas intra e interespecíficas.

Embora a identificação fotográfica seja um método de marcação e recaptura não-invasivo e de menor custo (MARSHALL; PIERCE, 2012; SPEED; MEEKAN; BRADSHAW, 2007), a técnica tradicionalmente utilizada em estudos com tartarugas

marinhas é a marcação com anilhas de aço inoxidável (BALAZS, 1999), ainda que necessite da captura dos indivíduos e possíveis riscos de promover injúrias (REISSER et al., 2008). Os efeitos negativos da captura, manejo e marcação de animais de vida livre são bem comuns, embora pouco discutidos. Marcadores que utilizam diferentes combinações de cores, por exemplo, podem expor os animais a predadores (WILSON; MCMAHON, 2006). Em pinguins, há aumento do gasto energético durante mergulhos para captura de presas, uma vez que são reduzidas a eficiência do tempo de mergulho e a massa de presa capturada (WILSON; MCMAHON, 2006). Animais marcados com dispositivos externos ao corpo demonstraram apenas 20% do desempenho de animais não marcados (WILSON; MCMAHON, 2006). Nesse sentido, o nível de desconforto pode ser avaliado pela observação do comportamento animal após a fixação do marcador, como a redução na eficiência para realização de atividades. O aumento no gasto de energia durante forrageio, por exemplo, pode comprometer a sua sobrevivência (WILSON; MCMAHON, 2006).

Entre as vantagens da fotoidentificação estão a estabilidade dos caracteres de identificação e a coleta de dados *in situ* sem exigência de manejo (CARPENTIER et al., 2016; REISSER et al., 2008). Embora as marcas naturais sejam variáveis entre as espécies e mesmo durante o desenvolvimento de cada indivíduo, ou cicatrizes possam ser adquiridas ao longo da vida do animal, estudos com elasmobrânquios apresentaram estabilidade de 30 anos (MARSHALL; PIERCE, 2012) e em tartarugas marinhas num intervalo de 10 a 20 anos (CARPENTIER et al., 2016). Isto permite que os estudos de recaptura sejam desenvolvidos em longo prazo, bem como difundem a participação de voluntários com pouco conhecimento técnico na coleta de dados, ampliando o tamanho amostral (CARPENTIER et al., 2016). Contrariamente, marcadores artificiais exigem que sua anexação seja feita de forma adequada, para que não haja perda da marca e, conseqüentemente, do indivíduo (WILSON; MCMAHON, 2006). Ainda que haja capacitação técnica para aplicação de uma marca artificial, é comum a perda dos marcadores em curto período, o que compromete os estudos a longo prazo em que a marcação poderia informar sobre padrões de residência e movimentação, comportamento reprodutivo, tamanho e estrutura populacional (BELLINI; GODFREY; SANCHES, 2001; MARSHALL; PIERCE, 2012; REISSER et al., 2008).

Entre as dificuldades apontadas em trabalhos de fotoidentificação está a captação de registros adequados, que são influenciados pela variação de luz, turbidez e aumento da profundidade em registros subaquáticos. Tais fatores podem gerar artefatos nas imagens, como ocultar uma mancha ou cicatriz ou mesmo criá-la erroneamente (CARPENTIER et al., 2016). Durante o processo de avaliação das imagens, também podem ocorrer falso-positivos (considerar indivíduos diferentes como um mesmo) e falso-negativos (múltiplas

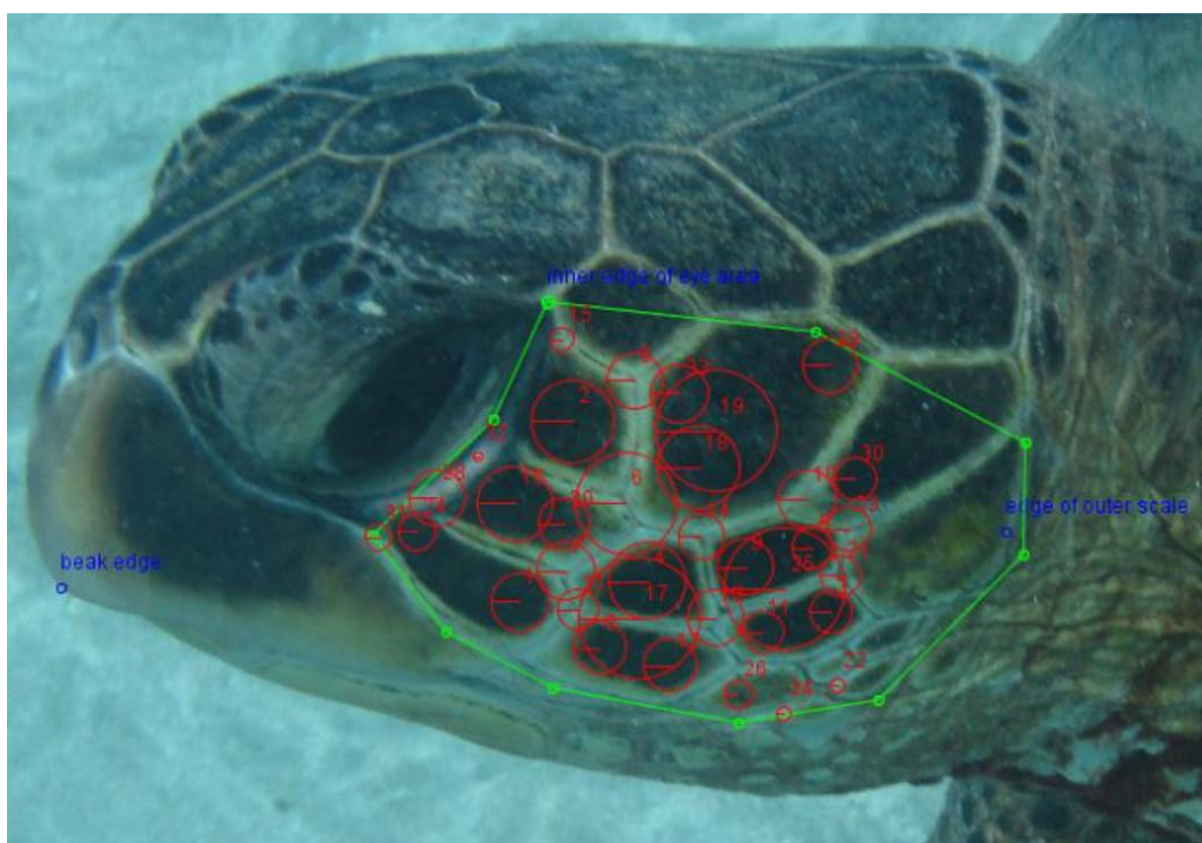
identificações de um mesmo indivíduo) (JEAN et al., 2010; REISSER et al., 2008). Da mesma forma, indivíduos cadastrados no banco de dados com perfis unilaterais podem propiciar os registros falso-negativos, por esta razão é recomendada a marcação dupla sempre que possível (MARSHALL; PIERCE, 2012). Isto é agravado em animais que possuem alta dissimilaridade entre os perfis, como as tartarugas marinhas (SU; HUANG; CHENG, 2015). A combinação do uso da fotoidentificação e marcador microssatélite de DNA se mostrou eficientemente superior a qualquer método isolado em estudos de abundância populacional de cetáceos, uma vez que pode ser capaz de corrigir o efeito da subestimativa do tamanho populacional, decorrente da heterogeneidade na população de *Megaptera novaeangliae* (Borowski, 1781) (MADON et al., 2011).

É recomendado o uso de programas de computador que façam a análise dos registros em grande volume de dados, com a finalidade de minimizar os possíveis erros de observação, aumentando a acurácia (CARPENTIER et al., 2016; JEAN et al., 2010; MARSHALL; PIERCE, 2012; REISSER et al., 2008). No entanto, uma triagem preliminar manual pode otimizar o funcionamento do processo computadorizado, bem como o uso exclusivo de fotos em alta qualidade e definição (HIBY et al., 2013). Como não há o manejo dos indivíduos fotoidentificados, uma alternativa para realizar a biometria e refinar os dados de estrutura populacional é a fotogrametria, com base na distância e dimensionamento do animal registrado (ARAUJO et al., 2016b).

O programa *Interactive Individual Identification System* (I<sup>3</sup>S) tem sido utilizado para a identificação fotográfica de indivíduos e apresentou resultados confiáveis em estudos com *Rhincodon typus* (Smith, 1828) (SPEED; MEEKAN; BRADSHAW, 2007), *Epinephelus itajara* Licht, 1822 (BERTONCINI et al., 2013), *C. mydas* e *E. imbricata* (ARAUJO et al., 2016b; DUNBAR et al., 2014), entre outros animais silvestres.

O software I<sup>3</sup>S cria “impressões-digitais” sobre as marcas de cada indivíduo, a partir de uma região de interesse informada pelo usuário e as compara entre os registros no banco de dados (DEN HARTOG; REIJNS, 2014). Possui quatro versões com finalidades apropriadas a grupos de estudo específicos. A versão *Classic*, primária e de funcionamento mais simples, opera pela localização do centro das marcas claramente identificadas em cada indivíduo, transformando os elementos em pontos. Essa versão é comumente utilizada em pesquisas com tubarões-baleia (*R. typus*). A segunda versão, *Spot*, considera o tamanho e a forma de cada elemento identificados, sendo bastante funcional em estudos com raias-manta (*Manta birostris* Walbaum, 1792 e *M. alfredi* (Krefft, 1868)). *Contour* é específico para cetáceos, enquanto *Pattern* cria elementos-chave a partir de padrões corpóreos mais gerais, como as placas faciais em tartarugas marinhas (DEN HARTOG; REIJNS, 2014).

A impressão digital na versão *Pattern* é gerada por meio de pontos-chave (definidos como elementos) criados a partir de informações de localização, num sistema de coordenadas, com tamanhos específicos de cada elemento (Fig. 2). O sistema de coordenadas funciona em um plano bidimensional e, para potencializar a leitura no programa, a imagem deve ser obtida perpendicularmente ao objeto, com distorção angular máxima de 30 graus (DEN HARTOG; REIJNS, 2014). Os perfis faciais de *C. mydas* se mostraram claramente em ângulos menor que 20 graus e o programa se mostrou funcional para um tamanho amostral de 30 a 40 indivíduos (ARAUJO et al., 2016b).

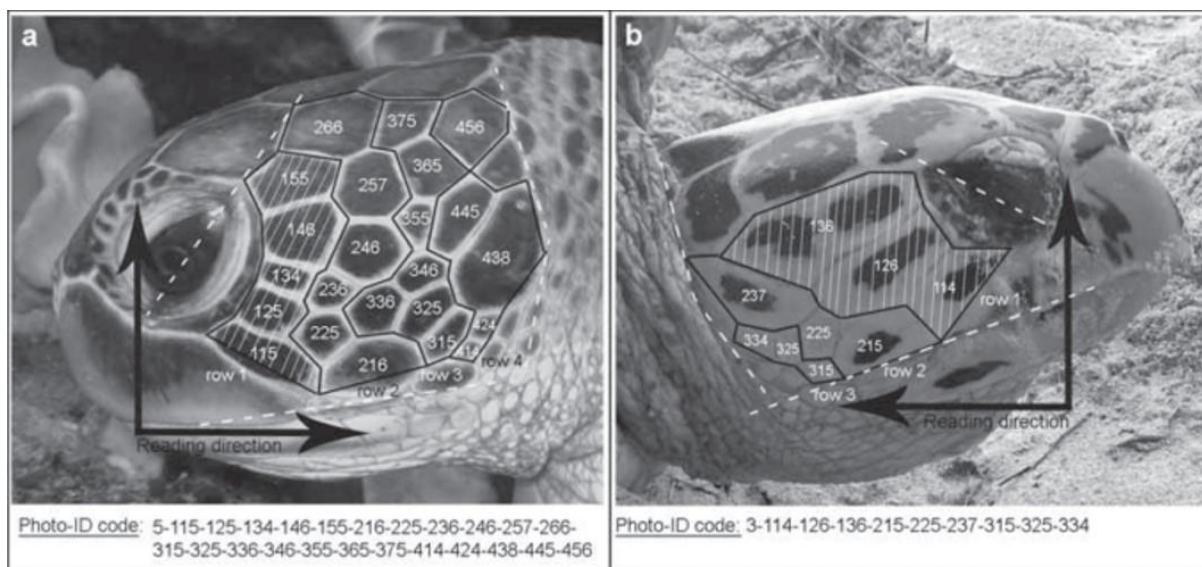


**Fig. 2** Processamento da imagem no programa I<sup>3</sup>S. Pontos de referência em azul (bico, canto dos olhos e placa marginal), polígono de análise em verde e elementos-chave do indivíduo de *C. mydas* destacados em vermelho (DEN HARTOG; REIJNS, 2014).

O reconhecimento entre duas figuras ocorre por meio da sobreposição dos elementos-chave num sistema de coordenadas de reconhecimento espacial bidimensional. São traçadas distâncias entre os pontos-chave de cada imagem em que foram considerados pares similares. O score, que é a diferença entre as imagens, será resultante da soma das distâncias de todos os elementos pareados dividida pelo quadrado do número de elementos. Dessa forma, para que seja confirmada a recaptura, é necessário que a diferença entre as imagens se aproxime a zero (DEN HARTOG; REIJNS, 2014). O software corrige as diferenças em ângulos de visão,

rotação e escala existentes entre fotografias de um mesmo indivíduo por meio de três pontos de referência, criados pelo usuário na região corpórea de interesse. O melhor desempenho do programa e a otimização dos resultados são obtidos conforme às premissas para escolha da área: (1) localização bem definida, (2) claramente visível em todos registros, e (3) formando um triângulo que cubra a maior parte da região de interesse, com ângulos próximos a 60 graus.

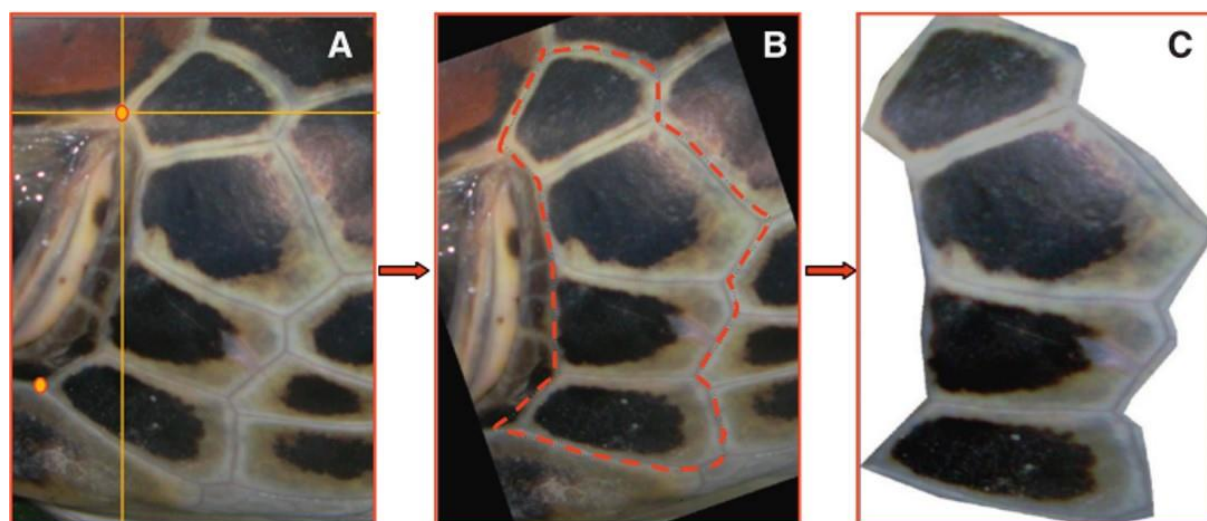
No intuito de minimizar o efeito da aleatoriedade, é recomendado que os testes de comparação sejam repetidos em série para atingir um escore médio. Também é relatada a sensibilidade da criação de elementos-chave a partir de artefatos nas imagens, como a turbidez da água e efeitos de reflexão da imagem. Nesse sentido, é possível eliminar manualmente os elementos criados a partir de artefatos. Um maior refinamento do banco de dados é alcançado a partir de metadados, informações categóricas complementares aos registros de imagem de cada indivíduo, como tamanho, sexo, espécie e presença de deformidades (DEN HARTOG; REIJNS, 2014).



**Fig. 3** Sistema de ordenamento produzido no TORSOOI, que considera a quantidade de placas faciais, a posição e o número de lados de cada uma delas (JEAN et al., 2010).

Outros softwares usados para identificação fotográfica de tartarugas marinhas são TORSOOI (JEAN et al., 2010) e MYDAS (CARTER et al., 2014), que utilizam diferentes algoritmos para analisar os perfis faciais. O primeiro programa cria um código para cada indivíduo por meio da ordenação de cada placa, a contar da coluna mais próxima dos olhos até as marginais, da base do bico ao topo da cabeça. Este código é composto de uma unidade seguida de conjuntos de três algarismos. A primeira unidade é referente ao número de placas próximas ao olho, os demais algarismos que correspondem cada tríade são relativos: (1)

número da coluna, (2) ordenamento da placa na coluna, (3) número de lados de cada placa (Fig. 3) seguido da posição de cada placa na coluna e, por fim, o número de lados presentes em cada placa. Inicia-se (Fig. 3). O método MYDAS (CARTER et al., 2014) analisa apenas as placas pós-orbitais exclusivamente do perfil esquerdo de *C. mydas* e corrige os desvios angulares por meio de dois pontos de referência na região dos olhos (Fig. 4).



**Fig. 4** Análise das placas pós-orbitais do perfil esquerdo de *C. mydas* no programa de identificação fotográfica MYDAS. (A) Pontos de referência angular em amarelo. (B) Placas de interesse destacada pela linha vermelha tracejada. (C) Região selecionada e com desvio angular corrigido (CARTER et al., 2014).

## CIÊNCIA CIDADÃ

Nos últimos anos tem crescido a participação da sociedade na ciência por meio do engajamento de voluntários na coleta de dados baseados na observação da natureza. Os monitoramentos envolvem grupos de fauna, flora, dados climáticos e até mesmo galáxias (BONNEY et al., 2009). A forma de ciência participativa, denominada ciência cidadã, tem contribuído para promover o conhecimento da ocorrência e distribuição de diversas espécies mundialmente. Estudos em maiores escalas de tempo e espaço se tornam possíveis sem que seja necessário o aporte financeiro adicional por meio da observação do público comum. A partir dessa perspectiva, é possível monitorar alterações em fenótipos, distribuição de espécies, estrutura e dinâmica populacional. O precursor estudo conduzido pelo Laboratório de Ornitologia da Cornell University tem reunido há cerca de 30 anos milhares de participantes, com dezenas de milhões de observações para responder lacunas de conhecimento acerca da biologia de espécies de avifauna (BONNEY et al., 2009).

Embora a participação de cidadãos cientistas tenha maximizado a coleta de dados, é bastante questionada a qualidade desse conjunto de informações. Como a maior parte dos monitoramentos não envolve um desenho amostral bem definido ou protocolo de campo, há

possíveis vieses associados a registros seletivos de observação e esforço amostral (VAN STRIEN; VAN SWAAY; TERMAAT, 2013). Outro ponto em questão é a alta taxa de erros encontrada na identificação de espécies ou grupos taxonômicos, quando esta informação é de competência dos voluntários e não de pesquisadores. Uma forma possível de minimizar este problema é a priorização de treinamentos em campo e em processo de capacitação continuada, visando à especialização do voluntário na atividade atribuída (RATNIEKS et al., 2016). Cidadãos cientistas que recebem treinamento ou possuem alguma experiência prévia com o grupo de estudo contribuem para o aumento significativo da confiabilidade dos resultados (SCHOFIELD et al., 2008). Também são recomendadas a criação de protocolos de amostragem (LUKYANENKO; PARSONS; WIERSMA, 2016) e o uso de análises estatísticas que corrijam a relação de espécies observadas e presentes (VAN STRIEN; VAN SWAAY; TERMAAT, 2013) no intuito de homogeneizar o conjunto de dados.

Com a finalidade de avaliar a qualidade dos dados coletados por cidadãos cientistas, foram propostos quatro indicadores para validação de estudos biológicos: (1) acurácia e precisão, (2) representatividade espacial e temporal dos dados, (3) tamanho amostral adequado e (4) sistematização na amostragem (LEWANDOWSKI; SPECHT, 2015). No entanto, ainda há poucos estudos que correlacionem o conjunto de dados coletados por cientistas profissionais e cidadãos não acadêmicos, o que compromete a afirmação de que há diferença significativa entre eles (LUKYANENKO; PARSONS; WIERSMA, 2016). A princípio, o superior esforço amostral promovido pelo aumento do engajamento de voluntários e aprimoramento do desenho amostral e protocolo de coleta ao longo dos anos (CERRANO; MILANESE; PONTI, 2016) tenderia a compensar os possíveis vieses que carregam consigo, podendo ser mais informativos, inclusive, que conjuntos de dados de pesquisas científicas pontuais, de escala e orçamento restritos (RATNIEKS et al., 2016). Também deve ser discutida a informação de ausência de avistamento, pouco relatada nos monitoramentos de voluntários, embora necessária para mensurar o esforço amostral real. Além disso, a motivação de participação e a frequência de monitoramento correspondem a outros problemas frequentemente reportados na ciência cidadã (WILLIAMS et al., 2015).

A perspectiva futura é integrar os estudos com fotoidentificação de espécies em esforços colaborativos de conservação, dado que espécies migratórias frequentemente transpõem as barreiras políticas. Para tanto, são necessárias a padronização das técnicas específicas de cada espécie entre os grupos de pesquisa e a contribuição em plataformas colaborativas de monitoramento (MARSHALL; PIERCE, 2012).

O presente trabalho discorre sobre a técnica de fotoidentificação na perspectiva da ciência cidadã, uma vez que envolve a participação de mergulhadores voluntários na coleta de

dados subaquáticos sobre tartarugas marinhas. Será testada a efetividade de reconhecimento dos indivíduos a partir das nadadeiras posteriores, além dos perfis faciais já conhecidos na literatura sobre o assunto. A iniciativa é resultante do interesse em utilizar registros por mergulhadores livres e autônomos e direcioná-los à pesquisa científica.

Em uma análise preliminar de vídeos fornecidos por mergulhadores na região de Pernambuco, Paraíba e Rio Grande do Norte, observou-se que o registro dos animais é feito, principalmente, nas porções superior e posterior, devido ao comportamento de fuga das tartarugas marinhas diante da aproximação dos mergulhadores. Visando o potencial de aproveitamento dos registros subaquáticos de voluntários, bem como o fomento de estudos futuros sobre marcação e recaptura de tartarugas marinhas e ciência cidadã, foram avaliadas a possibilidade de reconhecimento dos indivíduos a partir das nadadeiras posteriores e a qualidade dos dados coletados por cidadãos cientistas. Foi testada a hipótese de que as nadadeiras posteriores podem ser mais informativas para a identificação de tartarugas marinhas que as placas faciais, uma vez que possuem maior número de placas que podem auxiliar no reconhecimento de elementos específicos de cada indivíduo, e são uma região corpórea de fácil acesso para registros subaquáticos.

## **OBJETIVOS**

### **OBJETIVO GERAL**

Propor um novo método para fotoidentificação de tartarugas marinhas por meio de programa computacional e ciência cidadã.

### **OBJETIVOS ESPECÍFICOS**

- Testar a identificação de indivíduos a partir de fotografias das nadadeiras posteriores em vista dorsal.
- Verificar a acurácia da fotoidentificação entre duas espécies de tartaruga marinha.
- Definir o intervalo numérico para reconhecimento e diferenciação de indivíduos em programa de computador específico.
- Avaliar a qualidade de dados coletados por cidadãos cientistas.

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**Photo-identification of sea turtles from hind flipper and its potential use in citizen science initiatives**

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Texto submetido a Marine Biology em 12 de agosto de 2017

1 **MARINE BIOLOGY – Method article**

2 **Photo-identification of sea turtles from hind flipper and its potential use in citizen**  
3 **science initiatives**

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15

16 **Acknowledgments**

17 We thank the Projeto Tamar for logistic and institutional support. We are grateful to all  
18 citizen scientists from Mar Aberto Dive Center and Barracudas Imagens for sharing their  
19 records. The fieldwork complied with the current laws of Brazil and was authorized by the  
20 ICMBio under license number 56152-1. YCBBO received scholarship from Coordenação de  
21 Aperfeiçoamento de Pessoal de Nível Superior (CAPES). BAS thanks the Conselho Nacional  
22 de Desenvolvimento Científico e Tecnológico (CNPq) for providing research grant  
23 (310340/2016-0).

24

25 **Abstract**

26 Understanding the spatiotemporal distribution of migratory marine organisms is an old  
27 challenge for ecologists and conservationists. Part of this knowledge gap relies on the absence  
28 of methods able to accurately recognize an individual and distinguish it from conspecifics. In  
29 sea turtles, the face scales are commonly used in photo-identification, but the hind flippers are  
30 often filmed or photographed as well. Using the I<sup>3</sup>S Pattern photo-identification software, we  
31 propose an adaptation of a face-based method to the hind flippers of *Chelonia mydas* and  
32 *Eretmochelys imbricata* and assess its potential use in citizen scientist initiatives. We captured  
33 61 individuals of both species in Brazil (3°51'S, 32°25'W), took surface images from their  
34 face and flipper, and performed linear mixed models to validate our method. We also  
35 compiled and verified the quality of 83 underwater records from citizen scientists differing in  
36 dive experience and photographic ability. *E. imbricata* presented slightly higher scores than  
37 *C. mydas* to recognize an individual, but flipper and face were equally useful and accurate.  
38 Considering the minimum score difference to the nearest conspecific in the database, the  
39 flipper was helpful to distinguish individuals of both species, but even more in *E. imbricata*.  
40 About 28% of the citizen scientist records were useful for photo-identification. The most  
41 frequent error was the inadequate angle-of-view (43% of the discards). Our results  
42 demonstrate that (1) hind flippers are useful for recognition and differentiation of sea turtles  
43 and (2) citizen scientist data may support the photo-identification, although a brief guidance is  
44 necessary to ensure data quality.

45

46 **Key words:** Cheloniidae; citizen science; I<sup>3</sup>S; mark-recapture; photographic identification

47

## 48 **Introduction**

49           Understanding the spatiotemporal distribution of migratory marine vertebrates is a  
50 historic challenge for ecologists and an urgent demand for decision makers involved in ocean  
51 and coastal management and conservation (Fujioka et al. 2014; Doherty et al. 2017). The  
52 grounds of such knowledge are the correct recognition of each individual in a population and,  
53 consequently, its differentiation from other conspecifics (Bansemer and Bennett 2008;  
54 Williams et al. 2017). They allow to describe movement patterns, site fidelity and habitat  
55 selection at the individual level, as well as to estimate population size, structure and dynamics  
56 (Madon et al. 2011; van Strien et al. 2013; Colman et al. 2015; Mancini et al. 2015; Araujo et  
57 al. 2016b). Despite recent advances in our ability to monitor migratory marine species (e.g.  
58 Kraska et al. 2015), there is still a lack of reliable, cost-effective methods for individual  
59 recognition and differentiation (Eckert and Hemphill 2005).

60           The most common methods used to tag individuals in a population are satellite  
61 telemetry (Doherty et al. 2017), acoustic telemetry (Breine et al. 2017), molecular marking  
62 (Madon et al. 2011) and mark-recapture (White et al. 1982; Eckert and Beggs 2006). The  
63 mark-recapture method usually involve the use of metallic tags (Newton et al. 2016) or  
64 photographs (Speed et al. 2007; Marshall and Pierce 2012; Rees et al. 2016), being  
65 recognized as photographic identification, photo-identification or photo-id. This method,  
66 which has rapidly grown over the last decades due to remarkable advances in software and  
67 digital camera development, is based on the individual identification through natural marks  
68 from the animal body, such as fin shape (Friday et al. 2000), spot pattern (Marshall and Pierce  
69 2012) and scars (Speed et al. 2007). It has been reliably used in studies with cetaceans, sharks,  
70 sea turtles and other animals (Speed et al. 2007; Marshall and Pierce 2012; Dunbar et al.  
71 2014; Araujo et al. 2016a). In the case of sea turtles, the photo-identification has been based  
72 only on the head, either on the pattern of facial scales to identify Cheloniidae (Schofield et al.  
73 2008; Jean et al. 2010; Carter et al. 2014; Dunbar et al. 2014), or on the spot features of dorsal

74 head surface to identify Dermochelyidae (de Zeeuw et al. 2010). Their hind flippers have  
75 been not yet used for photo-identification purposes, despite many in situ records are from this  
76 body region.

77 Photo-id has many advantages over conventional tagging methods. In addition to be  
78 less expensive than traditional methods, it is a non-invasive procedure that allows in situ  
79 records without capturing the animal (Reisser et al. 2008; Marshall and Pierce 2012).  
80 Although individual marks can be modified and scars acquired during animal development,  
81 photo-id studies with elasmobranchs presented a minimum stability of 30 years (Marshall and  
82 Pierce 2012) and 10 to 20 years for sea turtles (Carpentier et al. 2016). On one hand, this  
83 supports the use of photo-id methods in long-term monitoring of migratory marine  
84 vertebrates. On the other hand, if properly designed and conducted, this encourages the  
85 participation of volunteers – as citizen scientists – on data collection, expanding the spatial  
86 and temporal scales of scientific researches (Williams et al. 2015; Carpentier et al. 2016).

87 Sea turtles are among the most studied marine vertebrates (Hamann et al. 2010). Most  
88 works have focused on metapopulation and demographic patterns, reproductive behavior,  
89 boundaries and connections among feeding areas, biogeography and conservation (Hamann et  
90 al. 2010; Rees et al. 2016). Nonetheless, important questions remain unanswered owing to  
91 inconclusive individual identification, such as those related to species ontogeny in open ocean  
92 and neritic habitats (Rees et al. 2016) and the design of protected area (Hamann et al. 2010).  
93 Improving our capacity to recognize and differentiate individuals is essential to make progress  
94 in this topic.

95 In this paper, we used the I<sup>3</sup>S Pattern software of photoidentification to adapt a face-  
96 based method of sea turtle identification and propose an alternative method based on the hind  
97 flipper of the animal. We validate our method with records from *Chelonia mydas* and  
98 *Eretmochelys imbricata* and assess its potential use in citizen scientist initiatives, as scientist  
99 and non-scientist divers often record sea turtles in situ from their hind flippers. By comparing

100 the scores generated by the I<sup>3</sup>S software for the head and the flipper, we tested the hypothesis  
101 that the hind flipper is technically better than facial scales for photo-identification due to the  
102 higher number of elements on fingerprints. We also identified the main mistakes in citizen  
103 scientist data after compiling underwater records from recreational divers differing in dive  
104 experience and photographic ability.

105

## 106 **Materials and Methods**

### 107 *Data collection*

108 We collected the data for two specific purposes: (1) validation of photo-id methods  
109 (hind flipper and facial scale patterns), and (2) quality evaluation of citizen scientists' records.  
110 The first part involved free diving for intentional capture of *C. mydas* and *E. imbricata* in the  
111 Fernando de Noronha Archipelago, Northeast Brazil. Diving operations were made between  
112 October and December 2016 in partnership with the Projeto TAMAR, the Brazilian sea turtle  
113 conservation programme created 35 years ago by Fundação Pró-Tamar and Centro  
114 Tamar/Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio), and officially  
115 sponsored by Petrobras (TAMAR 2011).

116 To compare the head-based with the flipper-based method of photo-identification, we  
117 manually captured and brought to the surface 61 individuals for artificial tagging and  
118 photographic record. We evaluated the physical condition of each individual searching for  
119 scars, injuries and tumors. Unmarked individuals received a metal tag with alphanumeric  
120 identification code, preferably in both front flippers between first and second scales (Reisser  
121 et al. 2008). When scars from previous tag were identified, tagging was done on the hind  
122 flippers, according to an established protocol (Eckert and Beggs 2006). We also attached  
123 colored seal-tags on metal tagging to inform the period of capture and avoid recaptures in the  
124 short term (i.e. less than three months). We took digital photos from facial scales in the lateral  
125 plane and from hind flippers in dorsal view, on both right and left sides. This double side  
126 marking was necessary because facial profiles are not similar between sides, making the

127 recognition based on single side unfeasible (Marshall and Pierce 2012; Su et al. 2015). We  
128 took the photographic records in continuous shooting and replica mode with digital camera  
129 GoPro Hero4 Silver from a parallel distance of 10 cm approximately.

130 To evaluate the quality of citizen scientists' records, we compiled a database with  
131 volunteer participation of free divers, scuba divers from local operator (Mar Aberto Dive  
132 Center) and underwater photographers (Barracudas Imagens). They provided video or images  
133 recorded at night or day from different sites of the states of Paraíba, Pernambuco and Rio  
134 Grande do Norte. Most records included in situ observations of sea turtles in coral reefs and  
135 shipwrecks during swimming, feeding, resting or at cleaning stations, but precise information  
136 of date, depth and other environmental conditions was generally rare. Underwater  
137 photographers were influenced by training, since the image selection from their personal  
138 collection was done after orientation about the photo-id method. The other citizen scientists  
139 provided their raw records without training. During fieldwork in the Fernando de Noronha  
140 Archipelago, free diver tourists were informed about the project and encouraged to get  
141 involved in the project by sharing their in situ sea turtle records.

142 To assess the usefulness of the citizen scientist data we considered four criteria:  
143 adequate light, correct focus, low brightness and clear visibility of facial scales and hind  
144 flippers with the naked-eye (Carpentier et al. 2016). We classified the main flaws and  
145 limitations of the incorrect records into the following categories: view (V) = inadequate  
146 angle-of-view covering flipper or facial scales; distance (D) = high distance of the sea turtle  
147 relative to the focal axis of the camera; turbidity (T) = haziness produced by suspended  
148 particles; illumination (I) = bad lighting and/or high glare. Video capturing was converted to  
149 useful image through GoPro Studio 2.5.

150

### 151 *Quantifying the image scores*

152           Body regions defined for photo-id were the (1) facial profiles according to the  
153 literature (Reisser et al. 2008; Dunbar et al. 2014; Araujo et al. 2016a) and the (2) hind  
154 flippers in dorsal view, with the area of interest defined between the sixth and the seventh  
155 marginal scales, and the outer and the inner fingers (Fig. 1). All individuals had three images  
156 taken from each profile (right and left sides) of each body region (facial scales and hind  
157 flipper), resulting in 12 images of each individual. We used the I<sup>3</sup>S Pattern software (version  
158 4.02) to generate the scores and compare the images (Speed et al. 2007; Dunbar et al. 2014;  
159 Araujo et al. 2016a). This software overlays two images and calculate the distances between  
160 key-elements of each image, resulting in a score. The value is defined by the sum of the  
161 distances of all paired elements divided by the square of the total number of elements (den  
162 Hartog and Reijns 2014). The smaller the score, the more similar are the images.

163           To recognize an individual (intraindividual validation) we considered the mean score  
164 among the three images of each body region and side, resulting in four mean scores per  
165 individual. According to our hypothesis, we expected that the average scores were lower in  
166 flipper than the face. To distinguish one individual from another (interindividual validation),  
167 we considered the lowest score generated by the most similar image from a different  
168 individual in the database. We expected that average differences in score were greater in  
169 flipper than the face. Because scales are less evident in *E. imbricata* than *C. mydas*, which can  
170 increase the distance between the key-elements in image comparison, we also expected that  
171 recognition and differentiation scores were higher in *E. imbricata* than *C. mydas* (Fig. 1).

172

### 173 *Statistical analysis*

174           We used linear mixed models to test for differences in scores within individual  
175 (recognition) and between individuals (differentiation) across body regions, species and their  
176 interaction. In the recognition model we set the code of the individual (1 to 61) and the side of

177 the animal (left and right) as random effects to allow comparisons of face and flipper for a  
178 given profile of the same animal (e.g. right flipper vs. right face). For the differentiation  
179 model, only the side was set as random effect, as a given animal had to be compared to  
180 another one in the database. In both models we adopted the residual maximum likelihood  
181 method to separate the variance of the fixed effects from that of the random effects (Grafen  
182 and Hails 2002). We applied a Chi-square test to compare the frequency of incorrect citizen  
183 scientist records across categories. All statistical analyses were performed in the JMP v.8  
184 software (SAS Institute Inc.).

185

## 186 **Results**

### 187 *Method validation*

188 We recorded 61 juveniles and subadults of *C. mydas* (n = 47, with four recaptures of  
189 four different individuals) and *E. imbricata* (n = 6, with four recaptures of the same  
190 individual), resulting in 39 hours of diving effort. The high number of recaptures of *E.*  
191 *imbricata* was due to its low abundance at Fernando de Noronha during the period of study.  
192 On the other hand, the abundance of *C. mydas* was high and the coding of colored seal-tags  
193 helped us to manipulate and stress less the same animal. Recaptures were included in the  
194 analyses given that they represented additional opportunity to validate the individual  
195 recognition and eventually uncover false differentiation. A low number of images (8 of 244  
196 photographs of the database) had to be discarded due to poor quality.

197 Recognition scores were consistently lower than differentiation scores across species  
198 (< 7 vs. > 15; Fig. 2a, b), reinforcing the robustness of the I<sup>3</sup>S Pattern scores for our goals.  
199 Regarding the recognition model, *E. imbricata* showed slightly but significant higher scores  
200 than *C. mydas* (Fig. 2a; Table 1), consistently with our expectations. However, flipper and  
201 face presented similar within-individual average scores, independently of the species (Fig. 2a;  
202 Table 1).

203           When the data was used to distinguish an individual from others in the database, *E.*  
204 *imbricata* followed expectations and showed higher between-individual average scores than  
205 *C. mydas* (Table 1; Fig. 2b). However, in *C. mydas*, hind flipper and face showed similar  
206 scores (Fig. 2b), indicating that the hind flipper is as accurate as the face to differ an  
207 individual from another. In *E. imbricata*, on the other hand, the hind flipper presented greater  
208 scores than the face (Table 1; Fig. 2b), suggesting a greater utility of this body region to  
209 distinguish individuals of this species.

210

#### 211 *Citizen scientist data*

212           A total of 83 records of videos (n = 62) and photographs (n = 21) were provided by  
213 citizen scientists, being composed of *C. mydas* (n = 35), *E. imbricata* (n = 37), *Caretta caretta*  
214 (n=10) and *Lepidochelys olivacea* (n = 1). Only 23 records (28%) fitted photo-id adequately,  
215 from which a half (12) was from the ‘trained’ underwater photographers. Most video records  
216 indicated that the sea turtle tended to leave the site when meeting the diver. This response was  
217 less common when the individuals were foraging, resting or at cleaning stations, favoring  
218 diver approach.

219           Among the 60 discarded records, 43% fell in the category ‘view’ (Chi-square test,  $\chi^2 =$   
220 14.00, df = 3, P < 0.01; Fig. 3), indicating that inadequate angle-of-view covering flipper or  
221 facial scales was the most common error of citizen scientists. Problems with distance from the  
222 animal were common as well, while turbidity and illumination accounted for less than 15% of  
223 the incorrect records each (Fig. 3). During the 20 activities of sea turtle capturing and tagging  
224 in Fernando de Noronha, approximately 2000 tourists (potential free divers) were encouraged  
225 to get involved in the project as citizen scientists. However, only two shared their records  
226 after the training. Most contributions (n = 58) were from scuba divers that periodically dive.

227

## 228 **Discussion**

229           Our analyses indicate that the well-known face-based method of sea turtle photo-  
230 identification may be modified and applied to their hind flippers, giving utility to apparently  
231 useless records from the posterior region of the animal. They confirm that both body regions  
232 are equally useful and accurate for individual recognition of either *E. imbricata* or *C. mydas*.  
233 In *E. imbricata*, the hind flipper seems to be a bit better than the face to distinguish an  
234 individual from another. This complementary flipper-based method may be particularly  
235 helpful when sea turtles are sighted by the posterior portion or when the observer is not able  
236 to record its facial scales due to restrictions in underwater navigation (e.g. against the current)  
237 or by limitations in dive time and depth. Nonetheless, our results also reinforces the  
238 usefulness of the face scales as key-sources for identification of these species (Reisser et al.  
239 2008; Jean et al. 2010; Carter et al. 2014; Dunbar et al. 2014), which should continue to be  
240 encouraged and scaled-up.

241           Photo-id methods of sea turtles often use computer softwares or visual analyses  
242 (Schofield et al. 2008; Jean et al. 2010; Carter et al. 2014). Only one study presents the  
243 validation of I<sup>3</sup>S software for photo-identification of *E. imbricata* (Dunbar et al. 2014) and in  
244 a pioneer version (I<sup>3</sup>S Classic) (den Hartog and Reijns 2014). The I<sup>3</sup>S Pattern, used here, is  
245 popular among photographic capture–recapture studies due to its robust analyses and  
246 automatic feature detection (Matthé et al. 2017). The I<sup>3</sup>S Classic relies on manual procedure  
247 to define the key elements, increasing the likelihood of user mistakes (den Hartog and Reijns  
248 2014; Matthé et al. 2017). Validation of accuracy in I<sup>3</sup>S Pattern is expressed by ranking top  
249 matches from 1 to 20 (Treilibs et al. 2016; Chaves et al. 2016), but to date there is no  
250 methodological standardization for sea turtles. A study with an Australian skink using I<sup>3</sup>S  
251 Pattern presents scores for correct matches (i.e. individual recognition) around 10, similar to  
252 those we found here (Treilibs et al. 2016). In fact, our analyses indicate that a score of  $3.5 \pm$   
253  $2.3$  (mean  $\pm$  SD) between two images of *C. mydas* corresponds to the same individual, while a

254 score of  $17.5 \pm 5.1$  corresponds to different individuals. For *E. imbricata*, these values are  $5.2$   
255  $\pm 2.4$  and  $29.4 \pm 10.2$ , respectively.

256 *Chelonia mydas* and *Eretmochelys imbricata* have pronounced differences in face  
257 scale pattern (Williams et al. 2017), which was demonstrated by the great amount of variance  
258 assigned to the species effect in the linear models. The higher number of face scales in *C.*  
259 *mydas* possibly reduces the incorrect matching (i.e. false positive error: treating two different  
260 individuals as the same) (Jean et al., 2010). On the other hand, the identification of *C. mydas*  
261 based on the facial scale is more susceptible to cause false negative errors (i.e. to consider the  
262 same individual as two different animals). As the score for individual differentiation are  
263 lower, false rejection may be caused due to minimum photographic artifacts, such suspended  
264 particles or inadequate lighting. For this reason, whenever possible, we recommend recording  
265 more than one body region for an accurate identification, such as the face and the hind flipper.

266 Our results support the potential use of volunteer records for scientific purposes  
267 (Williams et al. 2015), but with a minimum guidance. As argued elsewhere, it is critical to  
268 make the citizen scientists more familiar with the species (Gibbon et al. 2015; Williams et al.  
269 2017). The main error recorded – the inadequate angle-of-view – may be easily corrected by  
270 indicating the correct angle for taking the photo or video. Other errors observed, such as the  
271 correct distance from the sea turtle, turbidity and illumination levels, could also be reduced  
272 with continuous training (Ratnieks et al. 2016). We highlight that most citizen scientist  
273 records derived from personal collections without any orientation or concern with use for  
274 photographic identification. Half of the appropriate records were obtained from professional  
275 photographers, which beyond technical knowledge and experience, received previous training  
276 before their contribution. Dive skills play an important role in gathering high quality data  
277 concerning stability, focus and approaching without remove sediments (Cerrano et al. 2016).  
278 The growing number of recreational scuba and free divers around the world highlights the  
279 possibility to scale up the use of citizen scientist data in scientific studies. In our study region,

280 a little information during the briefing of scuba dive operations is likely to have a notable  
281 positive impact on citizen scientist data.

282         Despite the large number of voluntary audience in the activities of sea turtle capturing  
283 and tagging in Fernando de Noronha, their real participation was undermost (2 out 2000). It is  
284 well documented that there is a strong intention of volunteers to contribute to marine  
285 conservation projects, and their observations play an important role in scientific research  
286 (Martin et al. 2016). Their low participation in our project was possibly due to ineffective  
287 communication, resulting in incomplete understanding of which were the main goals of our  
288 research (Martin et al. 2016). However, because all potential volunteers were tourists  
289 enjoying the singular scenic beauty of the archipelago with family or friends, we believe that  
290 it may be rather explained by the profile of the volunteer (Williams et al. 2015). While free  
291 diver tourists made two contributions, resident divers contributed with 58 records, showing  
292 fidelity and engagement behavior (Branchini et al. 2015). This asymmetric contribution of  
293 different volunteers should be investigated in detail and taken into account in citizen scientist  
294 initiatives.

295         In summary, our results demonstrate that photographs of hind flipper of sea turtles  
296 may be much helpful than previously thought to recognize and distinguish individuals,  
297 complementing the facial records or even being the main body region to be used in the photo-  
298 identification. The images can be captured by the public, although a brief orientation is  
299 necessary to ensure data quality for scientific purposes. It is also necessary to acquire an  
300 effective strategy able to allow a comprehensive participation of different groups of citizen  
301 scientists. Our work helps to overcome problems of individual identification and may support  
302 new research opportunities on sea turtle ecology and conservation. We suggest the flipper-  
303 based method proposed here be evaluated on other species of Cheloniidae and  
304 Dermochelyidae.

305

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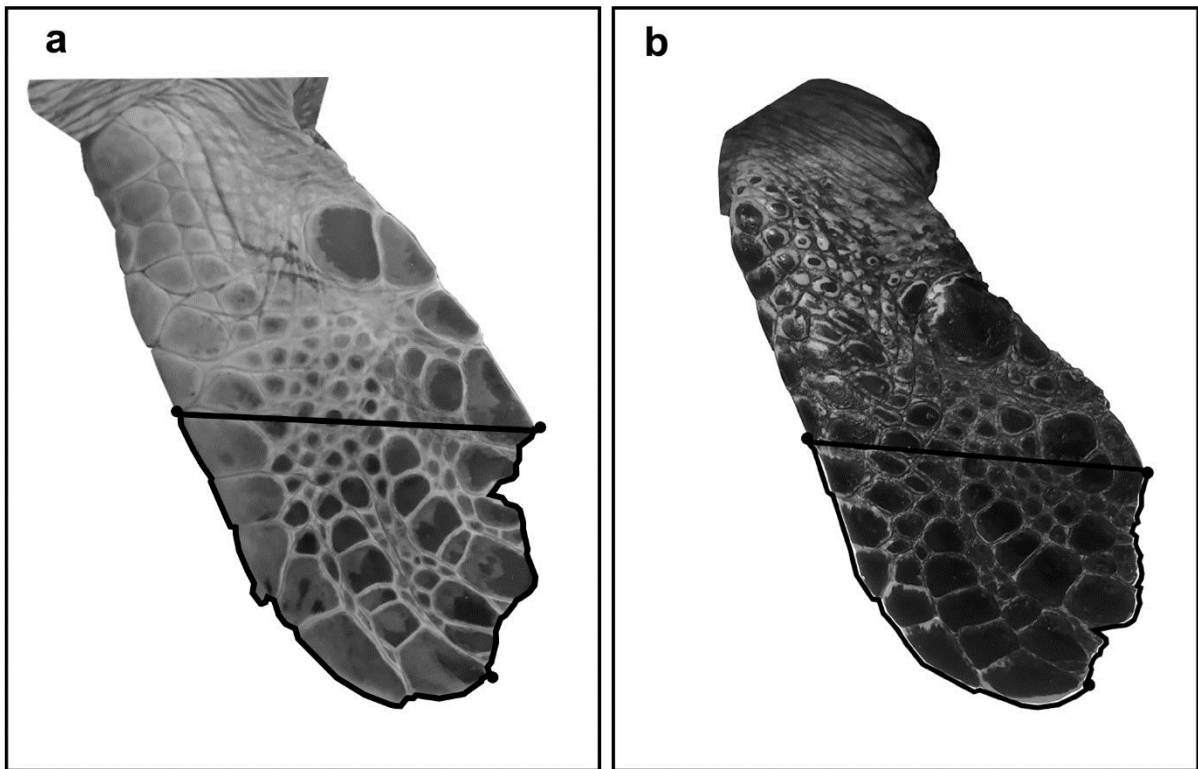
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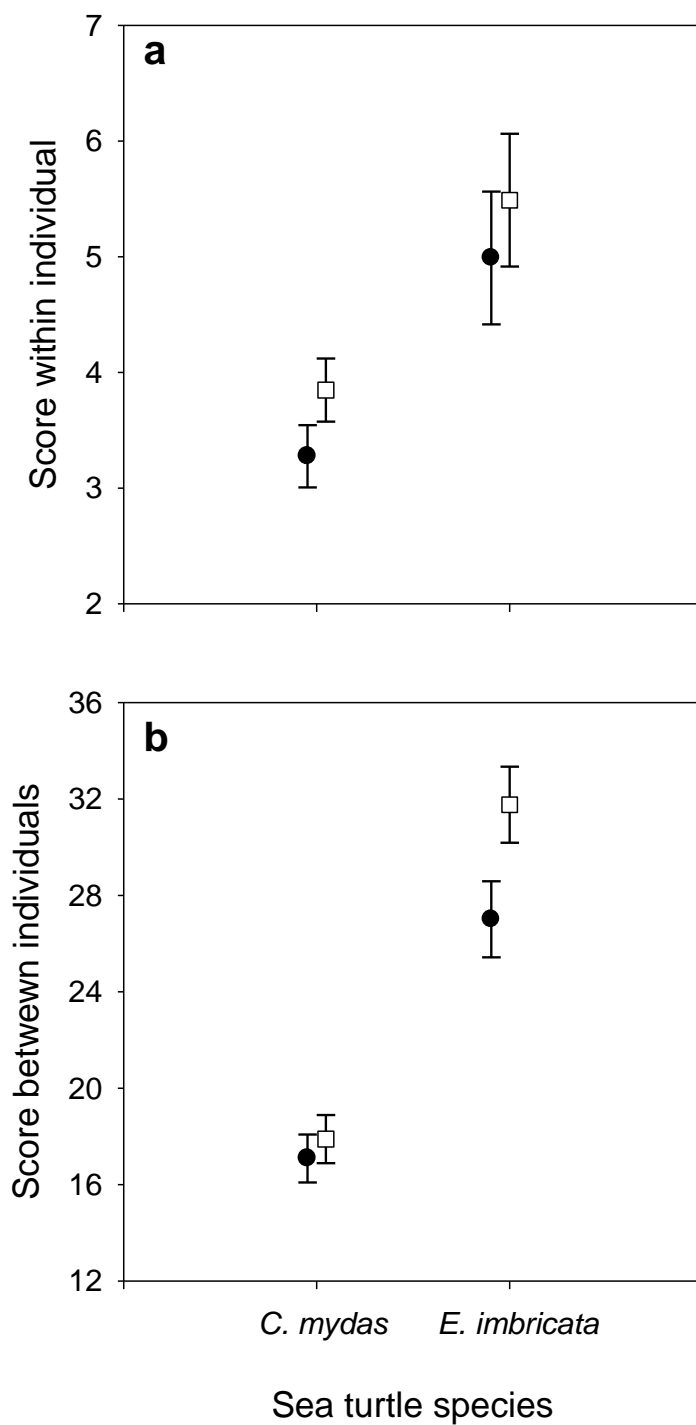
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418

419 **Fig. 1** Fingerprint from hind flipper of *Chelonia mydas* (a) and *Eretmochelys imbricata* (b)  
420 highlighted by black line. The three black dots are reference points between the sixth and  
421 seventh marginal scales, and the inner and the outer fingers (dorsal view)

422

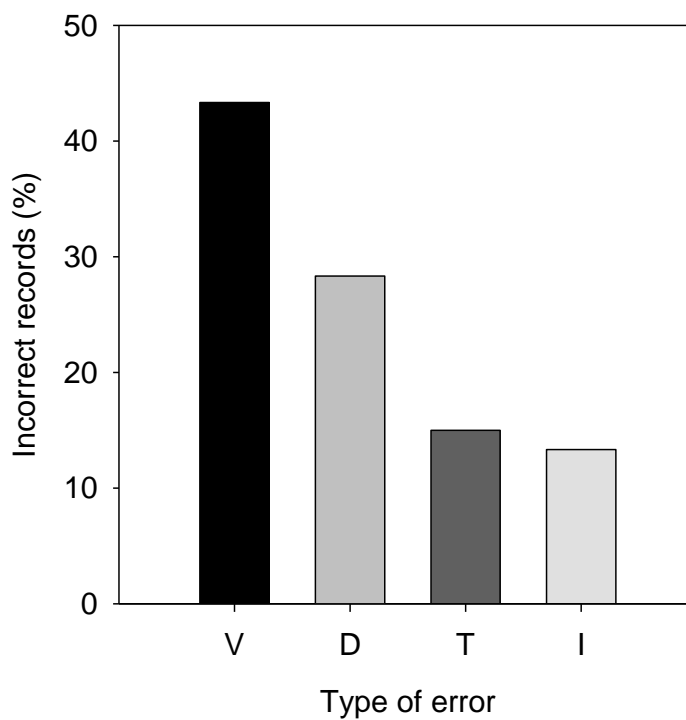


423

424 **Fig. 2** Box-plot (mean  $\pm$  standard error) of facial scale (black circles) and hind flipper scores425 (white squares) of *Chelonia mydas* and *Eretmochelys imbricata*: (a) indicates the recognition426 and (b) the differentiation of 61 individuals based on score calculated by the I<sup>3</sup>S Pattern

427 software

428



429

430 **Fig. 3** Main source of errors in images captured by citizen scientists. V (view) = inadequate  
431 angle-of-view covering flipper or facial scutes; D (distance) = high distance of the sea turtle  
432 relative to the focal axis of the camera; T (turbidity) = haziness produced by suspended  
433 particles; I (illumination) = bad lighting and/or high glare. N = 60 poor records

434

435 **Table 1** Results of linear mixed models fitted to test the effect of body region (face profile or  
 436 hind flipper) to recognize and differ individuals of *Chelonia mydas* and *Eretmochelys*  
 437 *imbricata* based on the scores calculated by the I<sup>3</sup>S Pattern software. Recognition model  
 438 (within individual) included individual code (from 1 to 61) and profile (left and right) as  
 439 random effects. Differentiation model (between individuals) included only profile as random  
 440 effect. Differences in degrees of freedom across models are due to their different random  
 441 effects  
 442

Model terms	df	F-ratio	P-value	Model $R^2$
<hr/>				
Score	within			
individual				
Species	1,58	10.50	<0.01	0.40
Body region	1,173	2.44	0.120	
Species × Region	1,173	0.01	0.916	
Score	between			
individuals				
Species	1,231	125.11	<0.0001	0.36
Body region	1,231	6.82	<0.01	
Species × Region	1,231	3.45	0.065	
<hr/>				

## INSTRUCTIONS FOR AUTHORS - SPECIFIC REQUIREMENTS

### General structure

The manuscript should be submitted as a word file or in LaTeX. The manuscript should be organized into Abstract, Introduction, Materials and Methods, Results, Discussion/Conclusion, Compliance with Ethical Standards, Acknowledgments, References, Figures (with captions) and Tables. Figures and Tables should be submitted as separate files (this structure is not needed for Reviews, Concepts, and Syntheses). Marine Biology does not publish footnotes or supplements, but additional data or videos may be submitted as electronic supplementary material which will be available online.

No full justification for the text should be used. Line numbers should run consecutively throughout the text, from the title page through the figure legends. Lines in tables or figures should not be numbered. Abbreviations and acronyms must be defined at first mention in the Abstract, again in the main body of the text, and also in the Figure Legends. A list of abbreviations may be included as a table, but should not appear at the beginning of the manuscript.

The **Title** should be meaningful and signal the importance of the study for the field. It should be descriptive and tell the reader what the paper is about. It should be general rather than restrictive to species and geographic areas. If scientific names of species are used, they must be accompanied by a higher taxonomic classification term and/or by a common name.

The **Abstract** should summarize the manuscript. It should be short and clear (150-250 words). The abstract should reflect what was done, why it was done, and what major results were obtained. It should not be written in the first person. The abstract should include the date(s) of the study and the latitude and longitude where the samples or experimental organisms were collected. It should not contain descriptions of the state of the art; such information should be limited to the introduction. No undefined abbreviations or unspecified

references should be used. The abstract may decide whether a manuscript will be sent out for review; papers may be rejected due to poor or confusing abstracts.

The **Introduction** should describe why the study was done and end with some testable hypotheses or clear objectives. Manuscripts which do not present a clear hypothesis are likely to be rejected without review.

**Methods:** All details required to repeat the work must be provided. Usage of publicly accessible data from repositories must be indicated. The respective accession information must be provided in the References.

Results: Where specific results are being presented or discussed the past tense should be used. The present tense should only be used for generalizations arising from the study results.

The **Discussion** should highlight the importance or significance of the study for the field and the resulting new insights.

**Compliance with Ethical Standards** must be included as a separate section. The authors should give information about funding and explicitly declare that they have no conflict of interest. They should declare that all applicable international, national, and/or institutional guidelines for the care and use of animals were followed, or that the article does not contain any studies with animals performed by any of the authors. Details about permissions (animal studies) should be provided as well.

Please do not write "Informed consent was obtained from all individual participants included in the study", if (as usual) no human participants were involved in the study.

In the **Acknowledgement** grants, funds, and contributing people should be mentioned. The reviewers should be acknowledged, but please consider that Marine Biology now allows reviewers to have their names disclosed on the manuscript. You might include the name of a reviewer who has agreed to disclose her/his name into the acknowledgements when you receive the proofs (names are printed at the first page of the paper). Write e.g. "We thank the reviewers....." or "We thank X.Y and an anonymous reviewer....."

The **References** must be formatted in MABI style (see more details under “Citations”). Data taken/used from public Databases (e.g. PANGANEA) must be cited by accession numbers.

**Figures:** Captions should be placed below the figures for ease of reviewing. More details are given under “Illustrations” and “Figure Captions” (see below). Submission of two copies of figures, one for the reviewers (with captions) and one for the production (source files without captions) is recommended.

**Tables:** Tables should be numbered using Arabic numerals and have a table caption (title) on top, explaining the components of the table. All abbreviations in the table should be explained in the caption. Tables must not contain vertical lines.

## **Specific Requirements**

### **Text Formatting**

Use 1.5 or double-space formatting and enable line numbering. No full justification for the text should be used. Superscript must be used to denote the denominator in units, e.g. kg y<sup>-1</sup>, 24 hr time for time of day, e.g. 0700 hr.

Use of a recent article as a guideline is recommended. Correct formatting is a prerequisite for acceptance of a manuscript. This concerns especially statistics, units, and citations/references.

### **Statistics**

Describe statistical methods in sufficient detail to allow a knowledgeable reader with access to the original data to verify the reported results. Use the same font for the same mathematical symbol regardless where it appears in the manuscript (text, equations, tables, figures, figure legends).

Give means and standard errors/standard deviations with their associated sample size in the format:  $X \pm SE = 35.09 \pm 0.07$  km,  $n = 15$ . When standard deviation/error is shown in an illustration,  $n$  should be given as well.

**Statistical tests** use the following formats:

(ANOVA,  $F(1,25) = 8.56$ ,  $P = 0.035$ )

(Kruskal-Wallis test,  $H_{25} = 123.7$ ,  $P = 0.001$ )

(Chi-square test,  $X^2_{22} = 0.23$ ,  $P = 0.57$ )

(Paired t test,  $t_{24} = 2.33$ ,  $P = 0.09$ )

(Linear regression,  $r^2 = 0.94$ ,  $F_{1,66} = 306.87$ ,  $P < 0.001$ )

(Spearman rank correlation,  $r_s = 0.60$ ,  $N = 33$ ,  $P < 0.01$ )

(Wilcoxon signed-ranks test,  $T = 7$ ,  $N = 33$ ,  $P < 0.05$ )

(Mann-Whitney U test,  $U = 44$ ,  $N_1 = 7$ ,  $N_2 = 24$ ,  $P < 0.02$ )

Please either give the exact P-value of a statistical test, or state  $P < 0.0xxx$ , if this is not possible.  $P = 0$  is not valid.

## Units

Use of SI and SI-derived units is preferred. Internationally accepted units can be also be used, e.g. “min” for “minute”. The capital letter “L” must be used for liter.

Please use superscripts instead of “/” or “per ...” for ratios. Exponents should also be written as superscripts.

When using a number and a unit of measure to make a qualifying adjective, put a hyphen between them, e.g. 300- $\mu\text{m}$  sieve.

Please refer to the following examples.

Length, Area, Volume: pm, nm,  $\mu\text{m}$ , mm, cm, m, km,  $\text{mm}^2$ ,  $\text{cm}^2$ ,  $\text{m}^2$ , L, mL,  $\mu\text{L}$ ,  $\text{mm}^3$ ,  $\text{cm}^3$ ,  $\text{m}^3$

Mass: pg, ng,  $\mu\text{g}$ , mg, g, kg, t, Da, kDa

Time: s, min, h, d, y

Temperature:  $^{\circ}\text{C}$ ,

Absolute quantity: pmol, nmol,  $\mu\text{mol}$ , mmol, mol

Concentration: pM, nM,  $\mu\text{M}$ , mM, M, N, %,  $\mu\text{g L}^{-1}$ ,

Work, Energy, Heat quantity: J, erg, cal, kcal

Force: dyn, N, gw, kgw

Pressure: Pa, mmHg, atm, bar

Electricity: V, W, mA, A, Hz

Photometry: if possible, avoid cd, lx, lm, cd m<sup>-2</sup>, energy or photon flux density would be preferable

Sound: Hz, kHz, mHz, Abar, dB Speed: cm s<sup>-1</sup>, m s<sup>-1</sup>, kn, rad s<sup>-1</sup> (some speeds, e.g. sedimentation rates are better expressed per day or even year)

Radioactivity: dpm, cps, cpm, mBq, Bq, kBq, Gy, kGy, mSv, Sv, R, kR Rotation: ×g, cycle

Use the symbols < and > to stand for less than and more than.

Also note that salinity has no units and should be presented as: salinity of X or salinity X.

### **Archiving of Data**

Data storage in a publicly accessible data library is highly recommended, for DNA sequence information it is obligatory.

DNA sequence information must be deposited in GenBank

(<http://www.ncbi.nlm.nih.gov/genbank/>) and accession numbers must be included in the manuscript such that the raw data can be accessed and compared against the presented data. For frequency-based data (microsatellites predominantly) a table of allele frequencies by population should be included (suitable for electronic supplementary material).

Phylogenetic information might be stored in TreeBASE, this repository accepts all kinds of phylogenetic data (e.g., trees of species, trees of populations, trees of genes).

Other data can be deposited in the data library PANGAEA (<http://www.pangaea.de/>). Data are archived by an editor in standard formats, in machine readable form, and are available with Open Access. After processing, the author receives an identifier (DOI) link to the supplement for proof-reading. Data can be referenced in the publication to facilitate linking between the journal article and the data. Send raw data with a description to [info@pangaea.de](mailto:info@pangaea.de). PANGAEA can be used free of charge.

For Tracking data (telemetry devices on animals) specific databases exist, such as Movebank or Seaturtle.org. Data can be stored with the option to apply different levels of access to internal and external users.

The Dryad Digital Repository DRYAD (<http://datadryad.org/>) provides a general-purpose home for a wide diversity of data types. Data storage is charged, but researchers from economically developing countries may submit data at no charge.

Other publicly accessible data libraries are welcome as well. A special archive for isotope data (IsoBank) is currently under construction.

If unpublished data sources are cited in the text or if a manuscript contains only highly derived data without basal data (e.g. diversity indices without species abundances) archiving of basal data might be requested by the Editor. In the latter case, electronic supplements might be used as an alternative to data archives.

### **Citations**

When citing references in the text, put them in parentheses in chronological order with the earliest first. Separate them with semicolons. Do not put a comma between the author(s) and date.

Examples:

- (Thompson 1990; Abbott et al. 2005; Elliott and Green 2009)
- Same author, multiple years. E.g. (Brown 1997, 2000, 2005)
- Same author, same year. E.g. (Brown 2005a, b)
- Two authors (Brown and Smith 2007; Abbott and Green 2009)
- Multiple authors (Zar et al. 1998; Brown et al. 2008)
- As part of a sentence, e.g. This result was later contradicted by Becker and Seligman (1996)
- Abbreviate Personal Communications to (pers comm)
- Abbreviate Unpublished data to (unpubl data)

### **References**

References should be alphabetized by the last names of the first author of each work.

When there are more than two references with the same first author, the references should be arranged so that the single-authored papers come first in chronological order with the earliest first, then the twoauthored papers in alphabetical order by second author, then the multi-authored papers in chronological order with the earliest first.

### Journal articles

Journal names must be abbreviated without punctuation. For abbreviations see <http://www.issn.org/222661-LTWA-online.php>. Ideally, authors are to provide DOI information for all journal articles. DOIs should be checked with the doi system website, to make sure that the cite is correct.

### Dissertations

Trent JW (1975) Experimental acute renal failure. Dissertation, University of California, Los Angeles

Trent JW (1975) Experimental acute renal failure. Master thesis, University of California, Los Angeles

Online documents (Websites should only be cited if absolutely essential because they will change with time).

Cartwright J (2007) Big stars have weather too. IOP Publishing Physics Web.

<http://physicsweb.org/articles/news/11/6/16/1>. Accessed 26 June 2007

Data from a database must be cited in the references by using a Digital Object Identifier (DOI).

Conference Proceedings should not be cited. Every cited printed work should be publicly accessible by ISBN or ISSN number.

When revising your manuscript please examine the validity of your journal references with the '**Automatic Reference Checking**' module of the Editorial Manager.

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provided in your “Main Menu” in the Editorial Manager, as well as in the PDF file containing your manuscript. If "not validated" is displayed for a reference, it should be checked carefully and corrected where appropriate, as in most cases typos, wrong journals, issues or pages preclude its validation.

### **Illustrations**

The illustrations are a very important part of the article. They must be prepared very carefully and be of good quality. Note that EXCEL is not a drawing program and figures generated in this program frequently require editing prior to inclusion in manuscripts. Legend material should be included on the panels, not hanging off to the side or as titles or labels at the top or bottom of the figures. Legend material can also be included in the figure legend if it does not fit on the panel(s). Manuscripts containing poor quality figures will not be considered for publication. The figures should be as simple as possible and all details must be clearly visible when the figures are reduced in size. Data should be provided in figures OR in tables. Data must not appear twice (Fig and Table).

Any information that is not absolutely necessary for understanding the article should be provided as numbered appendices in the electronic supplementary material (ESM).

For ease of reviewing the figures with captions (each caption placed below the respective figure) should be submitted. They can be inserted at the end of the manuscript or can be submitted as separate file(s). The source files (e.g. EPS, TIFF; JPG, each figure in its own file) required for later production (if), must be submitted as separate files without captions. To avoid confusion, no extra list of figure legend should be submitted when figures and captions are pasted together.

Figures must be numbered consecutively and referred to in the text. The illustrations should be selfexplanatory, i.e. with their captions they should be able to stand on their own without requiring further information from the main body of the text.

If a figure contains multiple panels, all panels should be on one page. They should be of the

same size and arranged properly. Axes titles must only be repeated on each panel when they are different. The same style should be used for all similar illustrations so that their appearance is consistent.

The same non serif font (e.g. ARIAL) must be used for lettering in all figures. All lines must be sufficiently thick to reproduce well and all lines, lettering, symbols and markings must be sufficiently large to be easily legible when reduced in size and must be in proportion to the rest of the drawing. If various degrees of grey shading are used, ensure that they are varied enough to differentiate among them or use patterns. Grid lines and boxes around symbol definitions should be avoided. Colors could be used if necessary. Marine Biology does not charge for color figures in the online or printed version of the journal; however, the Editors may refuse color prints if the use of color is not justified.

The source must be given for maps, photographs, and other materials. Scale bars should be placed on photographs and maps. Maps must have an arrow indicating due north or a compass rose and a border with the latitude/longitude marked on it. Please see also the chapter “Artwork and Illustration Guidelines” in the “Instructions for Authors” for examples and further details.

### **Figure Captions**

The Figure captions should be brief (“telegraphic style”), but contain all details necessary for understanding the figure without reading the text. They should not contain methodical details or results. All terms, abbreviations, and symbols must be explained in the caption and correspond with those in the text.

It is no longer mandatory for captions to be provided on a separate page. The manuscript file can comprise the figures with the captions (each caption placed below the respective figure). This makes it easier for reviewers. All figures (with captions) can be placed at the end of the manuscript or can be submitted as separate file(s). Please note that the figure captions must not appear twice, e.g. on a list and under the illustrations, as this is a frequent source of error.

The source files of the figures (JPG, EPS, TIFF, etc) without captions should be provided separately as single files. They are needed for later production (provided acceptance).

### **Organisms**

Genus and species name must be in italics. It is recommended that the species names appear in full at the beginning of each section of the manuscript and when they appear at the beginning of a sentence. In other places use the contraction e.g. *A. islandica* for *Arctica islandica*. Do not abbreviate genus names if several genera with the same initials can lead to confusion, or when only the genus name is used. Genus sp. and Genus spp. should only be used when speciation to species level was generally sought, but not completely reached and several species should be treated together, respectively.

The species author may follow the first use of the study species name in either the Abstract or the Materials and Methods. If it is included, the reference to the original description must appear in the References section.

Common names can be used in addition to the scientific names, they are useful especially in the title. Common names such as “water fleas” for cladocerans, or common names that might be misleading must be avoided. E.g.: Sandfish is a common name of: *Gonorynchus*, a genus of fish, *Scincus scincus*, a skink, and *Holothuria scabra*, a sea cucumber. It should only be used for the fish.

Only use the words ‘animal’ and ‘plant’ in the most general sense. When referring to the individual organisms used in a study, use the most specific term possible such as the species name (in full or contracted), the common name such as ‘mud shrimp’ for *Upogebia pugettensis*, or ‘individuals’ where appropriate.

When describing the general attributes of a species use a singular verb. When referring to the multiple organisms belonging to the species used in a study, use a plural verb.

### **Seasons**

When describing the seasonal timing of events, be aware that fall and winter occur at different

times of the year in the northern and southern hemispheres. It is best to specify the months rather than just the seasons.

### **Study Locations**

When writing the names of states in the USA do not use the postal abbreviation but write them in full– thus Virginia not VA.

If a map is used to show study locations, it must have a scale, an arrow indicating due north or a compass rose and a border with the latitude/longitude marked on it. It should show all geographical locations mentioned in the study. The source of the map must be given in the caption of the figure.

## CONSIDERAÇÕES FINAIS

Os resultados obtidos nesse trabalho demonstram que fotografias de nadadeiras posteriores de tartarugas marinhas podem ser extremamente úteis para o reconhecimento de indivíduos ou sua diferenciação em uma população. O novo método proposto potencializa o uso de registros subaquáticos, até então sem finalidade científica, além de superar problemas de identificação. Os registros das nadadeiras posteriores podem complementar a identificação fotográfica, já consolidada, baseada na face do animal, ou mesmo ser a principal região utilizada na fotoidentificação. Este trabalho também permite confirmar a utilidade de captação de imagens por cidadãos cientistas. No entanto, é necessária uma breve orientação aos voluntários para assegurar a qualidade das imagens captadas e evitar, principalmente, os registros parciais das áreas de interesse, que inviabilizam a análise dos padrões das placas. Também é necessária a adoção de uma estratégia adequada que possibilite maior participação voluntária dos cidadãos cientistas no projeto em questão. No caso de cientistas interessados na ecologia e conservação desses organismos, fica evidente que o método proposto permite auxiliar no monitoramento de tartarugas marinhas, criando oportunidades de estudo na ecologia e conservação dessas espécies-bandeira. Recomenda-se que o método seja avaliado em outras espécies de Cheloniidae e também em Dermochelyidae.