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Analysis of the scientific production on sea turtles in Cabo Verde

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Sea turtles constitute a threatened group of fauna, thus to know caveats in their knowledge it is crucial to lead research efforts. The present study aims to analyse the scientific literature published on marine turtles in Cabo Verde by means of a bibliographic analysis. We analysed the temporal and geographical variation in the publications, the number of authors and nationalities involved, and the extent of study of different research topics by species. The number of publications grew through the analysed time period (1979-2020), as well as the number of authors. The countries with the highest number of publications were Spain followed by Cabo Verde. Research areas of greater investigation effort were "Breeding and reproductive success", followed by "Conservation and management" and "Population dynamics". However, there were differences between species and islands. Most of the studies were conducted at Boa Vista, followed by Sal and Maio Islands. The most studied species was *Caretta caretta*. This analysis contributes to understand trends and caveats in sea turtle knowledge that could help guide future research lines in areas of particular concern.

Key words: authorship; bibliometric analysis; Cabo Verde; *Caretta caretta*; marine turtles; research trend.

Most sea turtles are endangered, since six of the seven existing species are considered as threatened by the *IUCN Red List of Threatened Species* (IUCN, 2021): hawksbill turtles (*Eretmochelys imbricata*) and Kemp's Ridley turtle (*Lepidochelys kempii*) are categorised as Critical Endangered; Green turtle (*Chelonia mydas*) is under the Endangered category and; olive ridley (*Lepidochelys olivacea*), leatherback (*Dermochelys coriacea*) and loggerhead turtle (*Caretta caretta*) are classified as Vulnerable. Among the numerous threats that are causing a decrease in sea turtle populations are fisheries (Lewison *et al*., 2004; Fiedler *et al*., 2012), infections by pathogens (Sarmiento-Ramirez *et al*., 2014; Gleason *et al*., 2020), climate change (Fuentes & Cinner, 2010), marine debris (Carr, 1987), egg and meat consumption (Veríssimo *et al*., 2020), and/or the degradation and loss of habitat (Lutcavage *et*

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al., 1996). In addition, sea turtles are migratory and long-lived animals that utilize separately breeding and feeding zones, expanding over large distribution areas (MUSICK & LIMPUS, 1997). They are found in all the oceans, except in polar regions (WALLACE *et al*., 2010). Sea turtles have natal philopatry to particular nesting beaches (BOWEN *et al*., 1992) and develop their complex life history patterns among terrestrial, neritic and oceanic habitats (BOLTEN, 2003).

Due to the biological features and often logistically unfeasible sampling of this group (WIBBELS *et al*., 2003), the implementation and integration of multiple methods and disciplines constitute a suitable approach to obtain valuable information (GODLEY *et al.*, 2010). There has been a significant increase in research of these marine vertebrates in the last few decades (HAMANN *et al*., 2010). However, although sea turtles are a relative well-researched group compared to others marine animals, there is still a shortness of key data on scopes related to turtle management and their evaluation (BJORNDAL, 1999; AMOROCHO, 2002). A really suitable discipline to assess this lack of information is bibliometry.

Bibliometric analyses allow us to study the evolution of scientific literature published over time (HOOD & WILSON, 2001; POWELL *et al*., 2010). Furthermore, these studies play a key role for taxonomic groups that have been long studied, since it offers an updated insight different from that provided by traditional bibliographic reviews (MENÉNDEZ-BLÁZQUEZ, 2020). Bibliometric analyses focused on sea turtles research are really scarce and relegated to global scale (ROCHA, 2016) or to a specific subject area such as plastic ingestion by marine turtles (NELMS *et al.*, 2016). Considering the threats and life history patterns of sea turtles, it is challenging to assess specific hazards that affect their biology. For this reason, the management and conservation actions in circumglobally marine fauna like sea turtles are applied at specific populations in a local or regional scale (DONLAN *et al*., 2010) pointing out the importance of focusing bibliometric analysis on a particular area.

Despite their large distribution, sea turtles tend to concentrate at important nesting and feeding areas such as the Cabo Verde Archipelago. Cabo Verde holds the third largest loggerhead turtle (*Caretta caretta*) nesting population at global scale, after Florida and Oman (MARCO *et al.*, 2012). In addition, the waters around Cabo Verde provide foraging grounds for juveniles of green (*Chelonia mydas*) and hawksbill turtles (*Eretmochelys imbricata*) (MONZÓN-ARGÜELLO *et al*., 2010a, 2010b; CAMACHO *et al*., 2014). Olive ridley (*Lepidochelys olivacea*) and leatherback (*Dermochelys coriacea*) turtles have also been observed around Cabo Verde (MARCO *et al*., 2011; VARO-CRUZ *et al*., 2011).

Previous bibliometric analyses on sea turtles did not focus on particular areas or regions (NELMS *et al*., 2016; ROCHA, 2016). The importance of Cabo Verde loggerhead turtle population relies on their strongly isolation from other rookeries, being considered as an independent Regional Management Unit (RMU) (WALLACE *et al.*, 2010). At conservation level, it is one of the 11 most endangered marine turtle RMU (WALLACE *et al.*, 2011), and the only endangered loggerhead turtle RMU in the Atlan-

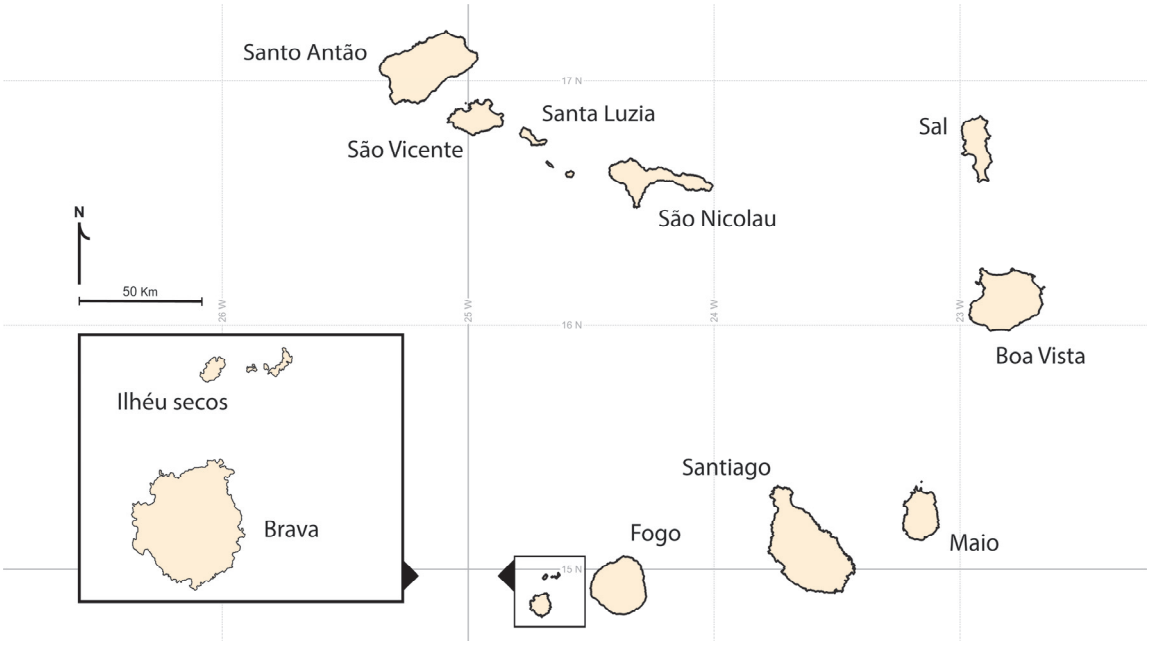

Figure 1: Cabo Verde Archipelago, location and division of the study area.

tic, according to IUCN (CASALE & MARCO, 2015).

Our main objective was to assess the historical trend of research on the sea turtles at Cabo Verde and to identify knowledge gaps. This is the first attempt to establish an appropriate reference baseline that will allow to pinpoint weaknesses in knowledge and to guide future research efforts.

MATERIALS AND METHODS

We conducted a bibliometric analysis of sea turtle literature from Cabo Verde, following the methodology described by MENÉNDEZ-BLÁZQUEZ (2020) to develop a bibliometric analysis focused in a specific taxonomic group. Scientific literature was searched for all available time range (from 1987 to 2020) in the main world coverage databases: Web of Science (all database), Scopus, Plos One, PubMed and BioOne. We also used Google Scholar as a non-indexed database to further identify non-indexed documents such as PhD dissertations, Master's and Degree's theses, conference papers and other publications (*e.g.*, reports). For publication selection process, identification, screening, suitability and its inclusion in the final analysis, we applied different-phases information flow of a systematic review described as the PRISMA criterion (PAGE *et al.*, 2021). We used the following key words and search formula in each database: "Sea turtle*" AND "Cape Verde" OR "Cabo Verde". All publications found were screened and their suitability for analysis was verified before they were classified as "Valid publications". A publication was considered as "valid" if it in-

cluded sea turtles exclusively or accompanied by other species, and if it was totally or partially conducted at Cabo Verde. In addition, all references cited in each publication were reviewed in order to identify new publications that had not appeared in the first search. Due to the low number of publications found, the utilization of a sample-size calculator was not necessary to determine a representative subsample with a high level of confidence as in modern reviews (ROULIER *et al*., 2020). The results of bibliographic search allow to explore the potential search-success (Numbers of valid publications / Numbers of total publications, shown as percentage) of each database. Repeated publications that appeared in more than one database were only counted once.

For each selected publication, we obtained the following variables: year of publication, number of authors, nationality of affiliation of each author, study area, sea turtle species and research topic. With the nationality of the author, we could infer the contribution (in percentage) of each nationality in each publication found: Number of authors of each nationality / Total authors of the study. This variable reflects the total contribution and weight of each nationality to each publication and therefore in the study of sea turtles in Cabo Verde. We divided the Cabo Verde territory into each of the islands of the archipelago: "Boa Vista", "Brava", "Fogo", "Maio", "Sal", "Santa Luzia", "Santiago", "Santo Antão", "São Nicolau" and "São Vicente" (Fig. 1). We added other territory categories, "Ilhéu Secos", to include the little islands called Ilhéu Secos or Ilheus do Rombo (Fig. 1). Finally, we used "Captivity" for studies conducted at zoological or wildlife recovery centres and "no specify" for the publications done at the Cabo Verde archipelago in which a specific region was not specified.

We defined research topics based on MENÉNDEZ-BLÁZQUEZ (2020) except for two categories included in MENÉNDEZ-BLÁZQUEZ (2020) that did not apply to our area. We used a total of 14 research categories: "Behaviour", "Biochemistry", "Breeding and reproductive successes", "Check-lists and Atlas", "Conservation and wildlife management", "Evolution and systematic", "Foraging and diet", "Genetics", "Habitat selection", "Morphology and biometric", "Parasites and diseases", "Physiology and histology", "Pollution" and "Population dynamics". We obtained information from the sections "Materials and Methods", "Results" and "Discussion" of publications to classify them into the different research-topic categories.

We used a Shapiro-Wilk's test to assess for Normality due to the historical temporal range found. We used descriptive statistics and Spearman correlations (as a non-parametric analysis) to evaluate the temporal trend of the variables mentioned, correlating each of them with the range-years. A simple linear regression was applied to analyse the variation in the average number of authors per publication and year over the time. All analyses were performed using the R program (R Development Core Team, 2020) through visual editor R Studio version 3.6.0 (RStudio Team, 2020). Significant level was set at $P < 0.05$ and the results were exposed as a mean ± SE. The sum of the values of these cited

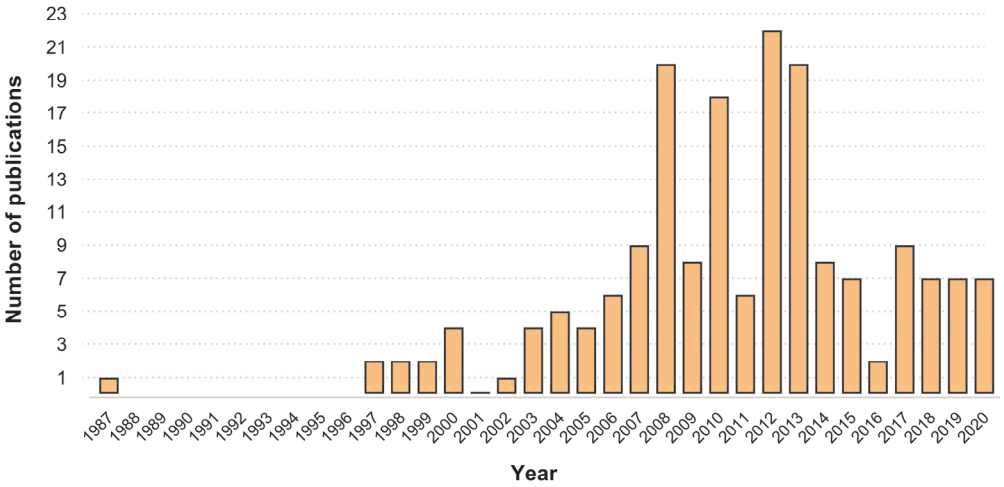

Figure 2: Number of publications on sea turtles per year in Cabo Verde between 1987 and 2020.

variables was greater than the number of total publications considered in the bibliometric analysis because the same study can cover more than one species, geographical area or research topic.

RESULTS

We found a total of 3049 publications as a result of the bibliographic search in all different databases. After applying the PRISMA criteria, 168 valid publications were obtained, representing a 5.25% of the total publications. Web of Science provided the highest number of valid publications (55), but it was surpassed in search-success percentage by Scopus (78.7%). The lowest number of valid publications on sea turtles and the lowest success percentage were found in BioOne, since only three valid publications of 262 results were detected (1.15% of search success) (Table 1). In addition, we found 43 valid publications during the review of all references cited. A total of 28 valid publications were discarded because those appeared in more than one database. We found two historic publications dating from the fourteenth century which were not included in the statistical analysis.

A total of 181 scientific studies have

Table 1: Number of total publications found, valid publications and percentage of search success in each database in the bibliography search of studies carried out on sea turtles in Cabo Verde.

Source	Search results	Valid publications	Search success (%)
Web of Science	984	55	5.59
Scopus	47	37	78.72
Plos One	85	4	4.71
PubMed	331	26	7.85
BioOne	262	3	1.15
Google Scholar	1340	43	3.21
Total	3049	168	5.51

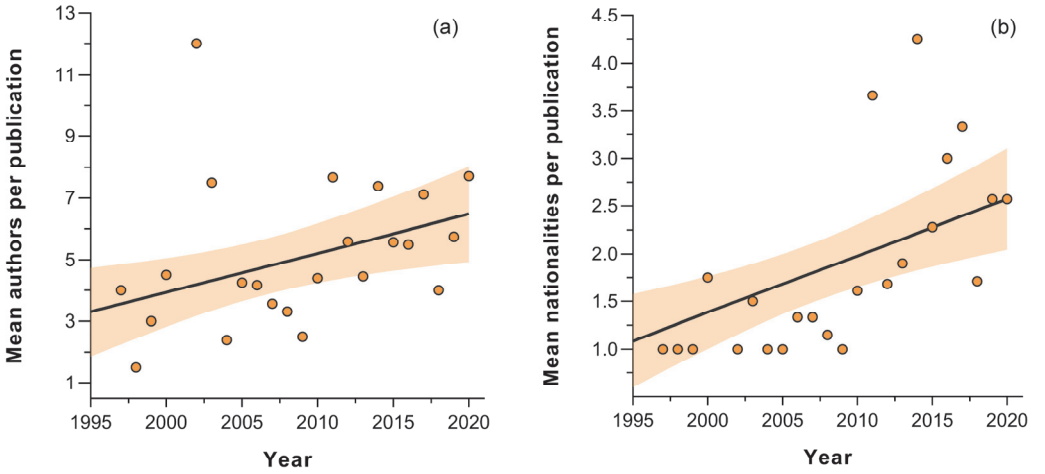

Figure 3: a) Distribution of average number of authors per publication and year; b) Distribution of average number of authors' nationalities per publication and year. The black line shows the linear regression fit and the coloured area represents the 95% confidence interval of the fit line in both images.

been published about sea turtles in Cabo Verde. This supposes a rate of 6.96 ± 6.19 publications per year (1979-2020), with a maximum of 22 publications in 2012 and a minimum of 1 publication in 1979, 1987 and 2002. We identified a growing trend in the number of papers over time (Spearman correlation, $\rho = 0.724$; $P < 0.001$). The first modern research was published in 1979 and there were no other publications until 1987, representing only a 1.1% of the total publications in this period. The last 25 years (1997-2020) of the study period accounted for 98.9% of published works (179 works) (Fig. 2).

Regarding authorship, there was a growing trend in the number of authors per publication ($\rho = 0.643$; $P < 0.001$; Mean authors per year = 0.127*year – 250.3; $R^2 = 0.25$; $P = 0.010$; Fig. 3a) with 4.61 ± 2.63 authors on average per publication (ranging from 12 in the maximum to 1 in the mini-

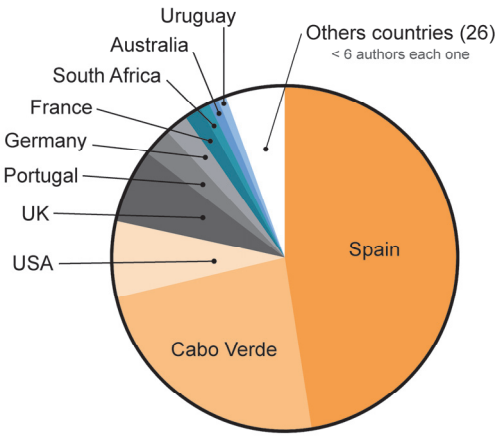

Figure 4: Distribution of the different nationalities of authors in sea turtles research in Cabo Verde. The remaining 26 countries correspond to: Italy, Brazil, Gabon, Argentina, French Guinea, Mexico, Switzerland, Turkey, Reunion Islands, Demark, Croatia, Ghana, Guinea, Senegal, Nigeria, Mauritania, Ascension Island, Mozambique, Seychelles, Canada, El Salvador, Chile, Costa Rica, Colombia, India and Malaysia.

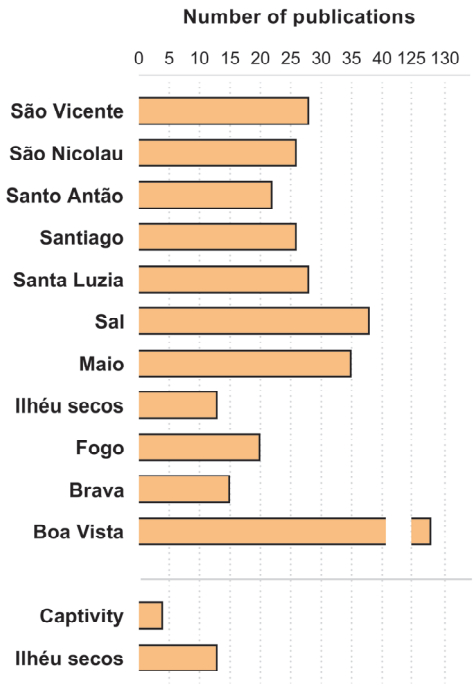

Figure 5: Number of total publications by delimited study area.

mum). These belong to universities, research centers or other affiliations from 36 different nationalities. There was on average, 1.78 ± 0.94 different nationalities per publication with an upward trend in the average number of nationalities per publication over the years (ρ = 0.802; $P < 0.001$; Mean nationalities per year and study = 0.059*year – 117.7; R^2= 0.38; $P < 0.001$; Fig. 3b). There was a total of 882 authors. Spain (419, 47.5% of the total authors) was the leading country authors were affiliated to, followed by Cabo Verde (210, 23.8%), United States (63, 7.1%) and the United Kingdom (61, 6.9%) (Fig. 4). In addition, there were authors from 17 more nationalities. Each one of these nationalities contributed only with one author per nationality in the analysed publications, assuming a contribution of 0.11% by each one of the publications in which they appear. In reference to the contribution of each nationality per study (Number of authors of each nationality / Total study authors), we found that Spain had the greatest contribution in number of researchers with 53.7% on average per publication, followed by Cabo Verde (26.4%), United States (7.5%), Portugal (6.3%), United Kingdom (5.1%), Germany (3.7%), France (1.3%), Brazil (1.2%), and Turkey (1.1 %). The remaining 27 nationalities contributed less than 1% each to the selected studies.

In relation to the geographical distribution, most studies were conducted at Boa Vista, accounting for 70.7% (128) of publications, followed by Sal and Maio islands which represent 21.0% (38) and 19.3% (35), respectively of the total. In contrast, the lowest number of scientific literature was for Brava, 8.3% (15), Ilhéus Secos, 7.2% (13) and publications on captive turtles, 2.2% (4) (Fig. 5). The study area was not specified in 12.15% (22) of the publications.

In relation to research topics, there were differences in the research efforts invested in each of the 14 subject areas. There was a high number of publications focused on "Breeding and reproductive successes" (30.4%, 55), followed by "Conservation and wildlife management" (25.4%, 46) and "Population dynamics" (12.7%, 23). In contrast, "Biochemistry" and "Evolution and systematic" were the topics of lowest occurrence (1.7%, 3) (Fig. 6). We detected a growing trend across years for all research topics ($P < 0.05$), except for "Evolution and

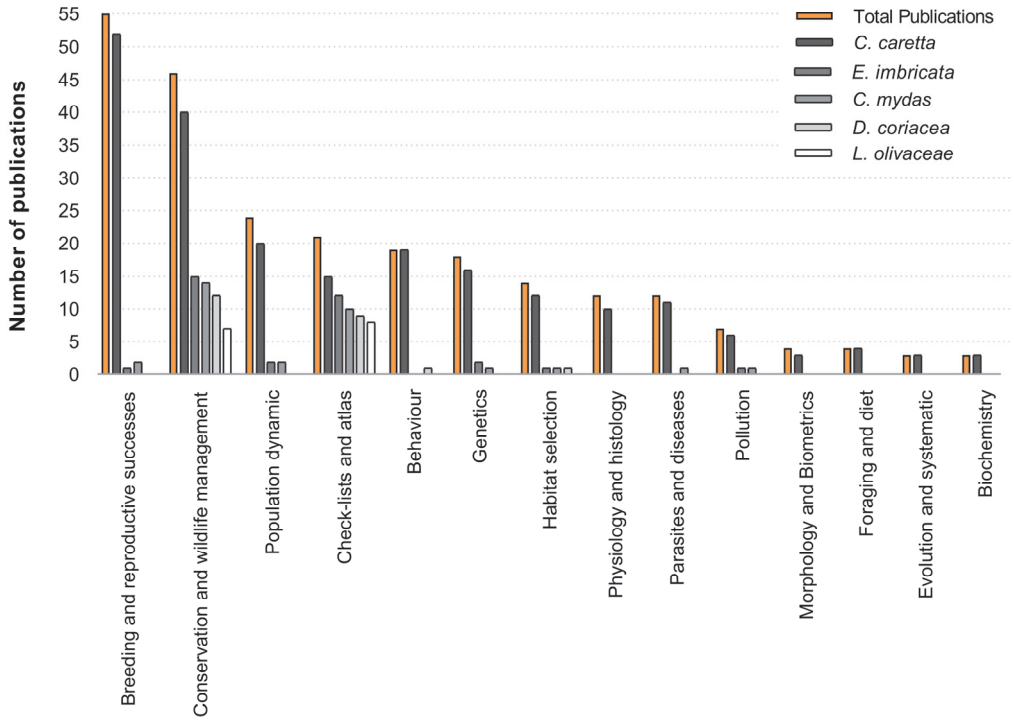

Figure 6: Number of total publications by research topic and number of total publications for each research topic in main sea turtles species in Cabo Verde.

systematic", "Genetics", "Conservation and wildlife management", "Behaviour" and "Habitat selection".

As far as the species of study, there was a strong bias towards *C. caretta* with 87.3% (158) of studies and it was the only species that experienced a positive increase over the years (ρ = 0.04; P = 0.04) in the number of publications. All other species together represented a 49.7% (90) of publications, in particular: *E. imbricata*, 15.5% (28); *C. mydas*, 14.9% (27); *D. coriacea*, 11.1% (20); and *L. olivacea*, 8.3% (15). The unequal proportions in the number of works for study species are evident in the different research topics, with *C. caretta* boasting the highest incidence in all of them (Fig. 6).

Discussion

Published studies on sea turtles in Cabo Verde have accumulated a total of 181 publications in all the databases consulted (Web of Science, Scopus, Plos One, PubMed, BioOne and Google Scholar). There has been a rising number, but not a constant trend in the number of published studies. Since 2002 onwards there has been a growth in the production of publications. This increase occurred in the same moment that Cabo Verde was identified by the United Nations Environment Program as conservation priority for loggerhead

turtles (UNEP, 2002) and that a great number of organisations (*e.g.*, non-governmental, research groups and public citizen groups) have focused their efforts in sea turtle monitoring and conservation activities worldwide (MAZARIS *et al*., 2014).

In recent decades, conservation NGOs have generated research studies with the aim to protect biodiversity and generate scientific bases of management. Likewise, the boosting trend in the sea turtle literature production in Cabo Verde matches with the start of NGOs establishment in the archipelago. The Cabo Verde Natura 2000 NGO has collaborated with local institutions since 1998 to protect the Cabo Verde loggerhead population at the high-nesting density area of the archipelago (65% of the nests) (MARCO *et al*., 2012). This NGO was instrumental in the elaboration and implementation of environmental laws and conservation plans for sea turtles (ABELLA, 2013). Moreover, peaks in literature production between 2008 and 2013, coincided with the establishment of camps and other organizations such as the Porto Ferreira (Cabo Verde Natura 2000) or the Turtle Foundation in Boa Vista, both in 2008. Since 2012, Bios.CV NGO has also conducted sea turtle research, conservation and outreach in the island. Thus, there is a link between NGOs settlement and scientific output, since NGOs provided human and resources for the development and implementation of research studies over the past 20 years. In addition, a National Network for the Conservation of Sea Turtles in Cabo Verde – TAOLA was created in 2009 to enhance communication among the NGOs that worked with sea turtles (MARCO *et al*., 2011). In their annual meetings, NGOs share information on their conservation projects, which could have also facilitated the production of scientific documents.

The protection and need for recovery of sea turtle populations at a global level have led to an increase in research efforts over the last four decades, reflected on the amount of peer-reviewed literature (HAMANN *et al*., 2010). Comparing the results of global studies with ours, the growing tendency of published documents that we found coincides with that generated by gap analysis in sea turtle research by ROCHA (2016), showing a concentration of publications after 2003. There is also an increasing global tendency in collaborations in sea turtle research (MAZARIS *et al*., 2018), also reflected on the increasing number of authors involved in sea turtle studies in Cabo Verde over the years. This has probably grown due to the focus of authors on a single scientific discipline. Therefore, the development of collaborations is a response to the increasing specialization of professions linked to the changes in the institutional incentives for publication (MCDOWELL & MELVIN, 1983).

In addition, transferring knowledge generated in different geographical sites (national, regional, international) can enhance effective conservation of sea turtles (HAMANN *et al*., 2010). The development of international collaborative networks also arises because there is a need to adopt new methods and techniques in sea turtle research (GODLEY *et al*., 2020). Integrating authors from different geographic representations could also include different points of view (BUGONI, 2014) and increase productivity (BEAVER & ROSEN, 1979). Fur-

thermore, articles with international co-authorships are more cited than those that are less international (NARIN *et al.*, 1991; PERSSON *et al.*, 2004).

We found that almost half of international research contributions were from Spain because of the settlement of NGOs (*e.g.,* Cabo Verde Natura 2000) managed by Spanish researchers and their close co-operation with local people and institutions (*e.g.,* Bios.CV, both managed by both Spanish and Cabo Verdean researchers). Likewise, Turtle Foundation in Boa Vista is led by German and Cabo Verdean members and the Cabo Verdean Project Biodiversity in Sal Island is managed by Spanish and led by British researchers (Queen Mary-University of London). These nationalities coincide with those we found that had a substantial participation in the publications' analyses. In addition, one of the most used approaches in Africa is the Community-Based Conservation, where international staff is employed in scientific projects, with the objective of involving Cabo Verdean personnel (PILUDU & COZENS, 2013).

Cabo Verde is the second country with the highest research participation, although the vast majority of conservation NGOs of the archipelago are from a domestic level (*e.g.,* Maio Biodiversity Foundation, Biosfera, Lantuna, Vito Project, etc). In addition, the National Plan for the Conservation of Marine Turtles was approved in 2010 (Resolution nº 72/2010), promoting a cooperative attitude from local people and organizations (MARCO *et al.*, 2011). This analysis of nationalities allows us to conclude that scientific production is related to, but not exclusively dependent on, the establishment of NGOs.

Boa Vista concentrates the vast majority (65%) of the nesting activity on the eastern side of the island (LÓPEZ-JURADO *et al.*, 2007; MARCO *et al.*, 2008; 2010; 2012), and consequently the highest number of publications. The lower nesting activity on other islands such as Sal and Maio explains why fewer researches have been carried out on these islands research (COZENS, 2009; COZENS *et al.*, 2009; LINO *et al.*, 2010), and points to a correlation between nesting.

In general, the level of publications per island is directly correlated with the nesting activity of loggerhead turtle and consequently with the NGOs settlement. Boa Vista and Sal are the most protected islands by sea turtles' conservation NGOs, generating a great amount of data (VEIGA, 2018). In addition, Santa Luzia Island hosts more than 1% of the Atlantic nesting population of loggerhead turtles (ROCHA *et al.*, 2015). Thus, the settlement of the NGO Biosfera in the island, allowed a large scientific production in comparison to that of other islands.

The vast majority of studies analysed were conducted in-situ probably because the main threats to Cabo Verde populations are illegal harvest of eggs and adult females on nesting beaches, and the harvest or incidental capture in fisheries (LÓPEZ-JURADO *et al.*, 2000; MARCO *et al.*, 2008). Thus, to ensure the long-term protection of sea turtles in Cabo Verde, intensive sea turtle protection and community work are needed (MONZÓN-ARGÜELLO *et al.*, 2010c), being the most suitable actions those that reduce the impacts in the field.

Loggerhead turtle is the most studied

sea turtle species in Cabo Verde because the Cape Verde's loggerhead turtle population is considered to be the third largest nesting population of this species in the world (LÓPEZ-JURADO *et al.*, 2007; MARCO *et al.*, 2012). Therefore, the research efforts have been largely focused on breeding and reproductive studies as well as the conservation management of loggerhead turtles. Historically, research has addressed nesting dynamics and management has focused on the protection of nesting beaches and bycatch reduction (DONLAN *et al.*, 2010). Thus, resources applied to sea turtle research are biased towards terrestrial-based hazards (DONLAN *et al.*, 2010) due to the sampling easiness of these reptiles in the nesting beaches, and the ability to assimilate population level datasets (HOPKINS-MURPHY *et al.*, 2003; MAZARIS *et al.*, 2005; HAMANN *et al.*, 2010).

The check-lists and atlas research topic is the one applied in a more similar way among the five study species, showing the presence but not the equally research of all the topics among the sea turtle species present in the area. Juvenile green and hawksbill turtles are very common in the archipelago (MARCO *et al.*, 2011) however, our results do not show high figures in foraging and diet studies for such species, becoming one of the least studied topics. It generates an interesting knowledge gap to be filled in future studies. The knowledge of their diet breadth allows investing conservation efforts to protect areas that provide such trophic resources (FORBES, 1999), including an insight into their foraging ecology and feeding behaviour. Likewise, at-sea biological characters of sea turtles are poorly understood (DONLAN *et al.*, 2010) because sampling at sea is unfeasible or difficult in several cases and this creates the need for up-to-date sampling methods. Some studies suggest the importance to integrate multiple technics to assess the feeding behaviour of sea turtles (*e.g.*, MCCLELLAN *et al.*, 2010; BURKHOLDER *et al.*, 2011; LEMONS *et al.*, 2011), which offers fundamental insights from the population (GODLEY *et al.*, 2010).

Some topics offer a shortness of interest for the implementation of management and conservation policies in the field. "Biochemistry", "Evolution and Systematic", "Morphology" and "Pollution" have received low research efforts, coinciding with the global knowledge gaps on sea turtles (ROCHA, 2016), and with the absence of information of some scopes. For example, for most pollutants there is a lack of knowledge about critical thresholds (HAMANN *et al.*, 2010). This general trend may be due to the need to use technologies that require specific and expensive sampling, which supposes a logistic challenge for implementation in some cases.

Some areas of knowledge such as genetics have earned popularity in sea turtles research, since the number of genetic papers presented at the Annual Symposium on Sea Turtle Conservation and Biology has risen over the last two decades (JENSEN *et al.*, 2013). The enhancement of DNA sequencing and genotyping technology has expanded the scope of molecular genetics (JENSEN *et al.*, 2013). Thereby, genetics implements pioneering techniques which allow obtaining a wealth of data from a straightforward sampling of tissue.

The bibliometric analysis of the sea turtles of Cabo Verde that we have conducted

provided an overview about the evolution of knowledge using a different approach than traditional bibliographic reviews (MENÉNDEZ-BLÁZQUEZ, 2020). This kind of analysis helps to identify knowledge gaps and can contribute to guide future research lines in areas that deserve special attention for sea turtle global conservation interests.

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