Online ISSN: 0718-1957
RBMO
Revista de Biología Marina y Oceanografía
Vol. 57, N° especial: 122-131, 2022
<https://doi.org/10.22370/rbmo.2022.57.Especial.3338>
ARTICLE

Research on chimaera with a thematic focus for life history: A scientometric analysis

Investigación sobre peces quimera con un enfoque de su historia de vida: Un análisis cienciométrico

Cicero Diogo Oliveira[1*], Lucia Vanessa Santos[1] and Carlos Yure Oliveira[2]

[1]Instituto de Ciências Biológicas e da Saúde, Universidade Federal de Alagoas, Lourival Melo Mota s/n, Tabuleiro do Martins, zip code 57072-970, Alagoas, Brazil
[2]Departamento de Pesca e Aquicultura, Universidade Federal Rural de Pernambuco (UFRPE), Dom Manoel de Medeiros s/n, Dois Irmãos, zip code 52171-900, Pernambuco, Brazil
*Corresponding author: linsdiogoc@gmail.com

Resumen.- Los peces quimera, representados por 52 especies existentes, son animales de aguas profundas por lo cual de difícil accesibilidad para su estudio; además, son vulnerables a la pesca debido a sus características k-estratégicas. A pesar de ser vulnerables, sobre su historia de vida hay pocos estudios, lo que dificulta comprender el estado de la población de las especies. Los parámetros de historia de vida son esenciales en la ecología de poblaciones para evaluar la situación y tendencias de las poblaciones. En este estudio se propuso evaluar la tendencia de las publicaciones sobre estos peces y las lagunas en el conocimiento, analizando qué temática y especies son más frecuentemente estudiadas. Para ello se utilizó el método de la cienciométrica, con búsqueda de artículos, utilizando un grupo de palabras dirigidas a quimera en bases de datos de referencias bibliográficas (Scopus® y Web of Science™). Los artículos se clasificaron por año de publicación, ubicación de los autores (a nivel de país), especie de interés y tema. El número de artículos por año muestra una tendencia de crecimiento exponencial, lo que indica que se están investigando cada vez más los peces quimera. Entre los países de autores, se destacan Estados Unidos de América y Reino Unido. Las especies más estudiadas fueron *Hydrolagus colliei*, *Callorhinchus milii* y *Chimaera monstrosa*. Los temas principales de los artículos fueron la anatomía, morfología y fisiología, seguidos de la sistemática y evolución. Los temas de investigación más disminuidos fueron la pesca y el crecimiento, para todas las especies. Por lo tanto, incluso con la tendencia de crecimiento, aún se requiere mayor esfuerzo y refuerzo en la investigación de estos peces, principalmente en los aspectos de la pesca, crecimiento y la reproducción.

Palabras clave: Holocephali, quimeras, historia de vida, bibliometría, tendencia de las publicaciones

Abstract.- Chimaera, represented by 52 species, are deep-sea animals, therefore difficult to access for study; moreover, they are vulnerable to fishing due to their k-strategic characteristics. Despite being vulnerable, there are few studies on its life history, which makes it difficult to understand the population status of the species. Life-history parameters are essential in population ecology to assess the status and trends of population. In this study, it was proposed to evaluate the publication trends on Chimaera and the gaps in knowledge, analyzing which subject and species are most frequently studied. For this, the scientometric method was used, based on search of articles using a group of words directed to Chimaera in databases of bibliographic references (Scopus® and Web of Science™). The articles were classified by year of publication, authors' location (at the country level), focus species and subject matter. The number of articles per year showed an exponential growth trend, indicating that studies on chimaera have been increased. Among the authors'countries, such as the United States of America and the United Kingdom, are prominent. The most studied species were: *Hydrolagus colliei*, *Callorhinchus milii* and *Chimaera monstrosa*. The main themes of the articles were anatomy, morphology and physiology, followed by systematics and evolution. The most diminished research topics were fishing and growth, for almost all species. Therefore, even with the growth trend, more effort and reinforcement is still required in the research of these fish, mainly in the aspects on fishery, growth, and reproduction themes.

Key words: Holocephali, chimaera, life-history; bibliometrics, publication trend

Introduction

The holocephalan, popularly known as chimaera, belong to the chondrichthyans class, one of the oldest groups of vertebrates which emerged in the Devonian period (Castro 1987, Grogan & Lund 2004). Chimeras are characterized by having a holosthetic mandible in which the palate-square merges with the neurocranium and inhabit a marine environment, mainly deep waters (Suárez *et al*. 2004, Didier *et al*. 2012); they are classified into three families and six genera (Didier 1995, Didier *et al*. 2012). Currently this group has 52 species in existence; the genus *Hydrolagus* presents the greatest diversity of species (21 species). Among these existing species, have a low proportion of threatened (8%) and NT (8%) species, but still exhibit some data deficiency (15%) (Finucci *et al*. 2021).

Despite the high ecological importance of the group (Didier *et al.* 2012, Finucci *et al*. 2021), information on the life history and reproductive biology of these fish, especially of the deeper water species, is very scarce (Sion *et al*. 2004, Shiffman *et al.* 2020). This low amount of information results from the low commercial value of the species, which are generally discarded (Blasdale & Newton 1998, Moura *et al.* 2004, Cotton & Grubbs 2015) and the lack of sampling due to them being in inaccessible locations, or are naturally uncommon or rare (Holt *et al.* 2013, Finucci *et al*. 2021).

Life history parameters (*e.g.,* growth, reproduction) are essential to provide baseline information on population dynamics and to assess a species' susceptibility to extinction (Cortés 2007, Dulvy *et al.* 2008, Rigby & Simpfendorfer 2015, Olivera *et al.* 2021). In general, the information for this subclass is relatively low; however, some studies have reported that these species are more vulnerable to extinction (Barnett *et al.* 2009, Didier *et al.* 2012, Chierichetti *et al*. 2017, Finucci *et al.* 2017, Francis & Maolagáin 2019). Chimaeras are characterized by low productivity, and have slow growth rates, late sexual maturity and low number of offsprings per reproductive cycle (Didier *et al.* 2012). Additionally, they are less able to offset increased mortality, either by fishing or environmental changes. Therefore, life history studies of these species are necessary for their conservation.

Scientometric analyses have become fundamental tools for analyzing current trends within scientific literature and to indicate knowledge gaps (Seppelt *et al.* 2011, Zhang *et al.* 2016, Oliveira *et al*. 2020, Santos *et al.* 2021). Assessing the research attention distributed by taxa and in which scientific research degree it is conducted have also proved to be a frontier for new researchers (Shiffman *et al.* 2020). These gaps can be used to assist in chondrichthyan conservation efforts, as well as stimulate new scientific research (Zhang *et al*. 2016, Shiffman *et al.* 2020). Therefore, scientific publications on the life-history, vulnerability, and fishing traits of chimera species have been highly important for understanding and determining the population status, and for making management and conservation decisions.

In view of this, the goal of this study was to identify patterns in the number of publications per species of chimaera, related to life-history traits and degree of population threat. To assess that, the following guiding questions were used: (1) Is there an increasing trend in chimera publications? (2) Which are the main countries that contribute to the knowledge and which topics are discussed on subclass? (3) What are the main species on this group? (4) Is there a correlation between the number of publications by species and their occurrence and threat status? To answer these questions, the distribution, description and threat status data available on the IUCN platform have been used to perform a scientometric analysis.

Materials and methods

Scientific articles were obtained from only two top-level bibliographic reference databases such as Scopus® and Web of Science™ on their respective web platforms. The search words were: Holocephalan* OR Callorhinchidae OR Rhinochimaeridae OR Chimaeriformes OR Holocephali* OR "Chimaera" OR Chimaeridae OR spookfish OR "rabbit fish" OR "ghost shark" OR "chimaeroid fish*" OR "elephant shark" OR Elephantfish OR Ghostshark OR Ratfish; present in the title, abstract or keywords, limiting the time until July 2020. The database with the largest number of articles was chosen, and regression between the number of articles and year of publication was performed to understand the trend on the publications. Then, network analysis of the countries and keywords, present in the base, was performed using VOSviewer version 1.6. (CWTS, Centre for Science and Technology Studies, Leiden University, The Netherlands), software tool for constructing and visualizing bibliometric networks.

In addition, a new search was conducted, following the same keywords and time limitation, however using only the keywords present in the title. This was done to select only the articles with focus on chimeras' fish. In this new database, the focus species were selected and then quantified for the absolute frequency of publication by species. In addition to the title and abstract, these articles were classified by their respective theme (Table 1). They were all sorted by the same person to reduce the change of inter-encoder reliability problems.

A generalized model analysis (GLM) was performed to understand the publication patter by species using variable response to the number of publications and four predictive variables: (1) area of distribution, (2) depth, (3) year of species description and (4) threat status. All these predictive variables were extracted from the International Union for Conservation of Nature and Natural Resources platform (IUCN 2020). For variable distribution, the species distribution shapefile available in the IUCN platform was used and calculated by the area polygons with the aid of the "gArea" function of the Rstudio raster package (Hijmans *et al.* 2020); for depth, the mean of maximum and minimum depth was used (IUCN 2020); the status of threats (Data Deficient - DD; Least Concern - LC; Near Threat - NT; Vulnerable - VU) were converted to numeric values following Dulvy *et al.* (2014), where species categorized as VU and NT were converted to value 1 and LC to 0. The MuMIn package in the R software was used for the GLM (Bartoń 2020).

The MASS package in the R software (Ripley *et al.* 2020) was used to calculate the value of the Akaike Information Criterion for small samples (AICc) for each model, then performed the ΔAICc, which is based on the subtraction of the AICc from the model and the value of the smaller AICc. The calculated AICc weight (AICc-Wt), which considers ΔAICc, was also done to choose the best model (Akaike 1973).

RESULTS

Searches on the search platforms resulted in 757 articles on the Web of Science™ and 1,242 on the Scopus® (Suppl. material: Table S1). According to the platform data, the first article published was in 1847, however the topic became more frequent from 1980 onwards. Annually, the publications show an exponential growth [Y= 0.8821*exp(0.0579*X); r^2= 0.8979] (Fig. 1), with a peak of 55 publications in 2011.

Table 1. Descriptions of the themes used to classify scientific articles / Descripciones de las temáticas utilizadas para clasificar los artículos científicos

Thematic	Description
Anatomy, morphology and physiology	Analysis and descriptions of anatomy and morphology, as well as the multiple mechanical, physical, and biochemical functions.
Conservation and management	Stock assessments, demographic analysis, population decline, designation of closed areas, ecotourism, and others.
Diet and feeding	Composition and feeding habits.
Distribution and occurrence	Description, distribution and/or abundance of species, records in new locations, with implications on the geographical distributions.
Ecology and behavior	Ethology and ecology of species interactions, effects of abiotic variables on populations or communities and similar, shark attack.
Fisheries	Description of catches, directed or bycatch, fishing effort, fishing gear, fish processing, marketing and consumption.
Habitat use and migration	Habitat use to breed, forage or grow, or focused on migration.
Life-history	Age and growth, reproductive biology, ontogeny.
Taxonomy, systematics, evolution and genetics	New species, updates on systematic and taxonomy, evolutionary history.
Others	Articles that were not classified in any of the previous themes, such as description of shark parasites, stranding records, etc.

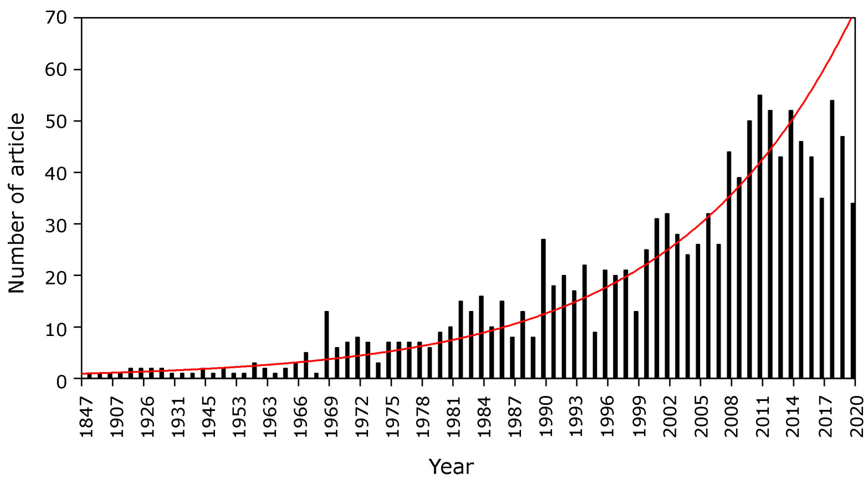

Figure 1. Trend in the number of publications on Holocephali fish in worldwide based on the Scopus® platform / Tendencia en el número de publicaciones sobre peces Holocéfalos en el mundo basado en la plataforma Scopus®

Among the countries with the largest number of publications, the United States of America (385), the United Kingdom (214), Canada (98) and Japan (98) stand out. Countries such as Portugal (27), Brazil (11 documents) and Iran (6), became more present after 2015 (Fig. 2).

The main keywords in the articles were: Chondrichthyes (present in 58 documents); holocephali (55); chimaera (46); and evolution (40). In addition, it is observed that words related to genetics (gene duplication; gene loss) have the frequency increased after 2015 (Fig. 3).

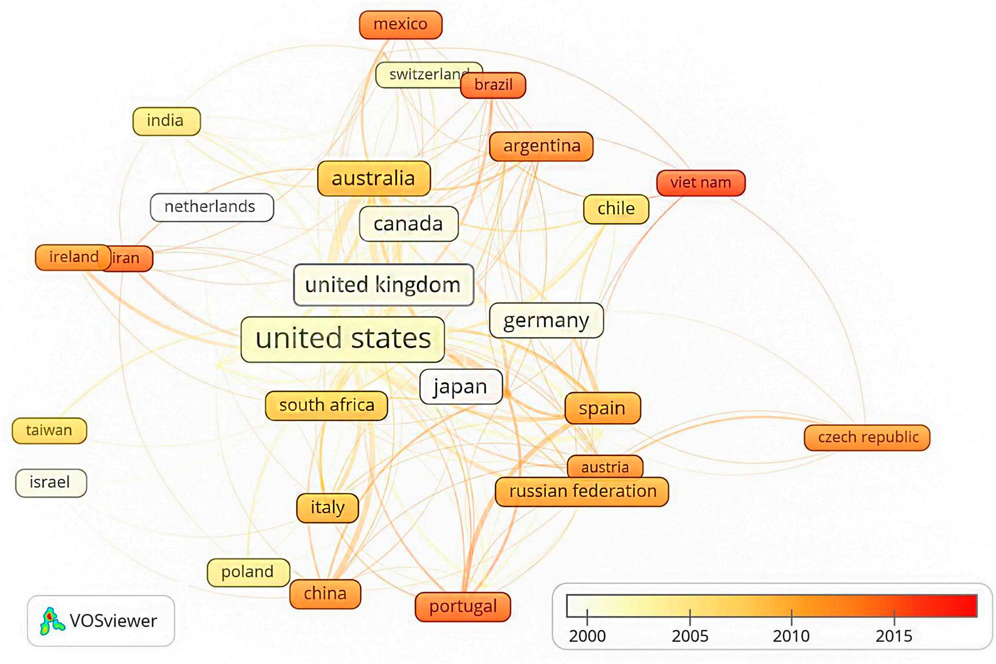

Figure 2. Network of countries that publish scientific articles on Holocephali, based on Scopus® platform / Red de interacción de países que publican artículos científicos sobre Holocéfalos, basada en la plataforma Scopus®

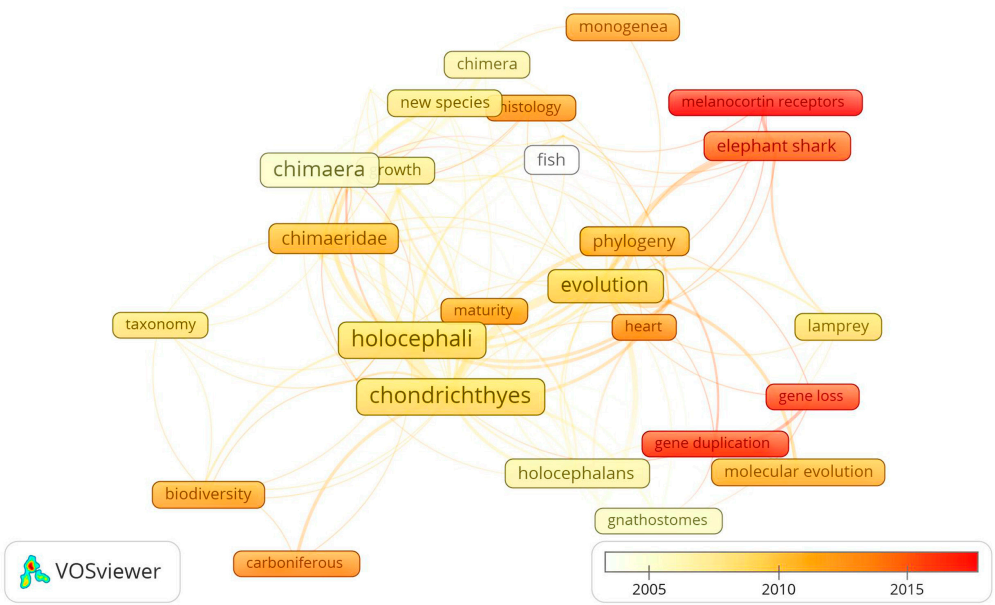

Figure 3. Keyword network of scientific publications on Holocephali, based on Scopus® platform / Red de interacción de palabras clave de publicaciones científicas sobre Holocéfalos, basada en la plataforma Scopus®

The second research focused on species resulted in 367 articles (30% of the first research), in which 37 existing species were mentioned (Suppl. material: Table S2). Among them *Hydrolagus colliei* (77), *Callorhinchus milii* (60) and *Chimaera monstrosa* (54) were the more frequent (Fig. 4). Other species have less than 17 articles, and the majorities have less than five articles (27 species).

The main themes of the articles are "Anatomy, Morphology and Physiology" (45.0%), followed by "Systematics and Evolution" (20.5%). However, in the last decade (2010s) the percentage of these two themes has declined, and the theme "Distribution and Occurrence" has increased (Fig. 5).

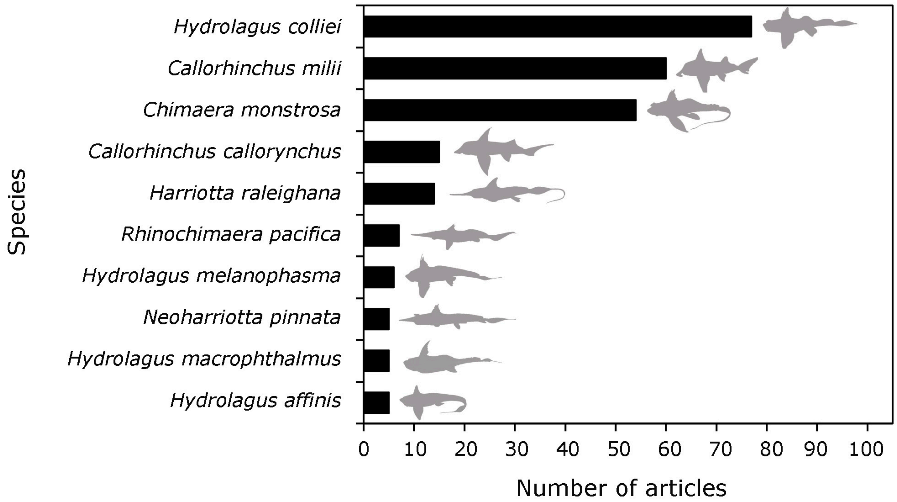

Figure 4. Representation of the number of publications related to species of Holocephali fish, based on Scopus® platform / Representación del número de publicaciones relacionadas con las especies de peces Holocephali, basado en la plataforma Scopus®

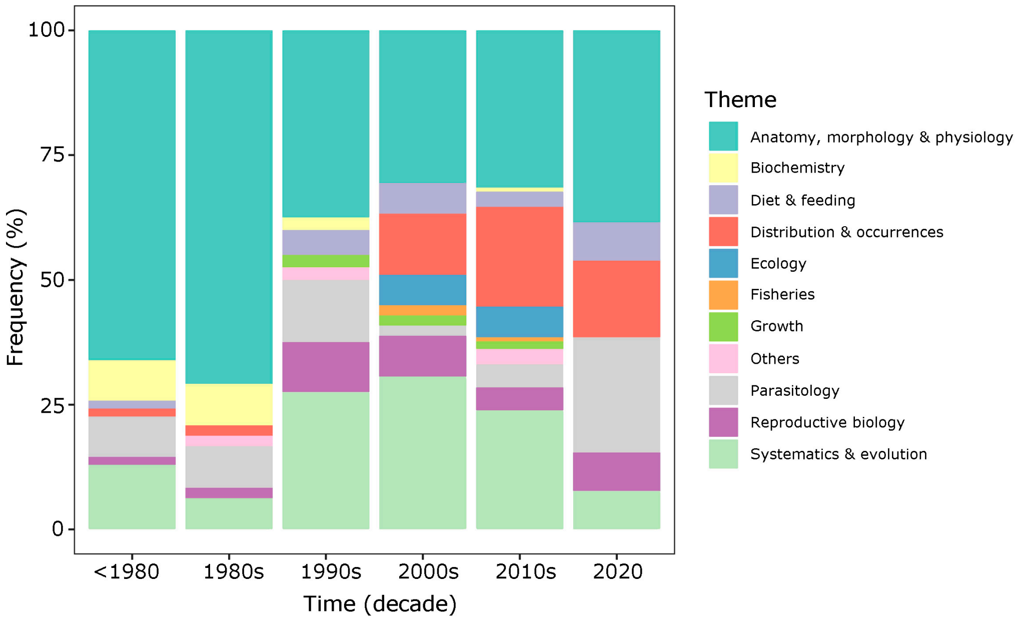

Figure 5. Thematic trend of Holocephali fish publications by decade, based on Scopus® platform / Tendencia temática de las publicaciones de peces Holocephali por década, basada en la plataforma Scopus®

The relationship between species by fundamental themes for management and conservation shows that only 22 species are present in publications containing one of the themes (Table 2); the other 30 species do not present any articles on these themes. The scarcest topics are fishery and growth, present in only two and three species, respectively.

The GLM that best represented the quantity of publications per species was the interaction between the variables area of distribution and time of description (Table 3). When each of these variables is observed individually, there is a positive correlation between the number of publications with distribution area and time of description of the species. The IUCN status and mean depth does not show a significant correlation (*P*-valor < 0.05) (Fig. 6).

Table 2. List of chimaera species *vs.* fundamental themes for management and conservation actions. 0= absence of articles; 1= presence of articles / Lista de especies de quimeras ***vs.*** temas fundamentales para las acciones de gestión y conservación. 0= ausencia de artículos; 1= presencia de artículos

Species	Diet and feeding	Distribution and occurrences	Ecology	Fisheries	Growth	Reproductive biology
Callorhinchidae						
Callorhinchus callorynchus	1	1	1	0	0	1
Callorhinchus capensis	0	0	1	0	0	0
Callorhinchus milii	0	0	1	0	1	1
Chimaeridae						
Chimaera cubana	0	1	0	0	0	1
Chimaera monstrosa	1	1	0	0	1	1
Chimaera opalescens	0	1	0	0	0	0
Hydrolagus alberti	0	1	0	0	0	0
Hydrolagus affinis	1	1	1	0	0	0
Hydrolagus bemisi	1	0	0	0	0	0
Hydrolagus colliei	1	1	1	1	1	1
Hydrolagus macrophthalmus	0	1	1	0	0	0
Hydrolagus melanophasma	0	1	1	0	0	1
Hydrolagus mirabilis	0	1	0	0	0	0
Hydrolagus novaezealandiae	1	0	0	0	0	0
Hydrolagus pallidus	0	1	1	0	0	0
Hydrolagus purpurescens	0	0	0	1	0	0
Hydrolagus trolli	0	1	0	0	0	0
Rhinochimaeridae						
Harriotta raleighana	1	1	0	0	0	1
Neoharriotta carri	0	1	0	0	0	0
Neoharriotta pinnata	0	1	0	0	0	0
Rhinochimaera africana	0	1	0	0	0	0
Rhinochimaera pacifica	0	0	1	0	0	1

Table 3. Coefficients of the Generalized Linear Models related to the variables: distribution area, mean depth, time of species description and threat status, and the parsimonious values (AIC < 4) / Coeficientes de los Modelos Lineales Generalizados relacionados con las variables: área de distribución, profundidad media, tiempo de descripción de la especie y estado de amenaza, y los valores parsimoniosos (AIC < 4)

Intercept	Distribution area	Mean depth	Description time	Threat status	Df	logLik	AICc	ΔAICc	Weight
-3.421	0.700	-	2.066	-	4	-98.333	205.719	0	0.286
-0.322	0.831	-0.963	1.702	-	5	-97.342	206.306	0.588	0.213
-3.554	0.652	-	2.240	-0.507	5	-97.814	207.250	1.531	0.133
-3.057	-	-	2.544	-	3	-100.451	207.518	1.799	0.116
-0.385	0.790	-0.994	1.883	-0.536	6	-96.728	207.790	2.071	0.101
-3.281	-	-	2.736	-0.642	4	-99.682	208.417	2.699	0.074
-1.583	-	-0.446	2.413	-	4	-100.225	209.502	3.783	0.043
-1.644	-	-0.503	2.607	-0.670	5	-99.384	210.389	4.671	0.028
4.931	1.491	-2.118	-	-	4	-102.387	213.827	8.109	0.005
4.954	1.493	-2.125	-	-0.030	5	-102.385	216.393	10.674	0.001

Df: degrees of freedom, logLik: Log-likelihood values, AIC: Akaike Information Criterion

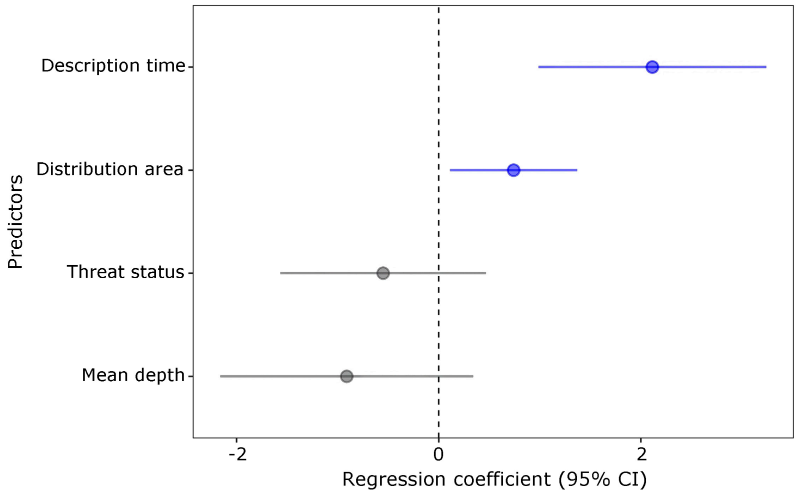

Figure 6. Coefficient estimates (±95% confidence intervals) indicating the magnitude and direction of predictors tested for a model of scientific production of Holocephali fish. Gray markers represent predictors without significant influence and blue represent positive effects / Estimaciones de coeficientes (intervalos de confianza de ±95%) que indican la magnitud y dirección de los predictores probados para un modelo de producción científica de peces Holocephali. Los marcadores grises representan predictores sin influencia significativa y los azules representan efectos positivos

Discussion

The number of publications per year showed an exponential growth trend, however from 2015 the number of publications was below the expected value. In 2020, of the 70 articles expected, only 34 were published (until the June). The countries which published the most are the most developed countries, which consequently have the greatest financial power to carry out the research (Huveneers *et al.* 2015). Developing countries tend to have less infrastructure for deep-sea fish research (Shiffman *et al.* 2020) as such research requires high-cost methods and technologically advanced means (Calis *et al.* 2005). However, according to the indexed journals in Scopus® from 2013 to 2015, some of these countries, such as Argentina and Brazil, have started to contribute to the knowledge about chimeras. This does not mean that before 2013 they had not published about chimeras, and there may be publications in journals that are not indexed in the database used.

Although the number of publications has shown an annual increase when compared to shark groups, there is a clear difference between the groups. According to Ducatez (2019) study, he counted 9,769 articles on sharks from 1978 to 2014; the species with the most articles was *Squalus acanthias*, with 739. This fact may be linked to the diversity of species and consequently their distribution, which is different. This also favors the number of publications, as can be observed in the study by Shiffman *et al.* (2020). When analyzing the trends of the American Elasmobranch Society conference abstracts, these authors observed that the number of studies focused on Holocephali is almost non-existent, and that the most studied species are commonly the most charismatic or easily accessible. According to Cotton & Grubbs (2015), the number of articles published is important because in addition to biological knowledge, this data is the basis for conservation management, without which species are unprotected.

Among the species studied, only five have more than 10 articles. Among these, only one species inhabits environments deeper than 750 meters, signifying that logistics (*e.g.*, easy access) is also a strong criterion for choosing the focus species, as diagnosed for elasmobranchs (Huveneers *et al*. 2015, Shiffman *et al*. 2020). Moreover, these five species represent 72% of publications. Such a high difference of some species with many publications and others without, interferes with scientific progress, especially of little-studied species (Stein *et al*. 2018). The species with higher mean depth (>1,000 m), have an average of three articles, in which they practically approach their taxonomy and/or occurrence, resulting in a research gap on life history. Efforts for a better understanding of less studied species are necessary, because as studies which explore marine areas that are little studied or difficult to access increase, a greater knowledge of the biology and the actual number of chondrichthyans species will be possible (Moral-Flores *et al*. 2016).

The present study corroborates with Sion *et al.* (2004), which have pointed out the scarcity of information mainly on the life history parameters of chimaera, showing that this problem is still recurring, and needs more attention. It was observed that few species have such well documented data, such as *Callorhinchus milii*, *Callorhinchus capensis*, and *Chimaera monstrosa*. On the other hand, other species which are virtually no records on growth and data on birth size and fecundity which makes it impossible to more accurately assess population status (Shiffman & Hammerschlag 2016, Shiffman *et al.* 2020). This scarcity of information is also visualized in the fishing data, where many gaps are observed in the actual catch rates (Bizzarro *et al.* 2009). It is known that these animals are commonly bycatch in various fisheries and due to their low commercial value, they are usually discarded (Blasdale & Newton 1998, Moura *et al.* 2004, Catarino *et al.* 2020). Moreover, many times when there is registration in the landings, there is an error in the species identification and the lack of sex differentiation, which ends up limiting the interpretation and understanding of the catch (Pequeño 1997, Mucientes *et al.* 2009, Bustamante *et al.* 2014). These fishery data are critical to assess fish production as well as understanding fishing dynamics and effort (Oliveira *et al.* 2021). In the absence of these published data, inferring that there is a lot of information distributed in gray literature (*e.g.*, reports, bulletins, theses, abstracts in events and others), even so, it can be perceived that it is essential to invest more in research about chimaera because they are highly vulnerable to extinction, being k-strategists.

The GLM shows that the number of publications per species has a significantly positive relationship with the time of the species description. Since the number of publications is accumulative, older species, in fact, stand out. The GLM was also positive with the area of occurrence, meaning the more restricted species tend to be less studied. The extinction threat category was not significant, so species classified in NT or VU are not the main focus of study, except for *Chimaera monstrosa*. Dulvy *et al.* (2014) and Shiffman *et al.* (2020) also stress this for elasmobranchs. Even though depth is a key factor on studies with these species, as reported by many authors, the GLM did not detect any pattern in the publications related to depth, because most of the inhabit have the same depth range.

Finally, it is clear that chimaera is often left aside, mainly due to the difficulty of obtaining data. The situation becomes even more complex for species with more restricted distribution, which according to the model is the least studied. Therefore, more efforts are needed on all topics, mainly on fishing, growth and population structure, so that it is possible to conserve them. Conserving them is to maintain evolutionary history, and to make these ancient beings present in the future.

Acknowledgments

We acknowledge the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) and the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq).

Literature cited

Akaike H. 1973. Maximum likelihood identification of Gaussian autoregressive moving average models. Biometrika 60(2): 255-265.

Barnett LAK, DA Ebert & GM Cailliet. 2009. Assessment of the dorsal fin spine for chimaeroid (Holocephali: Chimaeriformes) age estimation. Journal of Fish Biology 75(6): 1258-1270.

Bartoń K. 2020. MuMIn: multi-model inference. R package version 1.43. 17. <https://cran.r-project.org/web/packages/MuMIn/index.html>

Bizzarro JJ, WD Smith, JF Márquez-Farías, J Tyminski & RE Hueter. 2009. Temporal variation in the artisanal elasmobranch fishery of Sonora, Mexico. Fisheries Research 97(1-2): 103-117. <https://doi.org/10.1016/j.fishres.2009.01.009>

Blasdale T & AW Newton. 1998. Estimates of discards from two deepwater fleets in the Rockall Trough. ICES Document CM 1998/O: 11: 1-18.

Bustamante C, C Vargas-Caro & MB Bennett. 2014. Not all fish are equal: functional biodiversity of cartilaginous fishes (Elasmobranchii and Holocephali) in Chile. Journal of Fish Biology 85(5): 1617-1633.

Calis E, EH Jackson, CP Nolan & F Jeal. 2005. Preliminary age and growth estimates of the rabbitfish, *Chimaera monstrosa*, with implications for future resource management. Journal of Northwest Atlantic Fishery Science 35: 15-26.

Castro JI. 1987. The position of sharks in marine biological communities: an overview. In: Cook D (ed). Sharks. An inquiry into biology, behavior, fisheries and use, pp. 11-17. Oregon State University Extension Service, Corvallis.

Catarino D, K Jakobsen, J Jakobsen, E Giacomello, GM Menezes, H Diogo, A Canha, FM Porteiro, O Melo & S Stefanni. 2020. First record of the opal chimaera, *Chimaera opalescens* (Holocephali: Chimaeridae) and revision of the occurrence of the rabbitfish *Chimaera monstrosa* in the Azores waters. Journal of Fish Biology 97(3): 763-775.

Chierichetti MA, LB Scenna, EED Giácomo, PM Ondarza, DE Figueroa & KS Miglioranza. 2017. Reproductive biology of the cockfish, *Callorhinchus callorynchus* (Chondrichthyes: Callorhinchidae), in coastal waters of the northern Argentinean Sea. Neotropical Ichthyology 15(2): e160137. <https://doi.org/10.1590/1982-0224-20160137>

Cortés E. 2007. Chondrichthyan demographic modelling: an essay on its use, abuse and future. Marine and Freshwater Research 58(1): 4-6.

Cotton CF & RD Grubbs. 2015. Biology of deep-water chondrichthyans: Introduction. Deep-Sea Research Part II: Topical Studies in Oceanography 115: 1-10.

Didier D. 1995. Phylogenetic systematics of extant Chimaeroid fishes (Holocephali, Chimaeroidei). American Museum Novitates 3119: 1-86.

Didier DA, JM Kemper & DA Ebert. 2012. Phylogeny, biology, and classification of extant Holocephali. In: Carrier JC, JA Musick & MR Heithaus (eds). The biology of sharks and their relatives, pp. 97-121. CRC Press, Boca Raton, Florida.

Ducatez S .2019. Which sharks attract research? Analyses of the distribution of research effort in sharks reveal significant non-random knowledge biases. Reviews in Fish Biology and Fisheries 29: 355-367.

Dulvy NK, JK Baum, S Clarke, LJ Compagno, E Cortes, A Domingo, S Fordham, S Fowler, MP Francis, C Gibson, J Martínez, JA Musick, A Soldo, JD Stevens & S Valenti. 2008. You can swim but you can't hide: the global status and conservation of oceanic pelagic sharks and rays. Aquatic Conservation: Marine and Freshwater Ecosystems 18: 459-482. <https://doi.org/10.1002/aqc.975>

Dulvy NK, SL Fowler, JA Musick, RD Cavanagh, PM Kyne, LR Harrison, JK Carlson, LNK Davidson, SV Fordham, MP Francis, CM Pollock, CA Simpfendorfer, GH Burgess, KE Carpenter, LJV Compagno, DA Ebert, C Gibson, MR Heupel, SR Livingstone, JC Sanciangco, JD Stevens, S Valenti & WT White. 2014. Extinction risk and conservation of the world's sharks and rays. elife 3: e00590. <https://doi.org/10.7554/eLife.00590>

Finucci B, MR Dunn, EG Jones & J Anderson. 2017. Reproductive biology of the two deep-sea chimaerids, longnose spookfish (*Harriotta raleighana*) and Pacific spookfish (*Rhinochimaera pacifica*). Deep Sea Research Part I: Oceanographic Research Papers 120: 76-87. <https://doi.org/10.1016/j.dsr.2016.11.008>

Finucci B, J Cheok, DA Ebert, K Herman, PM Kyne & NK Dulvy. 2021. Ghosts of the deep–Biodiversity, fisheries, and extinction risk of ghost sharks. Fish and Fisheries 22(2): 391-412. <https://doi.org/10.1111/faf.12526>

Francis MP & C Maolagáin. 2019. Growth-band counts from elephantfish *Callorhinchus milii* fin spines do not correspond with independently estimated ages. Journal of Fish Biology 95(3): 743-752. <https://doi.org/10.1111/jfb.14060>

Grogan ED & R Lund. 2004. The origin and relationships of early Chondrichthyes. In: Carrier JC, JA Musick & MR Heithaus (eds). Biology of sharks and their relatives, pp. 3-31. CRC Press, Boca Raton.

Hijmans RJ, J Etten, M Sumner, J Cheng, D Baston, A Bevan, R Bivand, L Busetto, Mort Canty, D Forrest, A Ghosh, D Golicher, J Gray, JA Greenberg, P Hiemstra, K Hingee, C Karney, M Mattiuzzi, S Mosher, J Nowosad, E Pebesma, OP Lamigueiro, EB Racine, B Rowlingson, A Shortridge, B Venables & R Wueest. 2020. raster: Geographic Data Analysis and Modeling. R package version 3.3-13. <https://cran.r-project.org/web/packages/raster/index.html>

Holt RE, A Foggo, FC Neat & KL Howell. 2013. Distribution patterns and sexual segregation in chimaeras: implications for conservation and management. ICES Journal of Marine Science 70(6): 1198-1205. <https://doi.org/10.1093/icesjms/fst058>

Huveneers C, DA Ebert & SFJ Dudley. 2015. The evolution of chondrichthyan research through a metadata analysis of dedicated international conferences between 1991 and 2014. African Journal of Marine Science 37(2): 129-139.

IUCN. 2020. The IUCN Red List of Threatened Species. Version 2020-2. <https://www.iucnredlist.org>

Moral-Flores LFD, JJ Morrone, J Alcocer & LG Pérez-Ponce. 2016. Diversidad y afinidades biogeográficas de los tiburones, rayas y quimeras (Chondrichthyes: Elasmobranchii, Holocephali) de México. Revista de Biología Tropical 64(4): 1469-1486.

Moura T, I Figueiredo, PB Machado & LS Gordo. 2004. Growth pattern and reproductive strategy of the holocephalan *Chimaera monstrosa* along the Portuguese continental slope. Journal of the Marine Biological Association of the United Kingdom 84(4): 801-804.

Mucientes GR, N Queiroz, LL Sousa, P Tarroso & DW Sims. 2009. Sexual segregation of pelagic sharks and the potential threat from fisheries. Biology Letters 5(2): 156-159.

Oliveira CYB, CDL Oliveira, MN Müller, EP Santos, DMM Dantas & AO Gálvez. 2020. A scientometric overview of global dinoflagellate research. Publications 8(4): 50. <https://doi.org/10.3390/publications8040050>

Oliveira CD, CYB Oliveira, JPG Camilo & VS Batista. 2021. Demographic analysis reveals a population decline of the Longnose stingray *Hypanus guttatus* in Northeastern Brazil. Regional Studies in Marine Science 41: 101554. <https://doi.org/10.1016/j.rsma.2020.101554>

Pequeño G. 1997. Peces de Chile. Lista sistemática revisada y comentada: addendum. Revista de Biología Marina y Oceanografía 32(2): 77-94.

Rigby C & CA Simpfendorfer. 2015. Patterns in life history traits of deep-water chondrichthyans. Deep Sea Research Part II: Topical Studies in Oceanography 115: 30-40. <https://doi.org/10.1016/j.dsr2.2013.09.004>

Ripley B, B Venables, DM Bates, K Hornik, A Gebhardt & D Firth. 2020. Package 'MASS'. R package version 7.3-51.6. <https://cran.r-project.org/web/packages/MASS/index.html>

Santos LVR, JPG Camilo, CYB Oliveira, C Nader & CDL Oliveira. 2021. Current status of Brazilian scientific production on non-native species. Ethology Ecology & Evolution 2021: 1-14. <https://doi.org/10.1080/03949370.2020.1870570>

Seppelt R, CF Dormann, FV Eppink, S Lautenbach & S Schmidt. 2011. A quantitative review of ecosystem service studies: approaches, shortcomings and the road ahead. Journal of Applied Ecology 48(3): 630-636. <https://doi.org/10.1111/j.1365-2664.2010.01952.x>

Shiffman DS & N Hammerschlag. 2016. Shark conservation and management policy: a review and primer for non-specialists. Animal Conservation 19(5): 401-412. <https://doi.org/10.1111/acv.12265>

Shiffman DS, MJ Ajemian, JC Carrier, TS Daly-Engel, MM Davis, NK Dulvy, RD Grubbs, NA Hinojosa, J Imhoff, MA Kolmann, CS Nash, EW Paig-Tran, EE Peele, RA Skubel, BM Wetherbee, LB Whitenack & CS Nash. 2020. Trends in Chondrichthyan research: An analysis of three decades of conference abstracts. Copeia 108(1): 122-131. <https://doi.org/10.1643/OT-19-179R>

Sion L, A Bozzano, G D'Onghia, F Capezzuto & M Panza. 2004. Chondrichthyes species in deep waters of the Mediterranean Sea. Scientia Marina 68(S3): 153-162. <https://doi.org/10.3989/scimar.2004.68s3153>

Stein RW, CG Mull, TS Kuhn, NC Aschliman, LN Davidson, JB Joy, GJ Smith, NK Dulvy & AO Mooers. 2018. Global priorities for conserving the evolutionary history of sharks, rays and chimaeras. Nature Ecology & Evolution 2(2): 288-298. <https://doi.org/10.1038/s41559-017-0448-4>

Suárez ME, J Lamilla & C Marquardt. 2004. Peces Chimaeriformes (Chondrichthyes, Holocephali) del Neógeno de la Formación Bahía Inglesa (Región de Atacama, Chile). Revista Geológica de Chile 31(1): 105-117.

Zhang L, J Gong & Y Zhang. 2016. A review of ecosystem services: a bibliometric analysis based on web of science. Acta Ecologica Sinica 36: 5967-5977.

Editor: Francisco Concha
Received 28 August 2020
Accepted 05 October 2021

Supplementary material

Table S1. List of articles found on the Scopus® platform / Lista de artículos encontrados en la plataforma Scopus®

See: <https://rbmo.uv.cl/resumenes/v57S1/Oliveira-TablaS1.xlsx>

Table S2. List of articles found on the Scopus® platform for chimera fish species / Lista de artículos encontrados en la plataforma Scopus® para especies de peces quimera

See: <https://rbmo.uv.cl/resumenes/v57S1/Oliveira-TablaS2.xlsx>