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Prof. Eugenio de Jesús Marcano

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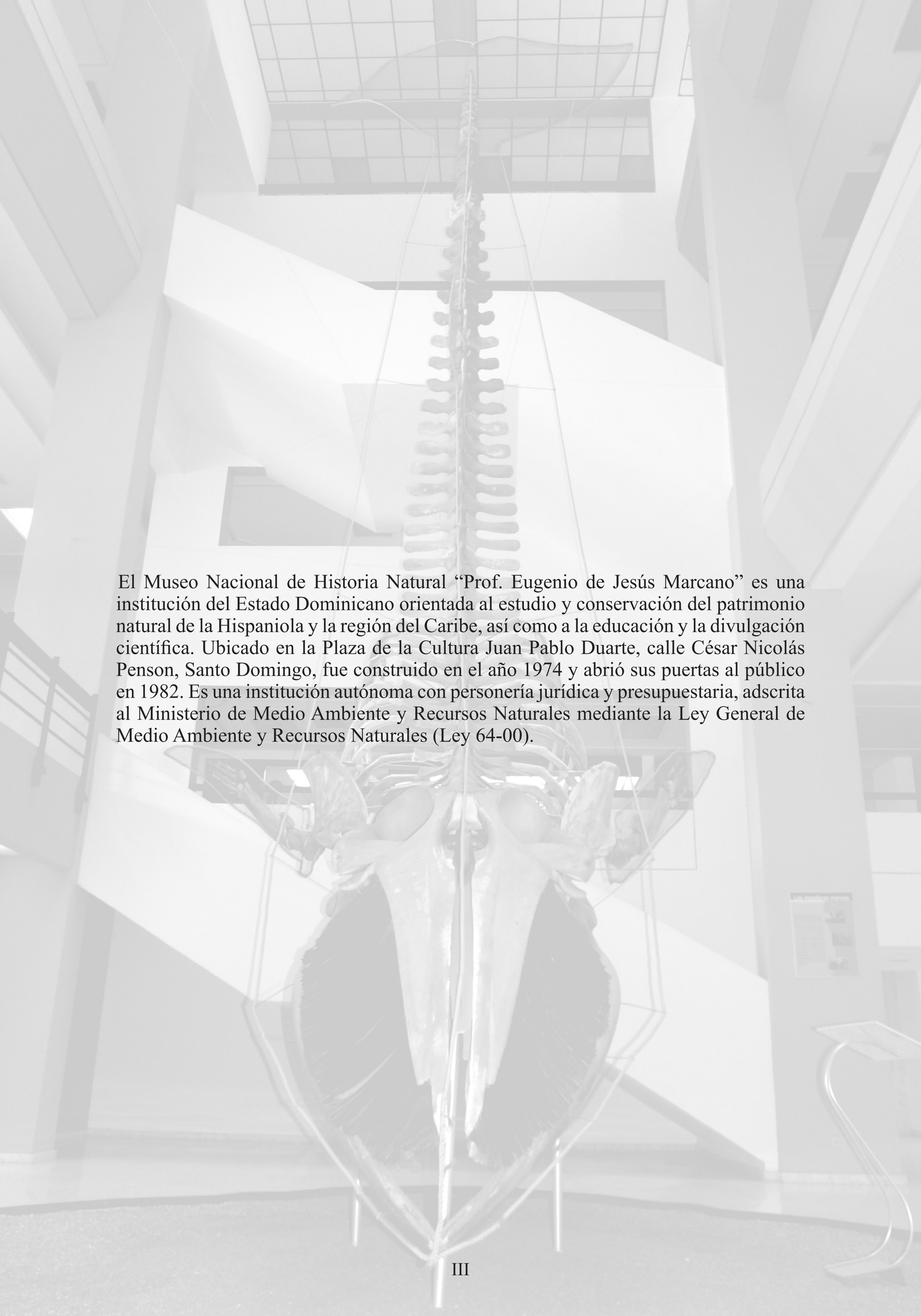

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MARIPOSAS (LEPIDOPTERA: PAPILIONOIDEA) DEL PARQUE BOTÁNICO DE CAMAGÜEY, CUBA

Butterflies (Lepidoptera: Papilionoidea) from Camagüey Botanical Park, Cuba

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RESUMEN

Como resultado de un proyecto destinado al manejo sostenible de la lepidopterofauna, se socializa la relación taxonómica de las mariposas (Lepidoptera: Papilionoidea) registradas en el Parque Botánico de Camagüey, Cuba y se ofrecen datos sobre su presencia en diferentes épocas del año, con vistas a seleccionar aquellas más propicias para ser criadas en el mariposario, que se encuentra todavía en proceso de construcción. Durante los años 2021 y 2022, se realizaron muestreos mensuales en diferentes espacios del área de estudio, lo que permitió identificar 56 táxones infraespecíficos, pertenecientes a 48 géneros, 15 subfamilias y cinco familias (Papilionidae, Nymphalidae, Pieridae, Lycaenidae y Hesperiidae). El endemismo a nivel específico alcanzó el 3.57 % y en el ámbito subespecífico llegó a ser del 8.92 %, por lo que el 12.5 % de los táxones tienen distribución limitada al territorio nacional. Se comprobó que 35 de las especies/subespecies reportadas, están presentes tanto en los meses de lluvia como en los de sequía (índice de similitud de Jaccard del 62.5 % entre ambas épocas), lo que se identifica como una potencialidad para fomentar la crianza de las mismas. De acuerdo al estudio realizado, se ofrecen, en un primer intento, argumentos sobre la selección de las especies para la cría.

Palabras clave: lepidopterofauna, endemismo, índice de similitud, conservación ex situ.

ABSTRACT

As a result of a project aimed at the sustainable management of the lepidopterofauna, the taxonomic relationship of butterflies (Lepidoptera: Papilionoidea) registered in the Botanical Park of Camagüey, Cuba is presented and data on their presence at different times of the year are offered, in order to select those more adequate to being raised in the butterfly farm, which is still under construction. During 2021 and 2022, monthly samplings were carried out in different sites of the study area, which allowed the identification of 56 infraspecific taxa, belonging to 48 genera, 15 subfamilies and five families (Papilionidae, Nymphalidae, Pieridae, Lycaenidae and Hesperidae). The endemism at the specific level reached 3.57 % and in the subspecific level it reached 8.92 %, so that 12.5 % of the taxa have distribution limited to the national territory. It was found that 35 of the species/subspecies reported, are present both in the months of rain and drought (Jaccard similarity index of 62.5 % between both seasons), which is identified as a potential to promote the breeding of the same. According to the study carried out, arguments on the selection of species for breeding are offered in a first attempt.

Keywords: lepidopterofauna, endemism, similarity index, ex situ conservation.

INTRODUCCIÓN

El Consejo Popular "Julio Antonio Mella" y la Universidad de Camagüey "Ignacio Agramonte Loynaz", en su condición de asesora, lograron en 2017 que el Programa de Pequeñas Donaciones del Fondo para el Medio Ambiente Mundial (perteneciente al Programa de las Naciones Unidas para el Desarrollo) y el Fondo Nacional de Medio Ambiente de la República de Cuba, asignaran un financiamiento para construir un mariposario en el Parque Botánico de Camagüey.

Dado que la nueva instalación aspira tanto a la sostenibilidad como a realizar un significativo aporte a la conservación de la biodiversidad, trabajará prioritariamente con recursos locales (mariposas, plantas hospederas, nectaríferas, entre otros). Para ello se necesita, ante todo, de un estudio riguroso de las especies de Papilionoidea representadas en el área, de manera que puedan seleccionarse aquellas con mayor potencialidad para ser manejadas *ex situ* e implementar tecnologías apropiadas en función de su crianza.

Por otra parte, el estudio de las especies de mariposas representadas en el Parque Botánico de Camagüey, constituirá un valioso referente para poder evaluar en el futuro el servicio de refugio a la fauna que realice la institución, ubicada dentro del propio ámbito urbano. Permitirá, también, estimar la contribución potencial que pueda realizarse desde allí a la conservación de este grupo zoológico y conocer mejor aquellos elementos de la lepidopterofauna con los cuales podrán interactuar los visitantes.

OBJETIVOS

- Revelar la relación taxonómica de las mariposas (Lepidoptera: Papilionoidea) que están actualmente en existencia en el Parque Botánico de Camagüey y caracterizarlas, desde el punto de vista biogeográfico.
- Analizar la representatividad de táxones en los diferentes espacios del parque y épocas del año.
- Seleccionar táxones promisorios para iniciar su cría en el mariposario.

MATERIALES Y MÉTODOS

Área de estudio

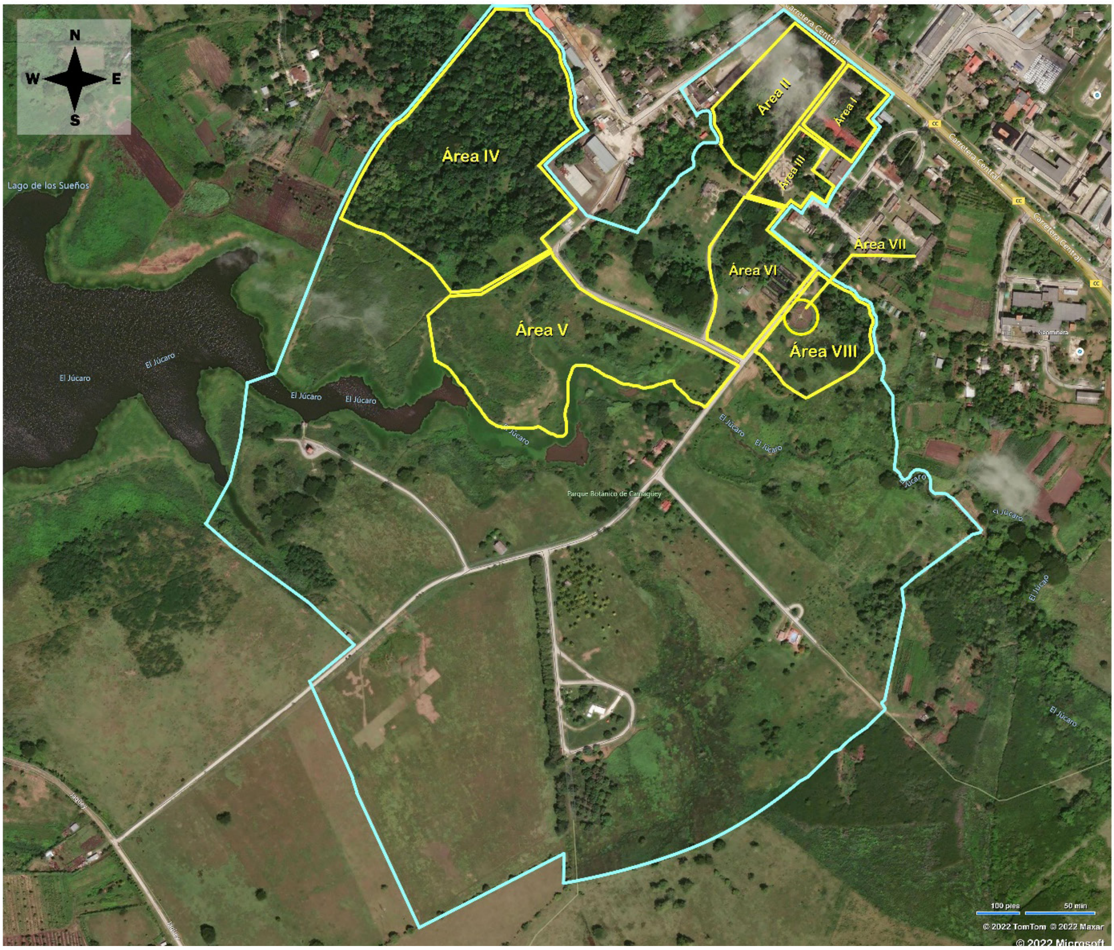

Figura 1. Imagen del Parque Botánico de Camagüey, en la que se muestran las áreas estudiadas. La línea azul corresponde a los límites exteriores, mientras que la línea amarilla representa los límites interiores entre las áreas temáticas de la entidad. Material utilizado: Imagen satelital tomada de https://www.bing.com/maps/?cp=21.351626%7E-77.878254&lvl=16.3&style=a. Composición: Roeris González Sivilla.

El estudio se realizó en el Parque Botánico de Camagüey, localizado en la ciudad y provincia homónima, perteneciente a la República de Cuba. El mismo forma parte del Consejo Popular Julio Antonio Mella, ubicado en el cuadrante sureste del perímetro urbano y se encuentra aledaño a la Carretera Central, vía al Este, km 5 ½ (donde se encuentra su entrada) y al Micro Embalse No. 17 “Monte Carlos”, a la vez que limita al sur con el Camino de Jagüey. Ocupa una extensión superficial de alrededor de 72 ha, cuyo punto central se encuentra en las coordenadas: 21.350905 -77.879276 (Fig. 1).

La institución, que abrió al público el 6 de septiembre de 2015, fue establecida en terrenos que anteriormente estuvieron dedicados a la producción agrícola para el autoconsumo del Instituto Politécnico “Álvaro Barba Machado” (antigua Granja Escuela de Camagüey), con el cual limita al noreste. Incluyó también un reducto de bosque semideciduo algo antropizado y un aboretum, ambos situados hacia el noroeste, que venían siendo utilizados por la Empresa Forestal Integral del Ministerio de la Agricultura para la producción de semillas (Méndez, 2018). Como parte de la readaptación del espacio a los objetivos del Parque Botánico, se han agregado durante los últimos siete años, entre otras: una plantación de bambúes (bambusetum), un área de vivero y un organopónico, a la vez que se ha incrementado considerablemente la superficie con jardinería diversa.

Muestreos. El muestreo se realizó durante los años 2021 y 2022, en espacios bien delimitados y con mayor desarrollo de vegetación dentro del parque. Estos fueron:

I) Jardín, con predominio de plantas suculentas y xerófitas en general.

II) Cafetal, con aislados árboles de sombra, nativos y exóticos; estrato herbáceo y arbustivo controlado mediante atenciones culturales.

III) Jardín, donde predominan plantas ornamentales herbáceas, arbustivas y arbóreas, en su mayoría exóticas.

IV) Bosque, compuesto por una plantación de árboles maderables, estrato herbáceo y arbustivo escasamente desarrollado o inexistente.

V) Sabana húmeda, con plantación de bambúes; estrato herbáceo y arbustivo controlado mediante atenciones culturales.

VI) Vivero, donde se cultivan diferentes tipos de plantas cubanas y exóticas, con vistas a ampliar las colecciones del parque, actualmente en desarrollo.

VII) Organopónico, con cultivo de hortalizas.

VIII) Zona en barbecho, formada por vegetación herbácea y aislados arbustos o árboles en crecimiento; flora compuesta mayormente por especies segetales y ruderales.

Entre ellas se establecieron recorridos lineales para la observación directa, divididos en secciones, con un total de hasta 500 metros (Mancina & Cruz, 2017). Cada recorrido tuvo una duración de una hora, siempre en el período comprendido entre 9:00 a. m. y 1:00 p. m. Se registraron todas las especies de mariposas observadas durante el recorrido, a la vez que se tomaron otras notas necesarias para el posterior procesamiento de la información. Cuando no fue posible observar los especímenes en reposo mientras se alimentaban, se procedió a su captura utilizando como técnica de colecta la búsqueda guiada con red entomológica. Los ejemplares apresados fueron liberados a su medio natural luego de ser identificados *de visu*, pero aquellos en los que no fue posible, se inmovilizaron y se colocaron en sobres de papel, con el registro correspondiente, para ser llevados posteriormente al laboratorio de Zoología de la Universidad de Camagüey “Ignacio Agramonte Loynaz”, donde se procedió a su montaje y a la determinación definitiva de la especie o subespecies a la que correspondía.

La identificación se realizó mediante la comparación de evidencias fenotípicas de los especímenes con descriptores de los diferentes táxones, claves y guías (Alayo & Hernández, 1987; Barro & Núñez, 2011; Mancina et al., 2020; Warren et al., 2020), la comparación con especímenes de colecciones científicas y la consulta a especialistas. La nomenclatura y la taxonomía, se asumió según aparece reportada en la red Facilitador Global de Información sobre Biodiversidad o GBIF por sus siglas en inglés (Global Biodiversity Information Facility Secretariat, 2023). Solo se exceptúa el caso de *Hamadryas amphichloe diasia* (Fruhstorfer, 1916), para la cual se asumieron los criterios de Garzón-Orduña et al. (2017).

Con las mariposas identificadas se confeccionó una relación taxonómica, en la cual se declara: superfamilia, familia, subfamilia, género, especie o subespecie a la que pertenecen. Se calcularon las frecuencias relativas de endemismo a nivel específico y subespecífico. Se realizó una caracterización biogeográfica utilizando como referentes las obras de Fontenla y de la Cruz (1989, 1992). También, se valoró la representatividad de mariposas con respecto a la registrada para el país y la provincia.

Se constató la presencia de cada uno de los táxones en diferentes épocas del año. Se calculó el índice de similitud de Jaccard (*Jaccard index*). Los datos fueron procesados a través del software PAST 3.0 para Windows (Hammer et al., 2001), en función de determinar la similitud entre los meses muestreados y entre los periodos de lluvia y seca.

RESULTADOS Y DISCUSIÓN

Composición taxonómica. Se constató la presencia de 56 táxones infragenéricos (Fig. 2) de mariposas en el Parque Botánico de Camagüey (Tabla I). Ello constituye el 28 % del total reportado para Cuba (Mancina et al., 2020) y el 44.6 % registrado en la provincia de Camagüey (Fernández & Rodríguez, 1998). Si bien dicha riqueza taxonómica no es alta con relación a la existente en otras regiones del país (Lauranzón et al., 2013; Luna & Hernández, 2013; Núñez, 2004, 2010, 2011, 2012; Núñez & Barro, 2003), sí puede ser considerada representativa de la registrada en localidades estudiadas en el ámbito provincial.

Los táxones identificados se clasifican en 48 géneros y 15 subfamilias. Están representadas cinco (Papilionidae, Nymphalidae, Pieridae, Lycaenidae y Hesperiidae) de las seis familias registradas para Cuba. Solo Riodinidae no está presente, lo cual no sorprende, dada la escasa presencia, restringida distribución y especificidad ecológica que caracterizan a la única especie *Dianesia carteri* (Holland 1902) registrada en el país (Alayo & Hernández, 1987; Fontenla, 1987; Núñez & Barro, 2012).

Tabla I. Relación taxonómica de mariposas (Lepidoptera: Papilionoidea) del Parque Botánico de Camagüey. * Especies endémicas; ** subespecies endémicas; *** especie introducida.

Fam.	Subfamilia	Taxon
Papilionidae Latreille, [1802]	Papilioninae Latreille, [1802]	*Battus polydamas cubensis* (Dufrane, 1946) **
		Battus devilliers (Godart, 1823)
		Heraclides andraemon andraemon Hübner [1823]
		Heraclides androgeus epidaurus (Godman & Salvin, 1890)
		Papilio demoleus malayanus (Wallace, 1865) ***
Hesperiidae Latreille, 1809	Eudaminae Mabille, 1877	*Cetropterus dorantes santiago* (Lucas, 1857)
		Urbanus proteus domingo (Scudder, 1872)
		Telegonus habana (Lucas, 1857) *
	Hesperiinae Latreille, 1809	*Asbolis capucinus* (Lucas, 1857)
		Calpodes ethlius (Stoll, 1782)
		Cymaenes tripunctus tripunctus (Herrich-Schäffer, 1865)
		Choranthus radians (Lucas, 1857)
		Euphyes cornelius cornelius (Latreille, 1824)**
		Hylephila phyleus phyleus (Drury, 1773)
		Nyctelius nyctelius nyctelius (Latreille, 1824)
		Panoquina lucas lucas (Fabricius, 1793)
		Panoquina ocola ocola (Edwards, 1863)
		Perichares philetes (Gmelin, 1790)
		Polites baracoa baracoa (Lucas, 1857)
		Synaptes malitiosa (Herrich-Schäffer, 1865)
		Wallengrenia misera (Lucas, 1857)
	Pyrginae Burmeister, 1878	*Burnsius oileus* (Linnaeus, 1767)
		Ephyriades brunnea brunnea (Herrich-Schäffer, 1864)
		Erynnis zarucco (Lucas, 1857)
Pieridae Swainson, 1820	Coliadinae Swainson, 1821	*Abaeis nicippe* (Cramer, 1779)
		Anteos clorinde (Godart, [1824])
		Aphrissa orbis (Poey, 1832)
		Eurema daira palmira (Poey, [1852])
		Natalis iole Boisduval, 1836
		Phoebis agarithe antillia Brown, 1929
		Phoebis philea philea (Johansson, 1763)
		Phoebis sennae sennae (Linnaeus, 1758)
		Phoebis statira cubana d´Almeida, 1939
		Pyrisitia lisa euterpe (Ménétriés, 1832)
		Pyrisitia nise nise (Cramer, 1775)
	Pierinae Swainson, 1820	*Ascia monuste eubotea* (Godart, 1819)
		Glutophrissa drusilla poeyi (Butler, 1872)

Fam.	Subfamilia	Taxon
Lycaenidae Leach, 1815	Polyommatinae Swainson, 1827	*Leptotes cassius theonus* (Lucas, 1857)
		Hemiargus ceraunus filenus (Poey, 1832)
	Theclinae Swainson, 1831	*Strymon limenia* (Hewitson, 1868)
		Strymon martialis (Herrich-Schäffer, 1864)
Nymphalidae Rafinesque, 1815	Biblidinae Bois-duval, 1833	*Hamadryas amphichloe diasia* (Fruhstorfer, 1916)
	Cyrestinae Guenée, 1865	*Marpesia eleuchea eleuchea* (Hübner, 1818)**
	Danainae Bois-duval, [1833]	*Danaus gilippus berenice* (Cramer, 1779)
	Heliconiinae Swainson, 1822	*Dione vanillae insularis* (Maynard, 1889)
		Dryas iulia nudeola (Bates, 1934) **
		Euptoieta hegesia hegesia (Cramer, 1779)
		Heliconius charithonia ramsdeni Comstock y Brown, 1950
	Limenitinae Behr, 1864	*Adelpha iphicleola iphimedia* Fruhstorfer, 1915**
	Nymphalinae Rafinesque, 1815	*Anartia jatrophae guantanamo* Munroe, 1942
		Anthanassa frisia frisia (Poey, 1832)
		Historis odius odius (Fabricius, 1775)
		Junonia lavinia Cramer, 1775
		Phyciodes phaon phaon (Edwards, 1864)
		Siproeta stelenes biplagiata (Fruhstorfer, 1907)
	Satyrinae Boisduval, [1833]	*Calisto herophile* Hübner, 1823*

Según se muestra en la Tabla II, las familias mejor representadas fueron Hesperiidae, Nymphalidae y Pieridae, como es de esperar para la fauna cubana (Fontenla, 1987; 1992; Mancina et al., 2020). La representatividad, con respecto a lo reportado para la provincia de Camagüey, fue más alta en Papilionidae y Hesperiidae. Los representantes de la familia Lycaenidae son escasos, lo cual corrobora la tendencia que tiene esta familia de habitar con mayor frecuencia en costas y bosques no asociados a montañas (Fontenla, 1992).

Al analizar los resultados desde una perspectiva biogeográfica, se constata que, de los 135 táxones infragenéricos registrados en la región zoogeográfica central del país (Fontenla & de la Cruz, 1989), el 41.5 % se localiza en el Parque Botánico.

Si bien era de esperar la presencia en el Parque Botánico de la mayor parte de los táxones registrados, dada la distribución anteriormente conocida de los mismos, existen al menos dos situaciones que merecen un análisis particular. Una de ellas es el caso de *Strymon martialis*, considerada rara en el territorio nacional (Alayo & Hernández, 1987) y observada mayormente en la vegetación cercana a las costas (Barro et al., 2020). Sin embargo, había sido registrada dos veces en el interior de la provincia de Camagüey (Fernández & Rodríguez, 1998; Fernández, 2007), una de ellas al norte de la ciudad capital, por lo que la constatación ahora de su presencia en el área objeto de estudio, reafirma lo planteado por Fernández (2007) respecto a que, estudios sistemáticos de campo, pudieran llevar a modificar concepciones que se han tenido hasta ahora sobre la distribución, ecología y abundancia atribuida a algunas mariposas cubanas.

Figura 2. Ejemplos de mariposas presentes en el Parque Botánico de Camagüey. **A)** *Heraclides andraemon andraemon*; **B)** *Danaus gilippus berenice*; **C)** *Agraulis vanillae insularis*; **D)** *Leptotes cassius theonus*; **E)** *Battus polydamas cubensis*; **F)** *Calisto herophile*; **G)** *Pyrisitia lisa euterpe.* De la A a la D, las fotos son de la autoría de Jesús Ávila Herrera y de la E a la G, fueron realizadas por Marisela de la C. Guerra Salcedo.

Tabla II. Representatividad de las familias de mariposas en el Parque Botánico de Camagüey, comparado con lo reportado para Cuba y la provincia.

Familias	Número de especies y subespecies			Proporción	
	P. Botánico	Camagüey	Cuba	P. Bot. / Cam. (%)	P. Bot. / Cuba (%)
Hesperiidae	19	40	57	47.5	33.3
Nymphalidae	15	35	72	42.8	20.3
Pieridae	13	29	35	44.8	37.1
Papilionidae	5	9	15	55.5	33.3
Lycaenidae	4	12	20	33.3	20
Riodinidae	0	0	1	0	0
Total	56	125	200	44.8	28

Otro análisis particular lo merece *Papilio demoleus malayanus*, llamativa mariposa que, de acuerdo con las observaciones realizadas desde el 2017 por los autores del presente trabajo, es relativamente común en diferentes áreas del Parque Botánico. De origen asiático, fue registrada por primera vez en Cuba durante el año 2007, en el Yunque, Baracoa, provincia de Guantánamo (Núñez, 2007). Con posterioridad, reportada para Santiago de Cuba (Lauranzón et al., 2011) y en Los Hoyos, en la costa norte de la ciudad de Gibara, provincia Holguín (Bermúdez, 2011). En Camagüey, el primer registro de su presencia se concretó en 2013 en el Reparto Jayamá, dentro de la propia ciudad capital. Luego, en el mismo año, se observó en el área protegida “La Belén”, Sierra del Chorrillo, en Najasa (Fernández & Minno, 2015). Dada su evidente tendencia a extender su presencia, la especie ha sido considerada invasora (Lauranzón et al., 2011).

La existencia de endemismos cubanos es escasa entre las mariposas registradas. Sólo clasifican en esta categoría, el 3.57 % de las especies y el 8.9 % de las subespecies. En cuanto a las primeras, están presentes: *Calisto herophile* y *Telegonus habana,* que son comunes y con amplia distribución en el territorio nacional. Entre las segundas, se destacan: *Battus polydamas cubensis*, *Euphyes cornelius cornelius*, *Marpesia eleuchea eleuchea*, *Dryas iulia nudeola* y *Adelpha iphicleola iphimedia,* las cuales, por lo general, también son consideradas de amplia distribución en el país (Álvarez et al., 2020; Azor y Barro, 2014; Fernández et al., 2020; Fontenla et al., 2022; Núñez et al., 2020); mientras *D. iulia nudeola* es común en diversos hábitats.

El hecho de que, en el espacio estudiado, el endemismo entre las subespecies sea cuantitativamente superior al que se aprecia en el caso de las especies, se corresponde con lo planteado por Fontenla y de la Cruz (1992), quienes sostienen que, en Cuba, las primeras han logrado mayor adaptabilidad que las segundas a la diversidad geográfica y ecológica, por lo que exhiben, de manera general, más amplia distribución, resultado de su mayor adaptabilidad.

Debe tenerse en cuenta que, el Parque Botánico constituye una entidad de reciente creación, al iniciar sus servicios en 2015, donde la mayor parte de sus espacios estuvieron dedicados anteriormente a la actividad agrícola y que, además, se ubica dentro de una zona urbana. Es de esperar entonces que los táxones faunísticos de amplia distribución y asociados a la actividad humana predominen con relación a los endémicos. Ello también se encuentra en consonancia con lo planteado por Fontenla y de la Cruz (1992), quienes comprobaron que el endemismo absoluto y relativo de las mariposas cubanas, es más bajo en los hábitat agrícolas, urbanos y costeros, que son también los de menor riqueza taxonómica. Además, el área estudiada se localiza en la región central del país, caracterizada por la presencia de un menor número de especies y de endemismos, en comparación con el resto del territorio nacional, por tratarse de terrenos predominantemente llanos y, por lo general, con avanzado grado de antropización (Fontenla & de la Cruz, 1989).

Los datos anteriormente expuestos indican que, al menos desde el punto de vista de la riqueza taxonómica de la lepidopterofauna local, se identifican amplias potencialidades para el fomento del mariposario que se construye en el Parque Botánico de Camagüey. Se aprecia, inclusive, la posibilidad de incorporar a la cría controlada algún taxon autóctono o endémico, lo cual permitiría lograr determinada exclusividad en los resultados que se alcancen y relativa especificidad en los servicios que se presten al público.

Representatividad de los táxones. La representatividad de las mariposas observadas en los diferentes espacios objeto de muestreo se expone en la Figura 3. Como se aprecia, la mayor cantidad de táxones (43; 76.78 %) se registró en el área VI, del Parque Botánico, lo que puede explicarse por la amplia disponibilidad de recursos en ella presente, lo cual asegura la amplia heterogeneidad de especies vegetales que conviven allí (bien sea en condiciones de cultivo o de manera espontánea) y que pueden actuar como hospederas o como proveedoras de néctar. En esta área, según observaciones realizadas por los autores, se avistaron también huevos y larvas sobre las hospederas.

Otras dos áreas en las que se registraron un número considerable de especies y subespecies fueron: el área II (35 táxones; 62.5 %) y el área III (34; 60.7 %). En ambos casos resalta la abundancia de plantas que son utilizadas por las mariposas como fuente de néctar.

En el área IV, de maderables cubanos, se observaron 31 táxones (57.14 %) y, como era de esperar, se encontraron especies que suelen habitar en los bosques y arbolados como, por ejemplo: *B. polydamas cubensis*, *Historis odius odius*, *A. iphicleola iphimedia*, *Siproeta stelenes biplagiata* y *Synapte malitiosa malitiosa.*

En este mismo orden, un número menor de mariposas fueron registradas en las áreas: V (24; 42.85 %), VII (20; 35.71 %) y VIII (14 táxones; 25 %).

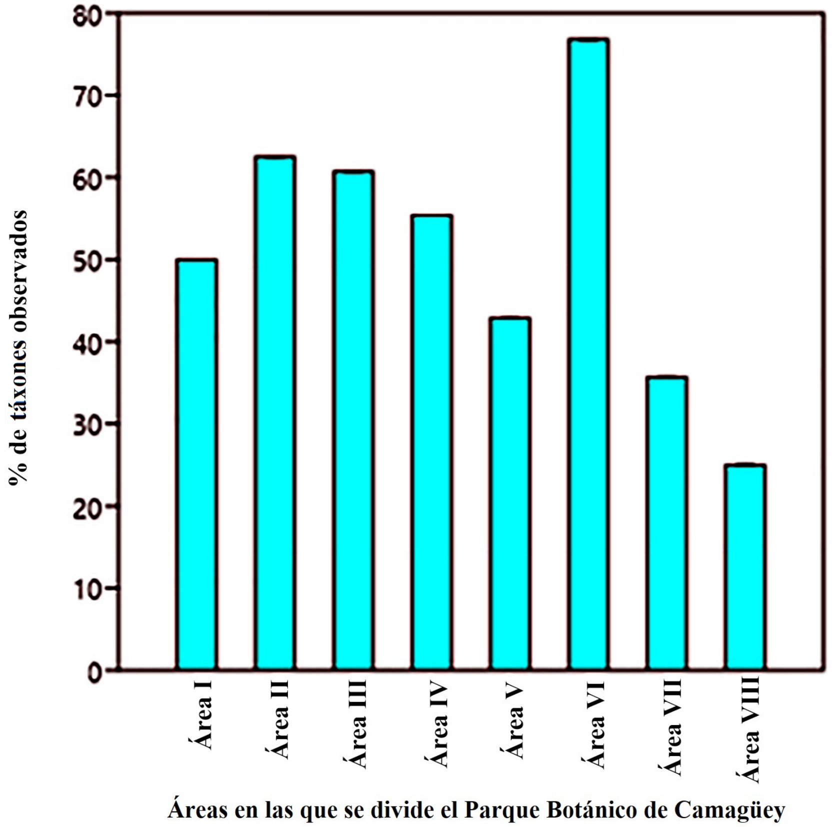

Figura 3. Representatividad de mariposas (Lepidoptera: Papilionoidea) en las zonas y áreas muestreadas en el Parque Botánico de Camagüey.

El área del vivero fue identificada como el más importante polígono para realizar los estudios que permitieran seleccionar las especies a incorporar a la cría y, una vez elegidas, proceder a la captura de pies de crías de las mismas en los diferentes estadios del ciclo vital del lepidóptero, aspecto esencial para el éxito del mariposario (Saragos & Dénommée, 2012). Igualmente, a partir de nuevas investigaciones, constituye un escenario propicio para liberar y monitorear la adaptación al medio natural de individuos maduros que hayan sido obtenidos de manera controlada, lo cual, de acuerdo con Dénommée (2010), debe alcanzar hasta un 20 % de la producción total de la entidad y que constituye un objetivo primordial del proyecto que se acomete en Camagüey. También esta acción se tendrá en cuenta como una posibilidad orientada a la restauración de los espacios que estas especies requieren para aumentar sus poblaciones.

Representatividad de táxones en los meses muestreados y similitud. El estudio de la presencia de los táxones registradas en el parque y su fenología a lo largo del año, adquiere especial importancia para el futuro funcionamiento del mariposario (Constantino, 2002; Dénommée, 2010; Saragos & Dénommée, 2012). Aportará información básica para la selección de las especies a incorporar a la crianza, la identificación de los momentos más propicios para el acopio de los pies de cría necesarios en cada caso (en cualquiera de los estadios de su ciclo vital), la planificación de los períodos y el estado en que podrán ser exhibidas al público, así como la programación de las liberaciones al medio natural.

En base a los criterios anteriores, los meses en que mayor número de táxones se observaron fueron (Fig. 4): noviembre (30), agosto (28) y julio (25). Evidentemente, es en estos cuando mejores condiciones ambientales se presentan para la actividad de los imagos, lo cual deberá estudiarse con detenimiento, como parte de la continuidad del presente proyecto, en función de lograr parámetros similares en la sala de vuelo y garantizar la sostenibilidad en la exhibición y reproducción.

Los meses con un alto número de táxones (junio, julio, agosto), corresponden al período de mayor humedad, lo cual coincide, en parte, con estudios realizados en otras áreas camagüeyanas (Fernández, 2007). Por otra parte, los meses con menos representación fueron septiembre, enero y abril.

Si bien la situación apreciada en enero entra en contradicción con los resultados obtenidos en investigaciones anteriores, se considera que se debió a circunstancias favorables que se dieron puntualmente en el período en el cual se realizó el muestreo realizado por Fernández (2007). Al respecto, para el presente estudio, este pico tuvo lugar en noviembre y diciembre, asociado a las lluvias que se produjeron en el último semestre del año.

En el estudio realizado fue necesario discernir entre aquellas mariposas que están presentes a lo largo del año, de otras que son estacionales y permanecen o tienen mayor abundancia en períodos concretos. En tal caso, las primeras pueden exhibirse todo el año, las segundas sólo en determinada estación.

En este contexto se analizó el número de táxones representados con referencia a los dos períodos que se distinguen con mayor nitidez, en cuanto a la manifestación de variables meteorológicas en Cuba, el seco y el de lluvia, lo cual aporta información sobre la mayor o menor dependencia de estos ante las variables físicas del ambiente, que distinguen dichas estaciones (temperatura, presión, humedad, radiación solar) y que tienen una influencia importante en el manejo de las mariposas en cautiverio (Sánchez, 2019) (Fig. 5). Como es de esperar, el mayor número de especies/subespecies se encuentra en el período lluvioso.

Llama la atención los casos de *Telegonus habana* y *A. iphicleola iphimedia*, que solo se observaron uno o dos veces en todo el año, lo que puede estar dado por su especificidad ecológica y no encontrar las condiciones propicias para un establecimiento permanente, particularmente esta última, considerada poco común (Alayo & Hernández, 1987; Núñez et al., 2020).

Por otra parte, el comportamiento específico de los táxones en cada uno de los meses del año, aporta elementos más amplios respecto a la interacción que establecen con los factores bióticos. En este sentido, es necesario destacar algunos ejemplos como la correspondencia entre los distintos estados del ciclo de vida de las mariposas y la fenología de las plantas hospederas y nectaríferas o la abundancia de depredadores en determinados meses.

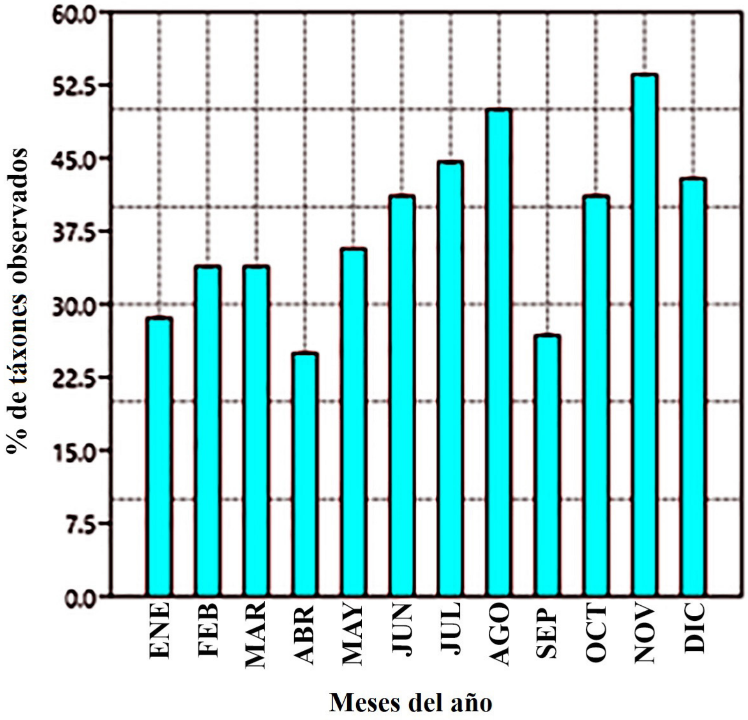

Figura 4. Representatividad de mariposas (Lepidoptera: Papilionoidea) en cada uno de los meses muestreados en el Parque Botánico de Camagüey.

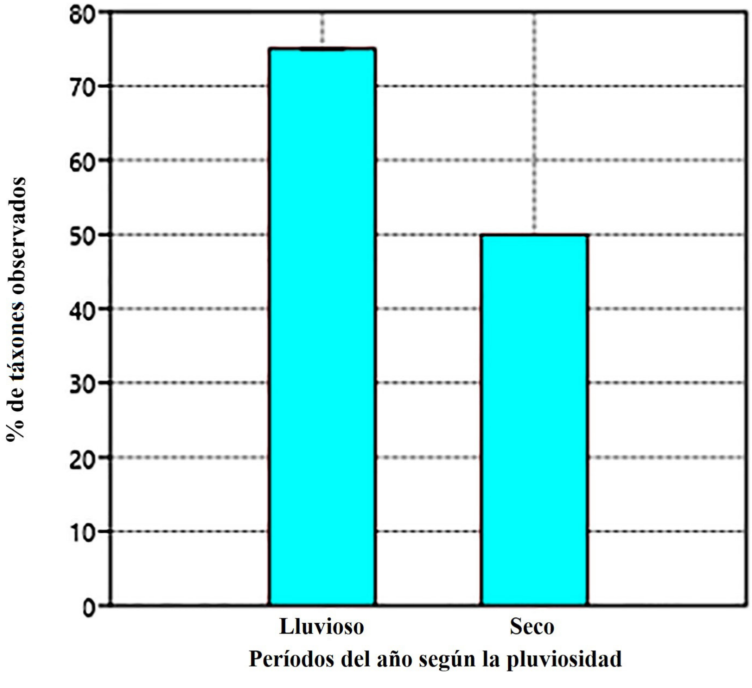

Figura 5. Representatividad de mariposas (Lepidoptera: Papilionoidea) en los periodos seco y lluvioso, que se distinguen en el Parque Botánico de Camagüey.

Sobre la base de un estudio inicial, se abren posibilidades para profundizar en cuáles son los parámetros ambientales óptimos para el desarrollo de los procesos de cría. Estas razones justifican que, tomando como punto de partida los datos expuestos sobre la presencia de táxones por meses del año y por estaciones, se calculó el índice de similitud de Jaccard, para ambas variables.

Como resultado de su aplicación, el índice de similitud de Jaccard mostró que, para un corte en 0.378, se identificaron tres conglomerados (Fig. 6). El primero comprende los meses de mayo-junio-julio-agosto; en este se destacan junio-julio (similitud 0.60), con el mayor grado de similitud entre todas las muestras, en tanto que mayo y agosto exhiben niveles de similitud menores. El segundo, corresponde a los meses de septiembre-octubre-noviembre-diciembre, en el que se distinguen noviembre-diciembre (0.59) y septiembre-octubre (0.52). El tercero abarca los meses de enero-febrero-marzo-abril; en este grupo sobresalen enero-febrero (0.52), mientras que marzo y abril muestran un más bajo grado de similitud.

Un análisis particular merece el comportamiento de la similitud en los períodos de lluvia y seca, ya que esta información posibilita ratificar, con mayor precisión, las especies que están presentes en ambos. También, permite, a partir de un estudio planificado, determinar las temporadas en las cuales cada uno de los táxones es de mayor abundancia (Dénommée, 2010). Dicha información resulta relevante para proyectar la exhibición de especímenes en el mariposario. Por otro lado, las fluctuaciones que se presenten en cada período pueden incidir en el desarrollo de las larvas por carencias en la disponibilidad de la planta hospedera (Constantino, 2002; Saragos & Dénommée, 2012), aspecto que resulta de gran interés para la cría.

El índice de similitud de Jaccard, según el dendrograma (Fig. 7), demuestra que la composición de las comunidades de mariposas durante los meses de lluvia y de seca son similares en un 62.5 %. Comparten 35 táxones de los 56 reportados para el Parque Botánico.

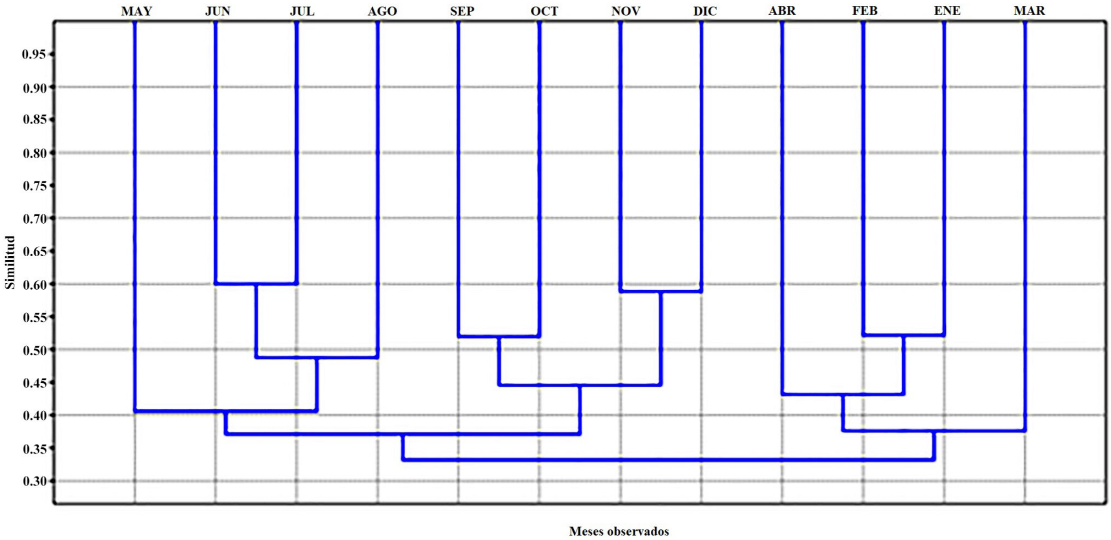

Figura 6. Dendrograma de similitud entre los meses muestreados.

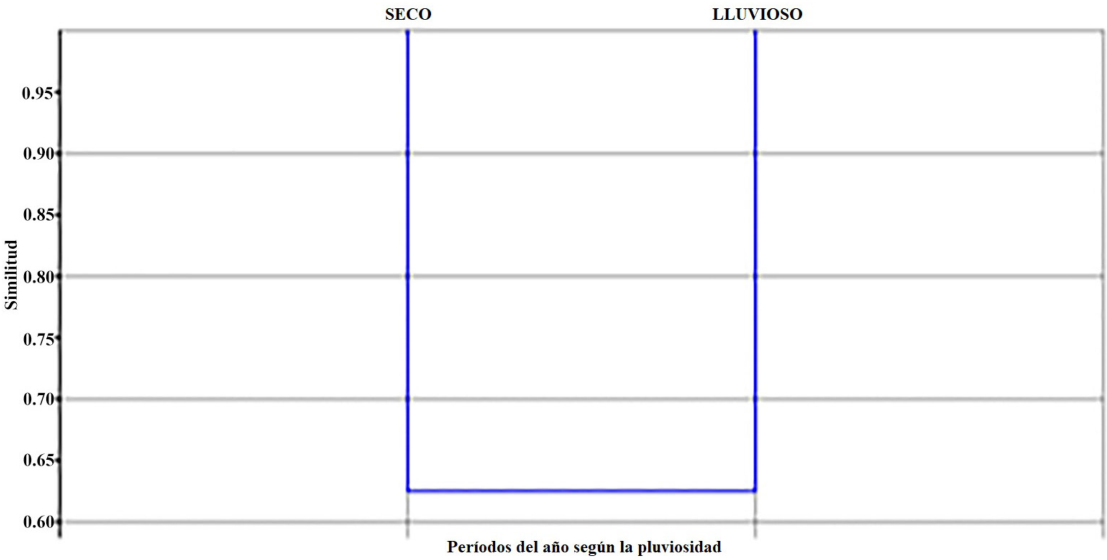

Figura 7. Dendrograma de similitud para los períodos lluvioso y seco.

Entre los ejemplos de mariposas cuya presencia coincide en la mayoría de los meses, tanto en el período de lluvia como en el de sequía, se encuentran: *Agraulis vanillae insularis*, *Anartia jatrophae guantanamo*, *Ascia monustes ebonina*, *B. polydamas cubensis*, *Calisto herophile*, *Danaus gilippus berenice*, *Eurema daira palmira*, *Heliconius charithonius ramsdeni*, *Leptotes casius theonus* y *P. demoleus malayanus*.

De este grupo fueron seleccionadas seis mariposas para su cría, reproducción y exhibición durante la primera etapa de trabajo del mariposario; *B. polydamas cubensis*, *P. demoleus malayanus*, *A. monustes ebonina*, *D. gilippus berenice*, *A. vanillae insularis* y *H. charithonius ramsdeni.*

Para la selección de estas mariposas, se tuvieron en cuenta los criterios expresados por Dénommée (2010) y por Saragos y Dénommée (2012):

- El valor estético de las mariposas, sus colores, tamaño y forma de las alas.
- La selección de táxones que fueron avistados y abundantes en todos los meses del año, lo que ofrece mayor facilidad para la obtención del pie de cría.
- La disponibilidad de hospederas, al tratarse de especies de plantas localizadas con facilidad en el parque, presentes en ambos períodos (lluvia y seca), potencialmente cultivables en la cuantía necesaria y que cuentan con exigencias mínimas ecológicas para su supervivencia.
- La prioridad para especies autóctonas y endémicas de la lepidopterofauna, dado el valor que ello le ofrece a la exhibición (tal es el caso de *B. polydamas cubensis*).

Los autores del presente trabajo, consideran oportuno adicionar a los anteriores criterios, los que se relacionan a continuación:

- Priorizar en el cultivo de plantas hospederas y nectaríferas a aquellas que son autóctonas y endémicas, como contribución a la conservación *ex situ* de los valores de la flora local o regional.
- Promover a cría de las especies/subespecies de mariposas presentes en las dos estaciones (lluvia y seca), por la posibilidad de ser exhibidas durante todo el año, dado su nivel de adaptación a disímiles condiciones ambientales. Ello no implicaría renunciar a la cría de otros táxones estacionales, que resulten significativos.
- La localización en el terreno, durante los muestreos realizados, de diferentes fases del ciclo de vida de las mariposas citadas, como un indicador de la pertinencia de criarlas en cautiverio, ya que se infiere que en el parque convergen condiciones ambientales favorables para su desarrollo completo.
- En la selección resulta peculiar el caso de *P. demoleus malayanus*, que, a pesar de su introducción en fecha reciente, ya manifiesta una amplia distribución en toda Cuba, tanto desde el punto de vista regional, como por la variedad de ecosistemas donde se ha establecido (Mancina et al., 2020). La cría y exhibición de este taxon puede ofrecer un importante atractivo al visitante, por su tamaño, su vuelo vistoso y su belleza en cuanto a forma y diseño. Por otra parte, brinda una oportunidad para educar a la población en la trascendencia del manejo de especies exóticas invasoras, desde las afectaciones que provocan sus larvas a cultivos de importancia como los cítricos y desde esta misma perspectiva, abre la posibilidad de investigaciones futuras, respaldadas por los recursos del laboratorio del mariposario, para perfeccionar dicho manejo en agroecosistemas que incluyen la producción citrícola.

CONCLUSIONES

La composición taxonómica de mariposas (Lepidoptera: Papilionoidea) del Parque Botánico de Camagüey consta en la actualidad de 56 especies y subespecies, que clasifican en 48 géneros, 15 subfamilias y cinco familias, con un bajo endemismo, como es de esperar en áreas urbanas y correspondientes a la región zoogeográfica central. No obstante, la riqueza de táxones infragenéricos puede considerarse en los rangos normales y propicia para la realización de acciones de conservación, dirigidas a la cría y exhibición de ejemplares autóctonos, una contribución significativa a la conservación ex situ de la lepidopterofauna cubana y camagüeyana.

Las épocas de lluvia y seca presentan similitudes en la composición de mariposas, lo cual constituye una ventaja para la selección de las especies que serán criadas y exhibidas en el mariposario, pues se presentan en ambas estaciones y pueden garantizar la continuidad del proceso de cría y exhibición que tendrá lugar en condiciones artificiales.

El diagnóstico efectuado, no solo permite establecer las bases para la cría y exhibición de especímenes en el mariposario, sino que, también servirá como referente para valorar las trasformaciones que se produzcan en la lepidopterofauna del Parque Botánico y proyectar estudios posteriores a partir de estos antecedentes.

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THE RECENT HISTORY OF AN INSULAR BAT POPULATION REVEALS AN ENVIRONMENTAL DISEQUILIBRIUM AND CONSERVATION CONCERNS

La historia reciente de una población insular de murciélagos revela un desequilibrio medioambiental y preocupaciones por su conservación

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ABSTRACT

With the global pandemic of Covid-19, the putative threats related to the increasing contact between wild animals, including bats, and human populations have been highlighted. Bats are indeed known to carry several zoonoses, but at the same time, many species are currently facing the risk of extinction. In this context, being able to monitor the evolution of bat populations in the long term and predict future potential contact with humans has important implications for conservation and public health. In this study, we attempt to demonstrate the usefulness of a small-scale paleobiological approach to track the evolution of an insular population of Antillean fruit-eating bats (*Brachyphylla cavernarum*), known to carry zoonoses, by documenting the temporal evolution of a cave roosting site and its approximately 250 000 individuals bat colony. To do so, we conducted a stratigraphic analysis of the sedimentary infilling of the cave, as well as a taphonomic and paleobiological analysis of the bone contents of the sediment. Additionally, we performed a neotaphonomic study of an assemblage of scats produced by cats that had consumed bats on-site. Our results reveal the effects of human-induced environmental disturbances, as well as conservation policies, on the bat colony. They also demonstrate that the roosting site is currently filling at a very fast pace, which may lead to the displacement of the bat colony and increased contact between bats and human populations in the near future. Our research outcomes advocate for a better consideration of retrospective paleobiological data to address conservation questions related to bat populations.

Keywords: Cave, French Antilles, Martinique, Island, paleoecology, taphonomy.

RESUMEN

Con la pandemia global de Covid-19, se han resaltado las amenazas putativas relacionadas con el aumento del contacto entre animales salvajes, incluidos los murciélagos, y las poblaciones humanas. Es cierto que los murciélagos son conocidos por portar varias zoonosis, pero al mismo tiempo, muchas especies enfrentan actualmente el riesgo de extinción. En este contexto, poder monitorear la evolución de las poblaciones de murciélagos a largo plazo y prever el futuro contacto potencial con los humanos tiene importantes implicaciones para la conservación y la salud pública. En este estudio, intentamos demostrar la utilidad de un enfoque paleobiológico a pequeña escala para seguir la evolución de una población insular de murciélagos frugívoros antillanos (*Brachyphylla cavernarum*), conocidos por portar zoonosis, documentando la evolución temporal de un sitio de descanso en una cueva y su colonia de aproximadamente 250 000 individuos. Para hacerlo, realizamos un análisis estratigráfico del relleno sedimentario de la cueva, así como un análisis tafonómico y paleobiológico del contenido óseo del sedimento. Además, llevamos a cabo un estudio neotafonómico de un conjunto de heces producidas por gatos que habían consumido murciélagos en el lugar. Nuestros resultados revelan los efectos de las perturbaciones ambientales inducidas por humanos, así como las políticas de conservación, en la colonia de murciélagos. También demuestran que el sitio de descanso se está llenando actualmente a un ritmo muy rápido, lo que podría llevar al desplazamiento de la colonia de murciélagos y a un aumento del contacto entre murciélagos y poblaciones humanas en el futuro cercano. Los resultados de nuestra investigación abogan por una mejor consideración de los datos paleobiológicos retrospectivos para abordar preguntas de conservación relacionadas con las poblaciones de murciélagos.

Palabras clave: cueva, Antillas Francesas, Martinica, isla, paleoecología, tafonomía.

INTRODUCTION

The interest in paleobiological data to address modern biodiversity issues has been increasingly pointed out in the context of the current environmental crisis (Barnosky et al., 2017; Boivin & Crowther, 2021; Dietl & Flessa, 2011). These approaches are especially relevant and impactful in islands whose Holocene ecosystems were often quickly anthropized and damaged before being studied by scientists (Hughes et al., 2023; Nogué et al., 2017) such as the Caribbean islands in which several studies already make use of the past record to address recent extinction and current conservation questions (Bochaton et al., 2021; Kemp & Hadly, 2015; Soto-Centeno & Steadman, 2015). Paleobiological approaches are most often the only way to describe the initial stages of natural environments and faunas before the impact of human colonization. In addition, as the relationship between health and environmental challenges is increasingly recognized such as with the "One Health" concept (Zinsstag et al., 2011), paleontological and historical data could also be of use to address past and even future sanitary issues. Regarding vertebrates, retrospective paleobiological data can, for instance, enable the documentation of the long-term evolution of wild animal populations which are possible carriers of zoonoses diseases. Such a study could have strong implications as the long-term increasing human pressure on natural environments progressively leads to an increase in the contact between human and animal populations, and thus of the risks of inter-specific transmission of diseases (Morand, 2020; Morand & Lajaunie, 2021). Recently, bats have been at the center of these preoccupations because, in addition to having many species currently facing extinction risks (Mickleburgh et al., 2002), they are known carriers of several diseases including coronaviruses diseases (Banerjee et al., 2019; Li et al., 2005) but also some that are known to be directly transmissible to human, such as histoplasmosis (Diaz, 2018). However, obtaining good-enough subfossil data to allow for a precise description of the evolution of a given faunal community, in the long run, is extremely challenging. Indeed, such approaches are mostly based on accumulations of subfossil bones. However, the composition of such assemblage is subject to many biases that mostly reflect the parameters of the accumulation processes of the bones (e. g. behaviors of a predator). For instance, even in caves that are currently occupied by bats, these animals might have been absent in the past and the fossil bone accumulation preserved in the substrate be made by a predator accumulator agent (Pedersen, Kwiecinski, et al., 2018). One of the ways to limit the biases impacting such study is to focus the investigation on very small chronological scales and geographic ranges in which the different parameters could be less susceptible to strong variations and in an in-depth study of a high-resolution paleobiological record is possible. This does not however mean that paleobiological approaches are unable to provide information relevant to tackle questions at broader scales as the evolution of the biological community in a single site can also reflect external large-scale phenomena.

In this study, we attempt to demonstrate the usefulness of a small-scale paleobiological approach to address broader biodiversity conservation and sanitary questions related to the Martinique Island population of Antillean fruit-eating bat (*Brachyphylla cavernarum* Gray, 1834). To achieve this goal, we try to reconstruct the recent history of a bat roosting site, the Chancel Cave located on the Chancel Islet, to document the evolution of the site and its bat colony through time. To do so, we use sedimentological and stratigraphic analysis of the sedimentary infilling of the cave as well as a taphonomic and paleobiological analysis of the bone contents of the sediment layers including an assemblage of animal scats collected in the stratigraphy of the site. Using the obtained paleobiological data we discuss the putative effects of environmental disturbances and conservation policies on the bat colony and address the question of its future evolution concerning potential sanitary issues related to the zoonotic pathogens the population is known to carry.

Regional setting

The Chancel Islet is a small volcanic island of 0.7 km² located 300 m from the Eastern Coast of Martinique Island in the Southern Lesser Antilles (Fig. 1). The Chancel Cave (60° 52.940' W 14° 41.666' N) is located in a cliff on the Northern coast of the Islet (Fig. 1), around 15 m above the sea level. The cave itself is around 30 m long, 20 m wide, and between 2 to 3.5 m high for a surface of around 444 m². Its opening is pretty narrow, less than 1.5 m high and 15 m wide. The cave is formed of volcanic puddingstone, a rock in which caves usually do not form. The formation process of the site remained thus unclear especially because the nature and content of the sedimentary infilling were never documented. The site is renowned to be hosting the biggest colony of Antillean fruit-eating bats (*Brachyphylla cavernarum* Gray, 1834) of Martinique. The first scientific testimony regarding the Chancel Cave and its bat colony dates back to 1979 when around 500 individuals of *B. cavernarum* were observed in the site (Magnaval, 1984) although the owner of the Chancel Islet indicates that the cave was already densely populated by bats at least several decades before that. Subsequent testimonies indicate the occurrence of several hundreds of bats in the cave in 1994, and a hundred in 1997 (Breuil, 1997).

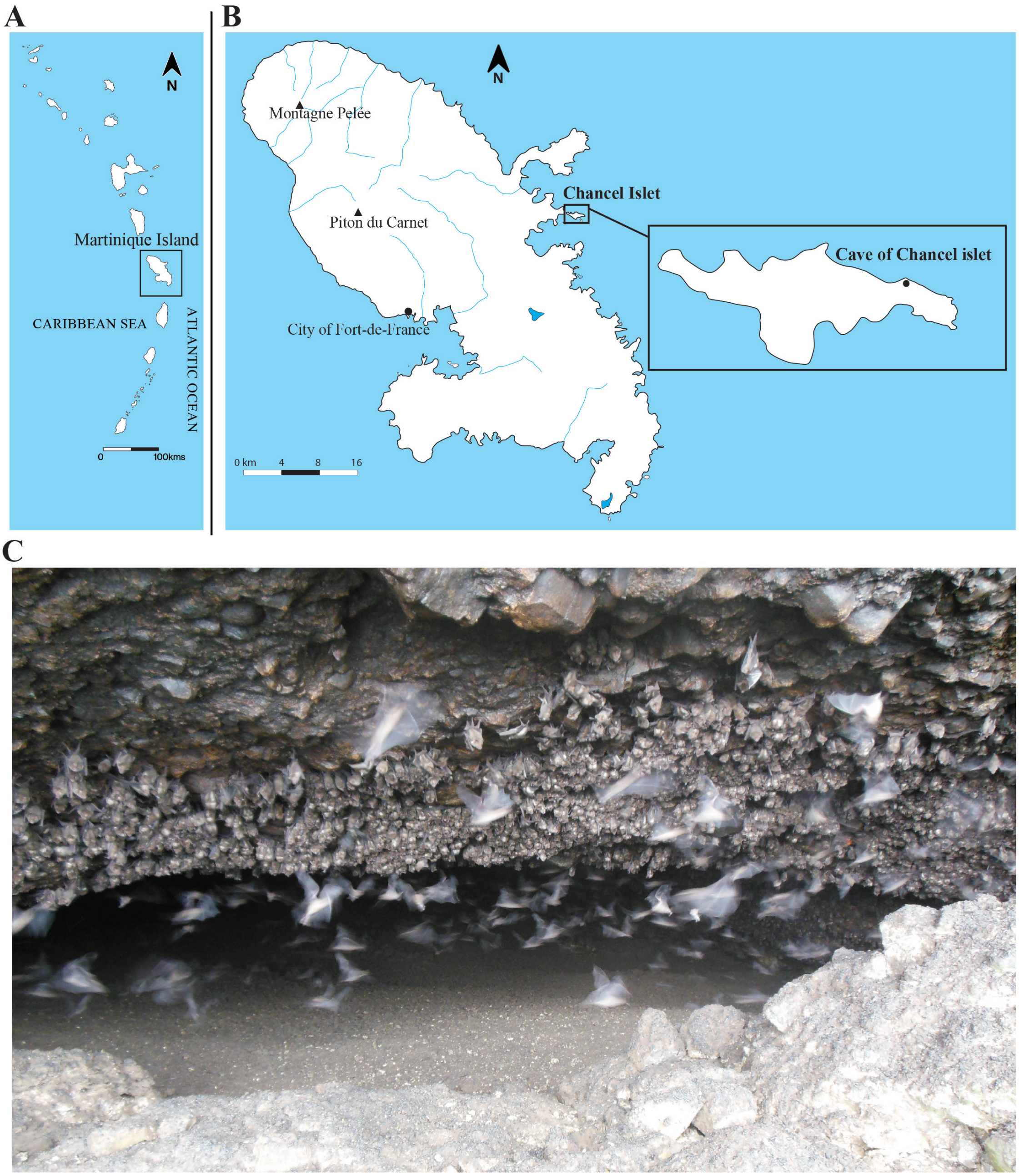

Figure 1. **A)** Map of the Lesser Antilles with the location of Martinique Island. **B)** Map of Martinique Island and the Chancel Islet with the location of the Chancel Cave. **C)** A picture of the entrance of Chancel Cave during the day showing *B. cavernarum* individuals being present very close to the entrance due to the lack of space on the cave's roof inside.

For this last observation, *B. cavernarum* was the most abundant species but the occurrence of four additional species was signaled: *Artibeus jamaicensis*, *Natalus stramineus*, *Pteronotus davyi*, and *Noctilio leporinus*. In 1999, the cave was occupied by 5000 *B. cavernarum* and at least 1500 *P. davyi* (Issartel, 2000). In 2004, 5000 *B. cavernarum*, and 200 *P. davyi* were observed (Issartel & Leblanc, 2004). In 2010, the cave was occupied by at least 24 000 individuals of *B. cavernarum,* and no other species was observed (Rufray com. pers.). In 2012, some individuals of *P. davyi* have been observed in the cave which was otherwise full of individuals of *B. cavernarum* (Questel com. pers.). Since 2013, all the observers have indicated that the cave was completely occupied by bats but the indicated number of individuals suffers some variation depending on the methodology used to count them. Indeed, the colony has been successively estimated to 250 000 (Lenoble & Queffelec, 2016), 353 250 (Issartel & Jemin, 2017), and 300 000 individuals (Issartel & Jemin, 2017). Our observations in the course of our paleobiological excavations in 2017 indicate the occurrence of between 100 000 and 250 000 individuals of *B. cavernarum* in the cave (Picard, 2017). The size of the colony has thus critically increased since 2004 and now attained its maximum size as there is no place left on the ceiling of the cave during daylight when the bats are inside the site.

Regarding the occurrence of putative predators, M. Breuil reports the presence of hundreds of cat scats on the floor of the cave in 1994 as well as of at least six mummified cats (Breuil, 1997). A living cat has been observed on the site in 2012 (Questel com. pers.) and some rare cats have been observed on the Chancel Islet between 2006 and 2015 but never more than one or two individuals (Ourly, 2006; C. Rodriguez, com. pers.). Due to the systematic eliminations of these cats to preserve the iguana (*Iguana delicatissima*) population of the islet, the species was absent from the island at the time of our investigation in 2017 (M. Bally pers. com.). It is likely that the situation of the 90's with several cats being present in the vicinity of the cave never happened again. The 1994 reports also indicate the occurrence of a rifle cartridge in the cave which indicates the possibility of human predation on the bat colony although this could also be related to the elimination of the cats (Breuil, 1997).

OBJECTIVES

- Study the long-term evolution of the bat population of Chancel Island.

MATERIALS AND METHODS

Excavation and recovery of bones and scats samples

Two excavation test pits have been performed on the site: one of 1 m² on the bench near the entrance of the cave (test pit 1), and one of 2 m² in the deepest part of the cave (test pit 2) (Fig. 2a). At the exception of a unique modern plastic artifact both test pit were free of manufactured remains. For logistical reasons, half of the sediment of only the first test pits has been fully sampled and divided into 12 spits 5 cm high each to allow for the search of small bone remains. To do so, 200 kg of sediment were water-sieved with 2 mm mesh, and the remaining bone elements were extracted and sorted to be studied. Samples of scat observed in the stratigraphy were also collected in both test pits to extract their bone content for additional studies.

After having been identified as cat scats based on their size and morphology, these scats were prepared individually by being soaked in water to enable their bone content to be manually extracted. The content of each scat has been isolated and studied. In total, 16 204 bone remains have been collected from the sediment of test pit 1, and 4365 from the scats. The sediment contained an important quantity of insect remains that were not collected. The stratigraphy of both test pits has been recorded, described, and drawn on-site. In both test pits, we reached a depth of respectively 0.6 m and 2 m before having to interrupt the excavation on a thick layer of scree that was impossible to pass through. A carbon-14 date (Lyon-15659(GrM)) has been performed on a sample of several bat bones collected at the base of the stratigraphy of test pit 1 (unit d) at the radiocarbon laboratory of Lyon. The 14C date obtained was calibrated using the software Oxcal v4.3.2 and the Intcal20 curve (Reimer et al., 2020).

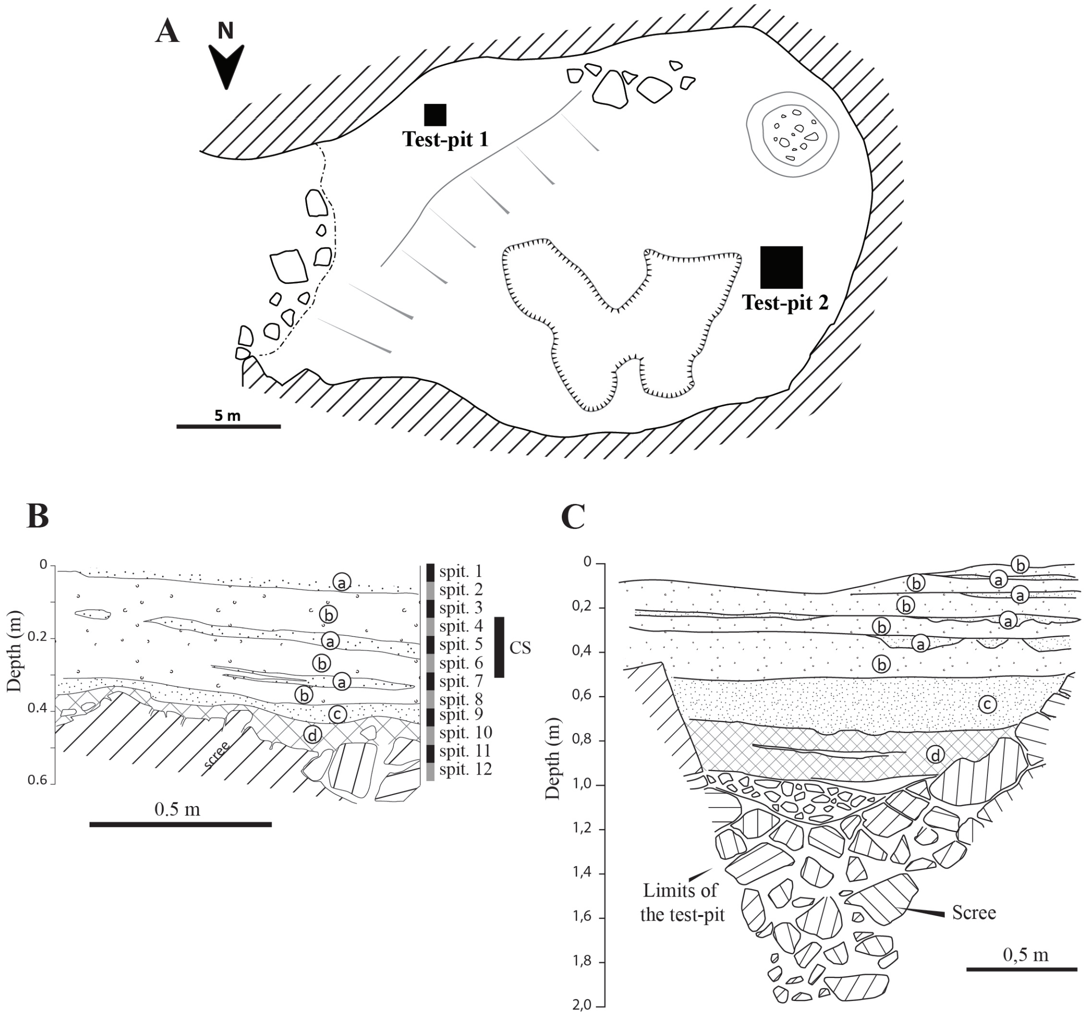

Figure 2. **A)** Map of the cave with the location of the two test pits. **B)** Stratigraphy of the first test pit. **C)** Stratigraphy of the second test pit. **CS:** Layers in which the cat scats were collected; **a, b,** and **c** are the different sedimentary facies described in the part of the result section dedicated to the stratigraphy of the cave.

Study of the bone assemblages

To follow the long-term evolution of the bat colony of the Chancel Cave in terms of taxonomic composition, number of individuals, size structure, predation pressures it might have been confronted with, as well as its use of the cave, we choose to perform detailed taxonomic, taphonomic, and paleobiological studies of the full sample of bones collected in the sediment and the scats. The general observation of the bones has been performed using a binocular microscope. The taxonomic identifications of the bones were obtained through a direct comparison of the recovered bones to modern individuals from the osteological comparative collection of the PACEA laboratory (Bordeaux, France). The morphology of *B. cavernarum* teeth and long bone has been used to define the maturity stage. We considered a specimen as immature as long as at least one of its teeth was not fully erupted or its roots not fully developed, and if at least one of the epiphysis of its long bones (humerus, radius, femur, and tibia) was still unfused to the diaphysis. These data were combined with the Minimal Number of Individuals (MNI) of each spit and scat, to determine the proportion of juvenile and mature individuals in each context. Generally in bats, the complete formation of the definitive teeth is synchronous with the starting of the flight of young individuals (Brunet-Rossinni & Wilkinson, 2009). There is however no study regarding the relationship between bone maturity and the first flight in *B. cavernarum*. In some species (e. g. *Myotis lucifugus*) the first flight occurs once the radius diaphysis is fully fused with both its extremities (Adams, 2000) but no data were collected on the other long bones although this should probably be also true for the bones that need to be rigid enough to support the physical constraints related to a flying activity (i.e. the humerus). Considering the proportion of bones of many different sizes we recorded as immature in comparison to the adult ones, it is possible that most subfossil specimens were not mature enough to fly. To make the interpretation of the data easier we thus choose to arbitrarily consider our juvenile age category as specimens who never flight even if the largest juvenile specimens might have been able to fly at least to some extent (Kunz & Anthony, 1982). The sex of the adult specimens has been identified when possible based on the morphology of the pelvic bone (Pelletier et al., 2017).

To investigate the anatomical distribution of the bone remains, a Proportional Representation (PR) (Dodson & Wexlar, 1979) of each considered anatomical part has been performed to compare the different spits of the test pit 1 and the samples collected in the scats. To do so, the count of each anatomical part has been divided by the number of occurrences of that given anatomical part in a complete skeleton. The obtained number was then divided by the Minimal Number of Individuals in the considered sample (e. g. a spit of the test pit). The Minimal Number of Individuals (MNI) has been defined using the frequency of the most abundant anatomical element in the considered sample (Lyman, 2008). Regarding the scats, to keep methodological homogeneity and to keep the comparison relevant with the material collected in the test pit, we defined the MNI using the full bone sample collected in all the scats and did not add up the MNI of each scat. The MNI of *B. cavernarum* in the stratigraphy of the test pit 1 has been estimated based on the number of radius bones recovered. In the scats, this number has been estimated based on the number of superior canines recovered. Both these anatomical elements were the best represented in their respective bone assemblages. Fragmentation of the remains has been registered on every bone element recovered from the scats and only on the humerus and radius of the bones collected in the sediment. For the bones collected in the sediment, we limited the documentation of the fragmentation to the basic condition of the bones (complete, sub-complete, or fragment) but for the scats, a completion rate (CR) corresponding to the percentage of the complete bone represented by each fragment has been estimated. This was made to allow for future comparisons with neotaphonomic studies. The maximal length of the complete juvenile and adult radius and humerus bones has been measured. The mixture analysis of the distribution of the bone sizes in the assemblage has been performed using the package “mixtools”(Young et al., 2016) on the open-source software R (https://cran.r-project.org/). The possible occurrence of digestion and tooth marks on the bones have been recorded using a binocular microscope on every bone attributed to a given anatomical part in the scat sample, and only on the humerus and radius bones collected in the sediment. To do so we followed the methodology and classification proposed by Stoetzel et al. (2021).

RESULTS

Stratigraphy and dating of the infilling

The infilling of the cave is similar in both test pits. Below the surface layer of fresh guano that has been removed before the excavation was a layer of fresh guano thick between 0.5 m (Test pit 1) and 1 m (Test pit 2) overlying a scree layer of unknown thickness. The guano layer displays four sedimentary facies (indicated in Fig. 2B and 2C): a) A medium fine grey sand rich in insects exoskeleton fragments of Tenebrionidae and Blattidae; b) An agglomerate of grey-brown multi-centimetric aggregates rich in hair, with a “Puerh cake” facies. The sediments on this facies are rich in chiropteran remains, represented by connected bones sometimes preserving the patagium of individuals with some rare fragments of elytra; c) A pseudo-sand formed of millimeter-sized fragments of light grey cylindrical droppings. The sediments on this facies are poor in chiropteran bones; d) A mass of sub-centimetric brown aggregates with felting linked to the abundance of hairs and presenting shimmering mineralizations, probably of gypsum. The organization of these facies is identical in the two test pits, with an alternation of the facies “a” and “b” in the upper part of the deposits, while the superposition of facies “c” and “d” characterizes the lower part of the guano layer (Fig. 2B and 2C). The preservation of bat specimens in the facies “b” is remarkable with the presence of partly complete bat mummies. However, a gradient of preservation is noted, with a progressive loss of the integrity of the desiccated skin of the specimens with depth. The astonishing preservation of organic elements in the guano layer is also made visible by the occurrence of preserved tree leaves, observed at a depth of 20 cm in test pit 1, and by the occurrence of connected cockroach exoskeletons observed below 50 cm of depth in the same test pit. Both test pits also yielded a stratigraphic horizon characterized by an abundance of cat scats at the base of the upper third of the guano layer (see CS in Fig. 2C and 2B). The same scree layer was encountered under the accumulation of guano in both test pits. It presents all the characteristics of a rockfall eboulis: open structure, unsorted blocks, random arrangement of elements, and fragmented block with a jigsaw fit (i.e. fractured blocks with no or limited displacement of the different fragments).

The most obvious particularity of the guano accumulation of the Chancel Cave is the very slow bacterial decomposition of organic matter. This is probably linked to the combined absence of humidity (dry cave) and the presence of salts in this coastal environment, playing an aseptic role (Magnaval, 1984). It is also likely that the very high ammonia content of the sediment, caused by the very high impregnation of the deposit with bat urine, also limits the development of microbiota. In these conditions, the decomposition has to be mostly done by the insect soil fauna present on the site (Tenebrionidae and cockroaches). Such activity can be linked to the formation of the facies "a" and "c" which are formed of droppings and fragments of these insects. Conversely, sediments on facies "b" are characterized by the absence of this decomposition process. There is thus a succession of phases when the guano is decomposed by soil fauna and phases when it is not, maybe in response to fluctuations in the abundance of insects in the cave. The cause of these fluctuations is however unknown. It could be a climatic signal (seasonal), a sign of natural events (sudden influx of salt into the cave during storms/hurricanes), or a variation in the number of bats roosting in the cave. In any case, the guano might not decompose during some periods in the cave which lead to a very high sedimentation rate caused by the quantity of guano created by the population of hundred thousand bats occupying the site. This is confirmed by the dating elements collected in the lower lens (facies d) of the guano layer, namely a plastic gun was made by the Gualandi company and circulating since the '60s or '70s, and a 14C date of 150 ± 30 BP (1667-1950 cal. AD) (Lyon-15659) obtained on bat bones in the same layer. These elements indicate that this lens might correspond to a longer period than the other layers that all formed in about 50 years. In addition, shimmering mineralizations (gypsum) in the facies "d" lens could indicate an incipient reaction horizon between the accumulation of guano and the rockfall eboulis (Hill & Forti, 1997). The acidification of this horizon and the resulting alteration of the bones it contains are all the more pronounced as the cave is formed in a volcanic breccia and, as such, no calcareous element buffers the action of acid solutions.

Analysis of the bone remains collected in the stratigraphy of the test pit 1

The 16 204 bone remains collected in the sediment of test pit 1 (this does not include the bones collected in the cat scats) were mostly located in the spits 1 to 7 with a better representation in facies "b" lenses (mean of 64 bones / dm^3) than in the sedimentary facies "a" ones (mean of 42 bones / dm^3) (Table I). Below the spit 7 the concentration of bone falls abruptly and become extremely low below the spit 8 in the facies "c", and "d".

In the sample, 99.9% of the collected bones were referred to as *Brachyphylla cavernarum*. The remaining vertebrate taxa are *Pteronotus* sp. represented by 5 bones in the upper facies "a" (spits 1 and 2), *Mus musculus* represented by 7 bones from the spits 2 and 7, and *Rattus* sp. represented by 7 bones (a mummified forelimb) in the spit 2. The minimal number of individuals of *B. cavernarum* in the whole assemblage is 380. In the first spit, the adult individuals of *B. cavernarum* are better represented than the juveniles with two adults for one juvenile (Table I). This tendency is reversed in every other spit where there is 1.9 juvenile for one adult in the second spit then between 2.7 to 6.6 juveniles for one adult in the subsequent spits. Determination of the sex of the *B. cavernarum* individuals was possible on 86 pelvic bones and indicated a ratio of 2.3 males for 1 female in the full assemblage but there was not enough sex data to enable a comparison between the different spits.

Table I. Counting and concentration of the bones collected in the sediment of the different spits of the test pit 1 along with the counts and observations made on the *B. cavernarum* bone remains. NISP: Number of Identified Skeletal Parts; MNI: Minimal Number of Individuals. This count does not include the bones recovered from the scats.

					Brachyphylla cavernarum					
Spit	**Stratigraphic facies**	**Volume décapage (dm^3)**	**NISP**	**Concentration bone/dm^3**	**MNI**	**Proportion juvenile/ adulte**	**% complete/ subcomplete Humerus**	**% complete/ subcomplete Radius**	**Digestion marks (humerus and radius)**	**Tooth marks**
1	a/b	36.8	1775	48	59	0.5	16.9	52.9	36	6
2	b	39.2	2466	63	52	1.9	51.8	82.3	4	1
3	b	26.7	1797	67	45	4.7	82.1	84.5	6	1
4	a/b	62.5	2119	34	47	2.7	72.5	94.5	1	0
5	a/b	45.0	1994	44	52	4.2	82.5	70.7	0	0
6	b	47.5	3094	65	62	4.5	82.6	92.5	0	0
7	b	23.3	1419	61	24	6.6	86.4	92.1	0	0
8	a/b	63.0	1108	18	30	4.1	84.2	55.8	3	1
9	c/d	64.5	309	5	6	/	/	/	0	0
10	d/scree layer	63.3	34	1	1	/	/	/	0	0
11	scree layer	60.8	27	0	1	/	/	/	0	0
12	scree layer	36.7	62	2	1	/	/	/	0	0
13	scree layer	84.2	0	0	0	/	/	/	0	0
		Total	**16204**	**Total**	**380**					

The length of the 104 measured fully fused and complete radius bones was between 57.5 and 64.7 mm and that of the 33 measured humerus bones was between 34.8 and 41.7 mm. The length of the unfused complete bones is between 16.7 and 56.8 mm for the radius and between 14.4 and 35 mm for the humerus. The size distribution of the adult radius is most likely bimodal as indicated by the results of a Hartigans' dip test for unimodality (P-val. > 0.05) and of a mixture analysis (Fig. 3A). The sizes of the immature radius are more evenly distributed but larger individuals closer to maturity are better represented (Fig. 3B). There is no difference in the size of the radius collected in the different spits. The bimodality of the size distribution of adult radius is difficult to explain, *B. cavernarum* is not known to present a strong sexual dimorphism if any (Catzeflis et al., 2018), and the size difference could potentially correspond to the presence of lineages of different size in the caves.

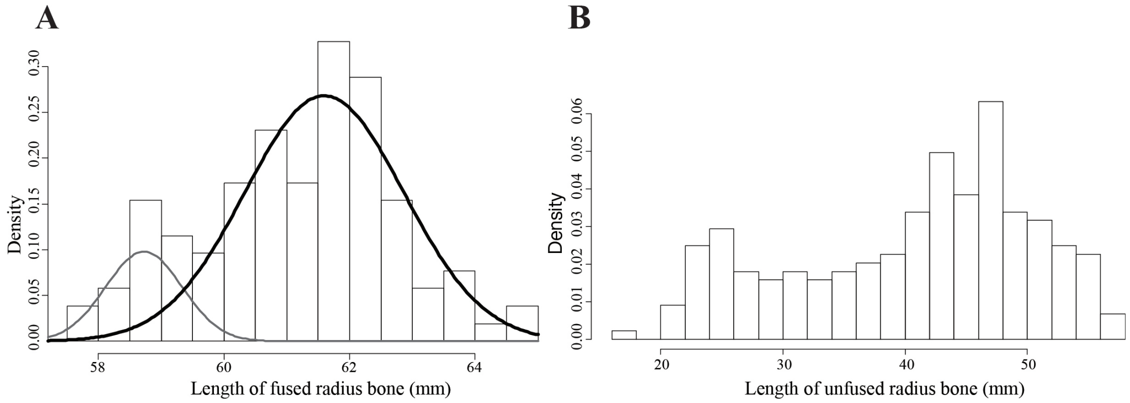

Figure 3. Size of adult (**A**) and immature (**B**) radius bones of *B. cavernarum* measured in the bone material collected in the test pit 1. The figure A shows the two normal populations resulting from the mixture analysis.

Regarding the anatomical distribution of the *B. cavernarum* remains, in every spit, we observed a tendency for a better representation of the anterior limbs toward the posterior ones and a strong under-representation of the smallest and most fragile anatomical parts (vertebrae, ribs, and clavicles) (Fig. 4A). This last tendency is the most pronounced in the deepest and thus oldest spits (8 and 9). The spit 1 was the most singular with its stronger representation of humerus, metacarpus, and anterior phalanx combined with a more pronounced scarcity of scapula bones and posterior elements. The mean PR of spit 1 (29%) was also lower than that of the others spits (43–35%). This is probably related to the abundance of the mummified bats' wings collected in this layer which increased the MNI of this layer. Otherwise, the overall anatomical distribution of the bone elements is mostly similar in every spit.

The fragmentation of *B. cavernarum* humerus and radius is limited with an average of 66.3% of humerus and 77.6% of radius being complete or sub-complete in the assemblage. The fragmentation of the humerus is far stronger in spit 1 (16% of complete or sub-complete bones) and becomes weaker in spit 2 (51% of complete or sub-complete bones) and subsequent spits (71% of complete or sub-complete bones). Among the broken humerus, the distal part represents 125 of the 132 fragments and a clear breakage pattern has been observed in the material collected in spit 1 and 2 (Fig. 4A). Similar observations could be made on the radius which are more fragmented in the spits 1 and 8 (50% of complete or sub-complete bones) than in the other spits (between 70 and 94% of complete or sub-complete bones). Similarly, with the humerus, the distal part of the radius is also better represented than the proximal part with respectively 47 and 27 fragments. Putative digestion marks have been observed on 3.8% of the humerus and radius fragments of the sample (50 occurrences). Most of these traces are from spit 1 (N=36) and spit 2 (N=10). The rare tooth marks (N=9) were observed in spit 1 (N=6).

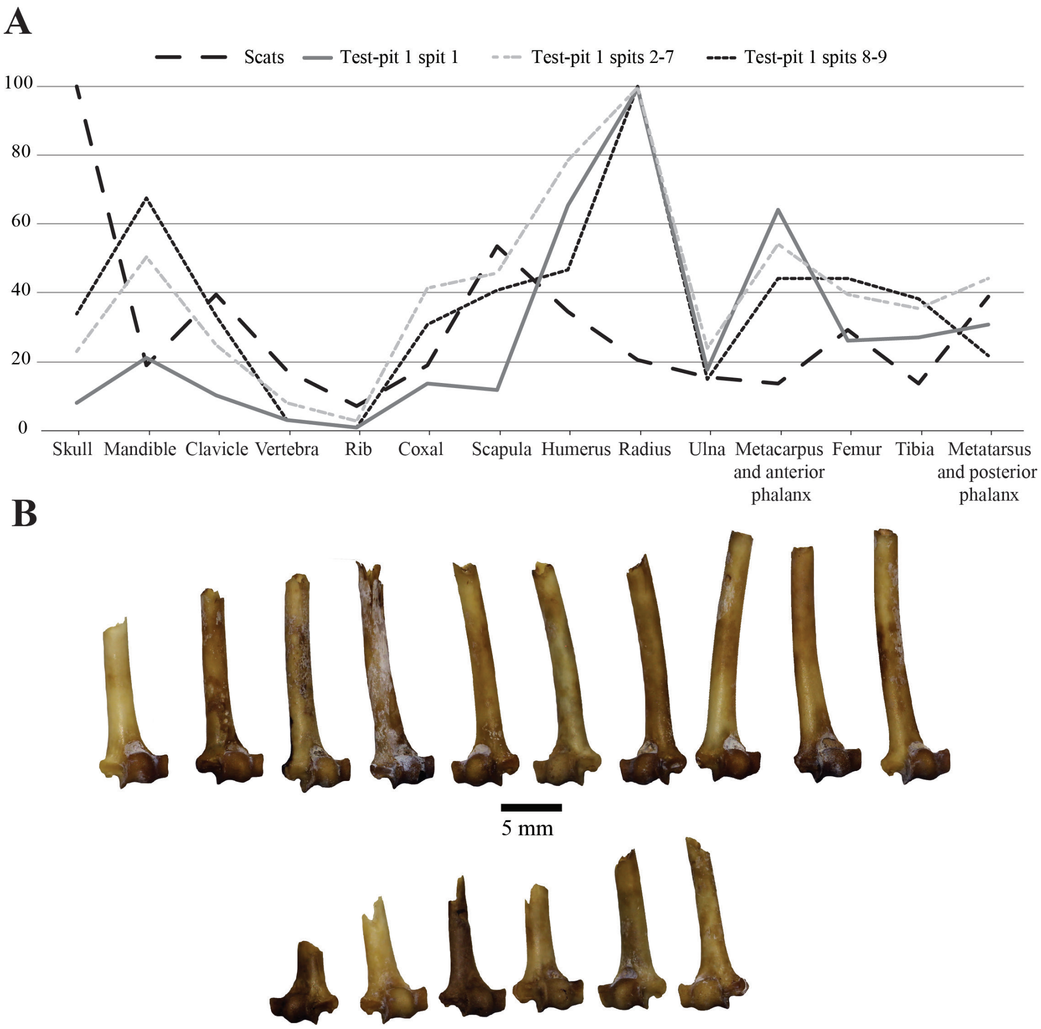

Figure 4. **A)** Anatomical distribution of the remains of *B. cavernarum* in the scats and the different spits of test pit 1. **B)** Broken humerus collected in spits 1 and 2 of test pit 1.

Analysis of the scats

The 67 analyzed scats contained between 1 and 564 bone remains (mean=65) for a total of 4365 bone remains (Sup. Tab. I). The assemblage is nearly only composed of remains of *Brachyphylla cavernarum* (NR=3569; MNI=29) a bat represented in nearly every scat (65/67) with some rare additional taxa. The only other bat represented in the assemblage is *Pteronotus* sp. (NR=9; MNI=1) which was identified in a single scat. Rodents are also represented with four scats containing remains of *Rattus* sp. (NR=86; NMI=2). Non-mammal vertebrate taxa are represented in two scats, one containing many remains of *Anolis* lizards (NR=560; MNI=9), and one containing bones of an *Eleutherodactylus* sp. frog (NR=4; MNI=1). Regarding the maturity of *B. cavernarum* individuals identified in the scats, one out of three (33%) was an immature individual (Sup. Tab. I).

Out of *B. cavernarum*, no taxon had well-represented enough remains in the scats to enable useful observations of the anatomical distribution of their bones in the assemblage. Regarding *B. cavernarum*, the skull was the best-represented anatomical part thanks to the high proportion of teeth in the assemblage (Fig. 4A). Overall, all the anatomical parts were represented and no anatomical parts were excluded from the assemblage. However, the smallest and bulkiest bones that are less likely to be fragmented and destroyed during the mastication and digestion processes are the best represented (teeth, proximal scapula, and posterior extremity). The slightly better representation of the axial and posterior parts of the skeleton might indicate that the wings of the prey were not consistently ingested by the predator but this could also only reflect a preservation difference. Regarding the humerus, there is no tendency for a better representation of the distal or proximal parts and thus no clear relation between the anatomical distribution of the remains observed in the scats and the complete bat wings collected in the sediment of the spit 1.

The average completion rate (CR) of the bones in the scats is 36% with the largest bones (e. g. skull: 6%, mandible: 24.5%, long bones: 13%) being much more fragmented than smaller ones (e. g. posterior phalanx 3: 91.5%; teeth: 90%). Only 11.4% of the bones of the overall sample were complete, 90% of these being teeth, metatarsus, and posterior phalanx. The overall breakage is very strong as attested by the fact that 1847 bone remains out of the 4365 composing the full assemblage were small fragments that could not be attributed to a given anatomical part. The strong fragmentation of the bones did not enable any measurement of the long bones or sexing of the specimens.

In the whole scats sample, 81% of the bones were presenting digestion marks ranging mostly from high (63%) to medium (27%) and low (9%) intensity (Fig. 5). These traces are distributed evenly on all anatomical parts at the exception of the terminal posterior phalanxes whom 36% lack any digestion marks thanks to the protection of their keratin sheath that was in many cases preserved in the scats.

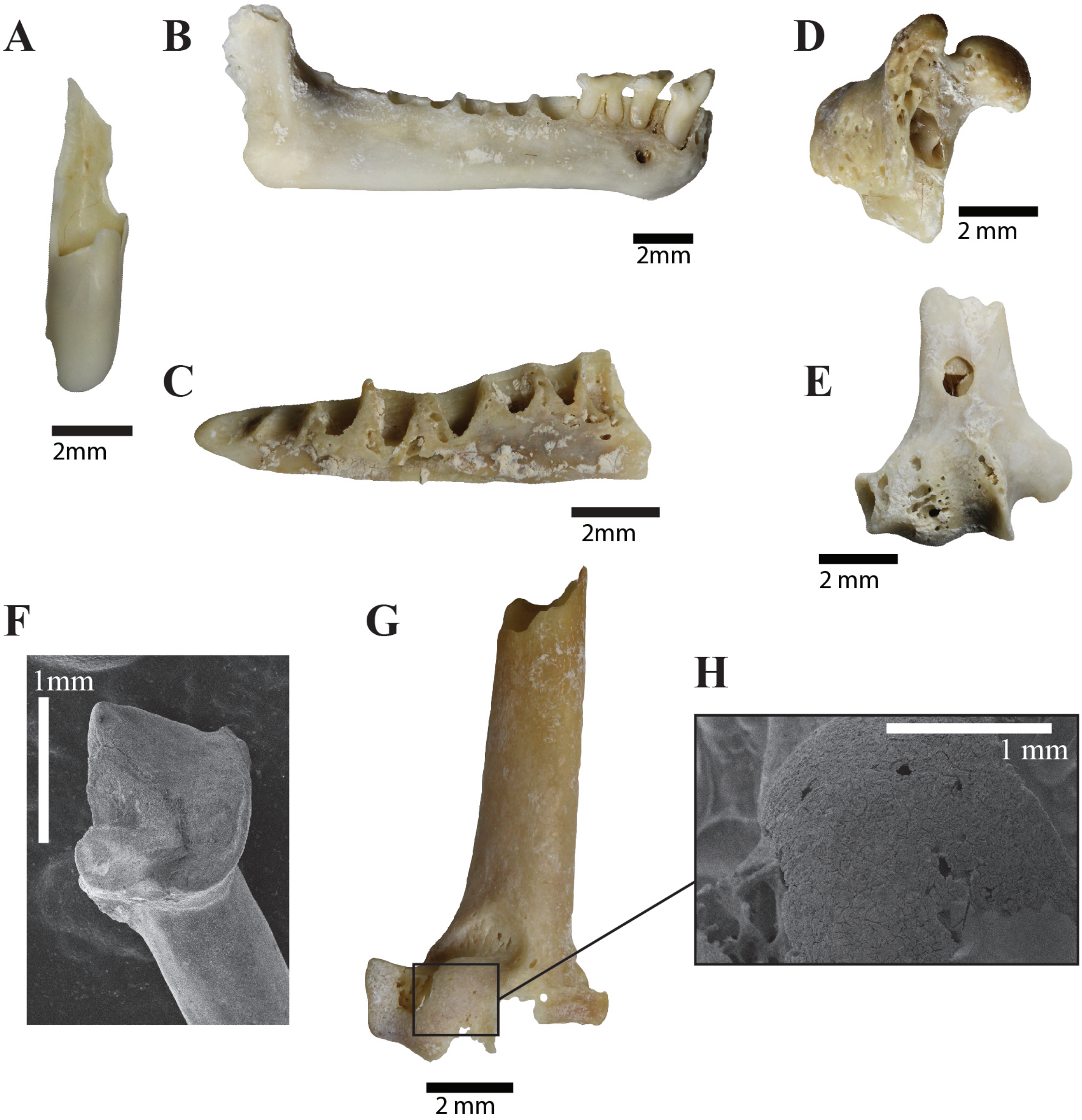

Figure 5. Digested *Brachyphylla* bones and teeth from the cat scat samples. **A)** Heavily digested long bone diaphysis; **B)** heavily digested right mandible; **C)** heavily digested left mandible; **D)** heavily digested proximal humerus; **E)** heavily digested distal humerus; **F)** heavily digested teeth with the enamel partly detached from the crown; **G)** heavily digested humerus; **H)** focus on the distal epiphysis of the picture G showing the surface state of the bone.

DISCUSSION

Accumulation process of the sedimentary infilling and the history of the cave

The sedimentological and faunal bone data collected in the stratigraphy indicate that the complete sedimentary infilling of the cave is composed of bat guano which is associated with a high frequentation of the cave by the Antillean fruit-eating bat (*B. cavernarum*), a species that is over-dominant in the bone assemblage. Juvenile specimens account for the majority of *B. cavernarum* individuals in every layer of the Chancel Cave infilling except for the first spit in which they only account for around 30% of the specimens. This unambiguously indicates that the cave has always and still functions as a maternity roost. Gravid *B. cavernarum* females usually leave their colony roosting site to establish maternity roosts which means that only some sites are used by females to give birth and take care of their newborn. In some cases, this segregation of the bats' individuals can take place in a single site. However, the use of the Chancel Cave as a maternity roost was never evidenced during the observations made directly on the bat colony (Issartel & Jemin, 2017). An explanation could be a seasonality pattern in the exploitation of the cave by the colony. Indeed, the birthing period of *B. cavernarum* is from end-April to end-June (Pedersen, Kwiecinski, et al., 2018; Pedersen, Larsen, et al., 2018; Swanepoel & Genoways, 1983) while the cave has been visited during winter or at the beginning of the spring. Regarding the sex ratio of the adult *B. cavernarum* individuals studied in our subfossil bone assemblage, it is biased toward males with more than two males for one female. Such a ratio is not congruent with a maternity roost in which adult males should be absent (Bond & Seaman, 1958; Genoways et al., 2007, 2012) but is coherent with a site not working as such (Pelletier et al., 2017). This discrepancy could be explained by the position of the test pit from which the bones were collected, near the entrance of the cave. Indeed, in some sites, both male and female individuals are present in maternity sites but with spatial segregation. In such sites, females occupy the deepest parts of the roost (Genoways et al., 2007). It is thus possible that the Chancel site is widely used throughout the year with spatial segregation of the male and female inside the cave at least during the birthing period.

Apart from the cat droppings collected in the sediments and the bone they contain, the paleobiological and taphonomic data indicate that the bone remains collected in most of the stratigraphy correspond to an attritional mortality of bats roosting in the cave. Most of these bones are complete and lack predation marks. Another indication is the fact that most represented specimens found in the sediment are juvenile individuals. The taphonomic observations made on the scat samples indicate that the bone contents of the layers of test pit 1 do not correspond to the content of dislocated scats. The size distribution of the immature radius does however not correspond to a typical attritional mortality profile. Indeed, it has been documented that the mortality of juvenile bats is much higher in newborns (Foster et al., 1978; Hermanson & Wilkins, 1986) and decreased over time until maturity. Our size profile shows the exact opposite with an increased occurrence of larger individuals in the bone samples. Apart from the cat scats, there is however no evidence of predation in the material below the spit 2. Thus, this strong representation of large immature individuals could reflect a preservation bias with the bone of the youngest individuals being less well preserved and may have been destroyed by scavengers because of their poor calcification state. The cave is currently occupied by an important population of American cockroaches (*Periplaneta americana*) that are known to consume and destroy bones (Parkinson, 2012), and we observed feeding from bats carcasses in the cave.

Another explanation for the absence of newborns in the bone assemblage could also be that these individuals were located in other areas of the cave maybe in the deepest parts from which we did not collect bone samples. The taphonomy of the bone assemblage is in any case different in the uppermost part of the infilling (spit 1–2) in which several clear pieces of evidence of predation are present in addition to the attritional mortality profile visible in the other spits. These two most-upper spits were also the only one to contain remains of a second species of bats (*Pteronotus* sp.) but their bones remains scars in respect to the proportion of this species observed in the cavity between 1999 and 2010. This could have several explanations including different use of the cave by the different bat species.

The spits 4–6 contained many cat scats whose content was nearly only composed of *B. cavernarum* remains. Our results indicate that the cats who produced these scats were consuming all the body parts of both adult and juvenile bats. This evidence of predation from the scats is associated with some predation marks in the material collected in the sediment but this phenomenon is difficult to characterize on the bone assemblage collected in the sediment. At the time of the formation of these layers, we can confidently say that the cave was exploited by cats. This population of cats was probably heavily reliant on the bat colony given the content of the scats and also the fact that Breuil described the cats present in the cave in 1994 as starving which indicates the lack of food sources available to them (Breuil, 1997). In spit 1, reversely to all other splits, adult specimens of *B. cavernarum* dominates the bone assemblage and a lot of wings intentionally separated from the body of the bats, most of the time at the level of the humerus were present in the sediment. The anatomical distribution of the remains also indicates that the other body parts corresponding to these wings were absent from the bone assemblage. This kind of behavior (separation of the wings and body of the predated bats) has been observed on cats predating bats in Puerto Rico (Rodríguez-Durán et al., 2010) but spit 1 does not contain cat scats and this behavior is not backed by the observation made in our taphonomic analysis of the scats from spits 4 to 6 which indicate that bat wings were also consumed by the cats. These arguments make it difficult to attribute this strong concentration of wings in the spit 1 to predation by cats and the strong standardization of the behaviors we observed might also correspond to hunting by humans as bats are known to be occasionally consumed in Martinique (Lenoble, 2020; Negre, 1967) and that accumulations of bat wings in poaching sites have been observed by some of us in Guadeloupe. This hypothesis does however not explain the stronger representation of digestion marks on the bone material collected in the spit 1 which could be related to predation by another mammalian predator. In any case, this predation does not correspond to nowadays events as we removed the fresh guano before starting our excavation and during our visit to the cave, we saw no evidence of predation on bats other than the consumption by cockroaches and rats of individuals that felt naturally from the ceiling.

Regarding the dating of these different events, the occurrence of a plastic gun was produced since the ‘60s or ‘70s at the base of the guano deposit (facies “d” lens, just above the scree layer), combined with the obtained 14C date, allow us to estimate the minimum age of the base of the guano accumulation around 1960-1970 even if this layer as a whole may have formed during a much longer period (several hundred years). The layers containing the cat scats (spits 4–6) probably correspond to the situation observed by M. Breuil in 1994 (Breuil, 1997) but is now below 10–20 cm of additional sediment. These direct and hypothetical observations are coherent with a mean sedimentation rate of 1.6 cm per year in test pit 2. Considering this estimation and the few centimeters of fresh guano removed before the excavation, we estimate the formation of the upper layer of the stratigraphy to have formed around 5 years before our visit to the cave in 2017. The rate of sedimentation is lower in test pit-1, closer to the entrance of the cave, with the deposition of 0.85 cm of sediment per year. The maximal height of the cave is 3.5 m and its minimal height at the entrance is 1.5 m. In case the mean sedimentation rate generated by the bats stays the same, the site would be filled in 220 years and its entrance fully closed in 85 to 180 years. This means that the occupation of the site is not sustainable in the long run and that the colony will have to start looking for new shelters in the next decades.

Conservation and sanitary concerns raised by the future evolution of the colony

The observations from the literature indicate that the size of the *B. cavernarum* colony in the cave of Chancel Islet rose exponentially between 1979 and 2017. This is however in contradiction with the observations made in the historical record. Indeed, the speed of the guano deposition we estimated indicates that the cave has been densely occupied by this species since the formation of the "d" layer that we dated to around 1960-1970. We can thus hypothesize that the size of the colony shrank between 1960 and the first published observation of the colony in 1979 (Magnaval, 1984) which may be contemporaneous with the presence of cats in the cave even if this was only formally signaled in 1994 (Breuil, 1997). It is thus possible that the presence of cats in the cave led to a lesser frequentation of the site by *B. cavernarum* which also left some place for additional species to be present in the site as it is visible in the bone assemblage contemporaneous to the presence of cats as well as in the literature. The demise of the cats which exploited the cave seems to have reversed the situation to what it was previously with the presence of a massive monospecific colony of bats in the site that will inevitably lead to the filling and thus to the loss of the cave as bat roosting site in the next 100 to 200 years. In any case, we can observe that neither the predation by cats nor human seems to have had a significant long-term impact on the bat population size. Indeed, the past data provided by the paleoecological assemblages suggest that this site has been saturated by the colony for a long time and that the casual disturbances did not impact this global trend.

The stratigraphy of the Chancel Cave is very atypical as its sedimentation rate is several hundred times faster than the rate usually observed in the numerous cave paleontological deposits investigated in the Lesser Antilles in which *B. cavernarum* is a dominant bat species (Bochaton et al., 2015; Stoetzel et al., 2016; Stouvenot et al., 2014). The fact that such a sedimentation rate was never observed in the past record is a strong indication that the size of the colony of *B. cavernarum* and/or its concentration in the Chancel site is not a sustainable situation. This could reflect an imbalanced bat fauna reflecting human environmental modifications made on an island where synanthropic species dominate the now transformed environments. Several studies carried out in South American tropical forests show that environmental modification through deforestation and habitat fragmentation leads to a loss of species diversity in bat fauna and to the domination of modified environments by a few opportunistic species (Brosset et al., 1996; Cosson et al., 1999; Delaval & Charles-Dominique, 2006). In Martinique, such an imbalanced bat fauna is suggested by mist-net captures and acoustic detections showing that a few numbers of generalist species are overabundant in secondary environments (Barataud et al., 2017). *Brachyphylla cavernarum* is one of these species, along with the other Phyllostomid bat species, *Artibeus jamaicensis*, and the two insectivorous species *Molossus molossus*, and *Pteronotus davyi*. Moreover, *Brachyphylla cavernarum* is the most abundant species found in sampling stations (Barataud et al., 2017), notably in guava orchards where it is considered as a pest (Catzeflis et al., 2019). The fact that *Brachyphylla cavernarum* tends to become a dominant species in Lesser Antillean islands heavily impacted by humans is also evidenced in St. Lucia (Pedersen, Kwiecinski, et al., 2018) or Sint Eustatius (Pedersen, Larsen, et al., 2018). It is suggested as well by the fact that this species is one of the few species in the Lesser Antillean core bat fauna to occur on all the islands within its distribution range (Pedersen, Kwiecinski, et al., 2018). In addition, the beneficial effect of the human modification of the environment for this species is supported by the fossil record of Marie-Galante Island. This record shows that *Brachyphylla cavernarum* became a dominant species in the bat fauna during the Holocene and, even more so, in the second half of this period, i.e. when man was colonizing the archipelago. In the meantime, the species characterizing the pre-anthropic periods became very scarce or extirpated (Stoetzel et al. 2016). *Brachyphylla cavernarum* is a frugivorous bat (Nellis & Ehle, 1977), able to sustain on alternate forage (Pedersen et al., 2003), and to be occasionally or seasonally pollinivorous or insectivorous (Bond & Seaman, 1958; Lenoble et al., 2014; Pedersen et al., 1996), this dietary plasticity enabling it to cope with environmental vagaries (Pedersen, Kwiecinski, et al., 2018). In addition, the species benefits directly from the human transformation of the insular environments through the multiplication of the pioneer tree *Cecropia schreberiana* from which this bat obtains part of its subsistence (Barataud et al., 2017). It also strongly benefits from the introduction of fleshy fruits in the Lesser Antilles since the Amerindian times and their current concentration in the form of orchards (Picard & Catzeflis, 2013). All these conditions make *Brachyphylla cavernarum* a species that benefits from the competitive imbalance between the different bat species.

However, the saturation of the Chancel site could only indicate that the alternate best suitable roosts occupied by these bats are no longer available. It is noteworthy that all the medium and large caves in Martinique are occupied by animal colonies, birds, or bats, which demonstrates the saturation of the carrying capacity of the caves (Lenoble & Queffelec, 2016). The situation of the Chancel Cave saturated by *B. cavernarum* individuals can be encountered at a much smaller scale in man-made sites such as mines, wells, or old-building, as well as several important natural roosts of this species, hosting several thousand to tens of thousands individuals (Issartel & Jemin, 2017). The occupation of man-made roosting sites thus complements the small number of caves available on the island. The cave-nesting behavior of most West Indian bats is a factor of adaptation to the climatic and environmental hazards of the Lesser Antilles (Rodriguez-Duran, 2009) and these sites are thus crucial to maintain bat populations (Pedersen, Larsen, et al., 2018). The number of available roosting sites is thus likely to be the most important factor determining the size of the *Brachyphylla cavernarum* population in Martinique.

Whatever the explanation for the saturation of the Chancel site, sub-fossil data unambiguously demonstrates that the c.a. 250 000 bats of the Chancel Cave will have to find shelters others than this cave in a context of saturation of the existing roosts. The population of *B. cavernarum* roosting in Chancel corresponds to nearly half of the total population of this species in Martinique (Issartel & Jemin, 2017) and the unavailability of the Chancel Cave is very likely to have a major impact on the ecology of these bats in Martinique. This situation causes serious sanitary concerns as *B. cavernarum* is known to be able to roost near and inside human habitations and to be a vector of histoplasmosis in Martinique (Demoly, 2003; Leblanc & Issartel, 2008; Mouret, 1980), a disease associated to the fungus *Histoplasma capsulatum*, transmitted to human through the inhalation of the spores contained in bat guano. The occurrence of endemic cases of this zoonosis has been previously reported in Asia (Baker et al., 2019; Gopalakrishnan et al., 2012; Randhawa, 1970), Equatorial Africa, North and South America (Diaz, 2018), as well as in the Caribbean (Fincham, 1997; Tamsitt & Valdivieso, 1970), and La Martinique Island (Agossou et al., 2023; Demoly, 2003; Leblanc & Issartel, 2008; Magnaval, 1984; Mouret, 1980) where transmissions of this disease from bats to humans in anthropized areas occupied by *B. cavernarum* were also documented (Agossou et al., 2023; Minoza et al., 2016). Histoplasmosis is in most cases a benign disease for humans but its mortality rate can reach more than 6% in immunosuppressed patients (Assi et al., 2007; Kauffman et al., 1978). This disease as well as the potential threat caused by the presence of bat roosts in the area occupied by human populations cannot thus be ignored. In addition, bats can carry many other unknown zoonoses as may have been emphasized by the fact that several members of our excavation team presented, at the return of the fieldwork, symptoms of atypical lung infection, although we wore FFP3 masks during all the excavation, but were all negative to histoplasmosis serologies. The case of the Chancel Cave shows how anthropization phenomenon and conservation policies can impact the ecology of zoonoses which highlights the importance of integrative approaches to manage such diseases and prevent future outbreaks (Morand et al., 2019; Morand & Lajaunie, 2021; Schrag & Wiener, 1995).

CONCLUSION

Our investigation of the long-term evolution of the Chancel Cave shows how difficult it is to artificially keep the balance between species in environments disturbed by human activities. Paleobiological data alone are not enough to explain how the colony of *B. cavernarum* became so large and several hypotheses remain plausible. The most likely hypothesis, for now, is a combination of the feeding habits of *B. cavernarum* which favored the cultivated fruit easy to find in Martinique, the protected status of the species, and the absence of predators related to the conservation policies applied to the Chancel Islet. Independently of the causes, we unambiguously show that the roosting cave of the Chancel Islet runs to its demise as it cannot sustain such a large colony of bats in a near future. To avoid this situation, either control of the size of the bat colony should be set up or some work be conducted on the site to avoid its complete filling up. This last possibility would however be very difficult to put in place considering the poor accessibility of the site. The possible emergence of zoonosis from the Chancel colony should also not be overlooked and further work should be conducted on the pathogens these bats may carry. Finally, from a more global point of view, this study calls for further work regarding the often poorly investigated subfossil record to investigate biodiversity and sanitary questions to better understand past events and try to prevent arising and possibly elusive issues as it was the case for the Chancel Islet bat colony.

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Suplement of Table I

	Brachyphylla cavernarum		*Pteronotus* sp.		*Rattus* sp.		*Anolis* sp.		*Eleutherodactylus* sp.		cf. Aves	Vertebrata			Age of B. cavernarum		
Scat n°	**NISP**	**MNI**	**NISP**	**MNI**	**NISP**	**MNI**	**NISP**	**MNI**	**NISP**	**MNI**	**NISP**	**NISP**	**Total NISP**	**Total MNI**	**Juvenile**	**Adult**	**Unknown**
Cr-02	53	2											53	2	1	1	
Cr-03	24	1											24	1			1
Cr-04	18	1											18	1			
Cr-06	22	1											22	1	1		
Cr-07	243	1	9	1									252	2		2	
Cr-08	38	2											38	2	1	1	
Cr-09	97	2											97	2	1	1	
Cr-10	79	2											79	2	2		
Cr-11	18	1					60	2				21	99	3	1		
Cr-12	145	2											144	2	1	1	
Cr-13	38	1											38	1		1	
Cr-14	41	2											41	2			2
Cr-15	29	1											29	1		0	1
Cr-16	34	1											34	1		1	
Cr-17	30	1											30	1			1
Cr-18	32	1											32	1			1
Cr-19	65	1											65	1			1
Cr-20	13	1											13	1			1
Cr-21	83	2											83	2	1	1	
Cr-22							560	8	4	1			564	9			
Cr-23	6	1			20	1						42	68	2			1

	Brachyphylla cavernarum		*Pteronotus* sp.		*Rattus* sp.		*Anolis* sp.		*Eleutherodactylus* sp.		cf. Aves	Vertebrata			Age of B. cavernarum		
Scat n°	**NISP**	**MNI**	**NISP**	**MNI**	**NISP**	**MNI**	**NISP**	**MNI**	**NISP**	**MNI**	**NISP**	**NISP**	**Total NISP**	**Total MNI**	**Juvenile**	**Adult**	**Unknown**
Cr-24	66	1											66	1		1	
Cr-25	186	3											186	3			3
Cr-26	62	1											62	1		1	
Cr-27	80	2											80	2	1	1	
Cr-28	17	2											17	2	1	1	
Cr-29	84	1											84	1		1	
Cr-30	38	1											38	1		1	
Cr-31	47	2											47	2	1	1	
Cr-32	111	1										3	114	1		1	
Cr-33	1	1											1	1			1
Cr-34	46	1											46	1			1
Cr-35	6	1											6	1			1
Cr-36	9	1											9	1			1
Cr-37	49	1											49	1		1	
Cr-38	74	1											74	1		1	
Cr-39	14	1											14	1		1	
Cr-40	19	1											19	1		1	
Cr-41	49	2											49	2	1	1	
Cr-42	80	1									3		83	1		1	
Cr-43	80	1											80	1		1	
Cr-44	66	1											66	1		1	
Cr-45					1							5	6	1			
Cr-46	49	2											49	2		1	1
Cr-47	57	1											57	1		1	

Suplement of Table I. Continuation

	Brachyphylla cavernarum		*Pteronotus* sp.		*Rattus* sp.		*Anolis* sp.		*Eleutherodactylus* sp.		cf. Aves	Vertebrata			Age of B. cavernarum		
Scat n°	**NISP**	**MNI**	**NISP**	**MNI**	**NISP**	**MNI**	**NISP**	**MNI**	**NISP**	**MNI**	**NISP**	**NISP**	**Total NISP**	**Total MNI**	**Juvenile**	**Adult**	**Unknown**
Cr-48	97	1											97	1		1	
Cr-49					33								33	1			
Cr-50	154	2											154	2	1	1	
Cr-51	90	2											90	2	1	1	
Cr-52	29	1											29	1		1	
Cr-53	114	2											114	2	1	1	
Cr-54	105	2											105	2		2	
Cr-55	23	1			32	1							55	2		1	
Cr-56	14	1											14	1			1
Cr-57	37	1											37	1		1	
Cr-59	26	2											26	2	1	1	
Cr-60	179	2											179	2	2		
Cr-61	24	1											24	1		1	
Cr-62	18	1											18	1		1	
Cr-63	32	2											32	2	1	1	
Cr-64	64	2											64	2		1	1
Cr-65	2	1										3	5	1			1
Cr-66	60	1											60	1	1		
Cr-67	61	1											61	1		1	
Cr-68	23	1											23	1			1
Cr-69	19	1											19	1			1
Total	2779	85	9	1	86	2	620	10	4	1	3	74	4364	101	21	42	22

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DESCRIBING THE DYNAMICS OF RECRUITS AND JUVENILE SCLERACTINIAN CORALS USING 3D MODELS: A CASE STUDY FROM CAYO MERO REEF, MORROCOY NATIONAL PARK, VENEZUELA

Descripción de las dinámicas de reclutas y juveniles de corales escleractínidos utilizando modelos 3D: un caso de estudio del arrecife de Cayo Mero, Parque Nacional Morrocoy, Venezuela

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ABSTRACT

Understanding the dynamics of coral recruitment and post-settlement is fundamental to a better comprehension of coral reef dynamics and recovery. We studied the abundance and survivorship of coral recruits and juveniles together with benthic dynamics at a scale of months and centimeters in Playa Mero reef, a disturbed reef in Morrocoy National Park. For this, we used photogrammetry to monitor eight permanent 50x50 cm quadrats haphazardly deployed every 3–4 months over 18 months. Juveniles and recruits of *Agaricia* spp. were at least four times more abundant than reef builders such as *Orbicella* spp. A distance-based linear model showed that rugosity, macroalgae, coral cover, and sand were the most important benthic variables and predicted up to 46% of the spatial and temporal variation of recruit and juvenile corals. The mortality of juvenile corals was higher than net recruitment rates, and only a limited number of genera such as Agariciids, *Colpophyllia*, *Porites*, and *Scolymia* were observed as recruits. Using a logit model, we also found a positive relationship between the mean growth rate and survivorship of juvenile corals (Nagelkerke $R^2 = 0.67$). We concluded the lack of recruitment of large reef builders, and the rapid mortality of a limited number of juvenile species, might be a sign of a coral community's failure to increase coral cover.

Keywords: juvenile corals, disturbed reefs, photogrammetry, structural complexity, growth rates, Caribbean.

RESUMEN

Comprender la dinámica de reclutamiento de corales y la etapa de asentamiento es fundamental para un mejor entendimiento de la dinámica y recuperación de los arrecifes de coral. En este experimento, estudiamos la abundancia y supervivencia de reclutas y juveniles de coral junto con la dinámica bentónica a una escala de meses y centímetros en el arrecife de Playa Mero, un arrecife perturbado en el Parque Nacional Morrocoy. Para esto, utilizamos fotogrametría para monitorear ocho cuadrantes permanentes de 50x50 cm desplegados aleatoriamente cada 3–4 meses durante un período de 18 meses. Los juveniles y reclutas de *Agaricia* spp. fueron al menos cuatro veces más abundantes que los de constructores de arrecifes como *Orbicella* spp. Un modelo lineal basado en la distancia mostró que la rugosidad, las macroalgas, la cobertura de coral y la arena eran las variables bentónicas más importantes y predijo hasta un 46% de la variación espacial y temporal de los corales jóvenes y reclutas. La mortalidad de los corales jóvenes fue mayor que las tasas netas de reclutamiento y solo se observó la presencia limitada de géneros como Agarícidos, *Colpophyllias*, *Porites* y *Scolymias*. Usando un modelo logístico, también encontramos una relación positiva entre la tasa de crecimiento promedio y la supervivencia de corales juveniles (Nagelkerke $R^2 = 0.67$). Concluimos que la falta de reclutamiento de grandes constructores de arrecifes y la mortalidad rápida de un número limitado de especies podrían ser señales de una comunidad de coral fallando en la lucha por recuperar la cobertura de coral y, por lo tanto, podría haber ocurrido un cambio de fase en el arrecife estudiado.

Palabras clave: corales juveniles, arrecifes perturbados, fotogrametría, complejidad estructural, tasas de crecimiento, Caribe.

INTRODUCTION

Coral reefs are highly diverse and often resilient ecosystems and their ability to recover from disturbances is a common feature of their evolutionary history (Connell et al., 1997; Mumby & Steneck, 2011). Nevertheless, in the most recent few decades, many reefs have lost live coral cover and are undergoing rapid phase shifts from coral to macroalgal communities from local to global scales (Hughes, 1994; Souter et al., 2021). Understanding the ecological dynamics of highly disturbed reefs can shed light upon the causes of phase shifts, successful recovery, and/or lack thereof.

Ecological processes acting during the early life stages of corals (i.e., recruitment and post-settlement survivorship/mortality) are important bottlenecks that determine much of coral demography and the fate of coral communities after a disturbance (Birkeland et al., 1981; Chong-Seng et al., 2014; Connell et al., 1997; Edmunds et al., 2015; Hughes et al., 2010; Ritson-Williams et al., 2009; Vermeij & Sandin, 2008). These stages are important links to recovery trajectories on coral reefs, because survivors will likely become competitive and reproductive adults in the population and contribute to live coral cover (Chong-Seng et al., 2014; Doropoulos et al., 2015; Hughes & Tanner, 2000; McClanahan et al., 2014).

The survival of early-life stages of corals depends on a series of biotic and abiotic factors that vary in space and time (Carleton & Sammarco, 1987; Dajka et al., 2019; Doropoulos et al., 2015; Sebens, 1982). The abundance and distribution of substrate competitors (e.g. sponges and macroalgae) and/or calcareous coralline algae which provide the chemical cues for coral larval settlement are all believed to affect recruitment and survivorship of juvenile corals (Dajka et al., 2019; Sato, 1985; Vermeij, 2006). Likewise, the habitat structural complexity has been proven to have a positive relationship with coral juveniles and recruits' presence (Carleton & Sammarco, 1987; Dajka et al., 2019). Moreover, life history traits such as growth rate and morphology are key factors for corals determining early survivorship (Sato, 1985; Vermeij, 2006).

In the past, the study of coral recruits (i.e., new colonies recorded during consecutive periods [Caley et al. 1996]) and juveniles (i.e., each coral colony below or equal to 4 cm in diameter [Vermeij et al., 2011]) relied on the ability of divers to spot corals in the field, which can be challenging, expensive, and logistically complicated. Recent advances in digital photography, such as Structure from Motion technology (SfM), have allowed the creation of accurate 3-dimensional (3D) models of reef sections (Figueira et al., 2015) to study the dynamics of corals during their early stages (e.g. growth rates as in Ferrari et al., 2017). This technique has revolutionized the study of coral reef ecology, from polyps to landscapes (Gutierrez-Heredia et al., 2016; Martínez-Quintana et al., 2023; Urbina-Barreto et al., 2020).

This paper aims to evaluate the temporal and spatial dynamics of coral recruits and juveniles, and the surrounding benthic community in Playa Mero (PM), a section of Las Animas Cay within Morrocoy National Park, Venezuela. Historically estimated loss of living corals in this Marine Protected Area varies from 60 to 90% since 1996 (Laboy-Nieves et al., 2001; Villamizar, 2000). Former reef-building coral species in MNP and other Caribbean reefs such as *Orbicella* spp. were the main affected species by the massive mortality event that occurred in 1996 (Edmunds & Elahi, 2007; Laboy-Nieves et al., 2001; Villamizar, 2000), A survey conducted in 2017, showed a community dominated by macroalgae (Miyazawa et al., 2019). Using SfM technology to build 3D models of the habitat, we monitored the abundance and survivorship of juvenile corals and recruits on eight 2500 cm^2 quadrats to see if changes in the benthic community structure and the structural complexity explained spatial and temporal changes of these juvenile and newly settled corals over 18 months. We also tested if the probability of survivorship was determined by growth rates of specific coral genera.

OBJECTIVES

Despite the rapid decline of coral reef health in Morrocoy, there is limited information about the recruitment and survivorship of juvenile and coral recruits, both being important variables for the dynamics of this degraded ecosystems.

- The objectives of the study were to: 1) understand the spatial and temporal variability of juvenile corals and benthic community in Playa Mero reef at a spatial scale of centimeters and a temporal scale of months, 2) determine which biotic and abiotic factors of the substrate affect the abundance of juvenile corals at the scale of time and space studied, 3) observe the recruitment dynamics in Playa Mero Reef at the temporal and spatial scale studied, 4) model the relationship between the survivorship of the juvenile and the mean growth rates.

MATERIALS AND METHODS

Study Area

Playa Mero (PM) (10.8 N; -68.2 E) is a fringing reef located inside the boundaries of Morrocoy National Park (MNP) which is the largest Marine Protected Area (MPA) on the Venezuelan western coast (Villamizar, 2000; Weil, 2003). The area is seasonally exposed to terrestrial runoff from the Aroa, Tocuyo, and Yaracuy rivers. Two large human settlements are located near the MPA; one in Chichiriviche and the other at Tucacas. Intense fishing, tourism, and coastal development have been ongoing for decades (Bone et al., 2005). The area has also had a long history of chemical pollution from industrial operations that have expanded over the last 60 years.

Experimental design

We determined spatial and temporal variability on the abundance, mortality, and survivorship of juvenile corals and benthic composition over eight haphazardly placed 50x50 cm quadrats, along the reef scape. The quadrats were delimitated by 4 metal bars, each one representing a vertex from the quadrat, and marked with individual underwater tags. All the quadrats were followed over 18 months starting in March 2017 (**T1**), and monitored in September 2017 (**T2**), February 2018 (**T3**), and August 2018 (**T4)**. Thus, each quadrat represents a unique timeline for a 2500 cm^2 area, and therefore, conclusions are only valid for that section of the reef.

Data collection in the field

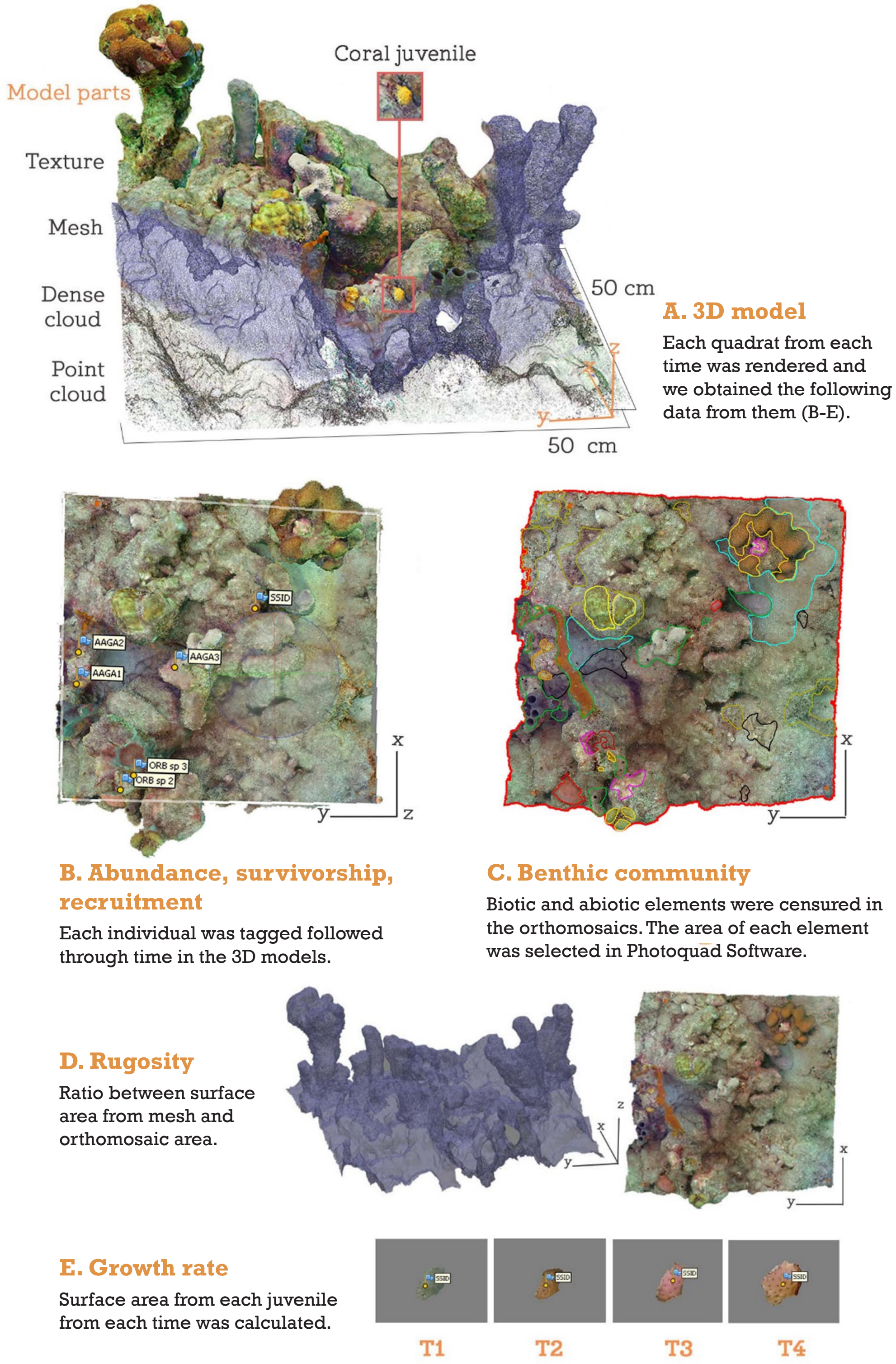
For each quadrat, 2-to-3-minutes videos were filmed with a GoPro Hero 3TM following the lawnmower procedure outlined by Young et al. (2017) with slight modifications. To reduce lens distortion, Structure from Motion (SfM) based techniques require loop closure by starting and finishing the video always at the same point. Two videos for each quadrat were taken following the contour of the reef: one at 1 m and the other at 50 cm from the substrate to capture finer-scale details. A known reference scale was placed for the posterior scaling in each quadrat.

Data processing in the laboratory

Data processing in the laboratory consisted of 3 steps 1) Video processing 2) Construction of 3D models and orthomosaics 3) Data extraction from the 3D models and orthomosaics.

Video processing

Every video was converted into still frames by sampling at 3 Hz using the software FFmpeg (http://www.ffmpeg.org/), to obtain a 60-80% overlap between consecutive images (Young et al., 2017). Color balance was empirically adjusted and calibrated for every batch of images using XNConvert (freely available at https://www.xnview.com/en/xnconvert/).



A. 3D model

Each quadrat from each time was rendered and we obtained the following data from them (B-E).

B. Abundance, survivorship, recruitment

Each individual was tagged followed through time in the 3D models.

C. Benthic community

Biotic and abiotic elements were censured in the orthomosaics. The area of each element was selected in Photoquad Software.

D. Rugosity

Ratio between surface area from mesh and orthomosaic area.

E. Growth rate

Surface area from each juvenile from each time was calculated.

Figure 1. Scheme used to obtain ecological data from the 3D models.

Construction of 3D models and orthomosaics

We produced the 3D models with Agisoft Photoscan Professional v 1.4.3 (Agisoft Software, 2016) from the colour-corrected images for each quadrat. Following standard workflow (Young et al., 2017), we first aligned the photos, then create the dense point cloud and from that we built the mesh, which is the geometric representation (Agisoft Software, 2016) of the quadrat surface. The final step consisted of adding texture to the model, that gives the realistic view of the surface adding the colors and textures. Detailed procedures explaining pipelines to generate 3D models in coral reef studies can be found in (Burns & Delparte, 2017; Ferrari et al., 2017; Figueira et al., 2015; Young et al., 2017).

During the post-processing phase, each model was rescaled using the reference placed during the video acquisition step. Then, the corners were identified and tagged to delineate the 50x50 cm2 polygon of the quadrat. Models were then rotated to align the corners with positive X and Y axis (Figueira et al., 2015). Finally, models were trimmed down by only selecting the area within the quadrat for posterior analyses (Fig. 1). The quadrat reconstruction models are available at sketchfab: https://sketchfab.com/gloria_mb/models.

For each model generated, we produced an orthomosaic, the orthogonal projection on a planar area of the model, selecting the “Orthomosaic Building” option in the Agisoft Software.

Data extraction from the 3D models and orthomosaics

Temporal and spatial changes in the abundance of juvenile corals

A visual census was conducted on each model to locate all present juvenile corals. Each individual bellow 4 cm in diameter was marked with the Agisoft Photoscan Professional marker tool and assigned a unique code for tracking over time. Coral juveniles were identified at the genus level (Vermeij et al., 2011).

Recruitment

To determine if Playa Mero provides suitable conditions for the settlement and survival of recruits, a visual survey was conducted to find settled coral individuals after time one. A recruit was defined in this work as a new individual that appeared between one time and another. Each recruit was marked with a unique identification code within the 3D model, and its development was tracked over time to determine whether it survived or not. Based on these data, the number of recruits that did not survive until the final time point was calculated by genus.

Benthic community structure

The substrate elements were surveyed for each quadrat at each time through the generated orthomosaics. Using the Photoquad program (Trygonis & Sini, 2012) the orthomosaics were scaled, and with the “Freehand ROI” tool each element of the substrate was delimitated by hand drawing a line around and then assigning the area inside to different categories (Fig. 1C). All substrate elements were surveyed following the functional group approaches for benthic community elements (Littler et al., 1983) macroalgae fleshy and calcareous, crustose coralline algae (CCA), turf, cyanobacteria. *Dictyota* spp. was identified because of its competitive importance with corals in the Caribbean (Box & Mumby, 2007). The other categories were sponges, anemones, octocorals, and scleractinian coral cover. The abiotic elements were grouped as sand and limestone debris, while unidentified elements, both biotic and abiotic, were categorized as “unknown elements.” A comprehensive survey of all substrate elements was conducted rather than using random points due to the spatial scale of the work (cm).

Surface rugosity

Another characteristic of the environment included in this analysis was surface rugosity, defined as the ratio between the mesh surface area (i.e., the three-dimensional area of the object or scene) and its orthogonal projection onto the surface plane (i.e., the two-dimensional area). This was represented by Equation 1, adapted from Friedman et al. (2012). The mesh surface area was calculated using the Agisoft PhotoscanPro program, while the orthogonal projection area was measured from the orthomosaic generated in Agisoft Photoscan and measured in the PhotoQuad software.

$$Rugosity = \frac{A}{A'}$$

Equation 1. Surface rugosity equation taken from Friedman et al. (2012). Where A = mesh surface area and A’ = orthogonal projection area.

Survivorship of juveniles

To study the survival dynamics of juvenile corals, surviving corals (i.e., individuals present at T1 and at the end of the experiment, at T4) and non-surviving corals (i.e., juvenile corals present at T1 but not at T4) were counted. As each individual had a unique identification code, survivors and non-survivors were identified in the abundance matrix.

Measurement of growth rates

The measurement of growth rates was based on changes in surface area in each individual between one time and the next. The surface area measurement tool in Agisoft PhotoscanPro was used. For each time and quadrat, each juvenile coral was cropped, and its surface area was measured. The growth rate was calculated for each individual using Equation 2. Regarding the corals that died, the growth rate was calculated using the area of T1 and the area from the time before their death. The average growth rate was used to obtain more information about growth behavior.

$$Growth\ rate\ X = \frac{A_X(\,T_{i+1}) \ - A_X(\,T_i)}{M}$$

Equation 2. Growth rate for the individual “X” between two adjacent times, where T = Time; AX(Ti+1) = Surface area of the individual “X” at time Ti+1; AX(Ti) = Surface area of the individual “X” at time Ti; and M = Number of months between Ti and Ti+1.

Statistical analysis

The data acquisition and statistical analysis stage is explained below. For all statistical analyses, a significance level of $p < 5\%$ or $p < 0.05$ and 999 permutations were used for ANOSIM analyses.

Temporal and spatial changes in the juvenile corals' abundance

To study if the variability in juvenile coral abundance was determined by the factor of time and/or space (i.e., different locations of the quadrats on the reef), an Analysis of Similarities without replication (ANOSIM; Clarke & Gorley, 2006) was conducted. A Bray-Curtis similarity matrix was constructed for the analysis using Primer 6 software (Clarke & Gorley, 2006).

Relationships between substrate characteristics and coral juvenile abundance

To determine the substrate variables (both biotic and abiotic) that best predicted the spatiotemporal variability of juvenile coral abundance, a Distance Based Linear Model (DistLM, Anderson et al., 2008) was used. This routine allows modeling the relationships between a multivariate data cloud described in the similarity matrix with one or more variables (Anderson et al., 2008). In this study, we constructed a Bray-Curtis similarity matrix. The predicted variables were the substrate elements (biotic and abiotic) along with surface rugosity. The routine allows for the adjustment of individual or combined variables, providing information on how much each predictive variable explains the behavior of the response variables (i.e., marginal tests) or how much variation in the response variables can be explained together by all the predictive variables (i.e., sequential tests) (Anderson et al., 2008). This analysis was conducted using the PERMANOVA + software of PRIMER 6 (Anderson et al., 2008).

Relationship between survivorship of juvenile corals and growth rates

To further investigate the differences between individuals who survived and those who did not, a logistic logit model (Hilbe, 2015) was used to establish whether the survival probability of individuals depended on their genus or their growth rate. A fraction of the previously collected abundance data was chosen for analysis. The experimental units were the groups of quadrats at each time point, and the sampling units were the juvenile coral individuals of each genus with at least three individuals, thus excluding *Colpophyllia* spp. from the analysis. The factors studied were the genera of juvenile corals (with six levels) and growth rates (continuous values). Logistic models are suitable for studying survival because they use binary response values, such as the success or failure of a particular attribute. In this case, successful response was defined as the survival of an individual (variable taking a value of 1), and failure was the lack of survival (variable taking a value of zero). The survival predictors were the genera and the averages of the growth rates.

The *effects* package (Fox & Hong, 2009; Fox & Weisberg, 2019) in R V 3.6.0 was used (R Development Core Team, 2019). An important condition to run logit models is that the predictors are not correlated. Therefore, before this test, an ANOVA was run in R to determine if the variability in the average growth rates was significantly related to the genera of the individuals. It was found that the genera did not significantly explain the differences in the growth rates ($p > 0.05$), so the logit model was used.

RESULTS

Patterns of temporal and spatial changes in the abundance of juvenile corals

A total of 83 juvenile coral colonies belonging to seven genera were found in Playa Mero during the study period. ANOSIM test showed spatial ($\rho av = 0.537$, $p = 0.001$) and temporal ($\rho av = 0.387$, $p = 0.001$) statistical differences in the composition of juvenile corals in PM. Our results show that only a few genera managed to settle and/or reach sizes above 4 cm in PM. The genus *Agaricia* spp. dominated the juvenile coral community, with the total number of individuals per each period varying from approximately 30 to 40 (Fig. 2), approximately four times more individuals than the other genera.

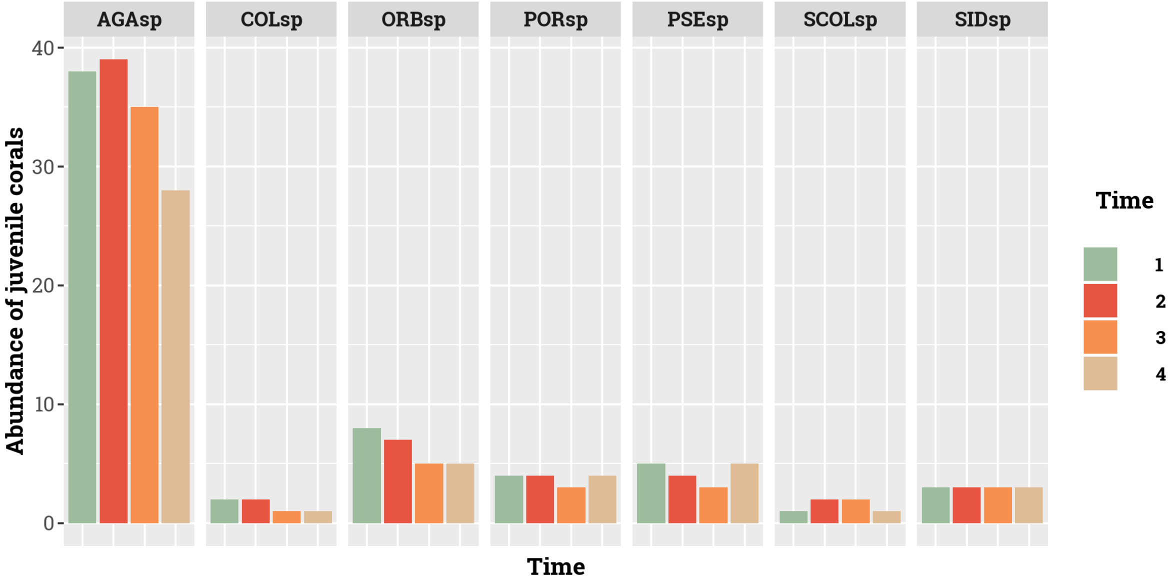


Figure 2. Total abundance of juvenile corals in Playa Mero Reef for 18 months and in eight 25 cm^2 quadrats. AGAsp = *Agaricia* spp., COLsp= *Colpophyllia* spp., ORBsp= *Orbicella* spp., PORsp= *Porites* spp., PSEsp= *Pseudodiploria* spp., SCOLsp= *Scolymia* spp., SIDsp= *Siderastrea* spp.

Relationships between substrate variables and coral juvenile abundance

In the DistLM relating juvenile coral abundance to other features of the substrate, the marginal tests showed that macroalgae, sand, scleractinian coral cover and rugosity independently correlated with variation of the juvenile coral community through time and space (Table I). Fleshy macroalgae alone explained nearly 23% of the variability in the juveniles' abundance, followed by calcareous macroalgae (near 16%). When all the variables are considered together in the sequential tests, the model explained up to 46% (Adj R2 = 0.46) of the spatial and temporal variability of juvenile corals at PM (Table II). The combination of macroalgae, sand, coral cover and surface rugosity explained most of the variation in this model, with up to 38%.

Table I. Marginal tests from de DistLM to predict juvenile coral abundance from substratum elements. SS(Trace)= Sum of squares; Pseudo-F= DistLM statistic, analog to Fisher's F; P= Type Error I probability; Prop= Variance explained percentage by each variable. The variables denoted by bold characters, hold statistical significance ($p < 0.05$).

Variable	SS(Trace)	Pseudo-F	P	Prop (%)
Actinaria	1187.2	0.764	0.538	0.0248
Crustose coralline algae	1084.7	0.696	0.565	0.0227
Cyanobacteria	2763.1	1.84	0.132	0.0578
Dictyota spp.	2357.3	1.55	0.169	0.0493
Octocorals	326.7	0.206	0.935	0.0683
Calcareous macroalgae	**7836.5**	**5.88**	**0.001**	**16.4**
Fleshy macroalgae	**10895**	**8.85**	**0.001**	**22.8**
Sponges	2689.7	1.79	0.143	0.0562
Rubble	2058.8	1.35	0.266	0.0431
Sand	**5787.2**	**4.13**	**0.003**	**12.1**
Scleractinian corals	**4851.8**	**3.39**	**0.014**	**10.1**
Turf	2479	1.64	0.174	0.0519
Surface rugosity	**5079.3**	**3.57**	**0.012**	**10.6**
Unknown elements	496.96	0.315	0.872	0.0104

Table II. Sequential tests from de DistLM to predict juvenile coral abundance from substratum elements. Adj R^2= Adjusted R^2; SS(Trace)= Sum of squares; Pseudo-F= DistLM statistic, analog to Fisher's F; P= Type Error I probability; Prop= Variance explained percentage by each variable; Res.df= Degrees of freedom. The variables denoted by bold characters, hold statistical significance ($p< 0.05$).

Variable	Adj R^2	SS(trace)	Pseudo-F	P	Prop (%)	Cumul.	Res.df
Fleshy macroalgae	**0.136**	**7836.5**	**5.88**	**0.004**	**0.163**	**0.163**	**30**
Calcareous macroalgae	**0.189**	**3726.9**	**2.98**	**0.039**	**0.078**	**0.242**	**29**
Surface rugosity	**0.262**	**4389.3**	**3.86**	**0.012**	**0.092**	**0.334**	**28**
Sand	**0.305**	**2923.2**	**2.73**	**0.067**	**0.061149**	**0.394**	**27**
Scleractinian corals	**0.387**	**4072.8**	**4.26**	**0.011**	**0.0852**	**0.480**	**26**
Dictyota spp.	0.378	876.5	0.914	0.407	0.0183	0.498	25
Cyanobacteria	0.387	1301.6	1.38	0.271	0.0272	0.526	24
Crustose coralline algae	0.412	1851.5	2.04	0.139	0.0387	0.564	23
Actinaria	0.437	1751.3	2.02	0.147	0.0366	0.600	22
Octocorals	0.447	1184.3	1.39	0.232	0.0248	0.626	21
Rubble	0.457	1170.6	1.40	0.266	0.0245	0.650	20
Turf	0.448	551.32	0.648	0.554	0.0115	0.662	19
Sponges	0.495	2159.7	2.78	0.085	0.0452	0.707	18
Unknown elements	0.461	112.39	0.135	0.967	0.0235	0.705	17

Survivorship of juvenile corals and growth rates

Regarding the survivorship of juvenile corals, about 40% (n= 24) out of 61 individuals recorded in March 2017 died by August 2018. While linear growth rates did not statistically differ among genera (Table III), the logistic regression model showed this variable explained the overall chances of survivorship of any given juvenile colony (Nagelkerke R^2= 0.67) (Table IV). The estimate of the variable mean growth rate is b= 5.225 which is positive, therefore an increase in the mean growth rate will increase the possibility of survivorship in the individual.

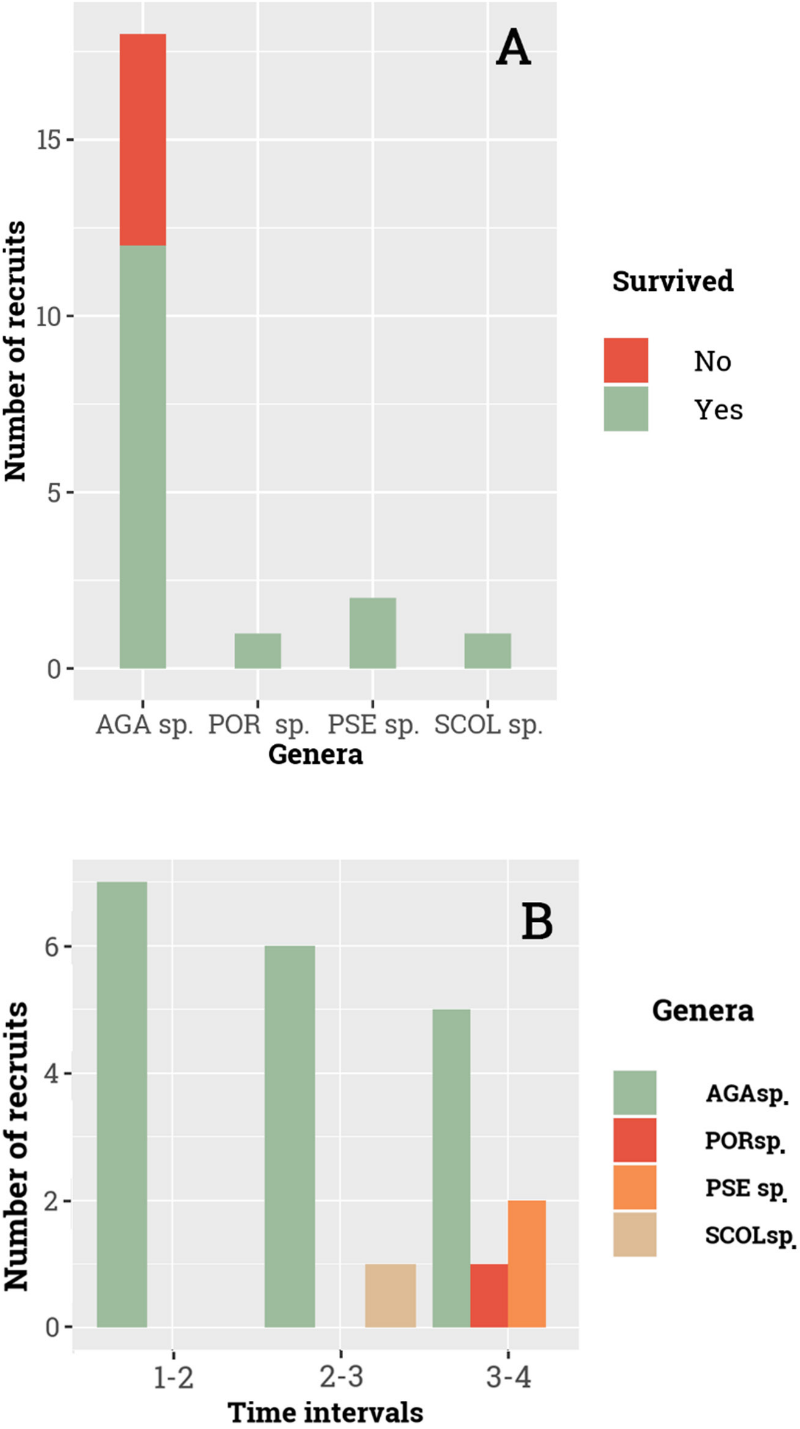


Figure 3. Recruiting patterns at Mero Reef during the study. **A,** total abundance of the recruits by genus and their survivorship until T4. **B,** changes in abundance over time per genus. AGAsp. = *Agaricia* sp., PORsp. = *Porites* sp., PSEsp. = *Pseudodiploria* sp., SCOLsp. = *Scolymia* sp.

Recruitment

We recorded 22 new colonies recruiting in our permanent quadrats, with the genus *Agaricia* spp. accounting for 82% of the new settlers for the 18-month period. From these recruits, 5 of them died during the study, and all of them belonged to the genus *Agaricia*. (Fig. 3A). New colonies of species in the genus *Pseudodiploria*, *Scolymia* and *Porites* were seldom recorded recruiting in PM (Fig. 3B). Our results indicate that only a few genera recruited during the study period with the genus *Agaricia* spp. being the genus with the highest number of new settlers but largest mortality during the study period.

Table III. ANOVA testing if the variability in growth rates can be explained by genus. Df= Degrees of freedom; Sum sq= Sum of squares; Mean sq= Mean square; F value= Fisher's statistic; Pr(>F) = Probability of making a type I error.

	Df	**Sum sq**	**Mean Sq**	**F value**	**Pr(>F)**
Genera	5	6.28	1.256	0.802	0.554
Residual	53	83.04	1.567		

Table IV. Logit model output. Estimate= the intercept (b0) and the beta coefficient associated to each variable; Std. Error= the standard error of the coefficient variables; z value= the z-statistic; Pr(<|z|) = P value corresponding to the z-statistic. The only significant variable for predicting survivorship in juvenile corals at Playa Mero were the mean growth rates.

(Intercept)	16.53	2728.420	0.006	0.99528
Agaricia	-15.973	2728.420	-0.006	0.99533
Orbicella	-14.470	2728.421	-0.005	0.99577
Porites	-14.798	2728.421	-0.005	0.99567
Pseudodiploria	-17.571	2728.426	-0.006	0.99486
Mean growth rate	**5.225**	**1.636**	**3.193**	**0.00141**

DISCUSSION

In this work, we utilized photogrammetry to study the change in coral communities at Playa Mero (PM) for 18 months. Our goal was to understand the ecological dynamics of juvenile and coral recruits from a disturbed reef in the Southern Caribbean. Our results showed that the variation in coral juvenile abundance was explained up to 46% by some benthic elements, such as fleshy algae and rugosity. Furthermore, there was recruitment of corals over 18 months, but these were dominated by a single genus (*Agaricia* spp.). Overall, this study demonstrated the strength of 3D reconstruction methodology in the detection and tracking of juvenile corals.

Patterns of temporal and spatial changes in the abundance of juvenile corals

Similar to other studies, this work reports the predominance of brooding species (e.g., *Agaricia* spp.), above species recognized as reef builders (e.g., Bak & Engel, 1979; Hughes & Tanner, 2000; Rogers et al., 1984; Vermeij et al., 2011). The most abundant genus in the juvenile community was *Agaricia* spp., but this genus had low adult coverage, according to a survey made the same year of this study (Miyazawa, 2019). Bastidas et al. (2006) visited another reef in MNP damaged by the same mortality event, Playa Caimán, where they also did not find some correspondence in the patterns of recruit abundance with the coverage of adult scleractinian corals in 2003. They discovered that over half of the the juvenile species were absent as adults. The dominance of *Agaricia* spp. in juvenile coral communities is not unusual in Caribbean coral reefs (Bak & Engel, 1979; Van Moorsel, 1985; Vermeij et al., 2011). This can be explained, among other reasons, by some characteristics of their life history. For example, *Agaricia agaricites* is a moderate sediment rejector (Bak & Engel, 1979) and tends to grow faster than other species, so they are expected to be better adapted to invade new substrates after disturbance (Hughes & Jackson, 1985). Despite the relative success in the juvenile life phase, it has been reported that *Agaricia agaricites* and other *Agaricia* spp. species such as *Agaricia humilis* are easily damaged and highly susceptible to mortality (Bak & Engel, 1979; Hughes & Jackson, 1985; Van Moorsel, 1985). This study shows that this species was the most recruited but also had the highest mortality recorded. This could explain its low cover as adult in the Playa Mero reef.

Relationships between substrate variables and coral juvenile abundance

The benthic elements commonly discussed in the literature as predictors for juvenile corals were established as factors predicting the patterns of juvenile abundance on the Playa Mero reef. Macroalgae, are significant reducers of juvenile coral abundance (Edmunds & Carpenter, 2001). They can make the substrate unsuitable for recruitment due to competition for space (Kuffner et al., 2006), directly damaging or killing juvenile corals by overgrowing them or through allelopathy (Edmunds & Carpenter, 2001; Sato, 1985; Vermeij et al., 2009). The presence of live coral cover, particularly the presence of certain genera surveyed in this study (e.g. *Siderastrea* spp. and *Agaricia* spp.), has been positively related to the abundance of juvenile corals. Vermeij (2005) demonstrated that larvae of *Siderastrea siderea* settle near parental colonies. This can partly explain why the presence of adult *Siderastrea siderea* corals is an important predictor of juvenile abundance patterns in Mero. Vermeij (2005) also found that the survival rate decreased near parental colonies and suggested that this could be because survival is dependent on density among recruits. This could explain the low abundance of *Siderastrea* spp. juveniles observed in the study.

Roughness, as an element of the topographic complexity of the substrate, was also important in determining juvenile abundance. Substrate irregularities and roughness have been positively correlated with the abundance patterns of benthic sessile organisms at various latitudes (Babcock & Mundy, 1996; Connell, 1961; Kuklinski et al., 2006), and specifically, with the abundance and survival of juvenile corals (Carleton & Sammarco, 1987; Gallagher & Doropoulos, 2017). Martínez-Quintana et al. (2023) found in the US Virgin Islands that roughness was an important predictor of recruitment of scleractinian corals. Greater roughness is associated with an increase in surface area (e.g., due to the presence of cracks and caves (Luckhurst & Luckhurst, 1978), and this can lead to a potential increase in microhabitat diversity (Sebens, 1991). Different microhabitats will vary the exposure of juvenile corals to predators (Gallagher & Doropoulos, 2017) or the flow of water currents over them that can lead to changes in the concentration, movement, or deposition of sediments around juveniles (Davis & Barmuta, 1989). But some studies have not found a relationship between the success of juveniles (i.e., survival) and different types of microhabitats (Edmunds et al., 2004; Roth & Knowlton, 2009). According to Edmunds et al. (2004), these negative results could be caused by spatial events at larger spatial scales that drive juvenile mortality. The mixed results found in the literature highlight the need to follow coral individuals over the long term to establish the cause-and-effect relationship between the structural complexity elements of the reef and the ecological dynamics of juvenile corals.

Survivorship of juvenile corals and growth rates

We found in this study that the success in the survival race in juvenile corals was defined by growth rates, regardless of their genus. However, Edmunds (2007) found differences in growth rates among juvenile coral taxa in the long-term experiment on the Caribbean Island of Saint John. Probably, in the study conducted in Playa Mero, there was a low number of samples with few replicates, as the survivors' data was obtained as subsamples of the original data. This could mean a lack of statistical power for this test. On the other hand, Hughes & Tanner (2000) discovered that the probability of survival within the same coral species depended on the size class, with the smaller ones being more vulnerable to death. In this regard, Edmunds (2007) reported that the variability of growth rates in the same species and the same initial size class was highly variable. Therefore, the study of growth rates may be more accurate if factored by species or genus and size class, rather than just genus. Growing faster can determine whether a colony survives competition with macroalgae (Ferrari et al., 2012) or other coral colonies (Zilberberg & Edmunds, 2001). Hence, this characteristic possibly allows corals to reach faster the sizes at which they can overcome environmental and biological stress present in Mero.

Recruitment

During the study period, recruitment occurred, yet the recruits' community displayed limited diversity and differed significantly from the adult coral community in 1996 (Villamizar, 2000). *Agaricia* species dominated the recruits while *Orbicella* sp. or other typical Caribbean reef builders were entirely absent at the time and depth of the investigation. *Agaricia* spp. have notably high and consistent recruitment rates, whereas *Orbicella* spp. have been reported to exhibit low or absent recruitment (Hughes & Jackson, 1985; Hughes & Tanner, 2000; Miller et al., 2000; Woesik et al., 2014). This disparity might stem from their reproductive strategies; *Agaricia* species release planulae with multiple reproductive cycles yearly (Van Moorsel, 1983), while *Orbicella* spp. spawn gametes only once or rarely twice annually (Van Veghel, 1994), affecting their capacity to colonize disturbed areas primarily reliant on successful sexual reproduction events (Szmant, 1986).

The observed dynamics of coral juveniles and recruits at Playa Mero indicate a remote likelihood of the reef restoring its pre-1996 coral-dominated community. Understanding the drivers and mechanisms perpetuating these dynamics stands as the subsequent pivotal step in comprehending Mero's recovery stagnation. These dynamics may stem from Morrocoy's chronic disturbance regime, prevalent since the early 1970s (Weiss & Goddard, 1977). Disturbance factors outlined in literature affecting recruitment and juvenile survival such as sedimentation (Babcock & Smith, 2000; Fabricius, 2005, Tuttle & Donahue, 2022; Van Moorsel, 1985), hydrocarbon pollution (Hartmann et al. 2015), and presence of diseases (Cróquer et al., 2022) are present in MNP (Bastidas et al., 1999; Bone et al., 2005; Cróquer & Bone, 2003; García et al., 2011; Jaffé et al., 1998; Latchinian et al., 2017; Weiss & Goddard, 1977).

CONCLUSIONS AND LIMITATIONS

In conclusion, this study elucidated the dynamics of juvenile and coral recruits in Playa Mero, revealing key patterns: (1) juvenile abundance dominated by non-reef-building species, exemplified by *Agaricia* spp.; (2) a fluctuating juvenile community with an overall declining trend in space and time; (3) absence of reef-building coral recruits; (4) net recruitment rates lower than juvenile coral mortality; and (5) limited recruitment of species. The persistence of these dynamics is proposed to potentially lead to the collapse of the remaining coral community at Playa Mero. Literature evidence supports the notion that chronic disturbances spanning over 60 years in PNM may be linked to the dynamics of Mero's recruits and juveniles, further studies should be followed to determine if and how these stresses are affecting coral early stages dynamics. However, while this paper seeks to explain temporal changes in recruitment using a deterministic approach, corals at this stage of their life cycle are likely driven by stochastic dynamics. Moreover, despite the limitations of 3D model analysis (i.e., paucity of light in areas partly shadowed where crevices are abundant and recruits often settle), we showed that photogrammetry is a useful tool to study the dynamics of coral during their early life stages as they digitally store the reef's state, offering extended observation time and the option to revisit raw data.

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Nota científica

A NEW RECORD OF BONY FISH PREY FOR THE GENUS *ISISTIUS* (CHONDRICHTHYES: DALATIIDAE) IN A COASTAL ZONE OF SOUTHEASTERN MEXICO

Nuevo registro de un pez óseo como presa del género *Isistius* (Chondrichthyes: Dalatiidae) en una zona costera del sureste de México

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ABSTRACT

The first report of bite wounds from cookiecutter shark in a specimen of cobia in the Southern Gulf of Mexico is described. The specimen was captured by artisanal fishery in the coastal zone of Tabasco, Mexico. It presented three bite wounds with 25 to 26 teeth marks per wound, major axis interval between 3.7 and 4.7 cm and all areas of less than 10 cm^2. This is new record of a bony fish as prey of genus *Isistius* maybe of *I. brasiliensis* in coastal waters over the continental shelf, in the Southern Gulf of Mexico.

Keywords: bite wounds, *Rachycentron canadum*, Tabasco, opportunistic feeding, continental shelf.

RESUMEN

Se describe el primer reporte de heridas por mordidas del tiburón cigarro a un espécimen de cobia en la parte sur del golfo de México. El espécimen fue capturado por pesquería artesanal en la zona costera de Tabasco, México. Presentó tres heridas por mordidas con 25 a 26 marcas de dientes por herida, un intervalo del eje mayor entre 3.7 a 4.7 cm y todas las áreas menores a 10 cm^2. Este es un nuevo registro de un pez óseo como presa del género *Isistius*, posiblemente *I. brasiliensis*, en aguas costeras sobre la plataforma continental, para el sur del golfo de México.

Palabras clave: heridas por mordidas, *Rachycentron canadum*, Tabasco, alimentación oportunista, plataforma continental.

The family Dalatiidae includes 10 species of sharks, all considered mesopelagic, with records of three species that predate on larger prey: *Dalatias licha* Bonnaterre, 1788, *Isistius brasiliensis* Quoy & Gaimard, 1824 and *I. plutodus* Garrick & Springer, 1964 (Ebert et al., 2021). The cookiecutter shark *Isistius brasiliensis* is a species that presents a maximum length of approximately 55 cm and is found in both coastal and oceanic habitats worldwide at depths ranging from 85 to 3700 m (Compagno, 1984; Ebert et al., 2021; Strasburg, 1963).

In the Gulf of Mexico, this species has been reported mainly in the northern zone with fewer records in the southern Gulf (Castro-Aguirre & García-Domínguez, 1988; Retzer, 1990; Ruiz-Abierno et al., 2016). Recently, Grace et al. (2018) reported cookiecutter shark bite wounds on cetaceans, showing the presence of this phenomenon over an extensive area of the Gulf of Mexico.

Cookiecutter sharks are small mesopelagic sharks that present diel vertical migrations (Strasburg, 1963; Widder, 1998) best known for their feeding behavior, which has been determined by some authors as ectoparasitic, feeding on pieces of flesh from large marine animals (Honebrink et al., 2011; Menezes et al., 2022) in addition to active predation over small bony fishes, squid and crustaceans (Compagno, 1984; Ebert et al., 2021). These sharks have been implicated as responsible for round-shaped wounds in marine megafauna (Dwyer & Visser 2011) and even humans (Honebrink et al., 2011). Cookiecutter attack wounds have been found in tuna, swordfish and billfish (Muñoz-Chápuli et al., 1988; Niella et al., 2018; Papastamatiou et al., 2010), white shark (Hoyos-Padilla et al., 2013), cetaceans (Dwyer & Visser, 2011), pinnipeds (Gallo-Reynoso & Figueroa-Carranza, 1992; Souto et al., 2009) and sirenians (Reddacliff, 1988).

The cobia (*Ranchycentrum canadum* [Linnaeus, 1766]) is a large and pelagic-coastal bony fish that is distributed in tropical and subtropical waters, in depths up to 70 m, except in the eastern Pacific (Shaffer & Nakamura, 1989). In Mexico, this fish is one of the fishing and aquaculture resources with high commercial importance (DOF, 2012), the dried-salted presentation works as a substitute for cod. However, even when its commercial importance is evident, there are no studies on its predators, leaving only anecdotes about the dolphin fish (Shaffer & Nakamura, 1989) and the mako shark (fisherman observations), with which the ecological niche of cobia cannot be reliably established.

Forensic analysis of shark bite wounds allows to establish a good approximation of the attacking species and the position of either the victim or the attacker and is widely used for shark-human relationship studies (Ribéreau-Gayon et al., 2017; Ritter & Levine, 2004). However, these studies have not been conducted on marks left by cookiecutter sharks on fish and marine mammals, allowing predator identification only at the supra-species level, with possible identification based solely on the current knowledge of the geographic distribution of the two *Isistius* species (Best & Photopoulou, 2016), without considering that the less abundant species increase their distribution when they are adequately identified (Zidowitz et al., 2004). An assertive identification of the attacking species would not only determine which species prey on the affected animals, but could also provide data that increase the regional taxonomic listings and allows a better understanding of the ecology and ethology of prey and predator.

The objective of this work is to provide the record of a new species of bony fish as prey of the genus *Isistius* in shallow Mexican waters of the Gulf of Mexico from the description of bite wounds on a cobia.

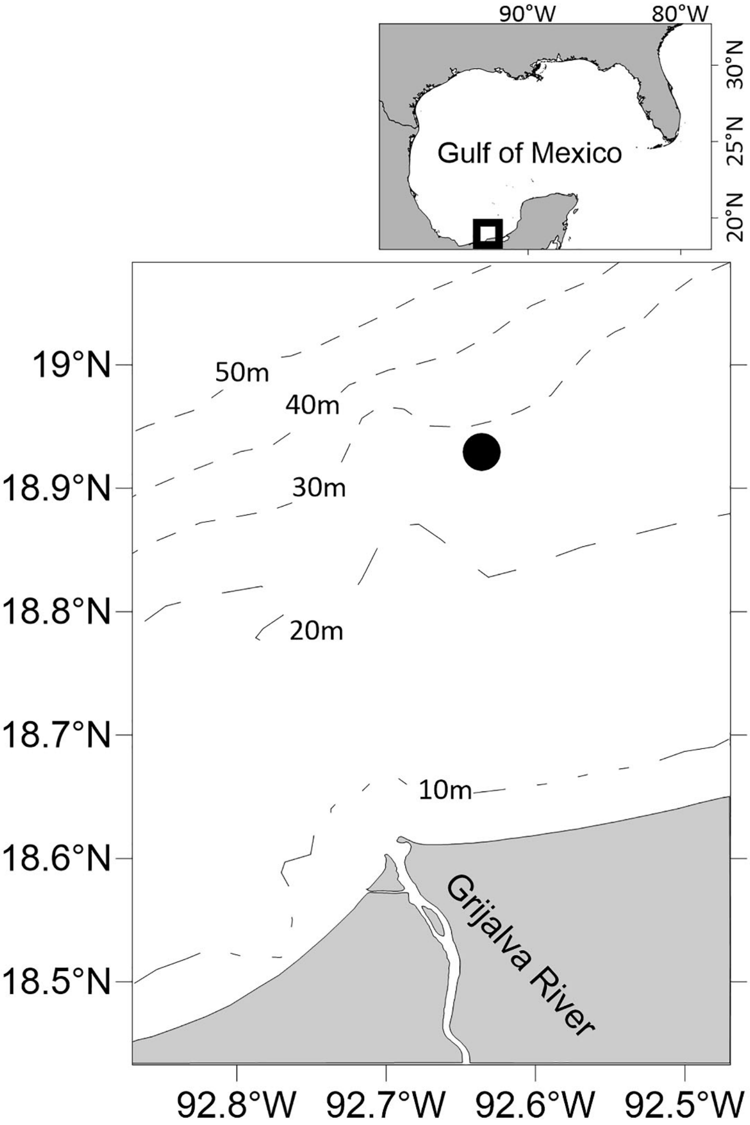

Figure 1. Sampling zone of the Cobia (*Rachycentron canadum*) with three cookiecutter shark (*Isistius* sp.) bite wounds in the Southern Gulf of Mexico.

On October 12, 2020, during a sampling performed at a monitoring of artisanal fishery in Barra Carlos Rovirosa, Tabasco, Mexico (92° 41’ 05” W, 18° 35’ 10” N), a cobia with three fresh wounds was found. It was caught with a 3.5 inch, 1389 m long gillnet operating at a depth of 30 m (92° 34’ 36.162 W, 18° 55’ 45.58 N) (Fig. 1). The specimen presents three ovoid shaped wounds in its right flank (Fig. 2a), with evident dental marks characteristic of those made by cookiecutter sharks (*Isistius* spp). The total length (TL) of the cobia and of the three wounds were measured with a 1.5 m tape measure (±1 mm). The wounds were measured along two axes (length and width) to calculate perimeters and areas.

The bite wounds were analyzed with Gimp 2.1 (Free Software Foundation), counting the entries or the grooves left by the cusps (Lowry et al., 2009) and delimiting them by the presence of shreds of skin or meat (Anislado-Tolentino et al., 2016). Since the bitemarks left on prey by *Isistius* leave a greater impression of the lower teeth (Ribéreau-Gayon et al., 2018), the counts obtained from the analysis were compared with the dental formulas of the lower jaw from the cookiecutter shark *Isistius brasiliensis* (12+1+13), the largetooth cookiecutter shark *I. plutodus* (9+1+9) (de Figueiredo Petean & De Carvalho, 2018) and the kitefin shark *Dalatias licha* (L 17–20) (Ebert et al., 2021).

The cobia had a TL of 82 cm, a standard length (SL) of 72 cm and weighed 8 kg. The three wounds were ovoid in shape with 25–26 lower teeth marks (Fig. 2b, c and d) and areas of less than 10 cm^2. The measurements of the bite wounds are presented in the Table I. Wound number 1 showed clearer evidence of 26 teeth marks (Fig. 2b). According to the counts carried out and the calculated wound areas, it could be deduced that the predatory species that caused the bites was a shark of the genus *Isistius*, with high probability was *Isistius brasiliensis*.

Ribéreau-Gayon et al. (2018) indicates that the major axis interval for *Isistius* bites is between 1–10 cm and the area is less than 10 cm^2. The measurements obtained in this study (Table I) show that the wounds are within the parameters established for the genus *Isistius*. Since *D. licha* (17–20) and *I. plutodus* (17–19) show fewer lower teeth than the dental marks (26) found in the bite wounds of the studied cobia (*R. canadum*), the species responsible for the feeding event was the cookiecutter shark *I. brasiliensis*.

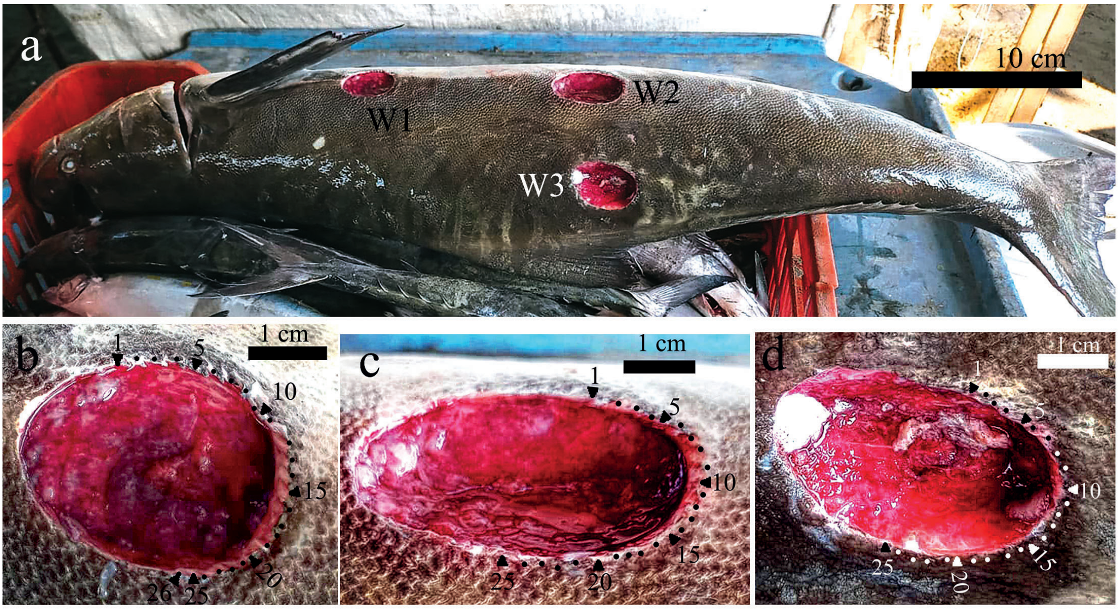

Figure 2. **a)** Studied cobia (*Rachycentron canadum*) with three bite wounds (W) on its right flank; **b)** wound 1 (W1) lower teeth mark count; dots indicate the lower teeth marks, visible shreds of skin from marks 1 to 11; in marks 12 to 26 the trajectory of the dental cusps can be appreciated; **c)** wound 2 (W2) with 25 lower teeth marks and **d)** wound 3 (W3) with 25 lower teeth marks. Photographs by Rodolfo Castro-Barbosa.

Table I. Measurements of the wounds shown in the right flank of the cobia (*Rachycentron canadum*). Numbers only identify the wounds (see Figure 1).

Wound (W) number	Major axis (cm)	Minor axis (cm)	Number of lower teeth marks	Perimeter (cm)	Area (cm^2)
1	3.3	1.7	26	6.28	4.41
2	4.7	2.1	25	10.88	7.75
3	4.1	2.7	25	9.83	8.91

Following the criteria of Papastamatiou et al. (2010), the bite wounds were fresh, which indicates that they could have been made when the organism was caught in the fishing net. On the other hand, the authors mention that most pelagic fish, caught with longlines present more than two wounds. Likewise, according to Widder (1998), since *I. brasiliensis* is a slow swimmer, attacks on large free-swimming prey results in only one bite per organism, with the shark displaying a feeding behaviour in which it holds on to the prey using its modified sucker-like lips and pharynx to later penetrate the skin and tissue with its large, cutting-type lower teeth, using the momentum of the fast-swimming prey to generate the rotational energy necessary to detach the piece of tissue, securing the piece of flesh with its upper teeth while the sharks pulls free (Ribéreau-Gayon et al., 2018). The presence of three wounds in the studied cobia suggests that the bites were the result of opportunistic predation by *I. brasiliensis*, taking advantage of the fish's inability to move when it was caught in the fishing net.

Some authors mention that cookiecutter sharks migrate at night from mesopelagic depths to shallower water (Compagno, 1984; Widder, 1998), and during the winter months (Papastamatiou et al., 2010), so the predatory events could be seasonal (Feunteun et al. 2018). This is also observed in the Mexican North Pacific of the Baja California peninsula, where during the winter and early spring months (February to March) that correspond to the fishing season of Pacific bluefin tuna *Thunnus orientalis* (Temminck & Schlegel, 1844), it is common for tuna caught using longlines to display bites of cookiecutter shark on their bodies.

According to Carlisle et al. (2021), *I. brasiliensis* preys upon epipelagic, mesopelagic, and vertically emigrant fishes (Table II) and presents a diel cycle, hunting during the day at the mesopelagic zone migrating, perhaps following prey, to the epipelagic zone at night. Fishing catches that normally show evidence of cookiecutter shark bites are tuna, billfish, and other large bycatch fishes at the offshore and open-ocean fisheries. For this work, the studied cobia was caught by artisanal fishery, at low depth (30 m) and at the littoral zone. The presence of the bite wounds by a cookiecutter shark on a prey in a low depth zone is evidence of their vertical migration diel behaviour. The cookiecutter shark, maybe *I. brasiliensis*, swim to the coastal zone in order to forage, and recently found a new prey, the cobia, on the continental shelf of southeastern Mexico. Because cobia along with other potential prey are important in the catches of small-scale coastal fisheries, it is necessary to establish a monitoring program to determine the diversity of prey of this type of shark in the coastal zone of the Gulf of Mexico.

Table II. List of cookiecutter shark *Isistius brasiliensis* identified fish prey species. Mesopelagic (MP), epipelagic (EP) and vertically emigrant fish species (VEF). The superscript letter in species column corresponding to: a, Carlisle et al. (2021); b, Hoyos-Padilla et al. (2013); c, Jones (1971); d, Nakano & Tabuchi (1990); e, Niella et al. (2018); f, Papastamatiou et al. (2010); g, this study.

Family	Species	Common name	Type
Lamnidae	*Carcharadon carcharias*[b]	White shark	VEF
Lampridae	*Lampris guttatus*[f]	Opah	MP
Ariommatidae	*Ariomma* sp.[a]	Driftfish	MP
Bramidae	*Taractichthys steindachneri*[f]	Sickle pomfret	MP
	Brama japonica[d]	Pacific pomfret	MP
Gempylidae	*Ruvettus pretiosus*[f]	Oil fish	MP
Scombridae	*Acanthocybium solandri*[f]	Wahoo	VEF
	Thunnus obesus[f]	Bigeye tuna	VEF
	Thunnus albacares[c]	Yellow fin tuna	VEF
	Katsuwonus pelamis[f]	Skipjack tuna	VEF
	Euthynnus affinis[c]	Kawakawa	VEF
	Euthynnus alletteratus[e]	Little tunny	VEF
	Sarda sarda[e]	Atlantic bonito	VEF
Carangidae	*Caranx* spp.[c]	Large jacks	VEF
	Elagatis sp.[c]	Rainbow runners	VEF
Coryphaenidae	*Coryphaena hippurus*[c]	Dolphinfish	VEF
Istiophoridae	*Makaira mazara*[f]	Pacific blue marlin	VEF
	Tetrapturus audax[f]	Striped marlin	VEF
	Tetrapturus angustirostris[f]	Shortbill sailfish	VEF
Rachycentridae	*Rachycentron canadum*[g]	Cobia	VEF
Xiphiidae	*Xiphias gladius*[f]	Swordfish	VEF
Scomberesocidae	*Cololabis saira*[a]	Pacific saury	EP

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Nota científica

PRELIMINARY CHECKLIST OF MOLLUSKS ASSOCIATED WITH THE ROCKY LITTORAL OF MALECÓN DE SANTO DOMINGO, DOMINICAN REPUBLIC

Listado preliminar de los moluscos asociados al litoral rocoso del Malecón de Santo Domingo, República Dominicana

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ABSTRACT

A preliminary checklist of the mollusks associated with the rocky littoral of Malecón de Santo Domingo is presented. The sampling consisted of an intensive search by niches in two localities selected on the basis of their heterogeneity and access. We preliminarily report 25 species, 19 genera and 14 families of mollusks, with gastropods being the most representative group in species. It is expected that future intensive and diverse sampling methodologies in the studied areas, and other locations, will increase the diversity reported in this note.

Keywords: rocky shore, mollusk fauna, urban area.

RESUMEN

Se presenta una lista preliminar de los moluscos asociados al litoral rocoso del Malecón de Santo Domingo. El muestreo consistió en una búsqueda intensiva por nichos en dos localidades seleccionadas con base en su heterogeneidad y acceso. Reportamos preliminarmente 25 especies, 19 géneros y 14 familias de moluscos, siendo los gastrópodos el grupo más representativo en especies. Se espera que futuras metodologías de muestreo intensivo y diverso en las zonas estudiadas, y en otros lugares, aumenten la diversidad reportada en esta nota.

Palabras clave: costa rocosa, fauna de moluscos, área urbana.

Mollusks are a highly diverse group, whose major richness is evidenced in tropical littoral macrohabitats (Baqueiro-Cárdenas et al., 2007; Masagca et al., 2010). Among these habitats, rocky shores maintain one of the most heterogeneous diversity of mollusks, especially within their benthic communities (Azevedo, 1992). The rocky littoral shore of Malecón de Santo

Domingo sustains a high biodiversity associated with coral limestone cliffs, and is distinguished by its coastal anthropized plant communities and more than 43 animal species (CIBIMA, 1992). This paper aims to provide an initial inventory of marine mollusks inhabiting this ecosystem, serving as a foundational resource for further studies and conservation efforts for this distinctive coastal environment.

The study area corresponds to the supralittoral or splash zone, and macrohabitats associated to the high intertidal zone or eulittoral, with a focus on the phytals settled on rocky coastal plateaus. Two main stations were selected (station 1: 18°27’21.6”N 69°54’48.6”W, Acción Caribe Beach; station 2: 18°27’26.3”N 69°54’35.7”W, beach in front of Hotel Catalonia Santo Domingo) based on microhabitat heterogeneity and access. We performed three field surveys during low tide on June 13th, 2019, January 22nd, 2020 and February 1st, 2021, where we conducted a thorough search in all potential mollusk habitats, including crevices, rotten logs, tidal pools, algae beds, rocks and cliffs. Micromollusks were not included as part of this preliminary study.

Mollusk species identification were done *in situ* when possible, if not they were collected and taken to the facilities of the Instituto de Investigaciones Botánicas y Zoológicas Rafael M. Moscoso (IIBZ). In the lab, they were either relaxed and preserved in a 70% ethanol solution or stored dry. Selected mollusk specimens were donated to the Museo Nacional de Historia Natural “Prof. Eugenio de Jesús Marcano” (MNHNSD). Identification of mollusks were done following monographs (Abbott, 1954; Warmke & Abbott, 1961; García-Ríos, 2003; García-Cubas & Reguero, 2004; Tejeda et al., 2015). High taxonomy follows Bieler et al. (2010) for Bivalvia, Bouchet et al. (2017) for Gastropoda and WoRMS (2023) for Polyplacophora. For molluscan genera and species current taxonomic status, we mainly follow WoRMS (2023).

A total of 25 species of mollusks are preliminarily reported, which are in three classes (Polyplacophora, Bivalvia and Gastropoda), 14 families and 19 genera (see Figure 1 and Table I for the display of the data). This corresponds to 24% of the total species reported to be associated to rocky littorals of the country (104) by CIBIMA (1992), and 4.8% of the marine molluscan fauna from the Dominican Republic enlisted by Herrera-Moreno & Betancourt-Fernández (2005). The families with the highest species richness were Neritidae and Littorinidae with four species both. Two genera, *Nerita* Linnaeus, 1758 and *Echinolittorina* Habe, 1956, were the most representative with three species each. Gastropods represent 76% of all species identified, followed by chitons with 16% and bivalves with 8%.

Caribbean rocky littoral molluscan diversity seems to be homogenous regarding representativeness. The preliminary faunistic composition recorded on this note is similar to other checklists of rocky littoral mollusks from past studies. Diez García & Reyes la Fuente (2014) reported a total of 20 species, 14 genera, and 9 families from four localities in Santiago de Cuba (Cuba) supralittoral and eulittoral zones. Subsequently, Jover Capote (2021) documented 38 species, 31 genera, and 22 families in the same localities. Both studies showed an overlap of 10 species, and their results have a similarity to ours of 44% regarding number of species, 47% for genera and 59% of the total families. As sharing 52 (42%) of the total taxa (species, genera, families) registered by the last authors, and six proper to our study areas, we assume that the diversity might increase with different sampling techniques, addition of micro-mollusk species and exploration of the lower eulittoral and sublittoral zones from other localities in future studies.

Figure 1. Some mollusks species associated to the Malecón de Santo Domingo Rocky Littoral. **A)** *Fissurella rosea*; **B)** *Tegula excavata*; **C)** *Nerita peloronta*; **D)** *Nerita tessellata*; **E)** *Nerita versicolor*; **F)** *Puperita pupa*; **G)** *Supplanaxis nucleus*; **H)** *Cenchritis muricatus*; **I)** *Echinolittorina angustior*; **J)** *Echinolittorina tuberculata*; **K)** *Echinolittorina ziczac*; **L)** *Mitrella ocellata*; **M)** *Rhombinella laevigata*; **N)** *Stramonita floridana*; **O)** *Plicopurpura patula*; **P)** *Tralia ovula;* **Q)** *Brachidontes exustus*; **R)** *Isognomon alatus*; **S)** *Acanthopleura granulata*; **T)** *Chiton marmoratus*.

Table I. Preliminary checklist of mollusks associated to the rocky littoral of Malecón de Santo Domingo.

Families	Genera	Species
	POLYPLACOPHORA	
Callistoplacidae	*Ceratozona* Dall, 1882	1. *Ceratozona squalida* (C. B. Adams, 1845)
Chitonidae	*Acanthopleura* Guilding, 1830	2. *Acanthopleura granulata* (Gmelin, 1791)
	Chiton Linnaeus, 1758	3. *Chiton marmoratus* Gmelin, 1791 4. *Chiton squamosus* Linnaeus, 1764
	BIVALVIA	
Mytilidae	*Brachidontes* Swainson, 1840	5. *Brachidontes exustus* (Linnaeus, 1758)
Isognomonidae	*Isognomon* Lightfood, 1786	6. *Isognomon alatus* (Gmelin, 1791)
	GASTROPODA	
Lottiidae	*Lottia* Gray, 1833	7. *Lottia antillarum* G. B. Sowerby I, 1834
Fissurellidae	*Fissurella* Bruguière, 1789	8. *Fissurella nodosa* (Born, 1778) 9. *Fissurella rosea* (Gmelin, 1791)
Tegulidae	*Tegula* Lesson, 1832	10. *Tegula excavata* (Lamarck, 1822)
Neritidae	*Nerita* Linnaeus, 1758	11. *Nerita peloronta* Linnaeus, 1758 12. *Nerita tessellata* Gmelin, 1791 13. *Nerita versicolor* Gmelin, 1791
	Puperita Gray, 1857	14. *Puperita pupa* (Linnaeus, 1767)
Planaxidae	*Supplanaxis* Thiele, 1929	15. *Supplanaxis nucleus* (Bruguière, 1789)
Littorinidae	*Cenchritis* Martens, 1900	16. *Cenchritis muricatus* (Linnaeus, 1758)
	Echinolittorina Habe, 1956	17. *Echinolittorina angustior* (Mörch, 1876) 18. *Echinolittorina tuberculata* (Menke, 1828) 19. *Echinolittorina ziczac* (Gmelin, 1791)
Vermetidae	*Petaloconchus* Lea, 1843	20. *Petaloconchus varians* (d'Orbigny, 1839)
Columbellidae	*Mitrella* Risso, 1826	21. *Mitrella ocellata* (Gmelin, 1791)
	Rhombinella Radwin, 1968	22. *Rhombinella laevigata* (Linnaeus, 1758)
Muricidae	*Plicopurpura* Cossmann, 1903 *Stramonita* Schumacher, 1817	23. *Plicopurpura patula* (Linnaeus, 1758) 24. *Stramonita floridana* (Conrad, 1837)
Ellobiidae	*Tralia* Gray, 1840	25. *Tralia ovula* (Bruguière, 1789)

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(9) AGRADECIMIENTOS. Se recomienda ser lacónicos en la mención de las instituciones y personas que colaboraron con el trabajo, sin hacer mención de títulos académicos o de otros tipos. Por razones éticas de mucha importancia, se pide a los autores que mencionen los permisos oficiales a cuyo amparo se realizaron recolectas de especímenes o se recibieron facilidades en el manejo de animales, así como decir los nombres de las instituciones que financiaron la investigación.

(10) REFERENCIAS. Las referencias bibliográficas deberán tener una correspondencia exacta con las citas o menciones incluidas en el cuerpo textual, todas las citas en el cuerpo del trabajo deberán aparecer debidamente referenciadas en REFERENCIAS, al tiempo que las referencias que figuren en esta deberán aparecer citadas en aquél. Se evitará sobrecargar el contenido de citas o referencias innecesarias, las que extienden exageradamente este acápite de REFERENCIAS.

Composición y formato de las Notas

Las secciones requeridas para este tipo de contribuciones son las siguientes: TÍTULO (en ambos idiomas), RESUMEN-ABSTRACT y PALABRAS CLAVE-KEYWORDS, a seguidas el cuerpo del texto de corrido y sin dividirlo en acápites. Es decir, las informaciones relativas a Introducción, Objetivos, Materiales y Métodos, Resultados y Conclusiones, irían incluidas dentro del cuerpo del trabajo, pero sin destacarlas con encabezados. Luego, AGRADECIMIENTOS y al final REFERENCIAS, con las mismas observaciones y recomendaciones para estas secciones enunciadas en los incisos anteriores para los Artículos.

Citas y referencias bibliográficas

A partir del número 20 (julio, 2022) la revista *Novitates Caribaea* asume para las citas y referencias las normas APA, siempre en su última versión (actual: séptima edición, 2020). Este estilo se aplica para los artículos y las notas. Para la organización de las referencias en el acápite REFERENCIAS, se recomienda el uso de gestores bibliográficos, algunos de los cuales son de código abierto, pero el autor podría hacerlo manualmente.

Siempre que un autor haga referencia a las ideas y pensamientos de otro autor, y más aún cuando utilice frases de otro, deberá dar crédito a ese autor mediante citas, de lo contrario se considerará como plagio. Se recomienda siempre usar las fuentes primarias, y en caso de no disponer de éstas por razones atendibles, el autor deberá referirla en el texto junto a la fuente secundaria consultada, aunque en su lista de referencias (Referencias) solo figure la fuente secundaria que ha utilizado (ver APA 2020). Siguiendo las normas APA, esta revista utiliza el sistema de Autor-Fecha para las citas. En el caso de las citas textuales o directas, se podrán presentar en dos formatos básicos, citas narrativas o basadas en el autor y citas parentéticas o basadas en el texto, contemplando algunas variantes dentro de estos dos. a) Cita narrativa o basada en el autor: *Espinosa y Robinson (2021) señalan que para la malacofauna terrestre viviente de la Hispaniola "se reportan 612 táxones distribuidos en tres subclases, 129 géneros y 39 familias" (p. 71); Cita parentética o basada en el texto: Para la malacofauna terrestre viviente de la Hispaniola "se reportan 612 táxones distribuidos en tres subclases, 129 géneros y 39 familias" (Espinosa & Robinson, 2021, p. 71).* En el caso de las citas directas con más de 40 palabras se aplican otras instrucciones (ver APA 2020). Sin embargo, dada la propia naturaleza y el ámbito temático de esta revista, la mayoría de las citas utilizadas son parafraseadas, es decir, citas en las que el autor narra o inserta con sus propias palabras ideas y planteamientos de otros autores; en estos casos no se usarán comillas, ni será requisito la indicación de páginas: *Para la Hispaniola, se han reportado 129 géneros, los cuales se ordenan en 39 familias dentro de tres subclases (Espinosa & Robinson, 2021).* Pero en estas citas de parafraseo no puede faltar la indicación de autor-fecha, siendo necesario tomar muy en consideración los siguientes detalles: 1) cada idea, consideración o resultado parafraseado deberá estar referenciado con precisión en paréntesis, aunque se tenga que repetir algunas de estas referencias; 2) no agrupar indistintamente las referencias en un mismo paréntesis en relación a resultados o ideas diferentes, provenientes de distintas fuentes; 3) no se aconsejan las autocitas, pero en los casos necesarios, y viéndose el autor precisado a insertar ideas o resultados propios publicados previamente, este deberá incluir las referencias correspondientes en paréntesis, evitando así el autoplagio.

En todos los casos anteriores, para las referencias de autor-fecha dentro del cuerpo textual, se tomará en cuenta lo siguiente: 1) ordenarlas por antigüedad y separarlas con punto y coma (Ruggiero & Hawkins, 2008; Nemésio & Vasconcelos, 2013; Fergnani & Ruggiero, 2017); 2) en todas las citas con tres o más autores se usará la expresión et al. (en itálicas) después del primer autor en todos los casos, salvo cuando se pueda originar alguna ambigüedad en la información (ver APA 2020); 3) en el caso anterior, se pondrán apellido e inicial del nombre en la lista de referencias hasta 20 autores, aplicándose lo que manda APA de 21 autores en adelante (ver APA 2020); 4) en los casos de dos o más publicaciones de un mismo autor en un mismo año, se usarán literales al final del año para diferenciarlas (a, b, c…), asignándose estas literales de acuerdo al ordenamiento alfabético de los títulos de esas publicaciones (Hedges, 2004a)… (Sangermano, 2015a, b).

La lista de referencias iniciará en una página separada, bajo el título REFERENCIAS, centrado en la parte superior, al igual que el resto de los acápites, sin subrayar y sin comillas. En esta lista, cada entrada deberá tener una sangría francesa a media pulgada del margen izquierdo debajo del primer renglón:

Referencias

Alonso, R., Crawford, A. & Bermingham, E. (2012). Molecular phylogeny of an endemic radiation of Cuban toads (Bufonidae: Peltophryne) based on mitochondrial and nuclear genes. *Journal of Biogeography*, *39* (3), 434–451. https://doi.org/10.1111/j.1365-2699.2011.02594.x

Gao, D. & Perry, G. (2016). Species–area relationships and additive partitioning of diversity of native and nonnative herpetofauna of the West Indies. *Ecology and Evolution*, *6* (21), 7742–7762. https://doi.org/10.1002/ece3.2511

Como se puede apreciar en los ejemplos, en ninguna referencia incluida faltará: 1. Apellido (coma) e inicial del nombre (punto) de cada autor; 2. Año, entre paréntesis; 3. Título del artículo (en redondas) o del libro (en itálicas); 4. Título de la revista, si no es un libro (en itálicas); 5. Volumen (en itálicas) y número (entre paréntesis); 6. Número de la página de inicio-número de la página final (separados con "en dash"); 7. Fuente de recuperación (doi, url, datos de editora).

Las anteriores directrices solo procuran resumir los aspectos fundamentales en cuanto a citas y referencias, pero siempre el referente obligado serán las propias normas APA 2020.

Revisión por pares

Los editores de *Novitates Caribaea* harán una primera revisión del manuscrito sometido para confirmar la pertinencia de su contenido con los objetivos y el alcance de la revista, así como el cumplimiento de nuestras normas editoriales establecidas en el documento "Directrices a los autores". Los resultados de esta revisión inicial se comunicarán al autor en un plazo no mayor de tres semanas, tiempo comprendido a partir de la publicación de cada número (enero y julio). En una segunda etapa, el manuscrito será enviado a *revisión por pares* siguiendo el sistema *doble ciego*: el autor y los revisores solo tendrán comunicación con los editores, quedando sus identidades ocultas entre ellos. En este proceso de arbitraje, de acuerdo al contenido sometido, participarán los miembros del comité editorial y académicos-investigadores externos a la revista, de diferentes universidades, museos e instituciones afines con quienes tenemos relación o que sean recomendados por estos o los miembros del comité. Los árbitros o revisores entregarán a los editores los resultados de su evaluación dentro de un tiempo no mayor de cuatro meses. En caso de retraso se notificará a los autores. Estos resultados se formalizarán en nuestro *Formulario para revisión*, documento descargable desde este mismo sitio. Los editores harán posible la comunicación biunívoca entre autores y revisores manteniendo su anonimato, al tiempo que garantizarán el respeto a las consideraciones de ambas partes y la incorporación de los cambios pertinentes en el manuscrito aprobado o la comunicación de su rechazo, en caso de ser este el resultado. En caso de rechazo para publicación, los editores harán llegar a los autores las correcciones y consideraciones de los árbitros, pero las decisiones de estos últimos serán inapelables, siempre que justifiquen su decisión ante los editores. Los trabajos aprobados, luego de incorporar todos los cambios resultantes de la revisión, se someterán a revisión de estilo final, de común acuerdo con el autor. Los editores se comprometen a enviar al autor un PDF de prueba con el trabajo final diagramado, requiriendo de su aprobación previo a la publicación.

Detección de plagio

Todo el proceso editorial en las publicaciones científicas deberá ceñirse siempre a normas éticas claras y firmes. Este principio es fundamental para *Novitates Caribaea*. De entrada, en su carta de intención, los autores deberán dar fe, por escrito y con su firma, que el artículo o nota que someten no se ha publicado previamente en ningún tipo de formato. Una vez recibido, el contenido será evaluado programas antiplagio, en la actualidad Plag.es. Pero esta no será nuestra única herramienta, sino que se usará Google Scholar y otros recursos de la web, además de la opinión experta de los árbitros, quienes deberán ser conocedores de la literatura publicada en el área correspondiente. Existen diferentes niveles de plagio, y todos serán firmemente rechazados por esta revista, aun tratándose de repeticiones involuntarias por los autores, pero con los intentos de fraudes flagrantes seremos drásticos y se impedirá por siempre todo intento de publicaciones futuras con los nombres de los involucrados.

Política de acceso abierto

Todos los contenidos publicados en Novitates Caribaea se ofrecen en acceso libre, siguiendo la definición de la Budapest Open Access Initiative (BOAI10), que dice:

> *Por "acceso abierto" [a la literatura científica revisada por pares], nos referimos a su disponibilidad gratuita en la Internet pública, que permite a cualquier usuario leer, descargar, copiar, distribuir, imprimir, buscar o añadir un enlace al texto completo de esos artículos, rastrearlos para su indización, incorporarlos como datos en un software, o utilizarlos para cualquier otro propósito que sea legal, sin barreras financieras, legales o técnicas, aparte de las que son inseparables del acceso mismo a la Internet. La única limitación en cuanto a reproducción y distribución, y el único papel del copyright (los derechos patrimoniales) en este ámbito, debería ser la de dar a los autores el control sobre la integridad de sus trabajos y el derecho a ser adecuadamente reconocidos y citados.*

Novitates Caribaea es una revista Open Access Diamante, por lo que el sometimiento o postulación, el procesamiento, la revisión, la publicación y la lectura de los contenidos está libre de todo cargo o cobro, para los autores y lectores.

Preservación de archivos

La revista *Novitates Caribaea* utiliza los programas Lockss y Clockss, implementados por PKP Preservation Network (PKN PN), incorporado a OJS. Adicionalmente, se hacen archivos (backup) desde el servidor institucional.

Protocolo de interoperabilidad

La revista Novitates Caribaea utiliza el protocolo OAI-PMH, el cual puede localizarse y consultarse en el siguiente enlace:

https://novitatescaribaea.do/index.php/novitates/oaiverb=ListRecords&metadataPrefix=oai_dc

Exención de responsabilidad

El contenido de las contribuciones publicadas será siempre de la responsabilidad de los autores.

Declaración de privacidad

Los nombres y las direcciones de correo electrónico introducidos en esta revista se usarán exclusivamente para los fines establecidos en ella y no se proporcionarán a terceros o para su uso con otros fines.

Author Guidelines

Scope and language

Novitates Caribaea journal publishes original scientific content in three major areas: zoology, paleobiology and geology, covering different aspects and approaches within these fields: molecular and morphological systematics, taxonomy, natural history, ecology, biogeography, evolution, genetics, embryology, behavior, conservation, comparative anatomy, paleoecology, paleogeography, geomorphology, and stratigraphy, among others. In all cases, we focus exclusively on the Caribbean region as a geographic scope.

The official language of the journal is Spanish, but works in English are also accepted, provided that the author or one of the co-authors is proficient in English; or by means of a certification from an English-speaking professional who has proofread the manuscript.

Publication Frequency

The *Novitates Caribaea* journal is published twice a year (January and July). Manuscripts may be submitted year-round, but always for publication in January or July. Generally, the deadlines for the inclusion of articles in a January or July issue are November or May, respectively.

Submission Types

We publish two types of scientific content: articles and notes.

a) Articles. Manuscripts should have a minimum length of 10 pages and a maximum of 30 pages, including bibliographical references, tables, and figures. Acceptance for review of submissions that exceed the maximum number of pages remains at the discretion of the editors. The expected structure for this submission type is detailed below (“Structure and format of Articles”).

b) Notes. Brief information on unique findings, new species records (not localities within the same country) or new contributions resulting from ongoing research projects or studies. Notes must be longer than three pages but shorter than 10 pages, including bibliographical references. Notes do not need to include all the sections required for the articles (“Structure and format of Notes”).

Structure and Format of Articles

New submissions must be uploaded as a Word document to the online platform (OJS) and sent to the journal’s email address (novitatescaribaea@mnhn.gov.do). Manuscripts should be in Times New Roman font, 11 points, 1.5 line spacing and titles (main and paragraphs) in capital letters. Under the title in the submitted language should be a translation of the title in the second language (English or Spanish, as the case may be). Figures (high resolution JPG) and tables must be sent separately, in addition to being inserted in the body of the manuscript in low resolution. Submissions must be signed with the names of the authors, their institutional affiliation, e-mail address, Orcid and/or Redalyc ID, and an indication of the corresponding author. Articles must be structured with the following components:

(1) TITLE. In Spanish and English, concise and relevant to the content of the work. The manuscript title should not exceed three lines written in capital letters. The authorship of species or of the major taxonomic categories should not be included in the title, unless the content of the manuscript focuses on status of a species or taxonomic group, or if the submission is a new report of a pest species. However, the names of the taxonomic categories (Class, Order, Family) can be included in the title, albeit without their authorship. The title must correspond to the essential aspects of the content.

(2) ABSTRACT and KEYWORDS. Abstracts must be written in both languages (Spanish and English), each followed by a list of 3-6 keywords in the corresponding language. The abstract must be informative and concise (maximum of 300 words) and should offer a panoramic view of the manuscript's content, including introductory aspects, the methodology and the most outstanding findings of the article. No citations or references should be included in the Abstract.

(3) INTRODUCTION. This section should include the necessary citations and references to reflect the most up-to-date literature on the subject, while giving the reasons and justification for the investigation. The artificial use of unnecessary references should be avoided.

(4) OBJECTIVES. Brief and precise. Must be written as sentences with verbs in the infinitive tense, in two or three lines.

(5) MATERIALS AND METHODS. This section should give a full account or support of all the results that are presented later in the manuscript. It must duly report what was done, how, where and what materials and equipment were used; the statistical analysis performed, if any, and how the results were organized. In all the points that are being considered, the pertinent references should be provided. The authors may subdivide this section into the necessary sub-sections, such as "study area", "materials used" and "statistical analysis".

(6) RESULTS. This section could include several sub-sections, with their respective subtitles, in order to organize the contents of the section as appropriate for the work submitted. The inclusion of tables and/or figures is highly recommended as a guide to order and present results. The presented results should not be interpreted within this section, but in the DISCUSSION. If the submission is a description of new taxa, under RESULTS, the authors must include: *Diagnosis* (in both languages), *Description of the Holotype*, *Types* (origin and destination, locations, collectors and dates) and *Etymology* (of the genus or of the specific epithet, according to the case). We suggests authors register the nomenclatural act in ZooBank and include the assigned url (LSID). The record of the new species published in *Novitates Caribaea* should also be recorded in the Zoological Record (Clarivate Analityc). In the case of new DNA sequencing, registration in the GenBank repository is recommended. The name of the new taxon should be indicated with the inscriptions sp. nov. or gene nov., depending on the case, each time it appears in the text (in bold type). All generic and specific names must appear in italics, and must be abbreviated from their first reference in the text by the initial letter of the genus followed by a period and the specific name (example: *Achromoporus heteromus…A. heteromus*). In general, for names and all nomenclatural acts, authors and publishers will be governed by the rules established in the latest edition of the International Code of Zoological Nomenclature, prepared by the International Commission on Zoological Nomenclature. The inclusion of other RESULTS blocks in these taxonomic manuscripts, such as *Natural History* and *Comments,* will be optional.

Tables and Figures: all tables and figures (graphs, drawings, photos, maps or other elements) will be included in the RESULTS section, duly identified with a concise title and numbered sequentially, using Roman numerals for tables and Arabic numerals for figures. The authors will include their figures in the manuscript as a suggestion of their location, but they must also send them separately in high resolution, as indicated below. Any explanatory notes and/or legends of Tables will go at the bottom of these (a space below) and in some special cases at the bottom of a column, using asterisks or floating numbers. Drawings must be made on white paper with black ink, well defined and assembled in sheets if there are several and the work requires it. All figures to be included in the manuscript must also be sent by email, in individual files with a BMP or JPG extension and with a resolution of 270-300 DPI. The scale must be indicated both on the drawings and on the photos. Figure captions must have a general title and details of their parts or components, separated by letters or numbers. All names and subtitles within the figure should be in Times New Roman, size 11.

(7) DISCUSSION. The length of this section will vary according to the content of the results presented, but the content must be precise and explain or interpret the results of the study, without being redundant. This section may not be necessary in taxonomy articles, and in other cases, in which the authors could use a RESULTS AND DISCUSSION combined section.

(8) CONCLUSIONS. Their presentation style will be left to the discretion of the authors, but in any case, they should be clear and precise, and closely linked to the DISCUSSION. In some Articles, as would be the case of those that consist of the description of new species, the CONCLUSIONS section will not be necessary. In other works, this section could be accompanied with pertinent recommendations, in this case title the section as CONCLUSIONS AND RECOMMENDATIONS.

(9) ACKNOWLEDGMENTS. It is recommended to be brief in the mention of institutions and people who collaborated with the work, without mentioning academic titles or other titles. For ethical reasons of great importance, the authors are asked to mention the official permits under which specimens were collected or facilities were utilized for the handling of animals, as well as the names of the institutions that financed the research.

(10) REFERENCES. The bibliographical references must have an exact correspondence with the citations or mentions included in the body of the text. All the citations in the body of the work must appear duly referenced in REFERENCES. Avoid overloading the content with unnecessary citations or references.

Composition and Format of Notes

The sections required for this type of contribution are the following: TITLE (in both languages), ABSTRACT and KEYWORDS, followed by the body of the text without dividing it into sections. That is, the information related to Introduction, Objectives, Materials and Methods, Results and Conclusions, would be included within the body of the work, but without highlighting them with headings. Then, ACKNOWLEDGMENTS and at the end REFERENCES, with the same observations and recommendations for these sections stated in the previous paragraphs for Articles.

Citations and Bibliographical References

As of issue 20 (July 2022), the *Novitates Caribaea* journal follows APA standards for citations and references in its latest version (current: seventh edition, 2020). This style applies to Articles and Notes. For the organization of references in the REFERENCES section, the use of bibliographic managers is recommended, some of which are open source, but the author could also do it manually.

Whenever an author refers to the ideas and thoughts of another author, and even more so when the author uses phrases from another, they must give credit to the referred author through citations, otherwise it will be considered plagiarism. It is always recommended to use the primary sources, and if they are not available for reasonable reasons, the author must refer to it in the text together with the secondary source consulted, even if only the secondary source appears in the list of references (see APA 2020). Following APA standards, this journal uses the Author-Date system for citations. In the case of textual or direct citations, they may be presented in two basic formats, narrative citations or based on the author and parenthetical citations or based on the text, contemplating some variants within these two. a) Narrative citation or based on the author: Espinosa and Robinson (2021) point out that for the living terrestrial malacofauna of Hispaniola “612 taxa distributed in three subclasses, 129 genera and 39 families are reported” (p. 71); Parenthetical citation or based on the text: For the living terrestrial malacofauna of Hispaniola “612 taxa distributed in three subclasses, 129 genera and 39 families are reported” (Espinosa & Robinson, 2021, p. 71). In the case of direct citations with more than 40 words, other instructions apply (see APA 2020). However, given the very nature and thematic scope of this journal, most of the quotes used are paraphrased, that is, quotes within which the author narrates or inserts in his own words ideas and approaches of other authors; in these cases, quotation marks will not be used, nor will page indication be required: For Hispaniola, 129 genera have been reported, which are arranged in 39 families within three subclasses (Espinosa & Robinson, 2021). But in these paraphrasing citations, the author-date indication cannot be absent, being necessary to take into consideration the following details: 1) each paraphrased idea, consideration or result must be precisely referenced in parentheses, even if some of them have to be repeated; 2) do not group references indistinctly in the same parentheses in relation to different results or ideas, coming from different sources; 3) self-citations are not recommended, but when necessary, and seeing that the author needs to insert their own ideas or previously published results, they must include the corresponding references in parentheses, thus avoiding self-plagiarism.

In all the above cases, for the author-date references within the textual body, the following will be taken into account: 1) order them by year of publication and separate them with a semicolon (Bouzan et al., 2017a; Bouzan, Iniesta, & Brescovit, 2018b; Bouzan, Pena-Barbosa, & Brescovit, 2017b); 2) in all citations with three or more authors, the expression et al. after the first author in all cases, except when some ambiguity may arise in the information (see APA 2020); 3) in the previous case, the surname and initial of the name will be put in the list of references (REFERENCES) up to 20 authors, applying what APA mandates from 21 authors onwards (see APA 2020); 4) in the cases of two or more publications by the same author in the same year, letters should be used at the end of the year to differentiate them (a, b, c...), assigning these letters according to the alphabetical ordering of the titles of those publications (Hedges, 2004a)… (Bueno-Villegas, 2020a,b).

The list of references will begin on a separate page, under the title REFERENCES, centered at the top, like the rest of the headings, without underlining and without quotation marks. In this list, each entry should have a hanging indent one-half inch from the left margin:

References

Alonso, R., Crawford, A. & Bermingham, E. (2012). Molecular phylogeny of an endemic radiation of Cuban toads (Bufonidae: Peltophryne) based on mitochondrial and nuclear genes. *Journal of Biogeography*, *39* (3), 434–451. https://doi.org/10.1111/j.1365-2699.2011.02594.x

Gao, D. & Perry, G. (2016). Species–area relationships and additive partitioning of diversity of native and nonnative herpetofauna of the West Indies. *Ecology and Evolution*, *6* (21), 7742–7762. https://doi.org/10.1002/ece3.2511

Kumar, S., Stecher, G., Suleski, M., & Hedges, S. B. (2017). TimeTree: a resource for timelines, timetrees, and divergence times. *Molecular Biology and Evolution*, *34*(7), 1812–1819.

As can be seen in these examples, the following components must be present: 1. Surname (comma) and initial of the name (dot) of each author; 2. Year, in parentheses; 3. Title of the article (in bullets) or of the book (in italics); 4. Title of the magazine, if it is not a book (in italics); 5. Volume (in italics) and number (in parentheses); 6. Number of the beginning page-number of the final page (separated with “in dash”); 7. Retrieval source (doi, url, publisher data).

The above guidelines only attempt to summarize the fundamental aspects of citations and references, but the obligatory reference will always be the APA 2020 standards themselves.

Peer review

The editors of Novitates Caribaea will make a first review of the submitted manuscript to confirm the relevance of its content with the objectives and scope of the journal, as well as compliance with our editorial standards as established in the document “Guidelines for Authors”. The results of this initial review will be communicated to the author within a period not exceeding three weeks, from the publication of each number (January and July). In a second stage, the manuscript will be submitted for peer review following the double-blind system: the author and the reviewers will only have communication with the editors, keeping their identities hidden from each other. The referees or reviewers will deliver the results of their evaluation to the editors within a time not exceeding four months. In case of delay, the authors will be notified. These results will be formalized in our Review form, a document that can be downloaded from this same site. The editors will make biunivocal communication between authors and reviewers possible, maintaining their anonymity, while guaranteeing respect for the considerations of both parties and the incorporation of the pertinent changes in the approved manuscript or the communication of its rejection, if this is the case. In case of rejection for publication, the editors will send the authors the corrections and considerations of the referees, but the decisions of the latter will be final, as long as they justify their decision before the editors. The approved works, after incorporating all the changes resulting from the review, will be submitted to a final style review, in agreement with the author. The editors undertake to send the author a proof PDF with the final work diagrammed, requiring their approval prior to publication.

Detection of Plagiarism

The entire editorial process for scientific publications must adhere to clear and firm ethical standards. This principle is fundamental to *Novitates Caribaea*. From the outset, in their letter of intent, the authors must attest, in writing and with their signature, that the article or note they submit has not been previously published in any type of format. Once received, the content will be evaluated by anti-plagiarism programs. We currently use Plag.es, but this will not be our only tool. Google Scholar and other web resources will be used, in addition to the expert opinion of the referees, who will be familiar with the literature published in the corresponding area. There are different levels of plagiarism, and all will be firmly rejected by this journal, even in the case of inadvertent repetition by the authors, but with flagrant fraud attempts we will be drastic, and any future publication attempts with the names of those involved will be forever banned.

Open access policy

All the contents published in Novitates Caribaea are freely accessible, following the definition of the Budapest Open Access Initiative (BOAI10), which states:

> *By "open access" [to peer-reviewed scientific literature], we refer to its free availability on the public Internet, allowing any user to read, download, copy, distribute, print, search, or add a link to the full text of those articles, track them for indexing, enter them as data into software, or use them for any other purpose that is lawful, without financial, legal, or technical barriers, other than those inseparable from access to the Internet itself. The only limitation on reproduction and distribution, and the only role of copyright (property rights) in this area, should be to give authors control over the integrity of their works and the right to be properly acknowledged and cited.*

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File Preservation

Novitates Caribaea journal uses the Lockss and Clockss programs, implemented by the PKP Preservation Network (PKN PN), incorporated into OJS. Additionally, files (backups) are made from the server.

Interoperability protocol

The Novitates Caribaea journal uses the OAI-PMH protocol, which can be located and consulted on the following link: https://novitatescaribaea.do/index. php/novitates/oaiverb=ListRecords&metadataPrefix=oai_dc

Waiver of liability

The content of published contributions will always be the responsibility of the authors.

Privacy statement

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Novitates
CARIBAEA
Número 23. Enero, 2024

CONTENIDO

Artículos

Notas