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Original article

Fishes in the Ciénaga Grande de Santa Marta: Bibliographic review

Peces de la Ciénaga Grande de Santa Marta: revisión bibliográfica

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Abstract

The Ciénaga Grande de Santa Marta (CGSM), the largest coastal lagoon system in Colombia, supports a diverse ichthyofauna and a highly productive artisanal fishery, yet its fish diversity has never been synthesized within a consistent taxonomic framework. We present a critical bibliographic reconstruction of the CGSM ichthyofauna, integrating records spanning nearly three centuries — from an 18th-century chronicle to a monitoring program extending into 2026 — and applying conservative criteria for species inclusion, systematic resolution of synonymies, and rigorous elimination of duplicate records. The resulting inventory recognizes 204 fish taxa, comprising 12 Elasmobranchii and 192 Teleostei across 37 orders, 86 families, and 161 genera. The most significant finding is the geographic reassignment of **Steindachner's** (1879) material — historically attributed to the Magdalena River — to the CGSM lagoon complex, supported by the author's own text and by Natural History Museum Vienna specimen records. This reassignment extends the scientifically documented baseline from approximately 1971 to 1876. The earliest record, **Nicolás de la Rosa's** chronicle (ca. 1746), contributes 37 taxa, including 16 unique to that source. The chronological accumulation analysis reveals a gradual increase over two and a half centuries, followed by a marked acceleration after 1987 driven by a single comprehensive survey, and subsequent stabilization under long-term commercial fisheries monitoring. The inventory represents a substantial advance over earlier compilations by combining historical depth, taxonomic consistency, and full traceability of every species record to a verifiable primary source, providing a robust baseline for future ecological, taxonomic, and fisheries research in this important ecological and socioeconomic system.

Keywords: Coastal lagoon; Ichthyofauna; Species inventory; Bibliographic review; Taxonomic standardization; Colombian Caribbean.

Resumen

La Ciénaga Grande de Santa Marta (CGSM), el mayor sistema lagunar costero de Colombia, alberga una ictiofauna diversa y una pesquería artesanal productiva, cuya diversidad íctica no había sido sintetizada dentro de un marco taxonómico consistente. Se presenta una reconstrucción bibliográfica crítica de la ictiofauna de la CGSM, que integra registros de casi tres siglos, desde una crónica del siglo XVIII hasta un programa de monitoreo extendido hasta 2026, y se aplican criterios conservadores de inclusión de especies, resolución de sinonimias y eliminación de registros duplicados. El inventario reconoce 204 taxones de peces: 12 Elasmobranchii y 192 Teleostei, distribuidos en 37 órdenes, 86 familias y 161 géneros. El hallazgo principal es la reasignación geográfica del material de **Steindachner** (1879), históricamente atribuido al río Magdalena, al complejo lagunar de la CGSM, respaldada por el texto original del autor y por registros de especímenes del Museo de Historia Natural de Viena. Esta reasignación amplía la línea de base científicamente documentada de aproximadamente 1971 a 1876. El registro más antiguo, la crónica de **Nicolás de la Rosa** (ca. 1746), aporta 37 taxones, 16 exclusivos de esa fuente. El análisis de acumulación cronológica

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muestra un incremento gradual durante dos siglos y medio, una marcada aceleración después de 1987 debida a un estudio exhaustivo, y la posterior estabilización bajo monitoreo pesquero de largo plazo. El inventario mejora compilaciones previas al combinar profundidad histórica, consistencia taxonómica y trazabilidad completa hasta fuentes primarias verificables, proporcionando una base sólida para futuras investigaciones ecológicas, taxonómicas y pesqueras en este importante sistema ecológico y socioeconómico.

Palabras clave: Laguna costera; Ictiofauna; Inventario de especies; Revisión bibliográfica; Estandarización taxonómica; Caribe colombiano.

Introduction

The Ciénaga Grande de Santa Marta (CGSM) is the largest coastal lagoon system in Colombia and a major estuarine ecosystem of the Caribbean region (**Rivera-Gutiérrez & Caicedo**, 1998; **Rodríguez-Rodríguez *et al.***, 2016). Situated at the former delta of the Magdalena River and at the foothills of the Sierra Nevada de Santa Marta—the world's highest coastal mountain range—the system forms a highly dynamic interface between marine, riverine, and continental environments (**Wiedemann**, 1973; **Perdomo-Trujillo *et al.***, 2021). This unique geographic and hydrological setting supports a diverse ichthyofauna and sustains a highly productive artisanal fishery (**Rueda & Defeo**, 2003). Its ecological functioning and fisheries productivity are closely linked to hydrological connectivity and salinity gradients driven by the Magdalena River and coastal processes (**Botero & Salzwedel**, 1999).

Given its great ecological and socio-economic importance, the ichthyofauna at the Ciénaga Grande de Santa Marta has been documented in a wide range of sources over nearly three centuries. Records range from early historical accounts of the 18th century to taxonomic descriptions of the 19th century and a wide spectrum of scientific studies conducted throughout the 20th and 21st centuries (**de la Rosa**, ca. 1746, published 1820; **Steindachner**, 1879; **Santos-Martínez & Acero**, 1991; **Invemar**, 2024). However, our comparison shows that these sources differ substantially in scope, methodology, spatial resolution, and taxonomic consistency, which complicates direct comparison and synthesis (**Text 1S;** http://raccefyn.co/index.php/raccefyn/article/view/4159/5446). Many studies focus on specific ecological aspects, habitats, or commercially important species (**Rueda & Santos-Martínez**, 1999; **Rueda & Defeo**, 2003), whereas others are compiled inventories where procedures used to assemble the species lists are not fully documented (**Franky-Vásquez & Rodríguez-Guerrero**, 1976; **Invemar**, 2024), further limiting their comparability.

Consequently, the current understanding of the ichthyofauna of the CGSM remains constrained by several methodological and taxonomic limitations. Species records are dispersed across a heterogeneous body of literature, including publications based on shared datasets (**Santos-Martínez**, 1989; **Santos-Martínez & Acero**, 1991) (**Texts 1S, 3S;** http://raccefyn.co/index.php/raccefyn/article/view/4159/5446). In addition, differences in taxonomic treatment—arising from synonymies, outdated nomenclature, and varying identification criteria—further complicate comparisons among studies (**Santos-Martínez & Arboleda**, 1993; **McBride *et al.***, 2010). The use of genus-level identifications (sp., spp.) and qualified identifications (cf.) requires case-by-case evaluation to assess taxonomic uncertainty and avoid double counting (**Mercado-Silgado**, 1971; **Botero-Arboleda & Marshall**, 1995) (**Text 1S;** http://raccefyn.co/index.php/raccefyn/article/view/4159/5446). The repeated reproduction of species lists in institutional reports does not, by itself, establish independent confirmation of the listed records.

Another limitation lies in the incomplete integration and interpretation of key historical sources. The account of **José Nicolás de la Rosa** (ca. 1746; published 1820) represents the earliest known documented description of fishes from the region. Although already discussed by **Dahl** (1971), this account has not previously been systematically evaluated within a modern taxonomic framework. Likewise, the seminal work of

Franz Steindachner (1879), published in German under the title *Zur Fisch-Fauna des Magdalena-Stromes*, has historically been interpreted as referring primarily to the Magdalena River system. The reassessment of his account and associated museum records indicates that this material originated from the Ciénaga Grande de Santa Marta lagoon complex, not the Magdalena River. **Steindachner** (1879, p. 20) reported acquiring more than 200 fishes from the "large, lake-like Cienega" in 1876–1877. This reassignment of geographic context represents a key step in resolving the early ichthyological record of the system and refining its historical baseline.

Previous efforts to summarize the ichthyofauna of the CGSM have provided valuable contributions, particularly in relation to fisheries resources and ecological studies (**Santos-Martínez & Acero**, 1991), and subsequent studies based on related datasets. However, we still lack a comprehensive synthesis integrating historical and modern records within a consistent taxonomic framework and explicitly addressing duplication, uncertainty, and misinterpretation of key sources. In this context, the present study reconstructs the ichthyofauna of the CGSM through a critical bibliographic analysis. By systematically reviewing available sources, standardizing taxonomy according to current references, and applying conservative criteria for the inclusion of species records, we compiled a traceable and internally consistent inventory of fish species reported for the system.

By organizing records chronologically, the study further elucidates the historical accumulation of knowledge on species and enables the distinction between persistent and isolated records. The explicit incorporation of early historical sources and the reassessment of foundational taxonomic works refine the temporal baseline of ichthyological knowledge for the CGSM. This approach not only improves the reliability of species richness estimates but also provides a transparent and reproducible foundation for future ecological, taxonomic, and fisheries-related studies. The resulting synthesis reveals a substantially refined and internally consistent species inventory, while clarifying the historical accumulation of records and resolving inconsistencies in key sources.

Materials and methods

Study area

The Ciénaga Grande de Santa Marta (CGSM; 10°40'–11°00' N, 74°20'–74°35' W) is the largest coastal lagoon system in Colombia, covering approximately 1,280 km² as a complex of open lagoons, tidal channels, and associated wetlands (**Salzwedel**, 2022). It is situated at the former delta of the Magdalena River, at the base of the Sierra Nevada de Santa Marta — the world's highest coastal mountain range — on the Caribbean coast of northern Colombia (**Figure 1**).

The CGSM is a shallow system, with mean depths generally between 1.5 and 2.5 m and maximum depths rarely exceeding 4 m (**Santos-Martínez & Acero**, 1991; **Rueda & Defeo**, 2003). Water temperatures are persistently high throughout the year, ranging from 27 °C to 32 °C, which reflects the tropical Caribbean setting of minimal seasonal thermal variation (**Santos-Martínez & Acero**, 1991; **Leal-Flórez *et al.***, 2008). The combination of shallow depth and high ambient temperatures creates conditions of frequent thermal mixing and pronounced diel fluctuations in dissolved oxygen (**Espinosa-Díaz *et al.***, 2021).

Salinity dynamics are highly sensitive and constitute a major structuring force of the system (**Wiedemann**, 1973). The CGSM operates as a positive estuary during the wet season (May–November), when freshwater inflow from the Magdalena River through the eastern *caños* (Clarín, Aguas Negras, and others) drives salinity toward oligohaline conditions. During the dry season (December–April), reduced river discharge combined with the strongly negative water balance imposed by high evapotranspiration rates, which frequently exceed freshwater inputs from both precipitation and river discharge, can shift large sectors of the lagoon toward hypersaline conditions. This sensitivity to the balance between evaporative demand and freshwater supply means that prolonged drought periods or restricted hydrological connectivity can rapidly produce extreme salinity gradients

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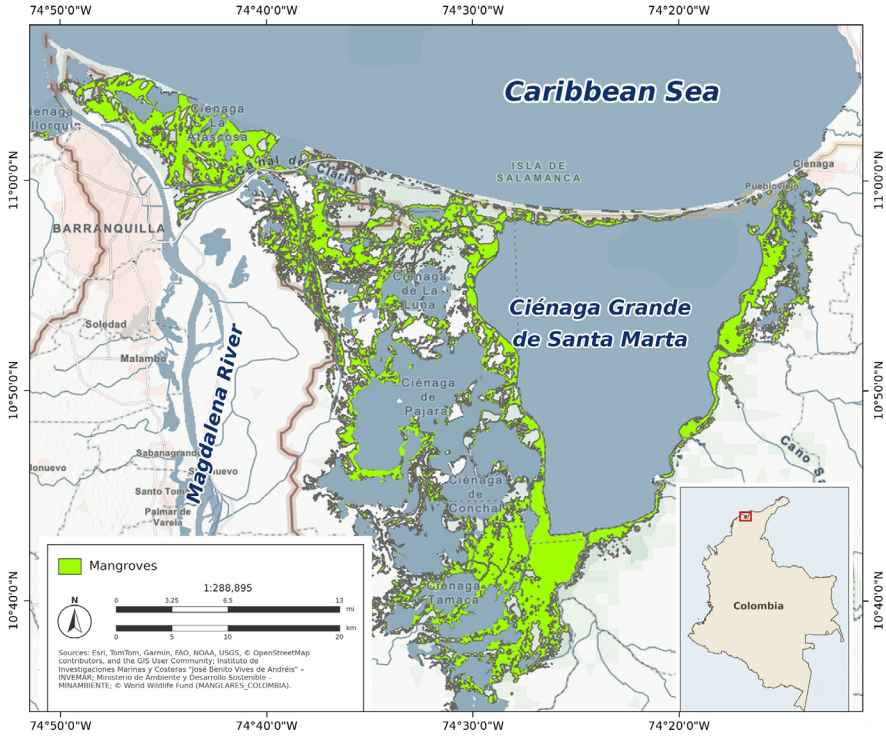


Figure 1. Study area at the Ciénaga Grande de Santa Marta lagoon complex

across the system (**Rueda & Defeo**, 2003; **Leal-Flórez *et al.***, 2008). Tidal exchange through Boca de la Barra, the main inlet connecting the lagoon to the sea, provides a further marine contribution that reinforces salinity build-up in the absence of sufficient freshwater input (**Wiedemann**, 1973; **Gocke *et al.***, 2003).

The CGSM supports extensive mangrove forests dominated by *Rhizophora mangle*, *Avicennia germinans*, *Laguncularia racemosa*, and *Conocarpus erectus* (***Schnetter et al.***, 1998), which serve as nursery and feeding habitat for a large proportion of the ichthyofauna (**Botero & Salzwedel**, 1999). The CGSM Ecoregion overlaps with, includes, or forms part of the following special areas: the Vía Parque Isla de Salamanca since 1964 (**Incora**, 1964), the Ciénaga Grande de Santa Marta Flora and Fauna Sanctuary since 1977) (**Ministerio de Agricultura**, 1977), the Ramsar Site No. 951 since 1998 (**Servicio de Información sobre Sitios Ramsar**, s. f.), and the Ciénaga Grande de Santa Marta Biosphere Reserve since 2000 (**Unesco**, 2000). The area was already listed as an Important Bird Area (IBA CO008) in 2005 (**Franco & Bravo**, 2005).

Beginning in the 1960s, the construction of the coastal highway and associated embankments progressively restricted tidal exchange and freshwater inflow, leading to widespread hypersalinization and near-total mangrove mortality across large sectors during the 1980s and early 1990s (**Botero & Salzwedel**, 1999). Rehabilitation works initiated in 1994–1996, including the reopening of several channels, partially restored hydrological connectivity and triggered a recovery of mangrove cover and fish community composition documented in detail by the Invemar monitoring program (**Pro-Ciénaga**, 1995; **Botero & Salzwedel,** 1999; **Invemar**, 2025).

Bibliographic reconstruction and taxonomic standardization of species records

We conducted a bibliographic reconstruction of the ichthyofauna of the Ciénaga Grande de Santa Marta (CGSM) based on a critical review and taxonomic standardization of historical and contemporary sources. The objective was to produce the most conservative

and traceable species inventory possible by integrating records spanning from early historical accounts to recent monitoring programs, while minimizing duplication and taxonomic ambiguity. This approach prioritizes taxonomic certainty over completeness and may therefore underestimate total species richness while ensuring maximum reliability of records.

We undertook a comprehensive literature review, including peer-reviewed publications, academic theses, technical reports, institutional monitoring datasets, and early historical sources. Each source was evaluated regarding its geographic relevance to the CGSM lagoon complex, the independence of its data, and the traceability of its species records, with particular attention given to distinguishing original observations from compilations based on earlier works.

Several sources were examined but not considered because they either lack primary records from the study area or largely duplicate earlier works already considered. For example, **Eigenmann** (1922) and **Wilson** (1916) do not report material from the area, while **Fowler** (1942) largely compiles earlier sources whose original records are already incorporated. Similarly, the records reported by **Álvarez-León & Blanco Racedo** (1985) were excluded because of insufficient spatial resolution and a lack of data independence. Likewise, **Grijalba-Bendeck *et al.*** (2012) were excluded because their study pertains to the marine area adjacent to, rather than within, the Ciénaga Grande de Santa Marta (CGSM) proper. This selective approach ensures that the resulting database is based on verifiable and non-redundant primary information.

Species records were extracted from each selected source, together with available contextual information, including sampling period, locality, and methodological details when reported. Because sampling years were not always explicitly stated, representative reference years were assigned where necessary to position records within a chronological framework. This enabled the construction of a temporally ordered dataset spanning from the earliest historical accounts to the present.

All extracted taxa were initially recorded using the manuscript species names (MS) as reported in the original sources and subsequently standardized to currently valid nomenclature based on Eschmeyer's Catalog of Fishes (**Fricke *et al.***, 2026) and FishBase (**Froese & Pauly**, 2026). Synonyms and outdated names were harmonized accordingly, while retaining the original designations for traceability. Vernacular names in English and Colombian Spanish were added when available, ensuring both historical fidelity and taxonomic consistency across the compiled dataset.

Historical records reported as *Elops saurus* were interpreted as *Elops smithi* following the taxonomic revision of the genus (**McBride *et al.***, 2010). Earlier authors treated *Elops* as a single western Atlantic species, whereas current taxonomy recognizes *E. smithi* as the species occurring in the southern Caribbean region, including Colombia. Original species names were retained in the database for traceability, but records were assigned to the currently accepted taxon unless evidence indicated otherwise.

To ensure a conservative species inventory, records identified only at the genus level (sp., spp.) were generally excluded unless they represented distinct taxonomic entities not otherwise documented at the species level in the dataset. Such exceptions are identified and discussed in Results. Records designated as cf. were evaluated individually and retained only when considered consistent with the known ichthyofauna of the Ciénaga Grande de Santa Marta region. Duplicate records resulting from repeated use of the same primary datasets across multiple publications were identified and removed. Generic-level records that did not contribute additional taxonomic resolution were not treated as separate taxa, thereby avoiding inflation of species richness estimates.

Early historical sources, including 18th- and 19th-century accounts, were evaluated critically. Only taxa that could be identified with sufficient confidence were included, while ambiguous vernacular records were excluded unless a reliable taxonomic assignment was possible. Where necessary, interpretations were supported by later literature and museum records to ensure consistency.

The 24 Invemar monitoring reports were treated as a continuous dataset rather than independent sources. Given the high degree of similarity among these reports, their species lists were critically compared, and the most consistent and recent version was used as the primary reference. Earlier reports were examined to identify additions, omissions, and inconsistencies in taxonomic reporting. This approach avoids artificial inflation of species counts resulting from repeated publication of largely unchanged species lists.

We constructed a cumulative database of species records by integrating all validated taxa in chronological order. Species counts were based on the earliest confirmed occurrence of each species, while later records were used only to assess persistence. Single records not confirmed by later studies were critically evaluated and retained only when no compelling evidence supported their exclusion. These records are easily identifiable in **Table 1S;** http://raccefyn.co/index.php/raccefyn/article/view/4159/5446, by the citation of a single reference only.

Only studies providing verifiable species records were incorporated into the chronological compilation of taxa. Studies focusing primarily on biological, ecological, or fisheries-related aspects were treated separately and are presented for contextual completeness in **Text 2S;** http://raccefyn.co/index.php/raccefyn/article/view/4159/5446: Fisheries biology, ecology, and resource assessment studies.

The standardized dataset forms the basis for the compilation in **Table 1S** (http://raccefyn.co/index.php/raccefyn/article/view/4159/5446), which includes original species names, current valid taxonomy, and vernacular names where available. Also, the dataset was used to construct a chronological accumulation table and to analyze temporal patterns in species discovery within the CGSM system.

Results

Chronological record of fish species

Records are presented in chronological order according to known or inferred sampling dates. Species-level identifications are preferred throughout; genus-level and cf. records are included only where they contribute unique taxonomic information not otherwise represented in the dataset. Duplicate records from repeated citations of the same primary source were excluded. The detailed methodological notes on each source, including gear descriptions, station layouts, and taxonomic decisions, are included in **Text 1S;** http://raccefyn.co/index.php/raccefyn/article/view/4159/5446.

José Nicolás de la Rosa (ca. 1746, published 1820) provided the earliest known documentation of fishes from the region. In Chapter X of his chronicle — entitled *Sea, rivers, and fish of the province of Santa Marta* — he recorded the vernacular names of 42 fish taxa, of which 37 were incorporated into the species inventory: 21 confirmed by subsequent authors and 16 representing unique taxa recorded exclusively by this source (**Table 2S;** http://raccefyn.co/index.php/raccefyn/article/view/4159/5446).

Franz Steindachner (presentation 1878, published 1879) described 46 fish species from more than 200 specimens collected in 1876 and 1877. Although his work has historically been attributed primarily to the Magdalena River, his own introductory (p. 20) and concluding (p. 75) statements, together with specimen records from the Natural History Museum Vienna documenting 144 specimens from overwhelmingly Ciénaga-related localities, demonstrate that the material originates from the CGSM lagoon complex (**Table 3S,** http://raccefyn.co/index.php/raccefyn/article/view/4159/5446). After synonymization —notably *Mugil brasiliensis* as a junior synonym of *M. liza*, *Auchenipterus insignis* and *A. magdalenae* as conspecific with *Trachelyopterus insignis*, and *Gerres zebra* subsumed within *Eugerres plumieri*— 43 species were recognized, of which five are unique taxa recorded exclusively by this source.

George Dahl (1971) compiled a comprehensive account of northern Colombia's fish fauna. Of 453 species treated, 19 were attributed to the CGSM based on textual evidence, of which 18 have been independently confirmed by other authors, while *Rachovia brevis*

remains an isolated record (**Table 4S;** http://raccefyn.co/index.php/raccefyn/article/view/4159/5446). For chronological placement, 1960 was assigned as the reference year.

Jorge Mercado Silgado (1971) surveyed the CGSM fish fauna in 1970–1971 with multiple gear types, reporting 33 taxa. After excluding genus-level records redundant with species already in the dataset and provisionally assigning nine unidentified records to the most plausible taxa, 31 validated species were retained. The study includes the earliest documented record of *Gobioides broussonnetii* for the system — also reported by Álvarez León (2003)— preceding the occurrence reported by **Acero & Arenas-Granados** (1990), who recorded 29 specimens in January 1989 from Boca de la Barra and adjacent northeastern areas; these records were subsequently cited by **Santos-Martínez & Acero** (1991).

Guerly Ávila de Tabarés (1975) reported eight recognized fish larvae from monthly zooplankton surveys (1970–1972), contributing two taxa unique to this source.

Simón Max Franky Vásquez and Pedro I. Rodríguez Guerrero (1976) presented a compiled inventory of 55 fish taxa within a broader national park synthesis. As no explicit sampling dates are provided, 1975 was assigned as the reference year. *Leporellus vittatus* was excluded on distributional grounds, yielding 54 taxa, 12 of which were unique to this source.

Thomas B. Thorson *et al.* (1983) recorded the three elasmobranch species *Dasyatis guttata* (*Hypanus guttatus* nowadays), *Himantura schmardae* (*Styracura schmardae* nowadays), and *Urotrygon venezuelae* during ray surveys in 1975–1976.

María Lupe Galeano and María Romero (1979a) reported 19 fish host species from a parasite survey (1978–1979). The more comprehensive thesis was used in preference to the subsequent journal publication, which covers only a subset of the data.

Edith González Afanador (1984) surveyed juvenile fish at Boca de la Barra and adjacent coastal stations (1979–1980). Only records from the Boca de la Barra column of her table 3 were considered for the CGSM, yielding 27 species.

Manuel Julian Barrios (1981) conducted monthly gillnet sampling in the estuarine zone (1979–1980) and reported 34 species. Two unidentified records (*Arius* sp., *Stellifer* sp.) were assigned to *Ariopsis canteri* and *Stellifer venezuelae*, respectively. *Ariopsis canteri* and *Stellifer venezuelae* represent the best options for these species, since the former, together with *Cathorops* spp., is among the most common species of the family Ariidae in the Ciénaga Grande de Santa Marta (CGSM) and has a higher commercial value than *Cathorops*, while no other species of *Stellifer* has been recorded within the CGSM.

Octavio Galvis Cortés (1983) studied ariid catfishes and their bycatch (1981–1982), reporting 31 species in total. Three unspecified genus-level records were assigned to the most likely congeners already present in the system.

Ricardo Álvarez León (2003) documented 41 species at mangrove stations (1984–1985), providing an important pre-restoration baseline for the CGSM ichthyofauna.

Adriana Santos-Martínez and Arturo Acero (1991) represent the most comprehensive single sampling effort to date, collecting 60 samples (1987–1988) and examining 14 additional species from the Invemar fish collection. Their **Table 1** reported 130 species in total; after excluding literature citations already incorporated from earlier sources and genus-level records redundant with species in the dataset, 100 taxa are recognized here, of which nine are unique to this source. The PEC catalogue numbers for the collection specimens are identified in their **Table 1**. The sampling program is based on the thesis of **Santos-Martínez** (1989); the earlier technical report (Santos, 1988b), the congress abstract (**Santos-Martínez**, 1993), and the summary Table 18 in **Botero *et al.*** (1988) all refer to the same underlying material.

Tadeo Castaño-Echeverry (1989) reported 19 taxa from 40 daytime surveys at Boca de la Barra and adjacent localities (1987–1988), contributing no unique species.

The **Comité Institucional de la Ciénaga Grande de Santa Marta** (1990) listed 13 commercially important species based on unpublished 1986–1987 data; 1986 was assigned as the reference year.

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Lilian Lamprea-Ochoa (1990) recorded 52 validated species from juvenile fish surveys at five stations (1988–1989). *Stellifer* sp. was excluded as redundant; *Eleotris* cf. *amblyopsis* was treated as *E. amblyopsis*.

Leonor Botero-Arboleda and Michael J. Marshall (1995) surveyed fish at 30 mangrove stations across dry and wet seasons (1992–1993), reporting 51 taxa. After excluding 10 indeterminate records and resolving two cf. designations, 39 species were retained. Species richness was markedly reduced in hypersaline degraded mangrove zones, where *Poecilia* cf. *gillii* dominated, contrasting with higher-diversity healthy zones dominated by *Anchovia clupeoides*.

Claudia Sánchez-Ramírez and Mario Rueda (1999) conducted monthly standardized cast-net sampling at 15 stations across three CGSM subregions (1995–1996). Of 57 taxa reported, three genus-level records were excluded as redundant, yielding 54 species; only *Anchoa hepsetus* and *Batrochoglanis raninus* are unique to this source.

Natalia Bateman-Vargas (1998) sampled the same three subregions monthly (1996–1997) with cast nets, recording 59 species. Community composition was dominated by *Mugil incilis*; inter-subregional differences exceeded interannual variation, with community changes attributed primarily to the Magdalena River flood dynamics rather than the local effects of the Clarín Channel reopening.

María Mercedes Criales *et al.* (2002) conducted larval fish sampling at Boca de la Barra (1998–1999), which formed the basis for the first Caribbean records of *Microdesmus carri* (**Amaya *et al.***, 2002) and *Akko dionaea* (**Acero *et al.***, 2005), each contributing one unique taxon to the inventory.

Invemar (2002-2025) **(Text 3S;** http://raccefyn.co/index.php/raccefyn/article/view/4159/5446**)** documented a commercial fisheries monitoring program conducted at the Ciénaga Grande de Santa Marta (CGSM) through periodic reports, following the methodology described in **Narváez *et al.*** (2005). The initial phase of the program was implemented between 1994 and 1996, then reinstated in 1999, and has continued uninterrupted to the present (**Santos-Martínez & Viloria**, 1998; **Invemar**, 2025). Since 1999, monitoring has generally been conducted three days per week between January and September at five landing sites across the CGSM: El Torno, Km 15 of Caño Clarín, Nueva Venecia, Tasajera, and Isla del Rosario. Local staff trained by Invemar collect data through mobile surveys, which are entered into the Fisheries Information System (**Invemar-SIPEIN**, 2026). Although the monitoring is primarily designed to assess fishing effort, the records are considered reliable at the species level, as unidentified specimens are routinely sent to Invemar specialists for taxonomic identification.

After standardization, the species list comprises 91 taxa and remained unchanged from report 14-2016 (Rep 14-2016) through to report 23-2024 (Rep23-2024). The report 23-2024 (Rep23-2024) was selected as the primary reference. The most recent edition, corresponding to report 24-2025 (Rep24-2025), was not used because it omits the taxon previously listed as "Rey bocachico," which is here assigned to *Abramites eques* based on the identification by the second author. Additional statistics from the same monitoring program are available through SIPEIN, the Invemar Fisheries Information System (**Invemar-SIPEIN**, 2026). Consultation of this database led to the addition of two species to the list: *Echeneis naucrates*, recorded at Isla del Rosario in 2012 and 2014, and *Isopisthus parvipinnis*, documented there in 2026.

Taxonomic standardization involved the following decisions: *Synodus* sp. and *Hemibrycon* sp. were retained as they appear consistently throughout the series. Within Ariidae, *Ariopsis* and *Cathorops* records were assigned to *A. canteri* and *C. mapale*, respectively (species newly described from CGSM material); *Cathorops* sp. 9 (Rep01–03) was likewise attributed to *C. mapale*. Records of *Loricaria* spp. (Rep08–Rep24) were excluded as they most likely represent *Dasyloricaria filamentosa* or *Rineloricaria magdalenae*, both already documented by **Steindachner** (1879). *Epinephelus* sp. was assigned to *E. itajara*; *Lutjanus* spp. and *Menticirrhus* sp. to *L. griseus* and *M. americanus*, respectively; and *Diodon* sp. to *D. hystrix*, following **Steindachner** (1879).

Selene spp. was omitted, as two species of *Selene* are already explicitly listed. *Sardinella aurita* was excluded as a marine species unlikely to occur within the lagoon proper. *Dormitator* sp. (Rep01–02) was not treated as a separate taxon given that *D. maculatus* — the only Caribbean congener — was already included. *Gymnotus* sp. (Rep01) was likewise not retained separately, as *G. carapo* is documented for the CGSM by subsequent sources. The cf. designation was removed from *Anchoa* cf. *spinifer* based on examination of CGSM material by the second author. *Poecilia* cf. *gilli* was retained, while *P. sphenops* was excluded, as the latter was reported only by Álvarez**-León** (2003), who did not record the former.

Cynoscion sp. was referred to *C. acoupa* throughout the series, supported by independent records from **Galeano & Romero** (1979a) and **Galvis-Cortés** (1983); the single larval record of *C.* cf. *leiarchus* (Ávila de Tabarés, 1975), unconfirmed over five decades, was excluded. All *Oreochromis* cf. *niloticus* and *Oreochromis* sp. records were standardized to *O. niloticus*.

Juan Carlos Narváez-Barandica *et al*. (2009) recorded 37 species from monthly sampling at five lagoons of the Vía Parque Isla de Salamanca (2004–2005), contributing one unique taxon. The assemblage was dominated by *Oreochromis niloticus* and *Mugil incilis*; 24% of species were listed as threatened in Colombia. *Gobiomorus dormitor* represents a unique taxon recorded exclusively by this source.

Daninso Gámez-Barrera *et al.* (2014) analyzed the diet of 12 species from the southeastern CGSM (2009), documenting the first record of *Lycengraulis batesii* for the system — the second species addition since 2004.

Invemar-SIPEIN (2026), the Invemar Fisheries Information System, provided additional statistics from the CGSM commercial fisheries monitoring program. Consultation of this database led to the addition of two species to the list: *Echeneis naucrates*, recorded at Isla del Rosario in 2012 and 2014, and *Isopisthus parvipinnis*, documented at the same site in 2026.

Main results

The study compiled the most comprehensive and taxonomically consistent inventory of fish taxa ever assembled for the Ciénaga Grande de Santa Marta. We recognized 204 taxa, comprising 12 Elasmobranchii and 192 Teleostei distributed across 37 orders, 86 families, and 161 genera (**Tabla 1**).

The inventory integrated records spanning nearly three centuries of documentation, from an 18th-century manuscript to a monitoring program extending into 2026, and differs from earlier compilations by its explicit traceability of every species record to a verifiable primary source, its systematic handling of synonymies and duplicates, and its deliberate conservatism in the face of taxonomic ambiguity. Our most significant contribution is the geographic reassignment of **Steindachner**'s (1879) material from the Magdalena River to the CGSM lagoon complex.

Steindachner's work, published as *Zur Fisch-Fauna des Magdalena-Stromes* and historically interpreted as a Magdalena River contribution, describes 46 species based on more than 200 specimens collected in 1876–1877. A critical re-reading of his own introductory statement (p. 20: "I acquired … more than 200 fish from the large, lake-like Cienega") and concluding remark (p. 75: "the species listed in this treatise [originate] only from the Cienega"), corroborated by 144 specimens in the Natural History Museum Vienna that are overwhelmingly associated with Ciénaga-related localities, demonstrates unambiguously that the material originates from the CGSM lagoon complex. This reassignment pushes the scientifically documented baseline of ichthyological knowledge for the system from approximately 1971 back to 1876, substantially expanding the historical species record. After synonymization —notably *Mugil brasiliensis* as a junior synonym of *M. liza*, *Auchenipterus insignis* and *A. magdalenae* as conspecific with *Trachelyopterus insignis*, and *Gerres zebra* subsumed within *Eugerres plumieri*— we

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Table 1. Fish orders reported from the Ciénaga Grande de Santa Marta (CGSM) based on historical and recent literature. Taxa are arranged by order according to the current systematic classification in Eschmeyer's Catalog of Fishes and FishBase. Numbers following each order (O) indicate the number of families (F), genera (G), and species (S) recorded in the present compilation.

Elasmobranchii - 3O, 8F, 9G, 12S				
No.	**Order**	**Family**	**Genera**	**Species**
1	Carcharhiniformes	3	3	4
2	Myliobatiformes	4	5	6
3	Rhinopristiformes	1	1	2
	3	**8**	**9**	**12**

Teleostei - 34O, 78F, 152G, 192S				
No.	**Order**	**Family**	**Genera**	**Species**
4	Acanthuriformes	1	1	1
5	Albuliformes	1	1	1
6	Anabantiformes	1	1	1
7	Anguilliformes	2	2	3
8	Atheriniformes	1	1	1
9	Aulopifomes	1	1	1
10	Batrachoidiformes	1	1	2
11	Beloniformes	2	4	6
12	Blenniiformes	1	1	1
13	Carangiformes	6	13	23
14	Characiformes	13	21	22
15	Cichliformes	1	5	5
16	Clupeiformes	3	8	13
17	Cyprinodontiformes	2	2	3
18	Dactylopteriformes	1	1	1
19	Elopiformes	2	2	2
20	Ephippiformes	1	1	1
21	Eupercaria inc. sedis	1	10	13
22	Gerreiformes	1	4	8
23	Gobiiformes	3	13	13
24	Gymnotiformes	2	3	4
25	Holocentriformes	1	1	1
26	Lobotiformes	1	1	1
27	Lophiiformes	1	1	1
28	Lutjaniformes	2	5	9
29	Mugiliformes	1	2	4
30	Perciformes	3	5	5
31	Pleuronectiformes	4	5	5
32	Scombriformes	3	5	7
33	Siluriformes	8	22	23
34	Spariformes	1	1	1
35	Synbranchiformes	1	1	1
36	Syngnathiformes	2	3	3
37	Tetraodontiformes	3	4	6
	34	**78**	**152**	**192**

recognized 43 species from **Steindachner**'s material, of which five are unique taxa recorded exclusively by this source (see **Text 1S and Table 3S** for details; http://raccefyn.co/index.php/raccefyn/article/view/4159/5446).

The historical scope is further extended by the systematic evaluation of **Nicolás de la Rosa's** chronicle (ca. 1746; published 1820), which provides the earliest known documentation of fishes from the region. Chapter X of his manuscript records the vernacular names of 42 fish taxa, of which 37 were incorporated into the inventory. Five taxa were excluded to avoid double counting or because their occurrence within the lagoon proper was considered highly unlikely (**see Text 1S and Table 2S for details;** http://raccefyn.co/index.php/raccefyn/article/view/4159/5446). Of these 37 taxa, 21 have been confirmed by subsequent authors, while 16 represent unique taxa recorded exclusively by this earliest source, historically significant, but dependent on a single, non-specimen-based account.

The chronological accumulation analysis revealed a marked acceleration of taxon discovery after 1987. By 1984, 156 taxa were known to occur in the system, reflecting a gradual increase driven mainly by scattered regional studies over two and a half centuries. Based on a comprehensive sampling program conducted in 1987–1988, **Santos-Martínez and Acero** (1991) contributed 100 taxa to the present inventory, of which 28 were newly recorded for the system, raising the cumulative total from 156 to 184 in a single study, which represents the most substantial single advance in knowledge of the CGSM ichthyofauna to date (**Figure 2**, **Table 2**).

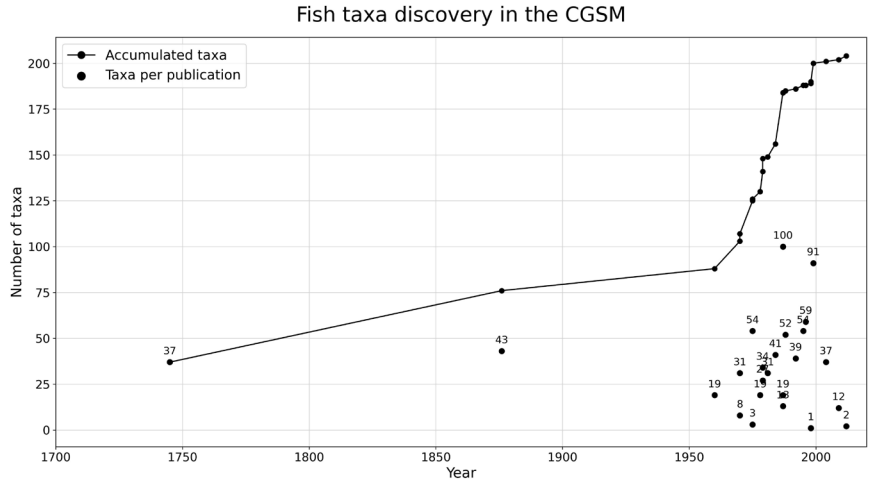


Figure 2. Reported and cumulative fish taxa richness in the Ciénaga Grande de Santa Marta, arranged by sampling year or, where unavailable, by a representative reference year assigned for chronological placement

Table 2. Chronology of fish taxa records in the Ciénaga Grande de Santa Marta, ordered by sampling year or, where unavailable, by a representative reference year assigned for chronological placement, showing reported taxa, cumulative taxa richness, and taxa unique to each source

Year	Author	Taxa	Acc taxa	Unique taxa
1745	de la Rosa (ca. 1746)	37	37	16
1876	Steindachner (1879)	43	76	5
1960	Dahl (1971)	19	88	1
1970	Mercado Silgado (1971)	31	103	0
1970	Ávila de Tabarés (1975)	8	107	2
1975	Franky Vásquez & Rodríguez Guerrero (1976)	54	125	12
1975	Thorson *et al.* (1983)	3	126	1
1978	Galeano & Romero (1979a)	19	130	0
1979	González Afanador (1984)	27	141	3
1979	Barrios (1981)	34	148	0
1981	Galvis Cortés (1983)	31	149	0
1984	Álvarez León (2003)	41	156	2
1987	Santos-Martínez and Acero (1991)	100	184	10
1987	Castaño Echeverry (1989)	19	184	0
1987	Comité Institucional (1990)	13	184	0
1988	Lamprea Ochoa (1990)	52	185	0
1992	Botero Arboleda and Marshall (1995)	39	186	1
1995	Sánchez Ramírez and Rueda (1999)	54	188	1
1996	Bateman Vargas (1998)	59	188	0
1998	Amaya, Acero & Criales (2002)	1	189	1
1998	Acero *et al*. (2005)	1	190	1
1999	Invemar (2002-2025)	91	200	0
2004	Narváez *et al.* (2009)	37	201	1
2009	Gámez Barrera *et al.* (2014)	12	202	1
2012	Invemar-SIPEIN (2026)	2	204	2

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The Invemar commercial fisheries monitoring program, initiated in 1999 and continuing through 2025, subsequently added a further 10 unique taxa, demonstrating that even a long-term monitoring framework focused on commercial species can yield genuine biodiversity additions. Since 2004, only four species were added: **Narváez *et al.*** (2009), sampling five lagoons of the National Park Vía Parque Isla de Salamanca (VIPIS), recorded *Gobiomorus dormitory*; **Gámez-Barrera *et al.*** (2014) documented *Lycengraulis batesii* for the first time in the system from dietary analyses in the southeastern CGSM, and consultations of the Invemar Fisheries Information System (**Invemar-SIPEIN**, 2026) led to the addition of *Echeneis naucrates*, recorded at Isla del Rosario in 2012 and 2014, and *Isopisthus parvipinnis*, documented there in 2026.

A critical methodological contribution of the study is its conservative taxonomic approach, which deliberately prioritizes reliability over apparent completeness. The rigorous application of current nomenclature according to Eschmeyer's Catalog of Fishes and FishBase, the elimination of duplicate records resulting from the repeated re-publication of the same underlying datasets, the resolution of synonymies, and the exclusion of genus-level records that do not contribute unique taxonomic information yielded an inventory that is smaller than those of earlier uncritical compilations. Notably, the 91-species list of the Invemar monitoring series is reduced through standardization of several generic-level records and the exclusion of taxa already represented at species level or unlikely to occur in the lagoon proper. This conservative stance ensures that the inventory constitutes a reliable baseline for future ecological, taxonomic, and fisheries studies, rather than an inflated catalogue of uncertain records.

Finally, the study establishes a transparent and reproducible bibliographic framework through the explicit distinction between primary sources and redundant publications, including the systematic identification of studies that reproduce earlier data without contributing independent observations, and through the full traceability of each species record to its original source, identified by standardized abbreviations in **Table 1S,** http://raccefyn.co/index.php/raccefyn/article/view/4159/5446. The inclusion of Invemar's fish collection (PEC) catalogue numbers for specimen-based records of **Santos-Martínez and Acero** (1991), the documentation of the Natural History Museum Vienna specimen data of **Steindachner** (1879), and the tabular presentation of all 24 Invemar monitoring reports with their URLs further contribute to the reproducibility of the compilation. This level of methodological transparency is rarely achieved in comparable regional ichthyofaunal inventories and is intended to serve as a foundation for the long-term documentation of fish biodiversity in this ecologically and socio-economically important system.

Discussion

Our study assembled a taxonomically standardized inventory of 204 fish taxa for the Ciénaga Grande de Santa Marta, making it the most comprehensive and methodologically transparent compilation produced for this system to date. The total substantially exceeds the 130 taxa reported by **Santos-Martínez and Acero** (1991), the previously most cited figure, primarily because the present compilation integrated records spanning nearly three centuries of documentation rather than a single sampling campaign. Also, the deliberate conservatism we applied through the systematic removal of duplicate records, the resolution of synonymies, and the exclusion of unresolved genus-level identifications ensured that the higher count reflected genuine taxonomic breadth rather than an accumulation of uncertain or redundant entries.

Historical baseline

The most consequential single finding of this study is the geographic reassignment of **Steindachner**'s (1879) material from the Magdalena River to the CGSM lagoon complex. The title *Zur Fisch-Fauna des Magdalena-Stromes* has led generations of authors to attribute this work entirely to the river, yet Steindachner's own text is explicit: the

introductory passage on page 20 and the concluding remark on page 75 both identify the large lake-like Cienega as the primary collection site, a reading corroborated by the Natural History Museum Vienna specimen records, which assign 144 of the examined specimens to Ciénaga-related localities. This reassignment pushes the scientifically documented baseline for the system from approximately 1971 —the starting point used in all previous syntheses —back to 1876, predating the earliest records incorporated in all previous syntheses of the CGSM ichthyofauna (**Dahl**, 1971; **Mercado-Silgado**, 1971). The five taxa recorded exclusively by **Steindachner** (1879) and not confirmed by subsequent sources (**Table 1S,** http://raccefyn.co/index.php/raccefyn/article/view/4159/5446) deserve targeted field verification, particularly given the profound hydrological changes the system has undergone since the late 19th century.

The earliest account, that of **Nicolás de la Rosa** (ca. 1746; published 1820), introduces a further layer of historical depth. The 37 taxa incorporated from Chapter X of his chronicle represent the first written documentation of fishes in the region and demonstrate that a recognizable estuarine fish assemblage, including mullets, *mojarras*, and catfishes, was already known to the inhabitants of the Santa Marta province in the mid-18th century. The 16 taxa recorded exclusively by de la Rosa, however, are based solely on vernacular names without specimen evidence, and their inclusion in the inventory required careful cross-referencing with subsequent literature. Their identifications should be treated as provisional; they are retained because no compelling evidence supports their exclusion, but they are clearly flagged in **Table 1** as single-source records.

Taxonomic standardization and duplication

A recurring methodological issue identified in this review is the uncritical propagation of species lists across publications. Several widely cited inventories have reproduced species records from earlier primary studies without explicitly acknowledging this dependency, obscuring the true independence of the underlying data. The Invemar monitoring series provides a particularly instructive case: the species list remained almost unchanged from Rep01-2002 through Rep24-2025, yet each annual report is a citable publication in its own right. Treating these as independent sources would misrepresent the evidential basis of the records, assigning the appearance of repeated independent confirmation to what is in fact a single continuous dataset. The approach adopted here —treating the entire monitoring series as a single dataset and selecting the most consistent recent version as the primary reference— preserves the longitudinal value of the program while correctly representing the independence of the underlying observations.

The taxonomic reassignments applied in this study also carry practical implications. The recognition of *Ariopsis canteri* and *Cathorops mapale* as distinct from the previously used *A. bonillai* / *C. spixii* designations, following descriptions based partly on CGSM material, is not merely nomenclatural but reflects genuine species-level differentiation within the system's dominant catfish assemblage. Similarly, the standardization of *Elops* records to *E. smithi* following the taxonomic revision of the genus, and the subsumption of *Mugil brasiliensis* under *M. liza*, remove artificial inflation from earlier lists without discarding the underlying occurrence data.

Accumulation patterns and knowledge gaps

The gradual accumulation of 156 taxa over two and a half centuries (1746–1984) was followed by a marked acceleration associated with Santos-Martínez and Acero's sampling program in 1987–1988. This study contributed 100 taxa to the present inventory, including 28 additions to the previously documented fauna, raising the cumulative total from 156 to 184. Of the 100 taxa, 10 are recorded exclusively by this source in the present compilation.

The Invemar monitoring series, initiated in 1999, added a further 10 unique taxa, bringing the total to 200, followed by single additions from **Narváez *et al.*** (2009), **Gámez-Barrera *et al.*** (2014), and two species from **Invemar-SIPEIN** (2026), reaching

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the current total of 204. This near-stabilization over the past two decades suggests that the commercially accessible component of the fish fauna is now well characterized, at least under current hydrological conditions. The detection of *Lycengraulis batesii* indirectly through dietary analyses rather than targeted fish surveys points to the potential of such approaches to reveal low-abundance or cryptic components of the fauna.

Conspicuous taxonomic gaps remain. The system's elasmobranch fauna is represented by only 12 species, documented largely from incidental captures and a single dedicated ray survey (**Thorson *et al.***, 1983). Given the connectivity of the CGSM with both marine and riverine environments, additional elasmobranch diversity is plausible, particularly for species tolerant of reduced salinity. The gobiid fauna is also likely underrepresented: the records of *Gobioides broussonnetii*, *Microdesmus carri*, and *Akko dionaea* — all detected through specialized or larval sampling — suggest that small-bodied benthic taxa may be systematically undersampled by the gear types employed in most survey programs. Molecular approaches, including environmental DNA (eDNA) metabarcoding, represent a particularly promising avenue for detecting such cryptic or rare species without the taxonomic uncertainties that accompany morphology-based identification of damaged or juvenile specimens.

Ecological context

Although this study is explicitly bibliographic in scope, the species inventory it produces carries direct ecological implications. The dominance of euryhaline estuarine-dependent species: mullets (*Mugil* spp.), *mojarras* (*Eugerres plumieri*, *Diapterus* spp., *Eucinostomus* spp.), catfishes (*Ariopsis canteri*, *Cathorops mapale*, *Sciades proops*), and anchovies (*Anchovia clupeoides*, *Anchoa* spp.) reflects the system's fundamental character as a productive shallow lagoon with strong salinity gradients. The documented decline of *Eugerres plumieri* following hydrological degradation (**Viloria-Maestre *et al.***, 2012) and the establishment of *Oreochromis niloticus* as a dominant species in disturbed sectors (**Leal-Flórez *et al.***, 2008; **Narváez-Barandica *et al.***, 2009) illustrate how shifts in hydrological connectivity translate directly into changes in fish community composition. Given that it is fully traceable to dated primary sources, the inventory compiled here can serve as a baseline for detecting further compositional changes in the decades ahead.

The occurrence of *Pterois volitans* in the CGSM, reported in the Invemar monitoring series since Rep06-2007 and confirmed by **Viloria and Acero** (2016), adds the system to the growing list of Caribbean estuarine habitats colonized by this invasive species and underscores the need for continued monitoring of non-native introductions alongside ongoing assessment of native biodiversity.

Conclusions

1. This study presents the most comprehensive and methodologically rigorous inventory of the ichthyofauna of the Ciénaga Grande de Santa Marta yet compiled, recognizing 204 fish taxa —12 Elasmobranchii and 192 Teleostei— distributed across 37 orders, 86 families, and 161 genera, and spanning nearly three centuries of documentation from ca. 1746 to 2026.

2. The geographic reassignment of **Steindachner**'s (1879) material to the CGSM lagoon complex, supported by the author's own text and by Natural History Museum Vienna specimen records, extends the scientifically documented baseline of ichthyological knowledge for the system from approximately 1971 to 1876 and represents the most significant historical revision in the ichthyology of this system.

3. The systematic application of current nomenclature, the elimination of duplicate records arising from repeated republication of shared datasets, and the deliberate exclusion of genus-level identifications that lack independent taxonomic value produce an inventory that is smaller than earlier uncritical compilations but substantially more reliable. This conservative approach does not preclude future additions but ensures that every taxon recognized here is traceable to a verifiable primary source.

4. The chronological accumulation analysis documents a marked acceleration of taxon discovery after 1987, associated primarily with the comprehensive sampling program of **Santos-Martínez and Acero** (1991), and a subsequent deceleration during three decades of continuous commercial fisheries monitoring. The apparent saturation of the commercially detectable fauna, combined with persistent gaps in coverage of small-bodied benthic species and elasmobranchs, indicates that future additions are most likely to come from targeted sampling with fine-meshed gear, larval surveys at inlet stations, and molecular approaches such as eDNA metabarcoding, which have proven effective at detecting cryptic and rare taxa in brackish coastal lagoon systems **(Suárez-Menéndez *et al.*,** 2020; **Castro-Cubillos *et al.*,** 2022; **Specchia *et al.*,** 2022; **Fernández *et al.*,** 2026; **Stinson *et al.*,** 2026).

5. The inventory, chronological accumulation table, and fully traceable species database presented here constitute a transparent and reproducible foundation for future ecological, taxonomic, fisheries, and conservation research in the Ciénaga Grande de Santa Marta, one of the most ecologically and socio-economically important coastal lagoon systems on the Caribbean coast of South America.

Supplementary material

See supplementary text and tables at: http://raccefyn.co/index.php/raccefyn/article/view/4159/5446

NOTE: The reference list includes all sources cited in the main text. A complete bibliography, including redundant references that rely on the same underlying data or primary sources as the cited works and therefore do not contribute independent information to the analysis, is provided in **Text 3S**.

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Author contributions

H.S.: Conceptualization, methodology, data collection, data analysis, writing of the original draft, review, and editing. **A.A.P.:** Data curation, including the systematic application of current nomenclature, the elimination of duplicate records arising from repeated republication of shared datasets, and the deliberate exclusion of genus-level identifications that lack independent taxonomic value; review and editing. **E.V.M**.: Data analysis, with particular focus on the Invemar monitoring dataset and the bibliographic records of Santos-Martínez and Viloria Maestre; review and editing.

Conflicts of interest

The authors declare no conflicts of interest.

Declaration on the use of generative AI and AI-assisted technologies in the writing process

During the preparation of this manuscript, the authors used Claude (Anthropic) and ChatGPT (OpenAI) exclusively to improve the clarity, style, and English-language editing of the text. The authors subsequently reviewed and edited all AI-assisted outputs as necessary and assume full responsibility for the final content of the publication. No generative AI or AI-assisted technology was used to produce original scientific content, define the objectives or results of the study, interpret data, or formulate conclusions. No AI-generated images, figures, or scientific data were used in this manuscript.

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