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Journal of Threatened Taxa

Open Access

10.11609/jott.2024.16.1.24451-24614
www.threatenedtaxa.org

26 January 2024 (Online & Print)
16(1): 24451-24614
ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

ISSN 0974-7907 (Online); ISSN 0974-7893 (Print)

Publisher
Wildlife Information Liaison Development Society
www.wild.zooreach.org

Host
Zoo Outreach Organisation
www.zooreach.org

43/2 Varadarajulu Nagar, 5th Street West, Ganapathy, Coimbatore, Tamil Nadu 641006, India
Registered Office: 3A2 Varadarajulu Nagar, FCI Road, Ganapathy, Coimbatore, Tamil Nadu 641006, India
Ph: +91 9385339863 | www.threatenedtaxa.org
Email: sanjay@threatenedtaxa.org

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Cover: Green Sea Turtle *Chelonia mydas* watercolour by Elakshi Mahika Molur.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 January 2024 | 16(1): 24589–24596
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8506.16.1.24589-24596
#8506 | Received 04 May 2023 | Finally accepted 27 December 2023
OPEN ACCESS
REVIEW

Fishes of Cocibolca, the great Central American lake

Topiltzin Contreras-MacBeath [1], Byron Josue Rodríguez Pérez [2], Humberto Mejia-Mojica [3] & Juan Manuel Rivas-González [4]

[1,3] Laboratorio de Ictiología, Centro de Investigaciones Biológicas, Universidad Autónoma del estado de Morelos, Av. Universidad #1001. Col. Chamilpa, Cuernavaca, Morelos, México CP 62209.
[2] Innovación Tecnológica y Servicios Ambientales, Kilómetro 152 Carretera Panamericana Norte, Estelí, Nicaragua.
[1,3,4] Labotarorio para la Conservación de Biodiversidad Dulceacuícola, Escuela de Estudios Superiores del Jicarero, UAEM.
[1] Freshwater Conservation Committee, IUCN-SSC.
[1] topis@uaem.mx (corresponding author), [2] byronrp83@hotmail.com, [3] humberto@uaem.mx, [4] manuel.rivas@uaem.mx

Abstract: The diversity of freshwater fish species from Lake Cocibolca (Nicaragua) is presented, describing the history of biological explorations in the lake from the first record in 1519, to the 52 species that are listed today. Information on current and future threats is also included.

Keywords: Conservation, fishes, fisheries, history, Nicaragua, threats.

Resumen: Se describe la diversidad de peces del lago Cocibolca (Nicaragua), describiendo la historia de las exploraciones biológicas en el sitio desde el primer registro en 1519, hasta las 52 especies conocidas en la actualidad. Se incluye además información sobre las amenazas presentes y futuras.

Editor: Anonymity requested.

Date of publication: 26 January 2024 (online & print)

Citation: Contreras-MacBeath, T., B.J.R. Pérez, H. Mejia-Mojica & J.M. Rivas-González (2024). Fishes of Cocibolca, the great Central American lake. *Journal of Threatened Taxa* 16(1): 24589–24596. https://doi.org/10.11609/jott.8506.16.1.24589–24596

Funding: None.

Competing interests: The authors declare no competing interests.

Author details: Topiltzin Contreras-MacBeath is head of the Conservation Biology Research Group at The Autonomous University of Morelos and is also Co-Chair of the IUCN/SSC Freshwater Conservation Committee; Humberto Mejia Mojica is in charge of the Ichthyology laboratory of the Biology Research Center UAEM; and Juan Manuel Rivas-González runs the Freshwater Conservation Laboratory at the School of Superior Studies UAEM, the three of the are Mexican Nationals. Byron Josue Rodríguez Pérez is a Nicaraguan professor that runs a private Environmental Agency (InnovaciónTecnológica y Servicios Ambientales) in Nicaragua.

Author contributions: Topiltzin Contreras-MacBeath lead and coordinated the publication; Humberto Mejia Mojica and Juan Manuel Rivas-González helped integrate the species list. While Byron Josue Rodríguez Pérez contributed by gathering and reviewing local information from Nicaraguan sources.

Acknowledgements: We wish to thank Dr. Arturo Angulo from the Museo de Zoología, Centro de Investigación en Biodiversidad y Ecología Tropical (CIBET), Universidad de Costa Rica, for reviewing the species list.

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A view of Central America from the International Space Station reveals the majesty of Lake Nicaragua (Image 1), known regionally as Cocibolca and recognized as the 19th largest lake in the world in terms of surface area (Routley 2019). Cocibolca is considered the most important freshwater ecosystem of the Central American Isthmus and is in the San Juan River Basin, which covers an area of 38,569 km^2, 64% of the land area of the basin is in southern Nicaragua and 36% in northern Costa Rica. The lake has a maximum length of 165 km, a maximum width of 70 km and has a water volume of approximately 104,000 Hm^3. It is located at an altitude of 31 m and has an area of 8,264 km^2, an average depth of 13 m and a maximum depth of 40 m. In it there are numerous islands, the main ones being: Ometepe, with an area of 275 km^2 and a perimeter of 89 km; Zapatera, with an area of 53 km^2 and a perimeter of 38 km; and the Solentiname Archipelago with an area of 14 km^2 and a perimeter of 44 km. Fifty-one rivers flow into Lake Nicaragua: 15 on the western coast, 17 on the eastern coast, and 19 on the southern coast. The main tributaries are the Malacatoya River and the Tipitapa River on the northwestern coast; the Oyate River on the east coast and the Frio, El Niño and Sapoá rivers on the southern coast. Its only tributary is the San Juan River, which has a length of 198 km and a discharge of approximately 250,000 liters per second. The main ports of the lake are Granada, San Jorge, San Carlos, San Miguelito and Moyogalpa (Ometepe Island) (Incer 1976; INFONAC 1976; Orellana 1983).

At the dawn of the Spanish colony, one of the first historians in the region, Captain Don Gonzalo Fernández de Oviedo y Valdés (1478–1557) narrates aspects of fishing in the lake and cites the presence of marine species, including sharks and in a passage of his book XII, chapter III, describes how one day in 1529 he finds a dead sawfish on the shore of the lake (Villa 1976), in what represents the first ichthyological record for Cocibolca. The first described species of the lake was carried out by Albert Günther of the British Museum of Natural History, and it was *Heros labiatus*, which we now know is *Amphilophus labiatus* (Günther 1864a). In a second publication, the same author (Günther 1864b) describes four new species (now recognized as *Amphilophus citrinellus*, *Hypsophrys nicaraguensis*, *Parachromis dovii* and *Gobiomorus dormitor*) and mentions nine fish species for the Lake. In their synopsis of Lake Nicaragua, Gill & Bransford (1878) list 21 species, while Meek (1907) brings the number of species present in the Lake to 35. For the second part of the last century, there are outstanding contributions by Astorqui (1972) who describes the presence of 45 species and a few years later, Villa (1976) recognizes 41 species.

Based on the afore mentioned studies, as well as some more recent ones in which the ichthyofauna of Lake Cocibolca is mentioned (INFONAC 1976; Orellana 1983; McKaye et al. 1995; Hernández 2007; Bussing 2008; Hernández & Corea 2013) and through the review of fish records for the lake contained in the Global Biodiversity Information Facility using the GeoCat® geospatial tool, we obtained a list containing 52 species, placed in 16 families and 34 genera. Four of these species are invasive (Table 1). In terms of richness, the families Cichlidae stand out with 15 species, as well as Characidae and Poeciliidae with nine species each, which represents 63% of the total (Image 2). The only species endemic to the lake is *Axtyanax cocibolca*, described by Bussing (2007), with specimens collected by Jaime Villa & Montserrat Llobert near Granada. The ichthyofauna of Lake Cocibolca reflects what occurs in the Central American region, being represented by primary, secondary and peripheral species. Despite the distance of the lake to the coast (198 km) it is important to highlight the presence of three species of elasmobranchs: the Bull Shark *Carcharhinus leucas*, and two species of sawfish—*Pristis pristis and P. pectinata*.

From the point of view of conservation status, based on Red List data (IUCN 2023), there are seven species at risk, two of them Critically Endangered (*Pristis pristis* and *P. pectinata*), and the remaining five are Vulnerable (*Megalops atlanticus*, *Carlana eigenmanni*, *Atherinella sardina*, *Phallichthys tico*, and *Xenophallus umbratilis*). Five species were listed as 'Near Threatened' and 28 in the 'Least Concern' category. It was not possible to assign a risk category to five species due to lack of data, including the only endemic species (*Astyanax cocibolca*) and finally, three species were Not Evaluated (Table 1).

Although originally the sharks of the Lake were described as an endemic species (*Eulamia nicaraguensis*), later studies with sharks tagged in the Nicaraguan and Costa Rican coasts, showed that it was the Zambesi Shark *Carcharhinus Leucas*, which makes migrations between the sea and the lake and vice versa (Thorson 1971). In this study it was also found that it took the sharks 2–25 days to go up the 198 km of the river, as well as 7–11 days to go downstream, back to the ocean and a specimen was found that made the trip back to the sea in just one day.

Lacustrine way of life was very important in pre-Columbian Mesoamerican culture (Williams 2014), since, in many lakes, as in the case of Lake Cocibolca, the capture of fish and any other aquatic species, including birds and reptiles, as well as the use of alluvial lands

Image 1. Central America from space, black circle highlights Lake Cocibolca (Source: NASA/JPL/NIMA 2002).

Image 2. Cichlid species dominate Lake Cocibolca, including the Moga *Hypsophrys nicaraguensis*. © iStock.com/Tetiana Garkusha.

for agriculture was fundamental for food (Image 3). Currently, the Lake Cocibolca Basin has an approximate population of 750,000 inhabitants and represents an important agricultural production area and is home to one of the main tourist attractions of the country, the colonial city of Granada and the Island of Ometepe (Banco Mundial 2013). Given its size as well as its location in Nicaragua, the lake continues to be a strategic resource for the country because economic activities such as fishing, and tourism are developed in it and its waters are used for human consumption, agriculture, and navigation (Salvatierra 2016).

Due to the multiplicity of uses that have been given to the lake and its biodiversity, as well as the large number of people living in its territory, or in areas close to it, there are a series of environmental impacts that have been identified and that were described in detail in a study carried out by the World Bank in 2013. These are briefly described below: Diffuse pollution, evidenced by a high sedimentation rate, which has a value of 13.3 tons per ha and is the result of deforestation of the catchment basin for the development of agricultural activities, which could cause eutrophication of the lake by the increase in the load of nutrients, mainly nitrogen and phosphorus contained in the sediments. They also find that a water imbalance (increased precipitation) caused by climate change could increase the severity of this threat. Point pollution in the form of discharge of urban and industrial wastewater with poor treatment or untreated. They found that spot bacteriological contamination near the beaches of Grenada and other lake populations limits recreational opportunities and is likely harmful to health. Pollution from tilapia farming, which has different and perhaps more damaging effects on the Lake than nutrient runoff caused by agricultural activities and soil erosion, is also mentioned, although precise data on the impact of this activity are not given.

As mentioned above, fishing has always been an important activity for the communities settled on the shores of Lake Cocibolca, one of the first records in the literature of this activity is that of Ephraim George Squire, who in 1852 cites that in lakes Managua and Nicaragua there is a great variety of fish that are caught by the communities of the banks (Villa 1976). In one of the sections of his publication, this same author narrates how the women of the community fish sardines with spoon nets and then cook them in the form of omelet. In a study on the fishery resources of Lake Nicaragua carried out in the 70s, it was found that the fishing production of artisanal origin in the lake amounted to 680,388 kg and the most caught species were the Gaspar

Image 3. Young fisherman with his catch on the shores of Lake Cocibolca. © Topiltzin Contreras.

Atractosteus tropicus, the Mojarra and Guapote Cichlids, as well as the Sawfish, of which an average of 90 kg per fisherman per week was fished (INFONAC 1976). For his part, Davies (1976) includes in the list of species of fishing importance the Sabalo *Megalops atlanticus*.

In an evaluation of the fishery resources of Lake Cocibolca carried out by the Fisheries Research Center of the Nicaraguan Fisheries Institute between October 1982 and May 1983, 31 fish species were identified, six of which are dominant in terms of biomass, with 82.7% of the catch (Orellana 1983). In this study, the Moga *Hypsophrys nicaraguensis* dominated with 19.8% of the catch, followed by the Red-breasted Mojarra *Cribroheros longimanus*) with 16.5%, the Mojarra *Amphilophus citrinellus* with 16%, the Machaca *Brycon guatemalensis* with 13.7%, the Sabalete *Dorosoma chavesi* with 10.5%, and the Gaspar *Atractosteus tropicus* with 6.2%.

An example of the negative impact of fishing activity relates to the three elasmobranch species of Lake Cocibolca, the Bull Shark *Carcharhinus leucas*, and the

Image 4. The Sawfish *Pristis pristis* species Critically Threatened globally, was very abundant in Lake Cocibolca, to the extent that in the 70s a commercial fishery was established that made it practically disappear. © Peter Kyne, Charles Darwin University, CC BY 3.0 <https://creativecommons.org/licenses/by/3.0>, via Wikimedia Commons) of Threatened Philippine Fauna and their Categories) status and endemicity.

sawfishes *Pristis pristis* and *P. pectinata*, which were traditionally fished in the lake in an artisanal way, but that as a result of the establishment in Granada in the early 70s of an industrial fishery that included a processing plant for shark meat and fins, as well as two boats and the hiring of 50 fishermen (Image 4). The installed storage capacity of both vessels was 8,409 kg, however, the number of fish (mainly sawfish fillets) delivered weekly to the processing plant did not exceed 2,275 kg and the plant focused on the processing of Gaspar, Mojarras, and Guapotes (Davies 1976). According to Thorson (1982), sawfish populations decreased considerably in the lake because of industrial fishing, and despite efforts by the Nicaraguan fishing authority, due to of poaching, this situation could not be controlled and some authors assume that these species have disappeared from the lake (McCrary et al. 2007; Poulakis & Grubbs 2019), which is unfortunate since both sawfish species are Critically Endangered globally and because they bred in the Lake (Thorson 1982), Cocibolca represented a true sanctuary for them. To conserve these species in Cocibolca, the Government of Nicaragua included a total ban of these species in the Fisheries and Aquaculture Law (489), article 75, published on 27 December 2004, however, it seems that this regulation has not had a significant benefit on elasmobranch.

Despite the diversity of native fish species as well as the fishing use that has traditionally been given to these fish species, Lake Cocibolca was not spared from the introduction of invasive fish. Since the 16th century and with total ignorance, Oviedo suggested to the original inhabitants of the lake the need to introduce fish, since in his way of seeing things, “there is no fish of any kind in it, but some fishmongers as small as cabo de agujetas, which cannot be eaten because they are so often better than in egg tortillas” (Villa 1976). In the early 80s three species of tilapias—*Oreochromis niloticus*, O. *mossambicus*, and *O. aureus*—were introduced in Cocibolca with the idea of developing aquaculture and improving fishing (McKaye et al. 1995). In 2003, the Nicaraguan Government granted an authorization to the company NICANOR, for the production of tilapia in floating cages in 86.87 ha of the lake, in the community of San Ramón, Ometepe Island, however, as a non-native species of the lake, the intrusion of tilapia represents a threat to biodiversity and ecosystem health (Banco Mundial 2013). In this sense, when evaluating the status of tilapia in Nicaragua, McCrary et al. (2007) found that they have been successfully established in the Lake and that their presence corresponds to a reduction in

Table 1. Updated list of fish species present in Lake Cocibolca, showing its Red List Category.

Family	Species	Common name	Category
Carcharinidae	*Carcharhinus leucas* (Muller & Henle, 1839)	Bull Shark, Tiburon Toro	NT
Pristidae	*Pristis pectinata* Latham, 1794	Smalltooth Sawfish, Pez Sierra	CR
	Pristis pristis (Linnaeus, 1758)	Largetooth Sawfish, Pez Sierra	CR
Lepisosteidae	*Atractosteus tropicus* Gill, 1863	Gaspar, Gar	LC
Megalopidae	*Megalops atlanticus* Valenciennes, 1847	Tarpon, Sabalo Real	VU
Clupeidae	*Dorosoma chavesi* Meek, 1907	Nicaragua Gizzard Shad, Sabalete, Sandillero	NT
Characidae	*Astyanax aeneus* (Günther, 1860)	Banded Tetra	LC
	Astyanax bransfordii (Gill, 1877)	Sabalito	NT
	Astyanax cocibolca Bussing, 2008	Sardina	DD
	Astyanax nasutus Meek, 1907	Sardina Lagunera	DD
	Brycon guatemalensis Regan, 1908	Machaca, Sabalete, Macabi	LC
	Carlana eigenmanni (Meek, 1912)	Sardinita	VU
	Hyphessobrycon tortuguerae Böhlke, 1958	Sardinita	LC
	Roeboides bouchellei Fowler, 1923	Crystal Tetra	LC
	Roeboides guatemalensis (Günther, 1864)	Guatemalan Headstander	NT
Pimelodidae	*Rhamdia quelen* (Quoy & Gaimard, 1824)	Catfish, Chulin Barbudo	LC
	Rhamdia nicaraguensis (Günther, 1864)	Bagre	LC
Gobiidae	*Gobiomorus dormitor* Lacèpede, 1800	Bigmouth Sleeper, Guavina	LC
	Gobiomorus maculatus (Günther, 1859)	Pacific Sleeper	LC
Synbrinchidae	*Synbranchus marmoratus* Bloch, 1795	Marbled Swamp Eel, Anguila	LC
Centropomidae	*Centropomus parallelus* Poey, 1860	Fat Snook, Robalo	LC
Cichlidae	*Amatitlania nigrofasciata* (Günther, 1867)	Convict Cichlid, Mojarra	DD
	Amatitlania septemfasciata (Regan, 1908)	Mojarra	LC
	Amphilophus citrinellus (Günther, 1864)	Midas Cichlid, Mojarra	LC
	Amphilophus labiatus (Günther, 1864)	Red Devil, Labiata	NE
	Archocentrus centrarchus (Gill, 1877)	Flier Cichlid, Mojarrita Rayada	LC
	Cribroheros longimanus (Günther, 1867)	Red-breasted Cichlid, Mojarra pechito rojo	LC
	Cribroheros rostratus (Gill, 1877)	Carate, Masamiche	LC
	Cryptoheros spilurus (Günther, 1862)	Blue-eye Cichlid	DD
	Herotilapia multispinosa (Günther, 1867)	Rainbow Cichlid, Mojarrita	LC
	Hypsophrys nematopus (Günther, 1867)	Poor Man's Tropheus, Picaculo	NE
	Hypsophrys nicaraguensis (Günther, 1864)	Butterfly Cichlid, Moga	LC
	Parachromis dovii (Günther, 1864)	Guapote	LC
	Parachromis friedrichsthalii (Heckel, 1840)	Monarch Cichlid	LC
	Parachromis managuensis (Günther, 1867)	Jaguar Guapote, Guapote Tigre	LC
	Vieja maculicauda (Regan, 1905)	Blackbelt Cichlid, Vieja	LC
Atherinidae	*Atherinella sardina* (Meek, 1907)	Sardina Plateada	VU
Cyprinodontidae	*Cynodonichthys isthmensis* (Garman, 1895)	Rivulinos	LC
Poeciliidae	*Alfaro cultratus* (Regan, 1908)	Pepesca	LC
	Belonesox belizanus Kner, 1860	Top Minnow	LC
	Brachyrhaphis holdridgei Bussing, 1967	Olomina	NT
	Gambusia nicaraguensis Gunther, 1866	Nicaraguan Mosquitofish	LC
	Phallichthys amates (Miller, 1907)	Merry Widow Livebearer, Olomina	LC
	Phallichthys tico Bussing, 1963	Olomina	VU

Family	Species	Common name	Category
	Poecilia gillii (Kner, 1863)	Gill's Molly, Pepesca	DD
	Poeciliopsis turrubarensis (Meek, 1912)	Barred Livebearer	LC
	Xenophallus umbratilis (Meek, 1912)	Olomina	VU
Haemulidae	*Pomadasys croco* (Cuvier, 1830)	Burro Grunt, Roncador	NE
INVASIVES			
Loricaridae	*Hypostomus* sp.	Pleco	
Cichlidae	*Oreochromis niloticus*	Tilapia	
	Oreochromis mossambicus	Tilapia	
	Oreochromis aureus	Tilapia	

Image 5. Isletas de Granada, one of the most important tourist areas in Nicaragua. © Topiltzin Contreras.

the presence of native species in local markets. From 2003, the fishermen of the lake began to find Plecos of the Loricaridae family (INPESCA 2008) that according to Hernández & Corea (2012) are increasingly abundant in catches.

One of the most pressing threats to Lake Cocibolca is perhaps the interest in building a transoceanic canal like that of Panama, which could irreversibly impact the ichthyofauna of the lake, a situation that has been discussed by several authors (Huete-Pérez et al. 2013, 2015, 2016; Härer et al. 2017). Within the country this issue has also been much discussed, Salvatierra (2016) describes how the public interest, indigenous and local communities, NGOs and organizations such as the Association of Municipalities of the Great Lake Basin (AMUGRAN), have promoted policies for the integrated and sustainable management of Cocibolca, which have led to legislative reforms such as the General Law of National Waters (620), published in 2007, article 96 of which provides that, "It is in the social interest to ensure the quality of national bodies of water, through the promotion and implementation of the measures and actions necessary for their due and permanent protection and conservation"; Article 97 "prohibits the introduction and cultivation of exotic and invasive species in Lake Cocibolca" and that "Lake Cocibolca should be considered as a natural reserve of drinking water, being of the highest national interest and priority for national security". On the other hand, Law 699 approved in 2009, which creates the "Commission for Sustainable Development of the Water Basin of Lakes Apanás, Xolotlán and Cocibolca and the San Juan River", whose

axis is the formulation of the Integral Management Plan of the Basin of the Great Lakes of Nicaragua, under the model of Integrated Water Resources Management (IWRM). Salvatierra (2016) comments that in contradiction with these legal commandments in 2012 Law 800 "Law of the Legal Regime of the Grand Interoceanic Canal of Nicaragua and the Creation of the Authority of the Grand Interoceanic Canal of Nicaragua" is published, without incorporating any reference to the provisions contained in laws 620 and 699.

Although many of the concerns on the part of environmentalists have not been resolved, with a cost of more than 50 billion dollars, the construction of the canal by the Chinese company HK Nicaragua Development Investment (HKND) officially began in 2014, however, the stock market crisis that hit China between 2015 and 2016 made it lose 85% of his patrimony to Wang Jing, communications tycoon and main investor of HKND, with which the project has been suspended, but the State of Nicaragua maintains its willingness to continue it (Sputnik 2020).

We do not know what the fate of Lake Cocibolca and its impressive ichthyofaunal diversity will be, either with or without the transoceanic canal. What is clear is that the future of Nicaragua and its people, but especially of that with a lacustrine way of life, is linked to the future of its great lake (Image 5).

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NAAS rating (India) 5.64

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Journal of Threatened Taxa

www.threatenedtaxa.org

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

January 2024 | Vol. 16 | No. 1 | Pages: 24451–24614
Date of Publication: 26 January 2024 (Online & Print)
DOI: 10.11609/jott.2024.16.1.24451-24614

Publisher & Host

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