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Patrones de diversidad de la fauna de metazoarios parásitos de peces marinos en la bahía de Mazatlan, Sinaloa.

Patterns of diversity of the metazoan parasite fauna of marine fishes from Mazatlan bay, Sinaloa.

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RESUMEN

La bahía de Mazatlán es un área que ha atraído la atención de parasitólogos en el pasado para estudiar la fauna de metazoarios parásitos de peces marinos; se han registrado helmintos desde la década de los años cincuenta y copépodos desde los sesenta. En los últimos años se ha renovado el interés por el estudio de estos organismos parásitos. En este trabajo de revisión se presenta la información sobre los metazoarios que viven como ecto o endoparásitos de peces marinos de la bahía de Mazatlán. La recopilación de datos se realizó utilizando bases de datos y búsquedas bibliográficas a través del ISI Web of Science. Todos los artículos fueron recuperados, revisados y la información relativa a cada taxón de parásito se actualizó de acuerdo con los tratamientos taxonómicos de cada grupo. Sólo se utilizan los nombres científicos válidos independientemente del nombre utilizado en el registro original. Se presentan tres listas, incluyendo dos listas parásito-hospedero conteniendo todos los registros de especies/taxones de metazoarios parásitos de helmintos o de crustáceos, con el nombre de su autoridad respectiva y el año de publicación y están organizadas alfabéticamente por grupo de parásitos, incluyendo el hábitat, hospedero y la referencia bibliográfica. La tercera es una lista hospedero-parásito donde se presentan todos los parásitos que infectan a cada especie hospedero (en orden alfabético por familia y luego por especie). En total se han

documentado 115 taxones de metazoarios, incluidos en 92 géneros y 51 familias, representando 91 helmintos, 23 copépodos y un isópodo; 95 de éstos se identificaron a nivel de especie. Los trematodos y monogeneos son los grupos mejor representados, con 39 y 34 taxones. Se han descrito 19 nuevas especies, 15 helmintos y cuatro copépodos. Sólo se han estudiado 47 especies de peces, incluidos peces óseos y elasmobranquios, en 43 géneros y 24 familias. El pargo rosado *Lutjanus guttatus,* la sierra del Pacífico*, Scomberomorus sierra*, el cochito naranja *Sufflamen verres* junto con el pajarito, *Hyporhamphus naos*, son los hospederos con la mayor diversidad de especies de helmintos en el área, con 25, 11, 9 y 9 taxones/especies, respectivamente. Se discute que el inventario está lejos de estar completo y, basándonos en el hecho bien conocido de que los parásitos son componentes importantes de los ecosistemas marinos, presentamos algunas ideas generales sobre cómo activar el trabajo de inventario en el futuro, mediante la realización de muestreos específicos de especies de peces y utilizando métodos modernos de sistemática molecular.

Palabras clave: Parásitos, Peces, Biodiversidad, Océano Pacífico, Taxonomía

ABSTRACT

Mazatlan Bay is an area that attracted the interest parasitologists in the past to study the metazoan parasite fauna of marine fishes. Helminths started to be reported since the 1950s, and copepods since the 1960s. In the last years there has been a renewed interest in studying these organisms. In this review, the information about the metazoan ecto and endoparasites of marine fishes of Mazatlan Bay is presented. The compilation of data was accomplished using databases and conducting literature searches through the ISI Web of Science. All reports were retrieved, carefully revised and the information regarding each parasite taxon was updated according to the current taxonomic treatments. Only the valid scientific names were used irrespective of the name used in the original record. Three lists are presented. Two parasite-host lists containing all the records of species/taxa of either helminths or crustaceans are presented; lists are organized alphabetically by parasite group, and authority's name and publication year, site in the host, host

species, and bibliographical reference for each record. The second is a host-parasite list where all the metazoan parasites parasitizing each host species (in alphabetical order by family and then species) is shown, indicating the taxonomic group and developmental stage of parasites. In total, 115 taxa of metazoan parasites have been reported, allocated in 92 genera and 51 families, including 91 helminths, 23 copepods and 1 malacostracan isopod. Of the 115 taxa, 95 were identified to species level. Trematodes and monogeneans are the most-well represented groups, with 39 and 34 taxa, respectively. Nineteen new species of parasites have been described, 15 helminths and four copepods. Only 47 fish species, including osteicthyes and chondrichthes have been studied for helminth parasites, allocated in 43 genera and 24 families. The Spotted rose snapper, *Lutjanus guttatus*, the Pacific sierra, *Scomberomorus sierra,* and the Orange-side triggerfish, *Sufflamen verres* as well as the Pacific silverstripe halfbeak, *Hyporhamphus naos* are the host species with the largest parasite species diversity in the area, with 25, 11, nine and nine taxa/species, respectively. We discuss that the inventory is far from complete and based on the well-known fact that parasites are important components of marine ecosystems, we put forward some general ideas on how to speed up the inventory work in the future, by conducting targeted sampling of fish species and using modern methods of molecular systematics.

Key words: Parasites, Fish, Biodiversity, Pacific Ocean, Taxonomy

INTRODUCTION

Parasites are probably the most diverse and abundant metazoans on Earth (Dobson, Lafferty, Kuris, Hechinger, Jetz, 2008; Poulin, Morand, 2005), and more importantly, they play a fundamental role in all ecosystems (see Rubio-Godoy, Pérez-Ponce de León, 2023 and references therein). Parasitism appeared several times during the evolutionary history of the earth. Most eukaryotic metazoans are comprised in the groups of crustaceans and the so-called 'helminths'. Crustacean comprise major groups such as copepods and malacostracan isopods parasitizing marine and freshwater fish, marine mammals and

some invertebrates. Helminths are metazoan parasites with a vermiform aspect which are found, as adults, in all vertebrate classes. The number of species is yet uncertain; it has been estimated that there are around 2244 siphonostomatid copepods and 1259 isopods including gnathids, bopyrids and cymothoids (Costello, 2016). Helminths do not constituted a monophyletic group and is composed by four phyla of organisms, platyhelminths, acanthocephalans, nematodes and Annelida (García-Prieto, Mendoza-Garfias, Pérez-Ponce de León, 2014a; García-Prieto, García-Varela, Mendoza-Garfias, 2014b; García-Prieto, Osorio-Sarabia, Lamothe-Argumedo, 2014c). The number of described species is also not known, but it has been proposed that there are between 23670 y 52000 named species (Hugot, Baujard, Morand, 2001; Poulin, Morand, 2000). Dobson et al. (2008) estimated between 100000 and 350000 species, and more recently Carlson, Dallas, Alexander, Phelan, Phillips (2020) re-estimated the number to 103078 species, of which 85% have not been described yet.

On the other hand, Mexico is considered as a megadiverse country due to the occurrence of species resulting from its geographical position between the Nearctic and Neotropical biogeographical regions. Among vertebrates, fishes, particularly those living in marine environments, are the more diverse. Even though parasitic organisms are usually neglected in studies aimed at describing and understanding biodiversity (Rubio-Godoy & Pérez-Ponce de León, 2023), Mexico has a long tradition in the study of helminths parasitizing vertebrates, and particularly fish. Marine fish are the most species-rich vertebrate group and are commonly parasitized by a wide array of metazoan parasites. The study of the helminth fauna of vertebrates in Mexico has been asymmetrical in terms of both, host, and geographical representation (Pérez-Ponce de León, García-Prieto, Mendoza-Garfias, 2011); the same pattern holds true for parasitic copepods (Causey, 1960). Sinaloa, on the Pacific slope of Mexico, is one of the states with the shortest number of surveys focused on the vertebrate parasitic fauna. Thus far, only 78 vertebrate species have been studied (including fish, amphibians, reptiles, birds and mammals) however, most studies have been conducted in marine fish; trematodes are the most species-rich, with 50 described species (Grano-Maldonado, Pérez-Ponce de León, 2023). Interestingly, 18 new species

were described as parasites of fishes from Mazatlan Bay, which makes the area an important site for the study of parasite biodiversity of marine fishes in Mexico; in particular, two host species, the "pargo lunarejo" (*Lutjanus guttatus*) and the "cochito naranja" (*Sufflamen verres*), are notable because from them three new species of monogeneans, and three new species of trematodes have been described, respectively (Grano-Maldonado and Pérez-Ponce de León, 2023). Mazatlan Bay, on the Pacific coast, is an area that has attracted the attention of fish parasitologists in the past and continues to do so in the present, since several research groups conduct research documenting the diversity of metazoan parasites of marine fauna.

With an area of 35 sq km and a coastline of 13.5 km, Mazatlan Bay is in the southeastern cost of Sinaloa, in the entrance of the Gulf of California. Three main currents influence the area seasonally, the California current (with cold water coming from the north), the North-Equatorial Counter current (with warm tropical waters from the eastern Pacific), and the warm-temperate waters (from the Gulf of California) (see Esqueda-González, Rios-Jara, Galván-Villa, Rodríguez-Zaragoza, 2022 and references therein). Even though there is not documented evidence in the form of a published checklist about the diversity of marine fishes and elasmobranchs in the area, fisherman in Mazatlan Bay hold an important commercial fishery on the coastline, as well as off-shore fishing for species as sardines and tuna, and other pelagic species such as marlin and dolphin-fish.

In Mexico, research projects devoted to describing an inventory of the helminth parasites infecting marine and estuarine fishes started in the decade of 1940's through the studies conducted by Eduardo Caballero and Harold Winter, followed by those of Margarita Bravo and Rafael Lamothe (Pérez-Ponce de León, Mendoza-Garfias, García-Prieto, 2012); for studies in Mazatlan Bay, the first report of helminths dates back to 1953 (van Cleave, 1953); instead, the description of the copepod parasite fauna of marine fishes started with Causey (1960). Still, up to now, the inventory of the diversity of metazoans parasitizing marine fishes in coastal areas of Mexico, including the Pacific, Gulf of Mexico and Caribbean Sea is far from complete; most studies represent isolated reports (taxonomic descriptions) recording the presence of certain

certain parasite species, or describing a new species, from a fish species from a particular locality, contrasting with very few studies devoted to establish a complete inventory of the parasite fauna of an area, like that conducted by Pérez-Ponce de León, García-Prieto, Mendoza-Garfias, León-Régagnon, Pulido-Flores, Aranda-Cruz, García-Vargas (1999) for the helminths of marine fish of Chamela Bay, Jalisco state, complemented by the study of Morales-Serna, Pinacho-Pinacho, Gómez, Pérez-Ponce de León (2014) on caligid copepods from the same locality.

The main objective of this review was to compile all the published data about the metazoan parasite diversity of marine fishes of Mazatlan Bay, and to analyze the patterns of diversity to point out areas of opportunity for future work in the area.

MATERIALS AND METHODS

Bibliographical search

The information used for the present study was updated to September 2023. Two main sources of information were used. First, the database of the helminth parasites of wildlife vertebrates of Mexico maintained at the Colección Nacional de Helmintos, Instituto de Biología, UNAM. For parasitic copepods, we followed the compilation by Morales-Serna, Gómez, Pérez-Ponce de León (2012). Second, we conducted a bibliographical search through the ISI Web of Science using the search terms (topic) in English and Spanish: 1) Mazatlan AND fish AND parasite*, 2) Mazatlan AND fish AND helminth, 3) Mazatlan AND fish AND copepod*, 4) Mazatlan AND fish AND isopod*, for the period between 2010 and 2023. All the papers retrieved in the search were analyzed to include only those reporting the presence of a parasite species in fishes of Mazatlan Bay. From each reference the name of the parasite, authority and publication year, site in the host, developmental stage, host species (and family), and bibliographical reference were obtained, and a database was built on Excel. With the information, two Parasite-Host lists were built, one reporting all the data on parasitic helminths, and one reporting parasitic crustaceans. A Host-Parasite list was also built, with all metazoan parasite species for each fish species

studied for parasites indicating the parasite group and developmental stage. This study considers all the published reports where authors obtained fish from fishermen who sell their products in Mazatlan, and our records only include formal bibliographical sources or specimens deposited in biological collections without being published, and we excluded grey literature.

RESULTS

The complete database consisted of 131 records of metazoan parasites of marine fishes of Mazatlan. These records were reported in 41 papers published by foreign and national researchers between 1953 and 2023. The metazoan parasite fauna consists of helminths and crustaceans. Helminths include taxa representing the Phylum Platyhelminthes (Trematoda, Cestoda and Monogenea), Acanthocephala, and Nematoda, whereas crustaceans include taxa belonging to Copepoda and Malacostraca. The database is presented in three tables. Tables I and II are parasite-host lists, showing the taxa of helminths and crustaceans parasitizing marine fishes of Mazatlan, respectively, whereas Table III presents the host-parasite list.

Regarding the number of metazoan parasites, in total, 115 taxa have been reported, allocated in 92 genera and 51 families. Ninety-five of them (82%) were identified to species level. Parasites were found in different habitats of their hosts, as the gastro-intestinal tract, kidneys, brain, mesentery, urinary bladder, gonads, spiral valve, swim bladder, underneath scales, skin, and gills (Tables I and II). Trematodes are the more diverse, with 39 taxa, followed by Monogenea, Copepoda and Nematoda with 34, 23 and 11, respectively (Fig. 1). Nineteen were described as new species, including seven monogeneans, six trematodes, two nematodes and four copepods. One of the new species was described from the eggs of the nematode, as *Huffmanela mexicana* (see Table I). Four species were named after Sinaloa or Mazatlan, i.e., the trematodes *Lecithochirium sinaloense* as a parasite of *Muraenesox coniceps* and *Pseudolepidapedon sinaloense*, the monogenean *Macrovalvitrema sinaloense*, and the ergasilid copepod *Acusicola mazatlanensis* (Tables I and II).

Fig 1. Number of parasite taxa in each parasite group expressed in percentage of the total number of species reported from Mazatlán marine fishes

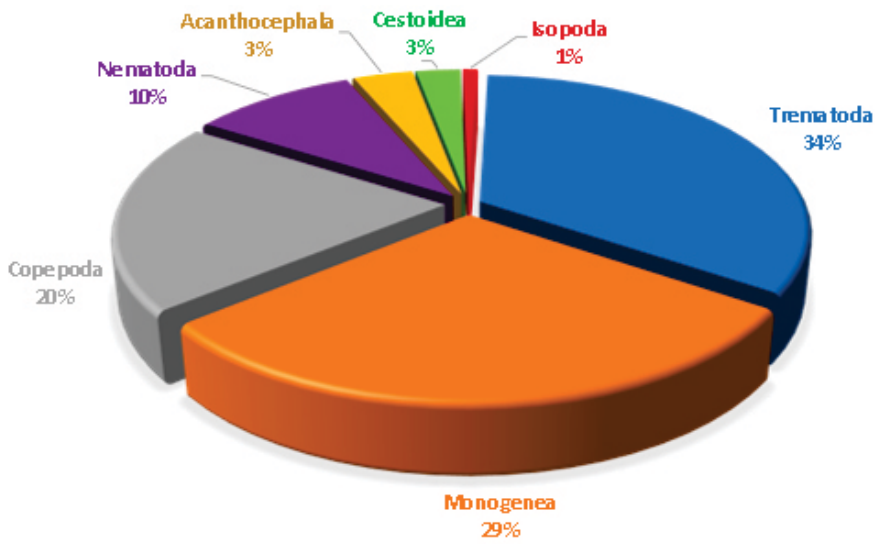


Table. I Parasite-Host list of published records of marine fish helminth parasites from Mazatlán Bay, Sinaloa, Mexico. New species are marked in bold with an asterisk.

Parasite Family	Parasite species	Author and publication year	Habitat	Host	Reference
Trematoda Rudolphi, 1808					
Acanthocolpidae Lühe, 1906	*Stephanostomun casum*	(Linton, 1910) McFarlane, 1936	Intestine	*Lutjanus guttatus*	Morales-Serna et al. (2017a)
Bucephalidae Poche, 1907	*Bucephalus gorgon*	(Linton, 1905) Eckmann, 1932	Intestine	*Citula dorsalis*	Bravo-Hollis & Sogandares-Bernal (1956)
	Prosorhynchus pacificus	Manter, 1940	Intestinal caeca	*Epinephelus analogus*	Winter (1959)
	Prosorhynchoides cf. cybii	(Park, 1939)	Intestine	*Scomberomorus sierra*	Bárcenas de los Santos et al. (2021)
Cryptogonimidae Ward, 1917	*Siphodera vinaledwardsii*	(Linton, 1901) Linton, 1910	Intestine	*Lutjanus guttatus*	Morales-Serna et al. (2017a)
Cyathocotylidae Sudarikov, 1959	*Mesostephanus microbursa*	Caballero, Grocott & Zerecero, 1953	Muscle	*Hyporhamphus naos*	Grano-Maldonado et al. (2023)
Didymozoidae Monticelli, 1888	***Lepidodidymocystis irwini****	Yamaguti & Kamegai, 1969	Underneath scales lateral line	*Menticirrhus nasus*	Yamaguti & Kamegai (1969)
	Anacetabulum sp.		Gills	*Scomberomorus sierra*	Bárcenas de los Santos et al. (2021)
	Didimozoon sp.		Gills	*Scomberomorus sierra*	Bárcenas de los Santos et al. (2021)
	Didymocylindrus sp.		Gills	*Scomberomorus sierra*	Bárcenas de los Santos et al. (2021)
	Didymocystis scomberomori	(MacCallum & MacCallum, 1916) Pozdnyakov, 1990	Mesentery	*Scomberomorus sierra*	Bárcenas de los Santos et al. (2021)
	Didymocystis sp.		Kidney	*Scomberomorus sierra*	Bárcenas de los Santos et al. (2021)

	Glomeritrema sp.		Gills	*Scomberomorus sierra*	Bárcenas de los Santos et al. (2021)
	Torticaecum sp.		Gills	*Lutjanus guttatus*	Morales-Serna et al. (2017a)
Diplangidae Yamaguti, 1971	***Diplangus mexicanus****	Bravo y Manter, 1957	Intestine	*Sufflamen verres*	Bravo-Hollis & Manter (1957)
			Intestine	*Gerres cinereus*	Estrada García (2015) In CNHE
Fellodistomidae Nicoll, 1909	*Lintonium vibex*	(Linton, 1900) Stunkard & Nigrelli, 1930	Intestine	*Sphoeroides annulatus*	Fájer-Avila et al. (2004)
Gorgoderidae Looss, 1899	*Phyllodistomum mirandai*	Lamothe, 1969	Urinary bladder	*Sphoeroides annulatus*	Fájer-Avila et al. (2004)
	carangis	Manter, 1947	Urinary bladder	*Citula dorsalis*	Bravo-Hollis & Manter (1957)
	Staphylorchis pacifica	(Caballero, 1945) Campbell, 2008	Body cavity	*Galeorhinus galeus*	Winter (1969)
	Xystretum caballeroi	Bravo, 1953	Urinary bladder	*Balistes polylepis*	Winter (1959)
Hemiuridae Looss, 1899	***Lecithochirium sinaloense****	Bravo, 1956	Stomach	*Muraenesox conceps*	Bravo-Hollis (1956)
	Parahemiurus merus	(Linton, 1910) Manter, 1940	Intestine	*Lutjanus guttatus*	Morales-Serna et al. (2017a)
Heterophyidae Leiper, 1909	*Opisthometra planicollis*	(Rudolphi, 1819)	Gills	*Hyporhamphus naos*	Grano-Maldonado et al. (2023)
Lepocreadiidae Odhner, 1905	***Haroldmanteria pacifica****	(Bravo & Manter, 1957) Bravo & Caballero, 1969	Intestine	*Sufflamen verres*	Bravo-Hollis & Manter (1957)
				Balistes polylepis	Bravo-Hollis &Manter (1957)
	Hypocreadium myohelicatum	Bravo-Hollis & Manter, 1957	Intestine	*Sufflamen verres*	Estrada García (2015) In CNHE
	Hypocreadium scaphosomum	(Manter, 1940)	Intestine	*Balistes polylepis*	Bravo-Hollis & Manter (1957)
				Sufflamen verres	Maldonado-Tapia, 2009 In Lamothe-Argumedo et al. (1997)
	Lepidapedoides nicolli	(Manter, 1934)	Intestinal caeca	*Epinephelus analogus*	Winter (1959)
	Pseudolepidapedon sinaloense*	Bravo, 1956	Intestine	*Sufflamen verres*	Bravo-Hollis (1956)
	Pseudolepidapedon balistis	Manter, 1940	Intestine	*Sufflamen verres*	Maldonado-Tapia, 2009 In Lamothe-Argumedo et al. (1997)
	Dermadena lactophrysi	Manter, 1945	Stomach	*Sufflamen verres*	Maldonado-Tapia, 2009 In Lamothe-Argumedo et al. (1997)
	Bianium plicitum	(Linton, 1928) Stunkard, 1931	Intestine	*Sphoeroides annulatus*	Fájer-Avila et al. (2004)
Megaperidae Manter 1934	*Homalometron caballeroi*	(Bravo, 1953) Cribb & Bray, 1999	Intestine	*Sufflamen verres*	Maldonado-Tapia, 2009 In Lamothe-Argumedo et al. (1997)
Monorchiidae Odhner, 1911	***Pseudohurleytrema longitestis****	(Bravo, 1956) Yamaguti, 1971	Intestine	*Citula dorsalis*	Bravo-Hollis (1956)
				Argyriosus brevoorti	Bravo-Hollis (1956)
	Alloinfundiburictus longicaecum	(Manter, 1940) Wee, Cutmore, Pérez-del-Olmo & Cribb, 2020	Intestine	*Sufflamen verres*	Bravo-Hollis (1956)
Opecoeliidae Ozaki, 1925	*Hamacreadium mutabile*	Linton, 1910	Intestine	*Lutjanus guttatus*	Morales-Serna et al. (2017a)
	Helicometrina nimia	Linton, 1910	Intestine	*Lutjanus guttatus*	Morales-Serna et al. (2017a)
	Pachycreadium gastrocotylium	(Manter, 1940) Manter, 1954	Intestine	*Calamus brachysomus*	Estrada García (2015) In CNHE
Pleorchiidae Poche, 1926	*Pleorchis americanus*	Lühe, 1906	Intestine	*Cynoscion reticulatus*	Bravo-Hollis (1956)
Strigeidae Railliet, 1919	*Cardiocephaloides medioconiger*	(Dubois & Pérez-Vigueras, 1949)	Brain	*Hyporhamphus naos*	Grano-Maldonado et al. (2023)
Monogenea van Beneden, 1858					
Ancyrocephalidae Bychowsky, 1937	Ancyrocephalinae gen. sp.		Gills	*Lutjanus guttatus*	Morales-Serna et al. (2017a)
Axynidae Monticelli, 1903	*Axinoides* sp.		Gills	*Hyporhamphus naos*	Grano-Maldonado et al. (2023)
Capsalidae Baird, 1853	*Capsala laevis*	(Verril, 1875) Johnston, 1929	Gills	*Tetrapturus audax*	Lamothe & Pulido-Flores (1998)

Monocotylidae Taschenberg, 1879	*Spinuris mexicana*	Bravo-Hollis, 1969	Gills	*Rhinobatos glaucostigma*	Bravo-Hollis (1969a)
	Anoplocotyloides papillatus	(Doran, 1953) Young, 1967	Gills	*Rhinobatos glaucostigma*	Bravo-Hollis (1969a)
Protomicrocotylidae Johnston & Tiegs, 1922	*Protomicrocotyle manteri*	Bravo-Hollis, 1966	Gills	*Caranx hippos*	Lamothe-Argumedo et al. (1997)
Thoracocotylidae Price, 1936	*Mexicotyle mexicana*	(Meserve, 1938)	Gills	*Scomberomorus sierra*	Bárcenas de los Santos et al. (2021)
	Thoracocotyle crocea	MacCallum, 1913	Gills	*Scomberomorus sierra*	Bárcenas de los Santos et al. (2021)
Cestoidea Rudolphi, 1808					
Order Trypanorhyncha Diesing, 1863	Trypanorhyncha gen. sp.		Intestinal lumen	*Lutjanus guttatus*	Morales-Serna et al. (2017a)
Order Tetraphyllidea Carus, 1863	Tetraphyllidea gen. sp.		Intestinal wall	*Lutjanus guttatus*	Morales-Serna et al. (2017a)
Rhinebothriidea *incertae sedis*	*Serendip danbrooksi*	Monks, Zaragoza-Tapia, Pulido-Flores & Violante-González, 2015	Spiral valve	*Rhinoptera steindachneri*	Monks et al. (2015)
Acanthocephala (Rudolphi, 1808)					
Cavisomatidae Meyer, 1932	*Filisoma bucerium*	van Cleave, 1940	Intestine	*Mugil cephalus*	García-Prieto et al. (2010)
Polymorphidae Meyer, 1931	*Corynosoma obtuscens*	Lincicome, 1943	Mesentery	*Mycteroperca pardalis*	van Cleave (1953)
Neoechinorhynchidae Ward, 1917	*Floridosentis mugilis*	(Machado, 1951) Bullock, 1962	Intestine	*Mugil cephalus*	Bravo-Hollis (1969b)
	Neoechinorhynchus brentnickoli	Monks, Pulido & Violante, 2011	Intestine	*Dormitator latifrons*	Monks et al. (2011)
Nematoda Rudolphi, 1808					
Anisakidae Railliet & Henry, 1915	*Anisakis sp.*		Mesentery	*Lutjanus guttatus*	Morales-Serna et al. (2017a)
	Hysterothylacium sp.		Mesentery and intestinal lumen	*Lutjanus guttatus*	Morales-Serna et al. (2017a)
			Intestine	*Scomberomorus sierra*	Bárcenas de los Santos et al. (2021)
	Pseudoterranova sp.		Mesentery, liver	*Lutjanus guttatus*	Morales-Serna et al. (2017a)
Ascarididae Baird, 1853	***Porrocaecum caballeroi****	Caballero-Deloya, 1973	Intestine	*Makaira mitsukurii*	Caballero-Deloya (1973)
Camallanidae Railliet & Henry, 1915	*Procamallanus* (*Spirocamallanus*) sp.		Intestine/stomach	*Lutjanus guttatus*	Morales-Serna et al. (2017a)
Capillaridae Railliet, 1915	Capillaridae gen. sp.		Intestine/stomach	*Lutjanus guttatus*	Morales-Serna et al. (2017a)
Cystidicolidae Skrjabin, 1946	*Ascarophis* sp.		Stomach	*Lutjanus guttatus*	Morales-Serna et al. (2017a)
	Spinitectus sp.		Intestinal lumen	*Lutjanus guttatus*	Morales-Serna et al. (2017a)
Philometridae Baylis & Daubney, 1926	*Philometra* sp.		Gonads	*Lutjanus guttatus*	Morales-Serna et al. (2017a)
	Philometra sp.		Gonads	*Scomberomorus sierra*	Bárcenas de los Santos et al. (2021)
	Philometra sp.		Gonads	*Hyporhamphus naos*	Rivera-Toscano et al. (2022); Grano-Maldonado et al. (2023)
Raphidascarididae Hartwich, 1954	*Goezia* sp.		Intestine	*Lutjanus guttatus*	Morales-Serna et al. (2017a)
Trichuridae	***Huffmanela mexicana****	Moravec & Fájer-Ávila, 2000	Swimbladder	*Sphoeroides annulatus*	Moravec & Fájer-Ávila (2000)
	*Capsala pricei**	Hidalgo, 1958	Skin	*Makaira mitsukurii*	Hidalgo-Escalante (1958)
	Capsaloides hoffmannae*	Lamothe-Argumedo, 1996	Gills	*Tetrapturus audax*	Lamothe-Argumedo (1996)
	Capsaloides sinuatus	(Goto, 1894) Price, 1938	Gills	*Tetrapturus audax*	Lamothe & Pulido-Flores (1998)
	Encotyllabe pagrosomi	MacCallum, 1917	Gills	*Pomadasys macracanthus*	Bravo-Hollis (1957)
	Neobenedenia melleni	(MacCallum, 1927) Yamaguti, 1963	Skin	*Sphoeroides annulatus*	Fájer-Avila (2004)
Chauhaneidae Euzet & Trilles, 1960	*Ahpua piscicola*	Caballero & Bravo-Hollis, 1973	Gills	*Vomer declivifrons*	Lamothe-Argumedo et al. (1997)

	Pseudomazocraes monsivaisae	Caballero & Bravo-Hollis, 1955	Gills	*Argyriosus brevoorti*	Caballero & Bravo-Hollis (1955)
		Caballero & Bravo-Hollis, 1955	Gills	*Carangioides otrynter*	Caballero & Bravo-Hollis (1955)
		Caballero & Bravo-Hollis, 1955	Gills	*Selar* sp.	Lamothe-Argumedo et al. (1997)
	Salinacotyle mexicana	(Caballero & Bravo-Hollis, 1963) Lebedev, 1984	Gills	*Hemicaranx atrimanus*	Lamothe-Argumedo et al. (1997)
Dactylogyridae Bychowsky, 1933	***Euryhaliotrema perezponcei****	García, Fajer & Lamothe-Argumedo, 2008	Gills	*Lutjanus guttatus*	García-Vargas et al. (2008)
	Euryhaliotrematoides mehen*	Soler-Jiménez, García-Gasca & Fájer-Ávila, 2012	Gills	*Lutjanus guttatus*	Soler-Jiménez et al. (2012)
	Haliotrematoides guttati*	(García, Fajer & Lamothe-Argumedo, 2008) Kritsky, Tingbao y Yuan, 2009	Gills	*Lutjanus guttatus*	García-Vargas et al. (2008)
	Haliotrematoides spinatus	(Zhukov, 1976) Kristky, Tingbao & Yuan, 2009	Gills	*Lutjanus guttatus*	Del Río-Zaragoza et al. (2010)
	Haliotrematoides plectridium	Kritsky &Mendoza, 2009 in Kritsky, Tingbao & Yuan, 2009	Gills	*Lutjanus guttatus*	Soler-Jiménez & Fajer-Ávila 2012
Diclidophoridae Yamaguti, 1965	*Heterobothrium ecuadori*	Meserve, 1938	Gills	*Sphoeroides annulatus*	Fájer-Avila et al. (2004); Grano-Maldonado et al. (2011)
	Macrovalvitrema sinaloense*	Caballero & Bravo-Hollis, 1955	Gills	*Micropogon ectenes*	Caballero & Bravo-Hollis (1955)
	Pterinotrematoides mexicanum*	Caballero & Bravo-Hollis, 1955	Gills	*Micropogon ectenes*	Caballero & Bravo-Hollis (1955)
Discocotylidae Price, 1936	*Pseudobicotylophora lopezochoterenai*	Lamothe-Argumedo & Pulido-Flores, 1997	Gills	*Trachinotus rhodopus*	Bravo-Hollis (1985)
Hexabothrididae Price, 1942	*Dasyonchocotyle dasyatis*	(Yamaguti, 1968) Boeger & Kritsky, 1989	Gills	*Hypanus longus*	Escorcia-Ignacio et al. (2015)
Loimoidae Price, 1936	***Loimosina parawilsoni****	Bravo-Hollis, 1970	Gills	*Sphyrna lewini*	Bravo-Hollis (1970)
Mazocraeidae Price, 1936	*Kuhnia* sp.		Gills	*Hyporhamphus naos*	Grano-Maldonado et al. (2023)
Microcotylidae Taschenberg, 1879	*Cynoscionicola srivastavai*	Bravo-Hollis & Caballero, 1970	Gills	*Isopisthus altipinnis*	Bravo-Hollis (1985)
	Jaliscia caballeroi	(Bravo-Hollis, 1960) Mamaev y Egorova, 1977	Gills	*Caulolatilus affinis*	Lamothe-Argumedo et al. (1997)
	Magniexcipula lamothei	Bravo-Hollis, 1980	Gills	*Calamus brachysomus*	Bravo-Hollis (1985)
	Microcotyloides impudicus	Caballero, Bravo-Hollis & Grocott, 1955	Gills	*Chanos chanos*	Bravo-Hollis (1981)
	Microcotyloides incisa	(Linton, 1910) Fujii, 1944	Gills	*Lutjanus guttatus*	Morales-Serna et al. (2017a)

Table. II Parasite-Host list of published records of marine fish crustacean parasites in Mazatlán Bay, Sinaloa, Mexico.

Parasite Family	Parasite species	Author and publication year	Habitat	Host	Reference
Copepoda H. Milne-Edwards, 1840					
Bomolochidae Claus, 1875	*Bomolochus nitidus*	Wilson N/D		*Mugil cephalus*	Causay (1960)
Caligidae Burmeister, 1835	*Caligus bennetti*	Causey N/D		*Caranx hippos*	Causay (1960)
	Caligus bonito	Wilson	Mouth	*Lutjanus* sp.	Causay (1960)
	Caligus constrictus	Morales-Serna, Oceguera-Figueroa & Tang, 2021	N/D	*Caranx hippos*	Causay (1960)
	Caligus fajerae*		Gills	*Scomberomorus sierra*	Morales-Serna et al. (2017b)
	Caligus mutabilis	Wilson	N/D	*Mugil cephalus*	Causay (1960)
			N/D	*Scomberomorus sierra*	Causay (1960)
			Skin	*Selene orstedii*	Causay (1960)
	Caligus omissus	Cressey & Cressey, 1980	Gills	*Scomberomorus sierra*	Morales-Serna et al. (2021)
	Caligus productus	Dana	N/D	*Calamus brachysomus*	Causay (1960)
	Gloiopotes huttoni	(Thomson)	N/D	*Istiophorus platypterus*	Causay (1960)
	Lepeophtheirus sp.		Skin	*Hyporhamphus naos*	Grano-Maldonado et al. (2023)
	Lepeophtheirus dissimulatus	Wilson	N/D	*Ariopsis guatemalensis*	Causay (1960)
	Lepeophtheirus mondacola*	Morales-Serna, Tang & Gómez, 2023		*Oligoplites refulgens*	Morales-Serna et al. (2023)
	Lepeophtheirus simplex*	Ho, Gómez & Fájer-Ávila, 2001	Body surface	*Sphoeroides annulatus*	Ho et al. (2001)
Ergasilidae Burmeister, 1835	***Acusicola mazatlanesis****	El-Rashidy & Boxshall, 1999	Gills	*Agonostomus monticola*	El-Rashidy & Boxshall (1999)
	Ergasilus sp.		Skin	*Hyporhamphus naos*	Grano-Maldonado et al. (2023)
Lernaeopodidae Milne Edwards, 1840	*Naobranchia lizae*	(Krøyer)	N/D	*Mugil cephalus*	Causay (1960)
	Parabrachiella gracilis	(Wilson)	N/D	*Genyonemus lineatus*	Causay (1960)
				Menticirrhus nasus	Causay (1960)
	Thysanote longimana	Wilson	N/D	*Lutjanus colorado*	Causay (1960)
Lernanthropidae Kabata, 1979	*Lernanthropus cornutus*	Kirtisinghe	N/D	*Tylosurus pacificus*	Cressey and Collete (1970)
	Lernanthropus pomatomi	Rathbun	N/D	*Lutjanus* sp.	Causay (1960)
Pennellidae Burmeister, 1835	*Lernaeenicus longiventris*	Wilson, 1917	N/D	*Seriola lalandi*	Causay (1960)
				Caranx caninus	Osuna-Cabanillas et al. (2023)
	Pennella filosa	(Linnaeus)	N/D	*Istiophorus platypterus*	Causay (1960)
			Skin	*Tunnus albacares*	Román-Reyes et al. (2019)
Pseudocycnidae Wilson, 1922	*Cybicola buccatus*	(Wilson, 1922)	Gills	*Scomberomorus sierra*	Morales-Serna et al. (2021)
Malacostraca Latreille, 1802					
Cymothoidae Leach, 1814	*Mothocya gilli*	Bruce, 1986	Gills	*Hyporhamphus naos*	Grano-Maldonado et al. (2023)

Table III shows the host-parasite list. Forty-seven fish species have been analyzed for metazoan parasites, and at least one species has been reported from them. Six species were reported from elasmobranchs whereas the remaining species/taxa were found in osteichthyes. These fish are allocated in 43 genera and 24 families. The number of metazoan parasite taxa infecting marine fishes is variable, ranging from 1 to 25. The species with the largest parasite species richness were the "pargo lunarejo" (*Lutjanus guttatus*) with 25 taxa, the "sierra" (*Scomberomorus sierra*) with 14, the "pajarito", *Hyporhamphus naos* with 9, the "cochito naranja" (*Sufflamen verres*) with nine, and the "botete" with 7 (Fig. 2). All the other fish species only possess between one and five parasite

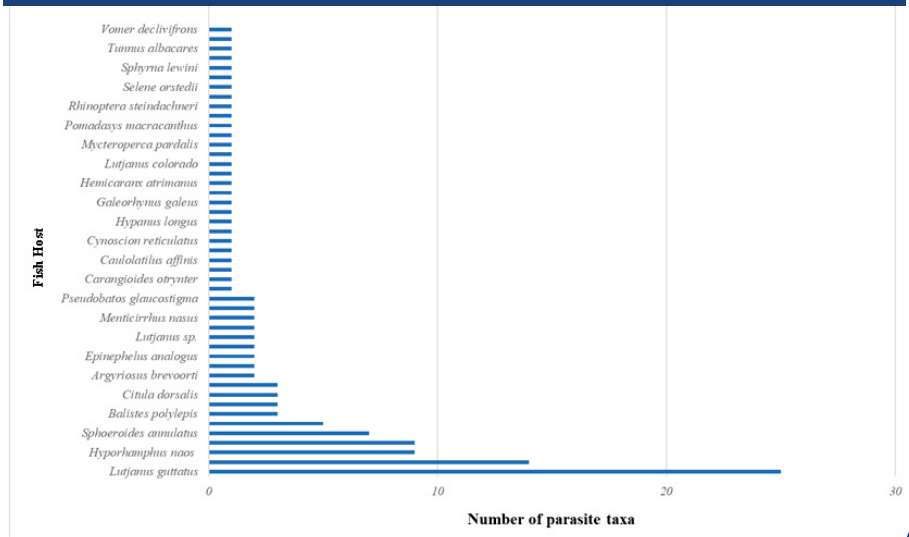
taxa; twenty-four fish species (57%) are infected by only one parasite taxa (Table III, Fig. 2). Excepting by six trematode species, five nematodes and one acanthocephalan sampled either as metacercariae, third stage larvae, or cysthacanth, all metazoan parasites infecting marine fishes in Mazatlan Bay were adult forms (Table III).

Table III. Host parasite list of the metazoan parasites of marine fishes from Mazatlan Bay, Sinaloa, Mexico.

Fish Family	Fish Species	Parasite species	Taxonomic group	Developmental Stage
CHONDRICTHYES				
Dasyatidae	*Hypanus longus*	*Dasyonchocotyle dasyatis*	M	Adult
Myliobatidae	*Rhinoptera steindachneri*	*Serendip danbrooksi*	C	Adult
Rhinobatidae	*Pseudobatos glaucostigma*	*Spinuris mexicana*	M	Adult
		Anoplocotyloides papillatus	M	Adult
Triakidae	*Galeorhinus galeus*	*Staphylorchis pacifica*	T	Adult
Sphyrnidae	*Sphyrna lewini*	***Loimosina parawilsoni****	M	Adult
OSTEICHTHYES				
Ariidae	*Ariopsis guatemalensis*	*Lepeophtheirus dissimulatus*	Co	Adult
Balistidae	*Balistes polylepis*	*Haroldmanteria pacifica*	T	Adult
		Hypocreadium scaphosomum	T	Adult
		Xystretum caballeroi	T	Adult
	Sufflamen verres	*Alloinfundibuirictus longicaecum*	T	Adult
		Dermadena lactophrysi	T	Adult
		Diplangus mexicanus*	T	Adult
		Haroldmanteria pacifica*	T	Adult
		Diplangus mexicanus*	T	Adult
		Haroldmanteria pacifica*	T	Adult
		Homalometron caballeroi	T	Adult
		Hypocreadium scaphosomum	T	Adult
		Pseudolepidapedon balisits	T	Adult
		Pseudolepidapedon sinaloense*	T	Adult
		Xystretum caballeroi	T	Adult
Belonidae	*Tylosurus pacificus*	*Lernanthropus cornutus*	Co	Adult
Carangidae	*Argyriosus brevoorti*	*Pseudohurleytrema longitestis*	T	Adult
		Pseudomazocraes monsivaisae	M	Adult
	Carangioides otrynter	*Pseudomazocraes monsivaisae*	M	Adult
	Caranx caninus	*Lernaeenicus longiventris*	Co	Adult
	Caranx hippos	*Caligus benetti*	Co	Adult
		Caligus constrictus	Co	Adult
		Protomicrocotyle manteri	M	Adult
	Citula dorsalis	*Bucephalus gorgon*	T	Adult
		Phyllodistomum carangis	T	Adult
		Pseudohurleytrema longitestis*	T	Adult
	Hemicaranx atrimanus	*Salinacotyle mexicana*	M	Adult
	Oligoplites refulgens	***Lepeophtheirus mondacola****	Co	Adult
	Selene orstedii	*Caligus mutabilis*	Co	Adult
	Selar sp.	*Pseudomazocraes monsivaisae*	M	Adult

Muraenesocidae	*Muraenesox conceps*	***Lecithochirium sinaloense****	T	Adult
Polynemidae	*Polydactylus approximans*	*Microcotyloides impudicus*	M	Adult
Sciaenidae	*Cynoscion reticulatus*	*Pleorchis americanus*	T	Adult
	Genyonemus lineatus	*Parabrachiella gracilis*	Co	Adult
	Isopisthus altipinnis	*Cynoscionicola srivastavai*	M	Adult
	Istiophorus platypterus	*Gloiopotes huttoni*	Co	Adult
		Penella filosa	Co	Adult
	Menticirrhus nasus	*Parabrachiella gracilis*	Co	Adult
		Lepidodidymocystis irwini*	T	Adult
	Micropogon ectenes	***Macrovalvitrema sinaloense****	M	Adult
		Pterinotrematoides mexicanum*	M	Adult
Scombridae	*Scomberomorus sierra*	*Anacetabulum* sp.	T	Metacercariae
		Caligus fajerae*	Co	Adult
		Caligus mutabilis	Co	Adult
		Cybicola buccatus	Co	Adult
		Didimozoon sp.	T	Adult
		Didymocylindrus sp.	T	Adult
		Didymocystis scomberomori	T	Adult
		Didymocystis sp.	T	Adult
		Glomeritrema sp.	T	Adult
		Hysterothylacium sp.	N	Larvae
		Mexicotyle mexicana	M	Adult
		Philometra sp.	N	Adult
		Prosorhynchoides cf. *cybii*	T	Adult
		Thoracocotyle crocea	M	Adult
	Tunnus albacares	*Penella filosa*	Co	Adult
Serranidae	*Epinephelus analogus*	*Lepidapedoides nicolli*	T	Adult
		Prosorhynchus pacificus	T	Adult
	Mycteroperca pardalis	*Corynosoma obtuscens*	A	Cysthacanth
Sparidae	*Calamus brachysomus*	*Caligus productus*	Co	Adult
		Magniexcipula lamothei	M	Adult
Tetraodontidae	*Sphoeroides annulatus*	*Bianium plicitum*	T	Adult
		Heterobothrium ecuadori	M	Adult
		Huffmanela mexicana*	N	Eggs
		Lepeophtheirus simplex*		
		Lintonium vibex	T	Adult
		Neobenedenia melleni	M	Adult
		Phyllodistomum mirandai	T	Adult

Fig 2.



largest helminth diversity with 129 taxa sampled from 76 fish species either osteichthyes or chondrichthes (see Pérez-Ponce de León et al., 1999, 2012). In Chamela Bay, a 5 year survey study of the helminth parasite fauna of marine fishes was conducted between 1992 and 1997; 1182 hosts representing 114 species were analyzed and around 35000 helminths of 92 species and 38 supraspecific taxa were identified (Pérez-Ponce de León et al., 1999). This contrasts with the data gathered for Mazatlan Bay since, considering both, the helminth and crustacean parasite fauna, after 50 years of mostly isolated parasitological work, only 115 parasite taxa have been reported in 47 fish species. In Mazatlan Bay, parasite sampling has been largely asymmetrical, and only a few commercially important fish species have been analyzed in certain detail (see Table III, Fig. 2). In Chamela Bay, many non-commercially important fish species were studied for parasites, although as a general tendency of the data on the parasite fauna of marine fishes of mexican coasts, researchers have preferred these species as the focus of their studies (Pérez-Ponce de León et al., 2012). The data on the parasites of "pargos" and "botetes" of Mazatlan is also related with the fact that these two species have been subjected to aquacultural practices, and the study of their parasite fauna in the wild is complementary for the studies under controlled conditions (see Fájer-Ávila, Roque, Aguilar, Duncan, 2004; Grano-Maldonado, Roque, & Fajer-Avila, 2010; Grano-Maldonado, Roque, Aguirre, Fájer-Ávila, 2011); Grano-Maldonado, Aguirre, Betancourt-Lozano, & Fajer-Avila, 2013, Morales-Serna, García-Vargas, Medina-Guerrero, Fájer-Ávila 2017a). There is also additional data from García-Vargas (2008)[1] describing several aspects of the helminth parasite fauna of *Lutjanus guttatus*; however, data was not included in the present review since our data was built up from published records only. Similarly, few studies have addressed the parasitological analysis of species with importance for the fisheries of the locality, as the hyporhamphid *Hyporhamphus naos* (Grano-Maldonado et al., 2023).

[1]García-Vargas, F. (2008). "Helmintos parásitos del pargo lunarejo, *Lutjanus guttatus* Steindachner, 1869 (Pisces: Lutjanidae) en dos localidades del Pacífico mexicano y estructura de las comunidades de endohelmintos". PhD Thesis. https://ciad.repositorioinstitucional.mx/jspui/handle/1006/936.

DISCUSSION

The inventory of the metazoan parasite fauna of marine fishes of Mazatlan is far from complete. Pérez-Ponce de León, Mendoza-Garfias, García-Prieto (2012) presented an analysis of the diversity of helminth parasites of marine and estuarine fishes of Mexico, concluding that until the year 2012, around 20% of the fish fauna (approximately 450 species of actinopterygians and elasmobranchs) had been studied for helminths and that information was gathered during a period of 60 years. The authors referred that around 800 helminth species had been reported until that year, most of them in osteicthyes (688 species). The pattern of occurrence of helminths in marine fishes shows that trematodes are the most common parasites, followed by monogeneans, nematodes, cestodes, and acanthocephalans. This corresponds with the pattern we observed in Mazatlan Bay. There are only few reports of metazoan parasites of elasmobranchs in the locality, a group of hosts predominantly parasitized by cestodes of the orders Trypanorhyncha and Tatraphyllidea (Pérez-Ponce de León et al., 2012; Merlo-Serna, García-Prieto, 2016). This result contrast with the large number of records, at least for helminth parasites of elasmobranchs, of the Gulf of California, where the largest number of species has been reported from at least 17 localities (Merlo-Serna and García-Prieto, 2016). Overall, for the state of Sinaloa, until 2012 a total of 73 helminth species had been reported parasitizing 50 host species, contrasting with other states of Mexico where the number of known marine fish helminths is higher. The states of Baja California Sur, Jalisco, Yucatan, Baja California, and Veracruz had, until 2012, 192, 180 129, 124 and 111 helminth taxa, respectively. In our study, helminths account for the largest species richness, with 92 of the 115 parasite taxa.

The parasitological record is asymmetric since some states of the Mexican Republic have been more intensively studied than others. Comparison among specific localities exhibits the same asymmetrical pattern. Pérez-Ponce de León et al. (2012) compared the number of helminth taxa reported in 10 localities across the Pacific, Gulf of Mexico, and Caribbean Sea. Chamela Bay in Jalisco state showed the

Most of the studies referred on tables I and II were conducted with a reduced sampling size, although most of the isolated papers usually do not report the sample size. It is common knowledge that parasite diversity increases with sampling size (Poulin and Morand, 2000, 2005). The fish species studied thus far in Mazatlan illustrates this trend. In Mazatlan Bay, the species with the largest species richness have been intensively studied, whereas most of the other species represent isolated reports. Carangids represent the fish family with the largest number of studied species, with 12. Carangids possess between one and three parasite taxa in Mazatlan (Table III). Two species, i,e., *Caranx hippos* and *Citula dorsalis* have three taxa, *Argyriosus brevoorti* has two, and only one parasite taxa has been reported from the other nine species, although none of them has been intensively studied. In comparison, Violante-Gonzalez, Gallegos-Navarro, Monks, García-Ibánez, Rojas-Herrera, Pulido-Flores, Villerías-Salinas, Larumbe-Morán (2016) studied 388 specimens of Caranx caballus from three localities of Guerrero in a 3 year period and identified 24 species of metazoan parasites; Violante-Gonzalez, Monks, Gallegos-Navarro, Santos-Bustos, Villalba-Vasquez, Padilla-Serrato, Pulido-Flores (2020) also studied 422 specimens of the carangid *Caranx sexfasciatus* from Acapulco Bay in a 3 year period, and 32 metazoan parasite taxa were identified. According to Fishbase, both carangid species are also distributed along the coast of Sinaloa. They have not been studied in Mazatlan, but it is possible to predict that they will have a similar parasite fauna. Another carangid, *Oligoplites refulgens* was studied by Santos-Bustos, Violante-González, Monks Rojas-Herrera, García-Ibáñez, Flores-Rodríguez, Almazán-Núñez, Moreno-Díaz (2018) in Acapulco Bay. In total, authors analyzed 114 specimens and found 12 species of metazoan parasites. In Mazatlan Bay, very few specimens of *O. refulgens* have been analyzed, and only one species of copepod has been reported (Morales-Serna, Tang, Gómez, 2023).

Finally, it is important to point out that the parasitological studies of marine fishes from Mazatlan have been mostly conducted using traditional morphological characters to establish parasite species identification. Nevertheless, we noticed that some current studies use scientific names that are not considered valid. For instance, Morales-

Serna, Chapa-López, Martínez-Brown, Ibarra-Castro, Medina-Guerrero & Fajer-Ávila (2018) referred to the species *Tagia ecuadori*, although the genus name is incorrect (see WORMS; World Register of Marine Species); the valid genus currently is *Heterobothrium* as we used it in this review. We caution about this practice for achieving a complete inventory as we also caution about not citing the proper bibliographical references of previous studies. Furthermore, until very recently, that some studies have used DNA sequences to achieve a more accurate species delimitation and for species description following an integrative taxonomy approach. Morales-Serna, Oceguera-Figueroa, Tan (2017b) described the copepod *Caligus fajerae* using a combination of morphology and DNA sequence data; Osuna-Cabanillas, Morales-Serna, Venmathi, Cruz-Barraza (2023) redescribed a copepod, *Lernaeenicus longiventris* and used some DNA sequences. Grano-Maldonado et al. (2023) used sequences of the 28S ribosomal gene to identify three species of trematode metacercariae infecting the gills, muscle, and brain of *H. naos,* as well as a species of nematode parasitizing the gonads of their host. Molecular data was very important for accomplishing more accurate species identification and was pivotal for identifying the larval of three trematode species that close their life cycle in fish-eating birds i.e., *Cardiocephaloides medioconiger, Opisthometra planicollis, and Mesostephanos microbursa* (Grano-Maldonado et al., 2023).

FINAL CONSIDERATIONS

We pose that the inventory of the parasite fauna of marine fishes from Mazatlan Bay require keep collecting data from species commercially and non-commercially important. It will be very important to try to report the entire parasite fauna of each host species, through a sampling size large enough to discover most of the parasite species, and this include ideally obtaining samples across several periods during the year. Secondly, it will be important to use modern methods of identification and data analysis. Sequencing ribosomal and mitochondrial markers will be necessary to accomplish more accurate species identification and will be very useful in the description of new metazoan parasites. Finally, funding agencies need to realize that completing an inventory of the

parasite fauna of marine fish is important because many parasite species are considered of zoonotic importance since the human population is exposed to numerous parasitic species transmitted by fish (ichthyozoonoses) especially when fish is raw or not properly cooked (Chai, Murrell, Lymbery, 2005). It will be also important to discover what species possess the potential to cause zoonotic diseases, and their prevalence of infection levels. In some studies, potentially zoonotic parasites reach high prevalence of infection levels (Chen, Shih, 2015), while in others prevalence is very low, and the risk of diseases for the population is lower (see Garrido-Olvera, García-Prieto, Osorio-Sarabia, Sánchez-Martínez, Rábago-Castro, Hernández-Mena, Pérez-Ponce de León, 2022). Finally, since parasites constitute a key element for regional studies of biological diversity, the Faculty of Marine Sciences (FACIMAR) of the Autonomous University of Sinaloa, through the Parasitology Laboratory has established a career development for undergraduate students to address questions on pathogens and parasites of marine organisms, as well as to address aquaculture health problems with fish parasites in farming systems, such as snappers, tilapia, Pacific fat sleepers, and striped mullets. We hope this review stimulate students to conduct research on parasites and contribute with the description and understanding of the biodiversity of Mazatlan Bay.

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