Topics of limnological research in Mexico

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UNIVERSIDAD DE COLIMA

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This book is dedicated to
Dr. Singaraju Sri Subrahmanya Sarma,
in gratitude for all his teachings in the world of limnology.

Index

The Freshwater and Brackish Hydrozoans of Mexico: An Overview of their Diversity

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Abstract

Hydrozoans constitute a diverse cnidarian group with different morphologies and ecological strategies, occurring in all aquatic environments, including continental water bodies. The global diversity of freshwater hydrozoans has been scarcely addressed. The number of recognized species (~60) is substantially lower than other marine groups with continental representatives, such as sponges and crustaceans. The hydrozoan fauna of Mexico is relatively well known through inventories and recent studies on brackish and marine environments, although more effort is needed. Nevertheless, freshwater taxa are not included in the last checklists, leading to a gap in the understanding of the diversity of this group in Mexico. This chapter aims to provide an image of the diversity of freshwater and brackish-water hydrozoans in Mexico by reviewing 27 works that included hydrozoans recognized as inhabitants of these environments. Our search resulted in 15 taxa grouped into two subclasses, three orders, and seven families, of which Olindiidae was the richest. Seven taxa are recorded exclusively in freshwater environments, while eight are in lagoons, estuaries, or open oceans. Additionally, four hydrozoans are considered potentially invasive in other regions of the world, and few studies have monitored their populations in Mexico. Future perspectives in the study of freshwater hydrozoans include expanding research in freshwater environments and considering molecular tools for species identification.

Keywords

Medusozoa, Cnidaria, polyp, estuarine environment, biodiversity, Hydrozoa.

Introduction

The members of the class Hydrozoa constitute a diverse cnidarian group, including approximately 3,774 accepted species (Schuchert, 2024), which usually present a life cycle with a succession of different stages, including a larval, a benthic asexually reproducing polyp, and a sexually reproducing medusa (Santander et al., 2022). Nevertheless, several variants of this cycle exist in which the medusa may be absent or vice versa (Boero et al., 1992; Miglietta & Cunningham, 2012; Bentlage et al., 2018). Hydrozoans occur in diverse aquatic ecosystems, going from freshwater to hypersaline environments, and from the surface to the deepest regions of the oceans (Jankowski, 2001; Bentlage et al., 2018). Of the total hydrozoan species, few are representative of freshwater or brackish environments (Jankowski, 2001; Jankowski et al., 2008). For instance, only seven genera of Hydrozoa develop exclusively in freshwater environments, *i.e*., *Hydra* Linnaeus, 1758, *Craspedacusta* Lankester, 1880, *Limnocnida* Günther, 1893, *Astrohydra* Hashimoto, 1981, *Velkovrhia* Matjasic & Sket, 1971, *Halmomises* von Kennel, 1891, and *Calpasoma* Fuhrmann, 1939, comprising around 60 species (Deserti et al., 2023; Schuchert, 2024). On the other hand, there are more representatives of the brackish environments, such as some members of the orders Limnomedusae (*e.g.*, *Vallentinia* Browne, 1902, *Olindias* Müller, 1861, *Gonionemus* A. Agassiz, 1862), Anthoathecata (*e.g*., *Moerisia* Boulenger, 1908, *Odessia* Paspalew, 1937, *Cordylophora* Allman, 1844) and Leptothecata (*e.g*., *Blackfordia* Mayer, 1910) (Schuchert, 2024).

The success of freshwater and brackish hydrozoans involves diverse adaptations throughout their evolutionary history, such as the presence of solitary reduced polyps in Limnomedusae (an order of the subclass Trachylinae where most of its members lack this stage) (Bentlage et al., 2018), and the development of adhesive structures to attach to macroalgae or seagrasses, commonly occurring in estuaries (Ahuatzin-Hernández et al., 2020). Unfortunately, their study has been scarce compared to those inhabiting marine ecosystems (Jankowski, 2001; Deserti et al., 2023), so taxonomy, evolutionary history, and ecological aspects of some of these taxa are poorly known (Jankowski, 2001). The knowledge regarding freshwater hydrozoans from Mexico is limited since most studies focus on new records or behavioral experiments (*e.g*., Moreno-Leon & Ortega-Rubio, 2009; Rivera-de la Parra et al., 2016). Despite more effort needed, brackish species are better known in the country since they are included in taxonomical and ecological studies conducted in estuaries or coastal lagoons (*e.g*., Álvarez-Silva et al., 2006; Ahuatzin-Hernández et al., 2020; Ocaña-Luna et al., 2021).

The number of studies concerning brackish-water environments in Mexico in the last years is comprehensive, likely due to some advantages of these environments, such as easy access and cheaper sampling costs (*e.g*., Sarma et al., 2000; Hendrickx et al., 2007; Castellanos-Osorio, 2009; Benítez-Díaz Mirón et al., 2014; Ahuatzin-Hernández et al., 2020). A similar scenario happens with the freshwater biota of Mexico, which shows a progressive advance in the knowledge of the main taxonomic groups over the years (Calderón-Gutiérrez et al., 2017; Álvarez et al., 2023; Cervantes-Martínez et al., 2023). However, hydrozoans are not considered in these works, which could be associated with the benthic behavior of some tiny taxa (*Hydra*) and the seasonal fluctuation between polyp and medusae stages (*e.g.*, *Craspedacusta*, *Moerisia*). Moreover, recent inventories about the medusozoans of Mexico do not include freshwater taxa, which represents a gap in the knowledge of this group (Segura-Puertas et al., 2003; Gasca & Loman-Ramos, 2014; Estrada-González et al., 2023).

Faunistic inventories are fundamental to improving the knowledge of the biodiversity of a region, which is necessary for applying good management of natural resources and conservation strategies (Cervantes-Martínez et al., 2023; Deserti et al., 2023). This task represents a challenge for a megadiverse country such as Mexico, so integrating dispersed literature about a taxonomic group allows us to improve the knowledge about that taxon, identifying gaps in the information, and recognizing future research fields. Herein, we gathered available published literature about freshwater and brackish-water hydrozoans from Mexico in order to provide a comprehensive picture of the state of the art and their biodiversity.

The information was integrated by reviewing available published literature, considering academic databases, such as Scholar Google, Scopus/Elsevier, ScieLO, and Web of Science/Clarivate, using keywords such as “Hydrozoa”, “freshwater”, “brackish-water”, “Mexico”, “medusa”, “polyp”, “anchialine fauna”, “Cnidaria”, both in Spanish and English. The information was assessed using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) protocol (Page et al., 2021). The name of the taxa was cross-checked with WoRMS (marinespecies.org; April 2024) and GBIF (Global Biodiversity Information Facility) to retrieve additional occurrences and correct synonyms, invalid species, and typing errors. In addition, we identified non-native species based on the information provided in the literature, which could be useful for future monitoring of the impacts that these species could exert on native populations.

Species Diversity

We found 27 works containing information about freshwater or brackish hydrozoans, resulting in 15 taxa grouped into two subclasses, three orders, and seven families (Table 1). The order Anthoathecata grouped nine taxa, distributed into five families, whereas Leptothecata was represented by one species. The order Limnomedusae was represented by five species grouped into one family. Seven of the 15 taxa were exclusively recorded in freshwater bodies, representing ~11.6 % and ~50 % of the worldwide and Neotropical freshwater known hydrozoans, respectively (Deserti et al., 2023; Schuchert, 2024). Five of the seven freshwater taxa were recorded in the polyp stage and two in the medusa stage. Family Olindiidae was the richest, matching previous studies (Jankowski, 2001) and supporting the hypothesis of independent origin in freshwater hydrozoan groups. This hypothesis states Olindiidae as the most diverse freshwater cnidarian group (Jankowski et al., 2008), suggesting an older origin of this taxon as representative of freshwater medusozoans. *Pachycordyle* Weismann, 1883 was not considered in the literature of the Neotropical region (Deserti et al., 2023), so we add this genus to the knowledge of the diversity of this group. This taxon was recorded in a reef lagoon in the Mexican Caribbean (Ramos & Segura-Puertas, 2004).

Table 1. Freshwater and Brackish-water Hydrozoans Recorded in Mexico. P=Polyp, M=Medusa, F=Freshwater, B=Brackish, O=Ocean.

Taxa	Morphology	Environment	Locality	Invasiveness	References
Subclass Hydroidolina Collins, 2000 Order Anthoathecata Cornelius, 1992 Suborder Aplanulata Collins, Winkelman, Hadrys & Schierwater, 2005 Family Hydridae Dana, 1846					
Hydra sp.	P	F	San Luis Potosi, State of Mexico		Osorio-Tafall, 1943; Zagmajster et al., 2011; Rivera-de la Parra et al., 2016
Hydra vulgaris Pallas, 1766	P	F	State of Mexico, Aguascalientes, Chihuahua		Marroquín-Cardona et al., 2009; Oseguera et al., 2016; Armas-Chávez et al., 2022; GBIF
Hydra viridissima Pallas, 1766	P	F	Nuevo León, State of Mexico, México City, Michoacán		Deserti et al., 2023 (Retreived from iNaturalist); Retrieved from iNaturalist through GBIF
Hydra oligactis Pallas, 1766	P	F	State of Mexico		Deserti et al., 2023 (Retreived from iNaturalist)

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Suborder Filifera Kühn, 1913					
Family Bougainvilliidae Lütken, 1850					
Nemopsis bachei L. Agassiz, 1849	M	B/O	Laguna Madre and Open Ocean (Tamaulipas),		Mendoza-Becerril et al., 2009; Gutiérrez-Aguirre et al., 2015
Pachycordyle sp.	M	B	Puerto Morelos (Quintana Roo)		Ramos and Segura-Puertas, 2004
Family Cordylophoridae von Lendenfeld, 1885					
Cordylophora caspia (Pallas, 1771)	P	F	Mandinga Lagoon (Veracruz), Nuevo León	X	Rioja, 1959; Guajaro et al., 1987; López-Ochoterena and Madrazo-Garibay, 1989
Family Hydractiniidae L. Agassiz, 1862					
Cnidostoma fallax Vanhöffen, 1911	M	B	Acapulco Bay (Guerrero)		Guerrero-Ruíz et al., 2015
Suborder Capitata Kühn, 1913 (sensu stricto)					
Family Moerisiidae Poche, 1914					
Moerisia inkermanica Paltschikowa-Ostroumowa, 1925	M	F	In Ballast Water of Tankers Loaded at Cayo Arcas Oil Terminal (Campeche)	X	Ahuatzin-Hernández et al., 2024
Order Leptothecata Cornelius, 1992					

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Family Blackfordiidae Bouillon, 1984					
Blackfordia virginica Mayer, 1910	M	B	Tampamachoco and Pueblo Viejo Lagoons (Veracruz), Lagunar System Chantuto-Panzacola (Chiapas)	X	Esquivel et al., 1980; Álvarez-Silva et al., 2003, 2006; Ocaña-Luna et al., 2021
Subclass Trachylinae Haeckel, 1879					
Order Limnomedusae Kramp, 1938					
Family Olindiidae Haeckel, 1879					
Craspedacusta sowerbii Lankester, 1880	M	F	Sinaloa, Nuevo León	X	Guajardo et al., 1987; Moreno-Leon and Ortega-Rubio, 2009
Cubaia aphrodite Mayer, 1894	M	B	Ascensión Bay, Puerto Morelos, Bojórquez lagoon, Mahahual reef, Chinchorro Bank (Quintana Roo)		Canché-Canché and Castellanos-Osorio, 2005; Segura-Puertas and Damas-Romero, 1997; Suárez-Morales et al., 1999; Gasca et al., 2003; Ramos and Segura-Puertas, 2004
Octobulbacea brachymera (Bigelow, 1909)	M	O	Open Ocean (Tamaulipas), Acapulco harbor (Guerrero)		Bigelow 1909; Gutiérrez-Aguirre et al., 2015
Olindias tenuis (Fewkes, 1882)	M	B	Ascensión Bay, Bojórquez Lagoon (Quintana Roo)		Canché-Canché and Castellanos-Osorio, 2005; Segura-Puertas and Damas-Romero, 1997
Vallentinia gabriellae Vannucci Mendes, 1948	M	B	Costal Lagoon in Progreso, Bocas de Dzilam (Yucatan), Puerto Morelos, Bojórquez Lagoon (Quintana Roo)		Foster, 1973; Segura-Puertas and Damas-Romero, 1997; Ramos and Segura-Puertas, 1997; Ahuatzin-Hernández et al., 2020

Eight brackish hydrozoans were recorded either in lagoons, estuaries, or open ocean, mainly in the Gulf of México and the Mexican Caribbean. Coastal environments of Mexico are characterized by the strong influence of freshwater, mainly in the coastal lagoons of the Yucatan peninsula (Herrera-Silveira & Morales-Ojeda, 2010; Camacho-Ibar & Rivera-Monroy, 2014), causing mixing zones where marine and freshwater biotas are found. The eight brackish taxa were recorded in the medusa stage, likely due to most studies conducted in coastal environments focusing on zooplanktonic organisms, so benthic representatives fell out of the scope of the traditional zooplanktonic methods.

Most brackish medusae reported here belong to Limnomedusae and Anthoathecata, being characterized by a metagenetic life cycle, alternating a benthic polyp and a free-swimming medusa. In Limnomedusae, a mostly neritic group of the subclass Trachylinae, a reduced polyp is present, which represents an adaptation to inhabit coastal environments. This fact is evident since other trachylines inhabiting the open ocean develop from zygote to medusa via a free-swimming larva, lacking the polyp stage (Bentlage et al., 2018; Ahuatzin-Hernández et al., 2023). The polyp represents a derived character (novelty) in the evolution of Hydrozoa (Cartwright & Nawrocki, 2010), providing several advantages in the adaptation and colonization of new habitats, either by producing cysts resistant to environmental changes (longer life spans) or attaching to vagile substrates, driving long distances (dispersal).

Fifteen states of Mexico, either in continental or coastal environments, recorded hydrozoans. The states of Mexico and Quintana Roo showed the richest composition, while nine states only presented one taxon (Fig. 1). The diversity of freshwater hydrozoans of Mexico is poorly known. For instance, conventional inventories of medusozoans leave out the freshwater representatives (Segura-Puertas et al., 2003; Gasca & Loman-Ramos, 2014; Estrada-González et al., 2023), and those works addressing the freshwater diversity of Mexico don't consider hydrozoans in their scope (*e.g.*, Álvarez et al., 2023; Cervantes-Martínez et al., 2023; Gómez-Marín et al., 2024). This fact contrasts with investigations on coastal hydrozoans, which have been constant in recent years (*e.g.*, Canché-Canché & Castellanos-Osorio, 2005; Ahuatzin-Hernández et al., 2020; Mendoza-Becerril et al., 2020). The gap in the knowledge of freshwater hydrozoans biases the understanding of the diversity of both medusozoans and continental biota in Mexico, so more research in this sense is needed.

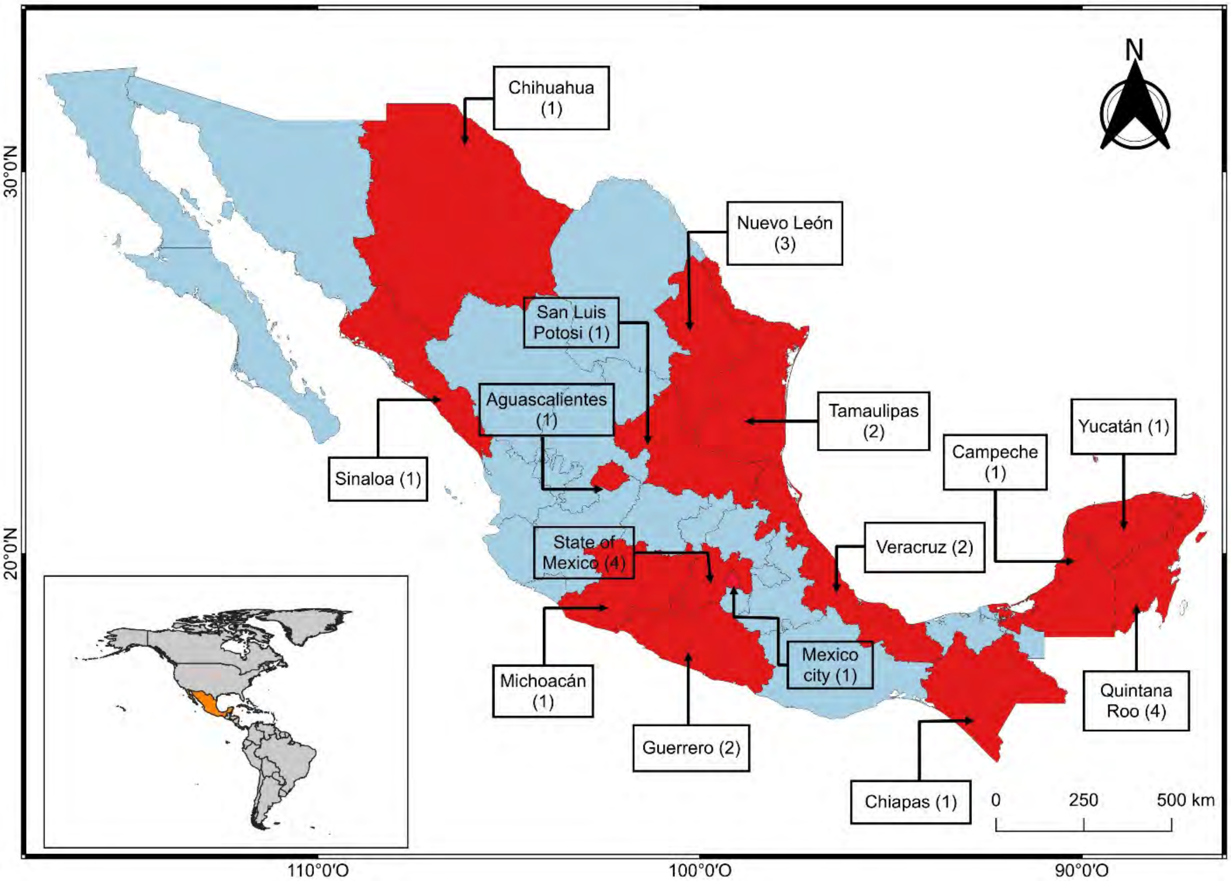

Figure 1. Mexican States with the Presence of Freshwater or Brackish-water Hydrozoans. The Number of Species per State Is Indicated in Parentheses.

Invasive Species

Four of the 15 hydrozoans are considered non-native based on literature records, *i.e*., *Cordylophora caspia* (Pallas, 1771), *Moerisia inkermanica* Paltschikowa-Ostroumowa, 1925, *Blackfordia virginica* Mayer, 1910, and *Craspedacusta sowerbii* Lankester, 1880. In the case of *M. inkermanica*, and *B. virginica*, recorded in brackish environments, the introduction in other regions of the world is attributed to maritime transport through the ballast water or biofouling (Nowaczyk et al., 2016; Ahuatzin-Hernández et al., 2024). The presence of these and other non-native species in the aquatic environments of Mexico encourages attention to the application of protocols that regulate the management of this type of water since it is one of the main vectors of invasion (Okolodkov et al., 2007; Okolodkov & García-Escobar, 2014).

On the other hand, the introduction pathways might be different regarding *C. caspia* and *C. sowerbii*, both recorded in continental water bodies. In this sense, a migratory route hypothesis by aerial dispersion due to bird migration is supported by observational evidence in *C. sowerbii* (Marchessaux et al., 2021). In this case, the role of the polyp stage, which is drought-resistant, is crucial for the long-transport success. A similar scenario may happen with *C. caspia*, recorded in freshwater and brackish-water environments of Mexico on multiple occasions (Rioja, 1959; Guajaro et al., 1987; López-Ochoterena & Madrazo-Garibay, 1989), which suggests its establishment in the country, yet more research on the distribution of this species in Mexico is needed. Of the species treated here, only *C. caspia* is reported in the lists of non-native aquatic species of Mexico (Okolodkov et al., 2007). Therefore, this study adds three species to the knowledge of non-native hydrozoans in the country and encourages us to continue exploring continental and brackish-water ecosystems where other unrecorded species may occur.

What do We Know about the Freshwater Hydrozoans of Mexico?

The knowledge about the freshwater hydrozoans of Mexico is scarce in many senses. The known number of species is likely underestimated due to the lack of research on this group. In addition, the taxonomy and evolution of the known taxa is also limited. In recent years, studies considering molecular data have shown that species previously considered cosmopolitan (*Hydra*, *Craspedacusta*, and *Cordylophora*) represent groups of species geographically delimited (*e.g*., Martínez et al., 2010; Schwentner & Bosch, 2015; Oualid et al., 2019; de Paula et al., 2024). However, studies conducted in Mexico regarding these taxa do not include molecular data or a suitable morphological analysis, so their taxonomic identity is uncertain.

The most studied genus of Mexico from freshwater environments is *Hydra*. Studies use it as a biological model to understand the effects of predation and the characterization of mycotoxins (Marroquín-Cardona et al., 2009; Rivera-de la Parra et al., 2016). Nevertheless, little is known about the relationship of this and other freshwater taxa with environmental variables. This fact leads to a gap in the knowledge of the ecology of these taxa. Thus, in the case of invasive species, their monitoring and prediction of further impacts on native populations is complicated.

More efforts are needed to improve the knowledge about the freshwater hydrozoans of Mexico. First, studies considering integrative taxonomy approaches are crucial to assigning an accurate identity to the Mexican taxa. Only then aspects related to the ecology of the species might shed light on their trophic relationships. Finally, these research lines could be integrated into an evolutionary frame to address issues such as biogeography, evolution, and distribution expansion by climate change through distribution models.

Conclusions

The diversity of freshwater hydrozoans in Mexico has been overlooked over the years. In contrast, brackish hydrozoan diversity is better known due to constant research efforts in coastal environments. Four species are considered non-native; however, few works have monitored their distribution patterns and potential impact on native populations. Future perspectives on freshwater hydrozoans encompass global and local challenges. Hence, more research efforts are needed locally since other unrecorded species might occur in unexplored continental ecosystems. Due to a metagenetic life cycle involving benthic and planktonic stages, studies should include methodologies considering both types of environments.

Relevant topics with little information about Mexican freshwater hydrozoans include taxonomy, ecology, and potentially biotechnology. For example, *Hydra*, *Craspedacusta*, and *Cordylophora* have proved cryptic speciation, but Mexican records usually assign specimens to the type species, which are currently considered species complexes (Martínez et al., 2010; Schwentner & Bosch, 2015; Oualid et al., 2019; de Paula et al., 2024). The feeding and trophic ecology of *Hydra* has been studied in Mexico and other regions of the world (Rivera-de la Parra et al., 2016; Deserti et al., 2017; Morales et al., 2018). However, these aspects remain unexplored for the rest of the freshwater hydrozoans of Mexico, which are fundamental to knowing their ecology, mainly for those non-native ones. Finally, *Hydra* is one of the most widely implemented taxa as a biological model, being the basis of several studies concerning toxicology, regeneration, proteomics, and aging (*e.g.*, Mocz, 2007; Galliot, 2013; Tomczyk et al., 2015; Murugadas et al., 2019), yet these approaches have not been implemented in the Mexican species. Addressing these lines would be crucial since it might change our view about the diversity of this group, recognizing new cryptic species distributed in the country, the potential impacts of those non-native ones, and their use as sources of natural compounds.

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Authors' Contributions

JMAH and LVLD conceptualized the idea. JMAH reviewed the literature and conducted the analysis. Both authors read and approved the final version of the manuscript.

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This book takes a significant step in showcasing the relevance of limnology to our survival. Freshwater habitats, though they cover less than 1 % of the Earth's surface, are home to a substantial portion of the world's biodiversity—at least 10 % of all known species. Freshwater habitats and the biodiversity they support are under threat. Moreover, our survival depends on access to high-quality freshwater. This book not only highlights the beauty of limnology and the scientific methods used to study it, but it also draws attention to the major causes of biodiversity loss in freshwater ecosystems. It shows all readers what it means to deal with inland waters as a scientist interested in understanding ecosystems and protecting them.

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