



Marine Platyhelminthes of the Maldives: A Review of Their Diversity and Distribution

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Abstract

The phylum Platyhelminthes is poorly studied in the Republic of Maldives, and its biodiversity remains largely undocumented. This study presents the first checklist of Maldivian flatworms, including both free-living and parasitic species, compiled through a comprehensive review of existing literature, citizen science platforms, and online resources. A total of 39 species (recorded from both databases and literature) from nine families are reported in the Maldives: 10 species were recorded in the published literature, and 29 species were contributed by citizen-science databases and online resources, underlining the impactful contribution of public participation in scientific research. The occurrence patterns were analysed based on 170 species records, revealing a higher abundance of sightings in the central and northern atolls, likely influenced by the high density of tourist resorts and associated diving activities. This study highlights the importance of citizen science in contributing to biodiversity data while emphasising the need for further research and integrative taxonomy approaches. The findings provide a crucial foundation for future studies and conservation efforts regarding Maldivian Platyhelminthes.

Keywords Marine flatworms · Maldivian biodiversity · Species checklist · Citizen science · Geographic distribution · Indian Ocean

Introduction

The Republic of the Maldives, located in the central Indian Ocean, is an archipelago comprising 1,192 islands naturally grouped into 26 atolls (Fig. 1). This region encompasses a diverse range of shallow water habitats, including coral reefs, mangrove forests, seagrass meadows, lagoons, and sandy bottoms (Dryden et al. 2020; Cerri et al. 2024). These ecosystems collectively sustain a remarkably high level of marine biodiversity, reflecting the Maldives as one of the most species-rich regions of the Indo-Pacific (Naseer and Hatcher 2004). Despite constituting a substantial component of this biodiversity, marine invertebrates remain largely understudied, with knowledge unevenly distributed across taxonomic and ecological groups. (Gibson et al. 2011; Fisher et al. 2015). As a result, some invertebrate groups remain notably poorly known, and one example is the phylum Platyhelminthes, whose diversity and distribution in the Maldives are still far from being fully understood.

Commonly referred to as ‘flatworms’, Platyhelminthes are characterised by the absence of a coelom and dorsoventrally

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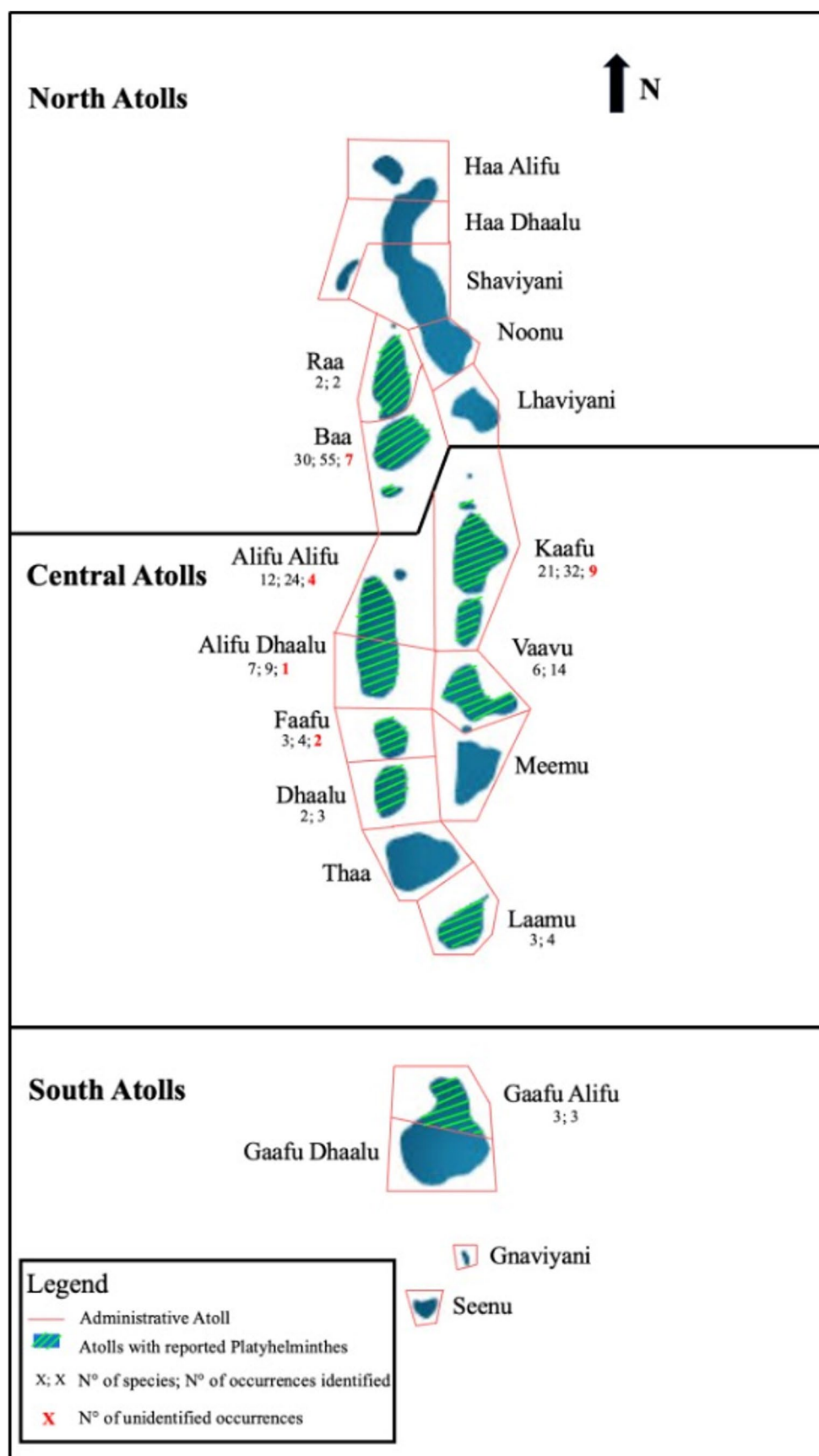
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Fig. 1 Map of the Maldives divided by administrative atolls. Green squares refer to atolls with reported Platyhelminthes; for every atoll, the number of species, identified and unidentified records, is specified



flattened bodies. This phylum includes both free-living flatworms, largely represented by Polycladida, and parasitic taxa, such as monogeneans and digeneans associated with vertebrate hosts (Kritsky 2012; Collins 2017). Free-living flatworms are typically found across shallow benthic habitats, including reefs, rubble, seagrass beds and sandy areas, whereas parasitic species often exhibit host-specific relationships that may limit their detectability (Kritsky 2012). Moreover, multiple free-living species exhibiting identical external and internal morphology, including colour patterns, may have led to identification errors, resulting in an underestimation of species diversity. Numerous studies have confirmed the existence of cryptic species and species complexes in Platyhelminthes, highlighting the need for integrative taxonomic analyses to ensure accurate identification (Miller et al. 2009; Litvaitis et al. 2010).

Despite their abundance across a wide variety of environments, the biodiversity of Platyhelminthes remains underestimated and poorly documented in many regions (Noreña et al. 2019). Previous research has shown a considerable diversity of Platyhelminthes in tropical areas, particularly in the Indo-Pacific and the nearby Laccadive and Lakshadweep islands (Gardiner 1903; Apte and Pitale, 2011; Dixit et al. 2020, 2021). These studies proved that adequate sampling efforts are crucial to understand the diversity and distribution patterns of these organisms. By contrast, although some research has been conducted in areas close to the Maldives, the National Biodiversity Strategy & Action Plan (2015), published by the Maldivian Government, contains no information regarding the diversity and distribution of Platyhelminthes.

Indeed, records of Platyhelminthes in the Maldives are limited and scattered. Despite some citizen science sightings documented in global species databases (e.g. iNaturalist), the literature remains rather sparse on the topic. Given the absence of a consolidated overview of Platyhelminthes in the Maldives, a systematic synthesis of existing information is required to contextualise the current state of knowledge, identify major gaps and guide future research. This review aims to analyse scientific publications, databases, and websites concerning Platyhelminthes across the entire Maldivian archipelago to i) assess their species richness, ii) compile current knowledge on their occurrence patterns and distribution, and iii) highlight inconsistencies and gaps in the existing literature, and propose avenues for future research.

Materials & Methods

Literature Status and List of Species

The bibliographic search was performed primarily through Google Scholar. Searches were conducted using

combinations of the following keywords: “PLATYHELMINTHES”, “FLATWORMS”, and “MALDIVES”. All potentially relevant publications were screened, resulting in a total of seven papers retained for subsequent analyses.

Moreover, available records were also retrieved from different biodiversity databases filtered by location (Maldives): the Global Biodiversity Information Facility (GBIF) and the Turbellarian Taxonomic Database (TTD), iNaturalist, and a specialised photographic resource (Maldives Marine Flatworms: <http://www.nudibranch.org/Flatworms/maldives/html/maldives-flatworms.html>). Occurrence data from GBIF, TTD, iNaturalist and Maldives Marine Flatworms were retrieved until December 2025. Citizen science sources, such as in Tee et al. (2019), have been used previously both to assemble regional checklists and to provide digitised records where primary publications are scarce. Records originating from crowd-sourced platforms and aggregated datasets were treated as opportunistic and were subjected to verification. Records showing clear photographic and geographic information were retained and observations with uncertain taxonomic assignments were excluded from species-level analyses but retained at higher taxonomic levels for occurrence patterns analysis. Additionally, photographic resources, such as Marine Life of the Maldives (Coleman 2019), were consulted. Records lacking geographic information, unreliable identification or unresolved genus information were excluded. The World Register of Marine Species (WoRMS 2025) was also checked for occurrences, but no further information on Platyhelminthes of the Maldives was found. Therefore, WoRMS was used solely to verify scientific names. Parasite records were annotated with host information whenever this was available from the source. For each parasite occurrence, we attempted to record the host scientific name, family, tissue, and collection method. Finally, duplicate records occurring across multiple databases were identified and removed.

Occurrence Patterns

Occurrences were categorised by geographic location. All records were considered to assess the overall distribution across the region, including those lacking precise species or genus identifications and referring to the order or taxon only. Specifically, sightings were assigned to administrative atolls based on the geographic coordinates. The administrative subdivision divides atolls into northern, central, and southern. This classification provides a consistent geographic framework for comparing occurrences across the archipelago while remaining consistent with the administrative divisions used in national biodiversity and environmental assessments. Sightings with imprecise location data were excluded to enhance the accuracy of our occurrence patterns

analysis. To assess regional differences in sampling, species richness and records per species were calculated for each region (north, centre and south). Species richness was defined as the number of distinct species recorded within each region. The ratio between occurrence records and species richness was also calculated to evaluate potential differences in sampling intensity.

Results and Discussion

The number of Platyhelminthes species found and recorded in the list is 39 species belonging to 20 genera and nine families (Table 1).

Of the recorded species, 13 are parasitic, all detected through host dissection among these, four species of *Euryhaliotrema* were recovered from the gills of the two-spot red snapper *Lutjanus bohar* and the humpback red snapper *Lutjanus gibbus* (Kritsky 2012). Members of the Cryptogonimidae were recorded from the intestines of *Lutjanus argentimaculatus*, *Lutjanus bohar*, *Lutjanus carponotatus*, *Lutjanus fulviflamma*, *Lutjanus gibbus*, *Lutjanus sebae* (Miller and Cribb 2007a, b; Miller et al., 2009, 2010). Trypanorhynch cestodes (Order Trypanorhyncha) were detected in the gastrointestinal tracts of fish *Lates calcarifer* (Palm et al. 1998). All parasitic species were detected by dissection of the host.

By contrast, free-living flatworms were primarily recorded through opportunistic sightings and photographic records rather than host-targeted sampling. The species with the broadest distribution, recorded in four or more atolls, were *Pseudobiceros bedfordi*, *Pseudoceros susanae*, *Thysanozoon nigropapillosum*, *Nymphozoon orsaki*, *Pseudobiceros splendidus*, and *Pseudoceros monostichos*. These species, all belonging to the family Pseudocerotidae (Fig. 2), represent 81% of all photographed occurrences, suggesting underlying ecological and biological drivers. The relatively large body sizes, between seven and ten centimetres in length, of certain species, such as *Pseudobiceros bedfordi* and *Thysanozoon nigropapillosum* (Andréfouet et al. 2012), make them more likely to be detected by divers, possibly leading to more frequent report. Bright colour patterns of Pseudocerotidae species, like the red pattern of *Pseudobiceros fulgor* or the blue and orange colouration of *Pseudoceros susanae*, further enhance their visibility. However, identical pigmentation in several species can, conceal cryptic taxa and may therefore hinder accurate species identification. Other biological factors, such as the effective and rapid reproductive strategies of Pseudocerotidae may facilitate colonisation of more environments across dispersal barriers, promoting rapid population growth and local abundance (Cannon 1998). Furthermore, diet may

also influence the local abundance of some species. Colonial ascidians, sponges, and small crustaceans, common throughout reef systems, serve as prey for many pseudocerotid flatworms, enlarging the abundance of these species (Newman and Cannon 1994). Although large sizes, bright colours, fast reproduction, and prey availability may explain why Pseudocerotidae thrive across several atolls, different constraints apply to other families. In particular, parasitic life cycles or secretive habits may limit the ranges of certain species, exacerbating this perceived scarcity. Families that include cryptic or nocturnal polyclads may appear rare simply because of lower detectability under conventional survey methods. Parasitic flatworms, such as monogeneans and digeneans, are almost entirely absent from photographic records and have been documented only through targeted taxonomic work (Miller and Cribb 2007a, b; Kritsky 2012). As shown in Table 1, the least distributed species recorded from a single atoll include those with specialised host requirements (i.e., parasitic species) and/or cryptic habits (Kritsky and Galli 2012). Indeed, the limited survey efforts, as well as sampling biases, may significantly contribute to their perceived rarity.

A total of 170 records were analysed, representing 39 species recorded in 10 atolls (Fig. 1). Occurrence counts were 64 in the northern atolls, 103 in the central atolls, and only 3 in the southern atolls (Fig. 3). When accounting for sampling intensity, the ratio between occurrence records and species richness was slightly higher in the central atolls (3.03 records/species) compared to the northern atolls (2.91 records/species), whereas the southern atolls showed a lower value (1 record/species), suggesting repeated observations of the same species in the central atolls rather than higher biodiversity. Moreover, this uneven distribution plausibly reflects differences in sampling effort, since central and many northern atolls host a higher density of tourist resorts and diving activities, rather than clear absences in the south (MEE 2015). Indeed, the central atolls account for 60.6% of all occurrence records, highlighting a strong spatial sampling bias likely associated with the higher concentration of tourism and diving activities in these areas. Moreover, the majority of records analysed come from citizen science databases (iNaturalist), further emphasising a tourism-driven sampling. Species occurrence datasets compiled from citizen-science platforms are well known to exhibit strong spatial and temporal biases toward accessible or attractive locations, which inflates detection probability in well-visited areas and depresses it in remote or less-visited regions (Boakes et al. 2010). Moreover, taxonomic and observer biases tend to favour conspicuous or charismatic taxa, while small, cryptic or meiofaunal taxa remain under-represented in regional inventories (Troudet et al. 2017). However, despite the taxonomic uncertainty that may arise

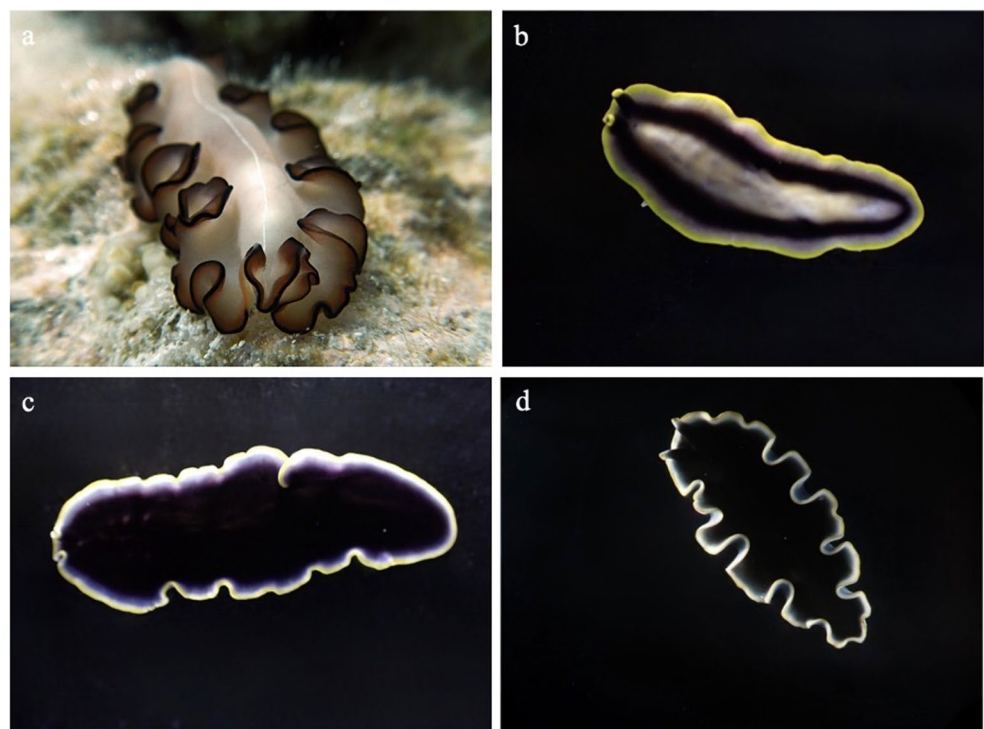
Table 1 Platyhelminthes species recorded from the Republic of Maldives. Data was compiled from systematic studies, Global Biodiversity Information Facility (GBIF), Turbellarian Taxonomic Database (TTD), and Maldives Marine Flatworms (WEB). The source database is marked with an X for each record, and the occurrences' location is reported. In the 'Species' column, the authority is also provided alongside the scientific name.

Order	Family	Species	Location	Literature	GBIF	TTD	Web
Parasitic flatworms							
Dactylogyridea	Ancyrocephalidae	<i>Euryhaliotrema cognatus</i>	Center: Kaafu	Kritsky 2012	X		
		<i>Euryhaliotrema distinctum</i>	Center: Kaafu	Kritsky 2012	X		
		<i>Euryhaliotrema tormocleithrum</i>	Center: Kaafu	Kritsky 2012	X		
		<i>Euryhaliotrema ramulum</i>	Center: Kaafu	Kritsky 2012	X		
Plagiorchiida	Cryptogonimidae	<i>Caulanus thomasi</i>	Center: Alifu Alifu	Miller and Cribb 2007a, b	X		
		<i>Lobosorchis polygongylus</i>	Center: Alifu Alifu	Miller et al. 2009	X		
		<i>Retrovarium brooksi</i>	Center: Alifu Alifu	Miller and Cribb 2007a, b	X		
		<i>Retrovarium sablae</i>	Center: Alifu Alifu	Miller and Cribb 2007a, b			
		<i>Varialvus charadrus</i>	Center: Alifu Alifu	Miller et al. 2010	X		
		<i>Latuterus tkachi</i>	Center: Alifu Alifu	Miller and Cribb 2007a, b			
		<i>Latuterus maldivensis</i>	Center: Alifu Alifu	Miller and Cribb 2007a, b			
Trypanorhyncha	Lacistorhynchidae	<i>Bombycirhynchus sphyraeniaicum</i>	Center: Kaafu		X		
	Pseudotobothriidae	<i>Pseudotobothrium dipsacum</i>	Center: Kaafu		X		
Free living flatworms							
Polycladida	Euryleptidae	<i>Maritigrella fuscopunctata</i>	North: Baa Center: Kaafu	Cannon 2003	X	X	
	Planoceridae	<i>Planocera armata</i>	South: Gaafu Alifu			X	
	Prosthiostomidae	<i>Prosthiostomum cooperi</i>	Center: Kaafu			X	
		<i>Prosthiostomum elegans</i>	South: Gaafu Alifu			X	
	Pseudocerotidae	<i>Nymphozoon orsaki</i>	North: Baa Center: Dhaalu, Faafu, Kaafu, Laamu	Andréfouet et al. 2012	X		X
		<i>Pseudobiceros bedfordi</i>	North: Baa Center: Alifu Alifu, Alifu Dhaalu, Dhaalu, Faafu, Kaafu, Laamu, Vaavu		X		X
		<i>Pseudobiceros damawan</i>	North: Baa		X		X
		<i>Pseudobiceros fulgor</i>	Not Specified		X		
		<i>Pseudobiceros gardinieri</i>	Center: Kaafu			X	
		<i>Pseudobiceros gloriosus</i>	North: Baa Center: Alifu Alifu, Alifu Dhaalu, Faafu		X		X
		<i>Pseudobiceros gratus</i>	North: Baa		X		X
		<i>Pseudoceros prudhoei</i>	North: Baa		X		
		<i>Pseudobiceros splendidus</i>	North: Baa, Raa Center: Alifu Alifu, Kaafu, Vaavu		X		X
		<i>Pseudobiceros stellae</i>	North: Baa		X		
		<i>Pseudoceros bifurcus</i>	North: Baa		X		X
		<i>Pseudoceros buskii</i>	Center: Kaafu			X	
		<i>Pseudoceros duplicinctus</i>	North: Baa				X
		<i>Pseudoceros goslineri</i>	Center: Kaafu	Newman and Anderson 1997	X	X	X
		<i>Pseudoceros leptostictus</i>	North: Baa Center: Kaafu		X		X
		<i>Pseudoceros monostichos</i>	North: Baa Center: Alifu Alifu, Kaafu, Vaavu		X		X
		<i>Pseudoceros paralaticlavus</i>	North: Baa		X		
		<i>Pseudoceros punctatus</i>	Center: Kaafu			X	

Table 1 (continued)

Order	Family	Species	Location	Literature	GBIF	TTD	Web
Parasitic flatworms		<i>Pseudoceros scintillatus</i>	North: Baa Center: Vaavu	Newman and Anderson 1997	X	X	X
		<i>Pseudoceros stimpsoni</i>	North: Baa		X		
		<i>Pseudoceros susanae</i>	North: Baa, Raat Center: Alifu Alifu, Alifu Dhaalu, Kaafu, Laamu	Newman and Anderson 1997	X		X
		<i>Pseudoceros zebra</i>	North: Baa		X		X
		<i>Thysanozoon nigropapillosum</i>	North: Baa, Alifu Alifu, Alifu Dhaalu, Vaavu South: Gaafu Alifu		X		X
		<i>Austrorhynchus maldivarum</i>	Center: Kaafu		X		
Rhabdocoela	Polycystididae						

Fig. 2 Photos of some listed species. (a) *Nymphozoon orsaki*; (b) *Pseudoceros paralaticlavus*; (c) *Pseudoceros prudhoei*; (d) *Pseudoceros duplicinctus*. Pictures were taken by the authors

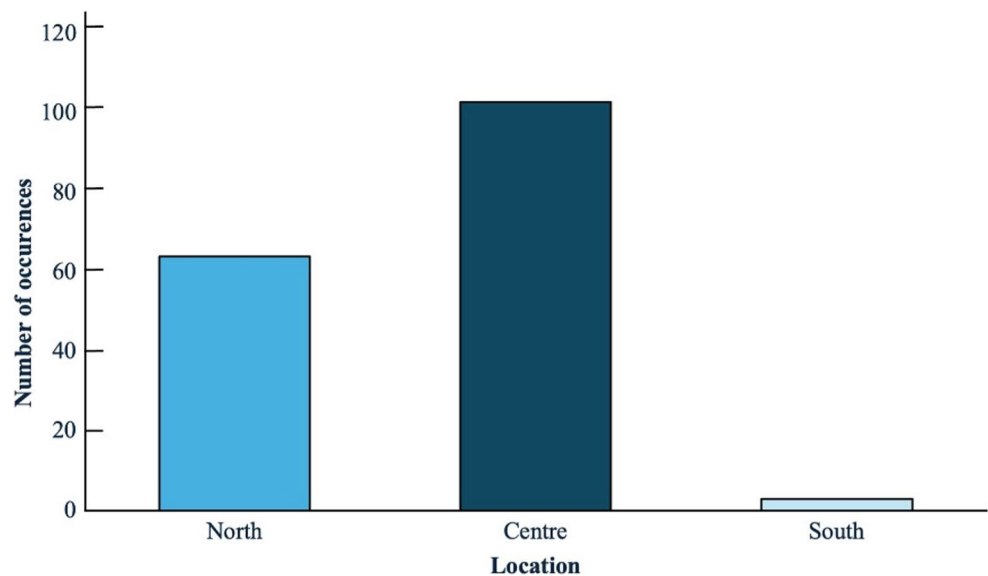


from opportunistic observations (Troudet et al. 2017), citizen-science platforms still provide an important source of occurrence data, especially for understudied taxa. Published Platyhelminthes studies have also predominantly focused on central atolls. For a more comprehensive understanding of flatworm distribution in the Maldives, future surveys should focus on underexplored southern atolls, as well as northern atolls with no prior surveys or recorded Platyhelminthes observations.

In addition to geographic gaps, taxonomic uncertainty further complicates the assessment of biodiversity. A distinct number of unidentified species have been recorded, labelled as “sp.” or identified only to genus or higher taxonomic

levels, as shown in Fig. 1 (red markers on the map), indicating that many specimens could not be identified to species level based solely on morphological observations. Certain families, such as Pseudocerotidae, present challenges in species identification due to their relatively simple external morphology, which can obscure cryptic diversity, lead to misidentifications and potentially hinder the detection of new or unreported species in the Maldives (Litvaitis et al. 2010). Similarly, the family Cryptogonimidae has demonstrated cryptic diversity, that cannot be resolved reliably from photographs alone (Miller and Cribb 2007a, b). Integrative taxonomic approaches that combine morphological and molecular analyses are therefore essential to confirm

Fig. 3 Distribution of Platyhelminthes in the Republic of Maldives, divided by geographic location. On the x-axis are displayed the number of occurrences, whereas on the y-axis the location of the findings, furtherly divided into North, Centre and South



species identities, uncover cryptic diversity, and produce a reliable regional biodiversity assessment (Litvaitis et al. 2010; Patel et al. 2023)

The scarcity and uneven distribution of recorded Platyhelminthes could be interpreted within a broader biogeographical and methodological framework, as similar challenges have been reported from many other regions across the tropical Indo-Pacific. Evidence from neighbouring areas of the Indo-Pacific suggests that the diversity currently reported for the Maldives is likely underestimated, as targeted surveys in nearby regions such as the Lakshadweep Islands and along the Indian coast have produced more extensive species inventories and new polyclad records, with 11 new species firstly reported in the region (Apte and Pitale, 2011; Dixit et al. 2020, 2021). Free-living taxa, and especially meiofaunal forms, such as proseriates, inequity is a recurrent problem due to their minute size, cryptic behaviour, or the inadequacy of sampling techniques (Curini-Galletti et al. 2012). These issues have also been addressed in other regions such as the Caribbean, Western Pacific, and Mediterranean, which have repeatedly revealed substantial hidden diversity (Wilkinson 2004; Curini-Galletti et al. 2012). Furthermore, dispersal mode and developmental strategy strongly shape distributional patterns, since taxa with direct development or lacking planktonic larvae typically exhibit restricted ranges. (Rawlison 2014) Limitations also apply to parasitic species, which form a significant component of flatworm diversity. These groups often require host-specific sampling and careful dissection (Kritsky 2012). As a result, their diversity is systematically underestimated.

Taken together, these patterns underline the lack of knowledge in the Maldives on Platyhelminthes, driven by both observational biases and the biological and ecological characteristics of these animals. This highlights the necessity of continued research, particularly through integrative

taxonomic approaches, to fully understand the diversity and evolutionary relationships within this phylum.

Conclusion and Future Perspectives

This work provides the first comprehensive review of Platyhelminthes species in the Maldives, compiling data from both scientific literature and citizen science platforms. The available data indicate that current knowledge of Maldivian flatworm diversity remains limited and unevenly distributed across the archipelago. Most records are concentrated in central atolls, likely reflecting differences in observation effort associated with tourism and research activity rather than true biogeographic patterns. These findings highlight the substantial role of citizen science in supplementing biodiversity data, particularly in understudied regions. However, to overcome the difficulties in morphological species identification, future projects should be carried out using standard taxonomic references in combination with DNA barcoding to confirm the identity of species.

A future research should prioritise systematic sampling across under-surveyed atolls, combined with integrative taxonomic approaches that include morphological and ecological examinations. A comprehensive study of their biodiversity, distribution, and ecological significance will ultimately contribute to more effective conservation and management strategies in the Maldives.

Author Contributions Eleonora Concari, Federico Cerri and Davide Maggioni conceptualised the study. Eleonora Concari analysed, visualised the data, and wrote the manuscript. Paolo Galli was responsible for funding acquisition. Federico Cerri, Yohan Didier Louis, Shazla Mohamed, Paolo Galli and Davide Maggioni reviewed, edited the manuscript. All authors have read and approved the manuscript.

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Data Availability All data associated with this study are enclosed in the paper.

Declarations

Competing Interests The authors declare no competing interests.

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