Research Article

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The benthic marine algae of the Maldives: historical insights into their diversity and distribution

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Abstract: In tropical ecosystems worldwide, benthic marine algae are important primary producers and habitat providers for many juvenile fish and invertebrate species. Calcified species are known to provide structural support to their respective communities, thus enhancing the overall system's productivity. In the Republic of the Maldives, algae are an important yet currently poorly studied biological resource. We reviewed the literature around algal diversity and distribution across Maldivian atolls and compiled an extensive and updated taxonomic list. The list contains 353 species, of which 31 are Cyanobacteria, 26 Phaeophyceae, 109 Chlorophyta, and 187 Rhodophyta. Algal collections have been reported from 12 out of 20 atolls, and these mostly occurred during 20th century expeditions. The taxonomic status of 110 species has changed since first reported. While several species have been documented from the country, identifications have thus far almost solely relied on morphological assessments. Many of the reported algal groups require molecular confirmation. This suggests that benthic algal diversity from the Maldives is likely an underestimate. Since anthropogenic activities can significantly alter algal community dynamics, a baseline understanding of algal diversity is necessary to determine how such shifts affect the ecosystem as a whole, thus underpinning future management and conservation efforts.

Keywords: benthic marine algae; tropical algae; algal diversity and distribution; Maldives; Maldives biodiversity

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1 Introduction

The Republic of the Maldives (Maldives) is a small island developing state located in the Indian Ocean (Di Biase and Maniku 2021). The country is an archipelago formed by more than 1,192 islands that are geographically distributed into 26 natural atolls, spread over 820 km from the northernmost point of Ihavandippolhu (7.006” N) to the southernmost point of Addu atoll (0.042” S), and 80–120 km east to west (Dryden et al. 2020, Figure 1). The total land area of 227 km^2 covers less than 1 % of the entire area of the country (Dhunya et al. 2017). Therefore, with limited agricultural land and freshwater, the country heavily relies on marine and coastal areas for food, resources and livelihoods. Indeed, marine biological diversity in the Maldives contributes to 71 % of employment, 89 % of Gross Domestic Product and 98 % of exports, with many industries that directly benefit from biological resources, including fisheries, tourism and handicrafts (Duvat et al. 2021). However, many important biological resources from Maldives are currently still poorly studied. Among these are the algae, photosynthesizing organisms known to provide essential services to ecosystems worldwide (Stevenson 2014). Being primary producers, algae play an important role in nutrient cycling and habitat provision for invertebrates within the reef and lagoon systems from tropical regions (Omer et al. 2021). For example, algal species with complex three-dimensional structures, such as those in the genus *Halimeda* J. V. Lamouroux, exert a great influence on other components of community assemblages primarily through non-trophic interactions, i.e. by modification of the physical environments via their own complex structure (McNeil et al. 2021). Benthic primary producers are also known to alter the concentration of minerals and nitrogen in the water column through mineralization and nitrification-denitrification processes (McGlathery et al. 2004). Some groups of algae can deposit calcium carbonate in their cell walls. This gives them a hard and rigid structure that plays a key role in cementing the reef structures and filling cracks (Lin et al. 2023; Schubert et al. 2020). There is also evidence that species of calcified coralline algae, such as *Hydrolithon onkodes*, promote larval settlement of key benthic invertebrates, including corals (Perrine et al. 2023), thus playing an important role in coral population recovery and reef resilience (Jeong et al. 2021, 2023).

The Maldives is currently facing several environmental threats, including the destruction of habitats such as reefs, lagoons, beaches, and mangroves due to land reclamation, harbor building, and many related infrastructure development activities (MEE 2015). These activities can substantially impact the environment, potentially altering ecosystem dynamics and leading to local extinctions. As a result of human impacts and climate change, algae are known to be declining from coastal regions worldwide (Smale et al. 2019). Moreover, changes in the distribution and composition of algal species, resulting primarily from higher average sea surface temperatures, as well as from sporadic heat waves, are globally expected to compromise the biodiversity and functioning of ecosystems (Martínez et al. 2018). A well-studied example in tropical waters is regime shifts due to competition between foundation and "turf-forming" macroalgal species. Foundation species provide shelter and food, and reduce environmental stress for other taxa, thus contributing to the cycling of energy and matter, but they are often being replaced by "turf-forming" algae with different ecological roles (O'Brien and Scheibling 2018). The effects of

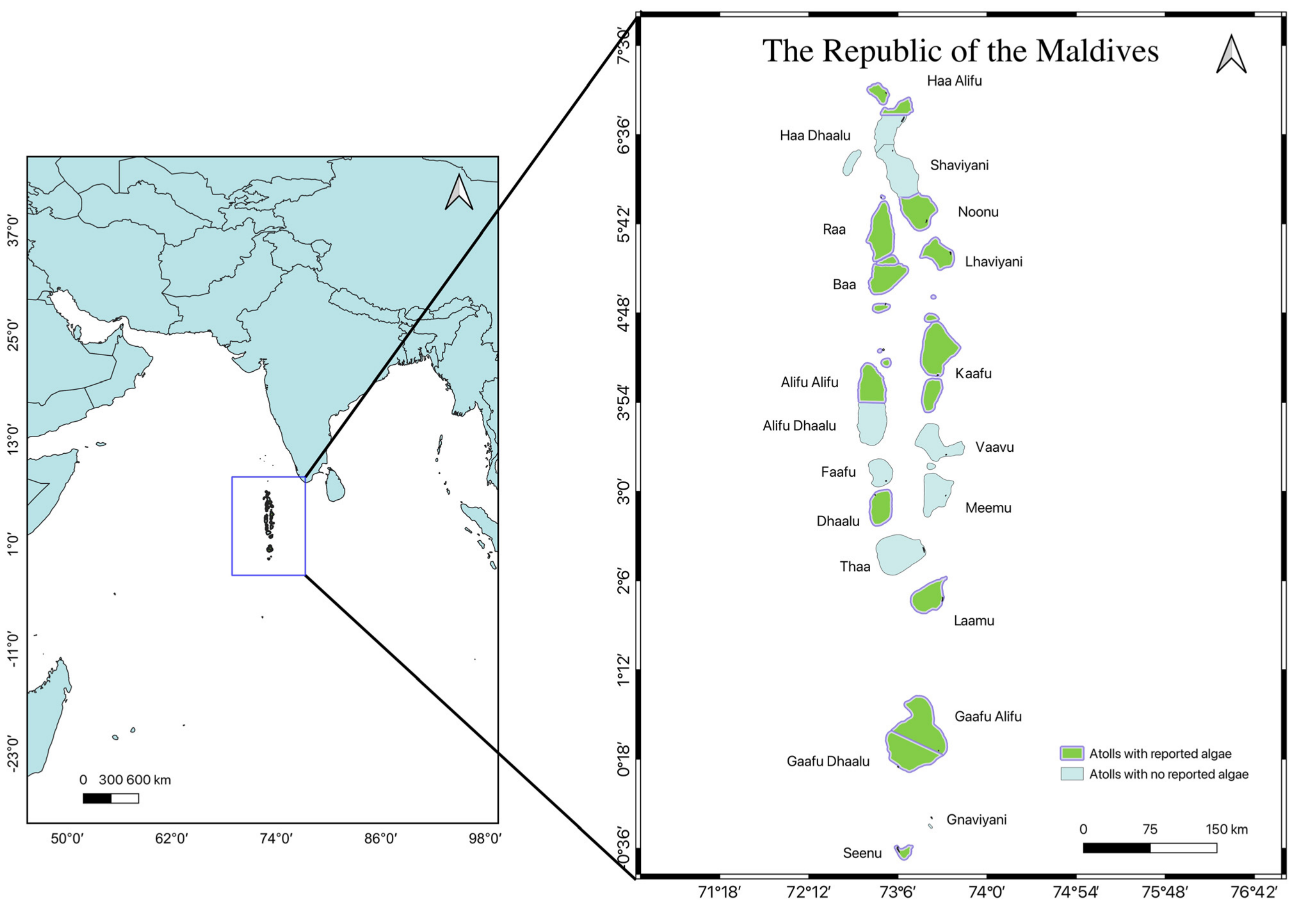

Figure 1: Maldivian atolls with reported algal collections. Map created using the free and open source QGIS.

global warming on seaweed communities are commonly observed to induce a shift toward “turf-forming” algae (Straub et al. 2019). The term “algal turf”, is typically used to describe multispecies assemblages of benthic filamentous algae 1–10 cm in height (Connell et al. 2014). In healthy tropical coral reef assemblages, turf algae form an important component of the epilithic algal community or epilithic algal matrix and contribute considerably to the total primary productivity and trophic transfer, especially in lagoon, reef flat, and back-reef habitats (O'Brien and Scheibling 2018). However, under climate change conditions and anthropogenic pressures, such as increased temperatures, sedimentation and nutrient levels, these algae can overgrow neighboring corals, and are therefore associated with a degraded reef state (Straub et al. 2019; Sura et al. 2019).

Data on the diversity and distribution of species spatially and temporally, particularly from poorly studied regions, becomes therefore important to understand the consequences of such future changes on the overall ecosystem function, and therefore to effectively guide environmental management practices. Records of algal diversity from the Maldives are highly sporadic, and currently no comprehensive and up-to-date list of algal diversity from the country is available. In the 20th century, a series of oceanographic studies were conducted to explore different aspects of the biodiversity of the country. During these expeditions, benthic algal samples were collected primarily by snorkeling or by SCUBA to depths of 10 m. The samples were typically processed into dried herbarium specimens, or preserved in formalin. The earliest collections of algae in the Maldives were made during the Percy Sladen Trust Expedition of 1899–1900 to the atolls of Seenu (Addu, Figure 1) and Huvadhoo (Suvadiva), under the leadership of John Stanley Gardiner. While this resulted in several publications, the collections made during this expedition were sporadic and the published articles only described a few algal specimens. The most extensive sampling, in terms of distribution range and quantity of specimens collected, was carried out by Hackett in 1964. He collected algae from nine different atolls across the country (Dhaalu, Kaafu, Laamu, Alifu Alifu, Haa Alifu, Lhaviyani, Noonu, Raa, Seenu) as part of a PhD project. In an article published in 1977, Hackett reported the presence and distribution of 205 species. A more recent major survey of benthic algae in the Baa Atoll was conducted by Payri et al. (2012), but molecular analysis of the algae collected was only carried out for samples of Dictyotales (*Dictyota*, *Padina*) and *Halimeda*. While several collections of algae were made during these expeditions to the Maldives, information about the algal diversity of the country still remains sporadic and incomplete. Moreover, with the exception of the 1964 Cruise B R/V *Te Vega* Expedition, algal collections were only made from a few sites within single atolls.

The number of algal species present in the Maldives is also inconsistently reported. For example, Dhunya et al. (2017) reported 321 species, the Maldivian Ministry of Environment and Energy (MEE) mentioned 285 algae (21 species of Cyanophyta, 163 Rhodophyta, 83 Chlorophyta, and 18 Phaeophyceae; MEE 2015) and more recently Dryden et al. (2020) indicated the presence of 280 species. All these counts primarily refer to the list provided by the major algal survey conducted by Hackett (1977) and do not account for the more recent study by Payri et al. (2012), nor include additional data from important historical references. Not all algal groups were always considered in previous surveys. For example, while Payri et al. (2012) brought the total number of species to 321 (200 Rhodophyta, 97 Chlorophyta, and 24 Phaeophyceae), the authors did not include Cyanobacteria. This group of algae, however, was included in previous counts from the Maldives (Hackett 1977; Sigee 1966; Tsuda and Newhouse 1966).

The aim of this review is therefore to provide a comprehensive and up-to-date list of macroalgal species that have been described from the Maldives, in order to aid future molecular work, and to gather information about the species distribution across different atolls, based on information provided from historical records. Understanding the changes in algal community composition that may have occurred in space and time can provide important information to elucidate the effects of anthropogenic activities on the marine biodiversity of the country. Ultimately, this information can contribute to more effective conservation and management practices.

2 Materials and methods

2.1 Taxonomic data

The dataset for the species of benthic algae in the Maldives was downloaded from AlgaeBase, a global database of taxonomic and distributional information on algae (Guiry and Guiry 2014). Several key papers (Table 1) and the book “Benthic algae of the Indian Ocean” by Silva et al. (1996) were consulted to obtain the names for all species currently reported from the country. The current nomenclatural status of all species in the list was checked on AlgaeBase and updated as needed following the latest update available at https://www.algaebase.org/(accessed 14th October 2024).

Cyanobacterial species were maintained in the present list, on the basis that these microscopic organisms are able to form mats or biofilms that are visible to the naked eye and

Table 1: Previous expeditions conducted in the Maldives that resulted in the collection and reporting of benthic marine algae. The references indicate the articles published following each expedition, used to compile the present list.

References	Collected by	Atolls	Year	Expedition name
Barton (1903), Foslie (1903, 1907), Gardiner (1903), Weber van Bosse and Foslie (1904), Weber van Bosse (1914)	Gardiner, J.S.	Seenu, Suvadiva	1899–1900	*Percy Sladen Trust expedition*
Newton (1953)	Newton, L.M.	Kardiva Channel	1933–1934	*John Murray expedition*
Sigee (1966), Tsuda and Newhouse (1966), Hollenberg (1968a), Hollenberg (1968b)	Sigee, D.	Addu (Seenu)	1964	*D.R. Stoddart*
Hackett (1977), Wynne (1993)	Hackett, H.E. and Rhyne, C.	Dhaalu, Kaafu, Laamu, Northern Ari, Haa Alifu, Lhaviyani, Noonu, Raa, Seenu	1964	*Cruise B R/V Te Vega*
Hackett (1977)	Rhyne, C.	Addu (Seenu)	1967	*U.S. Navy Biologicae Expedition*
Titlyanova and Butorin (1978)	Titlyanova and Butorin	Dhaalu, Noonu	1976	*NA*
Payri et al. (2012)	Payri et al.	Baa	2012	*NA*
Stanca et al. (2013)	Stanca et al.	Faafu	2013	*NA*

can be collected in a similar way as macroalgal species. For example, herbarium specimens of cyanobacterial samples collected by Hackett in the 1964 expedition were available on the "Macroalgae Herbarium Portal". The list provided by AlgaeBase included several microalgal species identified by Stanca et al. (2013), the majority of which are phytoplankton. Since the present list only includes benthic algae, these species were removed from the final list, except for the genus *Spirulina* Turpin *ex* Gomont (cyanobacteria), which contains several mat-forming, benthic species.

Many entries in previous lists were only identified to genus. These genus-level identifications were not considered in the final list and counts, because they were considered to be not sufficiently identified (e.g., "*Halimeda* sp.", "*Amphiroa* sp". in Payri et al. 2012). However, some of these unresolved identifications were maintained in the present list in order to include genera that would otherwise not be represented (i.e., lack of species-level identifications for the genus *Acetabularia* J. V. Lamouroux). When multiple identifications at the genus level were listed as multiple species (e.g., *Rhodymenia* sp. 1, sp. 2, sp. 3, sp. 5 in Payri et al. 2012), only one entry representative of the genus was included in the list.

2.2 Distribution data

The literature was consulted to obtain insights into which atolls were visited during the different expeditions and where the algal specimens were collected. Information about the historical expeditions and in which atolls algal collections were made is reported in Table 1. Herbarium specimens were also consulted to obtain further insights into the species diversity and distribution. The data from these were retrieved from the Macroalgal Herbarium Portal (www.macroalgae.org), a public digital repository of scanned herbarium collections from the last 150 years (Macroalgal Herbarium Portal 2024).

Some atoll names have changed since they were first visited, or they were reported with different versions of the official atoll names. For example, the atoll previously known as Suvadiva is currently named Huvadhoo, which is further divided into Gaafu Alifu (the northern part of the atoll) and Gaafu Dhaalu (the southern part of the atoll), the atoll of Seenu was previously known as Addu, and the atoll of Alifu Alifu was previously known as Northern Ari.

3 Results

3.1 Algal diversity in the Maldives

The AlgaeBase search yielded 326 names of species reported from the Maldives. These database entries reference the "Catalogue of the Benthic Marine Algae from the Indian Ocean" (Silva et al. 1996) and the phytoplankton species identified by Stanca et al. (2013). The names reported in the comprehensive 'Catalogue' provided in turn reference articles resulted from collections made during the 20th century expeditions to the country. After cross-checking these references, 117 species that have been reported by Hackett (1977); Payri et al. (2012), and Tsuda and Newhouse (1966) were missing from the list provided by AlgaeBase when searching for algae from the Maldives.

The current updated list contains 353 species, of which 31 are Cyanobacteria, 26 Phaeophyceae, 109 Chlorophyta, and 187 Rhodophyta (Supplementary Table S1). Of these, 110 taxonomic names have changed since they were first reported. The updated taxonomy reveals a higher diversity of genera than previously reported, mostly due to genera being split since their original cataloguing. For example, following the older taxonomy of the family Peyssonneliaceae reported from the Maldives, two genera (*Peyssonnelia* Decaisne and *Cruoriella* P.L.Crouan *et* H.M.Crouan) from this family were reported. Within these genera however, the currently accepted taxonomic classification of what were historically reported as *Peyssonnelia rubra* f. *orientalis* Weber Bosse, *P. calcea* Heydrich, and *P. capensis* Montagne reveals that they belong to three different genera in this family (*Agissea orientalis*, *Ramicrusta calcea*, and *Sonderophycus capensis*, respectively; Pestana et al. 2021). Similarly, in the Rhodomelaceae, the species currently accepted as *Vertebrata foetidissima* (Cocks ex Bornet) Díaz-Tapia *et* Maggs, *Wilsonosiphonia howei* (Hollenberg) D. Bustamante, Won *et* T.O.Cho, *Melanothamnus upolensis* (Grunow) Díaz-Tapia *et* Maggs, *M. sphaerocarpus* (Børgesen) Díaz-Tapia *et* Maggs, *M. savatieri* (Hariot) Díaz-Tapia *et* Maggs and *Kapraunia pentamera* (Hollenberg) Savoie *et* G.W.Saunders were all previously placed in the genus *Polysiphonia* Greville, although the achievement of monophyletic groups among Rhodomelaceaean tribes remains difficult (Díaz-Tapia et al. 2017; Savoie and Saunders 2019). A recent study by Boo et al. (2020) also revealed the occurrence of *Wilsonosiphonia fujiae* in the atolls in the islands of Fulhadoo (Baa atoll) and Dhidhdhoo (Alifu Dhaalu). In some cases, the updated taxonomy for particular groups results in less species compared to the historical reports being included in the present list. For example, for the species currently accepted as *Neogoniolithon brassica-florida* (Harvey) Setchell *et* L.R.Mason, which was previously regarded as five separate species and variants in two different genera (i.e., *Goniolithon frutescents*, *Goniolithon frutescens f. congestum*, and *Goniolithon laccadivum*, Hackett 1977; *Neogoniolithon brassica-florida*, and *Neogoniolithon laccadivum* Payri et al. 2012) that are now all regarded as one species (Kato et al. 2013; Villas-Bôas et al. 2015).

The search on the "Macroalgal Herbarium Collection" website yielded 819 results of herbarium vouchers of specimens from the Maldives. The vast majority of these vouchers was collected during the 1964 Cruise B R/V *Te* Vega expedition and deposited in different herbaria by H.E. Hackett. Often, multiple vouchers of the same species were deposited from the same location. Some of the vouchers available on the website were deposited by Gardiner (1903; Kaafu atoll), Sigee (1966; Seenu atoll), and Wynne (1993; Kaafu atoll). The Macroalgae Herbarium Portal data also included notes that were used to obtain information about the diversity of species that form "turfs" and those associated with mangroves. In the list published by Hackett (1977), the author reports the presence of the genera *Gelidium*. and *Jania* (Rhodophyta), and the species *Caulerpa racemosa* var. *macrophysa* (Chlorophyta) in association with the prop roots of the mangrove *Rhizophora mucronata*. However, in the notes written by the author on the herbarium specimens available on the Macroalgae Herbarium Portal website, the genus *Herposiphonia* (Rhodophyta), and the cyanobacterial species *Anabaena oscillarioides*, and *Hydrocoryne soluta* were also reported to be found in association with mangroves.

3.2 Distribution data

Benthic algal species have been reported from 12 out of the 20 atolls in the country (Figure 1). These algae have been collected in four northern (Payri et al. 2012; Haa Alifu, Lhaviyani, Noonu, Raa, Hackett 1977) and four central (Dhaalu, Kaafu, Laamu, and Alifu Alifu, Hackett 1977) atolls. Out of the three atolls in the southern region, algal species have been collected only in Seenu and Huvadhoo (Hackett 1977; Sigee 1966). The atoll of Huvadhoo is further divided into Gaafu Alifu (north) and Gaafu Dhaalu (south). Since we do not know the exact locations of the collections, we considered both as having algal reports.

The atolls of Kaafu, Baa, and Seenu show the highest number of algal species reported, with 131, 148, and 144 species, respectively (Figure 2).

The Percy Sladen Trust expedition of 1899–1900 resulted in the record of nine species in the Corallinales (Rhodophyta) and six species of green and brown algae in the atolls of Seenu (Addu) and Huvadhoo (Suvadiva) (Barton 1903; Foslie 1903, 1907). From this expedition, other species of Chlorophyta and Rhodophyta were reported by Weber van Bosse (1904, 1914) and six more articles were published (Table 1). After the last article from this expedition was published by Weber van Bosse, no studies reported on the diversity of algae in the Maldives until Newton (1953), which provided identifications of species collected during the 1933–1934 crossing of the Kardiva Channel, a channel between the Northern and Central Maldivian atolls, during the J. Murray Expedition. This resulted in 10 more species collections (one Cyanobacteria, two Phaeophyceae, four Chlorophyta, three Rhodophyta). The D.R. Stoddart Cambridge expedition (1964) to Addu atoll resulted in two new lists (Sigee 1966; Tsuda and Newhouse 1966), which added seven Cyanobacteria, 20 Rhodophyta, 25 Chlorophyta, and 7 Phaeophyceae species to the list of known algae. Two more studies were published after the D.R. Stoddart expedition of

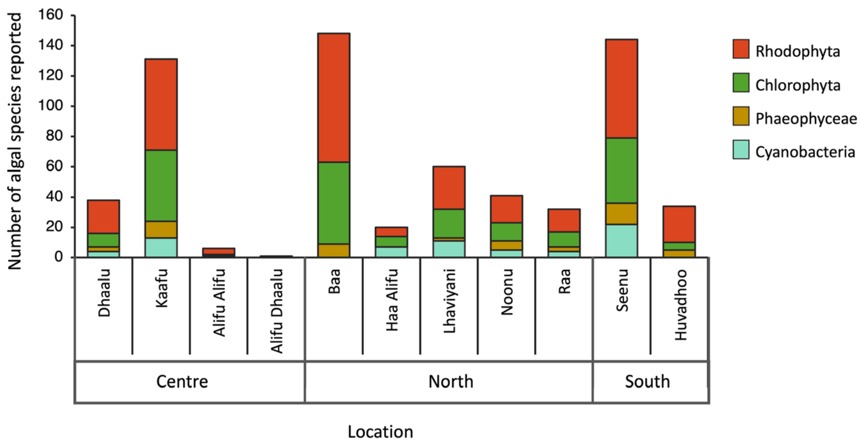

Figure 2: Number of benthic algal species, divided by major groups (Cyanobacteria, Phaeophyceae, Chlorophyta, Rhodophyta), reported from Central, Northern, and Southern Maldivian Atolls.

1964, although these only reported single accounts of the red algal genera *Herposiphonia* and *Polysiphonia* (Hollenberg 1968a, b). In 1964, Hackett extensively studied the benthic algal diversity of nine Maldivian atolls (Table 1), which he visited during the International Indian Ocean Expedition, Cruise B of the R/V *Te* Vega. In his 1977 article, he listed all the species collected and identified and also reported the species collected during the U.S. Navy Biological Expedition to the Chagos in 1967, collected by C. Rhyne at Addu atoll. In the last 20 years, only the article published by Payri et al. (2012) studied the diversity of benthic algae in the Maldives, while the article published by Stanca et al. (2013) focused on the diversity of phytoplankton species.

4 Discussion

The present review is the first report compiling the benthic algal diversity of the Maldives as presently known. Our extensive checklist also updates the taxonomic classification for these species and gathers information about their distribution across atolls. Our results show that 111 species names of benthic marine algae in the Maldives reported in the literature are outdated and that their taxonomic status had changed since they were first reported. The collections of benthic algae are also very uneven and occurred from only 12 out of the 20 atolls in the country. The bulk of publications regarding the diversity of benthic algae from the country dates back to the first half of the 20th century, while only one study on algal diversity was conducted in the last 20 years.

Since most collections were made before molecular data was available, almost all specimens were identified based on morphological traits without any molecular validation.

4.1 Lack of molecular evidence

Correctly identifying algal specimens based on morphological traits requires a significantly high degree of training. As historical observations were based on the morphological identification only, it must be assumed that previous collectors were sufficiently competent to judge critical differences between the specific entities represented. But still many identifications were in fact not resolved below the genus level, possibly because of a lack of identifying structures (e.g., reproductive parts) or lack of expertise in the investigators. Moreover, molecular techniques have only started revealing the cryptic diversity amongst algae (e.g., Payo et al. 2013) and also revealed incorrect taxonomy in many similar taxa (D'Archino et al. 2015, 2017). Based on the lack of systematic sampling and molecular evidence, it is plausible that the diversity of species in the Maldives is seriously underestimated, and that at least some of the previous identifications are incorrect. For example, while the occurrence of *Wilsonosiphonia howei* in the Maldives was reported in 1977 by Hackett, this species is morphologically very similar to *W. fujiae*, a species recently described by Bustamante et al. (2017) and whose occurrence in the Maldives was molecularly confirmed by Boo et al. (2020) using *rbc*L and 5P–COI. This raises questions about the true identity of the 1977 specimen, and highlights the need for molecular work to confirm algal identifications.

4.2 Ecological importance

4.2.1 Calcified algae

Species commonly reported in the Maldives, such as those in the genus *Halimeda*, are known to contribute to structural complexity in coral reefs worldwide, and their structures have been compared to rainforests, with a thick surface undergrowth, mid-layer subcanopy and shrubby canopy up to 30 cm above the seafloor (McNeil et al. 2021). According to the present list, there are 14 species of *Halimeda* reported from the Maldives. Payri et al. (2012) indicated that the lagoon reef flats and slopes account for many encrusting coralline red algae, mostly represented by the genera *Hydrolithon* and *Lithophyllum*. These ecologically important calcareous groups are almost certainly underrepresented by historical studies. Molecular tools are in fact essential to the correct taxonomical classification of these entities, particularly the encrusting forms, as DNA sequence data and phylogenetic analyses have led to major insights in the diversity and evolutionary history of the group (Twist et al. 2020). These families are increasingly found to have a high degree of cryptic diversity, with studies actively revising their classification at the species level and above (e.g., Coutinho et al. 2022; Cremen et al. 2016; Gabrielson et al. 2023, 2024; Giorgi et al. 2024; Gomes et al. 2024; Pestana et al. 2021; Nelson et al. 2015).

4.2.2 Turf algae

In the Maldives, turf algae are typically mentioned in government reports in the context of a system change toward algal-turf-dominated systems taking over the reef in response to cyclones and bleaching events, such as the one that notably impacted the Maldives in 1998 (Dhunya et al. 2017; MEE 2015). However, the term is often used in a broader context, as many different species are capable of forming “turfs”. In Hackett’s herbarium notes, for example, there are 34 different genera reported as “turf”, including species in the Rhodophyta, Chlorophyta, Phaeophyceae, and Cyanobacteria. Under healthy environmental conditions, these algae are essential components of reef systems. For example, they contribute significantly to the gross primary productivity, and the cyanobacterial species provide nitrogen to the systems through the fixation of atmospheric nitrogen (Bender et al. 2014). However, when compared to coralline algae and calcified macroalgae, turf algae can grow faster and can weaken and eventually overgrow neighboring corals, and hence they are increasingly seen to take over degraded coral reefs globally (O’Brien and Scheibling 2018). Understanding the species composition of these algal communities could therefore provide important information about the health status of the reefs in the Maldives.

4.2.3 Mangrove-associated algae

There are almost no reports of algae associated with mangroves in the Maldives (Cerri et al. 2024). However, mangrove-associated algae are globally known to enhance the productivity of these important ecosystems, contributing to nutrient cycling and providing an additional source of food to many species (Gao and Lin 2018; Omer et al. 2021). Mangroves around the world are known to host a macroalgal species complex named the “Bostrychietum” after the genus *Bostrychia* Montagne, which is commonly observed in these habitats (Post 1936), but the term also includes the red algal genera *Catenella* Greville and *Caloglossa* (Harvey) G. Martens. While these genera have not yet been reported from the Maldives, they have been observed in mangroves from other locations in the Indian Ocean (Kandaswamy et al. 2018; Lambert et al. 1987; Phillips et al. 1996; Steinke and Naidoo 1990). Members of the “Bostrychietum” are often exposed in the mangroves to strong environmental stressors as they experience diurnal tidal immersion-emersion cycles (e.g. West et al. 1992). *Bostrychia* and *Caloglossa* species synthesize and accumulate rather unusual polyols as organic osmolytes and these compatible solutes compensate salinity changes, as well as containing a widely variety of UV-sunscreen compounds (Karsten et al. 1996, 2000). These biochemical capabilities contribute to the pronounced stress tolerance of these red algae, and are increasingly gaining attention for potential commercial applications (Messina et al. 2019; Sun et al. 2020).

4.3 Lack of data

While at least some information on benthic macroalgae and cyanobacteria in the Maldives exist, other benthic algal groups such as microphytobenthic communities which are often dominated by pennate diatoms are completely unstudied. From an ecological standpoint microphytobenthic assemblages exert an important function in coastal waters, as they strongly contribute to the marine primary production and biogeochemical cycling of nutrients (Cahoon 1999), to sediment stabilization by excreting sticky extracellular polymeric substances (EPS) (De Brouwer et al. 2005) and as a food resource for benthic suspension- or deposit-feeders (Cahoon 1999). Therefore, knowledge on the occurrence and diversity of benthic diatoms in the Maldives is needed.

5 Conclusions

The present review provides an extensive and updated taxonomic list of algal species diversity and distribution across Maldivian atolls. Our findings highlight the lack of molecular studies confirming the identity of algal species historically reported from the country. Accurate information about the community composition of algae from the reef and mangrove habitats of the country would provide important insights into the primary productivity of these habitats, thus significantly contributing to our understanding of the overall system functioning. Moreover, understanding how species communities may have changed over time would elucidate the effects of anthropogenic pressures on the biodiversity of these systems. Finally, algae are increasingly recognized as an untapped marine source of bioactive molecules with diverse applications. However, the chemical profile of algae, and methods of analysis, can be highly variable across species. The present review provides important information to guide future studies exploring the commercial potential of algae from the Maldives.

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Research ethics: No samples were collected for the present review. All species names presented in the final list, and the databases they were obtained from, are referenced.
Informed consent: Not applicable.
Author contributions: Rossella Nicolai conceived the idea of the article, conceptualized the manuscript, performed the literature search, data analysis and wrote the first draft. Prof. Galli secured funding and resources necessary for conducting the review. Prof. Joe Zuccarello and Prof. Ulf Karsten contributed their expertise and critically revised the manuscript, ensuring the accuracy and depth of the review. All authors contributed to writing different sections and participated in the review and editing of the manuscript, ensuring adherence to journal guidelines.
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