First Report of *Halopithys incurva* (Rhodomelaceae, Rhodophyta) from the Marchica Lagoon of Nador (North-Est Morocco, Mediterranean)

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Abstract. The Nador-Marchica lagoon is located on the northeastern Moroccan coast between the Cap of the Three Fourches and the Cape of Water. It is a site of biological and ecological interest (SIBE) and is classified as a Ramsar site. It is part of the largest coastal wetland complex in the Moroccan Mediterranean with an estimated surface area of 115 km^2. The species *Halopithys incurva* (Hudson) Batters (Rhodomelaceae) was found and reported for the first time in the Marchica Lagoon Northeast Mediterranean-Morocco region (February 2021). It was collected from the centre of the lagoon and was grown with other seaweeds (*Gracilaria dura* and *Alsidium corallinum*) (Rhodophyta). The morphology, habitat, and water quality are presented and discussed in the present study. An analysis of the description, morphology and images of the macroscopic and microscopic characteristics of this seaweed is provided. This new seaweed indicates that the biodiversity is probably richer than generally thought in this lagoon.

1 Introduction

The Moroccan coast is home to numerous lagoons, the main lagoons on the Atlantic coast being the Moulay Bousselham Lagoon, Sidi Moussa Lagoon, Oualidia Lagoon, Khnifiss Lagoon and Dakhla Bay (Figure 1). On the Mediterranean coast, one of the most important lagoons is the Marchica Lagoon, which is the subject of this study. The latter, also called Nador Lagoon or Sebkha Bouareg. The latter is considered the largest Moroccan lagoon and the second largest lagoon in North Africa [1,2], with a surface area of 115 km^2 and a maximal depth of 8 meters. The Marchica Lagoon is characterized by its oval shape, and the major bordering locations are its southern bank (the city of Nador) and its two extremities to the northwest (Beni-Ensar) and southeast (Kariat-Arekman). It is separated from the sea by a 25 km long dune belt. It communicates with the sea via a pass recently built in 2010 that is 300 m long and 6 m deep.

The lagoon substrate is dominated by sand [3].

The aim of the new pass is to decrease the average turnover time of intralagoon water from approximately 60 to 16 days, with a tendency to increase during the summer [4], to improve the quality of the physicochemical parameters of intralagunal waters [5,6] and reduce eutrophication [7]. These changes contributed to changes in biodiversity, such as flora and fauna, in the lagoon [8, 9].

The Marchica Lagoon is considered to be one of the most productive areas in the Moroccan Mediterranean and plays an important biological and ecological role [10]. This lagoon is home to a wide variety of aquatic plant species, among which macroalgae stand out. Inventories began with Gonzalez and Corde [11], who assigned 62 Rhodophyta, 31 Chlorophta and 18 Phaeophyta to the lagoon 111 species list.

The genus Halopithys (Rhodophyta) was proposed by Kitzing Itys 1849. This species was mentioned by Crié (1876) as *Ritiphtaea pinastroides.* Cosson and Billard [12] described *Halopithys incurva*, which was subsequently found on a rocky coast south–southwest of Grande Ile. Later, the author named the taxon *Halopithys incurva* (Hudson) Batters in 1902. The genus *Halopithys* consists of only 1 species worldwide in Morocco.

The *Halopithys incurva* (Hudson) Batters species is a synonym of *Halopithys pinastroides* (Stackhouse) Kützing. *Halopithys incurva* plays an important role in several fields, such as chemistry. It is richer in chemical compounds, namely, arsenic, manganese and brominated compounds [13, 14], is rich in halogenated

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secondary metabolites [14, 15] and, in particular, is rich in polyphenols with high antioxidant power [15].

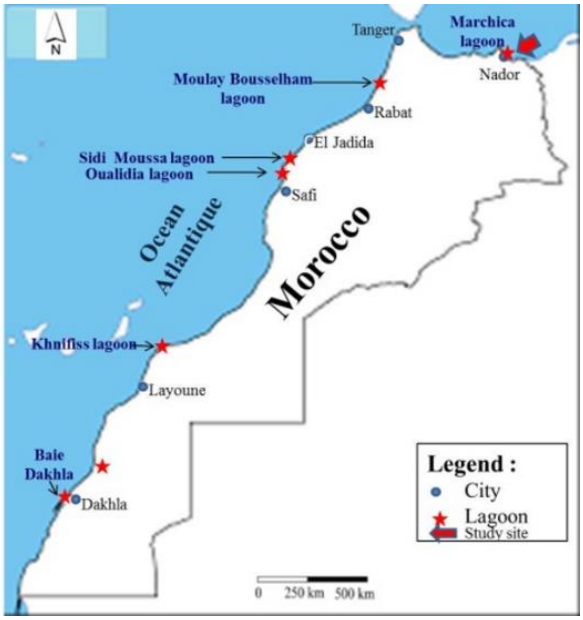

Fig. 1. Map of the local lagoons of Morocco and the study site (Marchica Lagoon).

Halopithys incurva acted as a good inhibitor of carbon steel corrosion in acid [16]. In the medicinal and pharmaceutical fields, through their antiamyloidogenic [17], antibacterial, antiviral, antimycobacterial, antiplasmodial, antifungal, antiprotozoal, and strong anti-inflammatory properties, they also have antitumour and antioxidant potential on human colorectal adenocarcinoma cells [18-22].
In addition, *H. incurva* has shown polysaccharide-mediated immunomodulatory effects [23]. In agriculture, it is a growth promoter and a source of phycocoloids [24]. The objective of this study was to report on the effects of a Halopithys species, *Halopithys incurva* (Hudson) Batters, on the Marchica Lagoon in the northeastern Mediterranean-Morocco region for the first time.

2 Materials and Methods

The sample was collected only in the wet season (February) of 2020 and was not collected during other seasons. The sample was collected from Marchica Lagoon, which is located only in the center of the lagoon (02°45’ – 02°55’ and 35°16’ – 35°06’). Sampling was carried out by diving to a depth of 6 m using a scuba gear. The sample was placed in polyethylene bags and stored at 4°C until arrival at the laboratory.

The different physicochemical analyses of the waters were carried out at the same sampling station for the algae, some of which were carried out in situ and others in the laboratory. The sampling of 500 mL of seawater was carried out using polyethylene bottles for the determination of nutrients

2.1 Analysis methods

2.1.1 Physicochemical parameters of the water

Several abiotic parameters, such as the routine hydrological parameters that were measured in situ, were measured in the studied ecosystems by a portable multimeter (HQ4300 Model HACH) with temperature (Tm °C), pH, salinity, and dissolved oxygen (DO) sensors, and turbidity was measured by turbidimeters. In the laboratory, the nitrate (NO_{3-}) content was determined via the cadmium reduction method, the ammonium (NH_4^+) content was determined via the indophenol blue method, followed by spectrophotometer measurements via a UV–VIS spectrophotometer (Pharo 300, Germany), and orthophosphate (PO_4^{3-}) was measured via molecular absorption spectrometry [25].

2.1.2. Identification Algae

In the laboratory, the sample was stored in 5% formulated seawater for the floristic study. The specimen studied was deposited in the Phycological Herbarium of Biology, Geosciences, Physics and Environment Laboratory, Pluridisciplinary Faculty of Nador, Morocco.

We used a binocular magnifying glass to observe the algal thallus, and anatomical sections were generated by hand with a razor blade and a binocular microscope (Olympus Model CX22). For nomenclature purposes, the following taxonomic databases were used: Cabioc'h et al. [26] and AlgaeBase (Guiry and Guiry [27]).

3 Results

3.1. Physicochemical parameters of the water

The physicochemical parameters of the water in the lagoon are shown in Table 1. The water pH was 8, indicating a well-oxygenated environment (9.7 mg/l).

Table 1. Physicochemical parameters of the water in the lagoon.

	T	pH	Sal	DO	Turb	NO_3^-	NH_4^+	PO_4^{3-}
H_2O	16.6	8	38.3	9.7	5.2	0.091	<0.01	<0.001

T: temperature (°C); Sal: salinity (‰); DO: dissolved oxygen (mg/l); Turb: turbidity (NTU); NO_3^-, NH^{4+} and PO_4^{3-} (mg/l).

The temperature and salinity of the surface water are 16.6°C and 38.3 ‰, respectively. Additionally, the results showed low concentrations of nitrogen and phosphate.

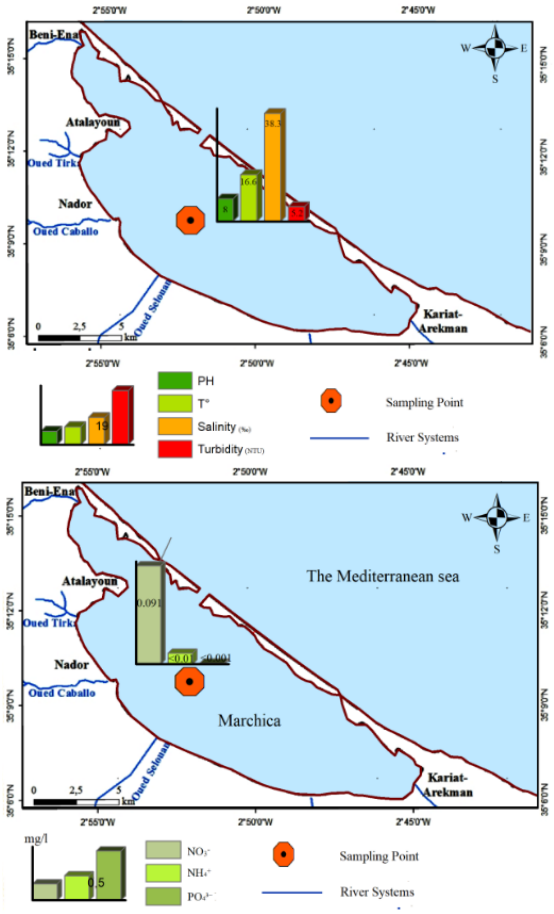

Fig. 2. Physicochemical parameters of the surface water in the lagoon.

3.2 Description of the algae

Macroscopic thalli appear on February. It is thickly covered by epiphytic algae. The morphological characteristics of the thallus are that it is 6 cm long, dark red, and solid, forming cylindrical axes 1 mm in diameter. The main branches alternate and curve into a crook at the tip (Fig. 3). With short secondary branches of the same size, the plants are sun-adapted and perennial to annual. Anatomically, the structure is uniaxial, with a central cell (Fig. 3-d and e) surrounded by five pericentrals outside of which is an assimilatory cortex. Cross-section of the upright axes showing the central cell surrounded by four pericentral cells.

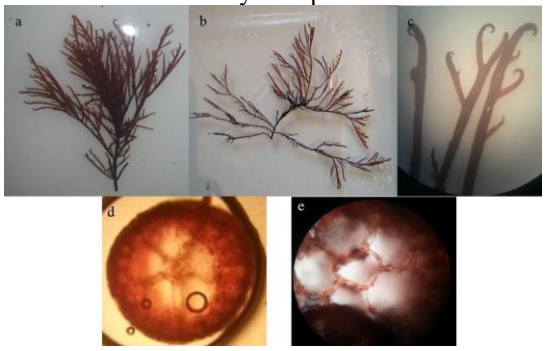

Fig. 3. *Halopithys incurva* (Hudson) Batters (a): General aspect of an epiphytized thallus; (b): Morphology of the species; (c): Extremity of hooked branches; (d) and (e): Cross section (d): obj 40 and (e) obj 100) (scale bar = 1 cm).

3.3 Ecology

Halopithus incuvus was found only in the center of the Marchica Lagoon in winter in a quiet mode at a depth of 6 m. *Halopithus incuvus* grows with other seaweeds, such as *Gracilaria dura* and *Alsidium corallinum*.

4 Discussion

This study represents the first report of the red alga *Halopithys incurva*. This species was collected in the center of the lagoon at a depth of 6 m, and the living environment of the species was characterized by good water physicochemical quality (T, pH, OD, salinity and nutrients). These parameters are related to the development of macroalgae [28], indicating that the living environment of *Halopithys incurva* is far from all sources of pollution and is a biological indicator of the quality of the environment. In other words, during the study period (winter), intense photosynthesis produced marked increases in dissolved oxygen (DO), pH, low water temperature, and good respiration. During the summer, there was an increase in water temperature and relatively low DO and pH values. This result was confirmed by Lenzi et al. [29]. The levels of nitrogen components were lower. The ammonium concentration was lower than that (<0.01 mg/l). According to Lenzi et al. [29], the highest content of ammonium in the water was associated with a high accumulation of organic matter in the sediments and consequent ammonification, causing the decomposition of benthic primary producers under anoxic sediment conditions [30], which can be considered among the factors influencing *Halopithys incurva's* abundance and distribution in the Marchica Lagoon. As reported by Avcin et al. [31] and Giaccone and Rizzi-Longo [32], *Halopithys incurva* reaches a maximum of 10 m [18]. In our present work, we found that the species is installed in an environment with low hydrodynamics, while Gorostiaga and Diez [33] and Gerbal and Verlaque [34] found that *H. incurva* is associated with low organic pollution concentrations, moderate nitrogen levels and high hydrodynamics.

According to Delepine et al. [24], *Halopithys* species are found on hard infralittoral substrates. Hiscock [35] and Cormaci and Furnari [36] are recorded in mediolittoral troughs. The species is considered to be a sediment fixer [37] or at least able to withstand biotopes with high sedimentation [38]. It can be linked to groups of nitrophilous algae [37] that are thermophilic and belong to the photophilic infralittoral thermophilic hard substrate ecological group [39]. Halopithys is an often epiphytic species [40]. The characters described are consistent with previous descriptions. *Halopithys incurva* is close to some species; if spiral ends are absent, *Halopithys* can be confused with other bottom-drifting algae, such as *Alsidium corallinum*. A cross-section will help to differentiate them. *Halopitys incurvus* is a cold-affinity species with a wide geographical distribution. On the eastern Atlantic coast, it is reported from the southern coast of England and the western coast of Ireland [35] and southwestern Spain near Cadiz [41]. It occurs all around the Mediterranean [24]: in Turkey [42], Italy [43], the Adriatic [43] in the

Atlantic, the East Coast of Gran Canaria, Spain [44], and Sicily [45]. On the French coasts, the species has been found in Corsica [46] and in Pyrénées orientales [47]. *Halopitys incurvus* also appear to be present in some international lagoons. However, it is present in small quantities on the hard substrates of some lagoons in the Venice of the Adriatic Sea [48], in the Gulf of Naples [48] and in the Thau Lagoon (France) [49]. The Mediterranean coast of Africa between the North African coasts includes Morocco [51], Algeria [50, 52], Egypt [53], and Tunis [54].

On the Moroccan Mediterranean coast, *Halopithys incurva* has been recorded in Saaidia, Mellila, Tetouan, Ksar Srgair (Tanger) [51], and localities in the Atlantic Ocean, such as Tangier, Rabat, Mohammedia, Casablanca, Essaouira, Agadir [51] and Sidi Bouzid to El Jadida [55]. According to Boudouresque [56], *H. incurvus* often forms very dense populations that exclude most large algae. In Marchica Lagoon, small quantities of *H. incurva* were found with dominant species of *Gracilaria dura*, which explains why this seaweed recently appeared in the lagoon. It is also among the biological indicators of global warming.

5 Conclusions

This is the first reference for the occurrence of *Halopithys incurva* in Marchica Lagoon. This indicates that the biodiversity is probably richer than generally thought, as the new dynamics and improved intralagoon water quality after the opening of the new pass in 2011 are likely indicative of the richness of the species. Further phycological studies in this lagoon could further increase the known algal biodiversity of the area and characterize the genetic diversity, population dynamics, and reproductive biology of *Halopithys incurva* as well as its interactions with other creatures in lagoon environments.

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