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A REVIEW OF ULVA INTESTINALIS, THE ONLY MACROSCOPIC ALGA OF URMIA LAKE

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There are little data on the presence of *Ulva intestinalis,* as the only macroscopic alga of Urmia Lake. This study tries to illuminate some historical, taxonomical, and ecological aspects of this macro alga of Urmia Lake which has not been observed in the lake since the late 1990s. *Ulva intestinalis* is a macroscopic alga that was previously recorded from Urmia Lake but disappeared from the lake flora in the late 1990s. This study is based on multiple visits to Urmia Lake since 1998 and a literature review. During many visits to Urmia Lake, we did not observe any samples of *Ulva intestinalis*. The reason remains unclear until now; natural or anthropogenic. However, it is a green alga belonging to the genus *Ulva* in Ulvaceae, with high carotene contents. Considering the human impacts on ecosystems and the probable extinction of some species, this study reviews the history of the occurrence of *Ulva intestinalis* in Urmia Lake and the possibility of its extinction. We believe that the documentation of the algal flora in an herbarium is very important in the interpretation of the presence, population decrease, or extinction of species. Therefore, we suggest the foundation of algal herbaria in institutions close to aquatic habitats, to keep records and monitor the algal and other aquatic flora.

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مروری بر گونه ***Ulva intestinalis***، تنها جلبک ماکروسکوپی دریاچه ارومیه

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سمیه زارع زاده: فارغ التحصیل دکتری سیستماتیک گیاهی دانشکده علوم و بیوتکنولوژی دانشگاه شهید بهشتی، اوین، تهران، ایران

اطلاعات کمی در مورد جلبک Ulva intestinalis به عنوان تنها جلبک ماکروسکوپی دریاچه ارومیه، در دسترس می‌باشد. در این پژوهش سعی شده است تاریخچه، تاکسونومی و اکولوژی این ماکرو–جلبک دریاچه ارومیه که از اواخر دهه ۱۹۹۰در این دریاچه مشاهده نشده است، نشان داده شود. Ulva intestinalis یک جلبک ماکروسکوپی است که قبلا از دریاچه ارومیه گزارش شده بود ولی در اواخر دهه ۱۹۹۰ از فلور این دریاچه ناپدید شد. این مطالعه بر اساس بازدیدهای متعدد دریاچه ارومیه از سال ۱۹۹۸ و مرور منابع، انجام شده است. در بازدیدهای متعددی که از دریاچه ارومیه صورت گرفته است، هیچ نمونه‌ای از U. intestinalis مشاهده نکردیم. دلیل این موضوع، طبیعی یا انسانی، تاکنون نامشخص است. با این حال، این گونه متعلق به شاخه جلبک‌های سبز خانواده Ulvaceae و جنس Ulva با محتوای کاروتن بالا می‌باشد. با توجه به تأثیرات انسانی بر اکوسیستم‌ها و احتمال انقراض برخی گونه‌ها، این مطالعه به بررسی تاریخچه حضور *Ulva intestinalis* در دریاچه ارومیه و احتمال انقراض آن

می‌پردازد. ما معتقدیم که مستندسازی فلور جلبکی در هرباریوم اهمیت زیادی در تفسیر حضور، کاهش جمعیت و یا انقراض گونه‌ها دارد. بنابراین، ما تاسیس هرباریوم‌های جلبکی در موسسات نزدیک به زیستگاه‌های آبی را به‌منظور حفظ نمونه‌های ثبت شده و نظارت بر فلور گونه‌های جلبکی و سایر گونه‌های آبزی پیشنهاد می‌کنیم.

INTRODUCTION

During the last two decades, the world has witnessed the drastic size reduction of Urmia Lake, the second-largest hypersaline lake in the world. In spite of this rapid shrinking, there is no updated information about its organisms, either extant or extinct; particularly one of the important green algae, *Ulva intestinalis*, as a sole important macroalga with high content of provitamin A, that had already been reported by Plattner (1960).

In a study by Riahi & al. (1994), the macroscopic algal genus *Monostroma* sp. was reported from Urmia Lake. This alga is very similar to *U. intestinalis* and is expected as a synonymy of it. *Ulva intestinalis* was observed in the lake in 1995-96 samplings for brine shrimp, *Artemia* (Van Stappen & al. 2001). Since then, it has not been recorded in the lake, particularly from the beginning of water level reduction (1998) afterward (Fig. 1). It seems that water reduction has increased the lake's salinity which acted as a main driver of this macroalga elimination. We had a routine visit to Urmia Lake and did not observe this alga since 1998. However, it was the only macroscopic alga in Urmia Lake that completely vanished from the lake in the late 1990s. Although there are few references on its pigments, and applications in food industries and medicine (Plattner 1960, Savage 1964, Saberi 1978), there are no studies on the history, morphology, taxonomy, and ecology of this macro-alga in the lake, which is under threat of complete drying up. Therefore, this paper attempts to shed light on some historical, taxonomical, and ecological issues of this alga in Urmia Lake mainly based on the literature.

Günther (1899) described this species as a vegetable portion of the planktonic community in Urmia Lake consisting of small green masses, either globular or membranous, flat and irregularly expanded form. The species was described as a soft or gelatinous alga that varied from 2.5 to 20 mm in diameter. This was probably *U. intestinalis* that he had observed in August 1898 during his exploring journey to the Urmia region. At first, he regarded them correctly as simple colonies of alga, but later, Murray mistakenly assured him that it was a symbiosis between globular bacteria and a number of small diatoms (Günther 1899); therefore, he failed to determine and record *U. intestinalis* for the first time from Urmia Lake. In fact, there is only a report from his empirical observations on this macroalga, in which he had observed and compared it with lichen (Günther 1899).

About sixty years later, Plattner (1960), a lecturer at Tabriz University, reported this green alga as the sole seaweed under the name of *Enteromorpha intestinalis*, as an excellent source of provitamin A in "Rezaeieh Lake". He described this macroalga of Urmia Lake as dark green strips several meters in length. These long strips of green seaweeds actually were the Günther's algal pieces that were torn up by the tidal waves of the lake. Plattner (1960) gathered samples of the alga and determined it as *U. intestinalis* and studied its carotene contents in the Tabriz University laboratory. He analyzed 100g. fresh gut weed (*U. intestinalis*) for carotenoids from Urmia Lake and found that 100g. of it had an average of 2.7 mg carotene which placed this alga among vegetables with high carotene contents.

Savage (1964) referred to the high value of this alga together with brine shrimp *Artemia* as the sole food source for common Shelduck (*Tadorna tadorna*) and Flamingos (*Phoenicopterus ruber roseus*) and other waterfowl that visited and nested in Urmia Lake.

The genus *Ulva* was one of the first seaweeds named by Linnaeus (1753) who included it in the seaweeds with wide thallus. It basically included a variety of unrelated algae. In the nineteenth century, its members were split into a few genera; and some tubular species of *Ulva* were categorized in *Enteromorpha* (Link 1820). Green seaweeds with dyschromatic thallus were maintained in *Ulva,* and tubular green seaweeds were moved to *Enteromorpha* (Link 1820). Although the name *Enteromorpha intestinalis* was made by both Link (1820) and Greville (1830), in fact, it was Nees (1820) who did so in the index (RMS= World Register of Marine Species: https://www.marinespecies.org), and published the collective work in a paper (Silva & al. 1987).

Nowadays, there is strong evidence that *Ulva* and *Enteromorpha* are not evolutionary distinct entities, and should not be recognized as separate genera (Hayden & al. 2003). Based on the phylogenetic analysis of DNA, it has been established that the separation of the two genera was artificial, and therefore the species of the genus *Enteromorpha* should be included in the genus *Ulva*. As *Ulva* is the oldest name, all species names under *Enteromorpha* have been reduced to synonymy with *Ulva* (Guiry & Guiry 2023).

There are about 135 *Ulva* species in the world (Hayden & al. 2003) with many more subspecies, varieties, and forms. According to Algal Base (Guiry & Guiry 2023), *U. intestinalis* includes several infraspecific taxa.

Originally Linnaeus (1753) described *U. intestinalis* for the first time, as a cosmopolitan species. This macroalga is considered a euryhaline species (Reed & Russell 1979, Edwards & al. 1987, Kamer & Fong 2000); therefore, its occurrence in the hypersaline Urmia Lake was not so surprising.

MATERIALS AND METHODS

This study is based on multiple visits of authors to Urmia Lake since 1998 and a literature review. During many visits to Urmia Lake, we did not observe any samples of *U. intestinalis*. On the other hand, after reviewing the literature, it was not clear when this alga disappeared from the lake. Our search result included 250 articles from the Scopus database with the keywords "macroalga", "alga", "Urmia Lake", "*Enteromorpha intestinalis*" and "*Ulva intestinalis*" up through February 2023. The authors also added other articles that addressed the research question.

RESULTS AND DISCUSSION

Ulva intestinalis Linnaeus, species plantarum 1753: 1163 (Fig. 2.)

Thallus is green to dark green or yellowish green in sheltered pools or lagoons. Plants up to 50 cm tall, tubular or with compressed apical part, narrowly to broadly cuneate in outline, surface often wrinkled. Cells in no definite order in surface view, rounded, 6-12 µm in diameter; chloroplast situated against the distal radial cell wall, with one pyrenoid. The thallus membrane (one cell layer) varies in thickness from 17 µm near the apex to 30 µm in the upper basal region. Rhizoidal cells are larger and darker than normal vegetative cells, the two types of cells mixed in the upper basal region (Anderson & al. 2016).

Type locality: Woolwich, London, England

Partly inflated, unbranched thalli together with cells with hood-shaped chloroplasts of *U. intestinalis* are shown in Fig. 3 a and b, respectively.

The green macroalgal genus *Ulva*, is especially notorious for green tide formation. This genus' members with a simple multicellular thallus structure show a wide range of complex shapes due to phenotypic plasticity and variations in morphogenesis mechanisms.

U. intestinalis has two life phases: the sexual phase, gametophyte, which produces gamete, and the asexual phase (sporophyte), which produces zoospore. Gametes are two-flagellated and zoospores are four-flagellated. In comparison to gametophytes, sporophytes tolerate a wider range of temperatures and salinity. Gametes may remain motile for 5-8 days (Kipp & al. 2022).

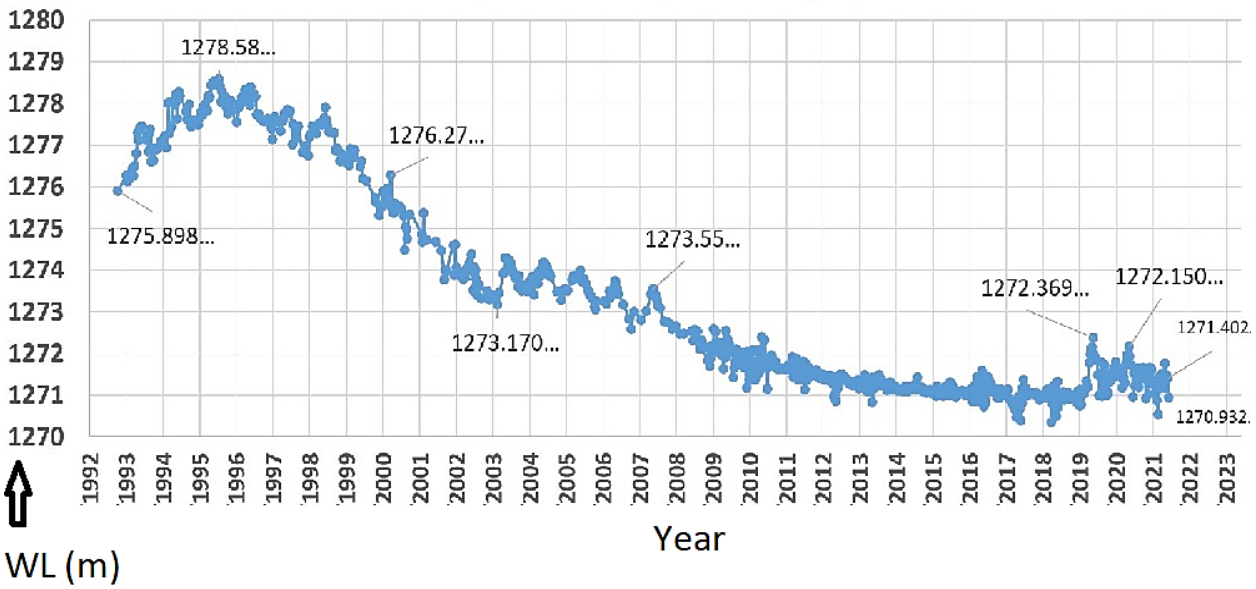

Fig. 1. Urmia Lake water level fluctuations during 1992-2023 (Adapted: Iranian Mapping Organization).

Fig. 2. *Ulva intestinalis* Kini Bay near East London (BOL 147292) (Adapted from Anderson & al. 2016).

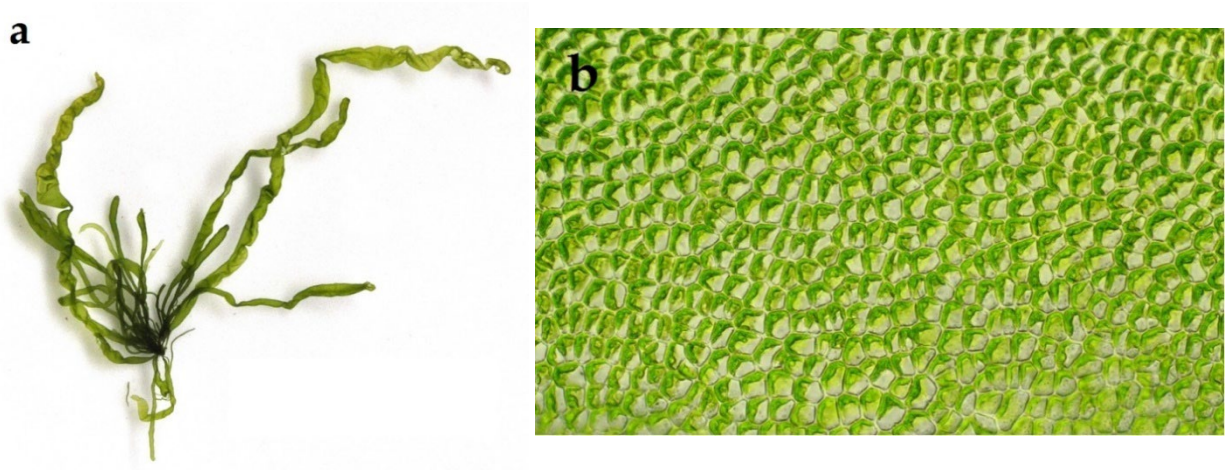

Fig 3. *Ulva intestinalis*. a. with tubular thalli, partly inflated, unbranched, except occasionally near the base. b. Cells in random order with hood-shaped chloroplasts and one pyrenoid per cell. Diameters of cells: 12.4-15.7 µm (up to 25 µm). (Adapted from https://www.outerhebridesalgae.uk/)

Distribution and habitat: *Ulva intestinalis* is a relatively cosmopolitan species known to form blooms in a diverse range of habitats around the world (Cummins & al. 2004). It is found in various habitats and takes multiple forms. The species can grow in lakes, ponds, canals, swamps, and ditches. The species takes forms of epiphytic, epilithic, floating plates or strips or attached to the substratum (Björk & al. 2004). *Ulva* members primarily occur in coastal zones. However, some species are reported from inland waters, either saline or freshwater (Strat 2015). *Ulva intestinalis* has a great capability to produce bloom in eutrophic conditions. Ecotypes of this species can be adapted to different salinities. The growth rate of *U. intestinalis* at various salinity levels has been studied under laboratory conditions (Martins & al. 1999). It has been shown that the macroalga has the lowest performance in salinities below 3 and above 25 ppt, and its optimum growth was in salinities between 15 and 20 ppt. At the salinity above 28 ppt, the growth rate is decreased, but the decrease is not as accentuated as for low salinity. In Urmia Lake, Plattner (1960) revealed that salinity may influence the *E. intestinalis* density i.e. in below or near 200 ppt the number of the alga fragments was higher than in the high salinity (280 ppt; during the summer of 1960). Salinity may be one of the parameters that impacted the disappearance of this alga from Urmia Lake in the late 1990s. It is still unclear if natural or anthropogenic influences caused this alga to vanish from Urmia Lake. However, due to the significant impact of human factors on the drying and salinity enhancement of Urmia Lake, through the enhanced unearthing of the wells and building dams (Rahimi & Breuste 2021), it can be concluded that anthropogenic factors are the main reason for the disappearing *U. intestinalis*.

Regarding the anthropogenic and climate changes that rapidly impact the natural ecosystems, particularly crucial ecosystems such as Urmia Lake, this study shows the significance of an algal herbarium on the national or regional scale to record and preserve specimens of algae that may be vanished someday from ecosystems.

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