
AQUATIC FLORA
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Lychaete herpestica (Cladophoraceae): a New Alien Species in the Black Sea

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Received March 10, 2025; revised June 16, 2025; accepted June 24, 2025

Abstract—This is the first record of the alien species *Lychaete herpestica* (Mont.) M.J. Wynne from the Black Sea. This macroalga is of Indo-Pacific origin and was previously included in the database of Exotic Macrophytes in the Mediterranean Sea developed by a CIESM. The immigrant species was found in the water area of the Cape Martyan Nature Park located at the Southern coast of Crimea (SCC) in the pseudolittoral zone. This corresponds to its confinedness to the littoral zone within its modern range limits. The studied specimens correspond to the taxonomic diagnosis, their key morphological and morphometric characters are specified for the new region and illustrated. The species entry into the Azov-Black Sea Basin probably occurred as a result of accidental introduction with a spat of mollusks directly from the primary range in 2023–2024. Within the boundaries of the new region, *L. herpestica* can widely disperse and successfully naturalize, while its development will likely have a pronounced seasonality peaking in summer. However, given its narrow biotopic confinedness and increased vulnerability to hydrodynamic factors, mass development of the species with subsequent structural transformation of native communities is unlikely. At the same time, the import of hydrobionts from donor regions and self-dispersal of invasive species from the Mediterranean Sea leave no doubt that the detection of new alien macrophytes in the Black Sea and the Sea of Azov will become more frequent. Against the background of global climate change, naturalization of some of them may seriously affect the structure of biota and the state of the natural environment of this semi-enclosed basin.

Keywords: Black Sea, Southern coast of Crimea, macrophytobenthos, *Lychaete herpestica*, alien species, invasion, distribution

DOI: 10.1134/S199508292560019X

INTRODUCTION

In modern times, the Black Sea is an extensive inland meromictic brackish-water body, but with deep-sea basin and the seabed formed by the oceanic-type crust (Ivanov and Belokopytov, 2011; Esin et al., 2021). It is a part of the Mediterranean basin of the Atlantic Ocean, to which it is connected via the straits Bosphorus and Dardanelles. The Black Sea macroflora as an impoverished variant of the Mediterranean one presently includes ~450 species (Minicheva et al., 2020). In the recent decades, it has been actively enriched due to immigration of species from other regions. Thus, beginning the mid-1970s, >30 species of the Mediterranean macrophytes entered and naturalized in the Black Sea (Shiganova et al., 2012). Particular species that have been thought to-date to be the native flora elements of the Black Sea, should be likewise considered to belong to its alien fraction (Sadogurskiy et al., 2025). As a result of globalization in the past 100–150 years, the vast majority of alien macrophytes, entering the Mediterranean basin, originated from the Pacific and Indian, rather than the

Atlantic Ocean (Verlaque, 2001; Verlaque et al., 2015; Cantasano and Di Martino, 2024). They further find their way to the Black Sea, while posing a threat to its biota. Thus, the new Indo-Pacific immigrant *Lychaete herpestica* (Mont.) M.J. Wynne was recorded by the present authors at SCC where invasion by the Pacific transformer species *Bonnemaisonia hamifera* Har. has been already developing (Sadogurskiy et al., 2023a, 2023b, 2024).

The goal of the present work is to establish a fact of entry of the alien species to new recipient region and make an attempt to characterize presumptive time, pathway, vector, and scale of the immigration, as well as likelihood of the invasion.

MATERIALS AND METHODS

Research was conducted in coastal marine water area located in SCC SPNA “Mys (Cape) Martyan” (beginning 1973, the State Natural Reserve; in 2015, Regional Nature Park) where composition and the state of vegetation cover of the benthic zone are con-

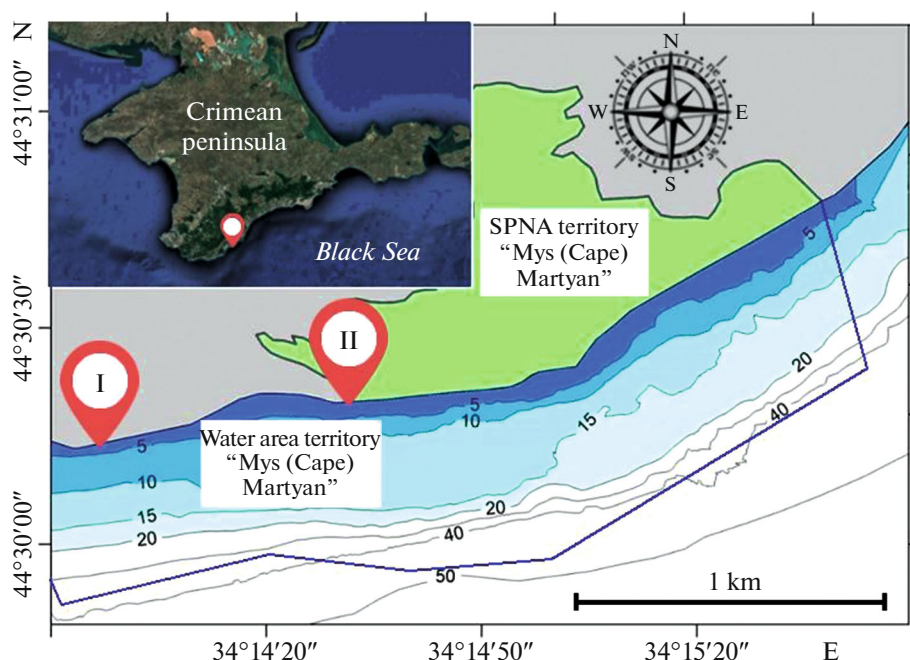


Fig. 1. Schematic map of the surveyed area. Sampling points: (I) 44°30'14.7'' N, 34°14'00.2'' E; (II) 44°30'18.9'' N, 34°14'30.6'' E.

tinuously monitored. Macrophytes were sampled on August 8, 2024, at the air temperature 33.1°C and sea-surface temperature 26.7–26.8°C¹ in the pseudolittoral zone² on hydraulic structures (wave-dissipating concrete blocks) at two points located in the western (44°30'14.7'' N, 34°14'00.2'' E) and central (44°30'18.9'' N, 34°14'30.6'' E) parts of the reserve water area, accomodating recreational beaches and berthing facilities (Fig. 1). Macrophytes were randomly sampled with a 0.01 m² frame with ten replicates; biomass values are presented as fresh (wet) weight. Nomenclature and taxonomy are adopted from “AlgaeBase” (Guiry and Guiry, 2025); names of the taxa authors are presented in standardized abbreviation, according to recommendations of the International Plant Names Index (IPNI, 2025).

RESULTS AND DISCUSSION

Lychaete herpestica (Mont.) M.J. Wynne [= *Cladophora herpestica* (Mont.) Kütz.; = *Cladophoropsis her-*

pestica (Mont.) M. Howe] (Cladophorales Haeckel, Cladophoraceae Wille) is a species widely distributed in the tropical and temperate waters of the Indian and Pacific Oceans, as well as most recently recorded from the Caribbean Islands in the Atlantic Ocean (Guiry and Guiry, 2025). It was first detected in the Mediterranean Sea basin in the 1940s (as *Cladophoropsis zollingeri* (Kütz.) Børgesen, nom. illeg.): in Palestine at the contemporary Israel coasts (Rayss, 1955; Einav and Israel, 2008) and in Egypt (Aleem, 1948, 1980, 1984; Shabaka, 2018); it was found at the coast of Lebanon in the 1970s (Bitar et al., 2017; Einav, 2023). Similar to the vast majority of other alien Indo-Pacific macroalgae, the species was apparently introduced into the basin waters via the Suez Canal with 1869 (the formal opening of the canal) conditionally designated to be a time of its entry (Aleem, 1984; Einav and Israel, 2008; Verlaque et al., 2015). To this date, all known Mediterranean localities of *L. herpestica* concentrate in Eastern Mediterranean, adjoining the Suez Canal (also known as Levantine Sea) where to-date this species has widely spread and naturalized and is included in the data base Exotic Macrophytes in the Mediterranean Sea developed by a task force of the Mediterranean Science Commission (CIESM) (Zenetos et al. 2010; Verlaque et al., 2015; Bitar et al., 2017). Within boundaries of the specified subregion, it occurs in the littoral zone slightly above or below the water level in the conditions of relative shadowing and moderate hydrodynamics where it can form a separate belt; in the conditions of pronounced climate seasonality its abundant development is associated with warm period (Aleem, 1948, 1980; Womersley, 1984; Verlaque et al.,

¹ Global climatic dynamics governed considerable changes in hydrometeorological parameters of the Black Sea, including a rise of annual average sea-surface temperature (at Yalta coast by 1.6°C over the past 40 years); but even against this background, its values exceeded the long-term annual average in August 2024 (Novikova and Polonskii, 2018; Ginzburg et al., 2021; Water ..., 2025).

² The Black Sea has small amplitude of astronomical tides, which is concealed by more pronounced wind-induced surges and baric seiches, governing an occurrence of water-level fluctuation zone, which does not ecologically differ from the “true” tidal littoral zone. The term *pseudolittoral zone* was introduced to denote it and gained a widespread acceptance (Arnoldi, 1948).

2015). The species has not been recorded from the Black Sea until the present time.

In the SPNA “Mys (Cape) Martyan” water area, *L. herpestica* thalli distinguished by the shape and color among other Chlorophyta were exclusively detected in the pseudolittoral zone at the level or slightly above the mean water level and largely on lateral walls of wave-dissipating concrete blocks (Fig. 2a); sporadic small specimens were recorded on the front surfaces of the blocks and the natural substrates (blocks and boulders). Species biomass is 21.2 g/m² (coefficient of variation $v > 100\%$), which accounts for 2.19% of the total vegetation biomass of 967.34 g/m². Uniseriate branched filaments form dark-green stiff cushion-like commonly semi-spherical thalli 2–6 cm in diameter, resembling mosses in the appearance (Figs. 2b and 2c). When increasing in size (length), particular specimens can coalesce, while forming larger irregularly-shaped sprawls. Cells of the basal and lateral branches are cylindrical, without bulges. Basal branches located in the oldest medial part of thallus are tightly entangled; branching is pseudo-dichotomous or polychotomous, sparse or moderate without formation of whorls; Leliaert et al. (2009) characterize it as “reduced branching”. Lateral branches located more loosely ramify pseudo-dichotomously proximal to distal ends primarily unilaterally. Basal septum does not commonly form with formation of lateral branches (Figs. 3a and 3b). Thickness of the cell walls is 10–35 µm; chromatophores are reticulate (Fig. 3e), small disk-shaped chloroplasts disintegrate with age (as well as material preservation). Cell width of basal branches is 180–270 µm; the length is greater than the width 6–12-fold. Lateral branches are of two types. Branches of the first type are composed of cells, which length exceeds width of 110–180 µm 15–18-fold; apical cells are with obtuse rounded tips (Figs. 3a and 3b). The second type of the branches is composed of cells, which length varies and exceeds the width of 40–90 µm from 7–10- to 80–90-fold (Fig. 3c). Commonly, growth of the apical cells of these branches considerably elongates them and, correspondingly, branches formed by these cells; in that, length measured by the present authors of one of the branches composed of one cell reached 2880 µm. Leliaert et al. (2009) refer to them as stolonoid “basal” cells. The point is that regardless of length of these basal cells, their distal ends commonly terminate with specific coralloid, digitate (finger-like) or lobed extensions (Figs. 3c, 3e, and 3f), which are able to attach to various substrates. A number of authors (Leliaert et al., 2009) refer to these extensions as rhizoids; others (in similar cases) use a term *rhizoid* for the entire branch (Hoek, 1963: 48; Zinova, 1967: 56). In this context, apical cells with these extensions are not identical to the “true” (primary) basal cells located in the oldest thalli parts and through which multiple species of the family Cladophoraceae attach to substrate at the early stages (no such basal cells could be detected by the

present authors in the examined specimens). These extensions are not separated from the parent cells by the transverse septa and are also colored, since they contain multiple chloroplasts. A number of researchers referred to these structures as tenaculae (Aleem, 1948), considering the similarity with specialized surgical instrument; others, secondary digitate attachment organs, while (similar to the present case) pointing out the absence of rhizoids in the examined specimens (Titlyanov and Titlyanova, 2012). In the opinion of the present authors, the latter more precisely reflects formation specifics, shape, as well as function of these extensions. They do not only provide for thalli attachment to substrates, but also promote multifold coalescence of separate branches, while similarity to clenched fingers of human hand is rather astonishing (Fig. 3f). This coalescence results in formation of the spongy air-saturated ball (Figs. 2b and 2c). On the one hand, this gives thalli of *L. herpestica* stiffness and tear resistance; on the other hand, incised trichal thalli lose their relative resistance to increased hydrodynamics characteristic of the pseudolittoral zone. Mass development of *L. herpestica* is observed during the summer calms, generally lasting from May to August (Kuklin et al., 2013; Evstigneev et al., 2017) and only on lateral walls of hydraulic structures less exposed to breaking waves than their front surfaces, facing the open sea. The first storm of three-state code value in the end of August broke off a significant part of *L. herpestica* thalli (particular specimens were still recorded in September, but they entirely disappeared in October). After the storm, spongy thalli, featuring high buoyancy, drifted by breaking waves and longshore current on water surface for another several days, though thalli of other filamentous macroalgae separated from substrate (for example, *Cladophora* Kütz., *Ceramium* Roth, and others) primarily concentrated in bottom boundary layer. This peculiarity appears to contribute to *L. herpestica* spread with surface currents. Reproductive organs were not detected.

Morphology, morphometry, as well as biotopic confinedness of *L. herpestica* specimens sampled in SPNA Cape Martyan water area correspond to diagnostic characters of the species (Aleem, 1948; Womersley, 1984; Titlyanov and Titlyanova, 2012). Selected specimens were deposited for storage in the herbarium funds YALT of Nikitskii Botanical Garden.

Two representatives of the genus *Lychaete* J. Agardh have been known to-date from the Azov–Black Sea basin; specifically, *L. pellucida* (Huds.) M.J. Wynne ($\equiv$ *Cladophora pellucida* (Huds.) Kütz.) and *L. echinus* (Biasol.) M.J. Wynne ($\equiv$ *Cladophora echinus* (Biasol.) Kütz.) (Afanas’ev et al., 2020; Minicheva et al., 2020; Guiry and Guiry, 2025). Morphological and morphometric distinctions between *L. pellucida* presently recorded only from the Turkish coast and *L. herpestica* are so conspicuous that do not need separate comparison. Another species, *L. echinus*, is more widely distributed (Minicheva et al.,

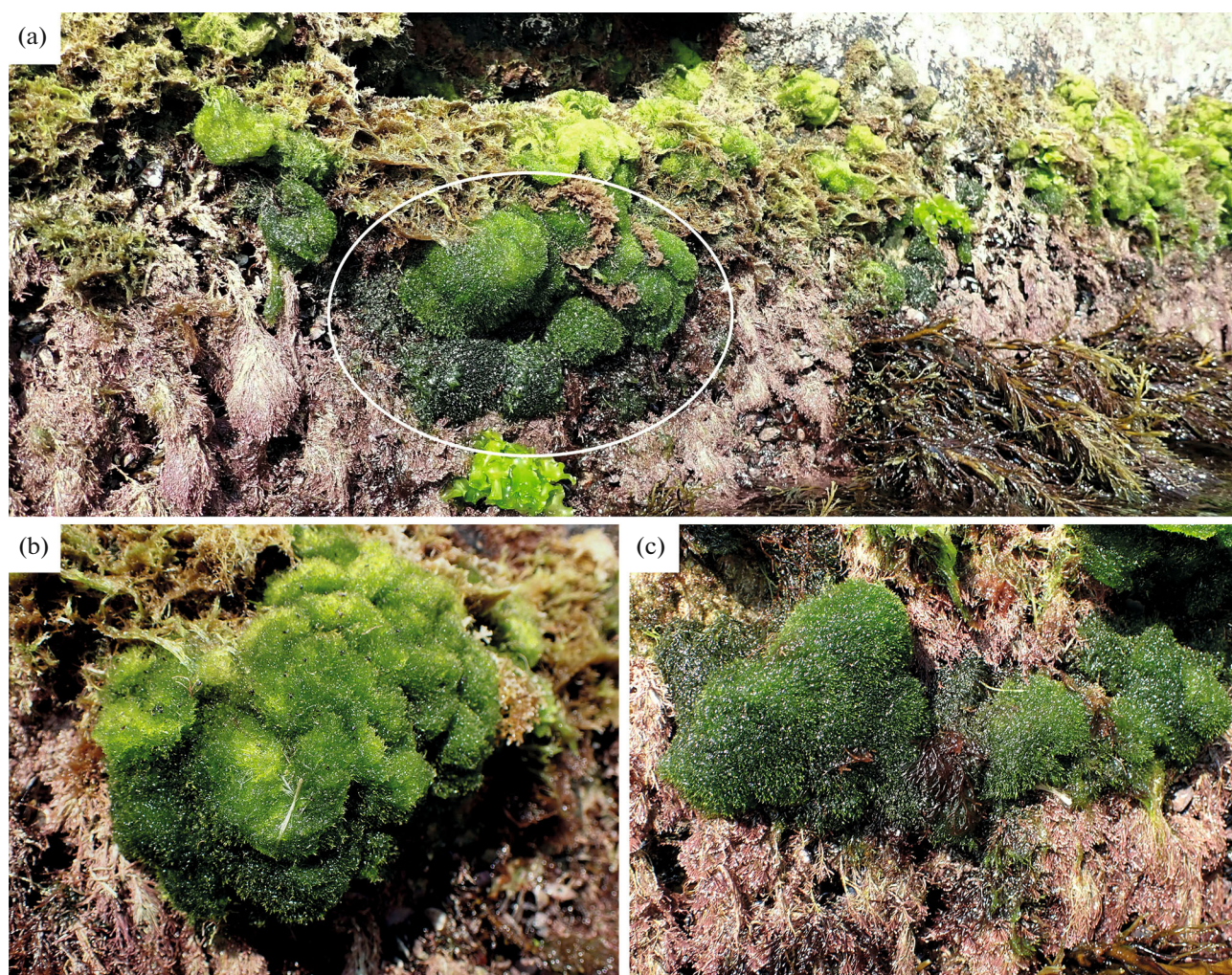


Fig. 2. Thalli of *Lychaete herpestica* found at SCC in the SPNA “Mys (Cape) Martyan” on August 24, 2024: (a) in a pseudolittoral biotope among other algae; (b) and (c) individual specimens of the species.

2020), but at Crimean coast, it was only recorded in the vicinity of Sevastopol and, presumably, in Karkinitskii Bay (Morozova-Vodyanitskay, 1959; Hoek, 1963; Kalugina-Gutnik, 1973; Mil’chakova, 2003; Prazukin et al., 2023; Tamoikin et al., 2024). Differences between *L. herpestica* and *L. echinus* are not so apparent. Similarity of outward appearance of cushion-like thalli, occurrence of secondary digitate attachment organs, and particular parameters of the morphometry can be misleading. However, morphological and morphometric differences are rather substantial and allow for their unambiguous differentiation. Cells of *L. echinus* (particularly in basal and medial parts of thalli) are considerably shorter and are clavate to nearly pear-shaped widening towards distal ends, at which, considering rather abundant branching characteristic of this species, whorls of three to five branches are formed (Hoek, 1963; Zinova, 1967; Aysel et al., 2004; Leliaert et al., 2009; Afanas’ev et al., 2020). All of the foregoing previously served as a

ground for inclusion of *L. echinus* with the genus *Aegagropila* Kütz. or homonymous section in the composition of the genus *Cladophora*; whereas other characteristics of *L. herpestica* morphology (see above) determined the membership in the genus *Cladophoropsis* Børgesen (Hoek, 1963; Leliaert et al., 2009; Guiry and Guiry, 2025).

Every alien species poses a series of relevant questions; primarily, when and through which pathway the species entered the new region.

In the course of hydrobotanical monitoring in the Cape Martyan area, *L. herpestica* was not detected either visually, or in samples processed in laboratory. Analysis of preserved samples and herbarium materials supported by the corresponding photographic images confirms that in summer 2020–2023 light-green aspect in the upper pseudolittoral zone formed due to *Cladophora* sp., while the characteristic dark-green stiff *L. herpestica* thalli were absent. Therefore,

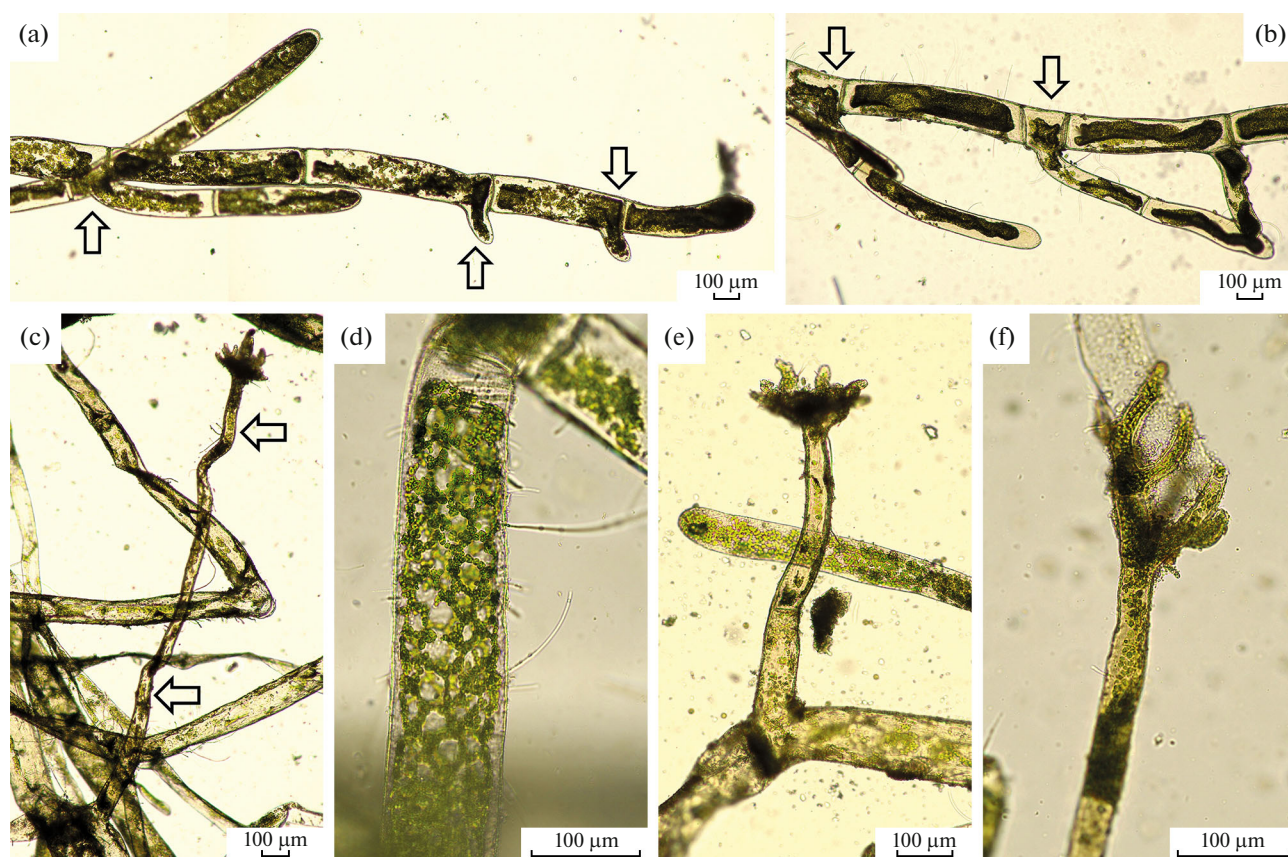


Fig. 3. Fragments of *Lychaete herpestica* thalli found at SCC in the pseudolittoral zone of the SPNA “Mys (Cape) Martyan” on August 24, 2024: (a) and (b) formation of lateral branches (indicated by arrows) without the formation of a basal septum; (c) thin lateral branch (indicated by arrows); (d) reticulate chromatophore; (e) and (f) secondary finger-like attachment organs.

entry through the boundaries to SPNA “Mys (Cape) Martyan” took place in the end of 2023—early 2024.

Overall, entry of *L. herpestica* to SCC and into the Black Sea could occur via various pathways and in different manners, of which three variants merit attention; specifically, from the Mediterranean Sea with longshore currents; from any of the World Ocean regions by ship through ballast waters or biofouling; or any other transport during importing the hydrobionts. Self-dispersal along the coast is not likely, since the species has not been detected anywhere between Eastern Mediterranean and SCC to-date. Besides, the Upper Bosphorus Current, with which *L. herpestica* thalli separated from substrate and featuring high buoyancy, could have entered the Azov–Black Sea region, is directed from the Black Sea to Marmara Sea, due to the water level difference (Greg and Özsoy, 2002). Transport with the ballast water and in biofouling is not unlikely, but accidental introduction with the juvenile bivalves (spat) imported from Asia is more probable. Precisely in this manner numerous Indo-Pacific macroalgae species entered the Mediterranean Sea; in the recent decades, they account for a vast majority of new immigrant species, while warming

further facilitates their dispersal and naturalization (Verlaque, 2010; Cantasano and Di Martino, 2024). A wide variety of aqua-enterprises function at the Crimean coast that until recently used bivalve spats of Indo-Pacific origin obtained from the primary range: deliveries from the regions within confines of the secondary range are presently unlikely, considering restrictive trade regime; while experiments on farming the material locally have not been launched until recently (*Scientists ...*, 2023). The nearest largest officially operating oyster farms are located at a distance of 30–50 km westward (Katsiveli village and Laspi Bay area), as well as 70 km eastward (Sudak town area) from the surveyed water area at Cape Martyan. Considering the rate of aquaculture development against the background of climate changes, governing an increasing complex “mediterraneanization” of the Azov–Black Sea basin, (Berdnikov et al., 2022; Kubryakov et al., 2024), prediction can be made of an accelerated entry and successful naturalization in it of various alien macroalgae species, including from the tropical regions of the World Ocean (Shiganova et al., 2012). In this regard, natural and geographic conditions in combination with a high level and variety of forms of

anthropogenic activity make SCC one of the most vulnerable regions of the basin.

CONCLUSIONS

This is the first record of new alien species in the Black Sea *Lychnis herpestica* of the Indo-Pacific origin previously included in the data base Exotic Macrophytes in the Mediterranean Sea. The immigrant species was detected in water area of SPNA “Mys (Cape) Martyan” (SCC) in the pseudolittoral zone exclusively, which corresponds to its confinedness to the littoral zone within the modern range limits. The examined specimens correspond to the species diagnosis; their key morphological and morphometric characters are refined and illustrated. It is established that the entry to SCC water area (and, from all appearances, to the Azov-Black Sea overall) occurred in the end of 2023—early 2024 likely as a result of accidental introduction with spat of the mollusks of the Indo-Pacific origin directly transported from the primary range. Considering a character and scale of the species distribution in the Mediterranean Sea, entry via self-dispersal along the coast of the region is unlikely. It is assumed that within the Azov-Black Sea basin boundaries, *L. herpestica* can widely disperse and successfully naturalize, while their development will have a pronounced seasonality throughout with the maximum in summer. Mass development of the species with the subsequent structural transformation of the native plant communities is unlikely, considering the narrow biotopic confinedness and sensitivity to hydrodynamic factor. However, direct import of hydrobiota from the donor regions and self-dispersal of a multitude of invasive species from the Mediterranean Sea leave no doubts that frequency of detection of new alien macrophytes in the Black and Azov seas will continue to increase. Naturalization of some of these species against the background of global climate changes can substantially affect a biota structure and the state of the natural environment of the semi-enclosed inland basin.

ABBREVIATIONS AND NOTATION

SPNA	specially protected natural areas
SCC	Southern coast of Crimea

AUTHOR CONTRIBUTION

All the authors make a substantial contribution to the concept development, conducting the research, and manuscript preparation.

FUNDING

This work was supported within a framework of the State-commissioned project no. 122041900097-3.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This work does not contain any studies involving human and animal subjects, corresponding to criteria of the Directive 2010/63/EU.

CONFLICT OF INTEREST

The authors of this work declare that they have no conflicts of interest.

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Translated by E. Kuznetsova

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