

**Rapid Communication****Northernmost occurrence of the tropical invasive red alga  
*Asparagopsis taxiformis* (Bonnemaisoniales, Rhodophyta) in European waters**Eva Cacabelos<sup>1,2,3</sup>, Alejandro Bernal-Ibáñez<sup>4</sup>, Ignacio Gestoso<sup>3,5,6</sup>, Marianela Zanolla<sup>7</sup> and João Faria<sup>8,9,10</sup><sup>1</sup>Hydrosphere. Laboratorio Ambiental para el Estudio de Ecosistemas Acuáticos. Vigo, Spain<sup>2</sup>Centro Oceanográfico de Vigo, Instituto Español de Oceanografía (IEO-CSIC), Vigo, Spain<sup>3</sup>MARE – Marine and Environmental Sciences Centre / ARNET – Aquatic Research Network, Regional Agency for the Development of Research, Technology and Innovation (ARDITI), Funchal, Madeira Island, Portugal<sup>4</sup>IFAPA Centro El Toruño, Junta de Andalucía, Camino Tiro Pichón s/n, El Puerto de Santa María, Cádiz 11500, Spain<sup>5</sup>Marine Research Institute (INMAR)-Department of Biology, Faculty of Marine and Environmental Sciences, University of Cádiz, Puerto Real, Cádiz, Spain<sup>6</sup>Smithsonian Environmental Research Center, Edgewater, MD, USA<sup>7</sup>Departamento de Botánica y Fisiología Vegetal, Facultad de Ciencias, Universidad de Málaga, Málaga, Spain<sup>8</sup>CIBIO -Research Centre in Biodiversity and Genetic Resources/InBIO Associate Laboratory and BIOPOLIS Program in Genomics, Biodiversity and Land Planning, University of the Azores, Ponta Delgada, Portugal<sup>9</sup>UNESCO Chair – Land Within Sea: Biodiversity & Sustainability in Atlantic Islands, University of the Azores, Ponta Delgada, Portugal<sup>10</sup>University of the Azores, Faculty of Sciences and Technology, Ponta Delgada, PortugalCorresponding authors: Eva Cacabelos ([eva.cacabelos@ieo.csic.es](mailto:eva.cacabelos@ieo.csic.es)) and João Faria ([joao.fo.santos@uac.pt](mailto:joao.fo.santos@uac.pt))

**Citation:** Cacabelos E, Bernal-Ibáñez A, Gestoso I, Zanolla M, Faria J (2026) Northernmost occurrence of the tropical invasive red alga *Asparagopsis taxiformis* (Bonnemaisoniales, Rhodophyta) in European waters. *BioInvasions Records* 15(2): 475–482, <https://doi.org/10.3391/bir.2026.15.2.21>

**Received:** 9 September 2025**Accepted:** 8 January 2026**Published:** 30 March 2026**Handling editor:** Quentin John Groom**Thematic editor:** Andrew Davinack**Copyright:** © Cacabelos et al.

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**OPEN ACCESS****Abstract**

*Asparagopsis taxiformis* (Delile) Trevisan, traditionally regarded as a tropical-subtropical red alga native to the Indo-Pacific and particularly the Australian region, is now widely established in the Mediterranean and Macaronesian archipelagos. Here, we document its first confirmed occurrence on the Galician coast (NW Spain), representing a northward extension of more than 500 km ( $\approx 4.5^\circ$  of latitude) beyond its previously known range, which until now was limited to southern Portugal. Molecular analysis confirmed assignment to lineage 2, a cryptic intraspecific genotype characterized by broad thermal and photosynthetic tolerance, which may facilitate persistence in warm-temperate areas such as Galicia. Morphological examination revealed the characteristic features of the species. The absence of reproductive structures and the detection of only a few individuals suggest a nascent, non-established population. This finding raises concern about the potential co-invasion of other warm-affinity macroalgae, such as *Rugulopteryx okamurae*, which could reshape Galician benthic communities. We emphasize the need of continuous monitoring and early management measures to reduce the risk of establishment and ecological impacts of non-native species.

**Key words:** invasive macroalgae, non-indigenous species, climate-mediated range expansion, co-invasion, lineage identity, monitoring, climate change

**Introduction**

Invasive macroalgae increasingly disrupt marine ecosystems by displacing native species and altering benthic structure. Since the 1970s, introduced macroalgae in Europe have steadily increased and now represent 4–10% of macrobenthic flora (van der Loos et al. 2024).

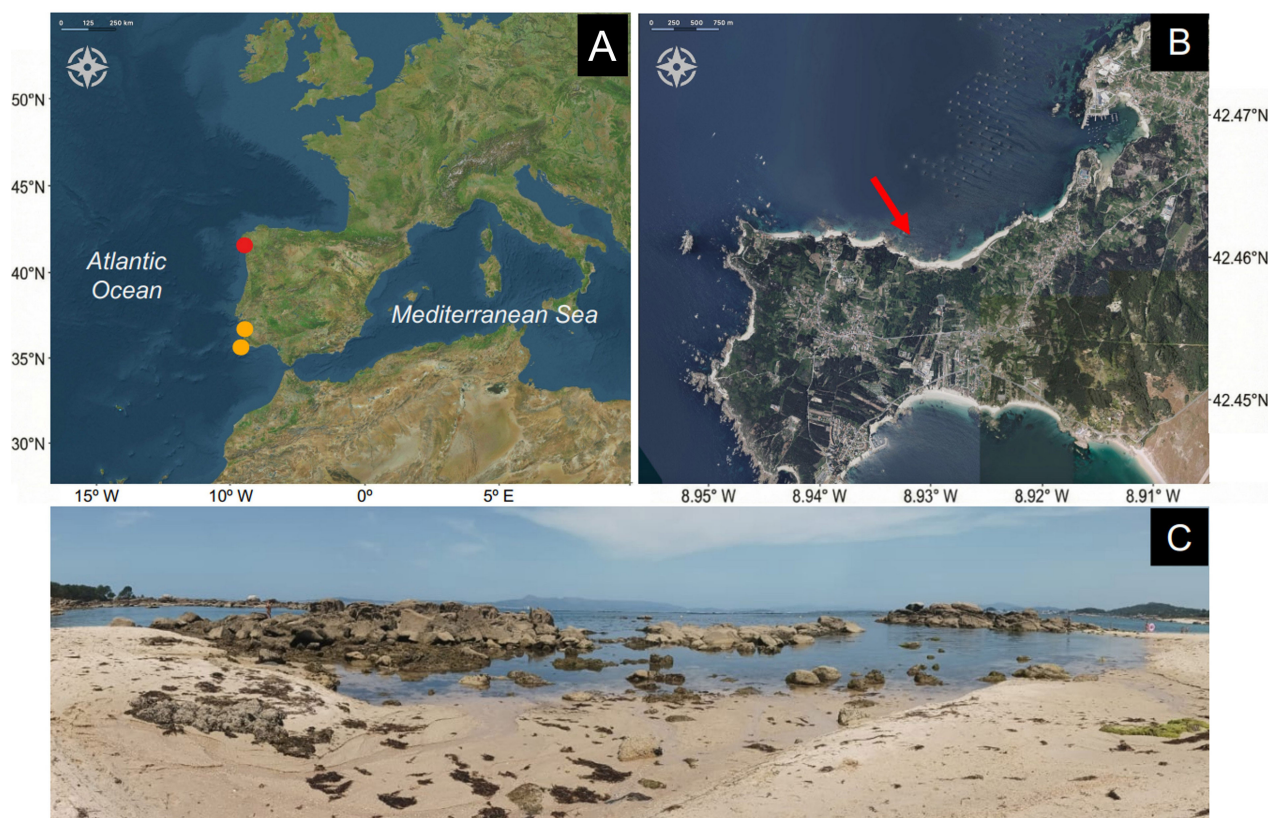
*Asparagopsis taxiformis* (Bonnemaisoniales, Rhodophyta), traditionally regarded as a tropical-subtropical red algae native to the Indo-Pacific, particularly tropical to warm-temperate regions of Australia (Bonin and Hawkes 1987), has spread across warm-temperate regions worldwide (Abbott 1999). Its high adaptive potential and broad tolerance to temperature variation have facilitated its establishment in the Mediterranean, southern European Atlantic, and the Macaronesian archipelagos (Ní Chualáin et al. 2004; Zanolle et al. 2015; Aires et al. 2016; Martins et al. 2019). In Spain (excluding the Canary Islands), it is officially recognized as an invasive species (MITECO, n.d.).

Molecular studies have revealed multiple cryptic phylogenetic lineages (intraspecific genotypes) within *A. taxiformis*, which are morphologically similar but differ in geographic distribution, physiological traits, and invasive potential (Andreakis et al. 2007; Zanolle et al. 2014). In fact, owing to its genetic complexity and the cryptic nature of the genetic lineages, the distinction between the native and invasive ranges remains debated in some regions of the world (Dijoux et al. 2014). While certain lineages are confined to the Indo-Pacific, others have spread through aquaculture and shipping. Because the risk of invasion is lineage specific (Zanolle et al. 2018a), molecular identification is critical to assess invasion risk and potential ecological outcomes.

The previously known distribution in the North Atlantic was restricted to Sines (37°56'56.17"N, 8°52'47.83"W) and Lagosteiros (37°0'37.21"N, 8°55'47.63"W) on the southern Portuguese coast (Aires et al. 2016). Climate-driven tropicalization is reshaping temperate coastal ecosystems by facilitating the poleward expansion of warm-affinity species, including both native and introduced macroalgae (Vergés et al. 2014; Canning-Clode and Carlton 2017). Invasive macroalgae may benefit disproportionately from rising sea temperatures, as many species display traits such as high ecological plasticity, rapid growth, or release from natural predators or competitors in newly colonized habitats (e.g. Atkinson et al. 2020). Consequently, warming waters and increasingly favorable conditions in temperate regions can accelerate the establishment and spread of invasive species such as *Asparagopsis taxiformis* or the recently recorded *Rugulopteryx okamurae* in the area (Díaz-Tapia et al. 2025), often reinforcing their ecological dominance. Understanding the environmental and lineage-specific traits that shape the distribution of *A. taxiformis* is essential for interpreting biogeographic patterns and for designing effective early-warning monitoring and management strategies in temperate coastal ecosystems.

## Materials and methods

In July 2025, a single gametophyte individual of *Asparagopsis taxiformis* was detected at 0.5 m depth in a rock pool on a sheltered rocky shore of the Rías Baixas, Galicia, Spain (42°28'33.29"N, 8°54'38.91"W; Figure 1), and was



**Figure 1.** Map showing previously reported southern localities (Aires et al. 2016; orange dots) and current record in Galicia (red dot) (A). The arrow indicates the exact site of occurrence (B). Global view of the habitat where lineage 2 of *Asparagopsis taxiformis* was found (C).

promptly collected. Morphological identification followed the diagnostic characters described by Bonin and Hawkes (1987). Additionally, genomic DNA was extracted from a fragment of the specimen using the DNeasy Plant Mini Kit (Qiagen, Germany), following the manufacturer's protocol. Two barcoding markers, the mitochondrial *cox 2–3* spacer and the plastid *rbcL*, were amplified by PCR to confirm species identity and lineage assignment (see Zuccarello et al. 1999 and Nahor et al. 2022 for primer details and PCR conditions). Sequences were edited and assembled using CodonCode Aligner V3.0, and then queried against the NCBI nucleotide database using BLASTn with default parameters. Only matches with  $\geq 98\%$  identity and low E-values were considered reliable. The specimen was photographed *in situ* and preserved as a voucher in the Herbarium of the University of Santiago de Compostela (SANT).

## Results

The collected specimen displayed the typical morphological features of *A. taxiformis*, including an erect thallus, finely branched filaments, and pinkish-red coloration. In contrast to the gametophytes of *Asparagopsis armata*, it did not possess lateral branches bearing harpoon-shaped hooks (Figure 2). It was found attached to rocky substrates among native algae such as *Bifurcaria bifurcata* R. Ross 1958 and *Ulva rigida* C. Agardh 1823,



**Figure 2.** *In situ* images of *Asparagopsis taxiformis* from Galicia (NW Spain), showing vegetative gametophytes with the characteristic plumose, filamentous tufts forming compact, feathery clumps attached to rocky substrates among native macroalgae. No reproductive structures were observed. Photographs by Eva Cacabelos.

with no reproductive structures observed. Sequences obtained (GenBank accession numbers: PX610173 and PX610174) were compared against the NCBI database using BLAST and matched exactly with reference sequences assigned to the cryptic lineage 2, with  $\geq 98$ –100% nucleotide identity,  $\geq 95$ –100% query coverage, and low E-values (see Supplementary material Tables S1, S2 for complete similarity metrics and accession numbers). Several sequences were identical (100% identity and 100% coverage) to established reference accessions for lineage 2 (see Andreakis et al. 2007 for genetic delineation). During a follow-up survey one month later, additional individuals were observed at the same site.

## Discussion

Here, we document the first known occurrence of *Asparagopsis taxiformis* in Galicia, the northernmost record in Europe to date, which indicates a probable poleward range shift of this tropical-subtropical species. Galicia lies within the Iberian upwelling system, characterized by relatively cool waters, yet recent warming and increased frequency of marine heatwaves (Lima and Wetthey 2012; Smale et al. 2019) may be reducing thermal barriers, thereby facilitating the establishment of warm-affinity species.

Comparable tropicalization trends have been documented across the Mediterranean and NE Atlantic, where subtropical and tropical taxa are progressively expanding into temperate ecosystems (Vergés et al. 2014; Franco et al. 2021; Biosecurity New Zealand 2024; Bellissimo et al. 2024). This is consistent with observations in other regions where this warm-affinity species has expanded northwards (CEAB-CSIC 2023).

Molecular analysis confirmed that the Galician specimen belongs to lineage 2, one of the most widely distributed and invasive genotypes of *A. taxiformis* (Andreakis et al. 2007; Zanolla et al. 2018a). This lineage occurs broadly in the Indo-Pacific, and has been previously reported on the Mediterranean and the southern Portuguese coast (Aires et al. 2016). Differences in the geographic distribution and invasiveness of *A. taxiformis* lineages are thought to arise from a combination of intrinsic environmental tolerances and historical introductions via aquaculture and shipping (Dijoux et al. 2014; Andreakis et al. 2016). Studies on thermal ecology indicate that *A. taxiformis* exhibits marked physiological plasticity, with optimal growth around 22–26 °C but survival possible at lower temperatures (~ 15 °C), depending on life stage (Padilla-Gamiño and Carpenter 2007). Within this framework, lineage 2 shows broad photosynthetic tolerance across 12–26 °C, with invasive Mediterranean isolates displaying low compensation irradiance and limited thermal sensitivity, suggesting higher physiological plasticity than native Australian isolates, and likely contributing to their invasive potential (Zanolla et al. 2015). This combination of broad environmental tolerance and historical dispersal pathways may facilitate the persistence of lineage 2 in Galicia, where summer conditions can periodically exceed thresholds favorable for growth, even if winter conditions remain limiting.

Although only a single individual was initially detected, additional observations were made one month later. The absence of reproductive structures in the observed individuals, together with the low number of specimens detected, suggests that this is a nascent, non-established population in the intertidal area. Although sexual or asexual reproductive structures are not strictly required for establishment, early-stage non-native populations often exhibit limited reproduction, which can constrain their immediate expansion. Further monitoring will be necessary to determine whether the population becomes reproductive and established. Early records of invasive macroalgae should be interpreted cautiously, as initial detection does not guarantee persistence or establishment, emphasizing the importance of long-term monitoring (Bellissimo et al. 2024). Nevertheless, the invasion history of *A. taxiformis* elsewhere in Europe, where it has successfully colonized the Mediterranean and Macaronesian archipelagos, demonstrates its potential to become invasive under favorable conditions (Altamirano et al. 2008; Martins et al. 2019).

Anthropogenic vectors, especially shipping and aquaculture, may facilitate dispersal, as documented for instance with the brown macroalga *R. okamurai* along the Iberian coast (Faria et al. 2022a; Díaz-Tapia et al.

2025). The possibility of co-occurrence with *R. okamurae* in Galicia could intensify ecological impacts, as both species are capable of monopolizing space and altering benthic assemblages (Zanolla et al. 2018b; Navarro-Barranco et al. 2019; García-Gómez et al. 2020; Faria et al. 2022b). Such scenarios may result in coinvasion processes, where multiple non-indigenous species interact not only with native assemblages but also with each other, potentially exacerbating ecological disruption (García-Gómez et al. 2021). Whether these invasion dynamics will be replicated in cooler Galician waters is uncertain, but ongoing warming trends may increase the likelihood.

Although only a few individuals of *A. taxiformis* lineage 2 were detected in Galicia, this record raises the possibility that climate change and anthropogenic vectors could shape invasion pathways. The case highlights the need for structured, long-term monitoring, coupled with molecular surveillance, to track establishment success, population dynamics, and interactions with co-occurring invaders. These biogeographic shifts reflect the pervasive impacts of ocean warming on temperate ecosystems and their potential to restructure coastal community composition and functioning.

### Author's contribution

EC: research conceptualization; sample design and methodology; investigation and data collection; data analysis and interpretation; writing – original draft; writing – review. AB-I: data analysis and interpretation; writing – review. IG: data analysis and interpretation; writing – review. MZ: data analysis and interpretation; writing – review. JF: research conceptualization; sample design and methodology; investigation and data collection; data analysis and interpretation; writing – review.

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### Acknowledgements

We gratefully acknowledge the constructive feedback and insightful comments provided by the anonymous reviewers, which significantly contributed to improving the clarity and quality of this manuscript.

### Funding declaration

We acknowledge funding by FEDER funds through the Operational Programme for Competitiveness Factors – COMPETE and by National Funds through FCT – Foundation for Science and Technology under the UID/BIA/50027/2020 and UID/50027/2025-Rede de Investigação em Biodiversidade e Biologia Evolutiva, as well as Azorean regional funds through DRCID (M1.I.A/FUNC.UI&D/015/2025/RTF/001/Apoio UI&D).

Publication of this study was supported by the European Union's Horizon Europe HORIZON-CL6-2024-BIODIV-01 project “GuardIAS - Guarding European Waters from IAS”, under grant agreement no. 101181413 (Katsanevakis et al. 2024).

### Data availability

Species georeferenced records are available at the European Alien Species Information Network: <https://easin.jrc.ec.europa.eu/easin/RJD/Download/1576378c-f7aa-4f4f-973c-9e32b0fd1fe2>.

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## Web sites, online databases and software

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## Supplementary material

The following supplementary material is available for this article:

**Table S1.** BLASTn similarity results for the mitochondrial cox2-3 spacer sequence obtained in this study.

**Table S2.** BLASTn similarity results for the chloroplast rbcL sequence obtained in this study.

This material is available as part of online article from:

[http://www.reabic.net/journals/bir/2026/Supplements/BIR\\_2026\\_Cacabelos\\_et\\_al\\_SupplementaryMaterial.pdf](http://www.reabic.net/journals/bir/2026/Supplements/BIR_2026_Cacabelos_et_al_SupplementaryMaterial.pdf)