

First record of a population of *Caulerpa okamuræ* (Bryopsidales) in the Mexican Pacific

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ABSTRACT. On the western coast of the Baja California Peninsula, 5 *Caulerpa* species have been recorded as part of a regional floristic checklist. However, in late 2023, the presence of *Caulerpa okamuræ* was detected in Ojo de Liebre Lagoon, on the Pacific coast of Baja California Sur, where its abundance increased notably during 2024–2025. This macroalga adheres to oyster cultivation systems, increases cleaning costs, and threatens seagrass meadows and other habitats, with potential effects on fishery resources. Distinguishing between cryptogenic, non-native, and invasive populations is crucial in research on species introductions, as a species is considered invasive when its presence threatens biodiversity, the economy, or health. In Mexico, guidelines and a national strategy exist to prevent, detect, and control these species. This work presents the first record of a *C. okamuræ* population on the coasts of the Mexican Pacific, based on morphological evidence from specimens collected in Ojo de Liebre Lagoon, in the absence of previous records in Mexico. Confirmation of this finding adds to the 16 introduced macroalgae already documented in the Mexican Pacific, the majority of which originate in Japan and Korea and whose spread is associated with maritime traffic and aquaculture. Given the introduction and potential establishment of *C. okamuræ* to Ojo de Liebre Lagoon, it is essential to implement continuous and rigorous monitoring programs to precisely determine its spatiotemporal distribution.

Key words: green algae, non-native species, invasive species, macroalgae, Mexico.

INTRODUCTION

Considerations for non-native and invasive species

To begin with, it is important to distinguish between a non-native or “exotic” species and an invasive species, since legislation often groups both concepts together. The *Ley General de Vida Silvestre* (General Wildlife Law of Mexico), in its section XVII, defines an invasive exotic species as: “any species or population that is not native, that is found outside its natural range, that is capable of surviving, reproducing and establishing itself in natural habitats and

ecosystems, and that threatens native biological diversity, the economy or public health” (DOF 2010). On the other hand, the *Comisión Nacional para el Conocimiento y Uso de la Biodiversidad* (National Commission for the Knowledge and Use of Biodiversity; CONABIO, for its acronym in Spanish), the *Comisión Nacional de Áreas Protegidas* (National Commission of Protected Areas; CONANP, for its acronym in Spanish), and the *Secretaría de Medio Ambiente y Recursos Naturales* (Ministry of Environment and Natural Resources; SEMARNAT, for its acronym in Spanish) consider that invasive specimens or populations are all those individuals or populations of an exotic species, introduced accidentally or

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intentionally outside their current or past natural distribution area, including their gametes, seeds, propagules, or eggs, with the capacity to colonize, invade, and persist, and whose introduction, establishment and dispersal threaten biological diversity, or cause damage to the environment, the economy, and human health (Comité Asesor Nacional sobre Especies Invasoras 2010).

As part of the commitments made by Mexico under the Convention on Biological Diversity (CBD) and the National Biodiversity Strategy, and in response to the challenges of biological invasions, SEMARNAT identified the need to create the “*Estrategia nacional sobre especies invasoras en México: prevención, control y erradicación*” (national strategy on invasive species in Mexico: prevention, control, and eradication), coordinated by CONABIO with the support of a national advisory committee on invasive species. The central objective of this strategy is to “contribute to the conservation of natural capital and human well-being through decisions aimed at the prevention, control, and eradication of invasive species in Mexico through the coordinated, proactive, and responsible participation of all stakeholders” (Comité Asesor sobre Especies Invasoras 2010). By 2020, the country was expected to have systems in place for prevention, early detection, and early response, and a comprehensive legal framework to address the problem of invasive species.

For the purposes of this document, it is important to distinguish between an exotic species, which is defined as one that is not native, is found outside its natural range, and is capable of surviving, reproducing, and establishing itself in natural habitats and ecosystems, and an invasive species, which is defined as one that threatens native biodiversity, the economy, or public health. Based on these assertions, distinguishing between populations whose origin cannot be classified with certainty (cryptogenic), those that are non-native, and those that are invasive is key in species introduction studies. Identifications of species considered in the literature as non-native, but supported only by morphological observations without molecular evidence, were categorized as cryptogenic in the sense of Carlton (1996), given the uncertainty regarding their introduction routes or dispersal vehicles and the potential effects they could have on the surrounding ecosystems (Pedroche and Aguilar-Rosas 2025).

This study presents the first record of a population of *Caulerpa okamurae* on the Pacific coast of Mexico, based on morphological evidence from specimens collected in Ojo de Liebre Lagoon, Baja California Sur, in the absence of previous records in Mexico (Pedroche and Senties 2020).

Introduced macroalgae in the Mexican Pacific

In the Mexican Pacific, the presence of 16 introduced marine macroalgae has been documented, of which 2 are green, 7 brown, and 7 red (Aguilar-Rosas et al. 2014). Of these, 8 can be considered invasive species due to their high abundance in areas where they have been recorded. Among

them, 4 species are brown algae (Ochrophyta): *Cladostephus spongiosus* (Hudson) C Agardh, *Sargassum horneri* (Turner) C Agardh, *Sargassum muticum* (Yendo) Fensholt, and *Undaria pinnatifida* (Harvey) Suringar; and 4 are red algae (Rhodophyta): *Chondracanthus squarulosus* (Setchell and NL Gardner) Hughey, PC Silva and Hommersand, *Grateloupia turuturu* Yamada, *Gracilaria vermiculophylla* (Ohmi) Papenfuss, and *Acanthophora spicifera* (Vahl) Børgesen. No green algae with invasive characteristics have been recorded to date (Aguilar-Rosas et al. 2014).

Approximately, 80% of these species are native to Japan or Korea. In most cases, studies suggest that their introduction occurred through maritime traffic, and to a lesser extent, through activities related to aquaculture or fishing. In the latter case, the introduction of *Sargassum muticum* to the Canadian Pacific coast has been attributed to an accidental event associated with the transport of the Japanese Oyster *Magallana gigas* (Thunberg, 1793) (as *Crassostrea gigas* Thunberg, 1793), whose shells possibly had small plantlets attached to them (Scagel 1956). After this event, studies have suggested that ocean currents have facilitated their natural dispersal southward, even reaching the coast of Baja California Sur in Mexico (Aguilar-Rosas et al. 2014). However, the lack of reliable information on the introduction routes or specific vectors for each of the non-native macroalgae has been noted. Therefore, it is considered a priority to develop studies aimed at identifying the introduction mechanisms of each of the species, which will enable the establishment of effective prevention measures.

In addition, 2 macroalgae, *Dactylosiphon durvillei* (Bory) Santiañez, KM Lee, SM Boo and Kogame (as *Colpomenia phaeodactyla* MJ Wynne and JN Norris) and *Ishige sinicola* (Setchell and NL Gardner) Chihara, have been registered within the list of macroalgae considered as introduced and invasive or potential to enter the coasts of the Mexican Pacific, in a CONABIO project entitled “*Estado actual de las especies de macroalgas introducidas e invasoras en la costa Pacífico de México*” (Current status of introduced and invasive macroalgae species on the Pacific coast of Mexico; CONABIO 2025).

The genus *Caulerpa*

The genus *Caulerpa* comprises several species of green algae and is distributed worldwide in marine environments. In general, *Caulerpa* species are found in shallow tropical and subtropical waters, although some species can inhabit brackish lagoons. In each *Caulerpa* species, the thallus is composed of coenocytic filaments, which means that they are formed by a single cell with multiple nuclei that lack dividing cell walls. These filaments exhibit numerous trabeculae, which are branched, cylindrical outgrowths of the cell wall.

Caulerpa species exhibit 2 types of propagation, sexual and vegetative, which allow even small fragments to give rise to new individuals and confer a high growth rate. These

characteristics, along with the frequent presence of toxigenic compounds that protect them from herbivores, especially in new environments, facilitate the rapid colonization of new areas (Gao et al. 2019). Furthermore, *Caulerpa* species possess adaptations that allow them to tolerate a wide range of environmental conditions, which further enhances their high potential for colonizing other locations (Park et al. 2022).

In Mexico, along the western coast of the Baja California Peninsula, 5 species of the genus *Caulerpa* have been recorded as part of the flora from various sites: *Caulerpa chemnitzia* (Esper) JV Lamouroux (as *Caulerpa peltata* JV Lamouroux), *Caulerpa cylindracea* Sonder (as *Caulerpa racemosa* [var. *laetevirens*] f. *cylindracea* [Sonder] Weber Bosse), *Caulerpa racemosa* (Forsskål) J Agardh var. *racemosa* (as *Caulerpa racemosa* var. *macrophysa* [Sonder ex Kützing] WR Taylor), *Caulerpa sertularioides* (SG Gmelin) M Howe, and *Caulerpa chemnitzia* var. *vanbosseae* (Setchell and NL Gardner) Fernández-García and Riosmena-Rodríguez (as *Caulerpa vanbosseae* Setchell and NL Gardner) (Francisco F Pedroche, pers. comm., November 2025). However, in late 2023, riverine fishers observed the presence of a green macroalga in Ojo de Liebre Lagoon, on the western coast of Baja California Sur, which had not been present previously. Subsequently, in late 2024, the presence and abundance of this macroalga was observed to have increased considerably (Fig. 1a). The specimens were identified as *C. okamuræ* by researchers from the *Centro de Investigaciones Biológicas del Noroeste S.C.* (Northwest Biological Research Center; CIBNOR, for its acronym in Spanish) and the *Universidad Autónoma de Baja California Sur* (Autonomous University of Baja California Sur; UABCS, for its acronym in Spanish). The arrival of this macroalga, along with the increase in its biomass and subsequent sightings at various sites in Ojo de Liebre Lagoon, poses a threat to seagrass meadows (Fig. 1b) and other macroalgae distributed in the area, and to various resources that are key elements of the ecosystem, such as habitat and food, including those of commercial importance. The impact is evident in oyster farming systems, in particular, which receive influxes of this macroalga. The cleanup efforts carried out by members of fishing cooperatives are exhausting and largely ineffective, given the ability of the alga to recolonize the farming systems in just a few weeks (Fig. 1c, d).

MATERIALS AND METHODS

Examined material

Specimens were collected manually on March 10, 2025, in Ojo de Liebre Lagoon, Baja California Sur, Mexico (La Concha, 27°48'51"N, -114°13'53"W) (Figs. 2, 3). The specimens were growing on sandy substrate, on oyster sacs, and, in some cases, on the shells of bivalve mollusks. Reference specimens were deposited in the *Herbario Ficológico de Baja California Sur*, UABCS (Phycological Herbarium of Baja California Sur, UABCS; FBCS 20347).

RESULTS

Taxonomic classification of *Caulerpa okamuræ* Weber Bosse

Empire: Eukaryota.

Kingdom: Plantae.

Subkingdom: Viridiplantae.

Phylum: Chlorophyta.

Subphylum: Chlorophytina.

Class: Ulvophyceae.

Order: Bryopsidales.

Family: Caulerpaceae.

Genus: *Caulerpa*.

Species: *Caulerpa okamuræ* Weber Bosse.

Okamura, 1897: p. 5, pl. I; Figs. 13, 14 ('*Okamurai*'). Weber-van Bosse, 1898: p. 385, pl. XXXIV; Fig. 9. Okamura, 1923: p. 11, pl. CIIV; Figs. 1-8.

Syntype locality: Japan; Suruga, Mikawa, Oki, Noto.

Heterotypic synonym: *Caulerpa okamuræ* f. *minor* S Narita.

Morphological description of *Caulerpa okamuræ* Weber Bosse

The fronds arise from a creeping axis that branches in several directions, forming a dense covering over the substrate. The rhizoids are arranged at irregular intervals (0.4 mm to 17.6 mm), generally in groups of 3 to 5. The fronds also arise at irregular intervals, from 5.7 mm to 43.4 mm, and occasionally in pairs. The fronds are cylindrical, single or with 1 to 4 irregular branches, and reach a maximum height of 14 cm (Fig. 2). The creeping axis has a diameter of 1.1 mm to 1.5 mm. The fronds have a similar diameter at their base (1.1 mm to 1.4 mm) and are slightly thinner at the apex (diameter: 1.1 mm to 1.2 mm). Throughout their extension, fronds are covered with branchlets arranged more or less densely imbricated. The color of the fronds varies; the exposed parts are bright green, whereas the unexposed parts are a dull straw color. The branchlets can be arranged distichously or oppositely, predominantly near the base of the frond, and gradually overlap or imbricate towards the apex. The axis is slightly constricted at the point of insertion of the branchlets, projecting laterally below the constriction, giving rise to a short pedicel

from which the branchlet emerges. The junction between the branchlet and the pedicel is clearly constricted. In general, basal branchlets are shorter than upper ones and are obovate;

upper branchlets are oblong or subclavate-cylindrical. The apical portion of the branchlets is slightly thicker than their basal portion (Fig. 3). At the base of the frond, the branchlets



Figure 1. Incidence of the macroalga *Caulerpa okamurae* in the oyster farming systems of the *Unión de Acuacultores del Complejo Lagunar de la Reserva de la Biosfera el Vizcaino* (Union of Aquaculture Producers of the Lagoon Complex of the El Vizcaino Biosphere Reserve). First observation at the end of 2024 in oyster farming in bags on beds (a). Coexistence and coverage of seagrass at the end of 2024 (b). Massive invasion in oyster farming lines in suspended bags (c). Cleaning efforts carried out by members of the Union of Aquaculture Producers of the Lagoon Complex of the El Vizcaino Biosphere Reserve in May 2025 (d). Photographs: Laura González-Ortiz, Sergio Scarry González-Peláez, and Ilie S Racotta.

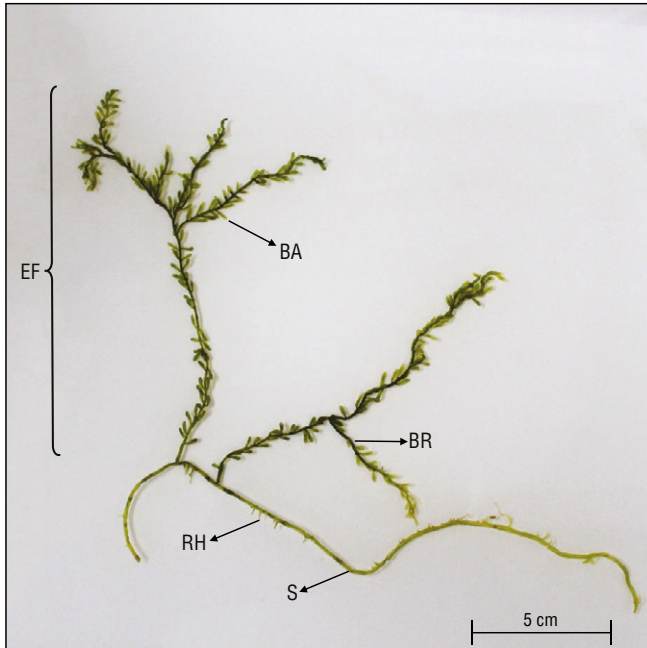


Figure 2. *Caulerpa okamurae* collected in Ojo de Liebre Lagoon, Baja California Sur, Mexico. Erect frond (EF), branchlet (BA), rhizoid (RH), branching (BR), and stolon (S). Photograph: Alejandra Mazariegos-Villarreal, Laboratorio de Macroalgas, Centro de Investigaciones Biológicas del Noroeste S.C. (CIBNOR).

measure 4.9–6.2 mm in length, with a basal diameter of 0.9–1.3 mm and an apical diameter of 1.2–1.7 mm. At the apical portion of the fronds, the branchlets are 4.7–6.8 mm long, with a basal diameter of 0.9–1.4 mm and an apical diameter of 1.1–1.5 mm.

The characteristics and dimensions of the specimens collected at Ojo de Liebre Lagoon correspond to the description of the species *C. okamurae* according to Okamura (1897). One form and an ecad of this species have been described; however, these were not observed in the specimens collected at Ojo de Liebre Lagoon. *Caulerpa okamurae* f. *oligophylla* Okamura has very elongated fronds, reaching or exceeding 15 cm in length, with irregular branching and a reduced number of pedicellate branchlets that are, occasionally, slightly imbricated (Okamura 1916). *Caulerpa okamurae* ecad *lamourouxii* is characterized by having a compressed axis (Prud'Homme Van Reine et al. 1996).

DISCUSSION

Distribution

The genus *Caulerpa* includes 104 species distributed across a wide geographic range, from temperate to tropical regions (De Gaillande et al. 2017, Zubia et al. 2020, Guiry and Guiry 2025). Some of these species, such as *Caulerpa taxifolia* (M Vahl) C Agardh, *Caulerpa brachypus* Harvey,

and *C. racemosa*, are well-known invasive species that exhibit a highly effective vegetative propagation mechanism (Boudouresque et al. 1995, Smith and Walters 1999).

The distribution of *C. okamurae*, native to the Asian Pacific, is restricted to Asia and some sites in Oceania and islands in the Pacific, with records from Asia (China, Japan, and Korea), Australia and New Zealand (Queensland), and Pacific Islands (Federated States of Micronesia and New Caledonia) (Guiry and Guiry 2025) (Fig. 4). In this study, *C. okamurae* is recorded for the first time in Mexico, specifically in Ojo de Liebre Lagoon, Baja California Sur (Fig. 4). In general, *C. okamurae* grows in shallow waters (to a depth of 5 m in the sublittoral zone). In Korea, the biomass of *C. okamurae* exhibits seasonal variations in natural habitats, with a maximum during the summer (Gao et al. 2019).

In the Mexican Pacific, *C. okamurae* is considered a non-native population, given the lack of bibliographic records and herbarium specimens confirming its prior presence in the region (Pedroche et al. 2005, Pedroche and Senties 2020).

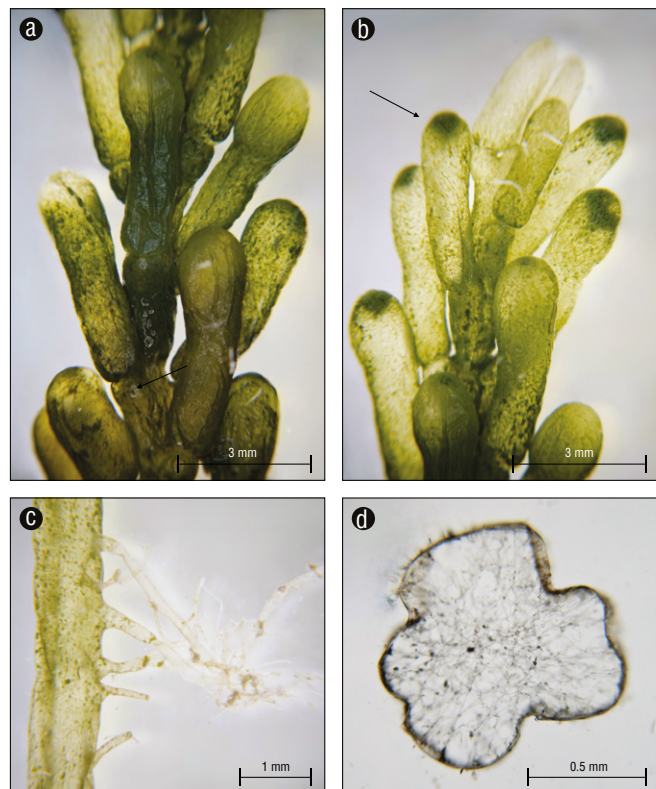


Figure 3. *Caulerpa okamurae*. Detail of the branching in the middle part of the frond; the short pedicel from which a branchlet and its constriction arise are indicated by an arrow (a). Detail of the branching at the apex of the frond; a branchlet is indicated by an arrow (b). Detail of the creeping axis showing a cluster of rhizoids (c). Cross-section of the creeping axis showing the trabeculae (d). Photographs: Alejandra Mazariegos-Villarreal, Laboratorio de Macroalgas, Centro de Investigaciones Biológicas del Noroeste S.C. (CIBNOR).

Draisma et al. (2025) suggest that *C. okamurae* may be restricted to the northwestern temperate Pacific. This absence of records, along with the morphological evidence, strongly suggests its non-native status. However, following the terminology of Carlton (1996), it could be considered cryptogenic until its taxonomic identity is definitively confirmed. Thus, ongoing molecular analyses are crucial to ratify its taxonomic identity and, if possible, its geographic origin.

Caulerpa okamurae has the capacity to rapidly increase its biomass and cover, giving it a high potential for expanding its geographic distribution. Its propagation occurs through 2 vegetative growth patterns: creeping stolon growth, which attaches via several groups of rhizoids (rhizophores), and vertical growth of highly dense assimilators arising from the stolon (Shin et al. 2021, Park et al. 2022). Both assimilators and fragmented stolons have shown a high capacity for regeneration under laboratory conditions (Gao et al. 2019, Shin et al. 2021, Park et al. 2022). This is a known capacity within the genus, as fragmented fronds of *Caulerpa* species can produce new thalli (Smith and Walters 1999). In wild populations, these fragments can result from wave action or herbivory and subsequently become buried in various types of sediments, such as silt or sand with different grain sizes. In fact, previous studies have shown that fragments of other *Caulerpa* species (e.g., *C. taxifolia*, *C. racemosa*,

and *Caulerpa lentillifera* J. Agardh) can survive, readhere to various substrates, and even grow in mud (Horstmann 1983, Trono 1990, Ceccherelli and Piazzzi 2001, Wright and Davis 2006, Mary et al. 2009). Likewise, in natural environments, the fronds of *C. okamurae* can adhere to various substrates such as silt, sand, rock, gravel, shells, and sponges. Finally, species of the genus *Caulerpa* exhibit resistance to herbivory by fish due to their high content of sesquiterpenes and other phytochemical compounds, which act as a chemical defense (Paul et al. 1987).

Invasions by the genus *Caulerpa* often cause serious ecological impacts, such as loss of biodiversity and alteration of native habitats (e.g., Santini-Bellan et al. 1996; Ceccherelli et al. 2000; Piazzzi et al. 2001; Fernández-García and Cortés-Núñez 2005, 2009; Smith et al. 2010), which lead to severe economic consequences (Francour et al. 1995, Baskin 1996). In the case of Ojo de Liebre Lagoon, invasions have already resulted in strong impacts on oyster farming, with an estimated 60% loss of production since the end of 2024, and competition for space with seagrasses. Given these evident ecological and economic impacts, taxonomic confirmation and determination of the possible geographic origin of this population through molecular analyses are priority steps. These data will not only help confirm the status of *C. okamurae* as a non-native species in Mexico but will

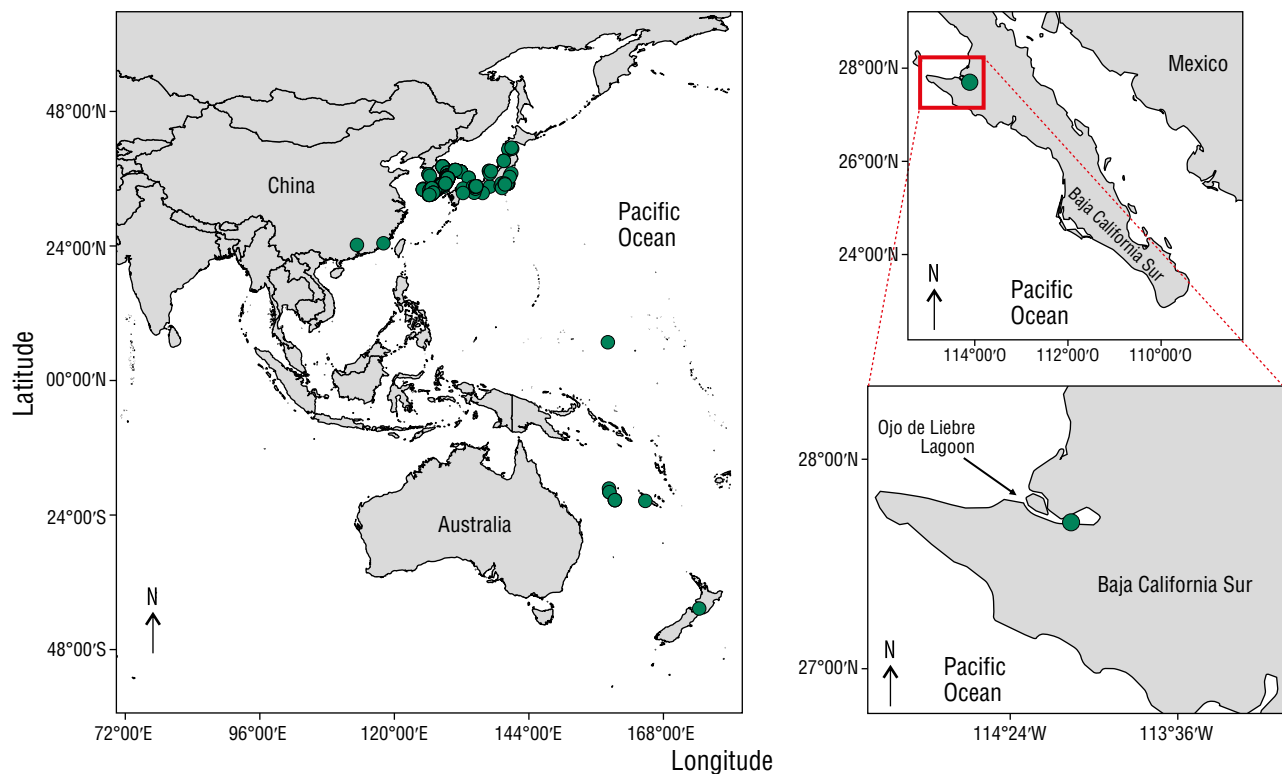


Figure 4. Distribution of *Caulerpa okamurae* (left) and location of Ojo de Liebre Lagoon, Baja California Sur, Mexico (right). Elaborated by: José Antonio González Rousseau, Laboratorio Botánica Marina, Universidad Autónoma de Baja California Sur (UABCS).

also be essential to assess the real risk of colonization in the northwest region of the country and will be the basis for designing and implementing management, control, and mitigation strategies.

CONCLUSIONS

Given its introduction and potential establishment, it is essential to implement continuous and rigorous monitoring programs to accurately determine the spatial and temporal distribution of *C. okamurae*. These efforts must go beyond mapping and include a thorough assessment of the existence of impacts on native biodiversity, ecosystem functions, and environmental services, as well as economic repercussions on fisheries and aquaculture, and potential implications for human health. This information will support evidence-based management decisions and guide public policies for the prevention, early detection, control, and mitigation of its effects. To this end, we propose the following goals.

Integral and early monitoring

It is necessary to evaluate the distribution and seasonality of *C. okamurae* and its potential impact on marine populations, combining data from transects or plots with information obtained using drones and eDNA to confirm its identity and areas of expansion.

Standardization and key metrics

It is necessary to evaluate the cover (%), biomass ($\text{g}\cdot\text{m}^{-2}$), recolonization rate (day^{-1}), cleaning effort ($\text{person}\cdot\text{t}^{-1}$), and meadow integrity.

Impact evaluation designs

It is necessary to quantify the effects on seagrass meadows, native macroalgae, and the productive performance (growth, survival, and biofouling) of oysters and other commercial sessile species.

Biosecurity and vectors

It is necessary to define protocols to standardize the disinfection and quarantine of equipment and vessels, improve the management of waste without viable fragmentation, implement controls at docks and transfer routes, and ensure the traceability of equipment between sites.

Control options

Pilot tests are required to evaluate the efficiency of targeted manual removal and physical barriers, with plans for safe disposal and subsequent follow-up to prevent regrowth.

Responsible exploitation

It is necessary to evaluate the potential uses (e.g., food, composting, biogas, and biomolecules), safety, and life cycle of *C. okamurae* to ensure that its exploitation does not facilitate its dispersal.

Taxonomic confirmation

Genetic analyses (e.g., COI and qPCR with specific primers) are required to confirm the identity of *C. okamurae*, avoid confusion with other *Caulerpa* species, and support its inclusion in official lists as a non-native or invasive species.

Governance and participation

It is necessary to promote interinstitutional coordination, between environmental authorities, academia, and fishing cooperatives, and the implementation of citizen science programs to ensure that the data they collect can be reliably integrated into reports.

Environmental scenarios

Climate variability (e.g., marine heat waves) and ecosystem eutrophication need to be incorporated into distribution and risk models to identify critical sites and prioritize them in conservation strategies.

Cost-benefit

It is necessary to estimate and compare the costs of inaction and those of management strategies, define action thresholds and establish measurable goals for 6–24 months.

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FINAL DECLARATIONS

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Conflict of interest

The authors declare they have no conflict of interest.

Author contributions

Conceptualization: ISR, VHCE, ESZ; Data curation: AMV, KLC, ESZ; Formal analysis: AMV, JMLV, ESZ; Investigation: LGO, ISR, ESZ; Methodology: AMV, JMLV, SSGP, ESZ; Resources: ISR, SSGP, ESZ; Software: AMV, JMLV, SSGP; Supervision: ISR, CRP, ESZ; Validation: RNAR, JMLV, ISR, VHCE, ESZ; Visualization: ISR, VHCE, ESZ; Writing—original draft: LGO, RNAR, ISR, VHCE, CRP, ESZ; Writing, review, and editing: LGO, AMV, RNAR, JMLV, ISR, VHCE, CRP, SSGP, APG, APM, MMO, KLC, CJBS, TChS, ESZ.

Data availability

The data for this study are available from the corresponding author upon reasonable request.

Ethical approvals and permissions for animal studies

The specimens were collected under the corresponding fishing permit No. PPF/DGOPA-073/25.

Use of AI tools

The authors did not employ any AI tools in this work.

REFERENCES

- Aguilar-Rosas LE, Pedroche FF, Zertuche-González JA. 2014. Algas marinas no nativas en la costa del Pacífico mexicano. In: Mendoza R, Koleff P (eds.), *Especies acuáticas invasoras en México*. Mexico City (Mexico): Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. p. 211-222.
- Baskin Y. 1996. Curbing undesirable invaders. *BioSc.* 6(10):732-736. <https://doi.org/10.2307/1312847>
- Boudouresque CF, Meinesz A, Ribera MA, Ballesteros E. 1995. Spread of the green alga *Caulerpa taxifolia* (Caulerpales, Chlorophyta) in the Mediterranean: possible consequences of a major ecological event. *Sci Mar.* 59:21-29.
- Carlton JT. 1996. Biological invasion and cryptogenic species. *Ecology.* 77:1653-1655.
- Ceccherelli G, Piazzini L, Cinelli F. 2000. Response of non-indigenous *Caulerpa racemosa* (Forsskål) J. Agardh to the native seagrass *Posidonia oceanica* (L.) Delile: effect of density of shoots and orientation of edges of meadows. *J Exp Mar Biol Ecol.* 243(2):227-240. [https://doi.org/10.1016/S0022-0981\(99\)00122-7](https://doi.org/10.1016/S0022-0981(99)00122-7)
- Ceccherelli G, Piazzini L. 2001. Dispersal of *Caulerpa racemosa* fragments in the Mediterranean: lack of detachment time effect on establishment. *Bot Mar.* 44:209-213. <https://doi.org/10.1515/BOT.2001.027>
- Comité Asesor Nacional sobre Especies Invasoras. 2010. Estrategia nacional sobre especies invasoras en México: prevención, control y erradicación. Mexico City (Mexico): Comisión para el Conocimiento y Uso de la Biodiversidad. Reporte. 94 p.
- [CONABIO] Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. 2025. Estado actual de las especies de macroalgas introducidas e invasoras en la costa Pacífico de México: CONABIO; [2025 August]. <http://ipttest.conabio.gob.mx/iptconabiotest/resource?r=SNIB-GN007>
- De Gaillande C, Payri C, Remoissenet G, Zubia M. 2017. *Caulerpa* consumption, nutritional value and farming in the Indo-Pacific region. *J Appl Phycol.* 29(5):2249-2266. <https://doi.org/10.1007/s10811-016-0912-6>
- [DOF] Diario Oficial de la Federación. 2010 Apr 6. Decreto por el que se reforman y adicionan diversas disposiciones de la Ley General del Equilibrio Ecológico y la Protección al Ambiente, y de la Ley General de Vida Silvestre. Mexico City (Mexico): Secretaría de Gobernación. Decreto. 416 p.
- Draisma SG, Sauvage T, Lagourgue L, Kato A, Dumilag RV, Lim PE, Zubia M, Payri CE. 2025. A species diversity assessment of the genus *Caulerpa* (Bryopsidales) in the Central Indo-Pacific marine realm based on tufA DNA sequences. *Phycologia.* 1-22. <https://doi.org/10.1080/00318884.2025.2575521>
- Fernández-García C, Cortés-Núñez J. 2005. *Caulerpa sertularioides*, a green alga spreading aggressively over coral reef communities in Culebra Bay, North Pacific of Costa Rica. *Coral Reefs* 24:10. <https://doi.org/10.1007/s00338-004-0440-8>
- Fernández-García C, Cortés-Núñez J. 2009. Propagación del alga verde *Caulerpa sertularioides* en el Pacífico de Costa Rica. *Biocenosis.* 22(1-2):200980. <https://revistas.uned.ac.cr/index.php/biocenosis/article/view/1258>
- Francour P, Harmelin-Vivien M, Harmelin JG, Duclerc J. 1995. Impact of *Caulerpa taxifolia* colonisation on the littoral ichthyofauna of north-western Mediterranean Sea: preliminary results. *Hydrobiologia.* 300(1):345-353. <https://doi.org/10.1007/BF00024475>
- Gao X, Choi HG, Park SK, Sun ZM, Nam KW. 2019. Assessment of optimal growth conditions for cultivation of the edible *Caulerpa okamurae* (Caulerpales, Chlorophyta) from Korea. *J Appl Phycol.* 31(3):1855-1862. <https://doi.org/10.1007/s10811-018-1691-z>
- Guiry MD, Guiry GM. 2025. AlgaeBase: National University of Ireland; [accessed 2025 March 15]. <https://www.algaebase.org>.
- Horstmann U. 1983. Cultivation of the green alga *Caulerpa racemosa*, in tropical waters and some aspects of its physiological ecology. *Aquaculture.* 32(3-4):361-371. [https://doi.org/10.1016/0044-8486\(83\)90233-8](https://doi.org/10.1016/0044-8486(83)90233-8)
- Mary A, Mary V, Lorella A, Jonathan RM. 2009. Rediscovery of naturally occurring seagrass *Caulerpa lentillifera* from the Gulf of Mannar and its mariculture. *Curr Sci.* 97(10):1418-1420.
- Okamura K. 1897. On the algae from Ogasawara-jima (Bonin Islands). *Bot Mag. Tokyo* 11:1-17.
- Okamura K. 1916. *Icones of Japanese algae. Vol. IV.* Tokyo (Japan): Kazamashobo. 372 p.
- Park SK, Kim JK, Choi HG, Jang KK. 2022. Effect of substratum types on the growth of assimilators and stolons of *Caulerpa okamurae* (Bryopsidales, Chlorophyta). *Algae.* 37(4):293-299. <https://doi.org/10.4490/algae.2022.37.12.10>
- Paul VJ, Littler MM, Littler DS, Fenical W. 1987. Evidence for chemical defense in tropical green alga *Caulerpa ashmeadii* (Caulerpales: Chlorophyta): Isolation of new bioactive sesquiterpenoids. *J Chem Ecol.* 13(5):1171-1185. <https://doi.org/10.1007/BF01020547>
- Pedroche FF, Aguilar-Rosas LE. 2025. Benthic marine macroalgae non-native to Mexico: An update (2024) for the Mexican Pacific. *Hidrobiológica.* 35(5):183-195.
- Pedroche FF, Silva PC, Aguilar-Rosas LE, Dreckmann KM, Aguilar-Rosas R. 2005. Catálogo de las algas marinas bentónicas del Pacífico de México. I. Chlorophycota:

- Universidad Autónoma de Baja California; [2025 August]. https://www.algaebase.org/search/bibliography/detail/?biblio_id=44769
- Pedroche FF, Senties A. 2020. Diversidad de macroalgas marinas en México. Una actualización florística y nomenclatural. *Cymbella*. 6(1):4-55.
- Piazzi L, Balata D, Ceccherelli G, Cinelli F. 2001. Comparative study of the growth of the two co-occurring introduced green alga *Caulerpa taxifolia* and *Caulerpa racemosa* along the Tuscan coast (Italy, western Mediterranean). *Cryptogam Algal*. 22(4):459-466. [https://doi.org/10.1016/S0181-1568\(01\)01059-5](https://doi.org/10.1016/S0181-1568(01)01059-5)
- Prud'Homme Van Reine WF, Verheij E, Coppejans E. 1996. Species and Ecads of *Caulerpa* (Ulvophyceae, Chlorophyta) in Malesia (South-East Asia): Taxonomy, biogeography and biodiversity. *Neth J Aquat Ecol*. 30(2):83-98. <https://doi.org/10.1007/BF02272230>.
- Santini-Bellan D, Arnaud PM, Bellan G, Verlaque M. 1996. The influence of the introduced tropical alga *Caulerpa taxifolia*, on the biodiversity of the Mediterranean marine biota. *J Mar Biol Assoc UK*. 76(1):235-237. <https://doi.org/10.1017/S0025315400029180>
- Scagel RF. 1956. Introduction of a Japanese alga *Sargassum muticum* into the northeast Pacific. *Fish Res Paper, Wash Dept Fish*. 1(4):49-58.
- Shin JH, Park SK, Choi HG. 2021. Growth differences in edible *Caulerpa okamuræ* (Weber-van Bosse) thallus parts with and without apex removal. *Korean J Fish and Aquat Sci*. 54(3):311-317. <https://doi.org/10.5657/KFAS.2021.0311>
- Smith CM, Walters LJ. 1999. Fragmentation as a strategy for *Caulerpa* species: fates of fragments and implications for management of an invasive weed. *Mar Ecol*. 20(3-4):307-319. <https://doi.org/10.1046/j.1439-0485.1999.2034079.x>
- Smith TB, Fong P, Kennison R, Smith J. 2010. Spatial refuges and associational defenses promote harmful blooms of the alga *Caulerpa sertularioides* onto coral reefs. *Oecologia*. 164(4):1039-1048. <https://doi.org/10.1007/s00442-010-1698-x>
- Trono GC. 1990. Status of production and utilization of seaweeds in the Philippines. Part II: Country status reports. Cebu City (Philippines): Food and Agriculture Organization of the United Nations. Report of the Regional Workshop on the Culture and Utilization of Seaweeds. p. 27-31.
- Weber-van Bosse A. 1898. Monographie des Caulerpes. *Ann Jard Bot Buitenzorg*. 15(2):243-401, plates 20-34.
- Wright JT, Davis AR. 2006. Demographic feedback between clonal growth and fragmentation in an invasive seaweed. *Ecology*. 87(7):1744-1754. [https://doi.org/10.1890/0012-9658\(2006\)87\[1744:DFBCGA\]2.0.CO;2](https://doi.org/10.1890/0012-9658(2006)87[1744:DFBCGA]2.0.CO;2)
- Zubia M, Draisma SGA, Morrissey KL, Varela-Álvarez E, de Clerck O. 2020. Concise review of the genus *Caulerpa* JV Lamouroux. *J Appl Phycol*. 32(1):23-39. <https://doi.org/10.1007/s10811-019-01868-9>