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Benthic marine macroalgae non-native to Mexico: An update (2024) for the Mexican Pacific

Macroalgas marinas bentónicas no nativas de México: una actualización (2024) para el Pacífico mexicano

Francisco F. Pedroche[1] and Luis Aguilar-Rosas[2]

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[1] Departamento de Ciencias Ambientales, Universidad Autónoma Metropolitana-Lerma, México & University Herbaria, University of California, Berkeley, USA

[2] Instituto de Investigaciones Oceanológicas, Universidad Autónoma de Baja California, Ensenada, Baja California, México

***Corresponding author:**
Francisco F. Pedroche: e-mail: fpedroche@correo.ler.uam.mx

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ABSTRACT

Background. There is concern about marine algae introduced in geographical areas other than their known distribution. These species are known as non-native. **Goals**. A discussion and an update of those species considered alien to the Mexican Pacific flora. **Methods**. The information published until 2024 was analyzed, gathering data on morphology, reproduction, molecular information, years of registration, and distribution of each species. The criterion for determining if it belonged to the non-native category was based on the availability of molecular information. To determine their current status, reproduction data, permanence time span, and distribution limits were considered. **Results**. There are 49 names of species considered non-native; 25 of them have been published in the compiled literature and 24 are new additions, which refer to recent records in the flora of the Mexican Pacific. Ten belong to Chlorophyta, 17 to Phaeophyceae, and 22 to Rhodophyta. Seventeen are restricted to the western coast of Baja California and 5 to the Gulf of California. Eight are distributed throughout the Mexican Pacific. Twenty-nine are recognized as populations of non-native species; 14 are cryptogenic. As for their current status, 9 are occasional and 20 are naturalized; none were considered invasive. **Conclusions**. The study of colonization in the Mexican Pacific faces several challenges, among them, the reliability of previously published data and their taxonomic and nomenclatural component, the consensus of the concepts used to characterize non-native species, the challenge of their detection, the stage of the populations and the effect of this colonization on the environment. Several of these challenges cannot be faced if we do not have a frequently updated and reliable census of the diversity of marine macroalgae in the Mexican Pacific.

Keywords: challenges, cryptogenic, invasive, naturalized, populations.

RESUMEN

Antecedentes. Actualmente, existe preocupación sobre las poblaciones de algas marinas introducidas en áreas geográficas diferentes a su distribución conocida. A estas especies se les conoce como no nativas. **Objetivos**. Presentar una discusión y una actualización de aquellas especies consideradas como ajenas a la flora del Pacífico mexicano. **Métodos**. Se analizó la información publicada hasta 2024, reuniendo datos sobre morfología, reproducción, información molecular, años de registro y distribución de cada especie. El criterio para determinar su pertenencia a la categoría de no nativas fue la existencia de información molecular. Para determinar su estatus actual se consideraron los datos de reproducción, el lapso de permanencia y los límites de distribución. **Resultados**. Hay 49 nombres de especies consideradas no nativas; 25 de ellos han sido publicados en la literatura compilada y 24 son nuevas adiciones, que se refieren a registros recientes en la flora del Pacífico mexicano. Diez son Chlorophyta, 17 Phaeophyceae y 22 Rhodophyta. 17 se restringen a la costa occidental de Baja California y 5 al Golfo de California. Ocho se distribuyen a lo largo del Pacífico mexicano. Se reconocen 29 poblaciones de especies no nativas, 14 como criptogénicas. En cuanto a su estatus actual, 9 son ocasionales y 20 naturalizadas, ninguna fue considerada invasora. **Conclusiones**. El estudio de esta colonización enfrenta varios retos, entre ellos, la confiabilidad en los datos publicados y su componente taxonómico y nomenclatural, el consenso de los conceptos para caracterizar a las especies no nativas, el reto de su detección y en que estadio se encuentran y, finalmente, cuál es su efecto en el entorno ambiental. Estos retos no pueden ser enfrentados sin un censo actualizado frecuentemente y confiable de la diversidad de algas marinas en México.

Palabras clave: desafíos, criptogénicas, invasoras, naturalizadas, poblaciones.

INTRODUCTION

Pacific Mexico has 1183 infrageneric taxa of seaweeds (Pedroche & Sentíes, 2020). Of these, 60% have type localities outside the region without any explanation to date; however, from the 1990s, in those areas with continuous observation of the flora were detected taxa not seen before. These were labeled as alien species to the floristic cast, in other words, nonindigenous species. This may be due to the new global perception of species introduced by man's hand and known as non-native.

The first comments about the possibility that certain species were introduced into Mexico as a result of the transfer by ships came from Dawson (1941) who mentioned *Ishige foliacea* Okamura as an Asian component in the Gulf of California, which was described in 1936 (Okamura, 1936); however, earlier, Setchell and Gardner (1924) had recognized *Polyopes sinicola* Setchell & N. L. Gardner as a component of the Gulf phycoflora. Chihara (1969) showed that they were conspecific by retaining as a basionym the taxon of Setchell and Gardner, by priority, but assigning them to the genus *Ishige* Yendo (an alga considered as rhodophyte, but which belongs to the class Phaeophyceae) and proposing the combination *Ishige sinicola* (Setchell & N. L. Gardner) Chihara. The first big unknown is if this taxon became a Mexican species introduced to Japan and not *vice versa*, as previously thought. Another taxon mentioned by Dawson was *Zanardinia prototypus* Zanardini nom. illeg. (= *Zanardinia typus* (Nardo) P. C. Silva), a Mediterranean species that made an impression on him because of its distribution; however, later he described it as a new species from Mexico, *Cutleria hancockii* E. Y. Dawson (Dawson, 1944), relegating *Z. prototypus* as a misapplied name for this species. Leaving this historical anecdote behind, the first record published for a non-native species corresponds to *Sargassum muticum* (Yendo) Fensholt, which supposedly arrived in Mexico around the 1970s (Nienhuis, 1982), but there is no precise locality nor a detailed record of this assertion. Records of this species began in 1978 (Devinny, 1978) and continued during 1982 (Aguilar-Rosas et al., 1982; Pacheco-Ruíz, 1982), without mention of its alien condition until 1985 (Aguilar-Rosas & Aguilar-Rosas, 1985), when *S. muticum* was recognized as a non-native species.

The first integration of information and records on macroalgae introduced to Mexico was published in Okolodkov et al. (2007) with a list containing six taxa: *Caulerpa taxifolia* (M. Vahl) C. Agardh, *Codium fragile* subsp. *tomentosoides* (Van Goor) P. C. Silva (= *Codium fragile* (Suringar) Hariot), *Ulva fasciata* Delile (= *Ulva lactuca* Linnaeus), *Cutleria cylindrica* Okamura (= *Mutimo cylindricus* (Okamura) H. Kawai & T. Kitayama), *Sargassum muticum* (Yendo) Fensholt, *Undaria pinnatifida* (Harvey) Suringar, and *Porphyra suborbiculata* Kjellman (= *Pyropia suborbiculata* (Kjellman) J. E. Sutherland & al.). Others joined this initiative to keep the records updated and detect new introductions (Miller et al., 2011; Riosmena-Rodríguez et al., 2012; Aguilar-Rosas et al., 2013; Pérez-Estrada et al., 2013; Aguilar-Rosas et al., 2014a, 2014b; Chávez-Sánchez et al., 2019; CONABIO, 2024). According to them, the Mexican Pacific has 25 species that are considered non-native.

In this study, we present an updated overview of species considered non-native to the Mexican Pacific, their status as of 2024, and a brief analysis of the challenges that, from our point of view, are faced by the study of these organisms.

METHODS

A synthesis of all the species published as non-native for the Pacific of Mexico was made, as well as the new records that have occurred since 2020 in the phycoflora of this region. This is thanks to the continuous monitoring to update the catalog of benthic marine algae in the Mexican Pacific (Pedroche et al., 2005, 2008, 2025). The nomenclature of the taxa was reviewed to cite only currently accepted (correct) names because some reports use synonyms. Special attention was paid to publications that mention the presence of reproductive structures or molecular studies that support the origin and affinity of populations that do not belong to the Mexican Pacific. The last two criteria have the purpose, on the one hand, to confirm the non-native nature of the taxa, either in other parts of the world with Pacific affinities or in the Pacific of Mexico itself, and second, to speculate as to the stage in which the introduced populations are currently found, according to table 1. The dates of the records, from their first observations to the date, were also considered to give an idea of the continuity of their presence on the coast mentioned above. Species identifications, considered in the literature as non-native but supported only by morphological observations, were considered cryptogenic in the sense of Carlton (1996). As there is no certainty about the routes of introduction or the vehicles of their dispersion, as well as about the possible effects they could have on the environment of the ecosystems, brief comments have been included.

RESULTS

To date, there are 49 names of species considered non-native (table 1): 25 of them have been published in the compiled literature, and 24 are new additions that concern recent records in the flora of the Mexican Pacific. Ten are Chlorophyta, 17 are Phaeophyceae, and 22 belong to Rhodophyta. In table 1, the names of 14 species that have changed their names are given in parentheses, one of them being a misapplied name *Cladostephus spongiosus* auct. non (Hudson) C. Agardh 1817, p. xxvi. Of these 49 species, one considered as cryptogenic in 2011 (Miller et al., 2011), is a new addition (table 1). Most identifications have only morphological support. In some of these (11), their non-native character has been evidenced by molecular studies in non-Mexican regions that confirm their origin outside of the Mexican Pacific, and 17 were studied based on the material from the Mexican Pacific, which supports their non-native character (table 2). Fourteen species, as molecular data do not support them, are considered cryptogenic in the sense of Carlton (1996) (table 3). As for their distribution, some of them (17) are restricted to the western coast of Baja California or the Gulf of California (5). Throughout the Mexican Pacific, there are 8, and the rest share two regions (table 2). Tables 4 and 5 show only the species with molecular support, their period of presence on the Mexican Pacific coasts, and their local or regional distribution interval from north to south. The oldest non-native macroalgal species date back to the 1920s (2) (table 5); three species were first recorded in the 1940s, and the largest number is recorded from 1980 onwards. The oldest ones generally have more extensive distributions (table 4).

Table 1. Species considered non-native from the Mexican Pacific.

Species name	Higher taxonomy	A	B	C	D	E	F	G	H	I
Acanthophora spicifera (M. Vahl) Børgesen	Rhodophyta	--	--	--	--	--	--	X	--	--
Asparagopsis taxiformis (Delile) Trevisan	Rhodophyta	--	--	XX	--	--	--	--	--	X
Caulacanthus okamurae Yamada	Rhodophyta	--	--	--	--	--	--	--	--	X
C. ustulatus (Mertens ex Turner) Kützing	Rhodophyta	X	--	X	--	--	--	X, X	--	--
Caulerpa verticillata J. Agardh	Chlorophyta	X	--	--	--	--	X	--	--	--
Chondracanthus squarrulosus (Setchell & N. L. Gardner) Hughey & al.	Rhodophyta	X	--	--	--	--	--	X, X	--	--
Cladostephus hirsutus (Linnaeus) Boudouresque & M. Perret-Boudouresque (**as** *Cladostephus spongiosus*)	Phaeophyceae	X	--	X	--	--	--	X, X	--	--
Codium fragile (Suringar) Hariot (= *Codium fragile tomentosoides* (Goor) P. C. Silva)	Chlorophyta	X	X	--	--	--	--	--	--	--
Colpomenia peregrina Sauvageau	Phaeophyceae	--	--	--	--	--	--	--	--	X
Dactylosiphon durvillei (Bory de Saint-Vincent) Santiañez & al. (= *Colpomenia phaeodactyla* M. J. Wynne & J. N. Norris)	Phaeophyceae	--	--	--	--	--	--	--	--	X
Dasya pedicellata (C. Agardh) C. Agardh (= *Dasya baillouviana* (S. Gmelin) Montagne)	Rhodophyta	--	--	--	--	--	--	--	--	X
Dichotomaria marginata (J. Ellis & Solander) Lamarck	Rhodophyta	--	--	--	--	--	--	--	--	X
Dictyopteris prolifera (Okamura) Okamura	Phaeophyceae	X	--	--	--	--	--	X, X	--	--
D. undulata Holmes	Phaeophyceae	--	--	--	--	--	--	--	--	X
Dictyota coriacea (Holmes) I. K. Wang & al.	Phaeophyceae	--	--	--	--	--	--	--	--	X
Gelidium robustum (N. L. Gardner) Hollenberg & I. A. Abbott	Rhodophyta	X	--	--	--	--	--	--	--	--
Gracilaria parvispora I. A. Abbott	Rhodophyta	X	--	--	--	X	--	--	--	--
G. textorii (Suringar) Detoni	Rhodophyta	--	--	--	--	--	--	--	--	X
G. vermiculophylla (Ohmi) Papenfuss	Rhodophyta	X	--	X	--	--	--	X, X	--	--
Gracilariopsis longissima (S.G.Gmelin) M. Steentoft & al.	Rhodophyta	--	--	--	--	--	--	--	--	X
Grateloupia turuturu Yamada	Rhodophyta	X	--	X	X	--	--	X, X	--	--
Hypnea musciformis (Wulfen) Lamouroux	Rhodophyta	--	--	--	--	--	--	--	--	X
Macrocystis pyrifera (Linnaeus) C. Agardh	Phaeophyceae	X	--	--	--	--	--	--	--	--
Melanothamnus harveyi (Bailey) Díaz-Tapia & Maggs	Rhodophyta	--	--	--	--	--	--	--	--	X
Mutimo cylindricus (Okamura) H. Kawai & T. Kitayama (= *Cutleria cylindrica* Okamura)	Phaeophyceae	X	X	X	--	--	--	X, X	--	--
Pachymeniopsis lanceolata (Okamura) Y. Yamada ex S. Kawabata (= *Grateloupia lanceolata* (Okamura) S. Kawaguchi)	Rhodophyta	X	--	--	X	--	--	--	--	--
Padina arborescens Holmes	Phaeophyceae	--	--	--	--	--	--	--	--	X
P. crassa Yamada	Phaeophyceae	--	--	--	--	--	--	--	--	X
Pikea yoshizakii C. A. Maggs & B. A. Ward	Rhodophyta	--	--	--	--	--	--	--	--	X
Planosiphon gracilis (Kogame) McDevit & G. W. Saunders (= *Scytosiphon gracilis* Kogame)	Phaeophyceae	--	--	X	--	--	--	X, X	--	--
Predaea japonica Yoshida	Rhodophyta	--	--	--	--	--	--	--	--	X
Pyropia suborbiculata (Kjellman) J. E. Sutherland & al. (= *Porphyra suborbiculata* Kjellman)	Rhodophyta	X	X	X	--	--	--	X, X	--	--
Rugulopteryx okamurae (E. Y. Dawson) I. K. Hwang & al.	Phaeophyceae	--	--	--	--	--	--	--	--	X
Sargassum horneri (Turner) C. Agardh (= *S. filicinum* Harvey)	Phaeophyceae	X	--	X	X	--	--	X, X	--	--
S. muticum (Yendo) Fensholt	Phaeophyceae	X	X	X	X	--	--	X, X	--	--
Scinaia interrupta (A. P. de Candolle) M. J. Wynne	Rhodophyta	--	--	--	--	--	--	--	--	X
Scytosiphon lomentaria (Lyngbye) Link	Phaeophyceae	--	--	--	--	--	--	--	--	X
Sporochnus pedunculatus (Hudson) C. Agardh	Phaeophyceae	--	--	XX	--	--	--	--	--	--
Spyridia filamentosa (Wulfen) Harvey	Rhodophyta	--	--	--	--	--	--	--	--	X
Ulva australis Areschoug (= *U. pertusa* Kjellman)	Chlorophyta	X	--	XX	--	--	--	X, X	--	X

Species name	Higher taxonomy	A	B	C	D	E	F	G	H	I
U. lactuca Linnaeus (= *Ulva fasciata* Delile)	Chlorophyta	X	X	X	--	--	--	X, X	--	--
U. lactuca (= *Ulva fasciata* Delile).	Chlorophyta	X	X	X	--	--	--	X, X	--	--
U. lactuca (= *Ulva lobata* (Kützing) Harvey)	Chlorophyta	--	--	--	--	--	--	X, X	--	--
U. lactuca (= *Ulva nematoidea* Bory)	Chlorophyta	--	--	--	--	--	--	X, X	--	--
U. ohnoi M. Hiraoka & S. Shimada	Chlorophyta	--	--	--	--	--	--	--	X	X
U. tepida Masakiyo & S. Shimada	Chlorophyta	--	--	--	--	--	--	--	X	X
U. torta (Mertens) Trevisan	Chlorophyta	--	--	--	--	--	--	--	X	X
Undaria pinnatifida (Harvey) Suringar	Phaeophyceae	X	X	X	--	--	--	X, X	--	--
Yendoa hakodatensis (Yendo) C. C. Santos (= *Lomentaria hakodatensis* Yendo)	Rhodophyta	X	--	X	--	--	--	X, X	--	--

In parentheses, old names used in the literature indicate = synonyms, **as** misapplied names. Species XX were considered cryptogenic in 2011; X, X were cited in both papers. A) CONABIO, 2024; B) Okolodkov et al., 2007; C) Miller et al., 2011; D) Aguilar-Rosas et al., 2013; E) García-Rodríguez et al., 2013; F) Pérez-Estrada et al., 2013; G) Aguilar-Rosas et al., 2014a, 2014b; H) Chávez-Sánchez et al., 2019; I) New additions (highlighted in green). Lines highlighted in blue indicate translocated natives, red indicates species confirmed as not present, orange denotes native species, and grey represents the same taxon.

DISCUSSION

Much has been written about introducing species outside their "natural" distribution range. As a starting point, see Carlton (1996), considered by many authors the father of this topic. Concerning algae, the integrative work of Williams and Smith (2007) is a good example. To interpret the results presented above, we have chosen an approximation based on what we consider to be challenges in studying this phenomenon. They are not the only ones and perhaps not the most important, but they allow us to highlight the problems found in this update.

Available information and its update. The first step to recording non-native algae comes from specialized literature. Above, we mentioned the main sources of information which may have some important deviations. The first point to consider is conceptualizing the processes and patterns in non-native algal events. Many sources do not include the concepts used, their origin, or what literature supports them. It is taken for granted that these species, since they were not present before and now appear, are non-native species, or, worse, they are treated as invasive (box 1). Second, there is a lack of a critical view when citing names, not only if they belong to the species mentioned (the taxonomic and nomenclatural challenge), but it is necessary to explain why it is considered a non-native species to support the mention with morphological data that allow the judgment of other authors and its comparison with the known circumscriptions of the taxa to avoid misidentifications (Golo et al., 2023; Pedroche, 2024). Third, databases must be carefully reviewed to verify the information deposited there. In a word, non-native species lists should be considered with reserves (McGeoch et al., 2012). Here are some examples. Two species recorded as non-native in table 1, *Macrocystis pyrifera* (Linnaeus) C. Agardh and *Gelidium robustum* (N. L. Gardner) Hollenberg & I. A. Abbott, were originally described and are considered to be native to the American Pacific (Gardner, 1927; Astorga et al., 2012), *Caulerpa verticillata* J. Agardh has not been recorded as a non-native species anywhere in the world (Smith & Walters, 1999), but its presence in Pacific Mexico could be the announce of it (Mateo-Cid & Mendoza-González, 1991; Pérez-Estrada et al., 2013). Translocation in contiguous areas is not considered an introduction (box 1) and, therefore, is not a non-native organism, such is the case of *Chondracanthus squarrulosus* (Setchell & N. L. Gardner) Hughey & al. Endemic to the Gulf of California and translocated to the Pacific coast of Baja California (Aguilar-Rosas et al., 2014a), it seems to have been eradicated. For several years, *Codium fragile* subsp. *tomentosoides* (Van Goor) P. C. Silva (= *Codium fragile* (Suringar) Hariot) was considered a non-native and invasive species. However, recently, molecular evidence ruled out, for now, its presence in Mexico (Pedroche, 2021), but it is still in the databases (CONABIO, 2024). Tables 1 to 4 synthesize the knowledge from the first records to date, including those records with molecular evidence of their origin or introduction, which ones are considered cryptogenic, our proposal of "true" non-native seaweeds, and the state they could be present right now. There is no solid evidence of how they arrived in the Mexican Pacific, and it is possible that different vectors are involved.

Taxonomic and nomenclatural issues. In this section, the change of position in the classification or the alteration of a scientific name entails consequences in the perception of a species as non-native. Of the 49 names cited in table 1, four of them located in the genus *Ulva*, have been translated, based on molecular studies, as synonyms of the species *U. lactuca* (Hughey et al., 2019; Hughe & Gabrielson, 2022). A species with a worldwide distribution now has diverse populations in Mexico, which are difficult to distinguish and define as non-native. On the other hand, the nomenclatural decision to synonymize *Colpomenia phaeodactyla* M. J. Wynne & J. N. Norris, described from the Gulf of California with *Dactylosiphon durvillei* (Bory de Saint-Vincent) Santiañez & al., a species from the Southern Hemisphere and considered non-native (invasive) in New Zealand, but with doubts about its discontinuous distribution (Lee et al., 2012), is at this moment considered as non-native to Mexico. *Caulacanthus ustulatus* (Mertens ex Turner) Kützing, which is treated as a possible non-native species (Aguilar Rosas et al., 2014b), could be confused with *Caulacanthus okamurae*, a taxon from Japan, also considered non-native. Zuccarello et al. (2002b) consider that *C. ustulatus* may be cosmopolitan, while studies by Yang and Kim (2023) suggest that this taxon is restricted to the Atlantic. So, could the records of *C. ustulatus* be misapplied names and correspond to the non-native species *C. okamurae*, or are both taxa found in the Mexican Pacific and both non-native? *Predaea japonica* Yoshida, with a distribution restricted to Japan (Guiry & Guiry, 2024), may be a non-native or a species new to science.

BOX 1. Native and non-native species classification

Native	**Non-native***
A population of a known species, originated in the geographic region under study or that was recently or some time ago established, but **without direct human action**.	A population of a known species introduced into the geographical area of study as **a result of direct human action**.
NATURAL DISPERSION **Colonization** Species (populations) that spread naturally without human action to places not previously occupied by them. **Recolonization** Species (populations) that return to previously colonized places. Generally, this is due to events in their life history. INDUCED DISPERSION **Neo-natives** Alteration in species distribution due to environmental modification indirectly caused by human activities. **Outbreak species** Native species that invade and displace other native populations. They have the potential to grow massively. TRANSLOCATION **Assisted colonization** Intentional alteration, in its native distribution, in contiguous areas.	OCCASIONAL **Temporal** They establish and even breed casually in an area, but without forming self-replacement populations. They usually rely on repeated introductions. **Permanent** They establish themselves in the introductory area and form self-standing populations without reproduction. NATURALIZED **Limited** They reproduce consistently and form populations over several generations after their introduction, but on a limited basis. **No limited** They reproduce consistently and form populations that expand their distribution unlimitedly after their introduction. INVASIVE** **Weeds** Non-native populations that grow massive and often have detectable economic or environmental effects. **Transformative** Non-native populations that change the character, condition, shape, or nature of ecosystems.
Cryptogenic: A species that is not demonstrably native or introduced (Carlton, 1996).	

* Known also as alien, exotic, non-indigenous, or introduced species.
** "Invasive alien species are animals, plants or other organisms that are introduced by humans, either intentionally or accidentally, into places outside of their natural range, negatively impacting native biodiversity, ecosystem services or human economy and well-being" (IUCN, 2023).

BOX 1. Native and non-native species classification (from Guzmán-Méndez et al., 2025).

The concept problem. Some of the concepts related to this discipline have come from more than a century ago, and therefore, it is expected that they have been applied in different contexts and have been modified and even originated new concepts. There have been efforts to make certain concepts homogeneous, but in animals or vascular plants, not for algae. Many papers include and use patterns, processes, or both for their definitions (Chapman & Carlton, 1991; Carlton, 1996; Richardson et al., 2000; Richardson & Pyšek, 2006; Blackburn et al., 2011; Pereyra, 2016; Essl et al., 2021). Trying to consensual or counsel how we deal with definitions, we used in this paper those recently published by Guzmán et al. (2025) (box 1). It is important to note that colloquially, we speak of species when, in reality, we should refer to them as populations of a species. Thus, it has been seen in the previous challenges that concepts are essential to understanding the manifestation of this introductory event. Several of the species mentioned in table 1 have been cited as invasive because this word is considered a synonym for alien species or exotic species, and without recognizing that in the process of "invasion" there are stages that consolidate their permanence or allow the degree of "maturity" of non-native populations to be recognized (table 4).

Table 2. Species considered non-native from the Mexican Pacific. Morphology studies, molecular studies, and distribution.

Species name	Morphology	DNA studies with material from the Mexican Pacific	DNA studies with material outside Mexico	Pacific Baja California	Gulf of California	Tropical Mexican Pacific
Acanthophora spicifera (M. Vahl) Børgesen	X	--	18	--	X	--
Asparagopsis taxiformis (Delile) Trevisan	X	--	19	X	X	X
Caulacanthus okamurae Yamada	X	--	20	--	X	--
Caulacanthus ustulatus (Mertens ex Turner) Kützing	--	1	--	X	--	--
Caulerpa verticillata J. Agardh	X	--	--	--	X	X
Chondracanthus squarrulosus (Setchell & N. L. Gardner) Hughey & al.	X	--	--	X	X	--
Cladostephus hirsutus (Linnaeus) Boudouresque & M. Perret-Boudouresque (**as** *Cladostephus spongiosus*)	--	2	--	X	--	--
Codium fragile (Suringar) Hariot (= *Codium fragile tomentosoides* (Goor) P. C. Silva)	--	3	--	X	--	--
Colpomenia peregrina Sauvageau	--	4	--	X	X	--
Dactylosiphon durvillei (Bory de Saint-Vincent) Santiañez & al. (= *Colpomenia phaeodactyla* M. J. Wynne & J. N. Norris)	X	--	--	X	X	--
Dasya pedicellata (C. Agardh) C. Agardh *(= Dasya baillouviana* (S. Gmelin) Montagne)	X	--	21	X	X	--
Dichotomaria marginata (J. Ellis & Solander) Lamarck	X	--	--	--	X	X
Dictyopteris prolifera (Okamura) Okamura	X	--	--	X	--	--
Dictyopteris undulata Holmes	X	--	--	X	X	--
Dictyota coriacea (Holmes) I. K. Wang & al.	X	--	--	X	X	--
Gelidium robustum (N. L. Gardner) Hollenberg & I. A. Abbott	X	--	--	X	--	--
Gracilaria parvispora I. A. Abbott	--	5	--	X	X	X
Gracilaria textorii (Suringar) Detoni	X	--	--	X	X	X
Gracilaria vermiculophylla (Ohmi) Papenfuss	--	6	--	X	X	--
Gracilariopsis longissima (S.G.Gmelin) M. Steentoft & al.	--	7	--	--	X	X
Grateloupia turuturu Yamada	--	8	--	X	--	--
Hypnea musciformis (Wulfen) Lamouroux	X	--	22	--	X	--
Macrocystis pyrifera (Linnaeus) C. Agardh	X	--	23	X	--	--
Melanothamnus harveyi (Bailey) Díaz-Tapia & Maggs	X	--	24	X	X	--
Mutimo cylindricus (Okamura) H. Kawai & T. Kitayama (= *Cutleria cylindrica* Okamura)	X	--	25	X	--	--
Pachymeniopsis lanceolata (Okamura) Y. Yamada ex S. Kawabata (= *Grateloupia lanceolata* (K. Okamura) S. Kawaguchi)	--	--	26	X	--	--
Padina arborescens Holmes	--	9	--	X	X	--
Padina crassa Yamada	--	10	--	--	X	X
Pikea yoshizakii C. A. Maggs & B. A. Ward	X	--	27	X	--	--
Planosiphon gracilis (Kogame) McDevit & G. W. Saunders (= *Scytosiphon gracilis* Kogame)	--	11	--	X	--	--
Predaea japonica Yoshida	X	--	--	--	X	--
Pyropia suborbiculata (Kjellman) J. E. Sutherland & al. (= *Porphyra suborbiculata* Kjellman)	--	--	28	X	--	--
Rugulopteryx okamurae (E. Y. Dawson) I. K. Hwang & al.	X	--	29	X	X	--
Sargassum horneri (Turner) C. Agardh (= *S. filicinum* Harvey)	--	12	--	X	X	--
Sargassum muticum (Yendo) Fensholt	--	13	--	X	--	--
Scinaia interrupta (A. P. de Candolle) M. J. Wynne	X	--	--	--	X	--
Scytosiphon lomentaria (Lyngbye) Link	X	--	30	X	--	--
Sporochnus pedunculatus (Hudson) C. Agardh	X	--	--	X	--	--
Spyridia filamentosa (Wulfen) Harvey	--	14	--	X	X	X

Species name	Morphology	DNA studies with material from the Mexican Pacific	DNA studies with material outside Mexico	Pacific Baja California	Gulf of California	Tropical Mexican Pacific
Ulva australis Areschoug (= *U. pertusa* Kjellman)	X	15	--	X	--	--
Ulva fasciata Delile (= *U. lactuca)*	X	--	--	X	X	X
Ulva lactuca Linnaeus	X	--	--	X	X	X
Ulva lobata (Kützing) Harvey (= *U. lactuca*)	X	--	--	X	X	X
Ulva nematoidea Bory (= *U. lactuca*)	X	--	--	X	X	X
Ulva ohnoi M. Hiraoka & S. Shimada	--	16	--	X	X	--
Ulva tepida Masakiyo & S. Shimada	--	16	--	X	X	--
Ulva torta (Mertens) Trevisan	--	16	--	X	X	--
Undaria pinnatifida (Harvey) Suringar	--	17	--	X	--	--
Yendoa hakodatensis (Yendo) C. C. Santos (= *Lomentaria hakodatensis* Yendo)	X	--	--	X	X	X

1) Zuccarello et al., 2002b; 2) Heesch et al., 2020; 3) Pedroche, 2021; 4) Lee et al., 2014); 5) García-Rodríguez et al., 2013; 6) Bellorin, 2004; 7) Gurgel et al., 2003; 8) Aguilar Rosas et al., 2012; 9) Vieira et al., 2024; 10) Vieira et al., 2021; 11) Aguilar-Rosas et al., 2006; 12) Riosmena et al., 2012; 13) Le Cam et al., 2020; 14) Zuccarello et al., 2002a; 15) Aguilar-Rosas et al., 2008; 16) Chávez-Sánchez et al., 2019; 17) Uwai et al., 2006; 18) O'Doherty & Sherwood, 2007; 19) Andreakis et al., 2016; 20) Petrocelli et al., 2020; 21) Cassidy et al., 2022; 22) Nauer et al., 2019; 23) Astorga et al., 2012; 24) Díaz-Tapia et al., 2017; 25) Kogishi et al., 2010; 26) Miller et al., 2009; 27) Boo et al., 2015; 28) Hughey & Miller, 2018; 29) Terradas-Fernández et al., 2023; 30) Hoshino et al., 2021.

The detection challenge. The easiest way to discover an alga, possibly not native, is to detect its presence in places where it was not before. This criterion can be used if the regions have been sufficiently sampled, and an updated and reliable floristic list is available before the possible introduction. For example, *Melanothamnus simplex* (Hollenberg) Díaz-Tapia & Maggs is a species recorded for the Pacific and considered native; however, *Melanothamnus harveyi* (Bailey) Díaz-Tapia & Maggs, a taxon from Asia that has been detected in San Diego, California, USA (Díaz-Tapia et al., 2017) could be confused with *M. simplex*, as Mcivor et al. (2001) have shown. It is important to establish the identity of the individuals recorded in the Mexican Pacific to distinguish which could represent an introduction and differentiate them from those representing *M. simplex* (Norris et al., 2017). Recurrent and systematized studies are necessary to ensure an evaluation of the expansion of the non-native algae. Examples of the latter were monitoring the expansion of introduced populations of *Sargassum muticum* (Aguilar-Rosas & Aguilar-Rosas, 1993) and *Sargassum horneri* (Turner) C. Agardh (Riosmena-Rodríguez et al., 2012; Marks et al., 2015) along the western coast of Baja California and those on *Acanthophora spicifera* (M. Vahl) Børgesen (Ávila et al., 2012; Méndez-Trejo et al., 2014; Mendoza Becerril et al., 2023) in Bahia de la Paz, southern Gulf of California. Other criteria may refer to the search for these organisms in environments formed by man and recently constructed (Chapman & Carlton, 1991) as wrecks or other subtidal structures; these studies just began in Mexico (Mendoza-González et al., 2013). These facts show that Mexico does not meet these early detection requirements.

Knowing the status. Another challenge is to evaluate or recognize the non-native condition in a list of algae presumably introduced in a specific area and the moments associated with the population's time since settling in a certain place, developing strategies to survive and expand. Richardson et al. (2000) discussed concepts related to the processes, among them naturalization. This process can be characterized by phases based on barriers (geographical, environmental, reproductive, and dispersal) that must be overcome. However, those who gave us a unified framework to explain these stages were Blackburn et al. (2011), resulting in the patterns mentioned in box 1. In the present case, the decision about non-native status was based on molecular information, not just morphology. Table 2 shows which taxon has this information. In some cases, information was obtained directly from Mexican material, and others had molecular evidence about their alien condition or their isolation in certain geographic areas. Those populations without that evidence were labeled as cryptogenic (table 3), corresponding to 14 species. Therefore, populations with genetic studies were considered non-native (table 4), with 29 species. To address a tentative category in the colonization stage, we select the following criteria: the presence of reproductive structures, area of distribution, and recorded time since their first observation (tables 4, 5).

Table 3. Cryptogenic species in the Mexican Pacific.

Caulerpa verticillata J. Agardh
Dactylosiphon durvillei (Bory de Saint-Vincent) Santiañez & al.
Dichotomaria marginata (J. Ellis & Solander) Lamarck
Dictyopteris prolifera (Okamura) Okamura
Dictyopteris undulata Holmes
Dictyota coriacea (Holmes) I. K. Wang & al.
Gracilaria textorii (Suringar) Detoni
Predaea japonica Yoshida
Scinaia interrupta (A. P. de Candolle) M. J. Wynne
Sporochnus pedunculatus (Hudson) C. Agardh
Spyridia filamentosa (Wulfen) Harvey
Ulva lactuca Linnaeus
Yendoa hakodatensis (Yendo) C. C. Santos
Melanothamnus harveyi (Bailey) Díaz-Tapia & Maggs *

* Norris et al. (2017, p. 44) mention the need to compare, morphologically and molecularly, *Melanothamnus simplex* with *Melanothamnus harveyi*.

Impact. The central element in defining invasive species (box 1) is its impact on ecosystems and, naturally, on humans or their activities. However, little has been done to specify the meaning of "impact" and the context in which it should be used to characterize an invasion. Blackburn et al. (2014), in their classification of impacts caused by non-native species, were careful to distinguish what they refer to as environmental impact as "measurable change to the properties of an ecosystem by an alien species." This definition "considers only effects on the native biota or the ecosystem processes that derive from that environment." The effects of a non-native species on the economy or human societies imply more complex interpretations, blurring the line between strictly environmental and non-environmental impacts (Blackburn et al., 2014). We agree with these arguments, which were used to rethink the case of *Acanthophora spicifera,* a native species from the tropical Atlantic (De Jong et al. 1999), discovered in the Mexican Pacific in 2006, specifically within Bahía de La Paz, southern Gulf of California (Ávila et al., 2012), with additional records documented (Mendoza-Becerril et al., 2023). It exhibits both asexual and sexual reproduction (Schnoller et al. 2016), and it is spreading into areas beyond the sites of introduction, overcoming dispersal barriers with records on the western Pacific side of Baja California (K. León Cisneros, pers. comm.). Schnoller et al. (2016) reported that it displaces native species due to its

TABLE 4. Non-native species in the Mexican Pacific.

Species name	Period of time recorded	From	To	Possible status
Acanthophora spicifera (M. Vahl) Børgesen	2010-2023	24° 58' 07	24° 20' 55	Naturalized/limited
Asparagopsis taxiformis (Delile) Trevisan	1924-2014	32° 26' 33	15° 45' 04	Naturalized/no limited
Caulacanthus okamurae Yamada	1944-2014	28° 03' 14	25° 30' 56	Naturalized/limited
C. ustulatus (Mertens ex Turner) Kützing	1961	28° 10' 15	24° 18' 21	Occasional
Cladostephus hirsutus (Linnaeus) Boudouresque & M. Perret-Boudouresque	2010-2020	31° 51' 41	27° 46' 33	Naturalized/no limited
Colpomenia peregrina Sauvageau	1982-2014	32° 20' 08	24° 25' 51	Naturalized/no limited
Dasya pedicellata (C. Agardh) C. Agardh	1957-2014	30° 22' 34	17° 37' 54	Naturalized/no limited
Dichotomaria marginata (J. Ellis et Solander) Lamarck	1944-2014	27° 23' 43	21° 27' 48	Naturalized/limited
Gracilaria parvispora I.A. Abbott	1996-2021	26º 48' 46	15° 09´ 58	Naturalized/no limited
Gracilaria vermiculophylla (Ohmi) Papenfuss	1993-2022	31° 53' 32	22° 32' 18	Naturalized/no limited
Gracilariopsis longissima (S.G.Gmelin) M.Steentoft & al.	1924-2011	29° 03' 52	16° 09' 53	Naturalized/no limited
Grateloupia turuturu Yamada	2012-2013	31° 50' 38	31° 50' 38	Occasional/temporal
Hypnea musciformis (Wulfen) Lamouroux	2011-2014	26° 52' 27	23° 22' 56	Naturalized/limited
Mutimo cylindricus (Okamura) H. Kawai & T. Kitayama	1994	32° 26' 33	31° 51' 36	Occasional/temporal
Pachymeniopsis lanceolata (Okamura) Y. Yamada ex S. Kawabata	2013	31° 50' 38	31° 50' 38	Occasional/temporal
Padina arborescens Holmes	2013-2021	27° 53' 44	27° 53' 05	Naturalized/limited
Padina crassa Yamada	2013-2021	24° 21' 16	19° 06' 17	Naturalized/no limited
Pikea yoshizakii C. A. Maggs & B. A. Ward	1996	32° 26' 33	32° 16' 08	Occasional/temporal
Planosiphon gracilis (Kogame) McDevit & G.W. Saunders	2006	31° 55' 09	31° 55' 09	Occasional/temporal
Pyropia suborbiculata (Kjellman) J. E. Sutherland & al.	2002-2014	32° 18' 06	31° 16' 24	Occasional/permanent
Rugulopteryx okamurae (E. Y. Dawson) I. K. Hwang & al.	1972-2010	31° 53' 32	31° 17' 42	Occasional/permanent
Sargassum horneri (Turner) C. Agardh	2007-2019	29° 04' 14	23° 00' 25	Naturalized/no limited
Sargassum muticum (Yendo) Fensholt	1972-2022	32° 26' 33	24° 25' 51	Naturalized/no limited
Scytosiphon lomentaria (Lyngbye) Link	1945-2010	32° 20' 08	29° 02' 10	Naturalized/limited
Ulva australis Areschoug	2008	31° 43' 28	29° 56' 58	Occasional/temporal
Ulva ohnoi M. Hiraoka & S. Shimada	1982-2022	32° 31' 46	23° 11' 25	Naturalized/limited
Ulva tepida Masakiyo & S.Shimada	1982-2019	32° 31' 46	22° 32' 00	Naturalized/limited
Ulva torta (Mertens) Trevisan	1982-2021	31° 44' 06	22° 32' 00	Naturalized/limited
Undaria pinnatifida (Harvey) Suringar	2004-2019	31° 48' 04	29° 47' 28	Naturalized/limited

TABLE 5. The time span of non-native species in the Mexican Pacific.

Species name	1920-1929	1930-1939	1940-1949	1950-1959	1960-1969	1970-1979	1980-1989	1990-1999	2000-2009	2010-2019	2020-2025
Acanthophora spicifera (M. Vahl) Børgesen											
Asparagopsis taxiformis (Delile) Trevisan											
Caulacanthus okamurae Yamada											
C. ustulatus (Mertens ex Turner) Kützing											
Cladostephus hirsutus (Linnaeus) Boudouresque & M. Perret-Boudouresque											
Colpomenia peregrina Sauvageau											
Dasya pedicellata (C. Agardh) C. Agardh											
Dichotomaria marginata (J. Ellis et Solander) Lamarck											
Gracilaria parvispora I.A. Abbott											
Gracilaria vermiculophylla (Ohmi) Papenfuss											
Gracilariopsis longissima (S.G.Gmelin) M.Steentoft & al.											
Grateloupia turuturu Yamada											
Hypnea musciformis (Wulfen) Lamouroux											
Mutimo cylindricus (Okamura) H. Kawai & T. Kitayama											
Pachymeniopsis lanceolata (Okamura) Y. Yamada ex S. Kawabata											
Padina arborescens Holmes											
Padina crassa Yamada											
Pikea yoshizakii C. A. Maggs & B. A. Ward											
Planosiphon gracilis (Kogame) McDevit & G.W. Saunders											
Pyropia suborbiculata (Kjellman) J. E. Sutherland & al.											
Rugulopteryx okamurae (E. Y. Dawson) I. K. Hwang & al.											
Sargassum horneri (Turner) C. Agardh											
Sargassum muticum (Yendo) Fensholt											
Scytosiphon lomentaria (Lyngbye) Link											
Ulva australis Areschoug											
Ulva ohnoi M. Hiraoka & S. Shimada											
Ulva tepida Masakiyo & S. Shimada											
Ulva torta (Mertens) Trevisan											
Undaria pinnatifida (Harvey) Suringar											

rapid growth and reproductive capacity. According to them, high population densities seem to negatively impact corals' ability to take up light and nutrients (Schnoller et al. 2016), and their rhizoids can penetrate sponge tissues (Ávila et al. 2012). Although we had decided to label it invasive for these reasons (Guzmán- Méndez et al., 2025), recent work did not reveal any impact on the communities where it grows (Licona Angeles et al., 2025). Therefore, we have decided to wait for stronger evidence before changing its status. Further studies are needed to assess the impact of non-native species with certainty. Finally, we assert that these challenges cannot be addressed without a frequently updated and reliable census of seaweed diversity in the Mexican Pacific.

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