

Taxonomy and morphologies of *Undaria pinnatifida* (Phaeophyceae, Laminariales) in Golfo Nuevo, Argentina.

Taxonomía y morfologías de *Undaria pinnatifida* (Phaeophyceae, Laminariales) en Golfo Nuevo, Argentina.

Graciela N. Casas*

Laboratory of Benthic Marine Algae. Institute of Biology of Marine Organisms (IBIOMAR- CONICET). 2915 Brown Boulevard. U9120ACD Puerto Madryn – Argentina.

*email: graciela@cenpat-conicet.gob.ar

Casas, G.N. 2020. Taxonomy and morphologies of *Undaria pinnatifida* (Phaeophyceae, Laminariales) in Golfo Nuevo, Argentina. *Cymbella* 6(2): 82-87.

ABSTRACT

Since 1992, after the accidental introduction of *Undaria pinnatifida* (Phaeophyceae, Laminariales) and its subsequent dispersion along the coasts of Argentina, the species has become part of the local benthic marine flora. In this note, after reviewing the background of *Undaria*, the taxonomic position of the forms found in Golfo Nuevo (Argentina) can be confirmed and the observed morphotypes discussed.

keywords: bioinvasions; Japanese kelp; marine macroalgae; Patagonian coasts; Undaria.

RESUMEN

Desde 1992, luego de la introducción accidental de *Undaria pinnatifida* (Phaeophyceae, Laminariales) y su subsecuente dispersión a lo largo de las costas de Argentina, la especie se ha convertido en parte de la flora marina bentónica local. En esta nota, luego de revisar los antecedentes de *Undaria*, se puede confirmar la posición taxonómica de las formas encontradas en Golfo Nuevo (Argentina) y discutir los morfotipos observados.

palabras clave: alga japonesa; bioinvasiones; costas patagónicas; macroalgas marinas; Undaria

About the taxonomy of *Undaria pinnatifida* (Harvey) Suringar 1873

Most of the genus of brown algae known as “kelps” historically were placed in the Laminariaceae, but according with the opinion of different authors they had to be excluded from this family (Miyabe 1957). In the modern systems the “kelps” were located in the order Laminariales Migula, being the Alariaceae family classified in this order (Setchell & Gardner 1925) and although many species have been transferred to other genera and many new taxa were described, this classification is still used (Guiry & Guiry 2020).

The genus *Undaria* Suringar (previously classified as *Alaria pinnatifida* by Harvey 1859) was placed within the Alariaceae family with four species: *Undaria pinnatifida* (Harvey) Suringar 1873, *Undaria peterseniana* (Kjellmann) Okamura 1915, *Undaria undarioides* (Yendo) Okamura 1915 and *Undaria crenata* Y.-P. Lee & J.T. Yoon 1998 (Guiry & Guiry 2020).

After Saito (1975) *Undaria pinnatifida* (Harvey) Suringar was described from samples collected in Shimoda, Shizuoka Prefecture, Japan. The f. *typica* Yendo is observed in the Southern districts of Japan especially in “shallow” tempered waters. Miyabe (1902) proposed another species: *Undaria distans* (based on the previous description of *Ulop-*

teryx pinnatifida (Harvey) Kjellman, but in opinion of Okamura (1915) it was a local and ecological form of *U. pinnatifida* and was located as f. *distans* Miyabe et Okamura (Miyabe 1957, footnote by J. Tokida). This form is widely distributed in Japan, but especially in the Northern districts and in the cold "deep-water" of Southern districts.

There is another form of *Undaria pinnatifida*, the f. *narutensis* Yendo, with stipe shortest, a less folded sporophylls which become confluent with the blade. This form, however, should be considered as an extreme case of the f. *typica*, and if one strictly distinguishes one from the other many more *formae* may be enumerated, but other than the two, f. *typica* and *distans*, are of less importance (Okamura 1915). Going back to history, Suringar in 1873 classified *U. pinnatifida* in:

- *U. pinnatifida* var. *vulgaris*
 - = f. *subflabellata*
 - = f. *elliptic*
- *U. pinnatifida* var. *elongata*.

But Suringar did not describe them. So, Suringar's 1873 classifications for these infraspecific taxa were disregarded.

Miyabe & Okamura described *Undaria distans* (Miyabe 1902, and translated edition 1957), but Yendo (1911) placed it as a form of *U. pinnatifida* f. *distans* and also suggested f. *typica* and f. *narutensis*.

This classification of Yendo (1911) was followed by Okamura (1915) and defined f. *narutensis* as an extreme form of f. *typica*, rather than as an independent one. Meaning that, Okamura did not recognize *U. pinnatifida* var. *vulgaris* with its forms: f. *subflabellata* and f. *elliptic*, nor *U. pinnatifida* var. *elongata*. For Lee & Yoon (1998) those infraspecific taxa are superfluous and should be discarded, because they were predated by Suringar in 1873 and have priority.

The concept of the genus was extended to include the species created by Okamura in 1915: *U. pinnatifida*, *U. undarioides* and *U. peterseniana* which differ from each other in the form of the adult thallus and in the position where the sporangia are formed (Saito 1975).

In addition to updating the use of the 1873 Suringar's infraspecific taxa, Lee & Yoon (1998) created the species *Undaria crenata*.

In a modern compilation of the marine algae of Japan (Yoshida 1998), three species were recognized: *Undaria pinnatifida* (Harvey) Suringar, *Undaria peterseniana* (Kjellman) Okamura and *Undaria undarioides* (Yendo) Okamura.

Undaria crenata Lee & Yoon was published later to

be included in this compilation and for T. Yoshida (*in litt.*) this species may be a hybrid between the three mentioned above, although this entity is currently accepted taxonomically (Guiry & Guiry 2020).

Undariella Y.-P. Lee (1998) is a valid name but it is not legitimate because it is a superfluous name for *Undariopsis* Miyabe & Okamura, being both genera based on *Laminaria peterseniana* Kjellman.

Yoshida (1998) did not recognize *Undariopsis*, then presumably neither he would had recognized *Undariella* if it had been published in time to be considered, and *Undariella* was subsequently invalidated by its author (Lee 1999).

The varieties and forms suggested by Suringar in 1873 were not recognized by Okamura (1915), causing a great confusion and although Okamura's classification was never well explained, it was and still is followed by Japanese researchers, who generally use *U. pinnatifida* f. *pinnatifida* (= *typica*), *U. pinnatifida* f. *distans* and *U. pinnatifida* f. *narutensis*.

About the morphological variations in Argentina

The samples of *Undaria* collected in the Golfo Nuevo (42° 45' S - 64° 55' W), were mostly related in their anatomical and morphological characteristics with the form *distans*, characterized by stipe elongated, almost equal to the length of deeply pinnated blade with large sporophylls limited to the base of stipe, without proliferations (Fig. 1).

Also were observed morphotypes coincident with the Japanese form *typica* (Fig. 2). In this form the stipe is short and the pinnate blade with relatively shallow sinuses between adjacent pinnae well distant from the midrib. The pinnate characteristic of the blade is sometimes diminished. The sporophyll is large, which upper portions confluent at the base of the blade.

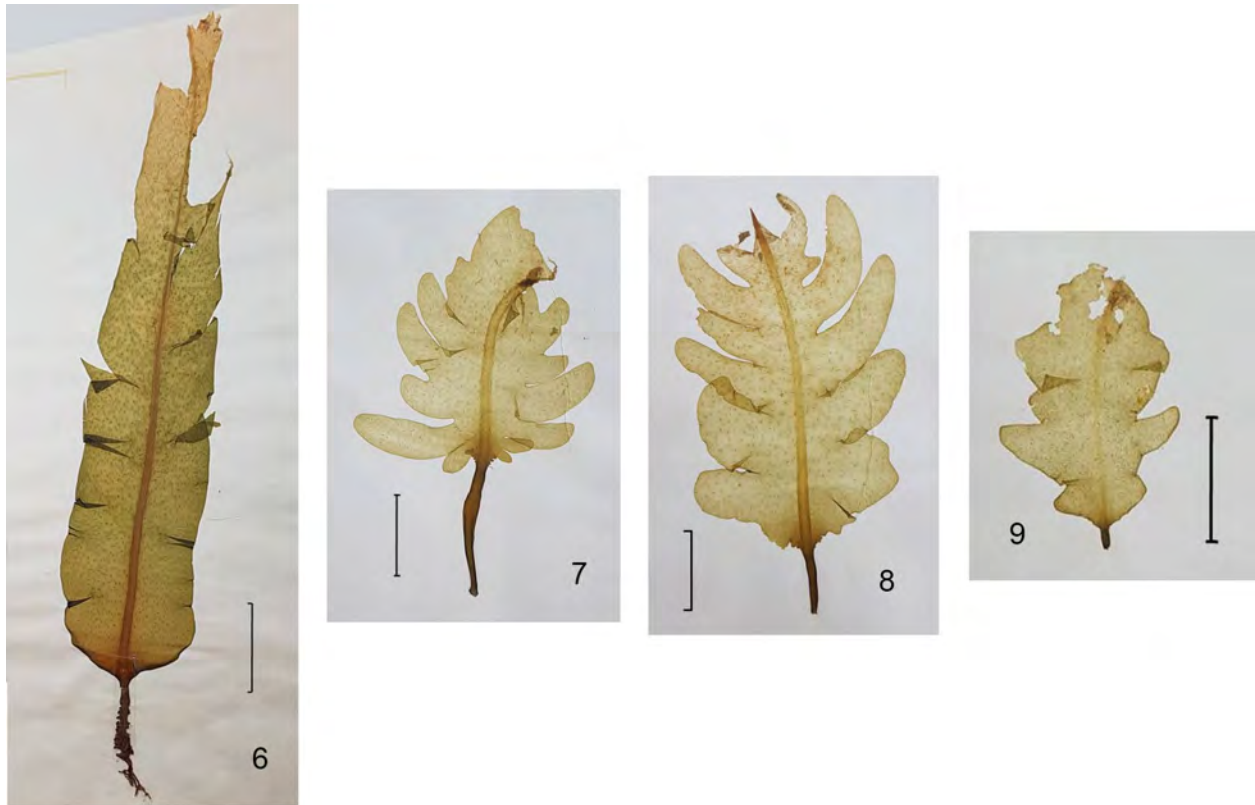
These two forms *typica* and *distans* were found on a regular basis, confirming that both integrate the local populations (Casas 2005, Casas & Piriz 1996, Casas *et al.* 2008).

Another morphotype, occasionally recorded within the samples, matched the description for f. *narutensis* with the sporophyll widely spread over the basal zone of the blade (Fig. 3). Its occurrence was associated with high sea surface temperature in summer and shallow waters.

In a spring sampling (October 1997) specimens collected did not resemble any of the taxonomic forms already described, or the occasional morphological alterations that were seen in Golfo Nuevo. These specimens were classified preliminarily by the author, as similar to *Undaria undarioides* (Fig. 4), opinion shared by Professor Masao Ohno (Kochi University, *in litt.*). But additional taxonomic and molecular studies



Figures 1 – 5. **1)** *Undaria pinnatifida* f. *distans*, collected in Golfo Nuevo, Argentina; scale: 20 cm. (Photo: G. Casas). **2)** *Undaria pinnatifida* f. *típica*; scale: 15 cm. (Photo: G. Casas). **3)** *Undaria pinnatifida* aff. f. *narutensis*, see arrow showing the sporophyll spread over the lowest side of the blade; scale: 20 cm. (Photo: G. Casas). **4)** Morphotype similar to *Undaria undarioides*; scale: 2 cm, collected in Golfo Nuevo in spring-summer (kindly given by Seaweed Herbarium of Cenpat - CONICET). **5)** Form called “aberrant”, collected in Golfo Nuevo: small form elongated; scale: 20 cm. See incipient sporophyll in the lowest third of stipe, resembling the f. *distans* (kindly given by Seaweed Herbarium Collection. Cenpat - CONICET).



Figures 6 – 9. **6)** Non pinnate form with incipient sporophyll; scale: 5 cm (kindly given by Seaweed Herbarium Collection. Cenpat - CONICET). **7)** Small specimen with long stipe; scale: 2 cm. See developed midrib, criptostomata and ligules in the lower part of the blade, characteristics of adult specimens (kindly given by Seaweed Herbarium Collection. Cenpat - CONICET). **8)** Small specimen with adult shape; scale: 2 cm (kindly given by Seaweed Herbarium Collection. Cenpat - CONICET). **9)** Small less pinnate form; scale: 2 cm (kindly given by Seaweed Herbarium Collection. Cenpat - CONICET).

would be necessary to confirm or reject this opinion. Frequently, were found specimens with very remarkable morphological alterations, which could not be related to changes in environmental variables, so they were considered as “aberrant” morphotypes (Figs. 5 - 9), which in a broad sense reflected the great phenotypic plasticity of the species (Casas 2005) and cannot be confused with juvenile specimens of *Undaria*, due to the presence of well-developed midrib and criptostomata, characteristics of adult specimens.

The plants of *Undaria pinnatifida* population living in Golfo Nuevo, can be classified in the forms *typica* and *distans* (Akiyama & Kurogi 1982, Okamura 1915, Tokuda *et al.* 1987; Ueda *et al.* 1963 and photographs kindly sent by K. Akiyama), even the occasional appearance of the *f. narutensis* could be mentioned, although the latter, is considered as an extreme case of *f. typica*.

We agree with Lee & Yoon (1998) that Suringar 1873 classification is valid, but most of the infraspecific taxa lack descriptions, which does not occur with

Japanese descriptions. So, in this work we followed the Japanese classification to identify the Golfo Nuevo specimens (Casas 2005, Okamura 1915). Based only on the morphology of the blade, it could be noted that one of the forms of *U. pinnatifida* present in Golfo Nuevo (Argentina) has characteristics indicative of the *f. typica*, as shortest stipe and pinnate blades although with less deeper incisions. When the differences are clearly referred to the length of the stipe and the location of the sporophyll in the lower third, it would belong to the *f. distans* (Fig. 1) (Casas 2005).

Occasionally, another form was observed with a very short stipe, little divided blade and sporophylic tissue widely extending on its basal portions, characteristics of *U. pinnatifida f. narutensis* (Okamura 1915).

No specimens with the characteristics of *Undaria peterseniana* have been found (Ueda *et al.* 1963, Yoshida 1998) therefore its presence in the Golfo Nuevo has been ruled out.

Regarding the probable presence of *Undaria undarioides*, it is not clear why only few specimens have been found in 1997, five years after the initial introduction of *Undaria pinnatifida* (Casas 2005). Assuming that it was such species, one of the possible explanations is that there have been new subsequent events of introduction of exotic species in the Golfo Nuevo. Then the appearance of *Undaria undarioides* may have been a later event or, that this species after its introduction did not prosper and did not generate a population as abundant as *U. pinnatifida*. The opinions on the different morphologies of *Undaria pinnatifida* are many and controversial. The occasional appearance in Golfo Nuevo of plants belonging to the form *narutensis* and others with important somatic modifications, undoubtedly induce to think on phenotypic alterations as a result of changes in environmental conditions. Observing the forms *typica* and *distans* together in the populations of Golfo Nuevo, leads to suppose that either the two forms have been introduced or these plants would have undergone processes of hybridization and combination of their phenotypic characteristics (Casas 2005). The morphological variations of the sporophytes of *Undaria pinnatifida* are huge and many researchers consider that such variations may be related to environmental conditions, mainly seawater temperature (Morita *et al.* 2003). It is also mentioned that f. *typica* (also called "Inner-bay type" or "Southern type") and f. *distans* ("Outer-bay type" or "Northern type") (Tokuda *et al.* 1987) seem to be caused by environmental and genetic factors (Saito 1972, Watanabe & Nisizawa 1984). In opinion of Pérez *et al.* (1991) the Northern type or f. *distans* and the Southern type or f. *typica* are only phenotypic, because a plant of the f. *distans* transferred to the South of Korea grows with characteristics of f. *typica* and reciprocal characteristics. Since Casas (2005) and Casas *et al.* (2008), the distribution and forms of *Undaria pinnatifida* in Golfo Nuevo, are associated with temperature changes and there is also a clear inverse relationship between this factor and the length of the plants, being the population pattern and phenology of *Undaria pinnatifida* in Golfo Nuevo, conditioned by the relatively small annual ranges of water temperatures. The two mentioned forms that are the most frequently found, and the appearance of the other morphologies that here were discussed might have a phenotypic base, conditioned by environmental factors concluding that the population of *Undaria pinnatifida* from the Golfo Nuevo is evidently polymorphic. This article is based only on morphological differen-

ces in a genus with great plasticity and the conclusions were not confirmed by molecular techniques. However, in the absence of such a resource, the manuscript provides a basis that could be useful for future research, proposing here an enthusiastic invitation to researchers in molecular techniques and taxonomy to join in the taxonomic challenge posed in this work.

REFERENCES

- Akiyama, K. & M. Kurogi. 1982. Cultivation of *Undaria pinnatifida* (Harvey) Suringar, the decrease in crops from natural plants following crop increase from cultivation. *Bulletin Tohoku Regional Fisheries Research Laboratory* 44: 91-100.
- Casas, G.N. 2005. Biology and ecology of *Undaria pinnatifida* (Phaeophyceae) in the Golfo Nuevo, Argentina. PhD Thesis in Biology, Universidad Nacional del Sur (UNS), Argentina. 234 pp.
- Casas, G.N. & M.L. Piriz. 1996. Surveys of *Undaria pinnatifida* (Laminariales, Phaeophyta) in Golfo Nuevo, Argentina. *Hydrobiologia* 326/327: 213-215.
- Casas, G.N., M.L. Piriz & E.R. Parodi. 2008. Population features of the invasive kelp *Undaria pinnatifida* (Phaeophyceae: Laminariales) in Nuevo Gulf (Patagonia, Argentina). *Journal of the Marine Biological Association of the United Kingdom* 88: 21-28.
- Guiry, M.D. & G.M. Guiry. 2020. *AlgaeBase*. World-wide electronic publication. National University of Ireland, Galway. <http://www.algaebase.org>; searched on 10 August 2020.
- Lee, Y.-P. 1998. *Undariella*, a new genus of the Alariaceae (Laminariales, Phaeophyta). *Algae* 13: 419-426.
- Lee, Y.-P. & J.T. Yoon. 1998. Taxonomy and morphology of *Undaria* (Alariaceae, Phaeophyta) in Korea. *Algae* 13: 427-446.
- Lee, Y.-P. 1999. Nomenclatural correction of *Undariella*, a new genus of the Alariaceae (Laminariales, Phaeophyta). *Algae* 14: 79.
- Miyabe, K. 1902. On the Laminariaceae of Hokkaido. *Report of the Investigation on the Marine Resources of Hokkaido* 3: 1-60.
- Miyabe, K. 1957. On the Laminariaceae of Hokkaido. *Journal of Sapporo Agricultural College (An English Edition)* 1: 1-80.
- Morita, T., A. Kurashima & M. Maegawa. 2003. Temperature requirements for the growth of young sporophytes of *Undaria pinnatifida* and *Undaria undarioides* (Laminariales, Phaeophyceae). *Phycological Research* 51: 266-270.
- Okamura, K. 1915. *Undaria* and its species. *The Botanical Magazine*, Tokyo 29: 266-278.
- Pérez, R., R. Kaas, O. Barbaroux, S. Arbault, N. Le Bayon & J.Y. Moigne. 1991. *Undaria*, une japonaise en Bretagne:

- nouvelle technique de culture d'une algue alimentaire. *Equinoxe* 36: 19-30.
- Saito, Y. 1972. On the effects of environmental factors on morphological characteristics of *Undaria pinnatifida* and the breeding of hybrids in the genus *Undaria*. In: I.A. Abbott & M. Kurogi (Eds.) *Contributions to the Systematics of Benthic Marine Algae of the North Pacific. Japanese Society of Phycology*: 117-131.
- Saito, Y. 1975. *Undaria*. In: J. Tokida & H. Hirose (Eds.) *Advances of Phycology in Japan*. VEB Gustav Fischer Verlag, Jena: 304-320.
- Setchell, W.A. & N.L. Gardner. 1925. The Marine Algae of the Pacific Coast of North America. *University of California Publications in Botany* 8: 383-898.
- Suringar, W.F.R. 1873. Illustrationes des algues du Japon. *Musée Botanique de Leide* 1: 77-90, pls 26-33.
- Tokuda, H., M. Ohno & H. Ogawa. 1987. *The Resources and Cultivation of Seaweeds*. Midori Shobo Co. Ltd., Tokyo (In Japanese, translated by Y. Aruga).
- Ueda, S., K. Iwamoto & A. Miura. 1963. *Aquatic Botany* (In Japanese, translated by Y. Aruga). Koseisha Koseikaku Co. Ltd., Tokyo.
- Watanabe, T. & K. Nisizawa. 1984. The utilization of wakame (*Undaria pinnatifida*) in Japan and manufacture of "haiboshi wakame" and some of its biochemical properties. *Hydrobiologia* 116/117: 106-111.
- Yendo, K. 1911. The development of *Costaria*, *Undaria* and *Laminaria*. *Annals of Botany* 25: 691-715
- Yoshida, T. 1998. *Marine Algae of Japan*. Uchida Rokakuho Publ. Co. Ltd., Tokyo.

Recibido: 15 de mayo de 2020

Revisado: 22 de julio de 2020

Corregido: 4 de agosto de 2020

Aceptado: 22 de agosto de 2020

Revisores: Dr. José Zertuche y Dr. Luis Aguilar.