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The genus *Sargassum* in the Adriatic Sea: Morphology, systematics and ecology

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In this paper we present long-term results (1947-1971) of morphological, systematic, and ecological studies of the genus Sargassum *collected in many coastal and island areas on the eastern side of the Adriatic. Morphologically, we describe in detail the three parts of the algae tallus: the holdfast or root (basal plate, rhizoid), the tree or stipe (cauloid, central axis), and the phylloid parts consisting of branches, blades (leaves, phylloclades), cryptostomata, aerocista, bladders (aerocysts, air bladders, gas-filled bladders, swim bladders), and fructifications. Further, we describe* Sargassum *tissue, which is divided into an epidermis, cortex (primary and secondary), and central (axial) tissue. Systematically, we provide data on the composition, shape, and dimension of reproductive recesses (conceptacles) of reproductive organs (oogonia and antheridia). Ecologically, we discuss the vertical and horizontal distribution, variations, and adaptations to ecological factors (temperature, light, sea movements, salinity) of the eastern Adriatic* Sargassum *species.*

Three species of Sargassum *are found in the eastern Adriatic. The species* S. vulgare *C. Ag. is represented by the typical form* S. vulgare *C. Ag. var.* vulgare, *the variation S. vulgare C. Ag. var.* megalophyllum *(Mont.) Grunow, a newly identified variation* S. vulgare *C. Ag. var.* jabukae *Špan, and a newly identified form* S. vulgare *C. Ag. var.* vulgare f. ercegovicii *Špan. The species* S. salicifolium *J. Ag. is represented by the typical form* S. salicifolium *J. Ag. var.* salicifolium *and the newly identified variation* S. salicifolium *J. Ag. var.* linifolium *Špan. The third species is* S. hornschuchii *C. Ag.*

Key words: benthic algae, *Sargassum*, Phaeophyta, morphology, anatomy, systematics, ecology, Adriatic Sea

INTRODUCTION

The genus *Sargassum* includes a large number of specific and intraspecific taxa with extensive geographic and depth distributions. Many of the taxa have great morphological variability. GRUNOW (1915, 1916) reported on 230 *Sargassum* species, varieties, and forms. These algae have a dominant position in the vegetation of tropical, subtropical, and temperate seas. The Australasian area is the center of the distribution of two subgenera, *Phyllotrichia* and *Astrophycus*, which mostly inhabit the coastal areas of Australia and Tasmania. Only a few species are distributed along the coasts of New Zealand, South Africa, and Japan. The subgenus *Eusargassum*, which includes about 168 taxa (GRUNOW, 1915, 1916), is particularly well represented in the warm waters of the Atlantic, Indian, and Pacific Oceans.

The first floristic studies of *Sargassum* began in the eighteenth century. Representatives were mentioned under different names – *Fucus, Baccalaria, Acinaria, Stichophora, Pterocaulon, Spongocarpus, Halochloa, Carpacanthus*, etc. (LINNÈ, 1735, 1753; DONATI, 1750; GINANNI, 1755; GMELIN, 1768; WULFEN, 1768, 1803; TURNER, 1808-1819). Information on the morphology, systematics, and distribution of *Sargassum* taxa were reported by C. AGARDH (1821-1828, 1824), J. AGARDH (1842, 1848, 1889), MONTAGNE (1846), DE TONI (1895), BÖRGESEN (1914, 1926), GRUNOW (1915, 1916), SETCHELL (1931, 1933, 1935, 1936), WOMERSLEY (1954), and others.

Sargassum is represented by a relatively small number of taxa in the Adriatic and Mediterranean. Researchers of Mediterranean and Adriatic benthic flora reported different numbers of *Sargassum* taxa, but all agreed that the number in this area is small compared to the total number of taxa in this genus.

ARDISSONE (1886) reported only two species for the Mediterranean: *S. linifolium* (Turn.) C. Ag. with three variations (var. *salicifolium*, var. *linifolium*, var. *pinnatifolium*), and *S. hornschuchii* C. Ag. J. AGARDH (1889) reported five species: *S. vulgare* C. Ag., *S. salicifolium* J. Ag., *S. linifolium* C. Ag., *S. troichocarpum* J. Ag., and *S. hornschuchii* C. Ag. DE TONI (1895) recorded seven: *S. parvifolium* (Turn.) C. Ag., *S. bacciferum* (Turn.) C. Ag., *S. vulgare* C. Ag. with four forms (f. *linearifolium*, f. *lanceolata*, f. *foliosissimum*, and f. *furcatum*), *S. trichocarpum* J. Ag., *S. salicifolium* (Bert.) J. Ag., *S. linifolium* (Turn.) J. Ag., and *S. hornschuchii* C. Ag. GRUNOW (1915, 1916) mentioned five species: *S. hornschuchii* C. Ag., *S. linifolium* (Turn.) J. Ag., *S. trichocarpum* J. Ag., *S. salicifolium* J. Ag., and *S. vulgare* C. Ag, of which only var. *megalophyllum* (Mont.) Grun., f. *pinnatifida* Grun., and f. *fissifolia* (Kütz.) Grun. occur in the Mediterranean. HAMMEL (1931-1939) reported four species in the western Mediterranean: *S. vulgare* C. Ag., *S. acinarium* (L.) Agardh, *S. trichocarpum* J. Ag., and *S. hornschuchii* C. Ag. FELDMANN (1937) reported two species, one variation, and one form in the Banyuls area: *S. linifolium* (Turn.) J. Ag., and *S. hornschuchii* C. Ag., *S. vulgare* C. Ag. var. *megalophyllum*, and *S. salicifolium* f. *diversifolia*, and two species and one variety along the Algerian coast (Cherchella area): *S. linifolium* Ag., *S. salicifolium* (Bertol.) J. Ag., and *S. vulgare*. Ag. var. *megalophyllum* (Mont.) Grunow.

Other authors reported on *Sargassum* taxa in the Adriatic Sea. ZANARDINI (1841) recorded *S. hornschuchii* C. Ag. and three varieties of *S. vulgare* (var. *salicifolium*, var. *linifolium*, var. *donati*). MENEGHINI (1842) reported three species: *S. hornschuchii* Ag., S. *linifolium* with one variety (var. *donati*), and *S. vulgare* with three varieties (var. *parvifolium*, var. *confertum*, and var. *salicifolium*). FRAUENFELD (1855) found three species: *S. boryanum* Mont., *S linifolium* Turn., and *Stichophora* (= *Sargassum*) *hornschuchii* Ag., while HAUCK (1855) found two: *S linifolium* Turn. and *S. hornschuchii* Ag. GRUNOW (1915, 1916) reported on three species: *S. salicifolium* J. Ag., *S. linifolium* (Turn.) J. Ag., and *S. hornschuchii* Ag and VOUK (1914, 1915, 1930) reported only *S. linifolium* (Turn.) Ag. in Kvarner Bay and *S. hornschuchii* Ag. the Dugi Otok and Kornati Islands. VATOVA (1928, 1948) and MUNDA (1960) reported two species: *S. linifolium* (Turn.) C. Ag. and *S. hornschuchii* C. Ag. in the Rovinj and Krk Island (Šilo Cape) areas, respectively. ERCEGOVIĆ (1960) recorded three species: *S. hornschuchii* C. Ag., *S. vulgare* C. Ag., and *S. acinarium* C. Ag. (= *S. linifolium*).

In spite of the facts that *Sargassum* occur in small numbers in the Mediterranean and Adriatic and that they have been intensively studied by a large number of respectable workers, they have never been sufficiently studied either separately or as a whole. Great ambiguity and controversy in taxonomic distinction, the intricacy of their synonymy, and the lack of information on their ecology and distribution constitute problems to present day scientists interested in these algae. Identification is made difficult by the exceptional variability in *Sargassum* taxa, the variety of basic criteria for distinguishing among taxa, and the considerable dependence *Sargassum* on environmental factors. *Sargassum* are perennial algae with wide depth and geographic distributions. Their morphology changes throughout the year and during different life stages. Therefore, material should be collected from a large number of habitats and at all periods of the year. Earlier authors could not satisfactorily work out the systematics and distribution of *Sargassum* in the Adriatic because available material was not sufficiently representative and there was little or no information on the ecological properties of the species.

Due to their importance among Adriatic benthic flora and vegetation, we carried out an inclusive morphological, systematic, and ecological study of *Sargassum* in the eastern coastal and insular areas of the Adriatic Sea. Our goals were to learn as much as possible about the morphology, systematics, and ecology of Adriatic *Sargassum* taxa. We paid particular attention to: (a) studies of morphological properties of Adriatic taxa, (b) establishing as complete an inventory as possible of all species, subspecies, and forms and describing them, (c) studies of depth (vertical) and geographic (horizontal) distribution of the taxa, and (d) variations between taxa in the Adriatic and in other environments.

The results of this study are presented in two sections. The morphology-systematics section discusses the morphologic and anatomic structures of *Sargassum*, with detailed descriptions of the Adriatic species and lower systematic taxa. The ecology section discusses the variability and adaptations of the taxa in relationship to the environment.

STUDY AREA AND METHODS

In this study, we attempted to clarify ambiguities in morphology, taxonomy, and synonymy inherited from earlier and incomplete studies of *Sargassum* in the Adriatic Sea. We also examined the distribution, variability, and ecology of the taxa of this genus in the Adriatic. First, we attempted to establish the exact inventory of species, subspecies, varieties, and forms of Adriatic *Sargassum* and to describe them in maximum detail using drawings to illustrate their morphology. Next, we evaluated the morphological variability and distribution (depth and geographical) and aimed to discover ecologic, genetic, and other relationships between the taxa and their habitats that would allow us to identify taxonomic distinctions between them. We mostly used comparative-morphology and geographic-morphology methods since they proved most suitable and were, in some cases, the only possible. Therefore we paid the greatest attention to discovering morphological differences between populations from different localities and how the populations were conditioned by external environmental factors.

We visited a large number of localities along the eastern Adriatic coast. Our studies included surface and deep waters of the coastal and insular areas of the central, northern, and southern Adriatic. At some localities, especially in the central Adriatic, samplings and ecological observations were performed seasonally or in successive years. Between 1954 and 1969 we visited over 250 stations along the eastern Adriatic coast. In addition, we made use of rich (algological) material collected in 1948-1954 from over 300 localities (Figs. 20A, 20B), kindly made available by the late ERCEGOVIĆ. Material was collected by dredges, grabs, trawl nets, rakes, and pliers. More recently, studies were carried out by SCUBA diving which allowed direct ecological observation and more complete collection of specimens from various depths.

MORPHOLOGY AND SYSTEMATICS

Outer thallus morphology

Representatives of the order Fucales are characterized by great morphological differentiation. The thallus has three main parts: (a) the lower small flattened plate called holdfast (rhizoid), (b) the central cylindrical to weakly compressed axis called stipe (cauloid), and (c) erect branches called leaf-like blades (phylloides). Within *Sargassum*, morphological diversity of the thallus is greatest among brown algae (Phaeophyta), especially in the phylloid where different parts may be distinguished. Elongated rod-like, flat leaf-like, bladder-like, and prickled parts as well as separate, short branches modified for reproduction (fructifications), together give a very special and characteristic appearance to these algae. Literature assigns a variety of names to these parts. Authors who wrote their reports or descriptions in Latin most frequently used the terms radix, caulus, frons, folium, vesicula, and receptaculum. More recent papers by English and German speaking authors frequently use holdfast (root), stipe (stem), frond, leave, vesicle, and receptacle or Basalscheibe, Stengel, (Hauptspross), Äste (Langtriebe), Blatt (Phyllocladium), Luftblase (Schwimmblase), and Fruchtkörper (Fruchtspross). French speakers used disque, tige, fronde, rameau, feuille, vésicule, and fructification. After SAUVAGE, ERCEGOVIĆ (1952) used terms that describe higher plants (branches, phylloclades, prickles) to describe thallus parts of Cystoseirae although they are simply differentiated parts of a primitive thallus of lower plants and do not reach the morphological, anatomical, and physiological levels of their analogues in phanerogams. Actually, the use of these terms is more appropriate to *Sargassum* than to *Cystoseira* and most have been accepted in world algological literature. Therefore, in the current report, we use these terms to describe Adriatic taxa.

Holdfast (root, basal plate, rhizoid). The holdfast is a special formation at the bottom of the thallus that attaches the organism to a substrate. It is an irregular oval at the base, and patchy divided at the edges. The upper part is cone-shaped and elongated and stretches to the erect stem (stipe).

Stipe (tree, stem, central axis, cauloid). The stipe is cylindrical, vertically erect, and supports a number of primary branches by cleavage of three-sided apical cells. In Adriatic taxa they are usually 1-7 cm long and 3-6 mm wide. The stipe can be cespitose, i.e., one or more trees may grow from a common complex holdfast as in *S. hornschuchii*. Frequently, new adventitious trees or tree branches (Fig. 1) grow from the lower parts or scars of fallen primary branches. They are ramified at the top or, if younger, have one or more ramified primordial blades (leaves). Numerous scars of fallen primary branches can be seen on the trees. The holdfast and stipe are permanent parts of a perennial alga and, in the course of development, their growth is limited in both length and width.

Phylloid. The ramified phylloid is an annual part of the alga that develops, falls, and decays during a single vegetative period. The phylloid includes branches of different degrees (primary, secondary, tertiary, etc.), blades (leaves, phylloclades), bladders (aerocysts, air bladders, gas-filled bladders, swim bladders), prickles, and fructifications (reproduction branches), each of which is morphologically well distinguished.

Branches. Primary branches at the tip of the stipe are short and have spirally arranged proliferations formed by cleavage of a three-sided vertex cell usually situated in the recessed part of the stipe tip. The branches are most frequently cylindrical (*S. vulgare* var. *vulgare*, *S. salicifolium* var. *salicifolium*), or elliptical and flat in the lower part and cylindrical in the upper part (*S. hornschuchii*). Primary branches vary considerably in length, depending on the taxon. In *S. salicifolium* var. *salicifolium*, the length frequently reaches 1.5 m and sometimes 2 m; in *S. vulgare* var. *vulgare*, primary branches are much shorter, sometimes no more than 10 cm. Primary branches usually ramify into branches of a higher degree (secondary, tertiary, etc.) that are shorter than the primary branches.

Since Adriatic *Sargassum* grow year-round, primary branches in different stages of development can always be found at the tree tops. While some are about to fall, others have just appeared as small proliferations at stipe tip. They differ considerably in appearance and size. Due to differences between young and old primary branches and other thallus parts (higher degree branches, phylloclades, receptacles), some morphological differences are of seasonal character in some taxa.

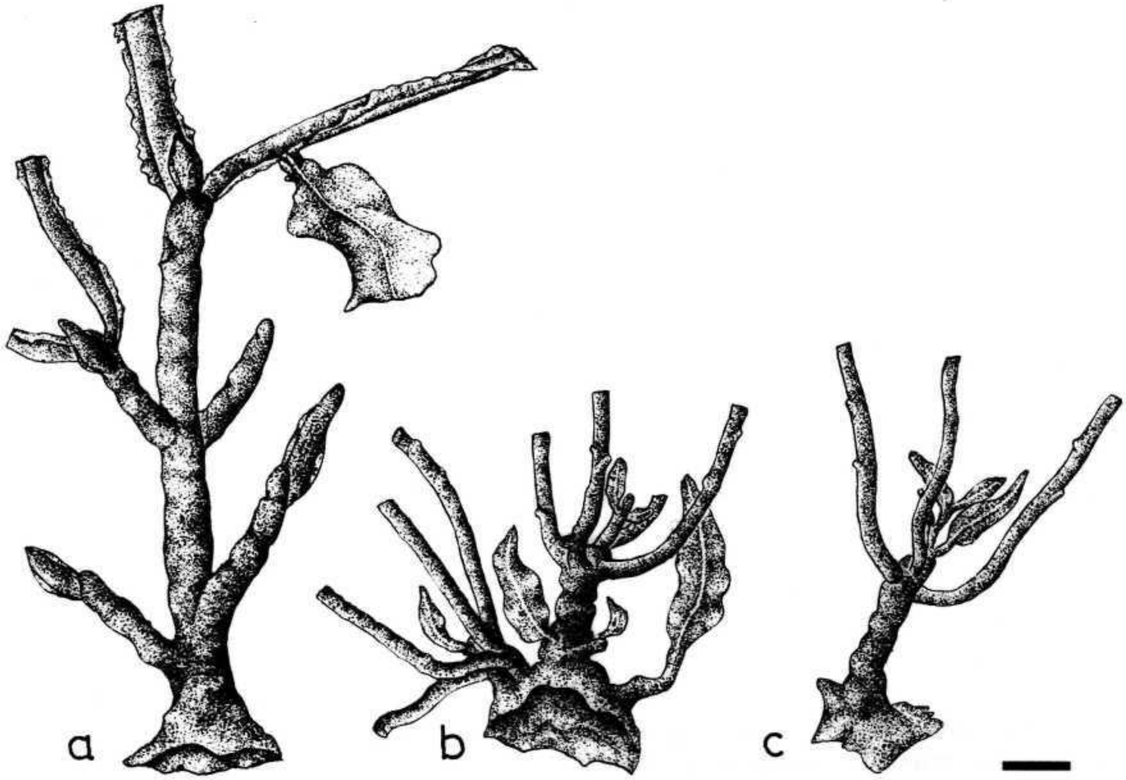

Fig. 1. Stipes (stem) and holdfasts (roots) in (a) Sargassum hornschuchii*; (b) and (c)* Sargassum vulgare *var.* vulgare*; scale = 1 cm*

Except for the lower parts, the branches are usually covered by prickles. These short, thorn-like formations, simple or ramified and tapered at the top, give a very characteristic appearance to *Sargassum* branches. In *S. hornschuchii*, the branches have no prickles although they have characteristically markedly serrated wings extending from both sides of the flat bottom part.

Blades (leaves, phylloclades). Blades occur on all branches and their offshoots. Blades are mostly leaf-like, giving a characteristic appearance to sargassums. The blades are flattened offshoots of the thallus, with histological and anatomical structures that do not essentially differ from those of the cylindrical branches except that the primary cortex cells are slightly flatter in the dorso-ventral direction. Blades are exceptionally diverse in length, width, density, form, serration, insertion, and ramification. They made be leaf-like, flat, wide, elongated, or spear-shaped. The middle rib and stiles of cryptostomata (see below) are clearly marked on the blade surfaces while the edges are usually serrated, sometimes resembling the toothed edge of a saw, and sometimes completely absent. In some taxa, the edges are markedly wave-like and folded, whereas they are completely flat in others. Sometimes some of the blades, particularly those that are long and narrow, markedly spiral. The middle rib frequently extends into a short cylindrical petiole, attaching the blade to the branch. In *S. hornschuchii*, the blades on the flat parts of the branch usually have no petiole and are predominantly embedded. Usually, they are not ramified but in some species (*S. salicifolium* var. *salicifolium, S. vulgare* var. *vulgare*), the lowest primordial blades that occur at stipe tops, stipe branches, or young primary branches are one or more times subdichotomously ramified (Fig. 18a). In some taxa, dichotomously branched blades occur on other parts of thallus as well. The blade density varies. They are dense in surface forms of *S. vulgare* var. *vulgare*, whereas they are relatively rare in *S. salicifolium* var. *salicifolium* and *S. hornschuchii*.

Cryptostomata. These are small recesses in the thallus tissue that communicate with the outer environment through small bodily apertures (ostioles). In *Sargassum*, cryptostomata are completely buried while the edges around the ostioles are slightly raised and, in some taxa darker in color, whereas cryptostomata are completely burried. Trichomes (an epidermal hair structure on a plant), normally present in cryptostomata, usually do not rise above the edges of the ostioles. Cryptostomata occur on blade surfaces, most frequently in rather large numbers although, particularly in taxa from greater depths, they can be very rare or almost completely absent. They are very rare on branches and their offshoots. Nowadays, it is believed that cryptostomata and conceptacles are homologous formations of epidermal origin, that their function is primarily for reproduction, and that they differentiate during later phyllogenetic development.

Bladders (aerocysts, air bladders, gas-filled bladders, swim bladders). These are 4-8 mm spherical siphon formations that, as part of a hydrostatic device, make possible the erect positioning of the thallus in the water. Bladders are attached to the ramified parts of the thallus, usually on its upper parts, by short cylindrical or, more rarely, slightly longer flat leaf-like petioles (Figs. 5a, 7a, 16c, 18d). They occur in large numbers in taxa with a long heavy thallus but are rare in specimens with a short thallus, especially those occurring close to the surface.

Fructifications (reproduction branches). These are branches of the highest degree on whose specially formed offshoots (receptacles) fertile cryptostomata (conceptacles) with reproductive organs (oogonia and antheridia) are numerous. In *Sargassum*, fructifications occur at the armpits of the blades. In Adriatic taxa, they consist mainly of a short or rather long ramified sterile part and simple or ramified fertile reproductive cells (receptacles). Receptacles may be spin-shaped or cylindrical and elongated with an oval, three-edged, or flat cross-section with serrated extensions. In individual taxa, conceptacles are considerably raised above the receptacle surface as hemispheric or cone-like protrusions. In addition, conceptacles can be deeply buried in receptacles in which case the surface of the receptacles is slightly dotted.

Anatomy

Compared to most other algae, Fucales are characterized by a relatively high differentiation of the inner thallus structure. Many authors working on the anatomical structure of Fucales reported histologically different cell tissues systems among genera of this order (REINKE, 1876; OLTMANNS, 1889, 1922; HANSTEEN, 1893; Le TOUZÉ, 1912; LINARDIĆ, 1949; ERCEGOVIĆ, 1952). REINKE (1876) distinguished between the epidermis, primary cortex, thickening layer (Verdickung-Schichte), inner tissue (Füllgewebe), and middle rib (Mittelrippe). OLTMANNS (1922) distinguished between the outer cortex (Innenrinde), and inner tissue (Füllgewebe), particularly the secondary cortex (Sekundäre Rinde). In Adriatic Fucales, LINARDIĆ (1949) distinguished between cortical (epidermis, primary and secondary cortex) and medullar (conductive and mechanical) systems while ERCEGOVIĆ identified the epidermis, cortex, and central (axial) tissue in *Cystoseira*

On the basis of our own studies and the literature, we believe that the following division of cell tissue is most appropriate for *Sargassum*: epidermis, cortex (primary and secondary), central (axial) tissue. The histological differentiation of cell tissue in Fucales is rather clear, supporting the opinion that there is a separation of at least some functions among the tissues, although less developed than in higher plants. In algae, tissue systems never have a single function, but always have two or more.

Epidermis. This singlefold cell layer (stratum) covers the outer thallus surface (Fig. 2). Observed from the surface, the cells are polygonal. In a cross-section, they are longer along the radial (20-32 μ) than the tangential (10-11 μ) axis. The membranes comprising the interface between the epidermis and the outer environment are slightly thicker (3-5 μ) than the

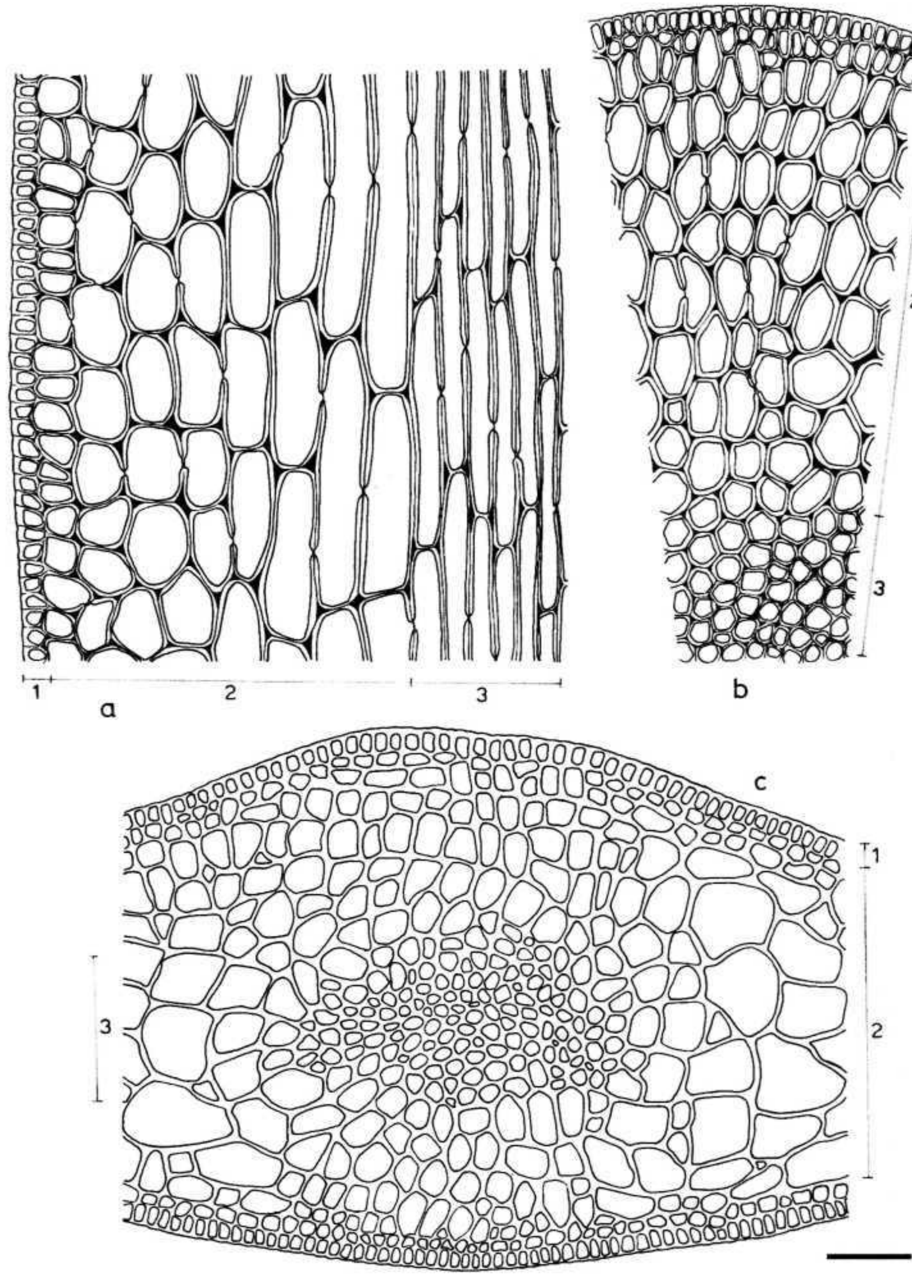

Fig. 2. Sargassum vulgare *var.* vulgare*: (a) longitudinal cross-section of a stipe; (b) transversal cross-section of a branch; (c) transversal cross-section of a blade (1 = epidermal cells, 2 = cortex cells, 3 = cells of axial tissue) x 300; scale = 100 µm*

others (2-2.5 µ). Epidermal cells originate from the vegetative apex; they multiply and grow together with the thallus. New cells are formed by anticlinal cleavage and the surface of the epidermis increases. The epidermis covers the entire surface of young thalluses. With age, i.e., with thallus growth, the epidermis begins to fall off until the lower parts of adult specimens have almost no epidermis. The number of pheoplasts in epidermal cells is very high, indicating that the epidermis has, predominantly, a role in assimilation. The thick outer wall of epidermal cells indicates a protective role.

Cortex (primary and secondary). The primary cortex is a direct extension of the epidermis. It is formed by periclinal cleavage of epidermal cells and consists of a single cell layer at the vegetative apices and multiple layers in the rest of the thallus. The first layer below the epidermis consists of small cells that differ little from those of the epidermis; these cells represent a transition between the epidermal and cortex cells. The cross-section of a thallus stipe shows that cells are elongated longitudinally, so that the length of some (those near the transition to central tissue) is five to ten times the width (Fig.2a). The cross-section of a thallus branch (Fig. 2b) shows that cortex cells stretch toward the radial axis, particularly in the central portion of the cortex system. These are up to 90 μ in length and 40-50 μ in width. Cell membranes are 3-6 (max 8) μ thick and usually have tiny bordered pits that are the means of intercell communication.

The primary cortex cells in *Sargassum* are so closely bound that intercellular spaces are invisible. The pectin lamella is thick and distinct, especially when dyed with methylene blue. The cortex cells are poor in pheoplasts, especially cells that are near the central tissue. The primary cortex has more than one function. Its peripheral layers, which contain many pheoplasts, have an assimilation role, while layers closer to the central tissue have a role in conduction. Judging from the thickness of the cell membrane, the primary cortex is a factor of thallus stiffness, since *Sargassum* possess no mechanical elements hyfes as in *Fucus*.

The secondary cortex occurs on the stipe and on lower parts of older primary branches where there is no epidermis due to denudation (Fig. 3a, b). It consists of four to six cell layers. Cells are mostly square or rectangular and arranged in longitudinal and radial rows.

Central (axial) tissue. The central tissue lies below the primary cortex in the central thalli. The gradual transition from cortex cells to central tissue cells is clearly seen in the transversal and longitudinal cross-sections of Fig. 2 as almost isodiametric longitudinally oriented cortex cells gradually narrow and elongate as they near the central tissue. There is no clear boundary between these two tissue systems. Central tissue cells are elongated along the longitudinal thallus axis and thinner than the cortex cells (20-40 μ). Central tissue is best developed in primary and secondary branches where it makes up 20-60% of the total diameter of the branch. In blades, the central tissue appears as a middle rib on the surface of the blade. Their longitudinal membranes have bordered pits and are rather thick (4-7 μ). Transversal membranes are very thin, frequently reduced to the central pectin lamella. These cells do not contain pheoplasts but are very rich in fucuous granulae. The histological and cytological structures of central tissue indicate that this tissue has a conductivity function and that its role in assimilation has completely disappeared. Hyfe reduction in *Sargassum* is compensated for by the reduction of cell lumen of central tissue in relation to the cell membrane, indicating that the central tissue has a protective as well as conductive function.

Reproductive organs

Reproduction in Fucales is heterogamous and oogamic. Reproductive organs (oogonia and antheridia) are formed in conceptacles that develop from an initial cell. Further development differs among genera. Formation of conceptacles, development of oogonia and antheridia, fertilization, and embryonic development in *Sargassum* were studied by THOURET (1885), OLTMANNS (1889, 1922), TAHARA (1909, 1913, 1929), NIEMBURG (1910, 1913), INOH (1930, 1932, 1937, 1940, 1941), NAKAZAWA (1954, 1955, 1956, 1957, 1958, 1959), CHAUCHAN & KRISHNAMURTHY (1967), and others.

Conceptacles. In *Sargassum* are small oval or siphon-like recesses in the thallus. At the upper parts of the conceptacles, there are small apertures (ostioles) through which reproductive cells (oospheres and antherozoides) are released. As to their contents, conceptacles are having only female (oogonia) or male (antheridia) gametangia. No bisexual cenceptacles have ever been recorded from the Adriatic *Sargassum*. Conceptacles at receptacle bases are most

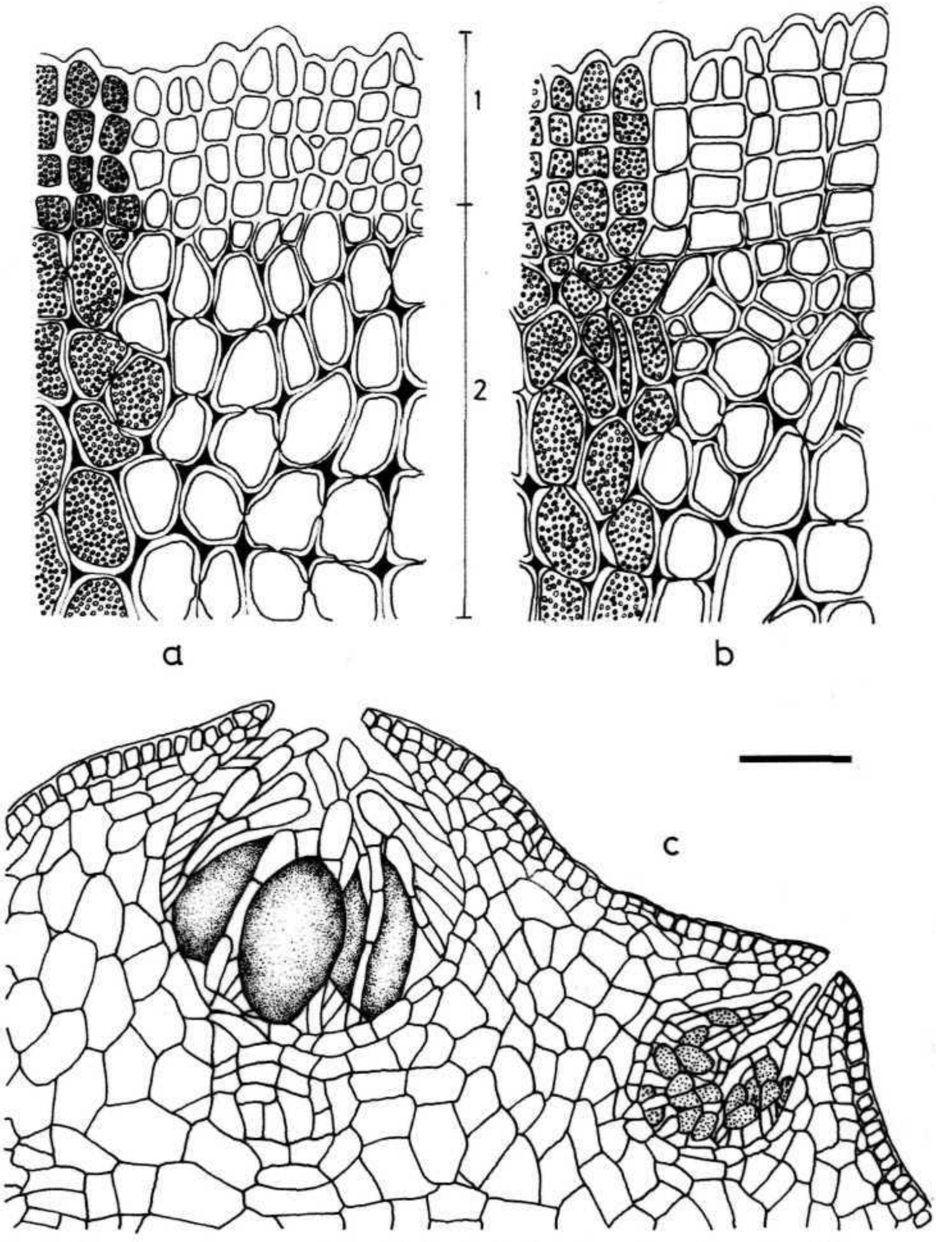

Fig. 3. Sargassum vulgare *var.* vulgare *(a) longitudinal cross-section of the stipe; (b) transversal cross-section of the stipe (1 = secondary cortex cells, 2 = primary cortex cells) x 300; (c) conceptacles cross-section x 150; scale = 100 μm*

frequently the largest, whereas those at the tips are smaller and less developed.

Completely developed female conceptacles are spherical or, occasionally, egg-shaped. In *S. hornschuchii*, their maximum size is about 550-600 μ in height and 520-550 μ in width. In other taxa, they are smaller, e.g., in *S. vulgare* var. *vulgare* they are 360-450 x 320-400 μ. A single oosphere is formed in each oogonium, which is mainly an elongated oval. In *S. hornschuchii*, maximum lengths and widths were 200-300 μ and 160-260 μ, respectively. In some Adriatic taxa they are smaller, 220-290 μ long and 160-170 μ wide (Fig. 3c).

Male conceptacles are elongated and most frequently siphon-shaped. They are largest in *S. hornschuchii*, where they reach a maximum of 400-440 μ high and 320-360 μ wide. Antheridia are more or less elongated ovals. They differ in size among species as well as within species and subspecies. They are largest in *S. hornschuchii*, reaching 42-44 x 21-23 μ. In other taxa they are slightly smaller, 23-26 x 16-18 μ.

DESCRIPTION OF ADRIATIC *SARGASSUM* TAXA

Sargassum vulgare C. Agardh var. *vulgare*

C. Agardh, 1820, I, 3-4; Menghini, 1848, 12; De Toni, 1895, III, 85; J. Agardh, 1889, XXIII, III, 108; Kützing, 1849, Pl. 37:III; Børgesen, 1914, II, 62, Fig. 43; Grunow, 1916, LXVI, 39; Gayral, 1958; Taylor, 1928, 130-131, Pl. 18: Fig. 11, Pl. 19: Fig. 12; Dangeard, 1952, XXXVI, 259; Rodriguez, 1960, Pl. VI: Fig. 2a.

Synonym: *Fucus natans* Linnaeus, 1753, Pl. II; Turner, 1807-1808, 103-107, Pl. 47.

The exceptional variability and wide distribution of this species were recorded and described by many researchers. TURNER (1808-1819) described four varieties and C. AGARDH (1821-1828) seven. No other species of this genus has such great variability (GRUNOW, 1915-1916). Thus, apart from the typical form, this author described 11 varieties and 12 forms. KUNZE (1880) reported as many as 27 varieties of the species. Most authors who studied this species agree that the drawing by TURNER (1808-1819) of *Fucus natans,* later changed to *Sargassum vulgare* by C. AGARDH (1821), typifies this species.

A number of authors recorded and described this species in the Adriatic Sea. MENEGHINI (1842) extensively described the typical form and three varieties but, unjustifiably, assigned var. *salicifolium* to it. To the contrary, HAUCK (1885) misidentified some Adriatic specimens of this species as *S. linifolium* and thus completely failed to report the presence of *S. vulgare* in the Adriatic. Investigation of the abundant material collected from many localities at different depths along the eastern Adriatic coast revealed the presence of *S. vulgare* (*S. vulgare* var. *vulgare*), two varieties (*S. vulgare* var. *jabukae* and *S. vulgare* var. *megalophyllum*), and one form (*S. vulgare* var. *vulgare* f. *ercegovicii*).

The morphological properties of *S. vulgare* C. Agardh var. *vulgare* are close to the description and drawings of BØRGESEN (1914, 1926), GRUNOW (1915-1916), TAYLOR (1928), HAMEL (1931-1939), GAYRAL (1958), and RODRIGUES (1960). We hereby report on specimens collected from Hvar, Vis, Šolta, Ugljan, Pašman, Pag, Rab, Krk, and Dugi Otok islands and along the coast of the eastern Adriatic mainland. Adriatic specimens are generally slightly smaller than those of other seas. The largest specimens rarely exceed 50 cm in length. The species are characterized by the density of all parts of the thallus (secondary branches, blades, bladders, and receptacles). Specimens growing close to the surface (0.4-1 m) differ considerably from those at depths of 3-4 m or 20-30 m. Following is a description of the algae collected on several occasions from a depth of 3 m off the southern coast of Hvar Island (near the small village Pitovske Plaže) (Fig. 4).

A number of erect stipes, 2-3 cm long and 3-4 mm wide with visible scars from fallen branches, grow from the holdfast. Each stipe has 3-5 primary branches at the tip. They are cylindrical, 30-35 cm long (occasionally 40 cm) and usually covered with dense short prickles although sometimes prickles are absent from the lower parts. Adult primary branches have 16-20 relatively short secondary branches (5-6 cm, occasionally 10 cm) at 10 cm intervals.

The branches have many blades of various forms and sizes (Fig. 5a). The blades are frequently elongated spears, 3-4 cm long and 3-5 mm wide; those on young branches or lower parts of adult primary branches are slightly longer (up to 4-5 cm) and wider (5-8 mm) and sometimes bifurcated. Their edges are most frequently folded and wave-like, resembling the toothed edge of a saw. However, sometimes serrations are barely visible, especially in older blades. The cryptostomata on the blades are large (sometimes a blade is pierced at the point from which the cryptostomata grow), but not numerous. They are irregularly arranged on

Fig. 4. Sargassum vulgare *var.* vulgare *(Hvar Island, Pitovske Plaže, 3 m depth): (a) specimen in full development (June); (b) secondary branch with blades, bladders, and fructifications, x 1.2; scale = 1 cm*

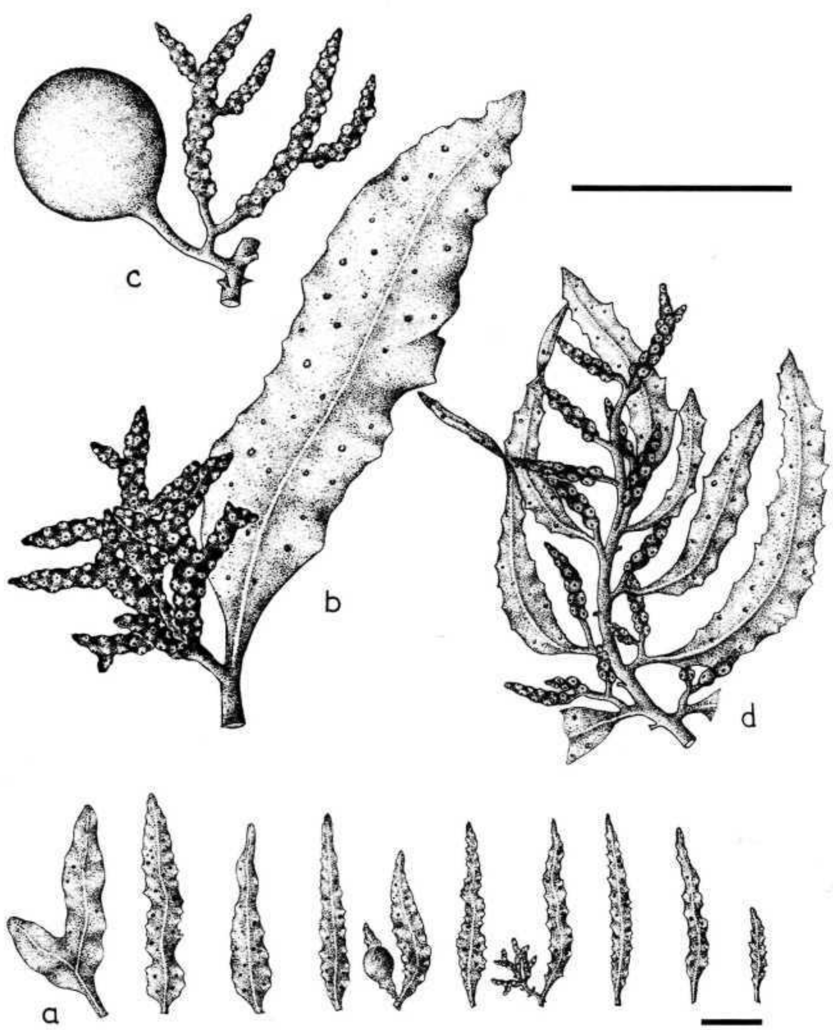

Fig. 5. Sargassum vulgare *var.* vulgare*: (a) blades (full scale); (b), (c) and (d) fructifications in specimens from 2, 4, and 30 m depth, x 4; scale = 1 cm*

each side of the central rib. There are many bladders, particularly in the upper half of the thallus. They are most frequently egg-shaped, rarely spherical, and 3-5 cm. The petiole is usually cylindrical and sometimes flat and leaf-like. Rare bladders have prickled or leaf-like flattened elongations on the top.

Fructifications occur on tertiary branches, either directly on the branches or on blades or aerocyst petioles. They consist of a sterile cylindrical part (4-8 mm long and up to 1 mm wide) and ramified or non-ramified receptacles (Fig. 5c). They bear male and female conceptacles. Male conceptacles are elongated and siphon-shaped, 240-280 x 170-200 µ. Apart from paraphyses, they contain 23-24 x 15-17 µ antheridia. Female conceptacles are spherical, 340-420 x 320-400 µ, and apart from paraphyses, contain 160-200 x 120-160µ oogonia. The fructification period starts at the end of winter and ends approximately mid-summer. The first fructifications appear in April. Conceptacles are fully ripe in June and July, but ripe conceptacles can sometimes be recorded from receptacles on the lower thallus parts as early as May.

The vegetative period of this species extends year-round with different intensities in different seasons. The most intensive development of annual thallus parts (in particular branches and blades) takes place in winter and spring, so that branches reach their maximum lengths approximately at the end of May. In midsummer, when fructification is finished, the appearance of the alga considerably changes. Most blades have fallen from the adult primary branches so that only bladders and fructifications remain. In August, they loose almost all older primary branches and only perennial thallus parts such as the holdfast and the stipe remain. At this time, the stipe usually bears new (young) primary branches.

The form and size of the thallus and its parts (branches, blades, bladders, fructifications) vary greatly, especially according to wave exposure and habitat depth. Specimens growing closer to the surface in more exposed coastal locations have a low, almost dwarfed, thallus, of no more than 10 cm. Secondary branches are no more than a few cm long. They are dense on primary branches (24-32 in every 10 cm interval). Blades are spear-like, rather short, stunted, and very slightly serrated at the edges. The bladders are predominantly oval and rare, sometimes even absent. Tertiary branches are so short that they are hardly noticeable. They become fertile along almost all their length and represent fructification formations consisting of a very short sterile part that adheres to compressed cylindrical and irregularly ramified receptacles up to 6-8 mm long and 1-1.4 mm wide (Fig. 5b).

The appearance of the thallus changes as the depth increases. All parts lengthen and become rare to a considerable extent, especially the branches and blades. Specimens collected from 20-30 m depths in the central Adriatic have a rather loose thallus and are frequently longer, 45-50 cm. Secondary branches sometimes reach 15 cm in length and are rather rare (14-16 in every 10 cm interval). Tertiary branches are 3-5 cm long and bear well-developed blades, bladders, and fructifications. The blades are more rare and slightly longer and wider that at shallower depths. They are spear-like, long, and thin, and are more markedly serrated than the surface forms. Cryptostomata are very small, sometimes even not visible. They are considerably more rare and loose, i.e., morphologically different, in deep sea specimens. Cryptostomata consist of a short sterile part and individual spin-like and poorly ramified receptacles up to 5-6 mm long and less than 1 mm wide.

Sargassum vulgare C. Agardh var. *vulgare* f. *ercegovicii*, form. nov.

Specimens collected on several occasions along the coasts of the inner islands and mainland of the northern and central Adriatic slightly differ from the above-described species (*S. vulgare* var. *vulgare*) in form and size of blades and fructifications. Such specimens were collected on several occasions from a mildly exposed locality in Kašjuni Cove near the Institute of Oceanography and Fisheries in Split at a depth of 0.5-2 m. Their well-developed, rather dense thallus up to 40 cm long and numerous, spear-shaped blades give this form a special appearance (Fig. 6). The blades are wider, harder, and less serrated than those of the typical species (above). Lower blades on the primary branches are 3.5-6 cm long and 9-11 mm wide and, especially at the apices of young stipes and stipe branches, sometimes bifurcated. Those on the upper parts of adult branches are shorter (2-4 cm) and narrower (up to 8-9 mm). The length to width ratio is 3:4.

There are many bladders, particularly on the upper thallus. They are most frequently oval and rarely spherical. They occur mostly on short cylindrical petioles and sometimes longer flat leaf-like petioles (Fig. 7a). Fructifications lie on the petioles of blades or bladders. They consist of a very short sterile part and irregularly ramified receptacles that are cylindrical or slightly flattened at the ends. The fructifications range 4-10 mm long and 1.4-1.6 mm wide. Male and female conceptacles are deeply buried into the receptacle tissue and, especially the males, barely visible above its surface (Fig. 7b). Female conceptacles are 350-450 μ and spherical in transversal and longitudinal cross-sections. They contain 220-240 x 140-170 μ oogonia. Male conceptacles are elongated and siphon-shaped, 260-350 x 180-250 μ. They contain 22-23 x 16-17 μ antheridia.

Fructification begins in the second half of April and ends in approximately July. The first fructifications occur on the petioles of blades

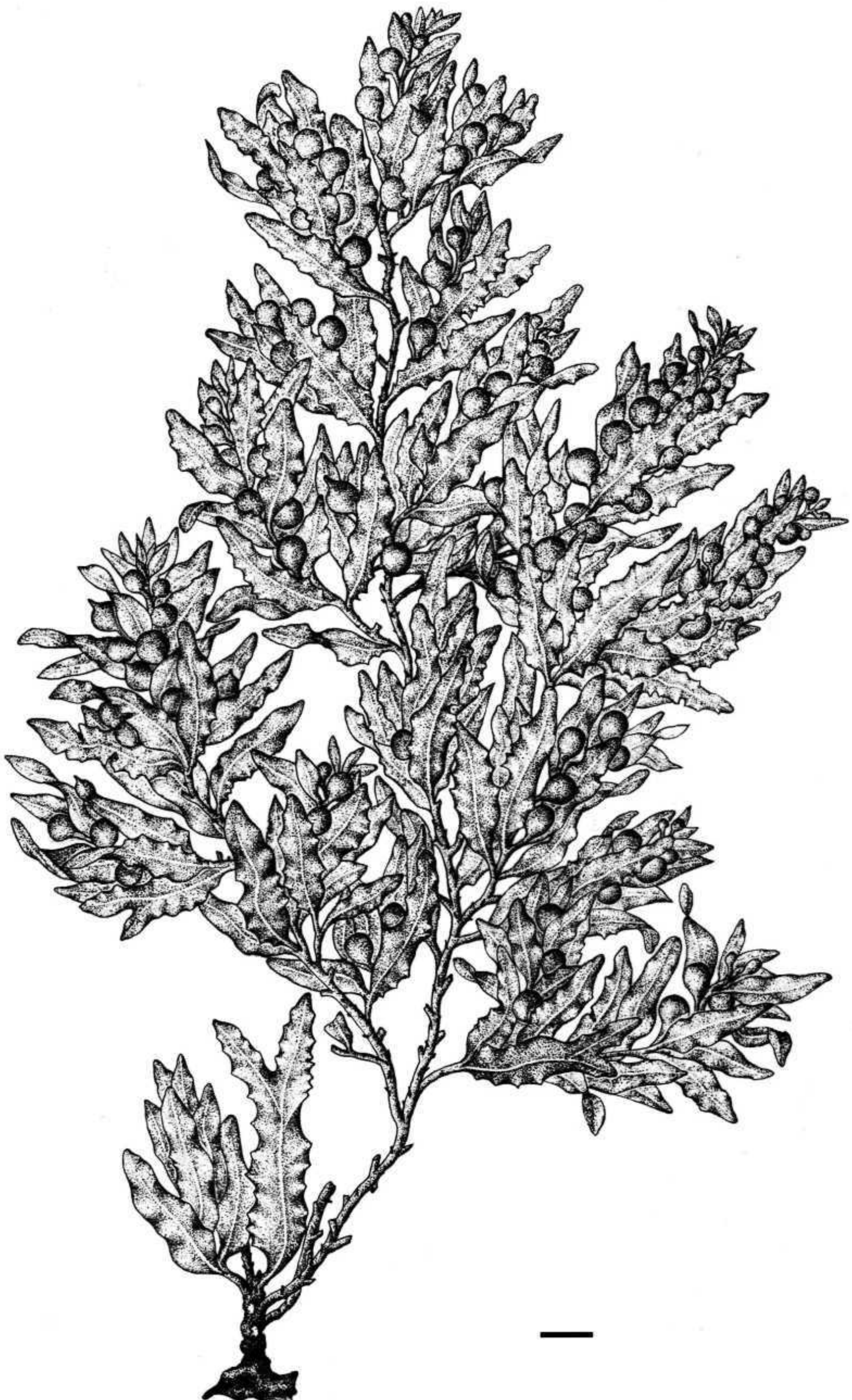

Fig. 6. Fully developed Sargassum vulgare *var.* vulgare *f.* ercegovicii *(Kašjuni Cove, Split, 0.7 m depth, May); scale = 1 cm*

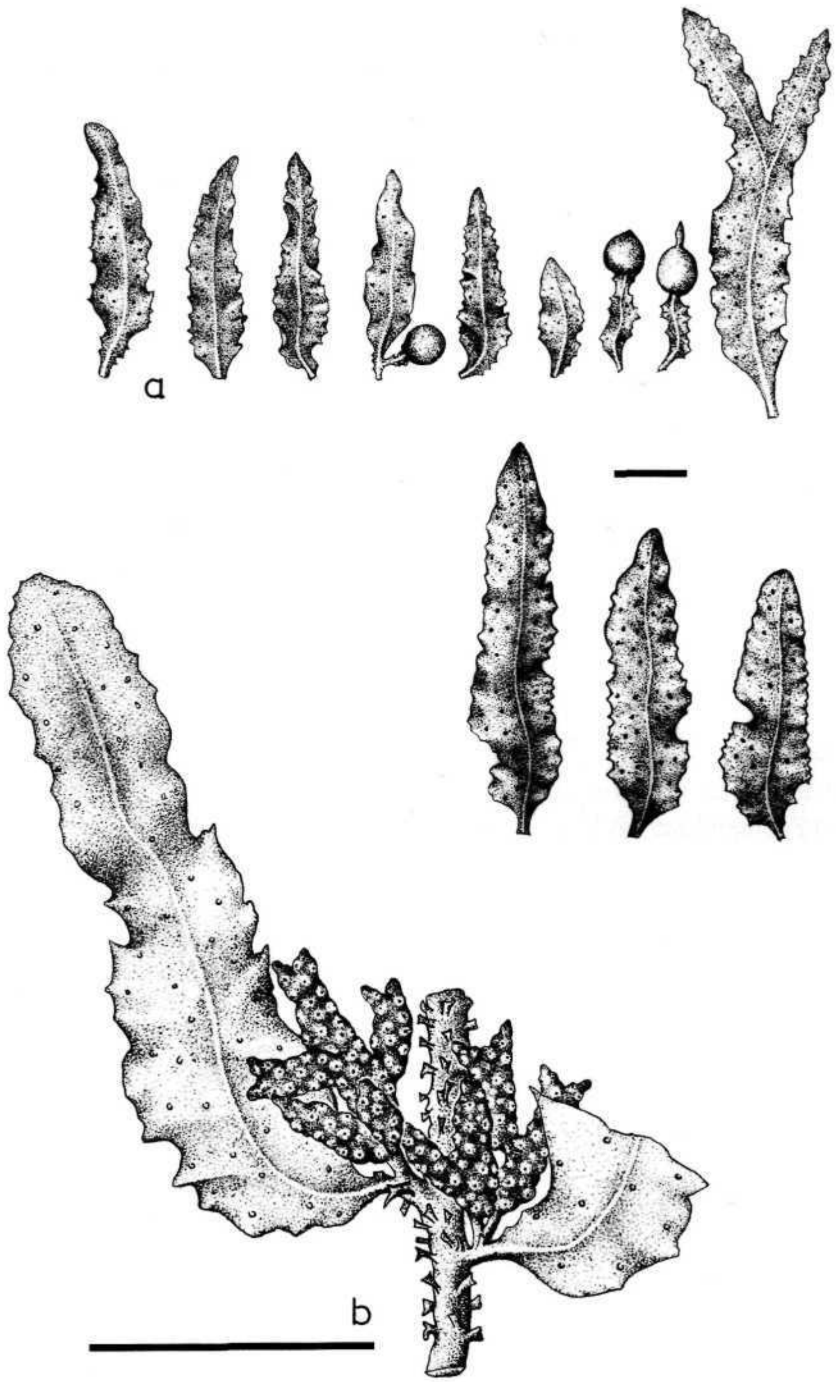

Fig. 7. Sargassum vulgare *var.* vulgare *f.* ercegovicii*: (a) blades in full scale; (b) fructification forms, x 4; scale = 1 cm*

or bladders and develop rapidly in May and ripen in June and July. Most conceptacles are empty by the beginning of August, except for some at the conceptacle tips where oogonia and antheridia can still be found.

Specimens of this form have an almost uninterrupted year-round vegetative period. At the stipe tip there are usually primary branches of various developmental stages and lengths. Growth is considerably slowed only during the

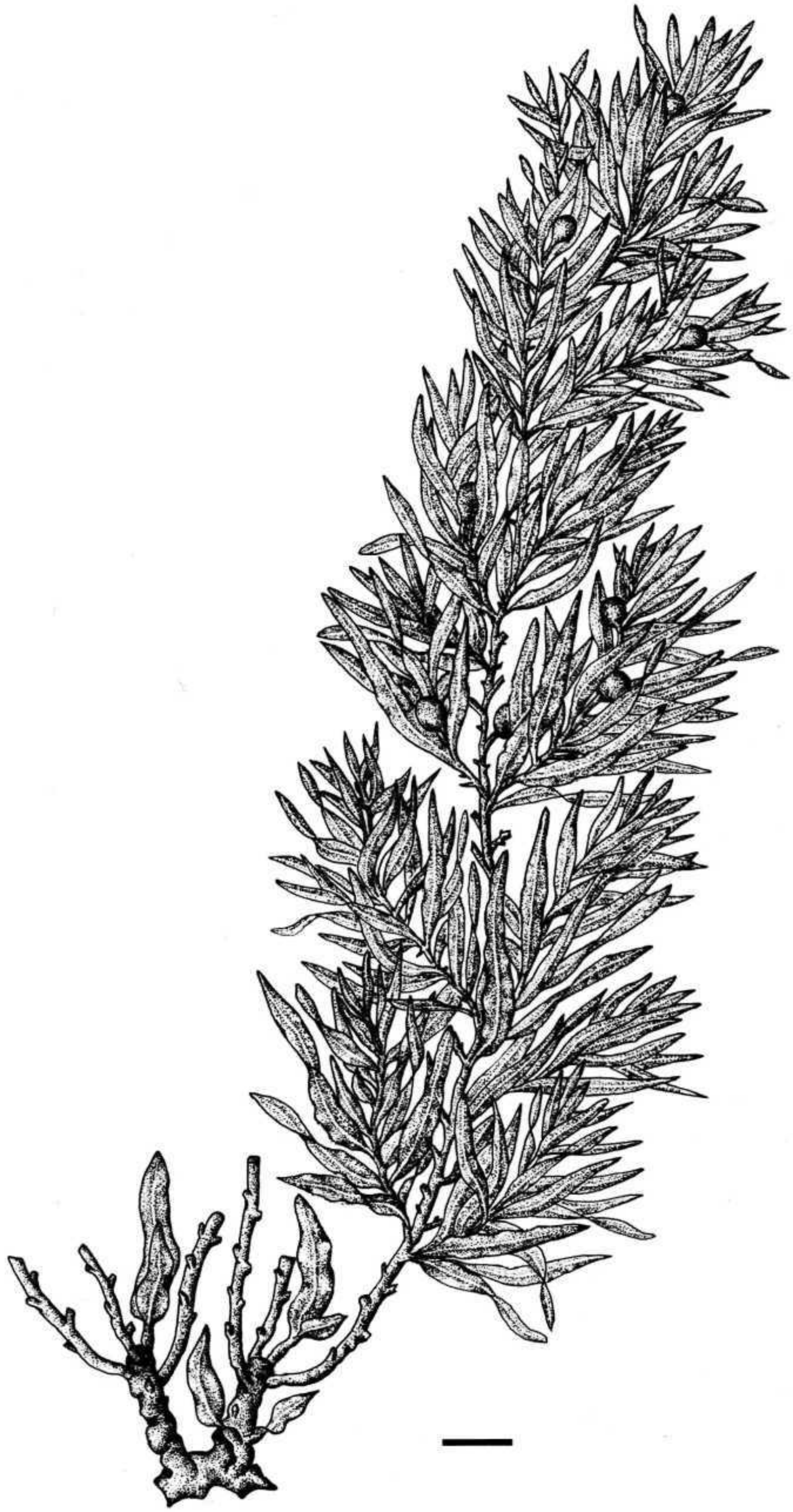

Fig. 8. Sargassum vulgare *var.* jabukae *(islet Jabuka, about 3 m depth) specimen collected in May, full scale; scale = 1 cm*

warmest summer months (July and August), whereas it is very intensive in autumn and particularly in winter and spring. In November, primary branches reach more than 15 cm in length and, at the end of May and beginning of June, specimens are at the peak of their vegetative development. Upon termination of fructification, the appearance of the plant considerably changes, like in the typical form. Most leaves have fallen, so that only branches with bladders and fructifications are left.

Sargassum vulgare C. Agardh var. *jabukae*, form. *nov*.

This alga was collected on several occasions from 1-3 and 15-20 m depths on the coast of Jabuka Islet and at 10 m on the reef near the islet. This form is characterized by special morphological characteristics. Therefore, it is described here as a separate variety of *S. vulgare*. The longest specimens grow in deep waters, reaching more than 50 cm in length. Those from depths of 1-3 m are much shorter (mostly up to 25 cm). Specimens from 1-3 m are cespitose, having 2-4 cm long, 3-4 mm thick stipes where the scars of fallen branches are visible (Fig. 8). Stipes support a number of cylindrical up to 23 cm primary branches and many (over 30 per 10 cm interval) short secondary branches (3 to mostly 5 cm long), so that the primary branches appear markedly elongated. The branches are covered with short prickles.

Blades have a particular form that differs from that of other *S. vulgare* varieties. They are spear-shaped, elongated, and markedly taper towards the top. Their edges are mainly neither wave-like nor folded or serrated, although a single serration can be noticed here and there. Blades on young primary or lower parts of adult branches are largest (3-4 cm long and up to 8 mm wide), whereas the rest of blades are considerably smaller, 3 cm long and 2-3 mm wide (Fig. 9a). Cryptostomata are frequent and distinct on blade surfaces. They are randomly distributed on wider blades and arranged in an apparent single row on each side of the central rib of narrow leaves. Bladders are rather rare and, if they occur, are located on the upper thallus parts. They are most frequently elongated 3-4 mm ovals with a short cylindrical petiole at the bottom. Rarely, three is a prickle-like extension at the top.

Buds of fructifications begin to appear on blade stems in April. This subspecies has sexual dimorphism manifested by an exclusively different receptacle form and size. Ripe fructifications (in July and August) consist of short ramified sterile stems bearing individual receptacles. Some specimens bear exclusively spinning and ramified receptacles, 3-6 mm long and 0.7-1 mm wide, with hemispheric protruding female conceptacles of 70-280 μ with wide apertures at their tops. The conceptacles contain elongated oval oogonia, 160-200 x 100-145 μ. Other specimens bear cylindrical and ramified receptacles, 10-11 x 0.7 mm, with short cone-like protruding male conceptacles, 180-280 x 140-160 μ, with small apertures at the tops that contain 20-22 x 11-14 μ antheridia.

This species grows year-round. Primary branches in different development stages, and therefore of different lengths, grow at the stipe tops. In contrast to the typical form of this species, growth in autumn and winter is slightly slower than in spring and summer, when maximum length is reached. For example, specimens collected from a depth of 1.5 m at the coast of Jabuka Islet reached 5 cm in January, 8-9 in April, 20-22 in July, and up to 25 cm in August. The lengths of specimens, including all thallus parts (stipe, branches, blades, receptacles), increase with depth. Specimens collected from a depth of 19-20 m at the northwestern part of Jabuka Islet reached 45-50 cm in July and stipes are usually 4-10 cm long. Secondary branches are usually longer than in the surface form, mostly 5-6 cm and rarely 10 cm long. They are densely arranged with 20-30 in each 10 cm interval along the primary branches. Secondary branches have a large number of blades. Lower blades on young primary branches that are still growing are slightly wider than blades on the upper and intermediate parts of adult primary branches. These blades are 4-6 cm long and 8-13 mm wide. The rest of blades are 2-4 cm long and 3-8 mm wide. Most frequently, they are

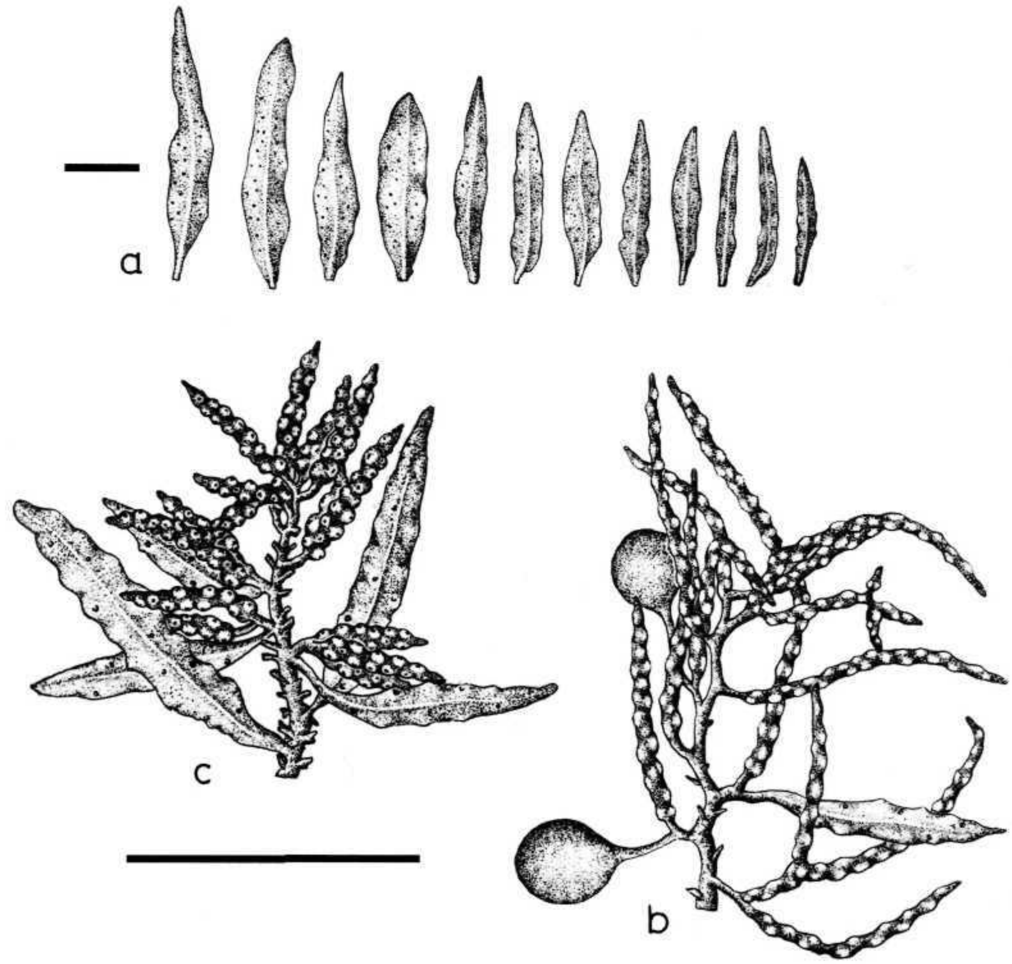

Fig. 9. Sargassum vulgare *var.* jabukae*: (a) blades in full scale; (b) male (antheridia) and(c) female (oogonia) fructifications in specimens collected in July, x 4; scale = 1 cm*

spear-like and elongated, the edges are almost without serration and they are rarely slightly folded. Sometimes the blades have tiny and rare serrations at the edges. Cryptostomata are rare and small, hardly identifiable.

Bladders are numerous, occurring mainly on upper thallus parts. They are most frequently oval and 3-5 mm. Receptacles are almost the same form as in surface specimens, but less ramified at greater depths. Typical spin-shaped receptacles, 3-7 x 1.0-1.1 mm, exclusively contain protruding hemispheric female conceptacles of 300-400 μ, with oval 220-260 x 150-200 μ oogonia (Fig. 9c). Ramified cylindrical receptacles, 10-13 x 0.7-1.0 mm, exclusively contain cone-like protruding male conceptacles, 180-300 x 140-170 μ, with 20-23 x 13-15 μ antheridia (Fig. 9b).

The specimens collected from a depth of 6-10 m at the reef west of Jabuka Islet are typical transitional forms between Jabuka's surface and deep-sea varieties.

Sargassum vulgare C. Agardh var. *megalophyllum* (Mont.) Grunow

Grunow, Addit. Cog. Sarg., 1916, p. 39; Feldmann, Alg. Mar. Alber., 1936-37, p. 320.

Synonym*:* *S. megalophyllum* Montagne, Fl. Alger., 1849, p. 7. Icon.: Montagne, Fl. Alger., 1849., Pl. I, Fig. 1.2; Kützing, Tab. Phyc., 18, XI, Pl. 23, II; Feldmann, Alg. Mar. Alber., 1937, Pl. I.

This variety was collected on several occasions from rocky shores in the vicinity of Rovinj (Sv. Katarina and Banjole Islands, Barabiga and Fabrosa Coves). Individuals grow on mildly exposed parts of the coast at a depth of 0.7-3 m. They are characterized by rather narrow spear-like elongated blades with well-serrated edges and a large number of tiny bifurcated receptacles. Their morphological properties well agree with descriptions and drawings of *S. vulgare* C. Ag. var. *megalophyllum* (Mont.) Grunow from the coasts of Algiers (MONTAGNE, 1849) and Banyuls (FELDMANN, 1937).

Thallus length is 10-30 cm (Fig. 10a). Cylindrical stipes are very short, 1-3 cm long and 3 to 4 mm wide, and usually partially grow together at the bottom. The tops of the stipes bear primary branches of different lengths and age. In July and at the beginning of August the longest (fully developed) branches reach 10-12 cm in length in specimens collected to a depth of 1 m, and 22-25 cm in specimens collected at 2-3 m. Secondary branches are numerous, usually 20-22 branches per 10 cm of primary branch. In specimens growing closer to the surface, there may be 24-26. The length of the secondary branches ranges 2-8 cm and never exceeds 10 cm (Fig. 10b), so that primary branches have an elongated or narrow pyramidal form. Both primary and secondary branches are covered with short ramified prickles that are sometimes absent from the lower parts of the primary branches. Blades are markedly elongated and spear-like, rarely slightly curved, or with two to three spiral turns. Lower blades of adult branches are largest, 6-8 cm in length and 5-9 mm in width. Young primary branches or stipe tips bear long, repeatedly bifurcated, ramified blades (primordial).

There are similar but slightly shorter and narrower blades on the upper thallus, particularly in specimens growing close to the surface. Blades of the intermediate and upper thallus parts are elongated and spear-like, 1-6 cm long and 3-6 mm wide. They have saw-like serrated edges, sometimes with double serrations (Fig. 11a). Cryptostomata are usually very numerous, tiny but easily identifiable, and distributed at random on blade surfaces. Bladders occur on the intermediate and upper thallus parts. They are normally spherical or oval, mostly 5-6 mm in size, with lower parts extending as short cylindrical stems. Fructifications are markedly small, reaching a maximum of 5-6 mm in length. They consist of short ramified sterile parts bearing short, 2-4 mm long, bifurcated, and sometimes partly flattened, receptacles at the top (Fig. 11c). Sometimes short serrations can be observed. Receptacles contain both male and female conceptacles buried into their tissue and visible as short cone-like and hemispherical protrusions. Female conceptacles are 250-300 μ ovals with 140-150 x 80-100 μ oogonia distributed among the paraphyses. Male conceptacles are up to 200 x 120-150 μ, with 19-20 x 10-13 μ antheridia and paraphyses.

On several occasions we collected similar specimens off the mainland coast and inner islands of central and northern Adriatic that had morphological differences. They were normally smaller, reaching a maximum length of 20 cm. The blades were usually slightly shorter, 1-5 cm, but wider, 4-10 mm, and had a spear-like shape (Fig. 11b). In specimens growing close to the surface, fructifications consisted of short sterile cylindrical and ramified parts as well as ramified receptacles. They were 2-3 mm long and less than 1 mm wide. In specimens from depths of 2-3 m, the receptacles were better developed, more ramified, 3-6 mm long, and up to 1 mm wide.

The plant fructifies from midspring to the end of summer. Fructifications occur on the stems of blades as early as April and fully ripen in July and August although conceptacles in some specimens were already ripe in May. It seems that the vegetative period is uninterrupted throughout the year.

Distribution the taxa of *Sargassum vulgare*

Sargassum vulgare is distributed in tropical and subtropical waters of the Mediterranean and adjacent Atlantic Seas. The species and its large number of lower systematic taxa were recorded

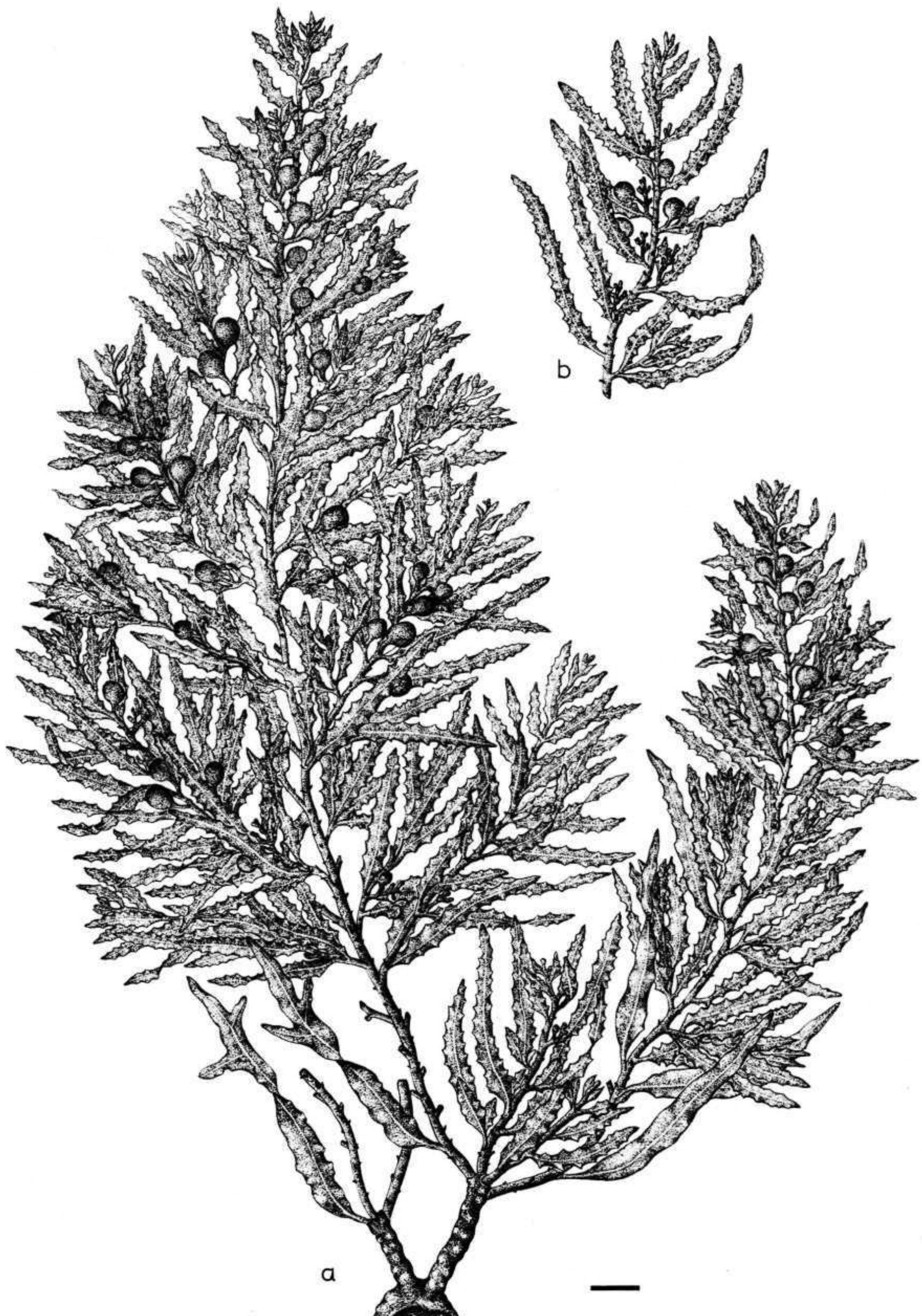

Fig. 10. Sargassum vulgare *var.* megalophyllum *(Istra, Faborsa Cove, 3 m depth, July): (a) a specimen in full development (July); (b) secondary branch, x 1.2 ; scale = 1 cm*

along the coasts of North and South America (Florida, Mexico, the Bahamas, Bermuda, Venezuela, Brazil), Europe (Spain, Portugal, France), and Africa (Morocco, Canary Islands and St. Thomas Islands). In the Mediterranean it was recorded off the coasts of France (Banyuls, Cannes), Italy (Livorno, Naples), Algiers (Cherchell), and Lebanon (Beirut).

Along the eastern Adriatic coast, it was recorded from Cape Savudrija to the Molunat Peninsula and from the mainland coast to the outermost Adriatic islands (Table 1; Figs. 20A, B). According to available data, it is at Venice, Ancona, and Chioggia in the western Adriatic. It grows at great depths, sometimes exceeding 200 m (ERCEGOVIĆ, 1960). The species seems to be most widely distributed and best developed in the central and part of the northern Adriatic, being rarer in the south. Since it is well-distributed in the channel and coastal areas of the Adriatic, we only partly agree with ERCEGOVIĆ (1960) that this species, as a whole, is an alga of the open sea. In the vast Adriatic, the species developed several populations which differ in morphology, so that four settlement groups can be distinguished: intermediate, inner, outer, and northern.

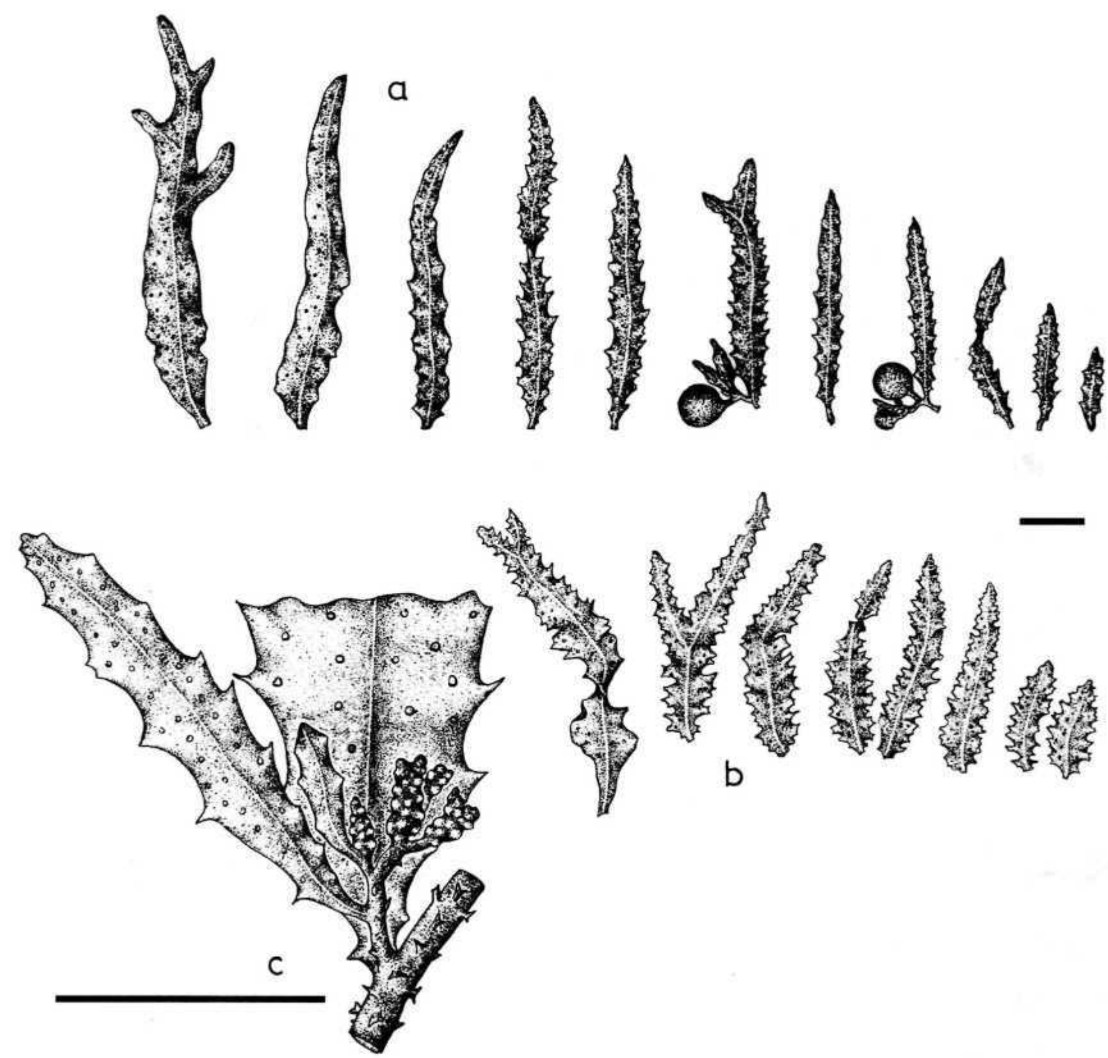

Fig. 11. Sargassum vulgare *var.* megalophyllum*:(a) and (b) blades (full scale); (c) fructifications, x 4 ; scale = 1 cm*

Table 1. Sites at which the taxa of Sargassum vulgare *was recorded*

No	Site	Geographic position	Date of collection	Depth (m)	Taxa
1	Platamun cape	42°16.1´N 18°47.2´E	10.05.1969	0.6–0.8	var. *vulgare*
2	Molunat island	42°26.7´N 18°26,0´E	10.05.1969	0.8–1	var. *vulgare*
3	Lokrum island (by Dubrovnik)	42°37.3´N 18°07.2´E	08.07.1970	0.3–0.6	var. *vulgare*
4	East of Jazine cove (Channel of Neretva)	42°55.0´N 17°36.6´E	02.06.1966	0.5	transitional to var. *megaloph.*
7	East of Rep od Kleka cape (Channel of Neretva)	42°55.9´N 17°34.4´E	03.06.1966	0.5–0.7	var. *vulgare*
8	By Rep od Kleka cape	42°56.0´N 17°33.6´E	03.06.1966	0.3–0.7	var. *vulgare*
9	Rep od Kleka cape	42°55.3´N 17°34.5´E	03.06.1966	0.5–1	var. *vulgare*
11	Small cape opposite Mali Škoj island	42°54.7´N 17°36.2´E	03.06.1966	0.3–0.5	var. *vulgare*
12	Small cape opposite Veli Škoj island	42°54.1´N 17°37.3´E	03.06.1966	0.3–0.5	var. *vulgare*
13	West of Bistrina cove (Channel of Neretva)	42°53.1´N 17°39.3´E	03.06.1966	0.3–0.5	var. *vulgare*
14	Čeljen cape (Pelješac peninsula)	42°52.1´N 17°40.9´E	04.06.1966	0.5–0.7	var. *vulgare*
15	By Duba Cape (Pelješac peninsula)	42°52.7´N 17°38.5´E	04.06.1966	0.5–0.7	var. *vulgare*
16	By Gnjili rat cape (Pelješac peninsula)	42°53.8´N 17°36.4´E	04.0.6.1966	0.5	var. *vulgare*
18	Besunlje cove (Pelješac peninsula)	42°54.1´N 17°35.5´E	04.06.1966	0.5–1	var. *vulgare*
20	By Crkvice cove (Pelješac peninsula)	42°58.7´N 17°22.3´E	04.06.1966	0.5–1	var. *vulgare*
21	Bezdija cove (Pelješac peninsula)	43° 2.0´N 17° 0.5´E	19.06.1966	0.5	var. *vulgare*
25	Osičac cape (Pelješac peninsula)	43° 0.7´N 17° 0.5´E	19.06.1966	0.5–1	var. *vulgare*
27	Osičac cape (Pelješac peninsula)	43° 0.2´N 17° 1.3´E	19.06.1966	0.4–0.6 1–1.5	var. *vulgare*
28	East of Duba cove (Pelješac peninsula)	42°59.2´N 17° 4.2´E	19.06.1966	1–1.5	var. *vulgare*
30	Orebić (port)	42°58.4´N 17°10.7´E	22.06.1966	1–1.5	var. *vulgare*
31	East of Orebić	42°58.3´N 17°14,1´E	22.06.1966	0.7	var. *vulgare*
32	Trstenik (Pelješac peninsula)	42°54.7´N 17°24.7´E	22.06.1966	1	var. *vulgare*

Table 1. cont'd

35	Lighthouse by Glavat island (Vrhovnjaci)	42°46.0´N 17° 8.9´E	05.1949 06.1950	18	var. *vulgare*
38	Between islands Lukovci and Stomorina	42°46.5´N 16°57.6´E	30.05.1961	6–20	var. *vulgare*
40	By Mrkjenta Bijela island (by Lastovo island)	42°46.8´N 17° 1.0´E	17.05.1948	1	transitional to var. *jabukae*
44	East of Kopišta (Group of Lastovo)	42°45.3´N 16°44.1´E	30.05.1961	20–50	var. *vulgare*
48	Proizd cape (Korčula island)	42°59.3´N 16°35.7´E	31.05.1961	15–16 40–20	var. *vulgare*
60	Kašjuni cove (by Split)	43°29.5´N 15°23.6´E	on several occasions over a long term period	0.5–0.7	*f.erceg.*
65	Garbina Mala cove (Čiovo island)	43°25.9´N 16°22.3´E	22.06.1965	0.5–1.0	var. *vulgare* *f. erceg.*
69	By Supetar (Brač island)	43°23.2´N 16°33.2´E	25.05.1963	0.5	var. *vulgare*
77	Milna cove (Brač island)	43°20.0´N 16°26.3´E	09.05.1963 04.08.1966	0.5–1	transitional to var. *megaloph.*
78	West of Milna cove (Brač island)	43°19.5´N 16°26.4´E	09.05.1963	0.5–1	transitional to var. *megaloph.*
79	Kobila cape (Brač island)	43°18.9´N 16°25.1´E	22.05.1963	0.3	var. *vulgare*
80	In front of Osibova cove (Brač island)	43°18.7´N 16°26.4´E	22.05.1963	0.5–1.0	var. *vulgare*
81	Lučica cove (Brač island)	43°18.5´N 16°27.6´E	20.05.1963	0.3–0.5 1–1.5–2	var. *vulgare*
82	Farska cove (Brač island)	43°16.3´N 16°32.1´E	10.06.1963	0.5–0.6	var. *vulgare*
83	By Sučurje (Hvar island)	43° 7.5´N 17°11.2´E	17.06.1966	0.7–1.0	var. *vulgare*
84	In front of Zavala cove (Hvar island)	43°12.1´N 16°34,1´E	11.06.1965	1.5	var. *vulgare*
88	Grebišće cove (Hvar island)	43° 9.6´N 16°43.0´E	07.07.1965	0.6–1	var. *vulgare*
89	Mina cove (Hvar island)	43° 9.7´N 16°42.8´E	07.07.1965	0.5–0.7	var. *vulgare*
90	By Jelsa (Hvar island)	43°10.1´N 16°42.4´E	07.07.1965	0.5–1	var. *vulgare*
93	Tiha cove (Hvar island)	43°12.7´N 16°33.5´E	11.07.1965	0.5–1	var. *vulgare*
94	Tiha cove (Hvar island)	43°12.8´N 16°32.5´E	11.07.1965	0.5–1	var. *vulgare*
96	By Starigrad (Hvar island)	43°11.2´N 16°35.2´E	11.07.1965	4–8 14–30	var. *vulgare*
97	By Pelegrin cape	43°11.8´N 16°22.0´E	05.1949	20–25	var. *vulgare*

Table 1. cont'd

101	South of Marinkovac island (Pakleni islands)	43° 9.1′N 16°25.1′E	31.05.1961	10–25	var. *vulgare*
102	Marinkovac island (Pakleni islands)	43°25.3′N 16°25.3′E	01.06.1963	1–4	var. *vulgare*
107	Vodnjak island (Pakleni islands)	43°10.4′N 16°18.8′E	31.05.1961	12–30	var. *vulgare*
108	Zub od Zaraća cape (Hvar island)	43° 8.7′N 16°32.0′E	29.06.1965	0.2 0.3	var. *vulgare*
109	Pitovske plaže (Hvar island)	43° 7.4′N 16°42,4′E	29.06.1965	0.5–3.0	var. *vulgare*
110	By Pitovske plaže (Hvar island)	43° 7.3′N 16°41.6′E	29.06.1965	1–3	var. *vulgare*
114	Duboka cove (Hvar island)	43° 6.9′N 17° 2.8′E	02.07.1965	0.5–0.7	var. *vulgare*
115	Kozja cove (Hvar island)	43° 6.9′N 17 3.2°′E	02.07.1965	0.5–1.5	var. *vulgare*
116	Leprinova cove (Hvar island)	43° 6.8′N 17° 4.7′E	02.07.1965	0.7–1.0	var. *vulgare*
117	Aržić cove (Hvar island)	43° 6.8′N 17° 5.4′E	02.07.1965	0.7–3.0	var. *vulgare*
118	Lestimerova cove (Šolta island)	43°20.6′N 16°23.3′E	13.06.1963	0.5	var. *vulgare*
122	Reef between of Stipanska and Mačaknar islands	43°24.4′N 16° 8.9′E	03.1968	6–8	var. *vulgare*
128	By Livka cove (Šolta island)	43°19.6′N 16°23.5′E	13.06.1963	2–5	var. *vulgare*
129	Reef east of Vis island	43° 1.5′N 16°21.4′E	08.05.1949	30	var. *vulgare*
131	Greben island east of Vis island	43° 3.2′N 16°16.0′E	25.07.1962	0.5 12–14	var. *vulgare*
133	Cape by Vela Smokova cove (Vis island)	43° 3.5′N 16°15.6′E	25.07.1962 30.05.1963	1–1.5	var. *vulgare*
134	Vela Smokova cove (Vis island)	43° 3.7′N 16°15.5′E	07.1956	15–40	var. *vulgare*
136	Gradac cove (Vis island)	43° 4.8′N 16° 8.3′E	on several occasions over a long term period	0.2–0.3 10–60	var. *vulgare*
137	Dobra Luka cove (Vis island)	43° 4.5′N 16°14.0′E	24.07.1962	1.5–8 22	var. *vulgare*
138	Ridge in front of Vis Port	43° 4.7′N 16°13.2′E	24.07.1962	1–10	var. *vulgare*
139	Nova Pošta cape (Vis island)	43° 4.8′N 16°11.3′E	21.07.1962	0.5–0.7	var. *vulgare*
140	Seget reef (by Vis island)	43° 4.1′N 16°1.2′E	30.05.1963	18	var. *vulgare*

Table 1. cont'd

142	Barjaci reef (by Vis island)	43° 3.2′N 16° 2.5′E	12.05.1948 0.8.10.1958	8 10–20	transitional to var. *jabukae*
143	Pretišćina cove (Vis island)	43° 0.4′N 16° 6.2′E	10.07.1956 05.1965	2–3 25–40	var. *vulgare*
144	Smričevica cove (Vis island)	43° 0.9′N 16° 9.8′E	10.07.1956 25.07.1962	1–5 10–15	var. *vulgare*
147	Polivalo cape (Vis island)	43° 0.8′N 16°13.0′E	07.1957	1.5	var. *vulgare*
149	Rukavac cove (Vis island)	43° 1.2′N 16°13.0′E	05.1948	25–30	var. *vulgare*
150	North of Palagruža island	42°23.7′N 16°15.3′E	05.1949	7	transitional to var. *jabukae*
151	North of Palagruža island	42°23.6′N 16°15.7′E	04.1955	1	transitional to var. *jabukae*
152	Northeast of Palagruža island	42°23.3′N 16°15.8′E	06.1950 04.1956	1	transitional to var. *jabukae*
153	Western coast of Palagruža island	42°23.6′N 16°15.1′E	07.1956	0.5–2.0	transitional to var. *jabukae*
156	North of Kamik island (by Palagruža island)	42°23.4′N 16°16.2′E	20.09.1961	40–70	transitional to var. *jabukae*
157	Southern coast of Palagruža island	42°23.5′N 16°15.3′E	on several occasions over a long term period	0.5–1	transitional to var. *jabukae*
158	South of Galijula island	42°22.7′N 16°20.2′E	05.1948	1	transitional to var. *jabukae*
161	In front of Mala Špilja (Biševo island)	42°58.8′N 16° 1.5′E	23.09.1961	20–50	var. *vulgare*
165	By Potok cove (Biševo island)	42°58.0′N 16° 0.0′E	10.05.1948	40–50	var. *vulgare*
166	Duga cove (Biševo island)	42°57.6′N 16° 0.1′E	20.04.1957 18.09.1959	0.5–1.0	transitional to var. *jabukae*
168	Trešjavec cape (Biševo island)	42°57.3′N 15°59.9′E	23.09.1961	1	transitional to var. *jabukae*
172	By Kamik island (Svetac island)	43° 1.2′N 15°43.1′E	on several occasions over a long term period	30–40	var. *vulgare*
173	West of Svetac island	43° 1.3′N 15°43.6′E	26.05.1961 26.06.1961	5–10 15–30	transitional to var. *jabukae*
174	East of Jabuka island	43° 5.5′N 15°27.8′E	on several occasions over a long term period	1–3	var. *jabukae*
175	Northeast of Jabuka island	43° 5.5′N 15°27.8′E	08.1951 07.1955	1–3	var. *jabukae*
178	Southwest of Jabuka island	43° 5.5′N 15°27.8′E	on several occasions over a long term period	0–3	var. *jabukae*

Table 1. cont'd

180	Reef by Jabuka island	43° 6.0′N 15°26.1′E	on several occasions over a long term period	6–10	var. *jabukae*
182	Jabuka Pit	43°18.8′N 15°54.4′E	20.04.1957	118–128	var. *vulgare*
184	By Primošten	43°35.0′N 15°55.3′E	06.06.1964	0.7–1	transitional to var. *megaloph.*
185	Cape in front of Grebaštica cove (by Primošten)	43°37.3′N 15°55.2′E	06.06.1964	0.6–0.7	transitional to var. *megaloph.*
186	Grebaštica cove (by Primošten)	43°37.9′N 15°55.1′E	06.06.1964	0.6	var. *vulgare f. erceg.*
190	Zmajan island (Islands of Šibenik)	43°40.9′N 15°46.5′E	08.05.1971	0.5	transitional to var. *vulgare f. erceg.*
198	Purara island (Kornati)	43°41.7′N 15°26.3′E	09.07.1948	1	var. *vulgare*
203	Lučica cove (south–east of Pakoštane)	43°52.2′N 15°33.4′E	27.05.1967	0.6	var. *vulgare*
204	West of Lučica cove	43°52.4′N 15°33.2′E	27.05.1967	0.3–0.4	var. *vulgare*
205	Southeast of Žakan cove (by Pakoštane)	43°52.7′N 15°32.6′E	27.05.1967	1	var. *vulgare*
206	By Dugovača cove (by Pakoštane)	43°53.7′N 15°31.8′E	24.05.1967	0.7	var. *vulgare*
208	Tukljača (Channel of Pašman)	43°58.7′N 15°23.8′E	22.05.1964	0.5	var. *vulgare f. erceg.*
211	Diklo (Channel of Zadar)	44° 8.1′N 15°12.5′E	24.05.1964	0.5–1	var. *vulgare*
212	By Sv. Bartul (Channel of Zadar)	44°10.2′N 15°10.7′E	24.05.1964	0.5	var. *vulgare f. erceg.*
215	By Brtalić cape (southeast of Privlaka)	44°14.2′N 15 8.2°′E	22.05.1964	1–3	var. *vulgare*
219	By Božava (Dugi otok island)	44° 8.6′N 14°54.9′E	03.06.1964	0.5–1.0	var. *vulgare*
220	Borji cape (Dugi otok island)	44°10.7′N 14°51.8′E	03.06.1964	0.5–0.7	transitional to var. *vulgare f. erceg.*
223	Shajanje cape (Dugi otok island)	44° 9.9′N 14°50.3′E	03.06.1964	1–2	var. *vulgare*
224	By Shajanje cape (Dugi otok island)	44° 9.7′N 14°49.3′E	03.06.1964	0.5	var. *vulgare*
225	By Shajanje cape (Dugi otok island)	44° 9.6′N 14°50.3′E	03.06.1964	1–1.5	var. *vulgare*
227	Vidilica cape (Dugi otok island)	43°52.1′N 15°12.2′E	06.1964	0.6–1.5	var. *vulgare*
228	Gnal cape (Pašman island)	43°53.9′N 15°27.6′E	05.06.1964	1–2	var. *vulgare*

Table 1. cont'd

229	Cape of Zaklopica cove (Pašman island)	43°53.9'N 14°27.4'E	05.06.1964	0.7–0.5	var. *vulgare*
230	In front of Tkon (Pašman island)	43°53.3'N 15°25.6'E	25.06.1964	1–1.5	var. *vulgare*
236	By Cablin cove (Pašman island)	44° 0.2'N 14°16.2'E	30.06.1964	0.3–0.5	var. *vulgare*
237	By Čerenje cove (Pašman island)	43°58.3'N 14°18.1'E	30.06.1964	03–0.5	var. *vulgare*
238	Cape in front of Soline cove (Pašman island)	43°56.1'N 15°21.0'E	29.06.1964	0.3–0.5	var. *vulgare*
239	Karantunić island (by Ugljan island)	44° 0.5'N 15°14.8'E	05.06.1964	0.3–0.5	var. *vulgare*
242	Cape in front of Sabušćica cove (Ugljan island)	44° 2.1'N 15°13.8'E	05.06.1964	0.7–2	var. *vulgare*
243	Cape by Sabušćica cove	44° 1.6'N 15°14.2'E	05.06.1964	0.3–0.4	var. *vulgare*
244	By Sabušćica cove	44° 1.4'N 15°14.6'E	05.06.1964	0.3–0.4	var. *vulgare*
241	Lamjana Mala cove (Ugljan island)	44° 2.6'N 15°13.4'E	05.06.1964	0.5–0.4	var. *vulgare*
245	Željina Vela cove (Ugljan island)	44° 4.3'N 15° 9.2'E	26.05.1964	0.5–1	var. *vulgare*
246	Ovčjak cape (Ugljan island)	44° 8.1'N 15° 4.2'E	26.05.1964	0.5–1	var. *vulgare*
247	Sv. Petar cape (Ugljan island)	44° 9.5'N 15° 4.2'E	27.06.1964	0.5–2	var. *vulgare*
251	South of Sipa cape (Maun island)	44°27'3N 14°53.1'E	06.1964	0.7–1	var. *vulgare*
252	Fortica cape (Pag island)	44°19.5'N 15°15.4'E	29.05.1964	0.5–2	var. *vulgare*
254	West of Šimuni cove (Pag island)	44°28.0'N 14°56.5'E	29.05.1964	0.5–1	var. *vulgare*
255	By Šimuni cove (Pag island)	44°28.0'N 14°57.2'E	29.05.1964	0.5–1	var. *vulgare*
256	Ogradice cape (Pag island)	44°34.9'N 14°50.7'E	12.06.1964	0.5–1	var. *vulgare*
257	Crnotinac cape (Pag island)	44°35.5'N 14°50.1'E	12.06.1964	0.5	var. *vulgare*
258	Kanić cove (Pag island)	44°35.9'N 14°49.8'E	12.06.1964	0.5	var. *vulgare*
259	In front of Dubac cove (Pag island)	44°36.7'N 14°48.7'E	12.06.1964	0.5–1	var. *vulgare*
260	By Potočnica cove (Pag island)	44°37.1'N 14°48.4'E	12.06.1964	0.5–1	var. *vulgare*
261	Sakarata cape (Pag island)	44°37.8'N 14°47.3'E	12.06.1964	0.5–1	var. *vulgare*

Table 1. cont'd

262	Jadrešnica cove (Pag island)	44°38.3´N 14°47.0´E	12.06.1964	1	var. *vulgare*
263	Galboka cove (Lošinj island)	44°38.2´N 14°21.9´E	07.1950	1	var. *vulgare*
264	Duboka cove (Unije island)	44°38.4´N 14°15.8´E	10.07.1950	1	var. *vulgare*
265	Sv.Fumija cove (Rab island)	44°45.4´N 14°45.0´E	14.06.1968	0.5–1	var. *vulgare*
266	Small cape in front of Gožinka (Rab island)	44°45.4´N 14°42.9´E	14.06.1968	0.5–1	var. *vulgare*
269	Planka cove (Rab island)	44°46.2´N 14°40.5´E	14.06.1968	1–3	var. *vulgare*
270	Sv.Mara (Rab island)	44°46.9´N 14°39.8´E	14.06.1968	2–6	var. *vulgare*
271	Donja Punta (Rab island)	44°47.5´N 14.39.2°´E	14.06.1968	0.5	var. *vulgare*
272	Gornja Punta (Rab island)	44°48.2´N 14°39.8´E	14.06.1968	0.8–1.5	var. *vulgare*
277	HVAR Expedition Station 39	43°22.0´N 14°46.5´E	26.07.1948 29.03.1959	115–121 115–118	var. *vulgare*
279	HVAR Expedition Station 50	43° 3.5´N 15° 7.0´E	15.04.1948 29.08.1948	256–254 256–262	var. *vulgare*
282	HVAR Expedition Station 57	43°19.0´N 15°35.0´E	11.02.1948	160–180	var. *vulgare*
286	HVAR Expedition Station 96	42°46.0´N 16°12.5´E	23.06.1948	150	var. *vulgare*
288	HVAR Expedition Station 164	40°25.5´N 19°25.5´E	04.06.1948	48	var. *vulgare*
289	Kršine cape (western coast of Istra)	44°46.2´N 13°54.4´E	10.07.1968	1–1.5	var. *megaloph.*
290	Barabiga cape (western coast of Istra)	45° 6.2´N 13°37.4´E	17.08.1965 17.07.1968	1	var. *megaloph.*
291	Banjole island (western coast of Istra)	45° 4.4´N 13°36.6´E	11.08.1965 31.08.1965	3.5 2.5	var. *megaloph.*
292	Sv. Katarina island (western coast of Istra)	45° 4.7´N 13°37.7´E	31.08.1965	3	var. *megaloph.*
294	By Križ cape (western coast of Istra)	45° 7.1´N 13°36.5´E	10.06.1968	1–2	var. *megaloph.*
295	Faborsa cove (western coast of Istra)	45° 7.1´N 13°37.0´E	14.08.1965	0.7	var. *megaloph.*
296	Saline cove (western coast of Istra)	45° 7.3´N 13°37.2´E	10.06.1968	1	var. *megaloph.*
300	Petolan cape (western coast of Istra)	45° 8.5´N 13°35.9´E	17.07.1968	1	var. *megaloph.*
306	Savudrija cape (western coast of Istra)	45°29.5´N 13°29.5´E	14.07.1968	1–2	var. *megaloph.*

The intermediate settlements consist of populations inhabiting the channels between the intermediate and inner islands (Krk, Rab, Pag, western and northern coasts of Dugi Otok Island, Kornati, Ugljan, Pašman, Brač Hvar), Pelješac Peninsula, and a part of the mainland coast. In this area, the forms closest to the typical form *S. vulgare* var. *vulgare* occur at a depth of 2-3 m. They differ from the typical form by a smaller but denser thallus and shorter narrower blades (length to width ratio 6:7). Forms characterized by a longer and looser thallus occur somewhat deeper, whereas the forms living near the surface (0.3-1 m depth) have a very short dense thallus.

The inner settlement includes populations inhabiting inner channels between inner islands and the mainland in the central and part of the northern Adriatic. Transitional forms between the typical species (*S. vulgare* var. *vulgare*) and *S. vulgare* var. *vulgare* f. *ercegovicii* dominate. Specimens of *S. vulgare* var. *vulgare* f. *ercegovicii* are frequently recorded from poorly exposed but not completely sheltered areas of the mainland coast, at depths of 0.5-1 m. They are characterized by a large number of rather large spear-like blades that are much wider and less serrated than those of the typical species (length to width ratio 3:4). Fructifications are compact, 5-10 mm long, 1.6 mm wide, irregularly ramified, and slightly flattened towards the tips. In populations growing on the shores of inner islands, particularly Brač, Šolta, some parts of Ugljan, Pašman, Pag, Rab, and Krk, the specimens are a transitional form between the typical species and *ercegovicii* with respect to morphology. Blades are slightly less wide than in the typical species (length to width 4:5), serrations are slightly better pronounced, and fructifications are more markedly cylindrical and ramified

The outer settlements live in waters surrounding the outer islands of Jabuka, Svetac, Lastovo, and Palagruža. Here, *S. vulgare* var. *jabukae*, which differs from the typical form to a considerable extent, forms the population. Basic characteristics of these specimens are high density of the thallus and its parts in surface specimens, narrowly tapered or spear-shaped primary branches in specimens from 20 m, narrow blades that thin towards the tips and edges almost without serrations (length-width ratio 8:9 in surface forms and 5:7 in deep forms), and sexual dimorphism manifested as fructifications of different forms and sizes. This subspecies grows on the rocky shores of Jabuka Islet at depths of 1-20 m and on the adjacent reef at 6-10 m. Specimens from Svetac, Palagruža, Lastovo, and some reefs near Vis Island (Barjaci and Ploča Reefs) slightly differ from this variety, so can be considered a transitional form between the typical species and the variety *jabukae*; their blades are, on average, somewhat wider, bigger, slightly more serrated, and longer, with a length-weight ratio of 5:6,

The northern settlement includes *S. vulgare* var. *megalophyllum* populations from the western Istrian coast and some islands and mainland coastal areas of the northern and central Adriatic. This variety grows at shallow depths of 0.7-3 m. It is characterized by elongated spear-like very densely serrated blades (double serrations are frequent). Specimens collected from some partly sheltered localities in the coastal and insular areas of the central Adriatic have morphological properties that considerably differ. For example, the specimens collected from Kaštela and Marina Bays near Split have slightly shorter and slightly wider blades (length to width 4:6) of a spear-like shape. Similar forms were recorded from a number of other localities in the coastal and insular areas (Čiovo Peninsula and Brač, Šolta, Ugljan, Pašman, and Rab Islands).

Sargassum salicifolium J. Agardh var. *salicifolium*

J. Agardh, Sp. Alg. Austr., 1889, p. 112; Naccari, Fl. Ven., 1828, p. 98; Alg. Adr., 1828, p. 89.

Synonyms: *Fucus salicifolius*, Gmel., 1768 Hist. Fuc., p. 98; Bertoloni, 1819, Amoenit. Ital., p. 283; *Sargassum linifolium* var. *salicifolium* J. Agardh, 1848-63, Sp. Alg., p. 342; Ardissone, 1886, Phycol. Medit., p. 15; *Sargassum vulgare*, var. *salicifolium* C. Agardh, 1821, Sp. Alg., p. 5; Zanardini, 1841, Syn. Alg. Mar. Adriat., p. 241; Meneghini, Alg. Ital. Dalm., 1842, p. 20; *Sargassum coarctatum* Kütz., Phyc., 1843, p. 361. Icon.: Bertoloni, Amoenit. Ital., 1819, Tab. IV, Fig. 1; Meneghini, Alg. Ital. Dalm., 1842, Tab. I, Fig. 2; Kützing, Tab. Phyc., XI, 22, 1849-1869; J. Agardh, Sp. Sarg. Austr., Tab. XXXI, 1889, Fig. 18-19.

Workers treated the species *S. salicifolium* and its varieties in different ways. DONATI (1750) described the species as *Fucus accinaria* while WULFEN (1786, 1803) distinguished between two species, *Fucus natans* and *Fucus accinaria*, in agreement with AGARDH's distinction between *S. salicifolium* (*F. natans*) and *S. linifolium* (*F. accinaria*). Later, BERTOLONI (1819) put both of AGARDH's species under the common name *Fucus salicifolium*, assuming *salicifolium* as the type and *linifolium* as a variety β. However, later authors who were very familiar with Adriatic and Mediterranean bottom flora did not recognize *S. salicifolium* as a species but described it as a variety of *S. vulgare* and *S. linifolium*. C. AGARDH (1821), ZANARDINI (1841), and MENEGHINI (1842) believed that the form *salicifolium* was a variety of *S. vulgare* while ARDISSONE (1886) considered it a variety of *S. linifolium*. J. AGARDH (1889) reconsidered the distinction between these forms and gave the name *S. salicifolium* to forms with spear-like blades and short receptacles and the name *S. linifolium* to forms with long cylindrical receptacles. He described the former as a typically Mediterranean form and the latter as the Adriatic species. After him, other well-known workers such as De TONI (1895), GRUNOW (1916), and FELDMANN (1931, 1936-1937) considered these forms two separate species.

By examining abundant material collected from a large number of localities and a variety of depths in the eastern middle Adriatic, we established the frequent presence of forms with morphological properties belonging to the species *S. salicifolium* J. Agardh and the more rare presence of forms that best correspond to the description of *S. linifolium* Turner. On this basis, it seems appropriate to unite both forms, as BERTOLONI (1819) did, in a single species named *S. salicifolium* J. Agardh, taking AGARDH's species *S. salicifolium* as a type, and TURNER's species *S. linifolium* as its subspecies.

As a typical *S. salicifolium* var. *salicifolium* we describe the form living at 6-8 m in the Kašjuni Cove near the Institute of Oceanography and Fisheries in Split (Figs. 12-15). The same or similar forms were collected from a large number of other localities in the channel and inshore waters at depths of 2-8 (max 12) m and, sometimes, from open Adriatic waters at 10-15 (max 30) m. The plant is characterized by a long abundantly developed thallus that sometimes reaches 150 cm. One or more erect stipes, frequently adjoining at the base, grow from a strong holdfast. The stipes, especially older ones, frequently ramify into stipe branches. The length of stipes is 3-5 cm and the width is 4-6 mm. The stipe tops and branches bear 3-6 primary branches that are slim, cylindrical, and overgrown with single or bifurcated prickles all along their lengths. The longest branches reach 150 cm. They ramify into very long secondary branches (up to 60-80 cm and in some specimens 100 cm) that are rather rare (10-12 per 10 cm interval) and normally covered by single or bifurcated prickles.

The primary and, particularly, secondary and tertiary branches bear blades that are longer and less numerous than those of *S. vulgare* var. *vulgare*. Fully developed blades are markedly tapered towards the top and somewhat less tapered towards the base, so they attain an exceptionally elongated spear-like shape. Blade stems are frequently very short, and sometimes appear embedded. Blades are frequently spiral, most frequently with serrated and slightly folded edges. Sometimes, particularly in young blades, the serration is better pronounced, although the serrations are neither big nor numerous. Blades occur first on the branches or stipe tops and are longest in young specimens. They frequently exceed 10 cm in length and 4-6 mm in width, and sometimes are bifurcated at their tips. Since these blades fall, they are usually

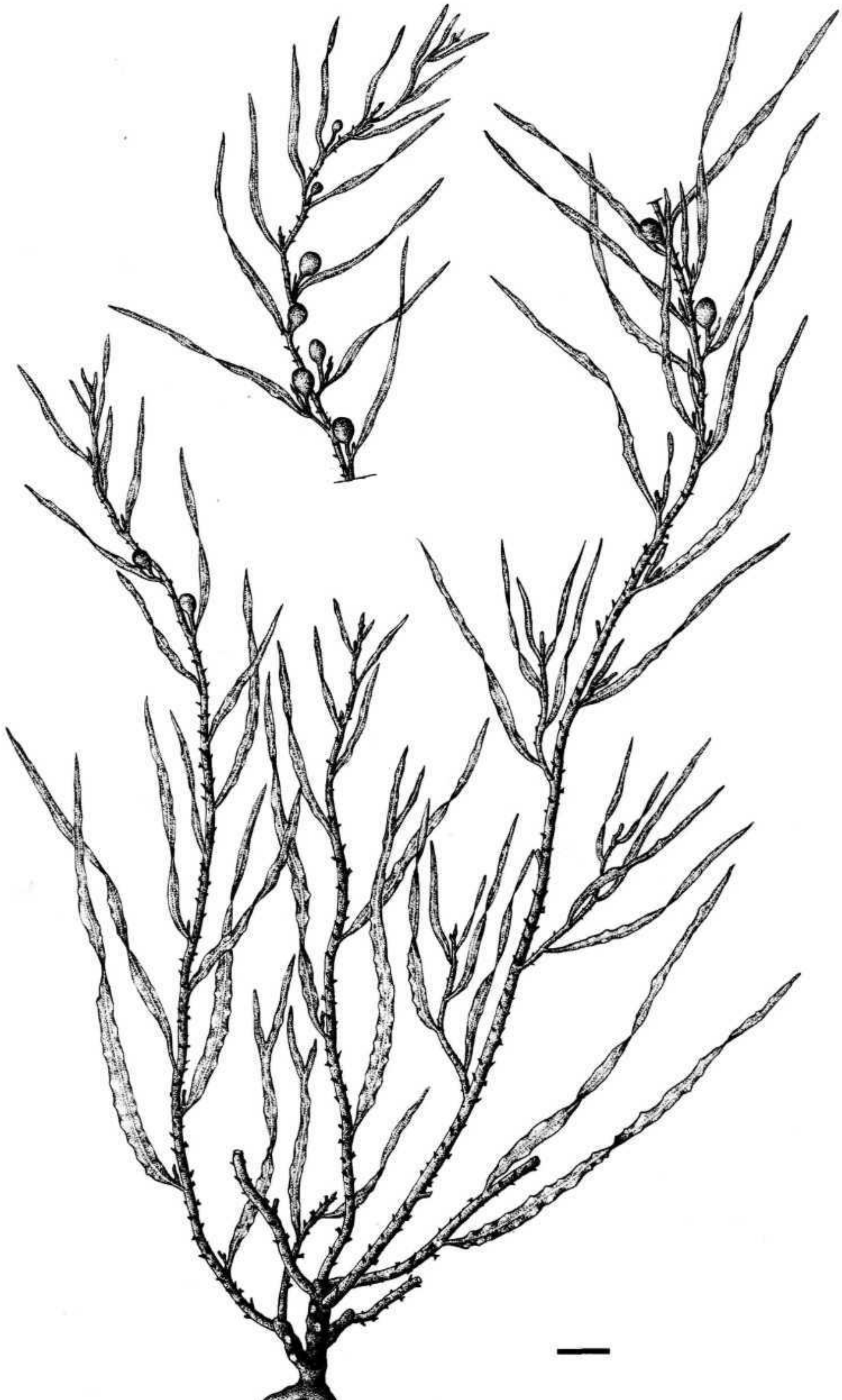

Fig. 12. Sargassum salicifolium *var.* salicifolium *(Marina Bay, near Split, 3-4 m depth). Specimen in development. Tree with young primary branches (August) ; scale = 1 cm*

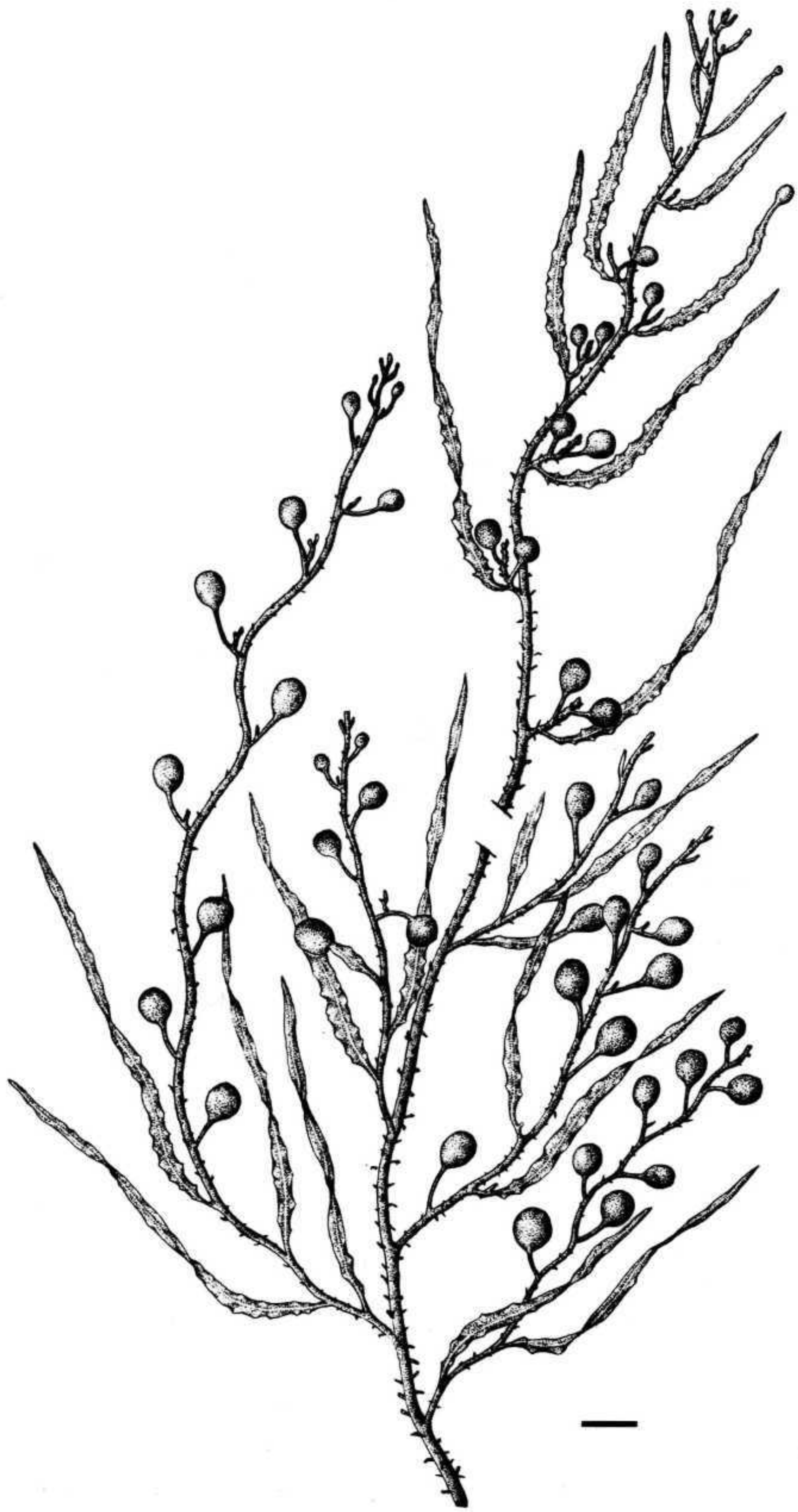

Fig. 13. Sargassum salicifolium *var.* salicifolium *(Marina Bay, near Split, 3-4 m depth). Lower and upper parts of primary branch under development (January) ; scale = 1cm*

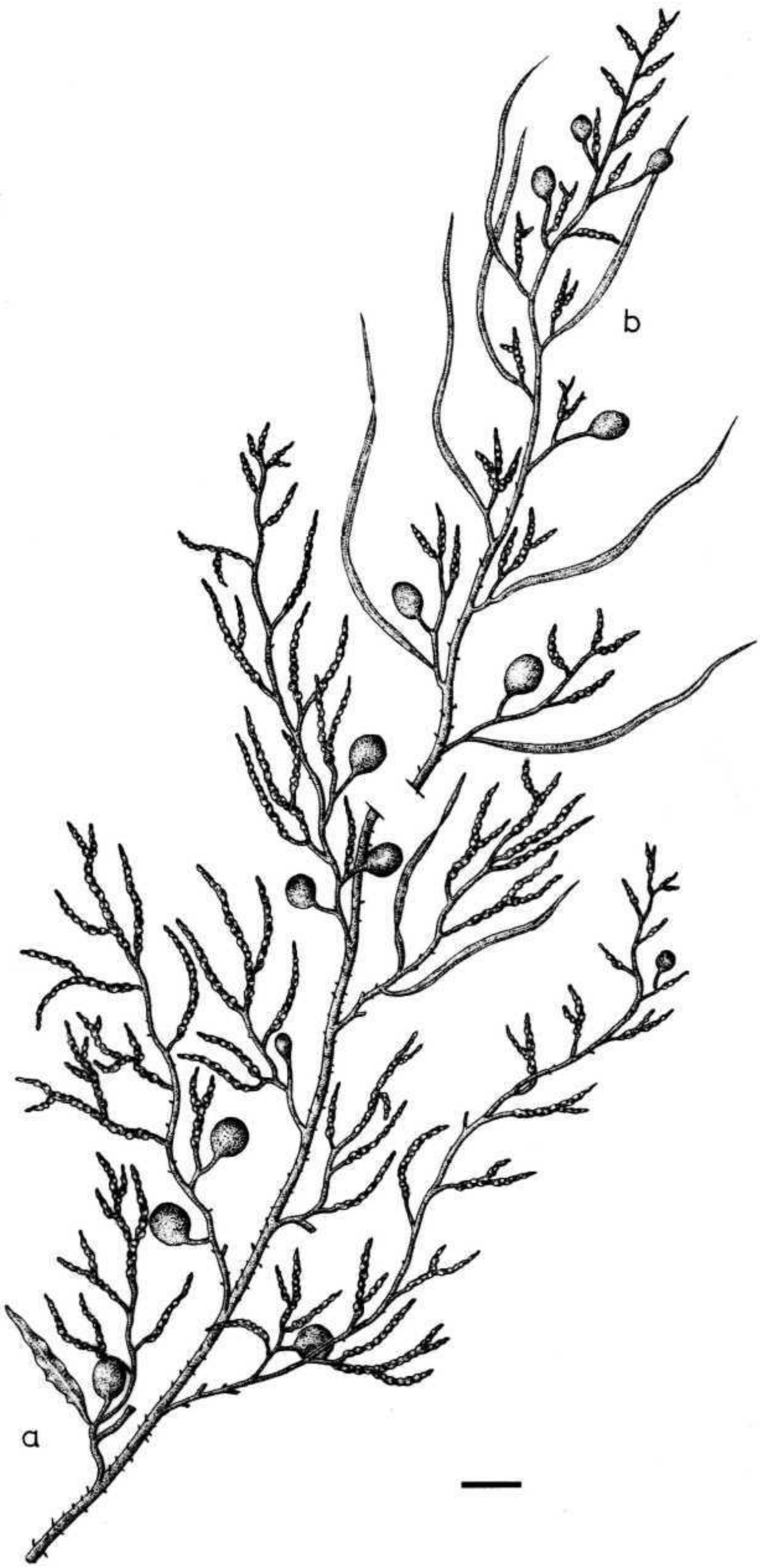

Fig. 14. Sargassum salicifolium *var.* salicifolium *(Marina Bay, near Split, 8-10 m depth): (a) lower and (b) upper parts of an older secondary branch with narrow blades, bladders, and fructifications (June) ; scale = 1cm*

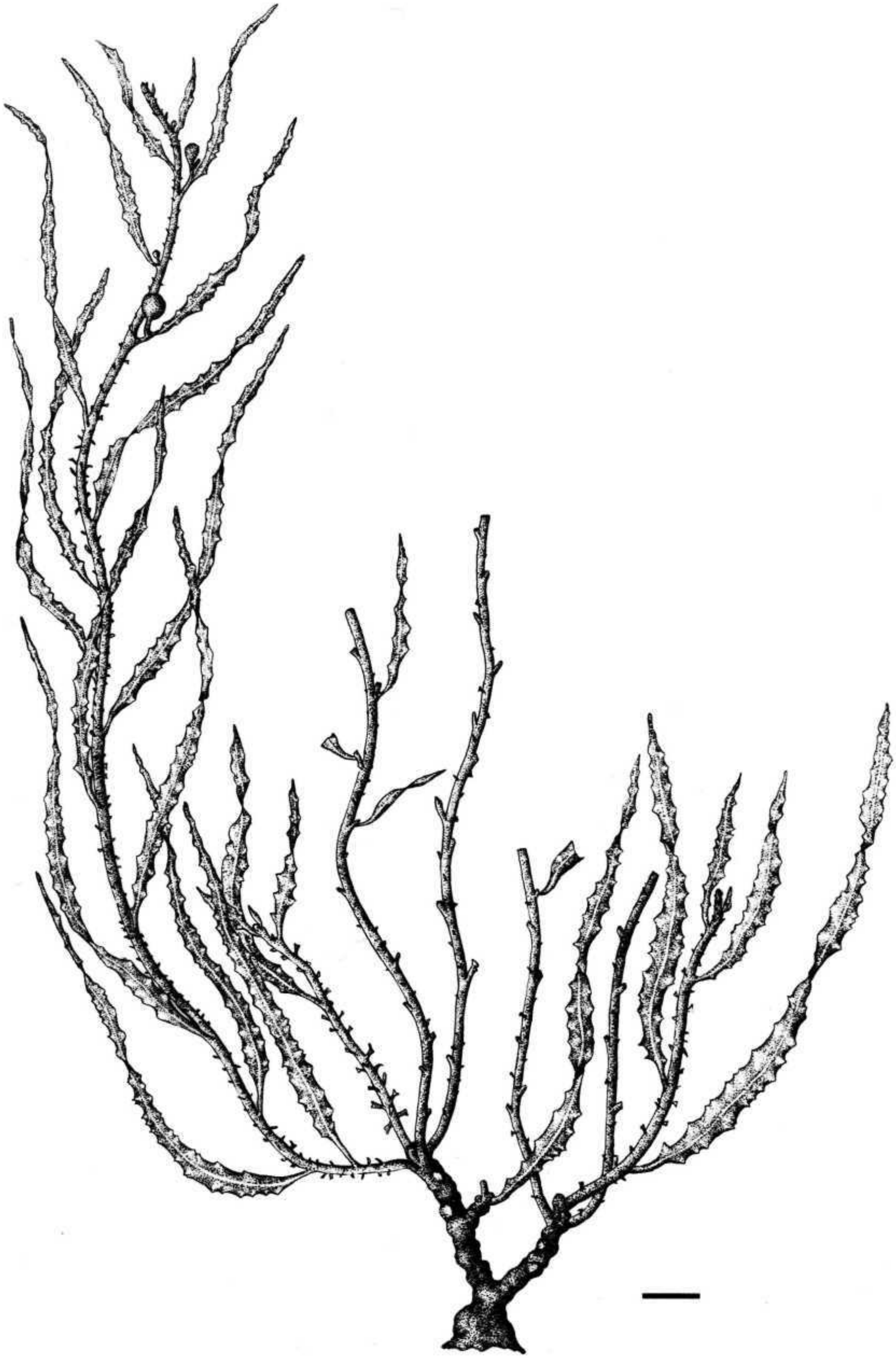

Fig. 15. Sargassum salicifolium *var.* salicifolium *(Marina Bay, near Split, 8-10 m depth). Stipe with young primary branches and residues of the old ones (June) ; scale = 1cm*

found in specimens collected between the end of summer and beginning of spring, during the period of intensive regeneration and growth. Blades on the intermediate and upper parts of the thallus are slightly shorter, 2.5-8 cm long and 2.5-7 mm wide. The length to width ratio is 8:15. Specimens collected from a depth of 4-8 m in Marina Bay near Split had narrower blades (ratio 10:30) than those collected farther offshore (near Vis and Hvar Islands; length to width ratio 8:12).

The form and length-width relationships of blades change with the season and developmental stage. In specimens from Marina Bay, where material was collected on an almost monthly basis in 1964-1965, blades collected in autumn, winter, and early spring (September, December-March) were longest in relation to width (not taking into account the first longest blades on the branches and stipe tips), with a ratio of 17:30. Those collected in winter and summer were shortest with a length-width ratio of 10:20 (Fig. 16a, b). Cryptostomata are small and arranged in two irregular rows on either side of the central rib on wider blades and in a single row on each side of the rib in narrower ones. Bladders occur in large numbers, particularly on the upper two-thirds of the thallus. They are most frequently spherical, rarely oval, and 3-9 cm long. The stem is cylindrical, maximum 1 cm, and frequently flat leaf-like, so that the bladders appear to occur at the ends of the blades (Fig. 16c).

Fructifications occur on blade or bladder stems on well-developed tertiary and, more rarely, secondary branches and, frequently, directly on branches. They consist of long cylindrical and sterile ramified parts and individual receptacles. Older receptacles, which first occur on the lower and intermediate parts of branches in April and May, are ramified and elongated. Younger receptacles occur later, in June and July, on upper branch parts. They are less ramified (sometimes not ramified at all), shorter, and mainly spin-shaped. Fully developed ripe receptacles are ramified, cylindrical, and elongated, 10-15 (max 20) mm long and 1.2-1.7 mm wide (Fig. 17a,b,d). Spin-shaped receptacles are considerably shorter (5-10 mm long, 0.8-1.2 mm wide) and less ramified (Fig. 17 c). Specimens have fully developed as well as younger receptacles (Fig. 14). Larger spherical rising female conceptacles and smaller cone-shaped rising male conceptacles are clearly distinguishable on the surfaces of the receptacles. Very frequently, the number of female conceptacles within a receptacle exceeds the male. Conceptacles differ in size and form. The cross-sections of female conceptacles are predominantly circular or slightly wider than long. Normal developed female conceptacles on cylindrically elongated receptacles are 380-500 (max 580) μ high and 350-500 μ wide. Those on shorter, spin-shaped receptacles are smaller, 300-450 μ high and 250-400 (max 450) μ wide. Apart from paraphyses, they contain oval oogonia (200-260 x 140-180 μ) that are slightly smaller in spin-shaped receptacles. Male conceptacles are elongated, siphon to oval shaped, and somewhat larger on low cylindrical receptacles (300-380 x 200-260 μ) than on short spin-shaped receptacles (250-320 x 150-200 μ). They contain paraphyses and antheridia which are 23-25 x 14-17 μ wide.

Fructification begins at the beginning of spring and terminates in approximately mid-summer. Fructification buds occur on the lower (and older) secondary and tertiary branches already in March. Later, during the spring and first half of summer, they occur on all other thallus parts (tertiary and secondary branches). Ripe conceptacles were recorded among older receptacles on the lower thallus part as early as May, and on all receptacles in June and July. Conceptacles were quite empty in the second half of August, with the exception of some of the youngest receptacles at the tips of the longest tertiary and secondary branches.

The vegetative period of the plant extends year-round, but development is not of equal intensity in all seasons. Therefore the appearance of the plant considerably changes during the year. In August, following the termination of fructification, old primary branches fall and are

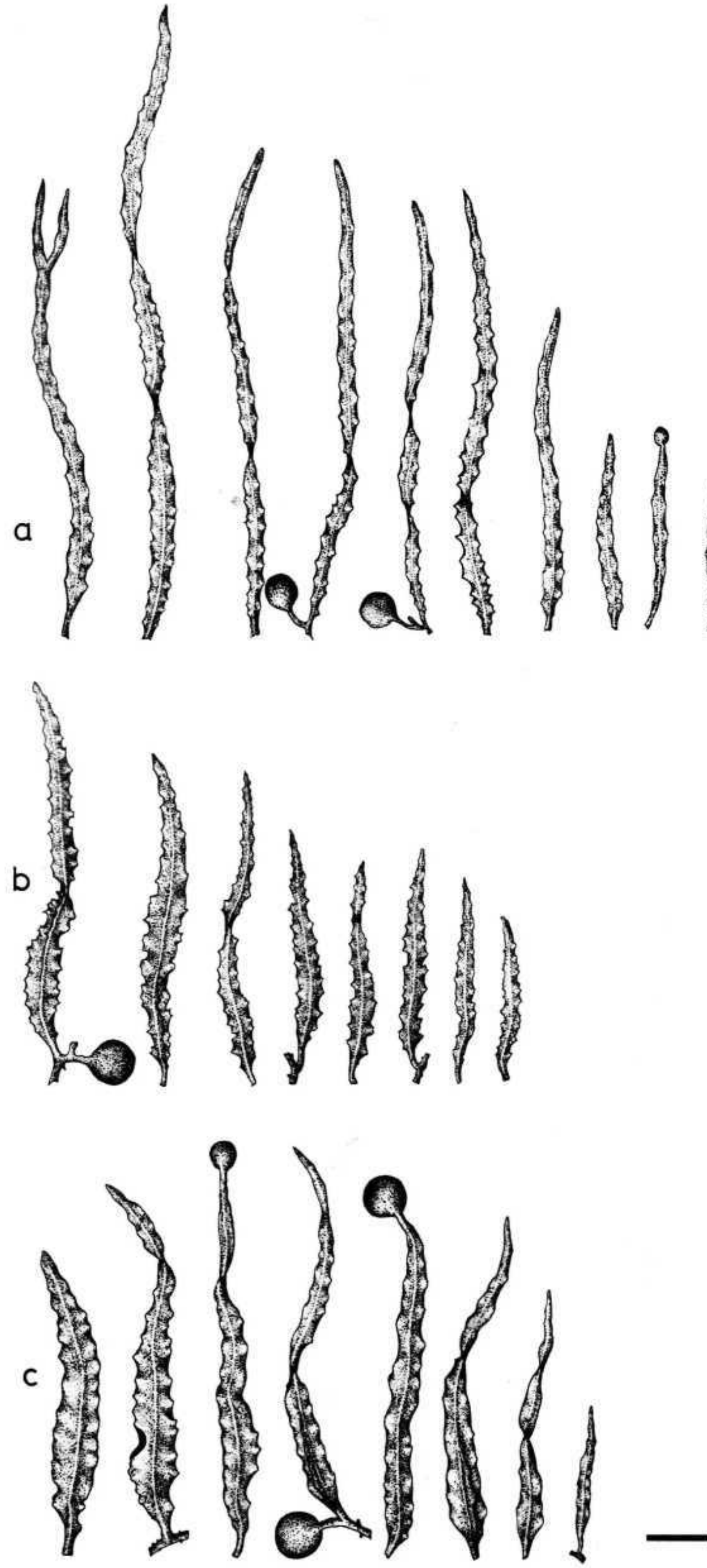

Fig. 16. Sargassum salicifolium *var.* salicifolium*: (a) blades in specimens collected at beginning of August and (b) in January (Marina Bay, 3-4 m depth); (c) in August (Kašjuni Cove, Split, about 8 m depth); scale = 1cm*

replaced by young ones (up to 30 cm) which begin to occur at stipe tips already in April and May. These young elongated and intensively growing branches bear very short (1-3 cm) secondary branches. During autumn and the first half of winter, primary branches grow quickly and secondary branches grow slowly. Intensive growth of the secondary branches begins after growth of the primary branches ends. In April-June, secondary branches reach 70-100 cm in length. Specimens collected at the end of August and in September (Fig. 12) differ considerably from specimens collected in January (Fig. 13) and, especially, May and June (Fig. 14). The former are light brown and small, bearing 20-30 cm primary branches with long (up to 10-12 cm), narrow (1.5-4 mm), serrated, and, very frequently, spirally turned blades. Sometimes some primary branches with a small number of blades and abundant bladders and fructifications remain. Specimens collected in May or June are in full fructification. They are usually brownish green. Primary and secondary branches are at their maximum lengths and bear a large number of blades, bladders, and fructifications. Blades are, on the average, slightly shorter and wider than in specimens collected at the end of summer. Very narrow blades (1.2-2 mm wide and 5-6 cm long) are frequently found on the upper parts of the thallus of specimens collected from calm coastal localities. Such blades are still under development (Fig. 14b) and are not found in July and August.

***Sargassum salicifolium* J. Agardh var. *linifolium*, comb. nov.**

Synonyms: *Sargassum salicifolium* var. β, Naccari, Fl. Ven., 1828, VI, p. 99; *Fucus salicifolius*, var. β, Bertol. Amoenit. Ital., 1819, p. 284; *Fucus linifolius*, Turner, Hist. Fuc., 1808-1819, III, p. 83; *Sargassum linifolium*, C. Agardh, Sp. Alg., 1821, I, p. 18; Syst., 1824, p. 300; Meneghini, Alg. Ital. Dalm., 1848, p. 23; J. Agard, Sp. Sarg. Aust., 1889, p. 113; *Sargassum vulgare* β *linifolium*, Zanardini, Syn. Alg. Mar. Adriat., 1841, p. 241. Icon.: Turner, Hist. Fuc. III, 1808-1819, Tab. 168; Bertoloni, Amoenit. Ital., 1819, Tab. 4, Fig. C; Meneghini, Alg. Ital. Dalm., 1841, Tab. I, 3; Kützing, Tab. Phyc., XI, 1849-1869, Tab. 24.

Specimens of *Sargassum salicifolium* var. *linifolium* were collected on several occasions from depths of 12-15 m in Marina Bay and Milna Cove (Brač Island). This alga is characterized by a long abundant thallus. Specimens grow to 200 cm in length. Several erect stipes, frequently adjoining at the base, are 4-7 cm long and 4-6 mm wide. Stipes grow from the holdfast by which the alga is attached to the ground. Primary branches are very long (reaching 170-200 cm), cylindrical, bifurcated at the top, and covered by dense single-leg or double-leg prickles all along their lengths. Secondary branches are also long (maximum 120 cm) but rather rare (8-10 per 10 cm interval on primary branch). Their form does not differ from that of primary branches. The branches bear blades which are, on the average, longer than in the typical form of this species.

Blades on the lower parts of young primary branches and tips of young stipes or tree branches usually exceed 10 cm and very frequently reach 12-14 cm long and up to 7-8 mm wide. Very frequently they are bifurcated once or twice (Fig. 18a). Similar to the typical species, blades fall rapidly and are found only in specimens collected in autumn and winter. There is great variation in form and size of blades occurring on the middle and upper parts of the branches (Fig. 18b). Most frequently, they are long and narrow but occasionally they are slightly shorter or wider, i.e., elongated spear-shaped. Serrations on the edges are marked, rather large, and sometimes double. Fully developed blades are 7-9 cm long and 2-8 mm wide. The length to width ratio is lowest at the end of the vegetative period (the second half of summer) when it is 10:20 and highest in winter and spring when it is 20:35 in some specimens. Blades of some specimens collected from depths of 8-12 m are, on average, slightly shorter and wider and very similar to those of the typical form.

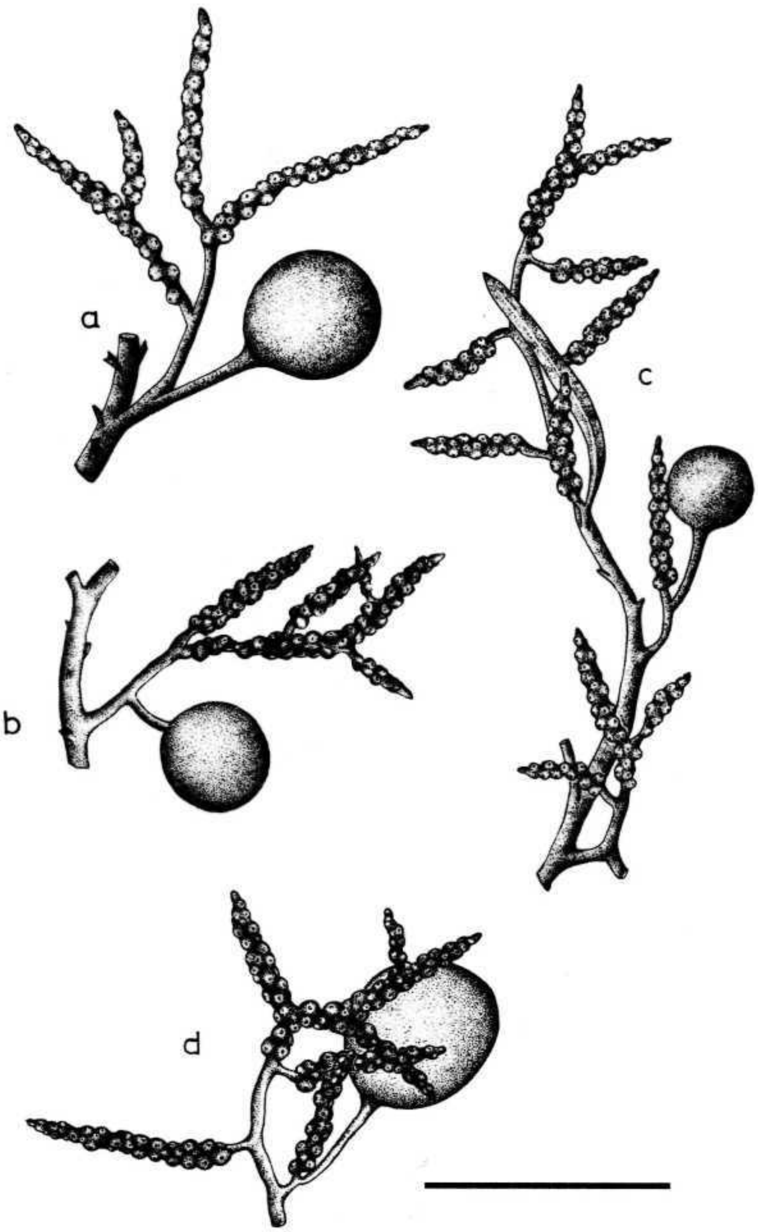

Fig. 17. Sargassum salicifolium *var.* salicifolium. *Fructifications in specimens from (a) Kašjuni Cove in Split, 8 m depth; (b) and (c) Vele Smokve Cove (Vis Island), about 20 m depth;(d) Smričevica Cove(Vis Island), about 25 m depth, x 4 ; scale = 1cm*

Cryptostomata are small and rare, sometimes barely visible, and arranged in one and two rather irregular rows on each side of the central rib on narrow and wide blades, respectively. Bladders are numerous, most often spherical though sometimes oval, rarely flat leaf-like, up to 3-8 mm, and occur on cylindrical stems up to 1 cm long.

Fructifications are well developed, as in the typical form. They occur on stems of blades and aerocyst bladders or directly on secondary and tertiary branches. They consist of well-ramified cylindrical sterile parts and markedly cylindrical very long receptacles (Figs. 18c,d). Well-developed receptacles are 1.5-4 cm long and 1.2-1.5 mm wide. Receptacles bear female and

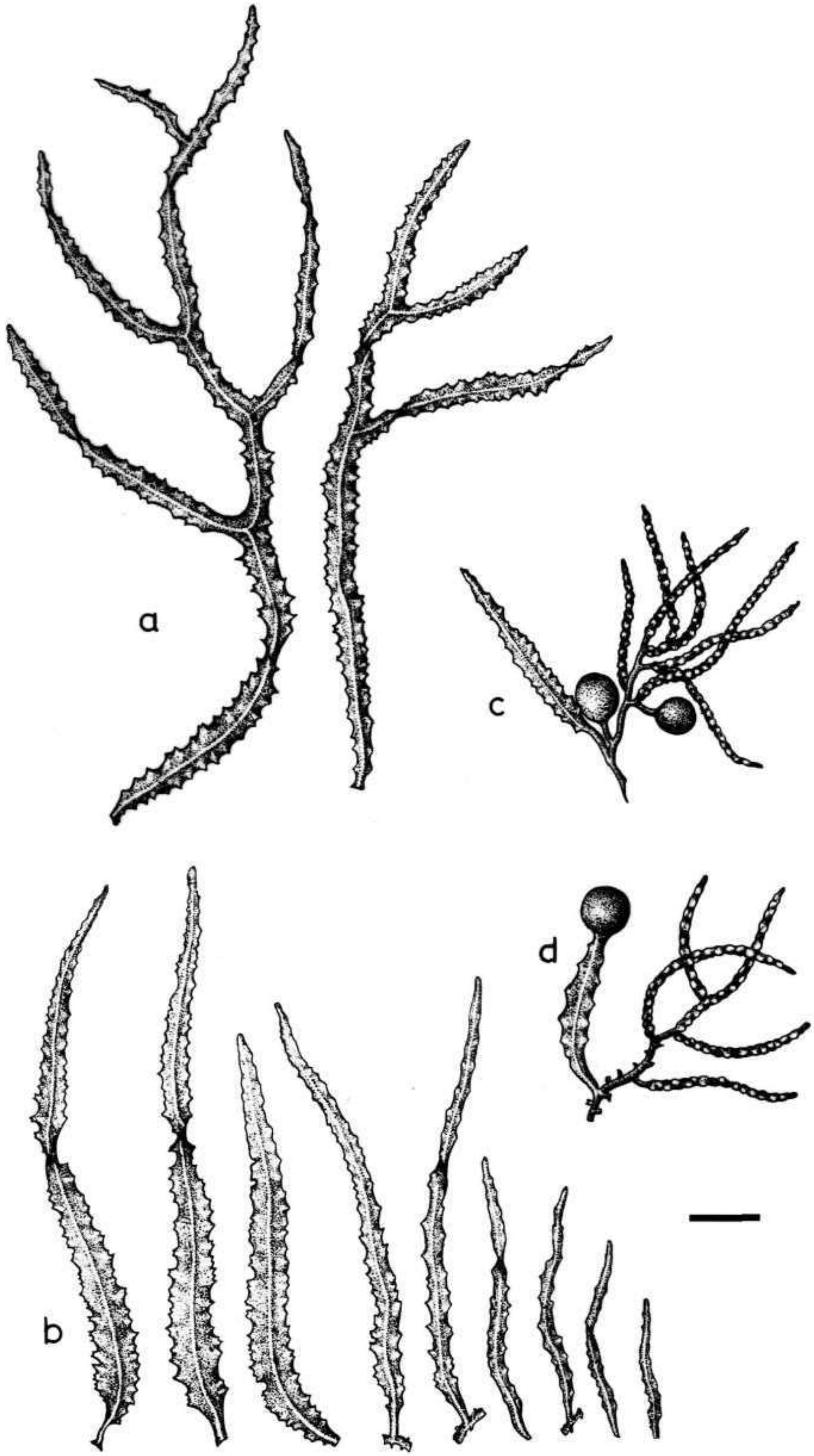

Fig. 18. Sargassum salicifolium *var.* linifolium*: Blades from (a) lower and (b) upper parts of the thallus (Milna Cove, Brač Island, 15 m depth, August); fructifications in specimens from (c) Marina Bay (August, about 12 m depth), and (d) Milna Cove (August, about 15 m depth); scale = 1cm*

male, and sometimes only male conceptacles. Female conceptacles spherically protrude from the tissue in which they are much deeper buried than in the typical species. The height of female conceptacles ranges 450-500 μ and width 350-450 μ. Oval oogonia are 200-230 x 130-150 μ. Male conceptacles have a syphon-like form and range 350-450 x 200-270 μ. Antheridia are 23-24 μ high and 15-17 μ wide. The sizes of the conceptacles, oogonia, and antheridia vary greatly depending on maturity and the size of the receptacles that contain them.

Fructification in this subspecies is about one month later than in the typical species: fructification occurs on the lower parts of the thallus as early as the beginning of April, ripening in June and July. We recorded fully ripe conceptacles in August and, in some specimens, the beginning of September.

This alga develops year-round. It grows most intensively in winter, spring, and the beginning of summer when primary and then secondary branches rapidly grow. Due to this uneven growth, the appearance of the alga changes during the year. We collected the longest most abundant specimens with developed blades, bladders, and fructifications in June and July. However, at the end of August and in September, the specimens had mainly young 15-30 cm primary branches, usually with spirally turned blades. Very often the stipe tips or stipe branches and lower parts of primary branches of these specimens had long multifurcated blades.

This subspecies may easily be mistaken for the typical species, particularly when specimens are defective. Specimens representing transitional forms between the typical species and this subspecies were found at 8-10 m in the coastal waters of Marina Bay and from Biograd to Zadar. In brief, typical specimens of this variety differ from the typical form of the species by somewhat longer, narrower, and more serrated blades and markedly elongated cylindrical and bifurcated receptacles.

Distribution the taxa of *Sargassum salicifolium*

J. AGARDH (1898) believed that *S. salicifolium* was a Mediterranean species and that *S. linifolium* was common in the Adriatic and possibly rare in the Mediterranean. GRUNOW (1916) and others who considered *S. salicifolium* and *S. linifolium* two separate species reported only some varieties and forms of *S. salicifolium* in some Adriatic locations and *S. linifolium* as an Adriatic species rarely occurring outside this sea. PAPENFUSS (1971) reported *S. salicifolium* as *S. linifolium* in the Red Sea and EARLE (1969) as *S. acinarium* in the eastern Gulf of Mexico. On the basis of studies of abundant material collected along the eastern Adriatic coast, we conclude that *S. salicifolium* var. *salicifolium* is widely and more frequently distributed in the eastern Adriatic than *S. salicifolium* var. *linifolium*, which was reported by earlier researchers as *S. linifolium* (Turn.) J. Ag. (Table 2; Figs. 20A, B).

Table 2. Sites at which the taxa of Sargassum salicifolium *was recorded*

No	Site	Geographic position	Date of collection	Depth (m)	Taxa
5	Jazine cove (Channel of Neretva)	42°55.0′N 17°37.4′E	02.06.1966	2–3	var. *salicifolium*
6	Polače cove (Channel of Neretva)	42°55.1′N 17°37.1′E	02.06.1966	2–3	var. *salicifolium*
10	Klek cove (Channel of Neretva)	42°56.5′N 17°34.0′E	02.06.1966	2	var. *salicifolium*
16	By Gnjili rat cape (Pelješac peninsula)	42°53.8′N 17°36.4′E	02.06.1966	2–3	var. *salicifolium*

Table 2. cont'd

17	East of Besunlje cove (Pelješac peninsula)	42°54.2′N 17°35.1′E	02.06.1966	6–8	var. *salicifolium*
19	Osobljava cove (Pelješac peninsula)	42°58.2′N 17°23.4′E	02.06.1966	2–4	var. *salicifolium*
20	By Crkvice cove (Pelješac peninsula)	42°58.7′N 17°22.3′E	02.06.1966	4–6	var. *salicifolium*
21	Bezdija cove (Pelješac peninsula)	43° 2.0′N 17°3.5′E	19.06.1966	4–6	var. *salicifolium*
22	Rasoha cove (Pelješac peninsula)	43° 2.3′N 17° 2.4′E	19.06.1966	5–6	var. *salicifolium*
23	Lovišće cape (Pelješac peninsula)	43° 2.4′N 17° 1.0′E	19.06.1966	4–6	var. *salicifolium*
24	Česminova cove (Pelješac peninsula)	43° 1.9′N 17° 1.0′E	19.06.1966	4–6	var. *salicifolium*
25	Osičac cape (Pelješac peninsula)	43° 0.7′N 17° 0.5′E	19.06.1966	4–10	var. *salicifolium*
26	South of Osičac cape (Pelješac peninsula)	43° 0.2′N 17° 1.2′E	19.06.1966	8–10	var. *salicifolium*
29	East of Duba cove (Pelješac peninsula)	42°59.9′N 17° 2.9′E	19.06.1966	4–6	var. *salicifolium*
34	Southwest of Vrhovnjak island	42°53.9′N 16°48.9′E	19.05.1948	10–15	var. *salicifolium*
38	Between Lukovci and Stomorina islands	42°46.5′N 16°57.6′E	19.05.1948	5–7	var. *salicifolium*
45	By Crnac island (Group of Lastovo)	42°45.4′N 16°45.0′E	27.05.1949	18–20	var. *salicifolium*
47	By Bijelac island (Group of Lastovo)	42°45.6′N 16°40.8′E	10.09.1959	20	var. *salicifolium*
56	Reef Žnjan (by Split)	43°29.0′N 16°28.9′E	31.06.1961	10–15	transitional to var. *linifolium*
57	Reef Žnjan (by Split)	43°29.4′N 16°29.0′E	01.06.1963.	13–15	var. *linifolium*
58	Trstenik cove (by Split)	43°30.0′N 16°28.4′E	01.06.1963.	12–19	var. *linifolium*
59	Firule cove (by Split)	43°29.8′N 16°27.4′E	01.06.1963.	6–7	var. *salicifolium*
60	Kašjuni cove (by Split)	43°30.4′N 16°23.8′E	on several occasions over a long term period	8–10	var. *salicifolium*
61	Marjan cape (by Split)	43°30.6′N 16°23.5′E	on several occasions over a long term period	5–6	var. *salicifolium*
62	By Bene cove (by Split)	43°31.2′N 16°25.3′E	on several occasions over a long term period	6–7	var. *salicifolium*

Table 2. cont'd

63	Reef Slatine (Čiovo island)	43°31.1′N 16°20.2′E	on several occasions over a long term period	10–12	transitional to var. *linifolium*
64	Saldun Bay (Čiovo island)	43° 3.6′N 16°13.1′E	on several occasions over a long term period	6–7	var. *salicifolium*
66	West of Okruk cape (Čiovo island)	43°29.9′N 16°13.3′E	on several occasions over a long term period	4–5	var. *salicifolium*
67	Marina Bay (west of Trogir)	43°30.6′N 16° 9.8′E	on several occasions over a long term period	4–10 10–15	between var. *salicifolium* and var. *linifolium*
68	Marina Bay (west of Trogir)	43°30.8′N 16° 9.1′E	on several occasions over a long term period	6–8	var. *salicifolium*
70	West of Sutivan (Brač island)	43°23.6′N 16°26.8′E	23.06.1963	6–8	var. *salicifolium*
71	West of Sutivan (Brač island)	43°23.5′N 16°27.7′E	10.06.1963	5–8	var. *salicifolium*
72	Stipanska cove (Brač island)	43°22.4′N 16°26.6′E	23.06.1963	6–8	var. *salicifolium*
73	South of Bobovišće cove (Brač island)	43°21.5′N 16°26.9′E	22.05.1963	4–7	var. *salicifolium*
74	Bobovišće cove (Brač island)	43°21.0′N 16.27.7°′E	22.05.1963	0.5–0.6	var. *salicifolium*
75	Milna cove (Brač island)	43°19.7′N 16°25.5′E	on several occasions over a long term period	6–10 12–15	between var. *salicifolium* and var. *linifolium*
85	Dubac cove (Hvar island)	43° 9.5′N 16°48.0′E	07.07.1965	6–8	var. *salicifolium*
86	By Zečija cove (Hvar island)	43° 9.6′N 16°48.0′E	07.07.1965		var. *salicifolium*
87	Prapratna cove (Hvar island)	43° 9.8′N 16°15.3′E	02.07.1965	6–7	var. *salicifolium*
91	Travna cove (Hvar island)	43°14.1′N 16°34.1′E	09.07.1956 11.07.1965	6–8 10–12	transitional to var. *linifolium*
92	Glavna cove (Hvar island)	43°13.7′N 16°32.0′E	11.07.1965	10–12	transitional to var. *linifolium*
95	Tiha cove (Hvar island)	43°13.0′N 16°33.2′E	11.07.1965	8–10	var. *salicifolium*
97	Pelegrin cape (Hvar island)	43°11.8′N 16°22.0′E	09.1959	10–25	var. *salicifolium*
98	Pelegrin cape (Hvar island)	43°11.8′N 16°22.0′E	01.06.1963	20–50	var. *linifolium*

Table 2. cont'd

99	Sv.Jerolim island (Pakleni islands)	43° 9.5′N 16°26.2′E	09.1959	10–20	transitional to var. *linifolium*
100	Southwest of Marinkovac island (Pakleni islands)	43° 8.9′N 16°25.0′E	09.1959 21.05.1961	20–30 30–50	var. *linifolium*
101	South of Marinkovac island	43° 9.1′N 16°25.1′E	31.05.1961	10–25	var. *linifolium*
102	Rasnik cape Marinkovac island	43° 9.0′N 16°25.3′E	09.1959	20–30	var. *salicifolium*
103	By Stambedar island (Pakleni islands)	43° 8.8′N 16°23.1′E	01.06.1963	18–23	var. *linifolium*
111	Goromin Dolac cove (Hvar island)	43° 7.5′N 16°44.0′E	30.06.1965	2–3	var. *salicifolium*
112	By Svrhov Dolac cove (Hvar island)	43° 6.8′N 16°55.0′E	11.07.1965	4–6	var. *salicifolium*
113	By Skazanje cove (Hvar island)	43° 6.8′N 16°55.9′E	01.07.1965	3–5	var. *salicifolium*
115	Kozja cove (Hvar island)	43° 6.9′N 17° 3.2′E	02.07.1965	4–6	var. *salicifolium*
116	Leprinova cove (Hvar island)	43° 6.8′N 17°4.7′E	02.07.1965	0.7–1	var. *salicifolium*
120	Mlin reef (between of Šolta and Čiovo islands)	43°26.9′N 16°14.8′E	11.06.1955 28.05.1963	6–10 22–23	transitional form to var. *linifolium*
122	Reef between of Stipanska and Mačaknar islands	43°24.4′N 16° 8.9′E	16.03.1961	10–12	transitional to var. *linifolium*
123	Reef between of Stipanska and Mačaknar islands	43°24.2′N 16° 9.5′E	16.03.1961	25–70	var. *linifolium*
124	Šešula cove (Šolta island)	43°23,5′N 16°13.0′E	16.03.1961	10–12	transitional to var. *linifolium*
126	Senjska cove (Šolta island)	43°21.5′N 16°18.7′E	05.07.1963	3–7	var. *salicifolium*
129	Reef east of Vis island	43° 1.5′N 16°21.4′E	26.05.1949 18.03.1961	20–30 10–20	transitional to var. *linifolium*
132	East of Milna cove (Vis island)	43° 2.1′N 16°14.5′E	25.05.1961	17–35	var. *linifolium*
133	Cape by Vela Smokova cove (Vis island)	43° 3.5′N 16°15.6′E	10.07.1956 05.1958 25.05.1961	15–14 15–20 30–35	transitional to var. *linifolium*
134	Vela Smokova cove (Vis island)	43° 3.7′N 16°15.5′E	25.05.1961.	30–35	var. *salicifolium*
135	In front of Vis Port (Vis island)	43° 4.5′N 16°11.7′E	30.05.1963	25	var. *salicifolium*

Table 2. cont'd

136	East of Gradac cove (Vis island)	43° 4.8′N 16° 8.3′E	25.05.1961	30–60	var. *salicifolium*
140	Seget reef (by Vis island)	43° 4.1′N 16°1.2′E	27.05.1961 25.09.1961	10–40	var. *salicifolium*
141	Ploča reef (by Vis island)	43° 3.8′N 16° 1.9′E	on several occasions over a long term period	10–15	var. *salicifolium*
142	Barjaci reef (by Vis island)	43° 3.2′N 16° 2.5′E	08.1951	10–40	var. *salicifolium*
146	West of Smričevica cove (Vis island)	43° 0.9′N 16° 9.8′E	10.07.1956	30	var. *salicifolium*
159	South of Mala Palagruža island	42°23.2′N 16°16.1′E	06.07.1950	7 15–20	transitional to var. *linifolium*
184	By Primošten	43°35.2′N 15°55.2′E	06.06.1964	5–10	var. *salicifolium*
186	Grebaštica cove (by Primošten)	43°37.9′N 15°55.1′E	06.06.1964	3–5	var. *linifolium*
187	Channel of Šibenik	43°41.2′N 15°52.9′E	07.08.1965	20	var. *linifolium*
188	Channel of Šibenik	43°42.4′N 15°52.0′E	07.08.1965	22	var. *linifolium*
169	Zablaće cove (Channel of Šibenik)	43°41.8′N 15°53.8′E	28.05.1967	3–5	var. *salicifolium*
191	Zmajan island (Islands of Šibenik)	43°41.6′N 15°46.0′E	17.06.1961	12	var. *linifolium*
193	Sovljak island (Islands of Šibenik)	43°45.5′N 15°43.5′E	14.04.1961	10–12	var. *linifolium*
194	By Tribunj	43°45.1′N 15°44.9′E	19.03.1971	8	var. *linifolium*
195	Zlarin Port (Islands of Šibenik)	43°42.4′N 15°49.8′E	05.07.1948	20	var. *linifolium*
201	North of Mala Sestrica island (Kornati)	43°51.3′N 15°13.2′E	07.07.1948	17	var. *salicifolium*
202	West of Mala Luka cove (by Pakoštane)	43°51.9′N 15°33.8′E	27.05.1967	3–4	var. *salicifolium*
203	Lučica cove (by Pakoštane)	43°52.2′N 15°33.4′E	27.05.1967	3–4	var. *salicifolium*
206	By Dugovača cove (by Pakoštane)	43°53.7′N 15°31.8′E	24.05.1967	3–4	var. *salicifolium*
207	Southeast of Pakoštane	43°54.1′N 15°31.2′E	24.05.1967	3–4	var. *salicifolium*
208	Tukljača (Channel of Pašman)	43°58.7′N 15°23.8′E	22.05.1964	3–7	var. *salicifolium*
209	Krmčine (Channel of Pašman)	43°59.9′N 15°22.8′E	22.05.1964	2	var. *salicifolium*
210	Sukošane (Channel of Pašman)	44° 2.7′N 15°18.8′E	23.05.1964	3	var. *salicifolium*

Table 2. cont'd

211	Diklo (Channel of Zadar)	44° 8.1′N 15°12.5′E	24.05.1964	5–6	var. *salicifolium*
212	By Sv.Bartul (Channel of Zadar)	44°10.2′N 15°10.7′E	24.05.1964	6–7	var. *salicifolium*
213	By Petrčane (Channel of Zadar)	44°11.0′N 15°10.0′E	23.05.1964	5–6	var. *salicifolium*
214	Dražnik cove (southeast of Privlaka)	44°13.7′N 15°10.3′E	25.05.1964	5–6	var. *salicifolium*
215	Brtalić cape (southeast of Privlaka)	44°14.2′N 15° 8.2′E	25.05.1964	2–3	var. *salicifolium*
216	Telašćica cove (Dugi otok island)	43°52.8′N 15°11.7′E	06.1964	7–8	var. *salicifolium*
219	By Božava (Dugi otok island)	44° 8.6′N 14°54.9′E	03.06.1964	4–10	var. *salicifolium*
221	Pantera cove (Dugi otok island)	44° 8.7′N 14°50.9′E	03.06.1964	5–6	var. *salicifolium*
222	Pantera cove (Dugi otok island)	44° 8.7′N 14°51.4′E	03.06.1964	1.5–3	var. *salicifolium*
229	Cape of Zaklopica cove (Pašman island)	43°53.9′N 14°27.4′E	05.06.1964	1–3	var. *salicifolium*
231	In front of Pašman island	43°57.6′N 14°23.3′E	25.06.1964	1–3	var. *salicifolium*
232	In front of Barotula (Pašman island)	43°58.1′N 14°22.1′E	25.06.1964	1–3	var. *salicifolium*
233	By Neviđane (Pašman island)	43°57.6′N 14°23.3′E	05.06.1964	3–4	var. *salicifolium*
234	By Dobropoljana (Pašman island)	43°59.5′N 14°19.8′E	05.06.1964	3–5	var. *salicifolium*
235	Ždrilac strait (between Ugljan and Pašman islands)	44° 0.9′N 14°15.3′E	30.06.1964	4–6	var. *salicifolium*
236	By Kablin cove (Pašman island)	44° 0.2′N 14°16.2′E	30.06.1964	3–5	var. *salicifolium*
237	By Čerenje cove (Pašman island)	43°58.3′N 14°18.1′E	30.06.1964	2–3	var. *salicifolium*
238	Cape in front of Soline cove (Pašman island)	43°56.1′N 15°21.0′E	29.06.1964	6–10	var. *salicifolium*
239	Karantunić island (by Ugljan island)	44° 0.5′N 15°14.8′E	05.06.1964	4–6	var. *salicifolium*
240	Lamjana Vela cove (Ugljan island)	44° 2.5′N 15°12.6′E	05.06.1964	3–4	var. *salicifolium*
241	Lamjana Mala cove (Ugljan island)	44° 2.6′N 15°13.4′E	05.06.1964	3–4	var. *salicifolium*
242	Cape in front of Sabušćica cove (Ugljan island)	44° 2.1′N 15°13.8′E	05.06.1964	7–8	var. *salicifolium*

Table 2. cont'd

243	Cape by Sabušćica cove	44° 1.6′N 15°14.2′E	05.06.1964	4–6	var. *salicifolium*
244	Sabušćica cove (Ugljan island)	44° 1.4′N 15°14.6′E	05.06.1964	3–8	var. *salicifolium*
245	Željina Vela cove (Ugljan island)	44° 4.3′N 15° 9.2′E	26.05.1964	10–12	var. *linifolium*
246	Ovčjak cape (Ugljan island)	44° 8.1′N 15° 4.2′E	26.05.1964	3–4	var. *salicifolium*
247	Sv.Petar cape (Ugljan island)	44° 9.5′N 15° 4.2′E	27.06.1964	10–12	var. *linifolium*
249	Reef between of Vir and Molat islands	44°16.2′N 15° 0.1′E	23.07.1948	15–20	var. *linifolium*
250	South of Sipa cape (Maun island)	44°27.2′N 14°53.4′E	06.1964	6–7	var. *salicifolium*
253	Zaglav cape (Pag island)	44°23.9′N 15° 2.1′E	12.06.1964	4–6	var. *salicifolium*
255	By Šimuni cove (Pag island)	44°28.0′N 14°57.2′E	29.05.1964	3–4	var. *salicifolium*
265	Sv.Fumija cove (Rab island)	44°45.4′N 14°45.0′E	14.06.1968	1.5–2	var. *salicifolium*
266	Gožinka cove (Rab island)	44°45.4′N 14°42.9′E	14.06.1968	4–5	var. *salicifolium*
267	Krištofor cape (Rab island)	44°45.3′N 14°42.2′E	14.06.1968	3–4	var. *salicifolium*
268	Kanitalj cape (Rab island)	44°45.5′N 14°41.7′E	14.06.1968	3–4	var. *salicifolium*
272	Gornja Punta cape (Rab island)	44°48.2′N 14°39.8′E	14.06.1968	6–7	var. *salicifolium*
273	Duboka cove (Channel of Velebit)	44°54.0′N 14°54.1′E	29.07.1966	8–10	var. *linifolium*
274	South of Sv. Juraj (Channel of Velebit)	44°55.1′N 14°54.8′E	28.07.1961	6–10	var. *linifolium*
275	West of Senj (Channel of Velebit)	44°59.8′N 14°53.8′E	28.07.1964	6–10	var. *linifolium*
276	Šilo cape (Krk island)	45° 9.4′N 14°40.3′E	15.06.1968	15–30	var. *linifolium*
296	Saline cove (western coast of Istra)	45° 7.3′N 13°37.2′E	10.06.1968	3–5	var. *salicifolium*
298	Channel of Lim (western coast of Istra)	45° 8.1′N 13°38.7′E	17.07.1968	3	var. *salicifolium*
299	Channel of Lim (western coast of Istra)	45° 8.2′N 13°37.3′E	17.07.1968	3–4	var. *salicifolium*
303	Small cape by Vrsar (western coast of Istra)	45° 9.1′N 13°36.0′E	17.07.1968	8–10	transitional to var. *linifolium*

Table 2. cont'd

304	Marmi (western coast of Istra)	45° 9.1′N 13°33.4′E	15.07.1950	10	var. *linifolium*
305	Veliki cape (western coast of Istra)	45°10.6′N 13°35.4′E	17.07.1968	1–2	var. *salicifolium*
306	Savudrija cape (western coast of Istra)	45°29.5′N 13°29.5′E	14.07.1968	4–8	var. *salicifolium*

Apart from some morphological differences, particularly with respect to the form and length of blades, the areas of distribution and accompanying ecological conditions differ between the two varieties. *Sargassum salicifolium* var. *linifolium* is characteristic to coastal and channel waters of the eastern Adriatic where they most frequently grow on gravel and rocky bottoms at depths of 3-4 to 8-10 m and sometimes grow in sheltered localities at 1 m depth. Inner waters between islands and the mainland coast are a true area of their distribution. We recorded this form at a large number of localities along the mainland coast, from Mali Ston to the vicinity of Rijeka, along the western Istrian coast, and on the shores of the Hvar, Brač, Šolta, Ugljan, Pašman, Pag, Rab, Krk, and Dugi Otok Islands.

Specimens from greater depths (20-30 m in the offshore area of Pakleni Otoci, Vis Island, and Dubrovnik) differ from *S. salicifolium* var. *salicifolium* in some morphological properties (slightly shorter wider blades, smaller wider receptacles) and are closer to *S. vulgare* var. *vulgare*. However, they differ from *S. vulgare* var. *vulgare* by longer primary branches; fewer secondary branches; fewer, longer, and narrower blades; larger, wider, and better ramified receptacles.

Compared to the typical form, *S. salicifolium* var. *linifolium* is rather rare. It is mainly distributed in sheltered areas of coastal waters. It grows on gravel-sandy and sometimes sandy-muddy substrates at depths of 15-20 m (sometimes at 8-10 m), where it attaches to small stones or dead shellfish and snails. According to the literature, the species is distributed in the Mediterranean, along the coasts of France, Greece, Egypt, and Algiers.

Sargassum hornschuchii C. Ag.

C. Agardh, Sp. Alg., 1821, p. 40; Zanardini, Syn. Alg. Mar. Adr., 1841, p. 140; Meneghini, Alghe ital. Dalm., 1842, p. 9; J. Agardh, Sp. Alg., 1848, p. 320; Hauck, Meeresalg., 1885, p. 301; Ardissone, Phyc. Med., 1886, p. 19; Grunow, Addit. Cog. Sarg., 1916, p. 439.

Synonyms: *Fucus natans* Bertoloni, Amoen. It., 1819, p. 220; *S. amygdalifolium* Bory, Moree. 1832, Nr. 1440; *S. vulgare* var. *salicifolium* Ag., 1848, p. 5; Syst., 1842., p. 204; *S. salicifolium* Montagne, Fl. Algérie, 1846, p. 2; *Stichophora Hornschuchii* Kützing, Tab. Phyc., 1845-1869, X, 71. Icon.: Meneghini, Alg. tal. dalm., 1842, Tab. I; *Stichophora Hornschuchii* Kützing, Tab. Phyc., 1859-1861, X, 71, Fig. 1; J. Agardh, Sp. Alg., 1889, Tab. IX.

This species is clearly distinguished from the preceding species by its morphological characteristics, which are rather consistent and vary little. The alga has a single cylindrical stipe, 2-6 cm long, 4-5 mm thick, upon which scars of fallen branches are visible as oval holes. Stipe branches frequently grow from older stipes. Like stipes, they bear primary branches. The lower part of the stipe extends into a strong holdfast by which the alga is attached to the substrate. The holdfast is most frequently oval and patchedly carved at the edges. On the tips or slightly below the tips, stipes bear a number of primary branches in different stages of development so that their forms differ (Fig. 19). Young branches are flat throughout their length, lined with strongly serrated narrow wings, do not have secondary branches, and have embedded blades. Fully developed branches are flat only

Fig. 19. Sargassum hornschuchii*: (a) a specimen at the end of the vegetative period, the stipe bears a single fully developed and several young adolescent primary branches (slightl y less than full scale); (b), (c), (d) and (e) fructifications in specimens from different habitats and depths; scale = 1 cm*

on the lower third and bear serrated wings; the upper two thirds are cylindrical. The length of primary branches varies greatly depending on ecological factors and the development stage of the specimens and branches. Maximum lengths exceed 50 cm. Secondary branches are markedly cylindrical, mostly up to 115 (120) cm long, and occur exclusively on the cylindrical parts of primary branches.

The species is characterized by well-developed blades which most frequently grow up to or even exceed 10 cm in length and 1.5-2.0 cm in width. In some specimens collected at depths of 60-70 m, the lengths and widths of the largest blades were 13-14 cm and 2-3 cm. The blades gradually taper towards the tip, and suddenly towards the base, so that they frequently are elongated spear-shaped. They usually have very short stems or, if occurring on flat branch parts, no stem. The blade edges and most of the surface are strongly folded wave-like and the edge resembles the toothed edge of a saw.

Cryptostomata are rather rare and occur on blade surfaces along the edge in irregular (rarely in two) rows. Sometimes, particularly in specimens from greater depths, cryptostomata are absent.

Bladders are very rare. They occur on secondary branches in the upper part of the thallus. They are spherical, sometimes slightly flat, 3-8 cm, most frequently smooth, and occasionally bear a short extension in the form of a prickle at the tip. They are attached to the branches with short cylindrical stems.

Fructifications consist of ramified sterile 2-4 cm branches that bear a large number of receptacles. The form and size of receptacles vary greatly. Receptacles are most often spin-shaped, 5-10 mm long and 1.2-2.0 mm wide, however, they are frequently flat, with serrations at the edges, 2-3 cm long and up to 3 mm wide. Sometimes, they are oval and three-edged. This species has bisexual and diclinous receptacles. Specimens with bisexual receptacles are distributed mainly in coastal and channel areas, whereas specimens with diclinous receptacles are rarer and prevalently distributed in the open sea. Conceptacles are always diclinous, i.e., either male or female, and they differ considerably in form and size. The cross-section of female conceptacles is spherical or, occasionally, slightly oval. The size of female conceptacles varies greatly. From the bottom to the outer rim of the ostioles is 430-600 μ and the width is 380-530 μ. Male conceptacles are mainly elongated in a radial direction to the receptacle axis and measure 360-400 (max 440) μ high, 250-320 (max 360) μ wide. Elogated oval oogonia, 260-370 x 160-260 μ, are located in the lower parts of the conceptacles and paraphyses mainly occur above or between them. Oval or knob-stick oval antheridia, 30-42 x 19-23 μ, almost fill the conceptacle hollow, except the upper parts next to the ostiolum. They are situated on rather short multicellular (2-4) ramified filaments at the tips or, sometimes, on the sides of the conceptacle.

Fructification occurs in different parts of the year, depending on the depth and geographic location. Fructification in specimens from depths of 15-30 m in the coastal mid-Adriatic begins in winter and extends into mid-spring. Fructification starts later in the open mid-Adriatic, where specimens from reefs and greater depths with deciduous receptacles prevail. Ripe conceptacles were recorded in summer (July) as well. For example, receptacles occurred in specimens from Jabuka reef in January as well as in June (20-40 m) and July (60 m). VATOVA (1928, 1948) reported spring and summer (March-June) as the fructification period for specimens from the eastern Istrian coast. FUNK (1925) stated that specimens from the Bay of Naples fructified in spring (from April to early June). The process of sexual maturation lags with an increase in depth, so that fructification in specimens from greater depths (60 m and more) ends one to two months later than in specimens from shallower depths.

It seems that the vegetative period continues year round with no lag or break in growth, especially in specimens from somewhat greater depths. Primary branches of different development stages are found on the tips of trees in all seasons. The appearance of the alga changes throughout the year. Young and adolescent specimens differ considerably from fully developed specimens. Most frequently, adolescent specimens look like a reduced form of the species due to the late start of ramification of young primary branches. Frequently, primary branches that have already reached 15 or even 20 cm in length have no strong secondary branches, but only buds in the armpit of the leaf stems. Primary branches obtain their rather wide pyramidal outline only once the secondary branches have grown and bladders and fertile branches with receptacles have appeared.

Distribution of *Sargassum hornschuchii*

The species is distributed throughout the Mediterranean and is particularly frequent in the Adriatic. ERCEGOVIĆ (1960) held it as one of the most frequent deep sea species, characterized by an exceptionally wide distribution throughout the Adriatic. On the basis of abundant material collected from various localities and depths along the eastern Adriatic coast, we established its distribution in the coastal, channel, and open waters (Table 3; Figs. 20A, B).

Sargassum hornschuchii is a typical representative of deep sea vegetation. It grows best at depths of 20-60 m but is very frequent at 10-15 m, particularly in the northern Adriatic. On several occasions it was found at depths exceeding 100 m in the open middle part of the sea. In spite of the wide range of depth distribution, the thallus does not significantly vary in form and color. Specimens from somewhat shallower waters (10-15 m) have a smaller thallus and are brown or brownish green, while specimens inhabiting greater depths are more abundant, longer (sometimes exceeding 50 cm), and brown or brownish gold.

Table 3. Sites at which Sargassum hornschuchii *was recorded*

No	Site	Geographic position	Date od collected	Depth (m)
3a	South of Lapad peninsula	42°38.9′N 18° 4.1′E	25.06.1971 16.09.1971	25–30 30
33	Vrulja cove (Channel of Brač)	43°23.7′N 16°52.9′E	09.11.1957	76
34	Northwest of Vrhovnjak island	42°53.9′N 16°48.9′E	19.05.1948	10–15
36	Northeast of Zvirinovik island	42°54.3′N 16°44.9′E	15.09.1948	40
37	Northwest of Korčula island	43° 1.5′N 16°30.0′E	09.09.1947	76
38	Between Lukovci and Stomorina islands	42°46.5′N 16°57.6′E	30.05.1961	10–50
39	Reef by Stomorina island	42°46.5′N 16°57.7′E	09.08.1948	10–20
40	By Mrkjenta Bijela island (by Lastovo island)	42°46.8′N 17° 0.9′E	12.10.1947	30–40
41	Lastovo Lake	42°46.6′N 16°50.3′E	30.05.1961	10–15 30–40
42	Duboka cove (Lastovo island)	42°43.9′N 16°50.1′E	27.08.1949	10–20
43	Southeastern cape of Kopište island (Group of Lastovo)	42°45.1′N 16°32.9′E	17.05.1948	30

Table 3. cont'd

44	East of Kopište island (Group of Lastovo)	42°45.3′N 16°44.1′E	on several occasions over a long term period	20–50
35	By Crnac island (Group of Lastovo)	42°45.4′N 16°45.0′E	27.05.1949	18–20
46	By Crnac island (Group of Lastovo)	42°45.4′N 16°45.8′E	27.05.1949	90
47	By Bijelac island (Group of Lastovo)	42°45.6′N 16°40.8′E	09.08.1948 10.09.1949	30–40
49	South of Šćedro island	43° 3.7′N 16°44.2′E	28.07.1957 12.11.1957	63
50	West of Šćedro island (by Lukavci island)	43° 5.6′N 16°34.2′E	27.05.1949	40–60
51	By eastern cape of Sušac island	42°45.8′N 16°32.3′E	17.05.1948	30
52	West of Sušac island	42°45.9′N 16°30.0′E	21.09.1961	40–70
53	West of Sušac island	42°46.2′N 16°30.2′E	05.08.1949	70
54	By southern cape of Sušac island	42°44.9′N 16°29.5′E	05.08.1949	40
55	South of Sušac island	42°45.1′N 16°29.6′E	21.09.1961	45
57	Žnjan reef (by Split)	43°29.4′N 16°29.0′E	31.06.1961	15–22
65	Garbina Mala cove (Čiovo island)	43°29.5′N 16°22.4′E	more frequently in 1968	15–25
67	Marina bay (west of Trogir)	43°30.6′N 16° 9.8′E	more frequently in 1968	15–30
76	Milna cove (Brač island)	43°20.1′N 16°25.1′E	more frequently in 1968	15–20
97	Pelegrin cape (Hvar island)	43°11.8′N 16°22.0′E	18.09.1959 01.06.1963	20–50
98	Pelegrin cape (Hvar island)	43°11.7′N 16°22.2′E	08.1951	30–40
99	Sv. Jerolim island (Pakleni islands)	43° 9.5′N 16°26.2′E	08.1951 01.06.1963	10–25 10
100	Marinkovac island (Pakleni islands)	43° 8.9′N 16°25.0′E	18.09.1959 05.05.1961	20–30 30–50
101	South of Marinkovac island	43° 9.1′N 16°25.1′E	31.05.1961	10–50
102	Rasnik cape (Marinkovac island)	43° 9.0′N 16°25.3′E	18.09.1959	20–30
103	By Stanbedar island (Pakleni islands)	43° 8.8′N 16°23.1′E	01.06.1965	20–30
104	Ražanj cape Sv.Klement island (Pakleni islands)	43° 9.1′N 16°23.5′E	31.05.1961	10–40

Table 3. cont'd

105	Sv. Klement island (Pakleni islands)	43° 9.3′N 16°23.7′E	08.1949	10
106	Sv. Klement island (Pakleni islands)	43° 9.1′N 16°23.9′E	05.1949	27
107	West of Vodnjak island (Pakleni islands)	43°10.4′N 16°18.8′E	05.1961 01.06.1963	15–30 30–38
119	East of Nečujam cove (Šolta island)	43°23.9′N 16°20.2′E	15.07.1956	20–40
121	South of Mačaknar island (Šolta island)	43°24.2′N 16° 8.6′E	11.03.1961 19.09.1961	18–25 65–70
122	Reef between Stipanska and Mačaknar islands	43°24.4′N 16° 8.9′E	16.03.1961	30–35
125	South of Šolta island	43°22.7′N 16°14.5′E	12.08.1954	30–40
127	By Straćinska cove (Šolta island)	43°20.0′N 16°21.8′E	15.07.1956	20–30
129	Reef south of Vis island	43° 1.5′N 16°21.4′E	26.05.1949 18.03.1961	14–15 10–20
130	Eastern side of Vis island	43° 2.4′N 15°16.2′E	07.1947 05.1961	60–80 50–60
133	Cape by Vela Smokova cove (Vis island)	43° 3.5′N 16°15.6′E	10.07.1956 30.05.1963	20–30 45
134	Vela Smokova cove (Vis island)	43° 3.7′N 16°15.5′E	25.05.1961	30–35 45–75
135	In front of Vis Port (Vis island)	43° 4.5′N 16°11.7′E	30.05.1963	20–40
136	Gradac cove (Vis island)	43° 4.8′N 16° 8.3′E	17.09.1959 25.05.1961	45–60
140	Seget reef (by Vis island)	43° 3.8′N 16° 1.2′E	on several occasions over a long term period	
141	Ploča reef (by Vis island)	43° 3.8′N 16° 1.9′E	12.05.1948 16.04.1957	20–30 50–60
142	Barjaci reef (By Vis island)	43° 3.2′N 16° 2.5′E	07.08.1951 18.10.1958	30–50
143	Pretišćina cove (Vis island)	43° 0.4′N 16° 6.2′E	24.05.1961	25–50
145	West of Smričevica cove (Vis island)	43° 0.8′N 16° 9.5′E	17.03.1961	30–35
146	Smričevica cove (vis island)	43° 0.9′N 16° 9.9′E	on several occasions over a long term period	20–80
148	By Rukavac cove (Vis island)	43° 1.0′N 16°13.2′E	18.09.1959	60
149	Rukavac cove (Vis island)	43° 1.2′N 16°13.0′E	17.05.1948 20.08.1948	15–20
150	North of Palagruža island	42°23.7′N 16°15.3′E	07.08.1949	25–30

Table 3. cont'd

151	North of Palagruža island	42°23.6′N 16°15.7′E	14.07.1956 02.08.1956	20 70–80
154	Western cape of Palagruža island	42°23.7′N 16°14.9′E	20.09.1961 18.09.1962	75–80
155	West of cape of Palagruža island	42°23′6N 16°14.8′E	07.08.1951	20 30–40
156	North of Kamik island (Palagruža island)	42°23.4′N 16°16.2′E	20.09.1961	40–70
157	South of Palagruža island	42°23.5′N 16°15.3′E	07.08.1951 20.09.1961	40 50–60
160	By Biskup cape (Biševo island)	42°57.6′N 16° 1.3′E	24.05.1961 23.09.1961	15–35 45–95
161	In front of Modra Spilja (Biševo island)	42°58.8′N 16° 1.5′E	19.03.1961 23.09.1961	20–50
162	Salbunara cove (Biševo island)	42°59.1′N 16° 0.0′E	19.03.1961	15–50
163	Northwest of Biševo island	42°58.7′N 16° 0.0′E	10.05.1948	30–40
164	West of Biševo island	42°58.5′N 15°59.9′E	10.05.1958 18.09.1959	30
165	Potok cove (Biševo island)	42°58.2′N 16° 0.1′E	10.05.1948 20.04.1957	40–50 40
167	Galiole cape (Biševo island)	42°57.3′N 16° 0.0′E	23.09.1961	40–80
169	Trešjavac cove (Biševo island)	42°57.6′N 16° 0.7′E	18.09.1959	40–50
170	North of Svetac island	43° 2.1′N 15°45.8′E	15.05.1948	20–30
171	Northwest of Svetac island	43° 1.6′N 15°43.9′E	16.09.1959	90
172	By Kamik island (Svetac island)	43° 1.2′N 15°43.1′E	15.05.1948 24.09.1961	20–30 40
173	West of Zlatna Glava cape (Svetac island)	43° 1.1′N 15°44.4′E	24.09.1961	40–45 70–90
175	Northeast of Jabuka island	43° 5.6′N 15°27.8′E	on several occasions over a long term period	50–75
176	North of Jabuka island	43° 5.6′N 15°27.4′E	15.05.1948	60–70
177	Northwest of Jabuka island	43° 5.7′N 15°27.6′E	15.04.1956	40–80
179	East of reef by Jabuka island	43° 5.8′N 15°26.9′E	on several occasions over a long term period	60–70
180	Reef by Jabuka island	43° 6.0′N 15°26.1′E	on several occasions over a long term period	15–70

Table 3. cont'd

181	South of reef by Jabuka island	43° 5.9′N 15°26.1′E	16.08.1949	20–30
182	Jabuka Pit	43°18.8′N 15°54.4′E	20.04.1957 21.04.1957	115–127 119–128
183	By Rogoznica	43°31.9′N 15°57.4′E	15.08.1948.	20–25
192	Mala Sestrica island (Islands of Šibenik)	43°40.3′N 15°48.7′E	12.08.1949	20–45
193	By Sovljak island (Islands of Šibenik)	43°45.5′N 15°43.5′E	16.04.1971	20–30
196	By Čavlin island (Islands of Šibenik)	43°44.1′N 15°34.9′E	05.07.1948	20–40
197	West of Murter island	43°49.5′N 15°32.6′E	05.07.1948	50
199	North of Purara island (Kornati)	43°41.9′N 15°26.6′E	21.07.1948	30
200	By Obručan island (Kornati)	43°50.3′N 15°13.9′E	22.07.1948	40
201	North of Mala Sestrica island (Kornati)	43°51.3′N 15°13.2′E	07.07.1948 12.08.1949	15–20
217	Telaščica cove (Dugi otok island)	43°53.1′N 15°12.9′E	22.07.1948	15
217a	By Garmenjak Veli island (Dugi otok island)	43°52.0′N 15°11.4′E	07.07.1948	20
218	Reef by Žman (Dugi otok island)	43°58.5′N 15° 7.9′E	12.08.1949	20
248	South of Parda cape (Iž island)	43°59.9′N 15°10.4′E	12.08.1949	40–45
249	Reef between of Vir and Molat islands	44°16.2′N 15° 0.1′E	23.07.1948	15–20
273	By Duboka cove (Channel of Velebit)	44°54.0′N 14°54.1′E	15.06.1968	10–25
274	South of Sv. Juraj (Channel of Velebit)	44°55.1′N 14°54.8′E	15.06.1968	15–20
276	Šilo cape (Krk island)	45° 9.4′N 14°40.3′E	15.06.1968	15–30
278	"Hvar" Expedition Station 44	43°35.0′N 15°32.0′E	03.09.1948	208–213
280	"Hvar" Expedition Station 53	43°28.0′N 15°40.0′E	14.04.1948	181
281	"Hvar" Expedition Station 54a	43°32.0′N 15°43.0′E	09.03.1949	163–167
283	"Hvar" Expedition Station 58	43°27.0′N 15°46.0′E	27.02.1948	157–165

Table 3. cont'd

284	"Hvar" Expedition Station 68	42°36.0′N 15° 8.0′E	28.08.1948	166–173
285	"Hvar" Expedition Station 92	42°25.0′N 15°50.0′E	10.05.1948	61
287	"Hvar" Expedition Station 101	42°59.0′N 16°27.0′E	06.10.1948	96–100
291	Banjole island (western coast of Istra)	45° 4.4′N 13°36.6′E	31.08.1968	10
293	By Rovinj (western coast of Istra)	45° 5.5′N 13°38.2′E	10.07.1968	10–15
297	By Channel of Lim	45° 7.6′N 13°36.2′E	10.07.1968	20–30
301	By Vrsar (western coast of Istra)	45° 8.8′N 13°35.6′E	10.07.1968	12–20
302	By Vrsar (western coast of Istra)	45° 8.8′N 13°34.9′E	10.07.1968	25–30
304	Marmi Lighthouse (western coast of Istra)	45° 9.1′N 13°33.4′E	15.07.1950	15–20

DIAGNOSES

Sargassum vulgare C. Agardh var. *vulgare* f. *ercegovicii*, form. nov (Figs. 6, 7)

Differt a typo imprimis aliquatenus majoribus, latius lanceolatis, rigidioribus foliolis, 2 ad 4 (4.5) cm longis et 8 – 9 mm latis. In ramis juvenilibus primariis aliquatenus longiora (3.5 ad 5 – 6 cm) et latiora (9 ad 11 mm) atque ordinarie furcata. Receptacula aliquatenus crassiora, longiora (ad 10 mm) et latiora (ad 1.4 – 1.6 mm), quasi ramosissima, cylindrica vel versus apices aliquatenus compressa atque leviter breviterque furcata.

Conceptacula mascula atque feminea ordinarie majoris magnitudinis quam in typo.

Periodus fructificativa incipit mense aprili desinit autem mense julio.

Periodus vegetativa toto anno perdurat. Mensibus julio et augusto planta crescit lentissime, mensibus autem autumnalibus atque magis hiemalibus crescit celerrime.

Habitat in aquis inter terram firmam et insulas interiores Adriatici medii atque partis septentrionalis, circiter 0.5 ad summum 2 m profunditatis.

Sargassum vulgare C.Agardh var. *jabukae*, var. nov. (Figs. 8, 9)

Differt a typo aliquibus characteribus morphologicis foliolorum et organorum fructificationis. Foliola ordinarie brevia, rigida, lanceolate elongata ac versus apicem coarctata sunt, ad 3 cm longa et 2 ad 3 mm lata, margine ordinarie non undulata neque dentata. Valde raro adsunt parvissima denticula. In partibus inferioribus ramorum juvenilium foliola aliquantulum longiora (3 – 4 cm) et latiora (ad 7 – 8 mm) sunt. Cryptostomata numerosa et maxima parte sine ordine disposita sunt. Vesiculae paucae ac fere semper formae sphaericae sunt.

Receptacula mascula ac feminea forma inter se diferunt. Aliqua individua portant receptacula fusiformia, ramosa (3 – 6 cm longa, et 0.7 ad 1 mm lata) cum conceptaculis femineis (270 ad 380 µ diametri). Alia individua portant receptacula cylindrice elongata, polyfurcata (10 ad 11 mm longa et ad 0.7 mm lata) cum conceptaculis masculis (180 ad 280 µ altis et 140 ad 160 µ latis).

Individua in aquis profundioribus (circa 20 m) dupliciter majora sunt (ad 40 – 50 cm) atque aliquae partes thalii (rami, foliola, receptacula) ordinarie longiores sunt. Cryptostomata magis sparsa et plerumque minora sunt, vasiculae aliquantum numerosiores, receptacula minus ramosa.

Periodus fructificativa a mense aprili usque finem augusti perdurat.

Periodus vegetativa hujus subspeciei toto anno perdurat, sed maxime intensiva est tempore veris atque aestatis.

Habitat prope litus insulae Jabuka, 1 ad 20 m profunditatis, atque proximam rupem submarinam in profunditate 6 ad 20 m.

Sargassum salicifolium J.Ag. var. *linifolium*, comb. nov. (Fig. 18)

Differt a typo thallo majore (ad 200 cm), foliis longioribus, artioribus ac magis dentatis atque receptaculis longioribus, cylindrice elongatis et furcatis. Rami primarii (170 ad 200 cm longi) aeque ac secundarii (ad 120 cm longi) dense unifide et bifide spinulosi sunt. Foliola longiora (7 ad 9 cm) atque artiora (2 ad 7 mm) sunt, margine autem magis aliquando etiam duplicato dentata, cryptostomatibus exiguis et rarioribus quam in typo.

Organa fructificationis parte sterili, cylindrica, satis ramosa atque receptaculis valde longis (1.5 ad 3 – 4 cm), totaliter cylindricis (1.2 ad 1.5 mm latis) ac furcate ramosissimis, androgynis vel rarius masculis composita sunt. Conceptacula feminea relate ad typum plenius involuta receptaculo (450 ad 500 μ alta et 350 ad 450 μ lata) sunt. Conceptacula mascula 350 ad 450 μ alta et 200 ad 270 μ lata sunt.

Maximum fructificationis aeque ac vegetationis unum mensem tardius quam in typo fit. Haec subspecies satis rara est, habitat autem locis protectis in aquis ad litus terrae firmae, saepissime 15 ad 20, exceptionaliter etiam 8 ad 10 m profunditatis.

EFFECTS OF ENVIRONMENTAL FACTORS ON MORPHOLOGY AND ADAPTATION OF *SARGASSUM*

Our investigations aimed not only at studying and establishing morphological properties of Adriatic *Sargassum* but also at better understanding the cause and effect relationships between environment (habitat) and forms of the genus. We also aimed at understanding the extent to which morphological differences and variations were affected by ecological factors and whether they have any ecological value.

Ecological factors act in common within a biotope to make an environment. To analyze the effects of these factors in detail, they should be studied separately, although that may sometimes be very difficult. Ecological factors can affect organisms directly, or indirectly when one factor affects another. In the case of the Adriatic *Sargassum*, substrate, temperature, light (illumination), and salinity are important direct abiotic factors while water movement is an important indirect abiotic factor.

Substrate

The substrate comprises two types of characteristics: chemical and physical. Chemistry seems not to directly affect the attachment and development of sargassums though it may indirectly influence them by affecting physical properties such as compactness, particle size, surface structure, etc., producing favorable or unfavorable conditions for the algae.

Immobility of the substrate is the most important physical property as it allows attachment and growth of sargassums. Sargassums grow best on immobile rocky substrates due to the form and size of the thallus, even though they frequently grow on less fixed substrates at greater depths. In rather exposed localities close to the surface, *S. vulgare* var. *vulgare*, a typical eurybathic species, occurs exclusively on hard rocks. However, it can also be found at greater depths on noncompacted mobile substrates of different origins and particle sizes that are immobile because of no intensive water movement. At the same time, the macrobathic species *S. hornschuchii*, which exclusively inhabits greater depths (below the 10 m isobath), grows well on less compacted bottoms such as stones, lithotamnium, and lithophilumial lumps, shells of dead snails and shellfish, etc. Nevertheless, rocky bottoms are best suited to *Sargassum* attachment, although they are rare at greater depths. Such localities (reefs and rocky bottoms) support more abundant and richer *Sargassum* settlements than looser deep water bottoms. *Sargassum salicifolium* var. *salicifolium* inhabits rocky substrates but frequently can be found on small rocks, dead snail and shellfish shells, or bottoms covered by sandy deposits at depths exceeding 10 m.

Attachment and survival are affected by mud settling. Mud settling is frequent and intensive in sheltered localities, particularly in channels between mainland coasts and inner islands. Mud settling occurs due to weak currents or input of inorganic particles from the land. ERCEGOVIĆ (1952) held that the presence or absence of great mud quantities on the bottom affects the occurrence of some *Cystoseira* species to a defined extent. He distinguished three groups of *Cystoseira* with different relationships to mud settling. The first group are algae that never occur in localities considerably affected by mud settling. The second group are algae that inhabit more or less muddy substrates. The third group are totally indifferent to mud settling. Adriatic *S. vulgare* var. *vulgare* exclusively inhabits locations where no, or very little, settling occurs. *Sargassum salicifolium* var. *salicifolium* is predominantly distributed in channel areas where mud intensively settles. *Sargassum salicifolium* var. *linifolium* exclusively grows where mud intensively settles and, especially near the end of the vegetative period, specimens may be covered by a layer of fine mud. *Sargassum hornschuchii* occurs where mud settling is almost negligible, although it can sometimes be found in sheltered coves near the coast and on bottoms where settling is intensive.

Temperature

Even though seawater temperature is considerably lower than land temperature, this physical parameter intensively affects the development and distribution of algae. In general, the Adriatic is a warm sea since its deepest layers never drop below 11-12°C (BULJAN & ZORE-ARMANDA, 1971). However, its intercontinental position and great eastern coast indentation affect the water temperature, so that the Adriatic is thermally heterogeneous and different parts of the sea have different temperatures.

The average annual surface temperature is highest in the southern and lowest in the northern Adriatic where extreme values were recorded (maximum 28.8, minimum 4.1°C). The highest average winter surface temperature occurs in the southern Adriatic (13.29°C) and the lowest in the northern Adriatic (9.94°C). In spring, the temperature is highest in the mid-Adriatic (18.02°C), followed by the northern (17.57°C) and southern (17.73°C) Adriatic. In summer, the temperature is highest in the southern Adriatic (23.96°C), and slightly lower in the middle (22.90°C) and northern (22.71°C). In autumn, it is highest in the middle (16.38°C), slightly lower in the southern (15.91°C), and lowest in the northern (14.69°C) areas.

The amplitude between the minimum average (winter) and maximum average (summer) temperatures is smallest in the middle Adriatic (10.3°C), slightly higher in the southern (10.67°C), and highest in the northern (12.77°C) parts of the sea. The annual temperature variation increases in a longitudinal direction, being highest in the north (24.7°C), intermediate in the middle (20.1°C), and lowest in the south (18.0°C; ZORE-ARMANDA, 1989). The variation in average mean annual and seasonal temperatures at different depths is greatest at 5 m (11.0°C) and at the surface (10.98°C), decreasing as depth increases to 4.25°C at 30 m, 3.08°C at 50 m, 1.36°C at 100 m, and 0.56°C at 150 m (ZORE-ARMANDA, 1989). Thus, the temperature variation at the sea surface increases along the longitudinal axis of the Adriatic from the southeast to the northwest, and decreases from the coast to offshore areas and from the surface towards greater depths.

The seawater temperature particularly affects vegetative periods and distribution. The Adriatic *Sargassum* can be divided into eurythermal (surface specimens of *S. vulgare* var. *vulgare* and *S salicifolium* var. *salicifolium*), stenothermal (*S. hornschuchii*), and transitional (deep sea specimens of *S. vulgare* var. *vulgare*, *S. vulgare* var. *jabukae*, and *S. salicifolium* var. *linifolium*) forms. The eurythermal forms have an uninterrupted vegetative period of varying intensity throughout the year. The principal period, during which the algae grow most intensively, is from mid-autumn to the end of spring or mid-summer. The secondary period, during which annual parts of the thallus fall off and new parts (primary branches) grow rather slowly, is from the beginning or mid-summer to mid-autumn. The stenothermal form seems to have an uninterrupted vegetative period all year round. Transitional forms have thermal characteristics lying between the eurythermal and stenothermal species.

Sargassum vulgare var. *vulgare* is completely eurythermal, especially regarding maximum temperature and variation, while some of its subspecies and forms behave differently. This species inhabits shores of inner islands and shoals in the channels between the islands, where the seawater temperature varies less than along the mainland coast and is the same or slightly exceeds the temperature in the open sea (approximately 10°C at the surface and considerably less at greater depths). Its vegetative period is uninterrupted during the year, even though the most intensive growth takes place in winter and spring (maximum at the end of June and beginning of July). Fructification extends from April to the beginning of July. Accordingly, the most suitable temperature for the development of this plant ranges 14-18°C, so that surface specimens are held to be transitional to stenothermal and specimens from greater depths truly stenothermal algal types.

Of its subspecies, *S. vulgare* var. *megalophyllum* is the most eurythermal. It tolerates the greatest average and absolute annual temperature variations (13°C and more in some localities). It is distributed in shallow surface areas in the northern Adriatic (from 0.5 to 2-3 m depth). The vegetative period extends year-round, but the subspecies seems to grow more intensively in spring, reaching maximum vegetative and generative development in the summer. The temperature at which this subspecies develops most intensively ranges 17.5-23.5°C.

The vegetative period of *S. vulgare* var. *ercegovicii* also extends year-round, but growth is considerably slowed during the warmest summer months. It develops most intensively in winter and spring. Fructification extends from April to the beginning of July. This surface form is adapted to temperatures prevailing in autumn through spring and the first half of summer when the average temperature ranges 11-21°C. Thus, this form is eurythermal.

Sargassum vulgare var. *jabukae* is adapted to the relatively average minimum (14.02°C) and mildly high maximum (23.5°C) surface temperatures of the open middle Adriatic. It tolerates temperature variations of 10°C and less. The amplitude of average annual temperature variations decreases progressively with depth, dropping to only 5-6°C at 20 m. Nevertheless, the vegetative period lasts all year, is most intensive in spring and summer, and reaches a maximum in August. Fructification extends from spring to mid-summer when it reaches its maximum. Since the optimum development of this species occurs in spring-summer, when the average ranges 19-23.5°C, it can be considered a transitional alga.

Sargassum vulgare var. *vulgare* is distributed mainly in the channels and shoals between intermediate and inner islands of the middle and northern Adriatic. It occurs in water characterized by temperate annual amplitudes of temperature variations. Its ability to tolerate relatively great temperature variations (about 10°C) makes possible its broad geographical and depth distribution in the eastern Adriatic. *Sargassum vulgare* var. *jabukae* is distributed in the area of some outer islands (Jabuka, Svetac, Palagruža) of the middle Adriatic, i.e., in waters with the lowest annual temperature variations (10°C at the surface and higher at greater depths). Its adaptation to slightly higher minimum (about 14°C) winter temperatures caused, in combination with other factors, this subspecies to be distributed in a relatively small area of the middle Adriatic. *Sargassum vulgare* var. *megalophyllum* is distributed along the western Istrian coast and along the mainland coast and shores of inner islands in the northern and middle Adriatic. It is resistant to greater annual temperature variations (about 13°C) which make possible its distribution in the northern Adriatic. *Sargassum vulgare* var. *vulgare* f. *ercegovicii*, with a slightly lower tolerance for variation (10°C), is distributed in a narrower area along the mainland coast and shores of inner islands of the middle Adriatic.

The distribution of *S. salicifolium* var. *salicifolium*, as a whole, is limited to the coastal area and channels of the middle and northern Adriatic; it is rather rare in the southern Adriatic. The species is tolerant to greater annual temperature variations. Therefore, its area of distribution is slightly broader. The typical form grows at 5-10 m depths in coastal and channel waters with an annual variation of 10.5-11.0°C. *Sargassum salicifolium* var. *linifolium* is adapted to a smaller temperature amplitude and mostly inhabits a small number of localities in exclusively coastal areas of the middle and northern Adriatic at depths of 10-20 m where the amplitude is 6-7°C. It would be incorrect to interpret the distribution of *S. salicifolium* var. *salicifolium* and *S. salicifolium* var. *linifolium* solely in terms of temperature effects, since it is also affected by light and extent of habitat exposure.

Sargassum salicifolium var. *salicifolium* has an uninterrupted vegetative period with intensive growth in autumn through spring (maximum at the end of spring and in June). Fructification extends approximately from mid-spring to mid-summer. According to its temperature requirements, the species, especially the typical form, is eurythermal, whereas *S. salicifolium* var. *linifolium* has weaker eurythermal characteristics. In both the typical form and its variation, maximum vegetative and generative development takes place when temperatures do not exceed 21°C. The temperature at 10 m ranges 12-21°C and at 20 m 11-17.5°C. Hence, *S. salicifolium* var. *salicifolium* may be classified as eurythermal and *S. salicifolium* var. *linifolium* as transitional.

Sargassum hornschuchii, a deep sea species, is stenothermal. It is adapted to lower temperatures at greater depths where the maximum is most frequently 16-17°C and minimum 12-13°C. Accordingly, the temperature variation does not exceed 5°C. In specimens from a depth of 50-60, the variation is 3°C or less. The vegetative period of this species, particularly in specimens from greater depths, is rather uniform year-round with no considerable seasonal differences. Specimens from 10-15 m, where the annual temperature varies as much as 10°C, are generally less developed than those from greater depths. In specimens from greater depths, the fructification period lasts a month or two longer than in specimens from 15-30 m in the coastal waters of the middle Adriatic. They bear well-developed receptacles as early as winter although specimens collected at the end of spring may lack receptacles or have receptacles with empty conceptacles and be in the state of decay. The winter-spring temperature ranges 12.5-16°C and never exceeds 17°C at this depth. On the western coast of the Istria Peninsula, maturation of sexual products extends from spring to the beginning of summer (VATOVA, 1928, 1948). This is a much shorter period than in the middle Adriatic and maturation lags behind almost the whole season. At depths of 10-30 m in the northern Adriatic, fructification takes place when the mean temperature is 13-15°C (maximum 16-17°C) in spring, coinciding with fructification of specimens from the coastal area of the middle Adriatic. In the open middle Adriatic (Jabuka reef), fructification at 15-30 m starts already in winter but, at 60 m, receptacles were found in June and, at deeper depths, in July and even August (near Biševo Island). The phenomenon of long lasting and late fructification period, characteristic of the specimens from deeper waters in the open middle Adriatic, may be accounted for by the fact that the limiting temperature of 17°C occurs at depths exceeding 20 m not earlier than in autumn and that, at greater depths, average temperatures are lower than that throughout the year.

The species *S. hornschuchii* is widely distributed throughout almost the whole Adriatic, in the southern, middle, and northern parts as well as in channels and open waters. However, it is restricted to deep waters and is only exceptionally found at depths less than 10 m. Its tolerance for small temperature variations (3-4 °C), its microstenophotic characteristics, and its need for sheltered habitats affect its distribution in a broad but specific area.

Light

The quantity and quality of light that penetrates sea water progressively change due to intensive absorption. Light intensity decreases with depth as the parts of the light specter with greater wave lengths (yellow and red) are more strongly absorbed than the parts with shorter wave lengths (blue and violet). Changes due to increasing depth directly affect photosynthetic activity, thereby limiting the distribution, especially zonal distribution, of algae. Little is known about light conditions in the Adriatic. Illumination increases from north to south and from the coast to offshore areas (GOLUBIĆ, 1967). The waters of the open middle Adriatic near Biševo Island are most transparent whereas the coastal waters of Lim Channel have much lower illumination. The percentages of light that penetrate the water in three locations (Lim Channel III, Banjole Islets, and Biševo Island) are, respectively: 80, 88, and 90% at 1 m; 60, 62, and 70% at 2.5 m; 37, 40, and 50% at 5 m; 16, 20, and 39% at 10 m; 7, 11, and 27% at 15 m; 3, 6, and 18% at 20 m; 1.4, 3, and 14% at 25 m; 1.7 and 11% at 30 m (for Biševo and Banjole Islets); and 4.8% at 40 m (for Biševo). Measurements of light extinction and spectral penetration in the middle Adriatic produced similar results (LEONARDIS *et al.*, 1970). Open water (off Šolta Island) allows more light to penetrate than coastal waters (Kaštela Bay) and some parts of the light spectrum penetrate better than others. Coastal waters best allow penetration of green light, whereas open waters best allow penetration of blue light.

Sargassum taxa respond to light that changes as a function of depth. The level of adaptation to changes of light quantity and quality affects vertical and horizontal distribution. Two basic groups can be distinguished with respect to depth distribution. Eurybathic forms grow at all depths from a few decimeters below the surface to great depths. These taxa tolerate great variations of light intensity and spectral characteristics of light and are euryphotic. Taxa occurring at depths of 0.7 to 3-4 m occupy a special position in this group. Specimens close to the surface grow in abundant light whereas those at 3-4 m occur in considerably reduced light. Macrobathic and microbathic taxa grow at one of the extremes, either in great depths (below 20-30 m) where light is greatly reduced and changed (microstenophotic) or close to the surface (0.5 to 1 m) where light is abundant (macrostenophotic).

Sargassum vulgare var. *vulgare* and *S. vulgare* var. *jabukae* are markedly euryphotic. The typical form grows from 0.5 m to great depths such as 50-60 m according to our studies and below 200 m according to ERCEGOVIĆ (1960). *Sargassum vulgare* var. *jabukae* grows at 1-20 m. These taxa, particularly the typical form, are tolerant to great light variation. Surface specimens receive more than 80-90% of the surface light while those at greater depths receive only a small percentage. *Sargassum vulgare* var. *megalophyllum* occurs at 0.7-3 m where specimens in the upper layer receive 90% light but specimens at 3 m receive only 60%. Therefore, this subspecies is euryphotic even though its growth at greater depths is very limited. *Sargassum vulgare* var. *vulgare* f. *ercegovicii* occurs only at 0.5-2 m where it receives 85-95%, so it is macrostenophotic.

Sargassum salicifolium var. *salicifolium* and *S. salicifolium* var. *linifolium* are also euryphotic due to their distribution at depths from 4-5 to 20 m, but they are much less euryphotic than *S.*

vulgare var. *vulgare*. *Sargassum salicifolium* var. *salicifolium* grows best at 4-5 to 10 m, where it receives 25-50% of the surface light. *Sargassum salicifolium* var. *linifolium* grows at 10-20 m, where 10-25% of light penetrates, so it is mesostenophotic. However, depth distribution of this species is also affected by other factors, especially wave activity. Abundantly developed specimens of the typical form frequently grow in sheltered locations even at 1-2 m depth.

Sargassum hornschuchii is a deep water species, occurring even at depths exceeding 200 m. Therefore, it has adapted to very reduced light levels. Depths exceeding 20-25 m receive less than 10% surface light, meaning that *S. hornschuchii*, especially specimens from great depths, are microstenophotic.

The phenomenon of aggregation of plastids around inner cell walls and fucosane granule around outer cell walls in Fucales (LINARDIĆ, 1949) and some *Cystoseira* taxa (ERCEGOVIĆ (1952) may be understood as protection against too intensive light. Similar aggregations of fucosane granules and pheoplasts, especially in epidermal cells, were recorded from surface *Sargassum* taxa. We assume that the fucosane cells act as the protective layer in a sensitive assimilation system against adverse effects of too intensive light at the surface.

An obvious change in thalli color in surface forms of *S. vulgare* var. *vulgare* also may be explained as an adaptation to too intensive light. Depending on the locality, changes are manifested as variations in color from brownish-green to yellowish green. *Sargassum vulgare* var. *megalophyllum* and *S. vulgare* var. *vulgare* f. *ercegovicii* that grow close to the mainland are markedly brownish green, whereas forms from the open Adriatic are prevalently yellowish-brown. A similar finding in some Adriatic taxa of *Cystoseira* was reported as an adaptation of the pigment system to light (ERCEGOVIĆ, 1952). Variations in color from brownish green to yellowish brown are due to the temporary prevalence of the chlorophyll pigment group (chlorophyll *a*) over the carotene group (carotene, xanthophyll, fucoxanthin) in specimens along the mainland coast. In specimens from the open sea, the carotenoid group prevails over the chlorophyll group. This partial reduction of pigments that are photosynthetically active at particularly long wave lengths (600-700 mμ) reduces light absorption for algae. It is very likely that changes of thallus color, i.e., reduction of pigments in surface forms of Adriatic *Sargassum*, plays a role in protective adaptation to too intensive light.

Some changes in deep sea specimens cannot, however, be explained in terms of adaptation for better light utilization of reduced and qualitatively changed light at great depths. This refers especially to changes in the color and form of the thalli. As depth increases, thallus color in eurybathic forms markedly changes from brown-greenish in surface specimens to yellowish-brown in deep sea specimens. MONTOFORT (1938) distinguished between so called xanthophylic and fucoxanthophylic taxa of brown algae. He held that only the latter (which contain fucoxanthin) could utilize green and blue spectral parts and therefore live at great depths.

Studies of SEYBOLD (1934), MONTFORT (1938), and LEVRING (1948) showed that yellow, which is characteristic of deep sea brown algae, originates in the carotenoid pigment group (particularly from carotene, xanthophyll, fucoxanthin) which utilizes the blue spectrum (an area of shorter wavelengths – 400-525 mμ) for photosynthesis. An increase in the carotene pigment group and respective reduction in the chlorophyll group makes the development and survival of algae at greater depths possible.

During the present study we observed that the deep sea *S. hornschuchii* and deep sea specimens of *S. vulgare* var. *vulgare* have a light brown to yellowish brown thallus and that the yellow intensifies with depth. Since we have no experimental data to prove that deep sea forms of Adriatic *Sargassum* are fucoxanthin algae, as explained by MONTFORT (1938), we cannot state with certainty that the group of mentioned pigments are really present and photosynthetically active in the Adriatic algae. However, since all recorded deep sea specimens had a yellowish-brown thallus and since brownish green specimens characteristic of surface forms were never found in deep waters, we assume that deep sea specimens are fucoxanthin algae and that their yellowish brown color results from increased carotenoids and decreased chlorophylls, representing a physiological adaptation to unfavorable light conditions in the deep sea. Similar changes in thallus color were recorded by ERCEGOVIĆ (1952) in Adriatic *Cystoseira*.

We also observed considerable changes in size, shape, and number of blades on the thallus, changes that might be due to light effects. Deep-sea specimens of *S. vulgare* var. *vulgare* have a smaller number of blades, which are longer than those in surface specimens. Macrobathic (*S. hornschuchii*) and mesobathic (*S. salicifolium* var. *salicifolium*) species were similar. *Sargassum hornschuchii* has very long (up to 13-14 cm) and wide (up to 3 cm) but rather rare blades, the surfaces of which are considerably increased by intensive folding of the blade plate. A considerably lower number and elongation of blades were recorded in *S. salicifolium* var. *salicifolium*. However, in the markedly deep sea species, *S. hornschuchii,* a progressive increase in length and width of blades was recorded as a function of depth.

Similar findings were recorded for *S. salicifolium* var. *salicifolium*, although to a lesser extent. This species shows an obvious increase in length and decrease in number of blades with depth, which may be partly explained as an adaptation to the intensive light to which surface specimens are exposed. The reduction in size of the blade plate and absorption surface area is due to the adverse effects of wave exposure. The reduced surface area is partly compensated by the greater number of blades that are so dense that they frequently overlap one another. The density may have a positive effect, i.e., it considerably reduces the light intensity that penetrates to the roofed blades. To the contrary, the pattern of fewer blades but of increased length recorded in specimens from intermediate and great depths may allow for better utilization of the greatly reduced light. These morphological and physiological adaptations enable deep-sea forms to utilize reduced light in deep water and surface forms to tolerate too intensive light at the surface.

Salinity

Salinity is the most important property of sea water. The level of salinity is influenced by temperature, evaporation, and wind and decreases with precipitation, riverine input, and ice. Salinity variations are greater in surface than in deeper layers and in coastal waters than in the open sea. Salinity averages about 33 psu (range 33-37 psu) in the oceans but varies considerably in enclosed seas such as the Mediterranean. For example, salinity reaches 41 psu in the Red Sea but is below 1.0 psu in some parts of the Baltic (PERES & DEVASE, 1963). Salinity varies in relation to depth, latitude, and other factors. Thus, salinity in tropical and equatorial parts of oceans decreases with depth due to great evaporation at the surface while it increases in polar areas. In enclosed seas, salinity increases with depth.

The Adriatic Sea has a high salinity (38.3 psu), slightly lower than in the eastern Mediterranean (39.0 psu) and higher than in the western Mediterranean (37.0 psu). Long-term studies (BULJAN, 1953) showed that salinity in the Adriatic varies little, ranging 38.48-38.6 psu in the open sea and 38.22-38.57 in Jabuka Pit. Surface salinity distribution varies by season. In summer, the most saline waters are in the middle part of the southern Adriatic, from Otranto Strait to the mid-Dalmatian islands, whereas the waters of Drim Bay and the rest of the middle and northern Adriatic are less saline. In winter, the open Adriatic waters along the line dividing the Adriatic longitudinally are most saline, whereas salinity is lower along both coasts. Salinity in the southern Adriatic usually exceeds salinity in the northern.

Long term salinity variations in the Adriatic have been recorded. Salinity was higher than normal in 1913, 1939, 1948/49, 1956, and 1969. Ingressions of more saline Mediterranean water seem to have been cause of these increases (BULJAN, 1953). During periods of low salinity, it does not exceed 38.5 psu north of Palagruža Sill. During periods of high salinity, even more saline waters may reach the Istrian coast.

According to response to salinity oscillation, Adriatic *Sargassum* may be divided into two groups. The first group comprises the deep sea species *S. hornschuchii*, the deep sea form of *S. vulgare* var. *vulgare* and its surface form from open waters, *S. vulgare* var. *jabukae*, and the mesobathic *S. salicifolium* var. *salicifolium*. This group inhabits areas and deep waters where salinity variations are limited, and they can be label stenohaline. They occur in waters of high salinity (38.3 psu) that varies little. The second group includes the surface forms of *S. vulgare* var. *magalophyllum* and *S. vulgare* var. *vulgare* f. *ercegovicii*. This group sometimes tolerates greater salinity drops, and may be classified as poorly euryhaline. *Sargassum* has never been recorded in localities with regular fresh water inputs where salinity is permanently low.

Water motion

Water motion, as a whole, is very complex and combines four factors: water particle movements, water exchange of physico-chemical properties, formative effects on substrate, and wave forcing. Each of these factors affects the development and distribution of benthic algae to a greater or lesser extent.

Water particle movements seem to positively affect algae by stimulating some life functions. BERTHOLD (1882) thought that formation of abundant settlements at great depths might take place only at localities where a defined water circulation is present. Other authors (PRUVOT, 1896; OLLIVIER, 1929) suggest otherwise, believing that while water movement has no direct effect on algae, it affects them indirectly by changing other environmental factors. The biological effect of water movement is poorly pronounced, but there is no doubt that it plays a role in the life of algae, even more so now that laboratory experiments have shown that some algae develop better in conditions of water movement (flow).

Considerably more important to algae, water motion effects changes in physico-chemical properties. Water motion intensively affects thermal conditions in the sea since it affects temperature variations of great extent that may occur due to high summer and low winter air temperatures. Development of algae is impossible in shallow and sheltered localities where temperature variations are considerable. Water motion exerts a special regulatory effect on water chemistry, its salinity, and its nutrient and gas contents.

Water motion is a formative factor in coast formation. It determines indentation, degree of compactness, particle size, and surface structure. These, in turn, affect the attachment of young algae and play an important role in the settling of organic and inorganic particles on the sea bottom. Mechanical effects of water motion are of particular importance. They include wave forcing and the influence of waves on shallow bottoms. The degree of wave forcing considerably affects the distribution of algae, particularly in shallow waters. The degree of wave forcing depends on wave exposure determined by the position of the shore in relation to the direction of the waves. Exposure depends on geomorphological, topographical, geographical, climatic, and depth factors. Straighter, steeper, and more vertical coasts are more exposed to wave action. Topographical-geographical factors have the same importance since, other conditions being the same, wave exposure increases in an offshore direction. The belt of islands that separates the open sea from coastal and channel waters reduces wave forcing in the latter areas. Among climatic factors, force and frequency of dominant winds are particularly significant. Southern and northern winds are dominant on the eastern Adriatic coast. The former are stronger in the southern and open middle Adriatic, while the latter are dominant in coastal areas of the mid-Adriatic. Therefore the southern and southeastern shores of islands in the southern and middle Adriatic are more exposed to waves than similarly oriented shores of islands in the northern Adriatic. Likewise, islands in the northern Adriatic are more exposed on their northern, northeastern, and northwestern shores than islands in the southern and middle Adriatic. Depth considerably affects wave forcing; both wave forcing and exposure are reduced with depth.

Wave forcing considerably affects the vertical and horizontal distribution of algae, influencing the occurrence and absence of particular taxa. *Sargassum hornschuchii*, which inhabits greater depths in the open Adriatic (40-60 m and even deeper) or channels and inshore waters below the 10 m isobath, seems not to tolerate wave forcing. On the contrary, *S. vulgare* var. *vulgare* tolerates considerable variations in the level of wave forcing. Specimens of this species and its varieties and form may be found at well or mildly exposed surface loctions as well as calm localities at greater depths. The species *S. salicifolium* var. *salicifolium* is adapted to a lower level of wave forcing. It occurs in coastal channels which are 4 m deep or more and sometimes at sheltered localities no deeper than 1 m. However, *S. salicifolium* subsp. *linifolium* occurs at markedly sheltered localities along the mainland coast and inner islands, most frequently at 10-20 m.

Wave exposure cause some morphological changes of the thallus in the tree properties and attachment plates and reduction of the entire thallus. Generally, surface forms have more massive attachment plates and short but firm and more resistant trees. Taxa from deep waters and less exposed localities have longer trees and slightly less developed attachment plates. Simplification of all or some parts of the ramified thallus is very significant in forms from exposed localities. This so-called reduction of the thallus plate may lead to dwarfism and relates to the dimensions and number of branches and blades; form, size, and number of bladders; form and size of fertile branches; and, general length, abundance, and appearance of the alga. Forms from more exposed habitats usually have a less developed thallus while those from markedly exposed localities close to the surface develop a dwarfish form (for example, some surface forms of *S. vulgare* var. *vulgare*). Branches of these forms are usually shorter than in specimens from slightly or considerably greater depths. The blades are shorter, generally wider and thicker, and fertile branches are short and pressed. Bladders in specimens from sheltered or deeper localities are larger and more numerous than those in specimens from exposed surface habitats.

CONCLUSIONS

The genus *Sargassum* is represented in the Adriatic by the following three species: *S. vulgare* C. Ag. var. *vulgare* , *S. salicifolium* J. Ag. var. *salicifolium* and *S. hornschuchii* C. Ag. These species are abundantly developed in the Adriatic and make up a significant part of its bottom flora.

The morphology of *S. vulgare* C. Ag. subsp. *vulgare* varies greatly so that, in addition to the typical species and variety *S. vulgare* C. Ag. var. *megalophyllum* (Mont.) Grunow, we established a new variety *S. vulgare* C. Ag. var. *jabukae* Špan, and form *S. vulgare* C. Ag. subsp. *vulgare* f. *ercegovicii* Špan, that differ from the typical species in morphology and distribution. *S. vulgare* var. *vulgare* is distributed throughout the Adriatic, from the surface to great depths. The species developed several settlements in ecologically different areas. These populations have considerable morphological differences and were divided into four groups: intermediate, inner, outer, and northern populations.

Apart from the typical species *S. salicifolium* J. Ag. var. *salicifolium*, we established a more poorly distributed taxon which conforms to the description of the species *S. linifolium* (Turn.) J. Ag. We report this form as *S. salicifolium* J. Ag. var. *linifolium* Špan (*comb. nov.*), which differs from the typical species in some morphological and ecological characteristics. *S. salicifolium* var. *salicifolium* is widely distributed along the eastern Adriatic coast, inhabiting coastal and channel waters at depths of 3-4 to 8-10 m and, rarely, open sea waters at 20-30 m. *Sargassum salicifolium* var. *linifolium* is rare, compared to the typical form. It occurs mainly at 15-20 m and sometimes at 8-10 m in sheltered localities in coastal water areas.

The deep sea species *S. hornschuchii* is distinguished from the preceding species by its relatively unvarying morphological properties as well as its ecological properties. *Sargassum hornschuchii* is distributed in coastal, channel, and open waters, most frequently at 25-60 m. It occurs at shallower depths (10-15 m) particularly in the northern Adriatic. On several occasions it was recorded from depths exceeding 150 m and, once, from deeper than 200 m.

The development, survival, and distribution of *Sargassum* are affected by abiotic factors. The substrate is most important, followed by temperature, light, salinity, and water movement. Some morphological and physiological properties are directly and/or indirectly dependent on these factors.

As to the substrate, *Sargassum* is rather indifferent to the compactness of the bottom whereas its chemistry does not directly affect the algae at all. Other environmental factors (wave force, light) allowing, these algae grow on strongly and poorly compacted substrates. At greater depths, *Sargassum* inhabits rocky bottoms (reefs, rocky parts).

As to thermal demands, eurythermal and stenothermal forms of *Sargassum* exist. *S. vulgare* var. *megalophyllum*, *S. vulgare* var. *vulgare* f. *ercegovicii*, and *S. salicifolium* var. *salicifolium* are eurythermal. *Sargassum hornschuchii* is markedly stenothermal. *Sargassum vulgare* var. *vulgare*, *S. salicifolium* var. *linifolium*, and *S. vulgare* var. *jabukae*, are less eurythermal and, especially the latter, represent transitional forms toward the stenothermal type. The Adriatic *Sargassum* have uninterrupted vegetation throughout the year, which slightly slows down in some forms in summer.

The markedly eurythermal character of *S. vulgare* var. *megalophyllum* and *S. vulgare* var. *vulgare* f. *ercegovicii* affects, together with other factors, their horizontal and vertical distribution in areas with great annual temperature variations (the northern Adriatic and the coastal area of the middle Adriatic). The more poorly expressed eurythermal character of *S. vulgare* var. *vulgare*, *S. vulgare* var. *jabukae*, and *S. salicifolium* var. *linifolium* caused these forms to be distributed only in waters with small annual temperature variations. As a markedly stenothermal and stenophotic species, *S. hornschuchii* is distributed over a wide area, but only at greater depths.

As to light demands, *S. vulgare* var. *vulgare* is markedly euryphotic and thus distributed from the surface to greater depths. *Sargassum vulgare* var. *jabukae* and especially *S. vulgare* var. *megalophyllum* are far less euryphotic and have a limited depth distribution. *Sargassum salicifolium* var. *salicifolium* is less euryphotic and inhabits depths of 4-10 m. *Sargassum vulgare* var. *vulgare* f. *ercegovicii* is macrostenophotic and occurs only at 1- 2 m depth. *S.salicifolium* var. *linifolium* is mesostenophotic, occurring at 10-20 m, while *S. hornschuchii* is markedly microstenophotic and occurs only at greater depths.

Most *Sargassum* taxa have morphological and biochemical properties that are understood as adaptations (photomorphoses) to light conditions. In deep-sea specimens, the prevalent yellow color of the thallus (due to an increased fucoxanthin content), the reduction of the number of blades, and the increase in blade length are adaptations to the reduced light. The aggregation of fucosane granules along the outer walls of epidermal cells that changes the thallus color in surface specimens of *S. vulgare* var. *jabukae* and the high density of shorter blades in all surface specimens are protective adaptations to too intensive light.

As to their tolerance to varying salinity, the Adriatic *Sargassum* may be divided into markedly stenohaline and less stenohaline. *Sargassum hornschuchii,* deep sea forms of *S. vulgare* var. *vulgare* and *S. vulgare* var. *jabukae*, and *S. salicifolium* var. *salicifolium* are markedly stenohaline. *Sargassum vulgare* var. *vulgare*, *S. vulgare* var. *megalophyllum,* and *S. vulgare* var. *vulgare* f. *ercegovicii* are less stenohaline, tolerating salinity reduction only temporarily and not occurring at all at localities with low salinity.

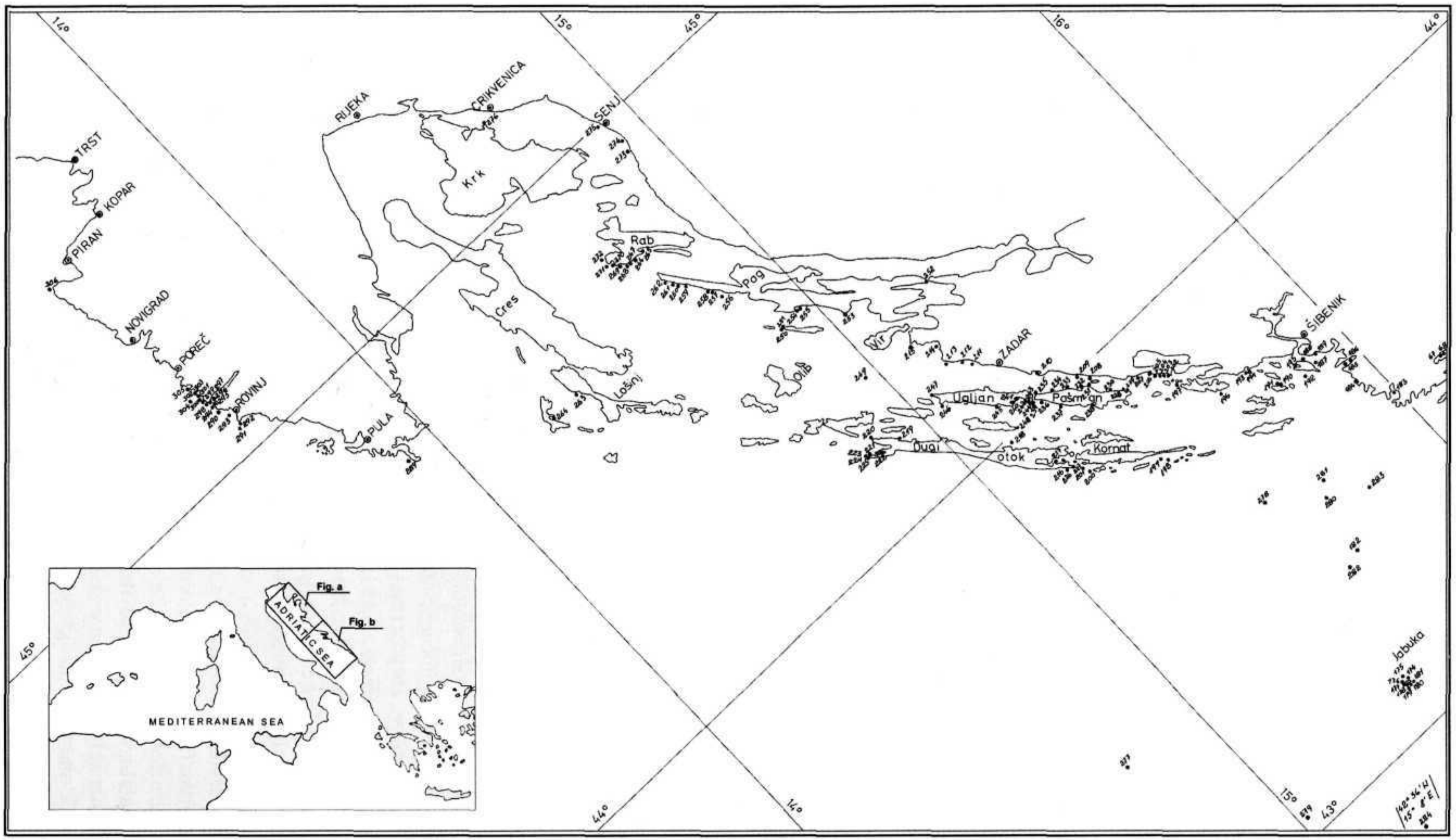

Fig. 20A) Sites at which genus *Sargassum* was recorded

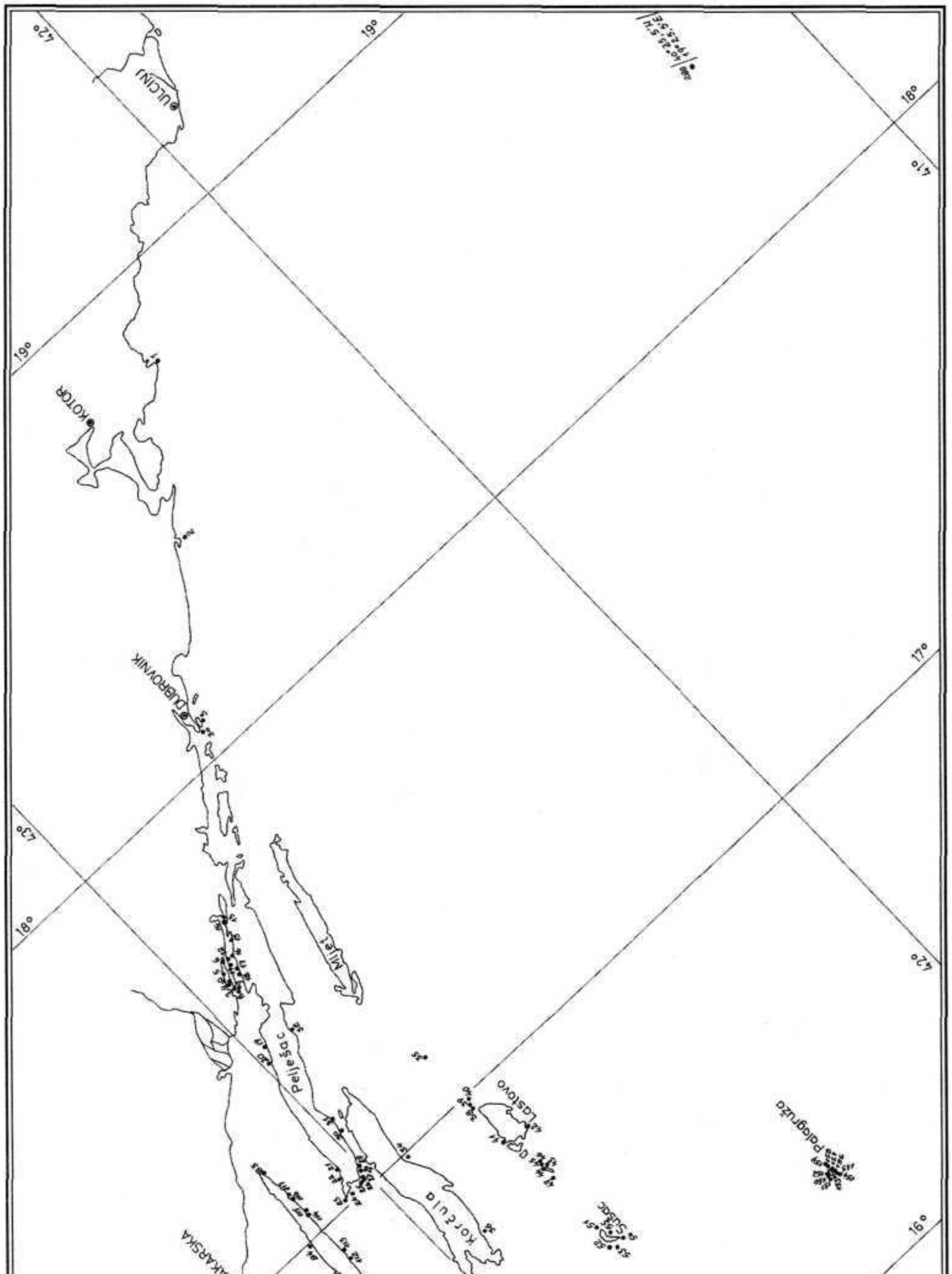

Fig. 20B) Sites at which genus *Sargassum* was recorded

Water movement, and particularly wave exposure (forcing factor), strongly affect vertical and, to a smaller extent, horizontal distribution of *Sargassum*. Their occurrence or absence in sheltered and exposed localities depends on tolerance to the degree of wave forcing. The eurybathic *S. vulgare* var. *vulgare* tolerates great differences in wave forcing, the mesobathic *S. salicifolium* var. *salicifolium* tolerates considerably less movement, while the macrobathic *S. hornschuchii* is not at all tolerant to wave forcing. Surface specimens of *S. vulgare* var. *vulgare* that inhabit exposed localities have more morphological changes of adaptive significance (a better-developed holdfast, reduced bladders, shorter branches and blades), adaptations that often lead to dwarfism.

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Rod *Sargassum* u Jadranu: Morfologija, sistematika i ekologija

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SAŽETAK

U radu se iznose rezultati višegodišnjih (1947-1971) istraživanja morfoloških, sistematskih i ekoloških značajki svojti roda *Sargassum* koje su sabrane na mnogim lokalitetima u priobalnom, otočnom i otvorenom dijelu istočne obale Jadrana. Detaljno se prikazuje vanjska morfologija pojedinih dijelova talusa alga: prihvatne pločica (rizoida), stabla (kauloida) i razgranjenih dijelova (filoida) koji se sastoje od grana, listića (filokladija), kripata, aerocista, plodnih grančica (fruktifikacija) s rasplodnim tjelešcima (receptakulima). U anatomskom dijelu istraživanja sistem tkiva kod roda *Sargassum* je podijeljen na epidermu, koru (primarnu i sekundarnu) i središnje (aksijalno) tkivo. Iznose se podaci o istraživanju građe, oblika i dimenzija rasplodnih jamica (konceptakula) i rasplodnih organa (oogonija i anteridija) kod pojedinih svojti alga ovoga roda. Proučavanje dubinske (vertikalne) i geografske (horizontalne) rasprostranjenosti svojti algi ovoga roda je omogućilo inventarizaciju ovih algi uz istočnu obalu Jadrana. Studirana je varijabilnost i adaptacija pojedinih svojti ovoga roda u odnosu na neke ekološke čimbenike (temperatura, svjetlo, gibanje mora i salinitet).

Na temelju tako opsežnih istraživanja zaključuje se da je rod *Sargassum* u Jadranu zastupljen s tri vrste (*S. vulgare* C. Ag. var. *vulgare* , *S. salicifolium* J. Ag. var. *salicifolium* i *S. hornschuchii* C. Ag.). Kod vrste *S. vulgare* C. Ag. var. *vulgare* razlikuje se pored poznatog varijeteta *S. vulgare* C. Ag. var. *megalophyllum* (Mont.) Grunow) jedan novi varijetet (*S. vulgare* C. Ag. var. *jabukae* Špan) i jednu novu formu (*S. vulgare* C. Ag. var. *vulgare* f. *ercegovicii* Špan). Pored vrste *S. salicifolium* J. Ag. var. *salicifolium* navodi se i varijetet *S. salicifolium* J.Ag. var. *linifolium* Špan kao nova kombinacija u koju je uključena i slabo rasprostranjena vrsta *S. linifolium* (Turn.) J.Ag.

Ključne riječi: bentoske alge, *Sargassum*, Phaeophyta, morfologija, anatomija, sistematika, ekologija, Jadransko more