Description of Ceramium Roth Species of Turkey with a New Record for the Mediterranean

Ali Rahmi Firat¹, Huseyin Erdugan²*¹

¹ Çanakkale Onsekiz Mart University, Graduate School of Natural and Applied Sciences Department of Biology, Çanakkale, Turkey.
² Çanakkale Onsekiz Mart University, Faculty of Arts and Science, Department of Biology, Çanakkale, Turkey.

Abstract
A guide for species identification of representatives of the genus Ceramium (Roth, 1797) along the Turkish coast is elaborated in this study. Some of the samples used in this study were collected from our previous field studies. However, inappropriate and missing samples in the Herbarium were collected again. The samples were also studied from the personal herbarium of Hüseyin ERDUĞAN. Twenty-six species of genus Ceramium Roth were found and identified along the shores of Turkey, with Ceramium camouii Dawson 1944, being a new record from the Mediterranean. In this study, a catalog based on the morphological and anatomical characteristics of genus Ceramium Roth found on the shores of Turkey is described.

Introduction
Classifications of living organisms began centuries ago and the process of addition of new species and re-examination of the systematic positions of some known species still continues. Currently, many studies have been used in the diagnosis of algae; for example, Agardh (1894), Kützing (1845-1855, 1856-1860, 1861-1865, 1866-1869), Hauck (1885), Reinke (1892), Schiffner and Vatova (1937), Feldmann-Mazoyer (1940), Kylin (1944), Feldmann (1949), Taylor (1967), and Kjellman (1971). These studies continue to set an example for much of today’s research.

The order of Ceramiaceae is composed of four families: Ceramiaceae, Delesseriaceae, Dasyaceae and Rhodomelaceae. Ceramium is the genus represented by most taxa in the Ceramiaceae family. In our country, Ceramium species were described in list studies (Aysel & Erdugan, 1995; Aysel, Erdoğan, Sukatar, Güner, & Öztürk, 1996; Erdoğan, Aysel, & Güner, 1996; Aysel et al., 2004; Aysel, Erdoğan, & Dural-Tarakçı, 2005; Aysel, Erdoğan, Dural-Tarakçı, & Okudan, 2005; Aysel, Erdoğan, Okudan, & Erk, 2005; Aysel, Erdoğan, & Okudan, 2006a; Aysel, Erdoğan, & Okudan, 2006b; Aysel, Okudan, & Erdoğan, 2006; Aysel, Erdoğan, Dural, & Okudan, 2006a; Aysel, Erdoğan, Dural, & Okudan, 2006b; Aysel, Dural, Şenkardeşler, Erdoğan, & Aysel, 2008; Aysel, Erdoğan, Dural, & Okudan, 2008; Öztürk, 2011; Taşkin, 2014). In spite of this, taxonomic confusion of Ceramium species still continues. Today, although 907 Ceramium species are given, only 268 of them are currently accepted (Algaebase, 2018).

In this study, the species of genus Ceramium Roth were studied along the Turkish coasts. Twenty-six species of genus Ceramium are described in terms of...
their morphological and anatomical characteristics with photographs. *Ceramium camouii* is also the first record for the Mediterranean.

**Materials and Methods**

In this study, samples of *Ceramium* species were studied from Hüseyin Erdoğan’s herbarium. These collections were obtained from all along the coast of Turkey. If any sample was found not suitable (i.e. morphologically deformed sample) for the study, it was collected again. The study included the coasts of Antalya, Muğla, İzmir, Balıkesir, Çanakkale, Bursa, İzmir, Kırklareli, Sinop, Trabzon and Rize (Figure 1). Samples were collected from 0-10 m depth using SCUBA equipment and were preserved in 4% formaldehyde. The algae samples were examined according to classical taxonomy rules (morphological and anatomical examination) with the help of the available literature. Macroscopic and microscopic photographs of the algae are provided in detail.

Anatomical sections were obtained using a new and effective method involving Styrofoam, elderberry and razor blade (original). The razor blade is cleaved horizontally from the middle into two pieces and stuck together. This process is used to obtain the best cross section.

For anatomical examination, 10% HCl was added dropwise to the sample and left to stand for 5 minutes. The sample was then crushed between the slide and lamella to separate thallus cells from the cortex. Prepared samples were examined with Zeiss Primostar, Olympus CX31, and Olympus CX21 microscopes. Photographs were taken with Olympus BX51, Novel N-200M and Olympus SZX7 stereomicroscopes. Photographs of unobtained samples were taken from the previous literature.

For species identification, the following literature was used: Altındağ (1976); Aleem (1993); Coppejans (1983); Cribb (1983); Feldmann (1949); Fisher (1987); Fritsch (1945); Grunow *et al.* (1885); Hiscock (1986); Jaasund (1976); Kapraun (1980); Kjellman (1971); Kornmann and Sahling (1983); Kützing (1843, 1861-1865); Kylin (1944, 1954); Lawson and John (1982); Leving, Hoppe, and Schmid (1969); Littler, Litter, Bucher, and Norris (1989); Maggs and Hommersand (1993); Milchakova (2003); Millan (1990); Newton (1931); Paciente and Cordero (1977); Pankow (1971); Sauvageau (1971); Schiffner and Vatova (1937); Schneider and Searles (1991); Smith (1944); Taylor (1967); and Van Den Hoek, Mann, and Jahns (1995). Algaebase 2018 was used to check the current names of the samples.

**Results**

In the present study 26 species of *Ceramium* were reported from the Turkish waters. This is compared to Taşkın, Öztürk, Kurt, and Öztürk (2008) who included 21 species of *Ceramium* in the Turkish algae flora list. Among the species of *Ceramium* recorded in the present study, *C. camouii* E.Y.Dawson 1944 is newly reported from the Mediterranean. The species *C. flaccidum* (Harvey ex Kützing) Ardissone from previous studies (Taşkin *et al.*, 2008) was named as *Gayliella flaccida* (Harvey ex Kützing) T. O. Cho & L. J. McIvor based on the morphological and molecular findings (Cho *et al.*, 2008).

The characteristics of 26 species of *Ceramium* are given in Table 1.

The characteristic of each species is described below:

*Ceramium arborescens* J. Agardh 1894

The thallus cortication of the *C. arborescens* is very similar to *C. rubrum*, but the thallus lower parts are in loose cortex cell array, like the lower parts of the *C. pseudostrichum* sample. Unlike the *C. rubrum* sample, the branches end towards the corymb and the ends of the branches do not roll inward but are slightly curved (Figure 2: 1-2). In our sample, tetraspores are embedded.
<table>
<thead>
<tr>
<th>Taxa names</th>
<th>Thallus type</th>
<th>Thallus branch</th>
<th>Branch type</th>
<th>Lateral ramuli</th>
<th>Spina</th>
<th>Transparent hairs</th>
<th>Fixed disc formation in the middle of the thallus</th>
<th>Pericentral cell number</th>
<th>Cortex cells around pericentral cells</th>
<th>Cortex cells</th>
<th>Thallus size</th>
<th>Branch diameter of Thallus top point</th>
<th>Branch diameter of Thallus midpoint</th>
<th>Branch diameter of Thallus substratum</th>
<th>Tetrapore sin nods</th>
<th>Cystoscarp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceramium arborescens</td>
<td>Irregular bifurcation</td>
<td>Usually corymb</td>
<td>Has</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>8</td>
<td>2 sequence</td>
<td>Continuous throughout the Thallus</td>
<td>8-15cm</td>
<td>100-250µ</td>
<td>50-250µ</td>
<td>150-300µ</td>
<td>800µ</td>
<td>Single-row or double-row</td>
<td>Surrounded by 3-4 branches</td>
</tr>
<tr>
<td>Ceramium camouël</td>
<td>Stolon thallus on substrate</td>
<td>Irregular bifurcation</td>
<td>Has</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>Has</td>
<td>5-7</td>
<td>Not continuous throughout the Thallus</td>
<td>1-5mm</td>
<td>60-80µ</td>
<td>50-150µ</td>
<td>Single-row</td>
<td>Surrounded by a few branches</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceramium ciliatum var. ciliatum</td>
<td>Regular bifurcation</td>
<td>Bifurcation, curved to inside and rarely erect</td>
<td>Has</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>Has</td>
<td>8</td>
<td>2 sequence</td>
<td>Not continuous throughout the Thallus</td>
<td>5-15cm</td>
<td>100-125µ</td>
<td>200-400µ</td>
<td>Single-row (alternate)</td>
<td>Surrounded by 2-4 branches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceramium ciliatum var. robustum</td>
<td>Regular bifurcation</td>
<td>Bifurcation, curved to inside and rarely erect</td>
<td>Has</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>Has</td>
<td>8</td>
<td>2 sequence</td>
<td>Not continuous throughout the Thallus</td>
<td>5-15cm</td>
<td>200-400µ</td>
<td>Single-row (alternate)</td>
<td>Surrounded by 2-4 branches</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceramium cimbicium f. cimbicium</td>
<td>Regular bifurcation</td>
<td>Erect, bifurcation, slightly curved to inside and rarely erect</td>
<td>Has</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>Has</td>
<td>5-6</td>
<td>1 sequence</td>
<td>Not continuous throughout the Thallus</td>
<td>4-12,5cm</td>
<td>100µ</td>
<td>80-300µ</td>
<td>Single-row</td>
<td>Surrounded by 2-3 branches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceramium cimbicium f. flaculatum</td>
<td>Regular bifurcation</td>
<td>Erect, bifurcation and curved to inside</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>Has</td>
<td>5-6</td>
<td>1 sequence</td>
<td>Not continuous throughout the Thallus</td>
<td>3-7cm</td>
<td>60µ</td>
<td>Single-row</td>
<td>Surrounded by a few branches</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceramium circinatum</td>
<td>Regular bifurcation</td>
<td>Branch tips are pinched and curved to inside</td>
<td>Has</td>
<td>Hasn't</td>
<td>Gölübölür başen gůlůmez</td>
<td>7-9</td>
<td>1 sequence</td>
<td>Not continuous throughout the Thallus</td>
<td>8-20cm</td>
<td>200µ</td>
<td>475-500µ</td>
<td>Single-row or irregular</td>
<td>Surrounded by 3-2 branches</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceramium codii</td>
<td>Stolon thallus on substrate</td>
<td>Irregular bifurcation</td>
<td>Generally simple straight ends, slightly curved or flat</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>Has</td>
<td>5</td>
<td>Hasn't</td>
<td>Not continuous throughout the Thallus</td>
<td>3cm</td>
<td>2350µ</td>
<td>Single-row</td>
<td>Rare</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceramium desbonghamii</td>
<td>Regular bifurcation</td>
<td>Erect bifurcation and get thinner to the top of branch</td>
<td>Has</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>Has</td>
<td>7</td>
<td>1 sequence</td>
<td>Not continuous throughout the Thallus</td>
<td>4-12,5cm</td>
<td>65-70µ</td>
<td>150-200µ</td>
<td>450µ</td>
<td>Single-row</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceramium diophanum var. decipiens</td>
<td>Regular bifurcation</td>
<td>Young branch tips in the form of two or three layers</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>Has</td>
<td>3-6</td>
<td>Not continuous throughout the Thallus</td>
<td>3cm</td>
<td>80µ</td>
<td>200-300µ</td>
<td>Single-row</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceramium gaditanum var. gaditanum</td>
<td>Regular bifurcation</td>
<td>Bifurcation, curved to inside, complicated cortical and</td>
<td>Has</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>Has</td>
<td>Continuous throughout the Thallus</td>
<td>5-8cm</td>
<td>Single-row</td>
<td>3cm</td>
<td>80µ</td>
<td>200-300µ</td>
<td>Single-row</td>
<td>Surrounded by 3 branches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceramium gaditanum var. mediterraneum</td>
<td>Regular bifurcation</td>
<td>Bifurcation, curved to inside, complicated cortical and</td>
<td>Has</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>Has</td>
<td>Continuous throughout the Thallus</td>
<td>3-4cm</td>
<td>Single-row</td>
<td>300-325µ</td>
<td>Single, double, triplet row</td>
<td>Surrounded by 4-5 branches</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceramium pseudostrictum</td>
<td>Regular bifurcation</td>
<td>Branch tips are pinched and curved to inside</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>Has</td>
<td>Continuous throughout the Thallus</td>
<td>3-4cm</td>
<td>Single, double, triplet row</td>
<td>300-325µ</td>
<td>Single, double, triplet row</td>
<td>Surrounded by 4-5 branches</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1: List of properties belonging to Ceramium taxa.
<table>
<thead>
<tr>
<th>Taxa names</th>
<th>Thallus type</th>
<th>Thallus branch</th>
<th>Branch type</th>
<th>Lateral ramuli</th>
<th>Spina</th>
<th>Transparent hairs</th>
<th>Fixed-disc formation in the middle of the thallus</th>
<th>Pericentral cell number</th>
<th>Cortex cells around pericentral cells</th>
<th>Cortex cells</th>
<th>Thallus size</th>
<th>Branch diameter of thallus top point</th>
<th>Branch diameter of thallus midpoint</th>
<th>Branch diameter of thallus subspot</th>
<th>Tetraspores in thallus</th>
<th>Cystocarp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceramium virgatum var. virgatum</td>
<td>The substrate is connected to a single point</td>
<td>Regular bifurcation and curved to inside</td>
<td>Has (Low)</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>8</td>
<td>2 row</td>
<td>Continuous throughout the Thallus</td>
<td>4-30cm</td>
<td>100-150µ</td>
<td>200µ</td>
<td>280-300µ</td>
<td>Irregular</td>
<td>Surrounded by 3-7 branches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceramium rubrum var. barbatum</td>
<td>The substrate is connected to a single point</td>
<td>Regular bifurcation and curved to inside</td>
<td>Has (Very)</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>8</td>
<td>2 row</td>
<td>Continuous throughout the Thallus</td>
<td>6-7cm</td>
<td>175µ</td>
<td>450-600µ</td>
<td>Irregular</td>
<td>Surrounded by 3-5 branches</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceramium virgatum var. implaccontortum</td>
<td>The substrate is connected to a single point</td>
<td>Regular bifurcation and curved to inside</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>Has (along thallus)</td>
<td>8</td>
<td>2 row</td>
<td>Continuous throughout the Thallus</td>
<td>1-5cm</td>
<td>190µ</td>
<td>425-450µ</td>
<td>1375µ</td>
<td>Irregular</td>
<td>Surrounded by 2-4 branches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceramium secundatum</td>
<td>The substrate is connected to a single point</td>
<td>Regular bifurcation and curved to inside</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>8</td>
<td>2 row</td>
<td>Continuous throughout the Thallus</td>
<td>1-8cm</td>
<td>300-350 µ</td>
<td>625-790 µ</td>
<td>Single-row or double-row</td>
<td>Surrounded by 3-4 branches</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceramium siliquosum var. siliquosum</td>
<td>The substrate is connected to a single point</td>
<td>Regular bifurcation and can be alternate</td>
<td>Bifurcation, slightly curved to inside and serrated edges</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>7</td>
<td>2 row</td>
<td>Continuous throughout the Thallus</td>
<td>4-20cm</td>
<td>40-125µ</td>
<td>375-500µ</td>
<td>Single-row or double-row</td>
<td>Surrounded by 2-4 branches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceramium siliquosum var. elegans</td>
<td>The substrate is connected to a single point</td>
<td>Regular bifurcation and curved to inside</td>
<td>Has (Low)</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>7</td>
<td>2 row</td>
<td>Continuous throughout the Thallus</td>
<td>7-8cm</td>
<td>125-250µ</td>
<td>250-330µ</td>
<td>Single-double-row</td>
<td>Surrounded by 2-4 branches</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceramium siliquosum var. lophophorum</td>
<td>The substrate is connected to a single point</td>
<td>Regular bifurcation and curved to inside, the secretion cells form a toothed ridge</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>8</td>
<td>2 row</td>
<td>Continuous throughout the Thallus</td>
<td>1-2cm</td>
<td>50-100µ</td>
<td>100-150µ</td>
<td>175-200µ</td>
<td>Single-row</td>
<td>Surrounded by 2-4 branches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceramium siliquosum var. zostericola</td>
<td>The substrate is connected to a single point</td>
<td>Regular bifurcation and less curved, thin and erect</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>5</td>
<td>2 row</td>
<td>Continuous throughout the Thallus</td>
<td>6cm</td>
<td>50-100µ</td>
<td>250-275µ</td>
<td>Single-row</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceramium diaphonum var. zostericola var. acrocarpum</td>
<td>The substrate is connected to a single point</td>
<td>Regular bifurcation and adventive branch tips are paraspores</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>3</td>
<td>2 row</td>
<td>Continuous throughout the Thallus</td>
<td>3cm</td>
<td>150-200µ</td>
<td>150-200µ</td>
<td>Always on branch tips</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceramium siliquosum var. minisulcimum</td>
<td>The substrate is connected to a single point</td>
<td>Upright forked, ends in the form of plasms</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>Has (Generally in the lower part of the thallus)</td>
<td>6-7</td>
<td>1 row</td>
<td>Continuous throughout the Thallus</td>
<td>1-1.5cm</td>
<td>50-75µ</td>
<td>100-175µ</td>
<td>200µ</td>
<td>Single-row</td>
<td>Surrounded by 1-2 branches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceramium tenerrimum var. tenerrimum</td>
<td>Stolon thallus on substrate</td>
<td>Regular bifurcation and curved to inside</td>
<td>Has (Rare)</td>
<td>Hasn't</td>
<td>Has</td>
<td>7-8</td>
<td>1 row</td>
<td>Continuous throughout the Thallus</td>
<td>2.5cm</td>
<td>80-100µ</td>
<td>125-250µ</td>
<td>Single-row</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceramium tenerrimum var. brevizonatum</td>
<td>Stolon thallus on substrate</td>
<td>Regular bifurcation and curved to inside</td>
<td>Hasn't</td>
<td>Hasn't</td>
<td>Has</td>
<td>Not continuous throughout the Thallus</td>
<td>50-100µ</td>
<td>Single-row</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
in the cortex and are in a single row around the axis (Figure 2: 3-5). In the thallus cross section, 8 pericentral cells and 2 rows of cortical cells were arranged around the central cell (Figure 2: 6). The width at the top of the thallus is 250 μm and the middle is 500-625 μm.

*Ceramium camouii* E.Y.Dawson 1944

This sample is partly similar to the *C. codii* taxon. This similarity to the sample of *C. camouii* can only be said to exist for secondary branches (Figure 3: 5, 8-12). The major axis of this sample was more developed than the cortical cords of the *C. codii* strain (Figure 3: 6-7) and banding was achieved with a greater number of cortical cells. If the thallus cannot be obtained as a whole, it may be confused with the *C. codii* species (Figure 3: 3-4). It has a kind of stolon thallus. As a result, the majority of nodes on the thallus appear to have an adherent disk formation (Figure 3:1-4). It is a small structured sample. Branch tips are erect (Figure 3: 3, 7-9). Main axis diameter is 100 μm in the node, 80 μm in the internode, 80 μm for node of lateral branches and 60 μm for internode of the lateral branches. The internodes can be up to 6 times the height of the nodes. The main axis nodes form a band with 3-4 rows of cells, with bands of 1-2 rows of cells in the side branches (Figure 3: 6-12). This taxon was collected from Yapıldak shore in the Dardanelles.

*Ceramium ciliatum var. ciliatum* (J. Ellis) Ducluzeau 1806

In the cross section of the thallus, 7-8 pericentral and 2 cortical cells are seen around the central cell (Figure 4: 5-6). When central and pericentral examinations are performed on *Ceramium* samples, it should involve taking several sections from various sections of the thallus regardless of section. When multiple sections were taken from thallus of most *Ceramium* species, it was identified that there were different numbers of pericentral cells (Figure 4: 5-6). Axial diameters to branch tips are 125 μm at nodes and 100 μm in internode.

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**Figure 2.** *C. arborcescens* 1-2: Thallus general appearance and corymbic structure of branch tips (stereo microscope), 3: Tetraspores in thallus (4x), 4-5: Tetraspores embedded in cortex (10x), 6: Thallus cross section (4x) (Original).

**Figure 3.** *C. camouii* 1-3: Thallus general appearance (4x), 4: Main axis filament and lateral branch (10x), 5-6: lateral branch extending from node and the node internode separation (40x), 7-9: The end of the major and lateral branches (10x), 10: Adherent disc structure (4x), 11-12: Cortex structure in lateral branch (10x) (Original).
*Ceramium ciliatum var. robustum* (J. Agardh) Mazoyer 1973

This sample has the same characteristics as the *C. ciliatum* taxon. The only difference is that the needles are usually 5-cell and rarely 4-cell (Figure 5: 1,3). Tetraspores have inflated nodes and verticillate in a row (Figure 5: 2). Thallus sections are similar to *C. ciliatum* taxa. Pericentrals can be 7-8 (Figure 5: 4-5). There are two rows of cortex around the pericentral cells (Figure 5: 5-6). Diameter of the middle part of thallus is 300 μm at the nodes and 250 μm in the internodes. Diameter of tetrasporic midpoint of thallus is 400 μm at the nodes and 250 μm in the internodes.

*Ceramium cimbricum f. cimbricum* H. E. Petersen 1924

Branch tips are inclined slightly inward, do not roll in, have equal height, with edges slightly serrated (Figure 6: 1). The number of cortical cells in the...
tetrasporophyte stage increases and changes the shape of the thallus (Figure 6: 1, 4-6). Thallus corticalization is very low (Figure 6: 2). Although the internodes are transparent, they appear to have line-shaped waves (Figure 6: 3). At branch tips, node internode width is equal and 100 μm. The internodes can be up to 4 times the height of the nodes.

*Ceramium cimbricum f. flaccidum* (H. E. Petersen) Furnari & Serio 1996

Branch tips are bifurcated to almost the same size with a slight curvature. The cortex at the tip of the branches is considerably reduced (Figure 7: 1). Corticalization of nodes is characteristically quite small (Figure 7: 2-3). The nodes are usually banded with 2 rows of cortical cells, sometimes banded with 3 rows of cells (Figure 7: 4). Transparent structures can emerge from the nodes (Figure 7: 2). In cross sections taken from thallus, we can see 5 pericentral cells around the central cell and an outermost single-row cortex cells (Figure 7: 5-6). In some Ceramium specimens, the outer cortices can be separated or dispersed from the pericentral cells because the cortex is loose in the node (Figure 7: 6). For this reason, sections should be taken several times and examined. The node and internode widths at the ends are 60 μm. The sample is tiny and has almost the same width throughout the thallus. Internodes can be up to 6-8 times the height of nodes. The nodes approach each other towards the branch ends.

*Ceramium circinatum* (Kützing) J. Agardh 1851

This sample can be likened to *C. pseudostrictum* as a sample, but the branch ends are split in this sample and bent inward, and cortical cells may form a slightly serrated edge at the ends of the branches (Figure 8: 1-2). The branch ends of the *C. pseudostrichum* sample are separated into two, then two again, before rolling inward and straightening at the edges. *C. circinatum* cortex is not constant in the upper parts of the thallus, internodes are transparent. Transparent internodes increase in the lower parts while the cortical cells in the nodes extend to the middle parts and partly cover the internodes (Figure 8: 3-4). For this reason, in the case of *C. pseudostrichum*, the lower parts of the thallus are similar to the lower parts of the *C. circinatum* strain, but the upper parts of the thallus consist of a continuous cortex, such as in the *C. rubrum* specimen. Regardless of the point at which the Ceramium specimens are examined, the thallus should be examined thoroughly and carefully. Otherwise, systematic errors may occur.

![Figure 7. C. cimbricum f. flaccidum 1: Branch tips form a sling (10x), 2-3: Node internode separation (10x), 4: Cortication in the node (40x), 5-6: Thallus cross section (40x) (Original).](image1)

![Figure 8. C. circinatum 1: Branch tip (4x), 2: Branch tip (10x), 3-4: Cortex cells which characteristically extend to internodes (4x), 5: Cystocarp structure (4x), 6: Thallus cross section (10x) (Original).](image2)
In this sample, the cystocarp can be surrounded by 1-4 small branches (Figure 8: 5). In the thallus sections 7-8 pericentral cells are observed and 2 rows of cortical cells are outermost (Figure 8: 6). Thallus cross sections are similar in most Ceramium species. The internodes can be up to 2 times the height of the nodes, but usually are equal or internodes are smaller. In the middle part of the thallus, the diameter of the node is 500 μm and the diameter of the internode is 475 μm.

_Ceramium codii_ (H. Richards) Mazoyer 1938

It is usually epiphytic and is the smallest Ceramium species. It is characterized by branch ends that are steep or slightly inclined with weak cortex and little branching (Figure 9: 1-3). Node diameter is 40 μm; internode diameter is 30 μm. They are usually found in low light areas, in the basal parts of rocky areas. Our sample is an epiphyte of the taxa of _Flabellia petiolata_ (Turra) Nizamuddin 1987, _Codium adhaerens_ C.Agardh 1822, _Halimeda tuna_ (J.Ellis & Solander) J.V.Lamouroux 1816 and _Peyssonnelia squamaria_ (S.G. Gmelin) Decaisne 1842.

_Ceramium deslongchampsii_ Chauvin ex Duby 1830

The most characteristic feature is that the branches end in a steep and conical shape (Figure 10: 1). The tips of the branch ends are terminated by a cell (Figure 10: 2). When the sample was first collected, red lines were observed in the internodes. Internodes can be up to 2-3 times the nodes. At the tip of the branches, the node diameter is 70 μm and the internode diameter is 65 μm. There is an obvious node-internode distinction (Figure 10: 3-4). The cortices in the nodes are weak and the cortical cells in the center of the nodes are large while cortex cells at the edges are small (Figure 10: 5-6).

_Ceramium diaphanum_ var. _decipiens_ Schiffner 1932

_C. diaphanum_ taxon has pinnate and alternate branching; however, this plant should be studied in a significant way. The young branch tips are in the form of two pliers, probably similar in character to _C. strictum_ and _C. orthocladium_ f. _maxima_ species. The nodes are fairly straight like _C.pseudostrictum_, but the tetrasporophyte stage is often small-branched such as in _C. orthocladium_ (Schifffner & Vatova, 1937). This taxon was not found in our samples. No photos of this taxon have been found.

_Ceramium gaditanum_ (Clemente) Cremades 1990

This taxon is matte red, more or less gigantic and fragile, without clusters, 5-8 cm in length, with filaments tapered upward. Branching is irregular and dichotomous, arranged in two rows, repeatedly forked. The branches in the upper part carry simple or forked branches. Standing or slightly open side branches are...
slightly narrower at the bottom, distinctly sparse and the end part is suddenly sharp. The branch tip is usually scattered and sometimes slightly curled, but never inwardly curved like a hook. The head spines are limited to the axis of the base. The head spines are spaced with vague highly pigmented basal cells. The knuckles and crusts occur on all thallus. This situation is two times wider in the lower part. The length and width of thallus are equal at the extreme end. Each node has a sharp edge with a structure like a small thorn. Together with several long-cell cystocarps surrounded by several upper lateral branches, pointed tetrasporangium occupies the entire node as a ring. It is often seen on top of other algae. Epiphytic small algae are found between the tide lines. It is not uncommon, but it is widely distributed (Hiscock, 1986; Newton, 1931).

This taxon was not found in our samples. The branch tips of the *C. gaditanum* taxon and the characteristic multi-cell irregularly arrayed needle structure are shown in Figure 11: 1-2.

*Ceramium gaditanum* var. *mediterraneum* (Debray) Cremades 1990

This alga height appears as a 1 cm thallus bundle. The diameter of the thallus at the base and central region is 200-300 μm. The diameter of the lateral branches reaches 80 μm. There is no continuous corticalization on the tips, which are flat and needle-free. Single-level cortical ones are bent and twisted. Needles usually consist of five cells; very rarely 4-8 cells. These needles are measured as 20 μm, 28 μm, and 45 μm at the base; however, they reach 35 μm, 75 μm, and 100 μm length in other regions. The smallest of the cortex cells are located on the upper edges of the nodes. The mean size is 4x6 μm and the largest can be measured as 15x20 μm. The width of the axis cells is equal to their height (Feldmann-Mazoyer, 1940).

![Figure 11. C. gaditanum 1: irregular thorn structure at the edge of the pincers (10x), 2: Spine structure extending from the thallus (40x) (Guiry M.D. in Guiry M.D. and Guiry G.M., 2014. Algae Base).](image1.png)

![Figure 12. C. gaditanum var. mediterraneum branch tips and thorn structure (Güner 1987).](image2.png)
This taxon was not found in our samples. A visual example is given in Figure 12 (Güner & Aysel, 1987).

**Ceramium pseudostrictum** Schiffner 1938

At first sight thallus is strongly reminiscent of the *C. rubrum* taxon (Figure 13: 1,4). When the lower parts of the thallus are examined, unlike the *C. rubrum* taxon, loose alignment is observed in the cortex cells and tight nodes become slightly distant from each other with internodes becoming more apparent. In this case, a structure such as *C. circinatum* appears in internodes (Figure 13: 5-7). Branch tips are slightly rounded and fork-like tips are more or less the same size (Figure 13: 2-3). In the thallus cross section 8 pericentral cells with cortex cells outermost are present around the central cell (Figure 13: 8). In the middle part of the thallus, the diameter of the nodes is 325 μm and the diameter of the internodes is 300 μm.

**Ceramium virgatum** Roth 1797

*C. rubrum* and *C. siliquosum* are most prominently classified according to the length of the tip cells and whether or not corticalization is continuous throughout the entire thallus (Hiscock, 1986). Our findings are similar for this taxon. Corticalization is continuous throughout the thallus (Figure 14: 1-3). The tetrasporic thallus is highly swollen and the axis edges are projecting and indented (Figure 14: 4-5). The cystocarps can even be found in the middle of the thallus and are surrounded by 3-7 ramuli (Figure 14: 6-8). The central cell is surrounded by 8 pericentral cells and an outer two rows of cortical cells in thallus transverse section (Figure 14: 9). The diameter of the upper part of the thallus is 125 μm, and the middle part is 200 μm.

**Ceramium rubrum** var. *barbatum* G.Feldmann-Mazoyer 1941 nom. illeg.

Extreme small branching at the bottom of the thallus is shown in Figure 15: 1-5. Large differences were
found in the cortices of two different *C. rubrum* var. *barbatum* specimens in the cystocarpal chamber of samples taken from the Çanakkale coast on May 12, 2013 from Yapıldak altı and Sarı sığlık stations. In the sample taken from the Sarı sığlık station, a structure such as gall formation is observed in the thallus nodes unlike the sample taken from Yapıldak altı station (Figure 15: 1-2, 4-5). Thallus variant differentiation is common in cases taken from various regions like this. *Ceramium* species are easily differentiated according to environmental conditions. If the examinations of the samples are not done carefully, it is possible to provide different names. The thallus cross section is similar to the *C. rubrum* taxon (Figure 15: 6-7). Tetraspores are present irregularly in the nodes (Figure 15: 8). The cystocarp is surrounded by 4-5 ramuli (Figure 15: 9). The upper part of the thallus has a diameter of 175 μm, and the middle part has an axis diameter of 450 μm.

**Ceramium virgatum var. implexocontortum** (Solier) G. Furnari 2003

In this sample, thallus differentiation was observed depending on stations similar to *C. rubrum var. barbatum* (Figure 16: 3-5). The most distinctive difference from the *C. rubrum* taxon is the presence of transparent hairs throughout the thallus (Figure 16: 1-3). At the beginning of the cystocarp, the branch tips can be seen to be perpendicular (Figure 16: 6). Stages of cystocarp formation are given in Figure 16: 6-9. The diameter of the thallus is 150 μm in the upper part, 450 μm in the middle part and 1.375 mm in the lower part.

**Ceramium secundatum** Lyngbye 1819

Morphology of this sample is partly similar to the *C. rubrum* taxon, but when carefully considered, the motif of corticalization is different and cortical cells are larger and more pronounced (Figure 17: 3-4). The

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**Figure 15.** *C. rubrum* var. *barbatum* 1-3: Samples of variants with different appearance (stereo microscope), 4-5: The same specimen shows different appearance of variants (4x), 6: Thallus cross section (4x), 7: Thallus cross section (10x), 8: Tetrasporated filament (4x), 9: Cystocarp surrounded by small branches (4x) (Original).

**Figure 16.** *C. virgatum* var. *implexocontortum* 1-3: Transparent hairs on thallus (4x), 3-5: Different filaments of the same sample (4x), 6-9: Cystocarp formation stages (4x) (Original).
corticalization covers the whole of the thallus. The characteristic feature is sequential (unidirectional) branching (Figure 17: 1-2). Thallus cross-sections show 7-8 pericentral cells around the central cell and two rows of outer cortical cells (Figure 17: 5-6). Branches end in different lengths and are rounded inward (Figure 17: 3). The diameter of the thallus is 125 μm in the upper part and 625-750 μm in the middle part.

*Ceramium siliquosum* (Kützing) Maggs & Hommersand 1993

This sample is quite similar to the *C. siliquosus* var. *elegans* taxon. The ends of the branches are rounded and the edges are serrated (Figure 18: 1). The edges of branch tips of *C. siliquosus* var. *elegans* tend to be flatter. Node-internode distinction is evident (Figure 18: 3-7). Tetraspores are single, double, and circumferentially sequenced in the nodes (Figure 18: 4-7). In the species of *C. siliquosus* var. *elegans*, tetraspores are arranged in 2 rows in the nodes. In the thallus cross-section, there are 7 pericentral cells and two rows of cortical cells around the central cell (Figure 18: 8-9). The internodes can be up to 3 times the size of the nodes. Node-internode is almost equal in thickness. The diameter of the thallus is 125 μm in the upper part and 375-500 μm in the middle part.

*Ceramium siliquosum* var. *elegans* (Roth) G.Furnari

The ends of the branches are rounded inward (Figure 19: 1, 4-5). Even if the nodes do not contain tetraspores, they are more swollen than internodes (Figure 19: 1, 6-7). Tetraspores are arranged in two rows in the nodes (Figure 19: 1, 2-3). In the thallus cross-section, there are 7 pericentral cells and two rows of cortical cells around the central cell (Figure 19: 8-9). The cystocarps are surrounded by 2-4 ramuli (Figure 19: 10-12). In the upper part of the thallus diameter are 150 μm in the nodes and 125 μm in the internodes, in the middle part it is 300 μm in the nodes and 250 μm in the internodes.

*Ceramium siliquosum* var. *lophophorum* (Feldman-
Branches are bifurcated and curled inward (Figure 20: 1-2). It is characterized by the secretory cells on the edges of the branch tips forming a serrated structure (Figure 20: 1-3). The internodes can be up to 5 times the size of the nodes. In some nodes, the cortex appears to be incomplete (two-sided concave lens) (Figure 20: 4-6). It is seen that on one side of some nodes there are smaller cortical cells than normal cortical cells (Figure 20: 7-8). The cystocarps are wrapped by 3-5 ramuli (Figure 20: 10-11). Tetraspores are circumferentially seen in a single row in the nodes (Figure 20: 12). Nodes and internodes are the same width. Thallus diameter is 100 μm in the upper part and 200 μm in the lower part.

_Ceramium siliquosum_ var. _zostericola_ (Feldman-Mazoyer) G. Furnari 1999

Branch tips are steep and slightly inclined (Figure 21: 1). Thallus is larger than _C. siliquosum_ var. _zostericola_ f. _minuscula_ and _C. siliquosum_ var. _zostericola_ f. _acrocarpum_. But these three species generally are small and live as epiphytes. Internodes can be up to two times the size of the nodes. The thallus diameter is 100 μm at the tip and 250 μm at the bottom.

_Ceramium diaphanum_ var. _zostericola_ f. _acrocarpum_ (Kützing) Feldmann-Mazoyer 1941

This Ceramium species is about 3 cm high, consists of several small ramuli showing dichotomous branching. The ends of the branches are terminated with parasporal mass. The nodes are very obvious. Nodes can be clearly observed on the entire surface of the algae. The height between two nodes is almost equal. Height (375x350μm) of the nodes is equal at the bottom. Nodes are 150 with 175 μm height and between 150 and 200 μm wide in the middle region. The lower part of the nodes is very clearly bounded. Cortex cells extend along the length of the upper edge, and then continue afterwards at intervals. The following cells of the cortex

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**Figure 19.** _C. siliquosum_ var. _elegans_ 1-4: Branch tips (4x), 2: Side branches from the thallus (4x), 3: Double row tetraspores in the nodes (10x), 5: Branch tips (10x), 6: Node and internode view of the thallus (4x), 7: Node and internode view of the thallus (10x), 8: Thallus cross section (10x), 9: Thallus cross section (40x), 10-11: Cystocarp formation stages (4x) (Original).
Figure 20. *C. siliquosum* var. *lophophorum* 1: Branch tips (10x), 2-3: Branch end secretory cells (40x), 4: Thallus node and internode view (4x), 5-6: Thallus node and internode view (10x), 7-8: Small sized cortical cells at the node edges (10x), 9: Small sized cortical cells at the edges of the node (40x), 10: Cystocarp structure (4x), 11: Cystocarp structure (10x), 12: Single row of tetraspores in the node (10x) (Original).

Figure 21. *C. siliquosum* var. *zostericola* 1: Branch tips (10x), 2: Thallus node and internode view (10x), 3: Single row arrayed tetraspores in the node (4x), 4: Single row tetraspores in the node (10x), 5: Body cross section (10x), 6: Body cross section (40x) (Original).

Figure 22. *C. diaphanum* var. *zostericola* f. *acrocarpum* 1: Thallus general appearance and characteristic branch tips, 2: Lobed paraspores in branch tips (Coppejans 1983).
edge are 8x10μm, 8x12μm, and 10x15μm, with cells in the upper edge are 6x30μm, 8x30μm, and 5x16μm. The adventive branches are from 100 to 120 μm wide and from 400 μm to 1 mm high. These ramuli often result in lobed parasporal masses. They are 200 μm wide and 160 μm high. The diameter of the paraspores is 20-25 μm. These forms are distinguished from other species by the height of their nodes and the presence of their paraspores (Feldmann-Mazoyer, 1940).

This taxon was not found in our samples. Images are taken from Coppejans (1983) (Figure 22).

Ceramium siliquosum f. minusculum (G. Mazoyer) Garreta et al. 2001

Branch tips are vertical, slightly inclined, and edges of the branch tips are transparent and serrated (Figure 23: 1-5). The internodes can be 1-2 times size of the nodes. The distinction between node and internode is very clear (Figure 23: 6-8). Tetraspores are arrayed in a single row in the nodes (Figure 23: 9-11). The cystocarps are surrounded by 2-4 ramuli (Figure 23: 12-13). In transverse sections taken from the thallus, 6-7 pericentral cells and single-row cortex cells are arranged.
around the central cell (Figure 23: 14-16). The diameter of the thallus is 75 μm in the upper part of the alga and 200 μm in the lower part.

*Ceramium tenerrimum* (G. Martens) Okamura 1921

The branch tips are curved inward. Branches and thallus have ciliate-like structures (Figure 24: 1-3, 6). In the lower parts of the thallus, transparent extensions protrude like rhizoid from the nodes (Figure 24: 4-5). Internodes can be 4-5 times the size of the nodes. The diameter of the thallus is 100 μm in the nodes at the upper part of the alga, and 80 μm in the internodes. The diameter of the thallus is 150 μm in the nodes in the lower part of the alga and 125 μm in the internodes. There are 7-8 pericentral cells around the central cell and an outermost single-row of cortical cells are seen in the thallus cross-section (Figure 24: 7-8).

*Ceramium tenerrimum var. brevizonatum* (H.E. Petersen) Feldmann-Mazoyer

Thallus is small and epiphytic. Our sample is the epiphyte of *Jania rubens* (Linnaeus) J.V.Lamouroux (Figure 25: 2, 4-5). The thallus is stolon-like and the holding disk protrudes from most of the nodes (Figure 25: 2, 4-5). Transparent protrusions are present almost everywhere in the thallus (Figure 25: 1-5). The nodes are

![Figure 25.](image)

*Figure 25. C. tenerrimum var. brevizonatum* 1-2: Transparent protrusions and holding discs on thallus (4x), 3-5: Transparent protrusions and holding discs on thallus (10x), 6: Thallus node and internode view (40x) (Original).

![Figure 26.](image)

*Figure 26. C. tenuicorne* 1: Branch tips (4x), 2: Branch tips (10x), 3-5: Thallus node and internode view (10x), 6: Thallus node and internode view (40x) (Original).
more swollen than internodes (Figure 25: 6). The internodes can be 7 times the size of the nodes. The diameter is almost the same for the whole thallus. Nodes are 75-100 μm, internodes are 75-50 μm. Corticalization is very weak. There are small cortex cells at the top of the node and large cortical cells at the bottom.

*Ceramium tenuicorne* (Kützing) Waern 1952

Branch tips are vertical, slightly inclined and the edges protrude (Figure 26: 1-2). The internodes can be twice as many as the nodes. Nodes are larger than internodes (Figure 26: 3-6). Some amorphous cortical cells protrude from the nodes (Figure 26: 6). Ball-shaped structures may extend from the nodes (Figure 26: 5).

**Discussion**

The information on species of *Ceramium* related to distribution, population sizes and trends is sparse. As mentioned in the introduction, although there are studies about *Ceramium* species in Turkey, there is no study including the descriptive properties and photos of all species together. In this study, *Ceramium* species were described with distinguishing features and images reflecting these features. However, species identification based on morphological and anatomical characteristics has been either approved or disapproved through studies of molecular analyses in recent years. For example, the species identified as *Ceramium flaccidum* (Harvey ex Kützing) Ardisson on the basis of molecular analysis has now been named as *Gayliella flaccida* (Harvey ex Kützing) T.O. Cho & L.J. McIvor (Cho et al., 2008). Therefore, there is a need to perform molecular analyses of the *Ceramium* species identified using morphological and anatomical characteristics in the present study as such data will be more reliable and useful. Small taxon groups such as *Ceramium* may be affected morphologically by environmental conditions and thus may show morphological differences in the same species (Kützing, 1841; Agardh, 1894; Dixon, 1960; Womersley, 1978; Rueness, 1992; Boo & Lee, 1994; South & Skelton, 2000; Cho, Riosmena-Rodriguez, & Boo, 2002; Maggs, McIvor, Evans, Rueness, & Stanhope, 2002). An attempt has been made to illustrate these differences with images. For example, small differences were observed in the cortex structures, in the nodes, and in the branches of samples of *Ceramium rubrum* var. *barbatum* and *Ceramium siliquosum* collected from two different spots along the Çanakkale coast in the same period. The formation of such minor differences may lead to different nomenclature of these species and thus lead to systematic confusion (De Barros-Barreto, McIvor, Maggs, & Gomes Ferreira, 2006; South & Skelton, 2000). Another reason for taxonomic problems relates to the lack of objective criteria for determining whether these are due to different phenotypes or result from environmental interactions (Maggs et al. 2002). Therefore, detailed taxonomic features of the samples in this study are given with tables and photographs to avoid such problems.

Previous systematic studies are very important in terms of determining the flora when systematic data are presented with photographs and supported by molecular studies, more reliable and more useful databases will be created.

In conclusion, systematic studies of species identification should be carried out in more detail and supported by molecular studies. Thus, the molecular database for the Turkish marine flora can be created and DNA sequences of the samples detected in subsequent studies can be compared with sequences of the samples in the GenBank database to allow verification of the species.

**References**


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