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Beckerella irregularis sp. nov. (Gelidiales, Gelidiaceae) from Japan

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Abstract

Beckerella irregularis, a new species of Gelidiaceae described from the Pacific coast near Tokyo, is the second member of the genus reported from Japan. In some respects the new species resembles *B. subcostata*, but differs in (a) the widely and irregularly spaced branches, (b) the considerable length of primary and secondary branches, (c) the fairly uniform width of axes and branches, and (d) the absence of midrib.

Introduction

In the course of a study on gelidiaceous plants of the Izu-shotô Archipelago near Tokyo, a well-known harvesting place of agarophytes in Japan, several collections were made by the first author at Kôzu-shima where *Beckerella subcostata* (Okamura) Kylin is of commercial importance. He found some plants which display the cortical cell morphology diagnostic of *Beckerella* (Akatsuka, 1970; 1982)[1)2)] but which differed markedly from *B. subcostata* in structure and habit. The newly collected specimens appear to be a hitherto unreported species and are distinguished from other members of the genus by their irregular branching and adventitious ramuli which are disposed unevenly along the branches. The material is hence described here as *Beckerella irregularis*.

Diagnosis

Beckerella irregularis sp. nov.

Plantae 24–64 cm alt., ca. 500 μm crass. in regione basali axibus diametro fere aequalibus (3.1–4.1 mm), e hapteris fibrosis ramossissimis enascentibus, omnino sine costa; rami longitudine variantes, latitudine satis aequi, in basi constricti, ramificationem 2 vel 3 ordinum, oppositam aut irregulariter alternam, praebentes; pinnulae ultimae distichae, usque ad 10 mm long., sparse irregulariterque, intervallis 2–63 mm dispositae; ramis ramificatione formaque similes saepe, autem pinnatae, axilla angulum latum praebente. Sori tetrasporangiales areolas maculiformes tumidasque, per superficiem planam pinnularum definitarum sparsas formantes, his pinnulis tenuissimis, usque ad 25 mm long., usque ad trichotome

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saepe ramosis; tetrasporangia ca 20 μm diam. cruciate divisa. Plantae sexuales ignotae. Structurae vegetativae generis typicae, praecipue in partibus inferioribus vetustisque axis principalis; medulla e filamentis elongatis ad axemn thalli parallelis composita et ca 10 μm diam., partem latam telae thalli occupans, per corticem interiorem pseudoparenchymatum circumdata, hoc cortice e stratis 3–5 cellularum magnarum composito, cellulis 20–70 μm diametro maiore, atque minus quam 10 μm diametro minore; cortex externus e cortice interiore abrupte enascens, cellulis eius a superficie visis elongatis, 10–25 μm longis, plus quam 1.5 plo longioribus plus quam latae; hae cellulae ad axem thalli regione in basali axis principalis perpendiculariter dispositae et regione in proximali axis repentis in catenulis anticlinaliter in ca. 5 stratis, in sectione minus quam 10 μm long., dispositae. Hyphae e cellulis membranas crassas atque lumen minus manifestum habentibus compositae, ca. 3 μm diam., in regione inter corticem exteriorem interioremque aggregatae, per telam vegetativam repertae, in regione basali axis principalis atque in parte proximali axis repentis praecipue prominentes, ad axem thalli in cortice exteriore parallelae, in medulla interplexae; cuticula cellularas corticales extimas superiaciens, regionem basalem axis principalis atque partem proximalem axis repentis versus prominenter spissescens.

Plants 24–64 cm tall, ca. 500 μm thick in the basal region, with axes of more or less uniform diameter (3.1–4.1 mm), arising from highly branched fibrous holdfasts and without midrib throughout; branches variable in length, fairly uniform in width, constricted at the base, branching of 2 to 3 orders, opposite or irregularly alternate; ultimate pinnules distichous, up to 10 mm long, spaced sparcely and irregularly at intervals of 2–63 mm, similar to branches in branching and shape, but often pinnate, axil with broad angle. Tetrasporangial sori forming patch-like and swollen areas, scattered over the flat surfce of limited pinnules which are very thin, up to 25 mm long and ramify often up to trichotomously, tetrasporangia ca. 20 μm diam., cruciately divided. Sexual plants unknown. Vegetative structure typical of the genus, especially in the lower and aged parts of the main axis; medulla composed of filaments which are elongated parallel to the thallus axis and ca. 10 μm diam., occupying the broad part of thallus tissue, surrounded by a pseudoparenchymatous inner cortex of large 3–5 cell layers, cells 20–70 μm in greater diameter and less than 10 μm in smaller one; external cortex arising abruptly from inner cortex, cells elongated in surface view, 10–25 μm long, more than 1.5 times longer than broad, arranged perpendicularly to the thallus axis in the basal region of the main axis and in the proximal region of the creeping axis, chained anticlinally in ca. 5 layers in section, less than 10 μm long. Hyphae with thick cell walls and less remarkable cell lumens, ca. 3 μm diam., aggregated in the region between the outer and inner cortex, occurring throughout the vegetative tissue, especially prominent in the basal region of the main axis and the proximal part of the creeping axis, running parallel to the thallus axis in the outer cortex, interlaced in the medulla; cuticule overlying outermost cortical cells, increasing prominently in thickness toward the basal region of the main axis and the proximal part of the creeping axis.

Japanese name: Naga-hirakusa (n.n.)

Holotype: collected by I. Akatsuka (Fig. 1). On flat bed-rock at a depth of 12–23 m, Kôzu-shima, Izu-shotô archipelago near Tokyo, 14 Sept., 1974, deposited in

Laboratory of Marine Botany, Faculty of Fisheries, Hokkaido University, Hakodate (HAK). Isotypes are in Department of Botany, Faculty of Science, Hokkaido University (SAP) and National Science Museum (TNS).

Other specimen: From Chigasaki, Izu-ôshima, Izu-shotô archipelago, Oct., 1960, W. Kida.

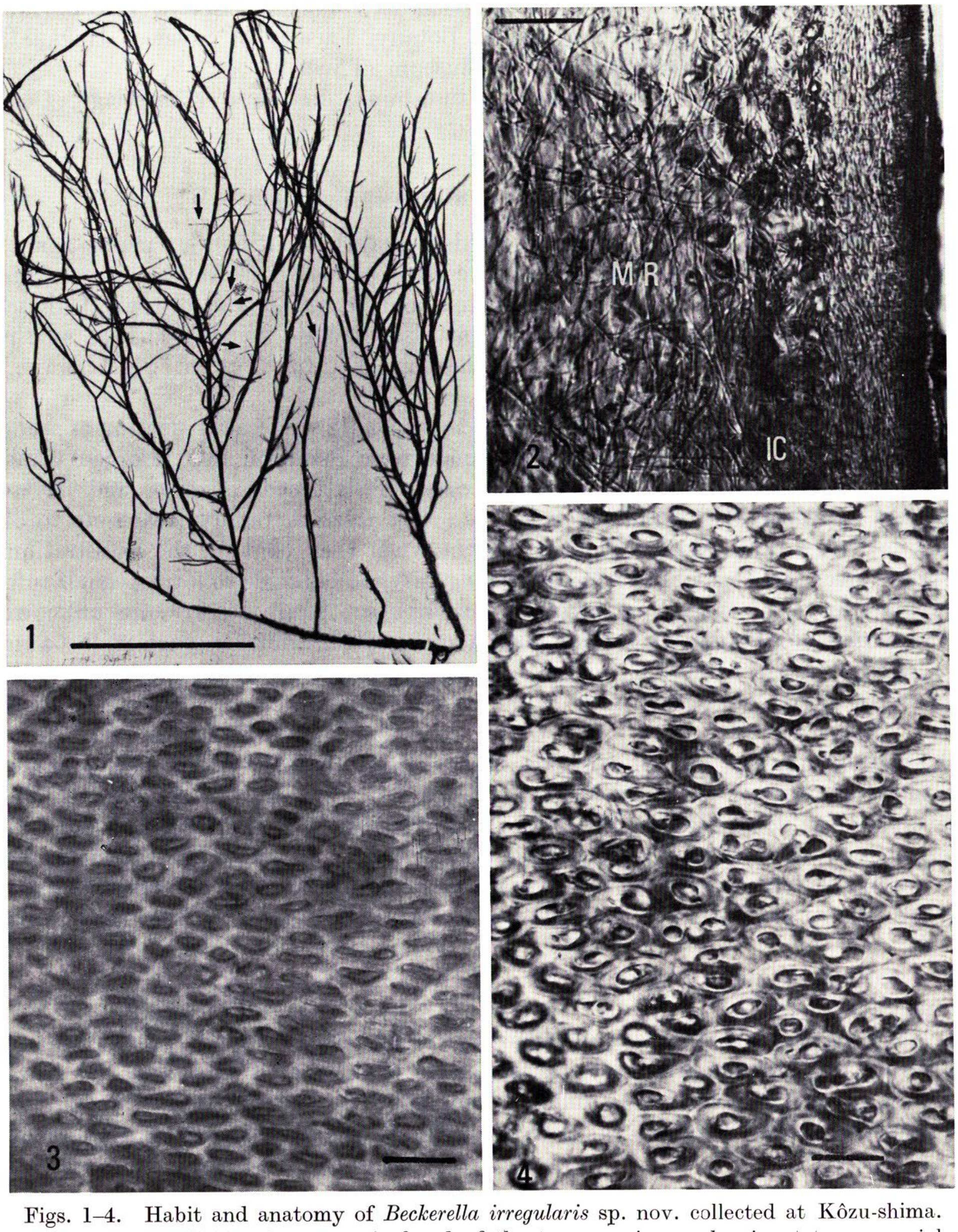
Observations

Habitat. The plants were found as dense patches within the population of *Beckerella subcostata* which dominated the flat bed-rock substratum at 12–23 m depths along the whole coast of Kôzu-shima and an offshore small rock, Onbase-jima. Scattered small clumps of the plant also grew on rough bed-rock at the same locality. The locality is subject to the warm Kuroshio current which flows at a steady 3–5 knots.

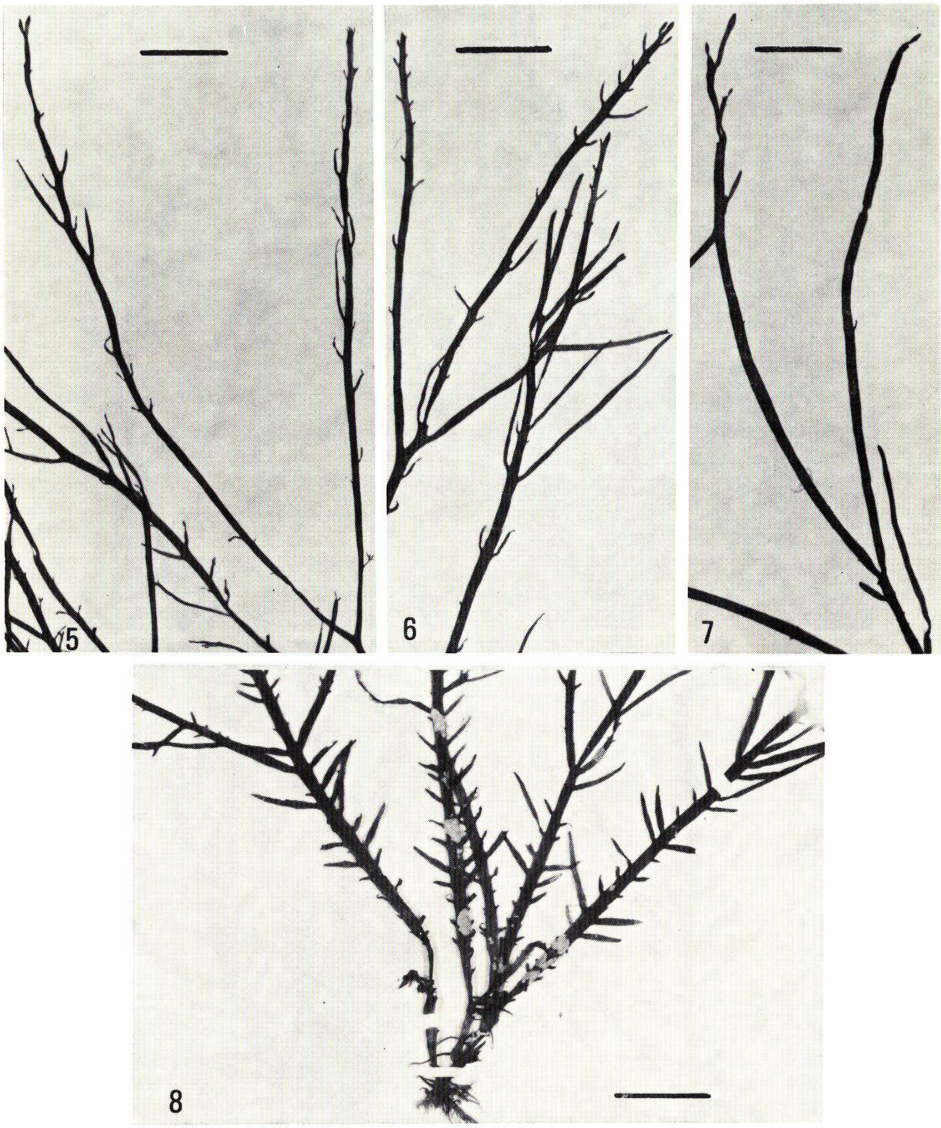
Habit. External measurements were made on 12 desiccated specimens using slide calipers, while microscopic observations were made on the resorked whole materials. Holdfasts are fibrous and consist of flattened rhizoids and terete heptera by which the plants are anchored. The rhizoids ramify, reach up to 35 mm in length, and issue anchoring haptera when they contact the substratum. Several erect thalli may arise from a creeping axis and entangle to form a small tuft. Proliferations, as reported in *Beckerella scalaramosa* (Kraft, 1976)[3] are unknown on any part of the main axis. The main axes and their branches reach 24 to 64 cm in length and are beset with marginal secondary branches at irregular and wide intervals. Midrib-like thickening is not clear even in the lowest part of the main axis. The main axes are 3.1 to 4.1 mm broad and fairly uniform in width from the bottom to nearly the apical region. The ultimate branches never bear pinnules with serrate margins (Figs. 5–8), as is the case in *B. subcostata* (Figs. 9–12) and several other *Beckerella* species. The main axis possesses alternate and opposite branches of three orders in maximum. The primary branches are characterized by having widely spaced secondary branches, but the secondary branches are often entire when their length is less than 5 cm. Where the axes of older thalli have been truncated by prior harvesting, wave action or animal grazing, new growth frequently takes place at the periphery of the wound, resulting in as many as six regenerated axes.

Vegetative structure. Cells are elongated in surface view of the basal region of the main axis and are arranged perpendicularly to the thallus axis (Fig. 3). However, in other parts such as the middle region and the area between the tip and two centimeters below it, the cell shape and the cell arrangement in surface view are not so characteristic as above. The surface cells of the branch, on the other hand, are not as long as those of the main axis. In creeping axes, the above mentioned surface cell morphology is prominent in proximal and middle regions (Fig. 4) but not in the distal tip.

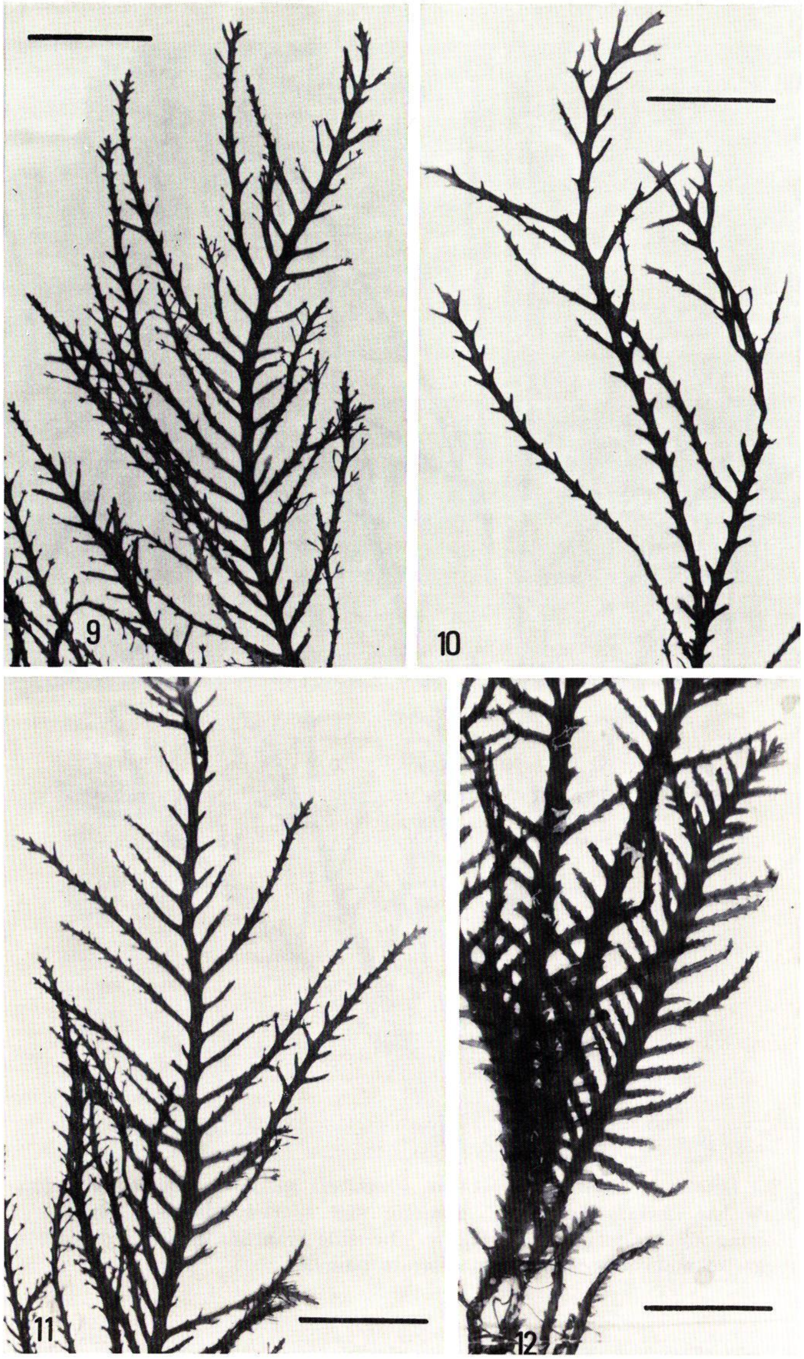
The following observations are based on longitudinal sections, unless indicated otherwise. The distal 2 cm of the main axis reaches ca. 90 μm in thickness and is internally devoid of an inner cortex of large parenchymatous cells, the interior being mostly filamentous. However, medullary filaments apparently are not continuous between the main axis and lateral branches, the bases of which are



Figs. 1–4. Habit and anatomy of *Beckerella irregularis* sp. nov. collected at Kôzu-shima. Fig. 1. Habit of tetrasporic frond of the type specimen, showing tetrasporangial stichidia (arrows). Scale bar =10 cm. Fig. 2. Longitudinal section through basal region of main axis, showing large round cells (IC) in inner cortex and abundant rhizoidal filaments (MR) in medullary region. Scale bar=100 μm. Fig. 3. Surface view of basal region of main axis, showing surface cells which are elongate perpendicular to thallus axis. Scale bar=20 μm. Fig. 4. Surface view of basal region of creeping axis, showing the same cell arrangement as above. Scale bar=20 μm.



Figs. 5–8. Details of habit of *Beckerella irregularis* sp. nov. collected at Kôzu-shima. Scale bar=2 cm. Figs. 5–7. Filiform and sparsely disposed ultimate ramuli, showing no serrate pinnule. Fig. 8. Juvenile branches of primary order in basal region of main axis, showing no serrate pinnule.



Figs. 9–12. Details of habit of *Beckerella subcostata* (Okam.) Kylin collected at Kôzu-shima (Figs. 9, 11 and 12) and at Izu-ôshima (Fig. 10). Scale bar=2 cm. Figs. 9–11. Serrate pinnules in upper region of branches. Fig. 12. Juvenile branches of primary and secondary orders in basal region of main axis, showing serrate pinnules.

pseudoparenchymatous. This absence of medullary filaments apparently weakens the consistency of branch bases, resulting in their breaking with ease and the subsequent regeneration of new branches. The outermost cortical cells have a length to width ratio as high as 1.5 in section through middle and basal regions of the main axis and are up to 1.5 times longer than cortical cells of the apical region. In these two regions of the main axis, the cuticle and cell walls lying nearest to it consist of several layers and are thicker than those of other parts of the thallus. The amount of medullary filaments increases towards the basal region of the main axes which reach 500 μm in thickness (Fig. 2), but is variable in other parts of the thallus. Floridean starch occurs in the form of globules in large parenchymatous cells of the inner cortex and is accumulated most densely at least in autumn.

In the creeping axis, the outer cortex is composed of anticlinal cell rows in transection, and its outermost cells, having the thicker wall, are fairly elongated. The internal hyphae and narrowly elongated parenchymatous cells run without any order in the medullary region of the creeping axis. The floridean starch also fills cells of the inner cortex and the medulla of creeping axes. This photosynthetic product occurs abundantly in the creeping axes rather than in the main axes. This fact shows that the creeping axis functions as a storage organ of nutrient available for the formation of the new fronds in spring.

Reproduction: Only tetrasporophytes have been collected so far. Cruciate tetrasporangia are born on nemathecia formed in terminal and subterminal areas of stichidia which issue from the apex or the margin of the branch of higher order. Stichidia become elongated considerably when fully matured and several constrictions are frequently observed along their long axis. It would appear that the constriction occurs between two successive growths as the partially damaged stichidium of the previous year regenerates. This assumption is also supported by the frequent occurrences of regeneration in other parts of the same thallus. If stichidial constrictions are formed yearly, their number could correspond to the thallus age. Tetrasporangia often remain abortive without being discharged in the portion of stichidium which is considered to be formed in the previous year on the basis of the constriction. Accordingly, spore liberation may be a minor means of propagation, with growth of the creeping axes perhaps being the dominant method of increasing the population.

Discussion

Kylin (1956)[4] established the genus *Beckerella*, based on *Gelidium pinnatifida* J. Ag., by reason of the presence of midrib which is evident below and becomes obscure gradually upward. Generally speaking, it seems likely that a relationship exists between midrib formation and the amount of medullary filaments produces in a given species. While the amount of medullary filaments in *B. irregularis* is variable depending on the part of the thallus, it is never so thick as to be discernible as the midrib throughout the plant. It is therefore apparent that the midrib is unstable genetically in *Beckerella* and is not reliable as diagnostic character.

The thallus surface-cell arrangement is the same as that shown by Akatsuka (1970, 1982)[1)2)] in the one other Japanese species of *Beckerella*, *B. subcostata*, and

Table 1. *Comparison of characters between two species of* Beckerella, B. irregularis *sp. nov. and* B. subcostata (*Okam.*) *Kylin.*

Characters	*B. irregularis*[3]	*B. subcostata*[4]
Ultimate pinnules	Filiform; variable in length, up to 10 mm	Serrate; up to 6 mm long
Distance between adjacent ultimate pinnules	Extremely variable at intervals of 2–63 mm	Uniform; up to 6 mm
Branch or axis emerging from thallus surface	Occasionally present	Absent
Distance between adjacent secondary branches	Extremely variable at intervals of 2–83 mm	Uniform; up to 9 mm
Width of short branches	Uniform	Acute toward terminal
Constriction at the base of long branches	Present	Absent
Axil of each branches	Broad	Narrow
Ramification	2 to 3 orders	3 to 4 orders
Length of branches and ultimate pinnules	Extremely variable	Fairly uniform
Midrib in basal region of main axes	Not clear	Distinct or not clear
Midrib in primary branches	Absent	Present[1] or absent
Holdfast	Fibrous; highly branched	Fibrous; highly branched
Hight of fronds	24 to 64 cm	15 to 50 cm[1]
Width of axes	(2)3–4(5) mm	2 to 5 mm[1]
Thickness of main axes[2]	90 μm in apex, 500 μm in base	500 μm in apex, 900 μm in base
Cells of inner cortex	Large and parenchymatous	Large and parenchymatous
Outermost cortical cells in surface view of main axis	Elongated perpendicularly to frond axis in basal region	Elongated perpendicularly to frond axis in middle and basal regions
Stichidia	Thin; up to 25 mm long; single or branched	Delicate and thin; up to 10 mm long; usually branched
Pinnules emerging from surface of branches	Absent	Absent

1) According to Schmitz (1894)[7] and Okamura (1934)[10]. 2) N=1. 'Apex' corresponds to area between the tip and 2 cm below it and 'Base' to area immediately above the creeping axis. 3) N=12. 4) N=29.

appears to be one of taxonomic criterions differentiating *Beckerella* from closely related genera of the Gelidiaceae.

Beckerella irregularis synthesized floridean starch under the dim light and the relatively low temperatures of its deep water (12–23 m) habitats. Dense deposits of floridean starch grains were observed in the large round cells of the inner cortex, particularly in specimens collected in autumn. Huvé (1962)[5] found that *Beckerella mediterranea* Huvé from the Aegean Sea lacked floridean starch in thalli collected in spring and in young parts of thalli collected throughout the year. It is supposed that reserve material assimilated by the aged thallus in the previous year becomes available for the formation of new fronds in spring.

The new species is similar to *B. subcostata* in its filamentous medulla, large parenchymatous cells in the inner cortex and the absence of ramuli emerging from the lower thallus surface. After reviewing the literatures (Hauck, 1886[6]);

Schmitz, 1894[7]; Holmes, 1896[8]; Lucas, 1931[9]; Oakamura, 1934[10]; Børgesen, 1943[11]; Dickinson, 1949[12]; Kylin, 1956[4]; Fan, 1961[13]; Huvé, 1962[5]; Kraft, 1976[3]) and examining Japanese materials and non-Japanese species of the genus *Beckerella*, the writers conclude that the present entity can be distinguished from other 10 species known to date in the genus by the extremely irregular length of branches, the widely and irregularly spaced branches, and the ultimate ramuli lacking serrate process.

Major characters of the two Japanese species of *Beckerella*, *B. irregularis* and *B. subcostata*, are listed in Table 1 for comparison. There still, however, remains some doubt as to whether *B. irregularis* is an aged form of *B. subcostata*. Although two species grow in the same community, *B. irregularis* unlike *B. subcostata* never exhibits regularly pinnate, equally spaced branching or serrate ultimate ramuli. In addition, *B. subcostata* lacks the creeping lower axes of *B. irregularis*. The most obvious distinguishing feature of the new species is its irregular pattern of branching, and *B. irregularis* is described here as new to science.

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