

## GRIMMIA VAGINULATA, (BRYOPSIDA, GRIMMIACEAE) A NEW SPECIES FROM THE CENTRAL COAST OF CALIFORNIA

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### ABSTRACT

A new California endemic species, *Grimmia vaginulata*, is described and illustrated. It is characterized by its very small size, julaceous habit, immersed capsule on a straight, centrally inserted seta, very large annulus, keeled unistratose leaves, autoicous sexuality, and a large cylindrical ochrea atop the vaginula that sheathes the seta to the base of the capsule. The differentiation and ecology of the new species is discussed.

Key Words: California, endemic moss, *Grimmia vaginulata*, Grimmiaceae, new species, ochrea, vaginula.

In the summer of 2008, prior to the annual meeting of the American Bryological and Lichenological Society, Dale Vitt asked to see *Orthotrichum kellmanii* D. H. Norris, Shevock & Goffinet in the field. During that short trip Dale noticed tiny little plants growing on the same sandstone boulders that supported the *Orthotrichum*. These plants were so scattered and insignificant that they appeared to be immature stems of a small *Grimmia*, and not worth collecting. That impression proved incorrect. Upon microscopic examination, it was immediately obvious that these plants represented a remarkable plant that was unlike any other *Grimmia* in North America.

Chief among the distinguishing characteristics was a transparent extension of the vaginula that extended to the base of the capsule. This extension, known as an ochrea, is not present in any North American *Grimmia*, and it is not mentioned in any North and Central American *Grimmia* literature (Flowers 1973; Crum and Anderson 1981; Crum 1994; Hastings and Greven 2007; Muñoz 1999; Muñoz and Allen 2002). To the casual student of the genus, this novel character suggested the possibility of a new genus. That hypothesis was supported by the scattered growth habit. A wider examination of *Grimmia* was undertaken resulting in the expansion of the North American parameters of the genus.

### TAXONOMY

*Grimmia vaginulata* Kellman, sp. nov. (Figs. 1A, 1C, 2, 3, 4, 5)—Type: USA, California, Santa Cruz Co., Big Basin Redwoods State Park, on dry vertical walls of calcareous sandstone boulders eroded from the sandstone bedrock in open chaparral, above the Basin Trail and below China Grade Road ca. 1.5 mi. beyond

the northern intersection with SR 236, elev. 685 m, 37°12'40"N, 122°12'42"W, 13 Aug 2008. Kellman, Vitt, & Shevock 5869 (holotype: CAS).

Species *Grimmia capillata* De Notaris affinis, sed differt ab statura brevior, foliis statu madido vel sicco persistenter julaceis, ochrea cylindracea longiore usque ad prope basem capsulae extendenti differt.

Plants up to 2 mm tall, scattered to very loosely tufted (Fig. 5), simple, or with a short, tightly appressed branch; green when young, tan or white in age; julaceous wet or dry. Lower and perigonal leaves short ovate, 1:1, muticous, increasing in length upwards. Upper stem and perichaetial leaves (Fig. 2B) obovate or elliptical, soft when moist, weakly keeled concave, unistratose throughout, with at least some portion of the leaf margin hyaline, most common at the base and often extending to midleaf or slightly beyond; 1–1.65 mm long  $\times$  0.4–0.75 mm wide (without the awn); the keel is even less pronounced in transverse section, appearing more convex, even tubular, especially on non-sporophytic plants (Fig. 4); apex acute or occasionally slightly acuminate. Basal juxtacostal cells short rectangular with thin to moderately thick, straight; relatively uniform across the base, but outer basal cells often somewhat narrower in 1 to 3 marginal rows. Distal and medial cells decreasing in length gradually from the base to the apex, 1–1.5(2.5):1, 12–16(26)  $\mu$ m long  $\times$  7–13  $\mu$ m wide; rectangular, triangular, or irregularly polygonal, thick-walled, often with some portion of the lumen rounded creating small trigones, not or weakly sinuose; in transverse section plane to slightly bulging. Margins weakly recurved on one or both sides; unistratose. Costa narrow, to 40  $\mu$ m wide at the base, broadening toward the apex; excurrent in a hyaline, weakly toothed awn shorter than the lamina, decurrent at most 1–2 cells down the margin, and those often projecting



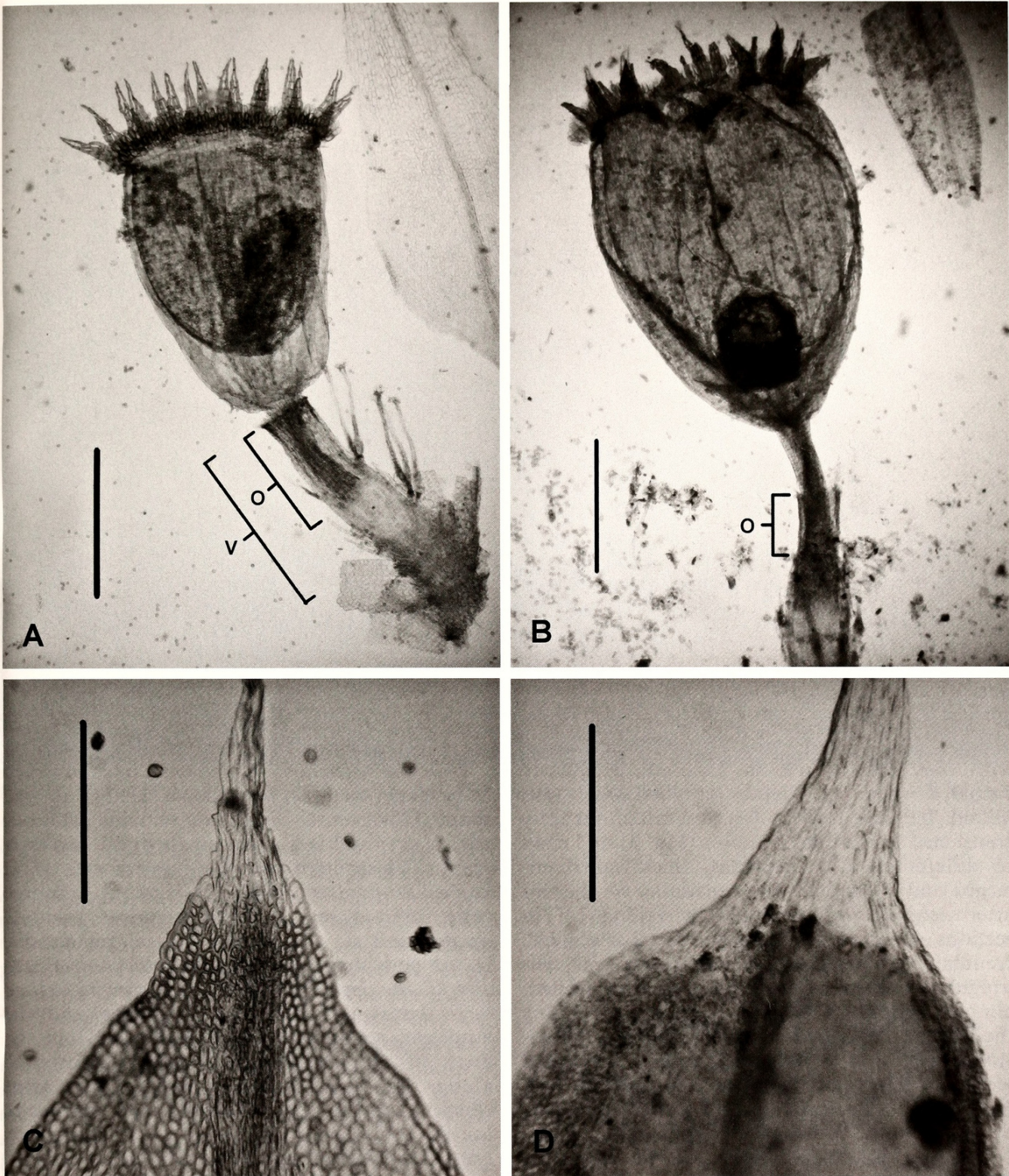


FIG. 1. A. *Grimmia vaginulata* with leaves stripped exposing the sporophyte. (O) ochrea (V) entire vaginula. Scale bar = 500  $\mu$ m (from the type); B. *G. capillata* with leaves stripped exposing the sporophyte. (O) ochrea. Scale bar = 500  $\mu$ m (*Handel-Mazetti* 1778, FH: syntype of *G. mesopotamica*); C. Detail of typical upper leaf apex of *G. vaginulata* Scale bar = 80  $\mu$ m; D. Detail of typical upper leaf apex of *G. capillata* Scale bar = 175  $\mu$ m.

as short, blunt teeth; costa in transverse section at midleaf with two homogenous rows of cells, 2 cells wide adaxially. Gonioautoicous or cladautoicous. Calyptra irregularly crenate at the base, conical or campanulate, hyaline at the extreme apex and at the base, naked and smooth, just covering the operculum. Vaginula (Fig. 1A),

measured with ochrea, 0.5–0.6 mm long, epidermal cells irregular, about 2–3:1, with very thin, straight walls; distally with a cylindrical ochrea surrounding but not connate to the seta and flaring just below the base of the capsule, 340–430  $\mu$ m long. Seta straight, attached to the center of the capsule, 0.5 mm long. Capsule immersed



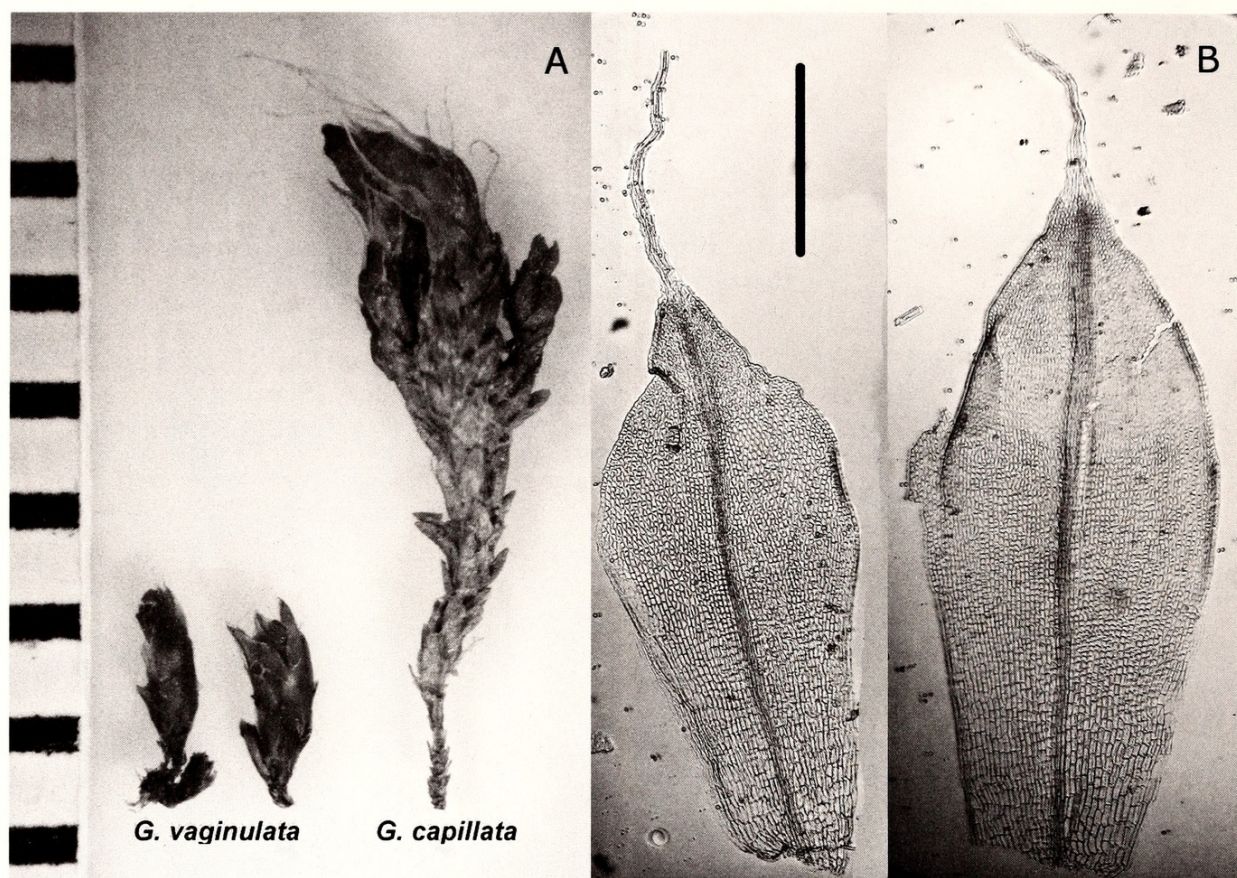


FIG. 2. A. Sporophytic plants of *Grimmia vaginulata* and *G. capillata* showing size difference. Marks are 1 mm apart; B. *G. vaginulata*, two upper and perichaetial leaves. Scale bar = 500  $\mu$ m.

with only the operculum exposed, irregularly wrinkled when dry, slightly wrinkled when wet, obloid, 0.9 mm long  $\times$  0.6 mm wide, abruptly contracted to the seta. Annulus (Fig. 3) of 3 rows of differentiated, transparent, thick-walled enlarged and elongated cells; remaining on the urn after dehiscence, but gradually falling off in sections. Operculum mammilose to low conical, crenulate to erose at the base. Exothecial cells irregularly rectangular to hexagonal, thin-walled, almost transparent when mature, easily revealing the stalked theca within. Stomata present. Peristome (Fig. 3) of 16 orange-red cribrate-dissected teeth, irregularly divided nearly to the base into 3–4 strongly spiculate filaments, ca. 185  $\mu$ m long. Spores smooth, 10–13  $\mu$ m in diameter.

The specific epithet refers to the persistent cylindrical ochrea atop the vaginula, which extends nearly to the base of the capsule.

#### IDENTIFICATION AND TAXONOMIC RELATIONSHIPS

*Grimmia vaginulata* can be distinguished from all other North American *Grimmia* by the following combination of characters: very small plants that are julaceous wet or dry, upper leaves with hyaline margins, dissected peristome, and a conspicuous and persistent ochrea sheathing the entire seta to just below the base of the capsule.

*Grimmia vaginulata* resembles *G. anodon* Bruch & Schimp. and *G. plagiopodia* Hedw. in leaf shape. However, *G. vaginulata* remains julaceous wet or dry, and is a much smaller and narrower plant. The straight, centrally inserted seta of *G. vaginulata* contrasts with the sigmoid, eccentrically inserted seta that characterizes both *G. anodon* and *G. plagiopodia*. The extremely dissected peristome resembles *G. orbicularis* Bruch and *G. moxleyi* R.S. Williams. *Grimmia orbicularis* shares the unistratose margins, and the autoicous sexuality with *G. vaginulata*, but the awns of *G. orbicularis* are evenly distributed along the stem. *Grimmia moxleyi* has awns restricted to the upper leaves like *G. vaginulata*, but the leaf margins are bistratose. Furthermore, both *G. orbicularis* and *G. moxleyi* have exerted capsules on arcuate setae. Again, both are much larger than *G. vaginulata*.

Both gametophytically, and sporophytically, *G. vaginulata* appears most closely related to *G. capillata* De Not., a species scattered around the Mediterranean Sea (Greven 2003). They share the keeled, entirely unistratose lamina with the margins at least somewhat recurved on one or two sides, a costa that broadens in the distal half of the leaf, perichaetial leaves with proximal hyaline areas, and autoicous sexuality. Sporophytically, the two taxa are very close. Lastly, both prefer calcareous substrates. Again, *G. vaginulata*



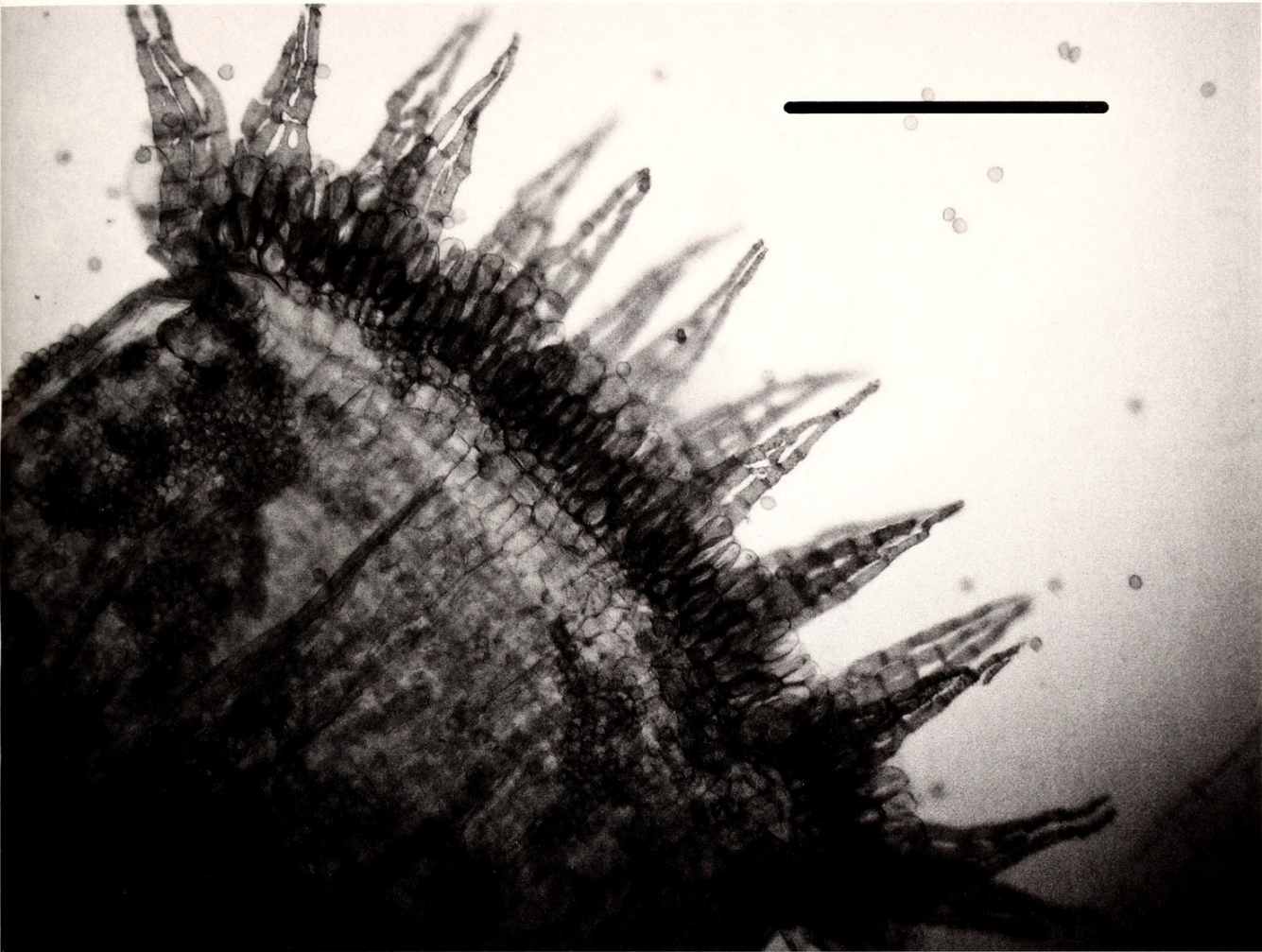


FIG. 3. Detail of annulus and peristome of *Grimmia vaginulata*. Scale bar = 120  $\mu$ m.

is a much smaller plant that stays tightly julaceous wet or dry. My examination of 16 specimens of *G. capillata* and *G. mesopotamica* Schiffn. (a synonym of *G. capillata* fide Muñoz and Pando 2000; Greven 2003) from FU, MUB, and NY show plant size in *G. capillata* averages around 7 mm, dwarfing *G. vaginulata*. (Fig. 2A) The dry leaves of *G. capillata* are erect to erect-patent and are usually strongly keeled. Thus the costae project from the rest of the leaves giving the dry plants a more tumid and textured appearance. When moist, the leaves of *G. capillata* are at least erect-patent, and are relatively easy to dissect from the stem. The tiny and tightly appressed leaves of *G. vaginulata* are very difficult to strip for examination without tearing. Leaf size is another point of separation, with the upper stem leaves of *G. capillata* measuring 2–3 mm long (Cortini Pedrotti 2001; Ignatova and Muñoz 2004), while the much smaller *G. vaginulata* has leaves with a maximum length of 1.65 mm. In *G. capillata*, the more or less rounded apex (Fig. 1D) is the most commonly hyaline portion of the leaf, while in *G. vaginulata*, the margins are hyaline, and the apex is acute. There is some small portion at the base of the awn that is hyaline, but at most it is one to two cells down the margin (Fig. 1C).

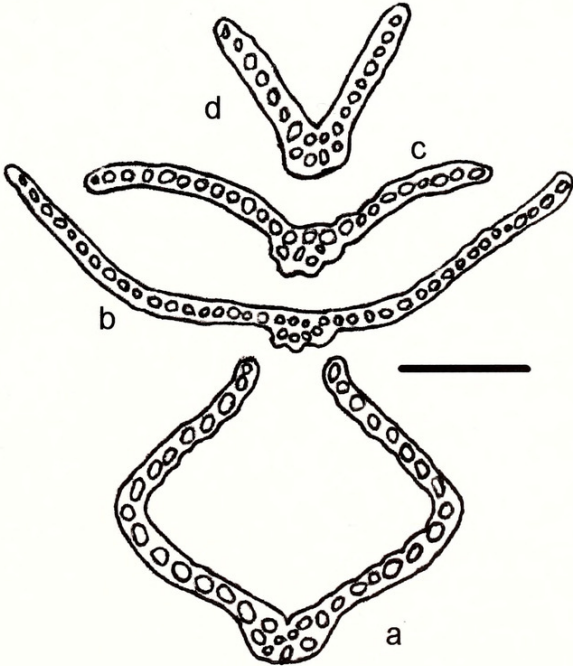


FIG. 4. Drawings of leaf cross sections, *Grimmia vaginulata*; a) leaf from sterile plant taken at midleaf; b, c, d) upper leaf from sporophytic plant. Scale bar = 100  $\mu$ m.





FIG. 5. *Grimmia vaginulata*. Photograph of growth habit on sandstone.

Although evidence is admittedly sparse, with the only known population being the type, the growth habit of *G. vaginulata* adds another basis for separation. In *G. vaginulata*, the plants are at best loosely associated (Fig. 5), not forming a continuous turf or clump. In *G. capillata*, the plants form dense green mats of sterile plants interspersed with a few fertile plants (Cortini Pedrotti 2001; Greven 2003; Heyn and Herrnstadt 2004; Ignatova and Muñoz 2004). The base of the capsule in *G. capillata* is less abruptly contracted to the seta than is seen in *G. vaginulata*. Lastly, in *G. capillata* the ochrea, while pronounced, extends only half way up the seta, not to the base of the capsule as in *G. vaginulata*. (Figs. 1A, B)

*Grimmia pseudoanodon* Deguchi, described in 1987 from Peru (Deguchi 1987), is another small autoicous plant (ca 5 mm tall) with immersed sporophytes with a centrally attached, straight seta, and like *G. vaginulata*, the base of its capsule is abruptly contracted. Examination of an isotype from NY, showed several important differences from *G. vaginulata*. First, *G. pseudoanodon* grows in cushions, contrasting the scattered habit of *G.*

*vaginulata*. *G. pseudoanodon* has no peristome, its cauline leaves are not reduced down the stem, being linear to lanceolate and bearing awns to the base of the plant. They are patent to spreading when moist, and are easy to separate from the stem. Similar to *G. capillata*, the apex of the leaf is hyaline for 15–20 cells, and the awn is often decurrent down the margins of the leaf. Most leaves of *G. pseudoanodon* show bistratose margins. The vaginula of *G. pseudoanodon* is extended, demonstrated by the aborted archegonia scattered throughout its length, however, the ochrea is at most represented by a few hyaline flaps at the apex of the vaginula, far from the tube sheathing the seta of *G. vaginulata*. Interestingly, slight pressure expels the seta from the end of the vaginula, leaving a conical stub at the base of the seta.

#### GENERIC TAXONOMY

It is clear that this new plant belongs in the Grimmiaceae. The only other familial possibility is Ptychomitriaceae, and that is ruled out by the



unlobed calyptra. Within Grimmiaceae, other genera can easily be dismissed as well. The large annulus, and the operculum falling independent of the columnella deny placement in *Schistidium*. Although the cribose peristome resembles those of both *Coscinodon* and *Jaffueliobryum*, and the autoicous sexuality, unistratose lamina and large annulus further support placement in *Jaffueliobryum*, both genera require a pleated and somewhat sheathing calyptra (Churchill 1987; Hastings 2007; Spence 2007). The calyptra of *G. vaginulata* is so short that it does not even split or tear during capsule development, sitting instead just atop the operculum. *Racomitrium* (*sensu lato*) is ruled out by the lack of sinuosity in the cell walls of the lamina or the vaginula (Deguchi 1978).

Not only can we suggest placement in *Grimmia* by elimination, but the dramatic characters displayed by *G. vaginulata* fit well within the limits of variation of plants already in that genus. Deguchi (1978) describes the “Affinis type” annulus as “well differentiated, composed of (2) 3–4 rows of cells, which are thick walled, but transparent, and becoming increasingly larger from the lower to the upper rows. ...Upper rows of cells of the annulus are also removed when the lid falls, but their lower rows usually remain attached to the orifice of the urn, disjoining little by little in the course of time.” This is a perfect description of the annulus in *G. vaginulata*. He attributes this “Affinis type” annulus to “*G. affinis*, *G. anomala*, *G. apiculata*, *G. brachydiction*, *G. curvata*, *G. olympica*, and *G. pilifera*.” Muñoz (1999) assigns this annulus type to “*G. involucrata*, *G. longirostris*, *G. poecilostoma*, and *G. trichophylla*” in the introductory section, and 14 other taxa in the species descriptions.

The ochrea is a structure that is poorly understood and has received little taxonomic discussion. Deguchi (1978) makes it clear that the ochrea is only a section of the vaginula, but Magill (1990) defines ochrea as “vaginula, or upper part of vaginula”. The haploid vaginula includes cells originating from both the archegonium and the upper part of the stem (Deguchi 1978). Deguchi’s proof of this contention is the “occurrence of aborted archegonia at the basal part of the vaginule” (Fig. 1A).

Maier (2002) discusses the vaginula and the ochrea and describes *Grimmia donniana* Sm. ex Spruce with “ochrea broad”, with most other species with ochrea “short” or “small”. Some species such as *G. orbicularis* (a close relative of the aforementioned *G. moxleyi*) she describes with “vaginula 0.8 mm, with ochrea.” Unfortunately, she does not provide illustrations to inform that aspect of her excellent descriptions, nor does she describe how she measures the vaginula. Delgadillo (Universidad Nacional Autónoma de Mexico, personal communication)

wrote “I believe the ochrea is a fairly common feature of the neotropical species of *Grimmia*. It can be demonstrated in *G. americana*, *G. donniana* and *G. elongata*. It is particularly evident in *G. anodon*.” But more convincing examples can be found in the persistent ochreae of *G. capillata* and *G. involucrata* Cardot.

Being clear then that this new plant properly belongs in *Grimmia*, it is necessary to at least explore its relationships within the genus. The history of the genus *Grimmia*, *s.l.*, is a tortured and complex story of confused concepts, alternating periods of splitting and lumping, and regional authors describing numerous plants that have been later synonymized in worldwide treatments (Muñoz and Pando 2000; Greven 2003). Deguchi (1978) and Ochrya et al. (2003) both provide a good summary of this nomenclaturally difficult subject. Although Hernández-Maqueda et al. (2008) casts some doubt on *Coscinodon*, most modern authorities agree on the separation of *Jaffueliobryum*, *Schistidium*, and *Coscinodon* from *Grimmia*, but there is disagreement whether *Grimmia* itself requires further subdivision. Ochrya et al. (2003) proposed to split *Grimmia* into five genera, with each genus corresponding in concept with the subgenera reluctantly suggested by Hastings and Greven (2007). Both systems are rooted in the work of Hagen (1909) and are summarized in Table 1.

*Grimmia vaginulata* can be ruled out of *Gasterogrimmia* based on the straight, centrally attached seta. *Litoneuron* requires 2-stratose, concave leaves with the costa not prominently projecting abaxially: *Grimmia vaginulata* meets none of these criteria. An expanded *Guembelia* that included unistratose leaves would fit all characters of *G. vaginulata*, but if one were to accept the Ochrya et al. (2003) concept of *Dryptodon*, which includes plants with short straight setae and plicate or wrinkled capsules, then *G. vaginulata* would belong there. In fact, Ochrya et al. (2003) places *G. capillata* in *Dryptodon*.

The difficulty is compounded, however, by statements by various authors suggesting that pairs of plants within *Grimmia s.l.* are closely related, but subsequent authors treat each member of the pair in separate subgenera or genera. For example, *G. capillata* is often paired with *G. crinita* Brid. (Greven 2003; Ignatova and Muñoz 2004) and in fact De Notaris (1836, 1838), who first described *G. capillata* in 1836, reduced it to a variety of *G. crinita* in 1838, and Maier (2010) reduced *G. capillata* into synonymy with *G. crinita*. In this pair, *G. crinita* is universally placed in *Gasterogrimmia* (*Grimmia sensu* Ochrya et al. 2003) but as stated above *G. capillata* is placed in *Dryptodon*. These cross subgeneric or generic affinities, as well as the taxa that defy placement within any system, illustrate the



TABLE 1. COMPARISON OF TAXONOMIC TREATMENTS OF GRIMMIA.

Hastings and Greven (2007)	Ochyra et al. (2003)	Description
<i>Gasterogrimmia</i>	<i>Grimmia</i>	Capsules immersed, smooth, seta sigmoid and eccentrically attached to the capsule, leaves 1- or 2-stratose that are concave or concave-keeled.
<i>Guembelia</i>	<i>Orthogrimmia</i>	Capsules immersed to exserted, smooth, seta straight and centrally attached to the capsule, leaves mostly 2-stratose and keeled.
<i>Litoneuron</i>	<i>Guembelia</i>	Capsules exserted or emergent, smooth, seta straight and centrally attached to the capsule, leaves 2-stratose that are concave with the costa not prominent dorsally.
<i>Rhabdogrimmia</i>	<i>Dryptodon</i>	Capsules emergent to exserted, ribbed, seta arcuate and centrally attached to the capsule, leaves mostly 1-stratose (2-stratose at the margins) and keeled.

complexity of *Grimmia s.l.* It is likely that this will only be sorted out by a massive study combining worldwide genetic and morphological data.

The very dramatic and persistent ochrea in *G. vaginulata* opens the question of the importance of the ochrea in *Grimmia* taxonomy. Only Maier (2002) and Deguchi (1978) discuss this character. Deguchi briefly mentions the ochrea in his introduction, and then does not use it in his species descriptions. It is ignored in Crum (1994), Muñoz (1999), Cortini Pedrotti (2001), Greven (2003), Ignatova and Muñoz (2004), and Hastings and Greven (2007). Maier (2002) lists *G. donniana* with ochrea “broad”, and *G. elatior* with ochrea “distinct”. Many other species were described with ochrea “small” or the character was ignored altogether. A quick examination of five specimens in CAS annotated by R. Hastings as *G. donniana* displayed three with no ochrea, one very juvenile capsule with an ochrea already disintegrating, and one specimen with a persistent ochrea about as long as broad at the base of a mature sporophyte. Thus, it seems that this character by itself does not seem to be reliable enough to be useful for separating *G. donniana*, one of the few taxa that Maier thought had a distinctive ochrea; it is likely, therefore, that the character is not useful beyond the *G. capillata*–*vaginulata* group. Nonetheless, further study of such taxa as *G. involucrata* may show that the ochrea could be an additional character useful for identification.

ECOLOGY AND DISTRIBUTION

*Grimmia vaginulata* has thus far only been found on vertical or underhanging surfaces on calcareous sandstone boulders that have eroded out of less calcareous sandstone bedrock of the Butano Formation. These rocks are scattered through a variably dense chaparral comprised of

*Adenostoma fasciculatum* Hook. & Arn., *Arctostaphylos tomentosa* (Pursh.) Lindl., *Ceanothus cuneatus* (Hook.) Nutt., *C. papillosus* Torr. & A. Gray, and *Eriodictyon californicum* Hook. & Arn.. The climate is Mediterranean with moderate but rainy winters, and hot rainless summers (Kellman 2003). The elevation is slightly below 700 meters, placing the site above all but the thickest summer maritime fog. The lack of summer fog keeps these sites very hot and dry until the winter storms arrive.

One of the more peculiar aspects of this very interesting plant is the substrate. With the exception of one recent collection from marble rock (Kellman, Shevock & Lodder 6133 [CAS]) the boulders are also the sole known substrate of *Orthotrichum kellmanii*, another rare coastal California endemic (Norris et al. 2004). The bedrock was deposited in the Upper Eocene, and is part of the Butano Sandstone Formation (Brabb 1989), but the geologic history of the boulders is not known. Presumably, the rocks were formed and eroded into their rounded shape some time prior to the Eocene deposits that formed the bedrock. In Santa Cruz Co., the Butano Formation is exposed along the western slopes of the highest mountains on the eastern side of the county (Brabb 1989), but the boulders are only present in a small patch in Big Basin Redwoods State Park. There is also a small field of the boulders in southern San Mateo Co., also in Butano State Park. Recently, this same formation with exposed boulders has been found in Monterey Co. within the Ventana Wilderness of the Los Padres National Forest. *Orthotrichum kellmanii* was collected here although much of the area remains to be surveyed. The new population greatly expanded its range to the south. Although access to these sandstone outcrops was difficult due to hiking through



dense stands of chaparral, the area subsequently burned in the summer of 2008. This area is now among the highest priority sites to survey for *G. vaginulata*—and to document the extent of *Orthotrichum kellmanii* in this area.

Associated bryophytes growing on and around the boulders include *Amphidium californicum* (Hampe ex Müll. Hal.) Broth., *Antitrichia californica* Sull. in Lesq., *Gemmabryum californicum* (Sull.) Spence, *Didymodon vinealis* (Brid.) R.H. Zander, *Tortula muralis* Hedw., *Grimmia torenii* Hastings, *G. pulvinata* (Hedw.) J. E. Smith, *Gymnostomum calcareum* Nees & Hornsch., *G. viridulum* Brid., *Orthotrichum kellmanii*, and *Cephaloziella divaricata* (Sm.) Warnst.

CONSERVATION

At the type location, *G. vaginulata* has been found on only four out of several hundred boulders, and these fit within a circle of ten meters. It is imperative that no further collections should be made until more populations are found. Additional surveys need to be conducted throughout the highly restricted habitat within the Butano Formation within State Park Lands and a federally designated wilderness area. Even if additional occurrences are discovered, *Grimmia vaginulata* will almost certainly remain a very narrowly restricted endemic that could be adversely impacted by stochastic events.

Even though the chaparral is a fire adapted ecosystem (Schoenherr 1992), the extreme rarity of *G. vaginulata* leaves open the possibility of fire killing the entire known population. In March of 2009, the author visited the Bonny Doon Ecological Preserve in Santa Cruz Co. Nine months before, in June of 2008, a very hot fire raced through the preserve, where sandstone rocks are scattered through a chaparral very similar to that found at the type location of *G. vaginulata*. Even in places where the brush was minimal, virtually all bryophytes were killed on the rocks, especially those bryophytes growing on the walls and underhanging surfaces of the rocks. A few mosses and liverworts survived on the tops of a few rocks. Apparently the heat of the fire was trapped under the rocks and then bathed the vertical surfaces, killing all plant life. It is conceivable that thick cushions, or gemmiform plants with densely imbricate leaves could insulate at least some part of a dry moss plant from the heat, but the loose colonies and cylindrical plant form of *G. vaginulata* offers no such protection.

To date, *G. vaginulata* is known only from the type and in general, taxonomic novelties should not be based on a single specimen, particularly in variable genera such as *Grimmia*. However, this plant's combination of characters, unique to *Grimmia* in North America, along with the conservation implications of its rarity, demand a

full description. Of course, it is always possible that further collections from new locations could alter the concept of *G. vaginulata*. Of all the characters discussed above, the most likely features to change would be the size and the growth form. It is possible that other populations of *G. vaginulata* could be composed of larger plants. Arguing against that possibility is the fact that both sterile and fruiting plants exhibit the same size and growth form in the type population. It seems more likely that *G. vaginulata* could be found growing in turfs or small cushions. However, turf and cushion formation require the survival of the originating stems. There are no subapical innovations in the type population which suggest that this species may be short lived and that individuals die after sexual reproduction.

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