

# The Bryological Times

NEWSLETTER OF THE INTERNATIONAL ASSOCIATION OF BRYOLOGISTS



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*Apotreubia nana* (Treubiaceae),  
on side of large rotten conifer log  
in temperate coniferous forest,  
Dawson Inlet, Haida Gwaii,  
British Columbia, Canada.  
53.2175°N, 132.4899°W. 60m.  
© Des Callaghan, 27 May 2023

The International Association of Bryologists (IAB) is holding a virtual biennial meeting on December 13 and 14, 2023 (UTC -5).

The meeting is composed of two sessions scheduled to promote attendance by members from across the globe. Each session will start with a keynote talk by invited speakers, Dr. Julia Bechteler and Dr. Nicole Fenton, followed by 12 regular presentations and concluded by five speed talks by students.

Registration for the conference is free but required via [http://bryology.org/registration\\_iab\\_2023/](http://bryology.org/registration_iab_2023/) to obtain the zoom link to the conference.

You will receive information with details about zoom links and access.

The organizing committee is thankful to The Field Museum for its critical support enabling this event.



**The organizing committee:**

Catherine Reeb (IAB Vice-President & incoming President — Museum d'Histoire Naturelle, Paris, France)

Bernard Goffinet (IAB President — University of Connecticut, Storrs, USA)

Matt von Konrat (Secretary Treasurer IAB — Field Museum, Chicago, USA)

Juan Carlos Villarreal (IAB Vice-President — Université Laval, Québec, Canada)

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ST 4	Mahoussi Henorck Boris: Bryophytes of Bénin (Africa): diversity and use	12:24pm	15
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# Abstracts of presentations

## Bryophytes phylogenomics and evolution.

[Julia Bechteler](#)

Non-vascular land plants or bryophytes are a major component of terrestrial plant biomass and play important roles in ecosystem functioning in all biomes. Phylogenomic inferences from large suites of loci are anticipated to resolve suprafamilial relationships within evolutionary old groups of organisms such as bryophytes, whose diversification spans at least 400 million years. The GoFlag probe kit for target enrichment provides a tool for generating large nuclear datasets to resolve phylogenetic relationships among flagellate land plants. We present a time calibrated phylogeny for 531 species, from 52 of the 54 orders of bryophytes, based on sequences from 405 nuclear exons found in 228 genes generated by targeted capture and the GoFlag-probe set and dated using 29 fossils. The data strongly support phylogenetic relationships across bryophytes and enabled us to resurrect or recognize eight liverwort orders and propose ten new moss orders. Topological conflict is visible in parts of the tree, suggesting complex processes of diversification. Most bryophyte orders originated in the Jurassic and species diversification mainly took place from the Cretaceous onwards. We provide an expandable phylogenomic framework for further investigations into the diversification and trait evolution of this important group of land plants.

OP1

## Bryophytes around the world.

[Des Callaghan](#)

Good-quality photographs of species in their natural habitat is a valuable resource. Planet earth supports a tremendous diversity of bryophytes, comprising about 20,000 species. Many of these have never been photographed, especially in the tropics. This long-term project aims to photograph in the field representatives from all families, including at least 2,000 species, and to make the images freely available to everyone for whatever purpose. Work began in 2021, and so far six destinations have been visited, including Canada (British Columbia and Alberta), Iceland, La Reunion, Madeira, South Africa (Western Cape) and the USA (Southern Appalachians). A website has been constructed ([bryophytes.myportfolio.com](http://bryophytes.myportfolio.com)), from where 320 images are available presently.

## Unraveling the complexities of bryophyte phenology.

[Jeff Duckett](#), Jill Kowal, Silvia Pressel

We review current knowledge of the timing of bryophyte sexual maturation cycles from spore germination to gametangia development and then to spore discharge. These two phases can be as short as 60 days in ephemerals but gametangial initiation can take several years in perennial taxa. Most mosses and liverworts have strictly seasonal sporophyte maturation cycles lasting from three months to sixteen months in the Polytrichales. Many liverworts show arrested sporophyte development which may last for several months, for example in *Pellia* and *Cephaloziella*. *Marchantia polymorpha* is unusual in having up to three cycles of carpocephalum production per year. Some stages in sporophyte development are highly protracted, for example the spear stage in *Polytrichum* may last up to six months and from capsule maturation to spore discharge in many mosses may take up to three months. Other stages last but a few days, for example setal elongation to spore discharge in liverworts. Monthly recording of bryophyte reproduction, even for common species, should become a goal for all bryologists.

OP3

## Punctuation and non-punctuation in morphology-based evolution.

[Richard Zander](#)

Evolutionary ancestor-descendant diagrams of monothetic genera are presented on a multichotomous, second-order Markov chain evolutionary model. Punctuated equilibrium is evident at least evolutionary time, if not geologic. A causal reason is hypothesized as regional or timely opportunism for distribution of the all-important immediate ancestor, that is, the very newest traits of the ancestral species that are shared by all descendants. Genera with secondary ancestral species that have modified immediate ancestors are possibly a result of environmental change tracked by a very old ancestral lineage.

## Non-structural carbohydrates of bryophytes in relation to their environmental resilience.

[Marianna Marschall](#)

Non-structural carbohydrates are photosynthesis products, provide substrates for growth and metabolism, and serve as energy storage components. Leafy liverworts (Jungermanniales) contain a diverse range of soluble carbohydrates, including sucrose, fructan and polyols such as mannitol, sorbitol and volemitol. Unlike leafy liverworts, mosses have a simple soluble carbohydrate pool consisting of sucrose, although *Sphagnum* species contain fructans. In both leafy liverworts and mosses, starch and reducing sugars are present at relatively low concentration. Carbohydrate composition of bryophytes in relation to their environmental resilience is discussed in the lecture. Sucrose and trehalose have shapes suitable for association with the polar head groups of phospholipids in place of water and for prevention of damaging phase transitions in membranes during desiccation. Additionally, these sugars maintain a vitreous phase in the cytoplasm of desiccated cells, which minimizes protein denaturation. Fructans can be inserted between the head groups of different kinds of phospholipids with some preference for phosphatidylethanolamine. They are the key regulators of adaptation to various environmental stresses, act as antioxidants, scavenging ROS and preventing cell damage under abiotic stress conditions. Fructan-accumulating species contain only traces (~1%) of starch, which means that fructan is a real alternative to starch. Fructans accumulate in the vacuole, where they play an important role in turgor regulation. More molecules mean that these cells are more resistant to osmotic pressure or even cold. The size of fructan polymers can be altered quickly; this could be an explanation for their role in osmotic adjustment. It is likely that fructans protect plants from various environmental stresses such as frost and drought by stabilizing membranes. Starch synthesis drops dramatically when the temperature decreases below 10°C, but photosynthesis and fructan production are much less sensitive to low temperatures, suggesting that fructan production benefits those plants, which actively photosynthesize during the winter and early spring. Reunion *Sphagna* generally increased the synthesis of fructans as the altitude increased. The soluble carbohydrate pool is well-balanced in bryophytes (sugar feeding, darkening, dehydration and cold have little effect), fructans are conserved at the expense of a substantial sucrose stock. Ultimately, desiccation, low and high temperature, salt and osmotic stresses all induce a water deficit at the bryophyte cell level. Accordingly, bryophyte resilience shown here shares a common physiological basis.

## Considerations on poikilohydry and why gametophytes lack stomata.

[Silvia Pressel](#), Karen Renzaglia, Jeff Duckett

The recent realization that bryophyte sporophytes are essentially homoiohydric now permits an evaluation of the features specifically associated with poikilohydry in the gametophytes. Intercellular spaces of schizolytic origin are the only morphological feature absolutely diagnostic of homoiohydricity since the previous hallmark, water-conducting cells, is found in both generations. In vascular plants, intercellular spaces are invariably gas-filled but, in bryophytes, are initially liquid-filled. The liquid is replaced by gas following stomatal opening in mosses and hornworts. Unlike those in vascular plants, moss stomata have fixed apertures and resemble those in some Devonian fossils. Homoiohydricity is an absolute prerequisite for stomata. As to suggestions of stomatal loss in liverworts, implicit in some recent configurations of the land plant tree, an elaborate placenta and a basic stomatal toolkit in the capsule walls of *Haplomitrium* are features suggestive of more complex sporophytes in liverwort ancestry. Under conditions of water stress bryophyte gametophyte cells undergo cytorrhysis (cell shrinkage) a condition usually fatal in vascular plants. Using 1M sucrose as proxy for cytorrhysis we find this to be the rule for gametophytes whereas sporophyte cells plasmolyse, even the thin-walled setal cells in liverworts. Unistratose lamellae, widespread across bryophyte gametophytes, are the optimal structures allowing rapid de- and rehydration.



## Distribution and conservation of the bryophytes of the mountains of Sicily.

[Gulia Bacilliere](#)

This research stems from an in-depth exploration conducted during both a three-year degree and master's degree thesis, revealing a concerning decline in the national study of bryophytic flora until the 80s, followed by a gradual, more recent resurgence. Recognizing the paramount importance of sustaining this branch of botany, our endeavour aims to provide essential support to conservation authorities and catalyse proactive measures for the protection of bryophytes. The choice of Sicily as our focal point is underpinned by its status as a biodiversity hot-spot within the Mediterranean basin. The unique climatic, orographic, and lithological features of the island, compounded by its mountainous terrain, necessitate a “dual-insularity” perspective. Our research focuses on the principal mountain groups—Peloritani, Madonie, Nebrodi, and Etna—initiating with a robust floristic analysis that integrates molecular, morphological, and ecological parameters. This comprehensive approach is complemented by a comparative study with ancient flora, offering a nuanced understanding of the current ecological landscape. A pivotal facet of our project involves employing Ecological Niche Modeling (ENM) as an analytical tool to anticipate the hypothetical future distribution of endangered species in response to environmental changes induced by climate change. Concurrently, in collaboration with the Bryology working group of the Italian Botanical Society, we are actively engaged in crafting the national red-list of mosses for Italy—an extension of the previously published liverwort red-list in 2023. This initiative serves as a precursor to our ambitious goal for 2024: identifying Important Bryophyte Areas at the national level. Field excursions, commencing from Sicily's highest peak, Etna, have already yielded valuable insights. Particularly noteworthy are reports of previously undocumented pteridophytes in the Sicilian region, prompting an exploration within the associated bryoflora. The resultant extraordinary dataset, compiled from these excursions, will soon be disseminated through forthcoming publications. This research not only contributes to the resurgence of bryophyte studies at a national level but also presents a comprehensive framework for the conservation and management of these critical species, particularly in the face of ongoing environmental challenges.

## The messy middle: linking local to continental drivers of boreal bryophyte communities in North America.

[Nicole Fenton](#)

The intricate link between bryophytes and their microhabitats, both substrates and microclimates, has been the focus of many studies in bryophyte ecology. Similarly, large biogeographic patterns across continents can be determined. However, what is driving the species composition of bryophyte communities across landscapes and regions? Building on previous frameworks, I suggest that at the North American scale, the distribution and population size of a bryophyte species will be determined by: (1) distribution and amount of habitat available, as mediated by past disturbances and regional gradients, (2) its ability to reach the habitat (dispersal capacity), and (3) species interactions that impede or facilitate habitat use. Recent results from our lab focus on the first two aspects. Landscape composition (amount and arrangement of habitat) influences bryophyte communities, but less than has been found in Europe. At a broader spatial scale, larger differences in composition are associated with differences in topographical gradients within and among stand types. In terms of dispersal, both distant dependant and independent dispersal have been well documented in the literature. We have previously found that dispersal did not have strong impacts at local scales, but rather at intermediate scales (1.5-10km). Going further on these results we were able to document dispersal functional trait groups that have differential influences on surrounding bryophyte communities at distances up to 50km. Taken together, we can conclude that the relative importance of landscape and regional habitat patterns and dispersal ability of species as drivers of bryophyte community composition varies with spatial and temporal scale. Beyond the biological interest of better understanding what structures bryophyte communities, understanding these drivers will allow us to predict with more accuracy community composition within and across regions and therefore better structure conservation efforts.

OP7

## New data on Paleozoic mosses.

[Misha Ignatov](#), T. Voronkova, U. Spirina, S. Polevova

The morphology and anatomy of additional recent collections of Late Paleozoic mosses are investigated. The genus *Arvildia* Ignatov shows similarity to extant Andreaeopsida, while most representative of that flora belong to the Protosphagnales, which appear much more diverse than previously assumed. Illustrations of new specimens show some neglected characters of previously described and still undescribed extinct mosses.

## **Ancient reticulation and incomplete lineage sorting at the dawn of hornwort diversification and the atavistic evolution of the hornwort pyrenoid during the Carboniferous.**

Gabriel F. Peñaloza-Bojacá, Adaíses Maciel-Silva, Christine Cargill, David Bell, Emily Sessa, Fay-Wei Li, Gordon Burleigh, Karen Renzaglia, Lorena Endara, Noris Salazar Allen, Peter Schafran, Sahut Chantanaorrapint, Stuart Mcdaniel, Christine Davis, and [Juan Carlos Villarreal](#)\*

A new paradigm in systematic biology has emerged: species diversity is largely underestimated, and the extant biodiversity is a product of complex processes such as rapid diversification resulting in incomplete lineage sorting (ILS) in molecular phylogenies, horizontal gene transfer, polyploidy, and hybridization, often not reflected in morphological traits. In this study, we used target enrichment to recover more than 230 genes to reconstruct hornwort evolutionary history and testing the impact of ILS and ancient reticulation during the evolutionary history of the group. In addition, we provide a fossil-calibrated time tree to shed light on the evolution of the hornwort pyrenoid.

## **Wither the sex chromosomes in the evolution of monoicy from ancestral dioicy in liverworts.**

[John Bowman](#)

The ancestral liverwort has been inferred to have been dioicous (unisexual) with chromosomal sex determination. In the ancestral liverwort the U chromosome of females and the V chromosome of males were dimorphic with an extensive non-recombining region. In liverworts, sex is determined by a U chromosomal “feminizer” that promotes female development, and in its absence, male development ensues. Monoicy (bisexuality) has independently evolved multiple times within liverworts. Here, we explore the evolution of monoicy, focusing on the monoicous species *Ricciocarpos natans*, and propose that the evolution of monoicy in *R. natans* involved the appearance of an aneuploid spore that possessed both U and V chromosomes. A survey of other monoicous liverworts suggests that similar genomic rearrangements may have occurred repeatedly in lineages transitioning to monoicy from dioicy.

## Biocontrol potential of bryophytes: a case study of *Conocephalum conicum* (L.) Dumort. (Marchantiophyta) against *Fusarium oxysporum* f. sp. *Lycopersici*.

[Preeti Chaturvedi](#)

Tomato, a high value vegetable crop, suffers huge production losses in tropics due to a wilt disease caused by *Fusarium oxysporum* f. sp. *lycopersici*. Present study was undertaken to find an effective biocontrol method to check fusarium wilt in order to curb the losses suffered by the crop growers. Disc diffusion and microbroth dilution assays were employed to assess the effect of crude organic extracts (acetone, methanol/ethanol) of two thalloid bryophytes (*Conocephalum conicum* (L.) Dumort. and *Marchantia papillata* Raddi subsp. *grossibarba* (Steph.) Bischl.) to control *F. oxysporum* f. sp. *lycopersici*. Methanol extract of *C. conicum* (L.) Dumort. showed significantly high antifungal activity (85.5% mycelial inhibition; 31.25µg/mL MIC and 125µg/mL MFC). Potential of the extract was also tested in a glasshouse experiment on tomato, which illustrated the efficacy of the plant extract to control the fusarial wilt. Morphological and ultrastructural alterations in the methanolic extract treated fusarium mycelia clearly indicated its inhibitory potential. GC-MS analysis of *C. conicum* extract showed the presence of 51 constituents, having bis (bibenzyl), acyclic alkanes, fatty acids, sesquiterpenoids and steroids as the predominant compounds. The lead compound present in *C. conicum* i.e., Riccardin C, is an efficient antifungal compound that can be utilized as a potent and eco-friendly alternative to conventional fungicides for green oliculture.

## Diversity and the distribution of the genus *Riccia* L. (Ricciaceae: Marchantiophyta) in the Western Ghats, India.

[Manju C. Nair](#) and Mufeed B.

The genus *Riccia* L. is a diverse group of liverworts with approximately 150 species worldwide, with India harbouring about 40 species, representing 24% of the global diversity. The Western Ghats, a biodiversity hotspot in India, is home to a rich bryophyte flora, including a significant representation of the genus *Riccia*. Studies on the diversity of *Riccia* in the Western Ghats have revealed a remarkable species richness, with over 24 species recorded from the region. It shows a high degree of variation in its form and structure, from thin, purely aquatic *R. fluitans* L. to *R. ciliata* Hoffm., seasonally appearing in the dry deciduous habitats with hairs. The most striking among them may be *R. sahyadrica* Manju & Cargill, with photosynthetic zone on its lower half, and a sole relative in Australia. This diversity is attributed to the varied habitats and microclimates found within the Western Ghats, along its varied environs across altitudinal ranges of coastal plains to more than 2000 m through the lateritic midlands to the hilly crests, ranging from moist tropical forests to dry deciduous forests. The genus *Riccia* plays an important role in the ecology of the Western Ghats, contributing to nutrient cycling, soil conservation, and providing habitat for various organisms. However, anthropogenic activities such as deforestation, habitat fragmentation, and pollution pose significant threats to the conservation of *Riccia* species in the Western Ghats. Urgent conservation efforts are needed to protect these valuable liverworts and preserve the biodiversity of this unique ecosystem.

## The Neotropical endemic liverwort subfamily Micropterygioideae had circum-Antarctic links to the rest of the Lepidoziaceae during the early Cretaceous.

[Antonio L. Rayos](#) Jr., Matthew A.M. Renner, Simon Y.W. Ho

Lepidoziaceae are the third-largest family of liverworts, with about 860 species distributed on all continents. The evolutionary history of this family has not been satisfactorily resolved, with taxa such as Micropterygioideae yet to be included in phylogenetic analyses. We inferred a dated phylogeny of Lepidoziaceae using a data set consisting of 13 genetic markers, sampled from 147 species. Based on our phylogenetic estimate, we used statistical dispersal-vicariance analysis to reconstruct the biogeographic history of the family. We inferred a crown age of 197 Ma (95% credible interval 157–240 Ma) for the family in the Australian region, with most major lineages also originating in the same region. Micropterygioideae are placed as the sister lineage to Lembidioideae, with these two groups diverging from each other about 132 Ma in the South American–Australian region. Our results suggest a circum-Antarctic link between Micropterygioideae and the rest of the family, along with extinction of the lineage in the region. Crown Micropterygioideae were inferred to have arisen 45 million years ago in South America, before the continent separated from Antarctica. Our study reveals the influence of past geological events on the evolution and distribution of a widespread and diverse family of liverworts.

ST1

## Using convolutional neural networks to predict the affinities of moss spores.

[Ryan Thummel](#)

Features of moss spores are typically not used in cladistic analyses, likely because of a lack of easily visible diagnostic features under light microscopy. SEM images allow for the surface perine sculpturing of such spores to be considered. However, such subtle features are difficult to distinguish and categorize using human manual descriptions. Here, we will develop Convolutional Neural Networks (CNNs) for the first time in mosses using SEM images of extant moss spores to predict their phylogenetic and/or ecological affinities. CNNs learn features directly from image data for classification tasks, without requiring manual feature selection. To develop this CNN, we will sample from over 200 moss species covering the breadth of the moss phylogeny. Lycophytes and ferns will also be sampled to use as outgroups. While CNNs have previously been used on 3D scans of pollen, this will be the first application of CNNs to spores. In addition to developing a neural network, we will produce an extensive SEM image database of moss spores that will be publicly available through the Cornell University Plant Anatomy Collection (CUPAC). This work also has the potential to allow for more fossil moss spores to be described from deep time, which so far has mostly just included representatives of *Sphagnum*.

## What is hiding within the moss? A sneak peek into bryosphere diversity in a changing tundra.

[Bastien Papinot](#), Snæbjörn Pálsson, Ingibjörg Svala Jónsdóttir

Bryophytes are abundant in Icelandic ecosystems, covering large parts of the island, which hosts more than 600 different species. They play vital ecological roles like storing carbon and nitrogen, regulating the soil environment, and impacting biogeochemical cycling but also fostering diverse microscopic food webs, which is often called the bryosphere. This biodiversity has often been overlooked because of identification issues or simply considering mosses as only one functional unit for ecosystems. The use of new identification techniques like environmental DNA could solve some of these issues. On another end, climate change, and especially rapid warming in the Arctic, is transforming the tundra vegetation: non-vascular plants are declining as shrubs and grasses thrive, although modulated by factors like livestock grazing. The impact of these factors on ecosystem processes linked to bryophyte species but also on the bryosphere diversity hiding within the moss layer could help us improve our knowledge on the functionality of bryophytes for ecosystems and their importance for Arctic environments. This presentation focuses on presenting the context, methods and first results of this study on the impact of sheep grazing on bryosphere diversity and ecosystem processes like litter decomposition.

## Biodiversity, biogeography and phylogeny of hornworts from sub-Saharan Africa and the Indian Ocean.

[Quentin Dejonghe](#)

Hornworts form a lineage comprising 220 described species, whose unique combination of characters makes them a key taxon for understanding plant evolution. In order to understand their role in this diversification and to deepen the global history of the lineage, we propose to explore the little-known diversity of African species, which have not been the subject of any specific study. The aim of the PhD thesis is to explore the biodiversity, biogeography and phylogeny of hornworts more specifically from sub-Saharan Africa and the Indian Ocean, and to place them within a global phylogeny of this group. The two main focuses are (1) Integrative taxonomy (morphology, morphometry and molecular); (2) Phylogeny and molecular biogeography. During this first year of the PhD, morpho-anatomical analysis was carried out on over 250 specimens, mainly from the Indian Ocean. This made it possible to create a matrix of characters that will be used to propose primary species hypotheses. The spores of over 50 specimens were observed under a scanning electron microscope, confirming that they are essential for the specific identification of hornworts. Molecular acquisition has so far yielded 80 ITS2 sequences, although difficulties have been and are still being encountered with the amplification of certain markers (rbcL, matK, etc.). The next steps in the PhD will be to finish acquiring a bank of spore images in order to carry out a morphometric study. And to resolve marker amplification problems in order to initiate phylogenetic analysis and biogeographical inference.

## **Bryophytes of Bénin (Africa): diversity and use.**

[Mahoussi Henorck Boris](#)

The aim of this first work on the non-vascular plants of Benin was to contribute to the knowledge and development of bryophytes. The results showed that bryophytes constitute an important compartment of biodiversity, currently representing 149 species. This three-year study revealed the presence of around 100 taxa new to Benin and one species new to science, as well as 23 ailments treated by bryophyte species in traditional medicine. This underlines the need to sample such a biological group.

## **Unveiling bryophyte propagation: A case study of ex- vitro culture of *Marchantia papillata* Raddi.**

[Sweta Negi](#) and Preeti Chaturvedi

Bryophytes, the pioneer plant community colonizing the land forms second largest taxonomic category of plants subsequent to angiosperms. Despite their numerous ecological roles and the abundance of biochemical compounds they possess, the exploration of their chemistry has been significantly limited, primarily owing to habitat specificity and the scarcity of available samples. This study addresses the protocol for large scale clonal propagation of *Marchantia papillata* Raddi. The ex-vitro culture of *M. papillata* was achieved on various types of soil mixtures supplemented with different nutrient media using male gametophyte as explants. Out of all the soil mixtures, the soil mixture B supplemented with rice-washed water showed best thallus proliferation. Different physical factors viz., light and temperature conditions were also optimized. Optimum thallus proliferation was seen in white light at 20°C. This breakthrough in thallus proliferation will open up avenues for growing these plants as biocrusts which can be used to control soil erosion besides decorating the landscapes. Furthermore, the propagation strategy will ensure year-round availability of the plant material for bioprospection and pollution surveys.



The International Association of Bryologists was established in 1969 to promote international cooperation and communication among all persons interested in the biology of bryophytes. This is achieved through sponsorship and arrangement of meetings and symposia that relate to the various aspects of bryology, and by IAB-sponsored publications including *The Bryological Times* and *Bryophyte Diversity and Evolution*. The Association also supports the publication of reviews, lists, software, and compendia.

Website: [www.bryology.org](http://www.bryology.org)

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*The Bryological Times* is published twice yearly.

This is a special issue.

Contributions can be emailed to the Associate Editor, [Mereia Tabua](#).

Articles should be less than 1500 words in files no larger than 15 MB.

Images should be no more than 2 MB each and may be emailed separately.

The deadline for the next issue is 31 March 2024.

Cover photo: Des Callaghan. All other photos: Mereia Tabua.