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## The newly recorded chrysophyte, *Bitrichia ollula* (Fott) Bourrelly: an intriguing find from a Hebridean machair loch, and its ecological niche compared with two similar species occurring in Scottish freshwaters

Pauline Lang, Jan Krokowski & Elizabeth Mullen

Ecology Assessment Unit, Scottish Environment Protection Agency, Angus Smith Building, 6 Parklands Avenue, Eurocentral, Holytown, North Lanarkshire, ML1 4WQ, Scotland, UK

E-mail corresponding author: [pauline.lang@sepa.org.uk](mailto:pauline.lang@sepa.org.uk)

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*Bitrichia* Wołoszyńska [= *Diceras* Reverdin] is a genus of 'golden' algae (Chrysophyceae, Hibberdiales) leading a solitary planktonic existence in freshwater lakes (Lang *et al.*, 2011). At least one species of this chrysophyte group, *Bitrichia chodatii*, is considered indicative of minimally-disturbed reference conditions in Northern European low alkalinity lakes (Järvinen *et al.*, 2013). Reflecting this, *B. chodatii* tends to be prevalent in oligotrophic low alkalinity lochs in Scotland, though it occurs, albeit to a lesser extent, across a range of typologies and water chemistry conditions (Table 1).

In the course of analysing phytoplankton samples collected as part of the Scottish Environment Protection Agency's ongoing assessment of the ecological status of freshwater lochs in Scotland (see Lang *et al.*, 2014), *Bitrichia ollula* (Fott) Bourrelly was found to occur quite frequently (e.g. 5 – 10 cells per 100 ml sub-sample) in East Loch Ollay (Scots Gaelic: Loch Olaidh an Ear) during the summer months of 2013. East Loch Ollay together with Mid (Loch Olaidh Meadhanach) and West (Loch Olaidh an Iar), collectively referred to as the "Ollay Lochs", are located on the machair plain along the west coast of South Uist, in the Outer Hebrides, off the north-west coast of Scotland (NGR: NF 76483 31111). The S. Uist machair designated a Special Area of Conservation (SAC) under the EC Habitats Directive (92/43/EEC), is a complex site comprising Annex I habitats (such as the Ollay Lochs), and within those supporting some Annex II species (e.g. the aquatic plant slender naiad, *Najas flexilis*: Wingfield *et al.*, 2005; Wingfield & Murphy, 2006). Positioned farthest inland, East Loch Ollay is shallow (ca. 2 m) and subject to a mixture of influences from the complex of substrate conditions typical of the machair: peat, highly calcareous sands

and naturally elevated phosphorus levels. It is characterized by relatively high alkalinity and oligomesotrophic water chemistry (Table 1).

Of the eight *Bitrichia* species recognized, only two are presently known to occur in British freshwaters (Kristiansen & Preisig, 2011), with *B. chodatii* (Reverdin) Chodat being the commonest (found in approximately half of all Scottish lochs presently monitored by SEPA: P. Lang, pers. obs.), whilst *B. longispina* (J.W.G. Lund) Bourrelly is exceptionally rare: observed only twice, from separate localities, 60 years apart (Lund, 1949; Lang *et al.*, 2011). Hence, finding *Bitrichia ollula* in a Hebridean machair loch comprises an entirely new record, not only for Scottish freshwaters, but it is also the first time it has been noted to occur in the UK (D. John, pers. comm.).

The protective casing or 'lorica' of *Bitrichia ollula* is spherical with a mean diameter ca. 7.5 µm, although perhaps the most striking feature is that this species possesses typically three, occasionally four, and seldom two or five, straight terminal spines of equal length, usually ranging between 25 – 32 µm (Fott, 1937; Nicholls, 1981; Starmach, 1985) (Figs. 1a,b). These are potentially useful characteristics for distinguishing *Bitrichia ollula* from *B. chodatii* and *B. longispina* (reviewed in Lang *et al.*, 2011), hopefully helping with potential future misidentification issues. However, there is also a possibility of *Bitrichia ollula* being mistaken for the green alga *Treubaria triappendiculata* C. Bernard (Figs. 2a,b), which may appear similar under the microscope when stained with Lugol's iodine as the ensuing staining or shrinkage can obscure or distort diagnostic features (e.g. chloroplast structure) and make identification problematic. Generally, the two species can be differentiated by the length, orientation, and texture of their spines (Reymond & Cronberg, 1981). The chloroplasts are also different but, perhaps crucially, the green alga completely lacks the visible lateral pore displayed by the chrysophyte's lorica (Fig. 1a,b), through which the cell's branch-like extensions or 'rhizopodia' are projected.

Since it was first described from Černé Lake in the Czech Republic by Fott (1937), records of *Bitrichia ollula* have been scarce, with limited accounts stemming from lakes in Sweden (Willén, 1963; Ramberg, 1978; Reymond & Cronberg, 1981; Willén, 2007), Switzerland (Preisig, 1979), and North America (Nicholls, 1981). Hence, *B. ollula* demonstrates a constrained ecological distribution and is less common than its relatives, *B. chodatii* and *B. longispina* (Nicholls & Wujek, 2003), although the latter species can be rather elusive too. Our recent discovery of *B. longispina* also came from the Outer Hebrides (Lang *et al.*, 2011), suggesting that these

island lochs offer unique habitat conditions for supporting rare *Bitrichia* spp. in the UK.

The distribution of the three *Bitrichia* species usually does not tend to overlap in Scottish lochs, except in East Loch Ollay where *B. ollula* co-occurred with small numbers of *B. chodatii* (P. Lang, pers. obs.). Though perhaps muddying the picture slightly, the two species were not found together in

neighbouring Mid Loch Ollay wherein *B. chodatii* has previously been observed (P. Lang, pers. obs.). The three *Bitrichia* species have drawn our interest through their relevance to algae-based water quality assessment (Lang *et al.*, 2011), and here we have explored some of the environmental factors which may help to explain their diverging ecologies (Table 1).

Table 1. Ecological distribution of three *Bitrichia* species occurring in Scottish lochs monitored by SEPA, during 2009 to 2013, with matching water chemistry data. Lake typology is defined as LA = Low Alkalinity, MA = Moderate Alkalinity, or HA = High Alkalinity; VS = Very Shallow, S = Shallow, or D = Deep. Indications of interim Water Framework Directive (WFD) ecological status determined using the UK phytoplankton classification tool, known as PLUTO, to analysis results of samples collected during the summer months (Carvalho *et al.*, 2013; WFD-UKTAG, 2014; SEPA, unpubl.). Significance testing: one-way ANOVA and application of Tukey's mean separation test. For variables with significant outcomes only, mean values ( $\pm 1$  standard error) sharing the same superscript letter are not significantly different. All analyses conducted using Minitab v 16.

|                                                                                                 | <i>Bitrichia ollula</i><br>(see Fig. 1a,b)<br>n = 1 loch | <i>Bitrichia longispina</i><br>(see Lang <i>et al.</i> ,<br>2011)<br>n = 1 loch | <i>Bitrichia chodatii</i><br>(see Lang <i>et al.</i> ,<br>2011)<br>n = 45 lochs                                                          | P <sub>ANOVA</sub> |
|-------------------------------------------------------------------------------------------------|----------------------------------------------------------|---------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|--------------------|
| Lake typology                                                                                   | HA; VS                                                   | LA; S                                                                           | LA; VS (n = 2)<br>LA; S (n = 20)<br>LA; D (n = 8)<br>MA; VS (n = 3)<br>MA; S (n = 5)<br>MA; D (n = 2)<br>HA; VS (n = 3)<br>HA; S (n = 2) | -                  |
| Interim PLUTO<br>classification (2012 –<br>2013)                                                | High ecological status                                   | Good ecological status                                                          | High ecological status<br>(n = 43)<br>Good ecological status<br>(n = 2)                                                                  | -                  |
| Annual mean pH<br>(2009–2013)                                                                   | 7.50 <sup>a</sup> ( $\pm 0.07$ )                         | 6.32 <sup>b</sup> ( $\pm 0.03$ )                                                | 6.73 <sup>c</sup> ( $\pm 0.02$ )                                                                                                         | P<0.001***         |
| Annual mean Alkalinity<br>concentration, mg L <sup>-1</sup> as<br>CaCO <sub>3</sub> (2009–2013) | 30.6 <sup>a</sup> ( $\pm 0.9$ )                          | 1.5 <sup>b</sup> ( $\pm 0.1$ )                                                  | 10.5 <sup>c</sup> ( $\pm 0.4$ )                                                                                                          | P<0.001***         |
| Annual mean Ca<br>concentration, mg L <sup>-1</sup><br>(2009–2013)                              | 13.9 <sup>a</sup> ( $\pm 0.5$ )                          | 1.6 <sup>b</sup> ( $\pm 0.1$ )                                                  | 4.3 <sup>c</sup> ( $\pm 0.2$ )                                                                                                           | P<0.001***         |
| Annual mean Si<br>concentration mg L <sup>-1</sup><br>(2009–2013)                               | 0.60 <sup>a</sup> ( $\pm 0.16$ )                         | 0.34 <sup>a</sup> ( $\pm 0.04$ )                                                | 1.34 <sup>b</sup> ( $\pm 0.03$ )                                                                                                         | P<0.001***         |
| Annual mean Total<br>Phosphorus (TP)<br>concentration, µg L <sup>-1</sup><br>(2009–2013)        | 16.9 <sup>a</sup> ( $\pm 2.1$ )                          | 18.4 <sup>a</sup> ( $\pm 0.7$ )                                                 | 10.7 <sup>b</sup> ( $\pm 0.3$ )                                                                                                          | P<0.001***         |

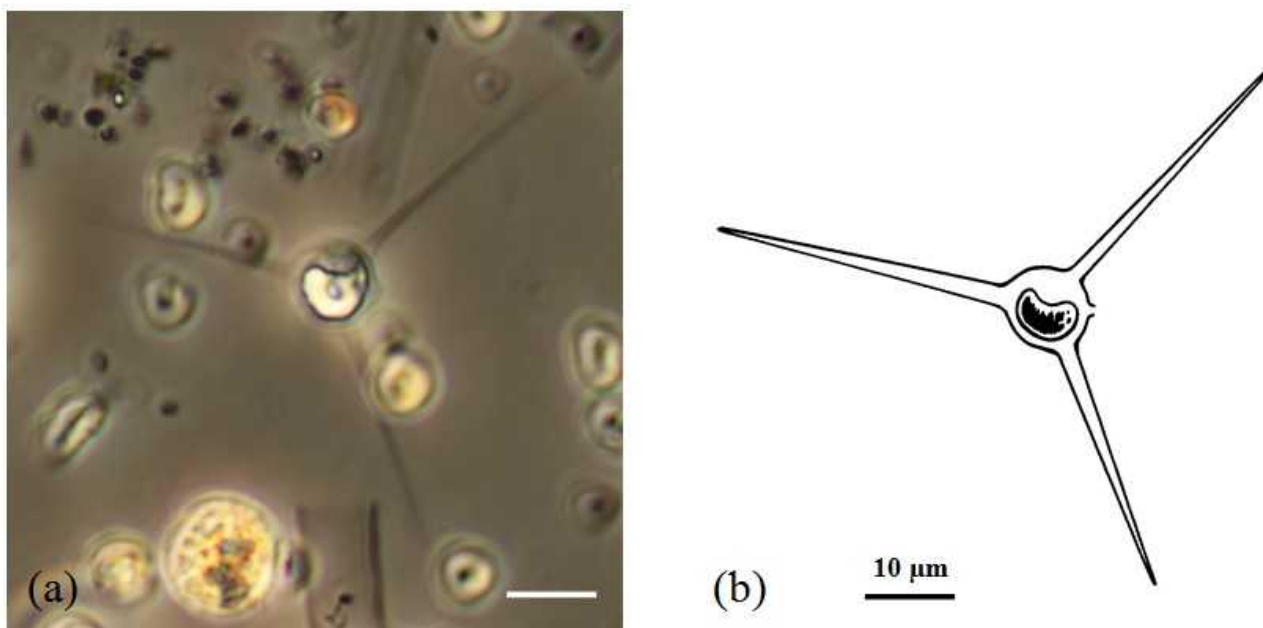


Fig. 1. *Bitrichia ollula*. (a) Photomicrograph of *B. ollula* preserved in Lugol's iodine. Scalebar, 10 µm. (b) Line drawing of *B. ollula*.

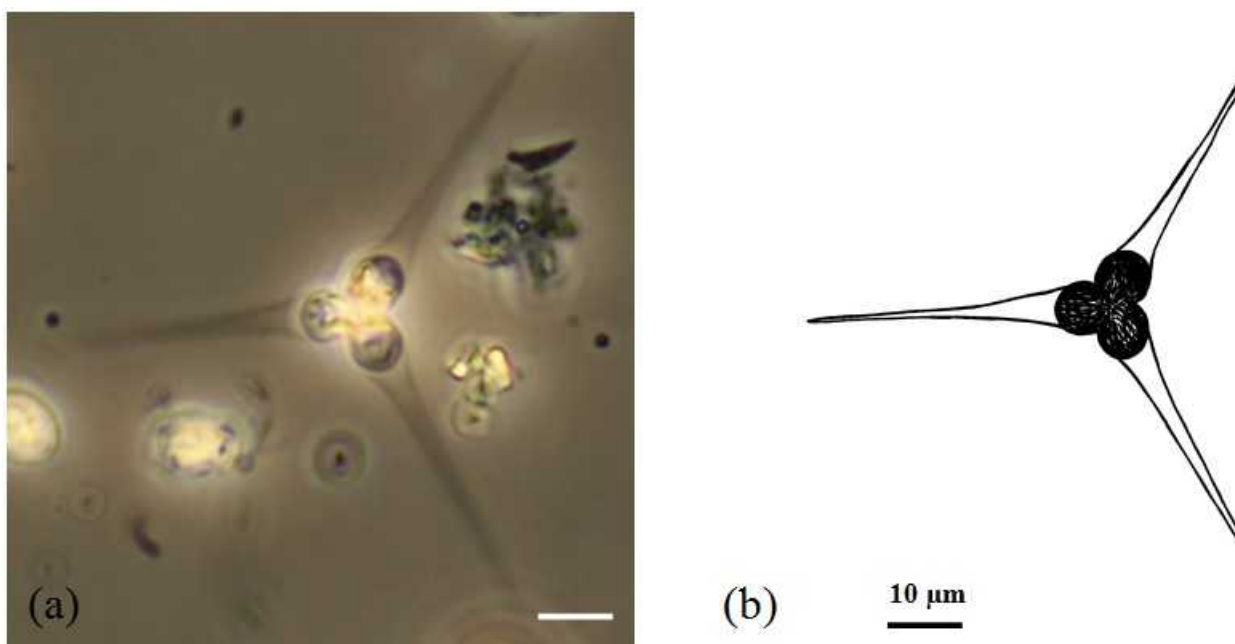


Fig. 2. *Treubaria triappendiculata*. (a) Photomicrograph of *T. triappendiculata* preserved in Lugol's iodine. Scalebar, 10 µm. (b) Line drawing of *T. triappendiculata*.

The water chemistry of East Loch Ollay (Table 1) is similar to that documented by Reymond & Cronberg (1981) for Lake Örsjö in Sweden, suggesting that *B. ollula* has a distinct habitat preference for highly calcareous and perhaps slightly phosphorus-enriched conditions. Though the other two species exhibited a preference for low alkalinity conditions, average total phosphorus (TP) concentrations were significantly different, being higher (and closer to that of East Loch Ollay) for *B. longispina* and lower for *B. chodatii* (Table 1). *Bitrichia ollula* is an intriguing find, particularly from a biomonitoring

viewpoint as nothing is presently known about its indicator value, with no allocated score in terms of the Phytoplankton Trophic Index (PTI: Phillips *et al.*, 2013) because the species was not known to UK freshwaters when this metric, for assessing UK lake quality, was developed. However, we have determined that all three *Bitrichia* species occurred in Scottish lochs with mean TP concentrations lower than 20 µg L<sup>-1</sup> and which were characterized, using the UK phytoplankton classification tool (PLUTO: WFD-UKTAG, 2014), as being at high or good WFD ecological status (Table 1). This suggests

they may each indicate least-disturbed, relatively oligotrophic conditions and generally concurs with observations from Swedish lakes (Willén, 2007).

We also found that average silicate concentrations were significantly lower in lochs containing *B. ollula* and *B. longispina* compared with those where *B. chodatii* occurred (Table 1). Applied molecular sequencing (i.e. DNA barcoding) could potentially decipher whether we are dealing with three separate *Bitrichia* species, or perhaps phenotypic plasticity responding to an underlying environmental gradient (e.g. Si limitation) controlling spine number, orientation and morphology. Hindák & Hindáková (1997) previously hinted at this, having queried the validity of *Bitrichia danubiensis* Juriš and concluded it comprised a morphological variant of *B. chodatii*. However, as far as we are aware there are no published studies detailing their phylogeny.

We present *Bitrichia ollula*, a newly recorded chrysophyte species for UK freshwaters and contribute to knowledge of its apparently restricted ecological niche, compared with two similar species occurring in Scottish lochs. Future work aimed at unravelling the environmental factors that affect the occurrence of *Bitrichia* spp., placed into the wider context of European lakes, would hopefully throw more light on what their differential distribution means from a water quality perspective.

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#### REFERENCES

Carvalho, L., Poikane, S., Lyche Solheim, A., Phillips, G., Borics, G., Catalan, J., De Hoyos, C.; Drakare, S.; Dudley, B.J., Jarvinen, M., Laplace-Tretyure, C., Maileht, K., McDonald, C., Mischke, U., Moe, J., Morabito, G., Noges, P., Noges, T., Ott, I., Pasztaleniec, A., Skjelbred, B. & Thackeray, S.J. (2013). Strength and uncertainty of phytoplankton metrics for assessing eutrophication impacts in lakes. *Hydrobiologia* 704, 127 – 140.

Fott, B. (1937). Dva nové druhy rodu *Diceras* Reverdin. [Two new species of the genus *Diceras* Reverdin]. *Věstník Královské České Společnosti Nauk* 2, 1 – 7.

Hindák, F. & Hindáková, A. (1997). Morphological variation and taxonomy of *Bitrichia chodatii*, incl. *B. danubiensis* (Chrysophyceae). *Biologia Bratislava* 52, 1 – 6.

Järvinen, M., Drakare, S., Free, G., Lyche-Solheim, A., Phillips, G., Skjelbred, B., Mischke, U., Ott, I., Poikane, S., Søndergaard, M., Pasztaleniec, A., Van Wichelen, J. & Portielje, R. (2013). Phytoplankton indicator taxa for reference conditions in Northern and Central European lowland lakes. *Hydrobiologia* 704, 97 – 113.

Kristiansen, J. & Preisig, H.R. (2011). Phylum Chrysophyta (Golden Algae) Pp. 306 – 307 In: John, D.M., Whitton, B.A. & Brook, A.J., (editors). *The Freshwater Algal Flora of the British Isles*, 2<sup>nd</sup> Edition. Cambridge University Press, Cambridge.

Lang, P., Ross, N., Krokowski, J. & Doughty, R. (2011). The elusive planktonic freshwater chrysophyte *Bitrichia longispina*: a first record for Scottish lochs and comparison with the commoner species, *Bitrichia chodatii*. *The Glasgow Naturalist* 25, 106 – 108.

Lang, P., Procházková, L., Krokowski, J., Meis, S., Spears, B.M., Milne, I. & Pottier, J. (2014). The bizarre Eustigmatacean alga, *Pseudostaurastrum limneticum* (Borge) Chodat, in a shallow, nutrient-enriched Scottish loch: new to the British Isles. *The Glasgow Naturalist* 26, 107 – 109.

Lund, J.W.G. (1949). New or rare British Chrysophyceae. I. *New Phytologist* 48, 453 – 460.

Nicholls, K.H. (1981). Six Chrysophyceae new to North America. *Phycologia* 20, 131 – 137.

Nicholls, K.H. & Wujek, D.E. (2003). Chrysophycean Algae. Pp. 495 In: Wehr, J.D. & Sheath, R.G. (editors). *Freshwater Algae of North America: Ecology and Classification*. Academic Press.

Phillips, G., Lyche-Solheim, A., Skjelbred, B., Mischke, U., Drakare, S., Free, G., Järvinen, M., de Hoyos, C., Morabito, G., Poikane, S. & Carvalho, L. (2013). A phytoplankton trophic index to assess the status of lakes for the Water Framework Directive. *Hydrobiologia* 704, 75 – 95.

Preisig, H.R. (1979). *Vergleichende Studien an Algenpopulationen in Kiesgrubenweiheren*. Inaugural-Dissertation, Universität Zürich.

Ramberg, L. (1978). Some rare Chrysophyta from Swedish oligotrophic lakes. *British Phycological Journal* 13, 141 – 147.

Reymond, O. & Cronberg, G. (1981). Morphological study of *Bitrichia ollula* (Fott) Hollande (Chrysophyceae) by optical and electronic microscopy and comparison with a green alga, *Treubaria* Bernard. *Saurea* 12, 79 – 90.

Starmach, K. (1985). *Süßwasserflora von Mitteleuropa 1: Chrysophyceae und Haptophyceae*. VEB Gustav Fischer Verlag, pp. 406 – 407.

Water Framework Directive – United Kingdom Advisory Group (2014). UKTAG Lake Assessment Method Phytoplankton:

- Phytoplankton Lake Assessment Tool with Uncertainty Module (PLUTO). WFD-UKTAG c/o SEPA, Stirling.
- Willén, E. (2007). *Växtplankton i sjöar, bedömningsgrunder*. SLU Institutionen för Miljöanalys. Report No. 5, 37 pp.
- Willén, T. (1963). Notes on Swedish plankton algae. *Nova Hedwigia* 5, 39 – 56.
- Wingfield, R., Murphy, K.J. & Gaywood, M. (2005). Lake habitat suitability for the rare European macrophyte *Najas flexilis* (Willd.) Rostk. & Schmidt. *Aquatic Conservation: Marine and Freshwater Ecosystems* 15, 227 – 241.
- Wingfield, R. & Murphy, K.J. (2006). Assessing and predicting the success of *Najas flexilis*, a rare aquatic macrophyte in relation to lake environmental conditions. *Hydrobiologia* 570, 79 – 86.