

A NEW RECORD OF *HERIBAUDIELLA FLUVIATILIS*,
A FRESHWATER BROWN ALGA (PHAEOPHYCEAE), FROM OREGON

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ABSTRACT.—Members of the algal class Phaeophyceae (brown algae) are almost entirely marine species. A few genera have been described from freshwater habitats, but their distribution and ecological requirements, especially in North America, are very poorly known. The 1st specimens of a freshwater species of brown algae from Oregon, *Heribaudiella fluviatilis*, were discovered in 3 localities of the McKenzie River, near McKenzie Bridge and Belknap Springs (44°22'N, 122°00'–15'W). This is the 4th extant population of this species known from the United States. The alga forms distinctive, macroscopic, dark brown patches on rocks in rapidly flowing water. In the McKenzie River it co-occurs, apparently year-round, with several other macrophytic algal species, including *Prasiola mexicana*, *Zygnema* sp. (sterile), *Nostoc parmelioides*, *N. verrucosum*, and *Phormidium* cf. *autumnale*. In cooler months the macroalgal species *Ulothrix zonata* and *Hydrurus foetidus* are also present with *Heribaudiella*. Photographs and ecological information are provided. We report a 380-km range extension south for the species, and thus far the most southerly population known from North America. This new record suggests that the alga may be more widespread than previously recognized and that other localities may be discovered with further study.

Key words: Heribaudiella, brown algae, stream, Phaeophyceae, Oregon.

The algal class Phaeophyceae (brown algae) is represented by a great variety of species, with an enormous range of sizes from microscopic forms to large kelps many meters long. More than 99% of all known species of brown algae occur in the marine environment (Van den Hoek et al. 1995). Seven species in 6 genera have been described from freshwater environments. All are benthic and most colonize rocks in rapidly flowing streams or various substrata in lakes (Wehr 2003). These are *Heribaudiella fluviatilis*, *Pleurocladia lacustris*, *Bodanella lauterborni*, *Sphacelaria fluviatilis*, *S. lacustris*, *Porterinema fluviatile*, and *Ectocarpus siliculosus*. Some are known from just one to a few locations worldwide (Jao 1943, Thompson 1975, Schloesser and Blum 1980, West and Kraft 1996). Interestingly, most of these species (except *Ectocarpus* and *Porterinema*) occur only in fresh waters and are not known from even brackish environments (Israelsson 1938, Waern 1952, Wehr and Stein 1985). Given the great abundance of marine relatives, their possible marine origin and ecological requirements remain elusive for future biogeographic and physiological studies.

Presently, the North American algal flora is known to include 5 species of these unusual

freshwater algae: *P. lacustris*, *S. fluviatilis*, *S. lacustris*, *P. fluviatile*, and *H. fluviatilis*; but most have been reported from few localities. *Pleurocladia lacustris* has been reported from 3 quite disjunct locations in North America, each more than 1900 km from the next nearest population: Devon Island, Territory of Nunavut (formerly Northwest Territories; Wilce 1966); northeastern Lake Michigan (Carter and Lowe 2001); and Green River, Utah-Colorado (Ekenstam et al. 1996). *Sphacelaria lacustris* is known from just a single locality in western Lake Michigan (Schloesser and Blum 1980). *Sphacelaria fluviatilis* was added to the North American flora after being discovered colonizing pebbles in Gull Lake, Michigan (Thompson 1975, Wujek et al. 1996), a habitat quite unlike the only other population in a rapidly flowing stream in central China (Jao 1943). Also disjunct, *Porterinema fluviatile* has been described from several marine and freshwater localities in northern Europe (Dop 1979), and from a single marginally freshwater habitat in North America (Wilce et al. 1970). One of the most widely reported, but still poorly known, species of freshwater brown algae is *Heribaudiella fluviatilis* (Holmes and Whitton 1975a, Wehr and Stein 1985). The taxonomic variations and

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synonymies have been discussed elsewhere (Wehr and Stein 1985, Wehr 2003). A recent review of its global distribution revealed several hundred populations worldwide and perhaps 30 in North America, but many of these are hundreds or thousands of kilometers from the next nearest population (Wehr 2003). This paper reports the recent discovery of a well-established population from a river in central Oregon. Photographs and some ecological information are provided that may enable researchers to locate other populations in North America.

Study Site

Collections were made from the McKenzie River, a 350-km-long tributary of the Willamette River in central Oregon, which drains off the western slopes of the Cascade Mountains. Sites were located within approximately a 16-km stretch of the river between the towns of Belknap Hot Spring, McKenzie Bridge, and Rainbow (Fig. 1), roughly 75–85 km east of Eugene, Oregon. In this section, the river runs mainly westward and joins the Willamette River approximately 300 km downriver, north of Springfield, Oregon. Study sites are located within the Willamette National Forest at elevations between 400 m and 495 m, and situated in a mixed western hemlock–western redcedar–Douglas-fir forest. This portion of the river has recently been designated as part of the critical habitat for evolutionarily significant units (similar to populations) of steelhead trout and Chinook salmon (Anonymous 2000). The river basin is immediately adjacent to (south of) the watersheds of the H.J. Andrews Experimental Forest (Jones et al. 2000). Further details of the regional landscape and riparian vegetation are given in Planty-Tabacchi et al. (1996).

Three study reaches were investigated: (1) Lost Creek trail, 100 m upstream of Lost Creek tributary; (2) ranger station, 100 m downstream of McKenzie Ranger Station; and (3) McKenzie Bridge, 10 m downstream of McKenzie Bridge (Oregon Highway 126 road bridge). Each study reach is characterized by rocky substrata with rapid current velocities in the riffles and deep pools ≥ 80 cm during normal base flow conditions, and varies from 15 m to 30 m in width. Stream water on each date was very clear. Sunlight reaching the streambed varies from fully open to moderately shaded. During the

summer and autumn, many of the larger rocks are colonized with conspicuous growths of macroscopic and microscopic algae, and bryophytes.

METHODS

We collected algal samples from rocks while wading the river and removed them from the streambed. We collected specimens as intact colonies on rocks by carefully hand-scraping them into sample vials using razor blades. Samples were collected from 3 sites in August 1997, July 1998, and September 1999. Relative cover estimates of the main macroalgal species observed in a stream-reach were based on the method outlined by Holmes and Whitton (1977a). Cover levels were scored as 0: absent; 1: $\leq 1\%$; 2: $>1\%$ to 10%; 3: $>10\%$ to 25%; 4: $>25\%$ to 50%; 5: $>50\%$. We made initial identifications in the field using a Swift FM-31 field microscope. One site (Lost Creek trail) was sampled (1997) for physical and chemical variables using triplicate water samples from that reach. Stream depth and width were measured using a meter stick and tape measure, temperature with a field thermometer, and current velocity was measured using a General Oceanics 2030 digital flow meter. Water chemistry samples were filtered (0.45 μm pore size) into 8 mL acid-washed vials for analysis in the laboratory. Algal and water chemistry samples were kept cool ($\leq 4^\circ\text{C}$) until analysis.

In the laboratory, algal samples were prepared for standard wet-mount microscopy, although samples of *Heribaudiella* required additional steps for observation. Samples were first carefully sliced off rocks using a razor blade and diced into thinner sections; layers of thalli were further broken up by chopping material on a microscope slide and applying pressure with a coverslip. This latter step was necessary to separate the 2 growth forms typical of this species (see Results). We observed specimens using a Nikon Eclipse E600 microscope with Nomarski optics, and photographed them using a Spot RT digital camera (Diagnostic Instruments, Sterling Heights, MI).

Unfiltered water samples were analyzed for pH in the laboratory using an Orion 720 pH meter. We analyzed samples for concentrations of dissolved inorganic phosphorus (DIP) using antimony-ascorbate-molybdate (APHA 1985; Bran+Luebbe Analyzing Technologies 1986a),

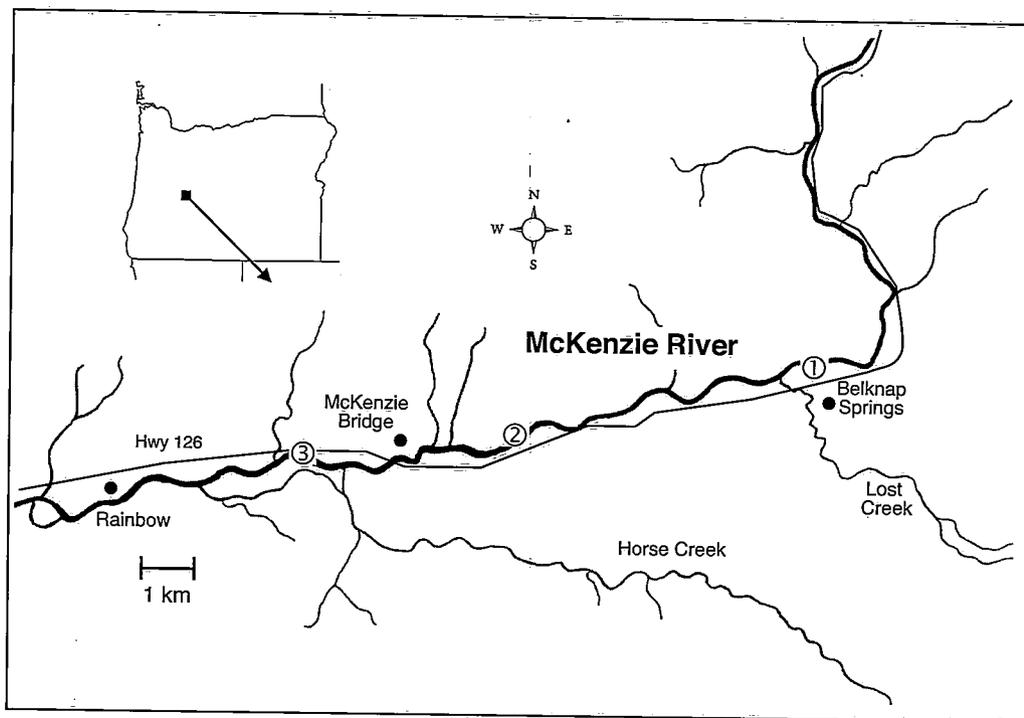


Fig. 1. Location of the study area (inset) and the 3 sample reaches (numbers in circles) with populations of *Heribaudiella fluviatilis* along the McKenzie River, Oregon (towns are designated by solid circles). The river flows south and west.

NH_4^+-N using phenol-hypochlorite, and NO_3^--N (after reduction to NO_2^- in a Cd-Cu column) via reaction with sulfanilamide=NNED (APHA 1985; Bran+Luebbe Analyzing Technologies 1986b, 1987). Dissolved organic carbon (DOC) was measured following removal of inorganic-C via acid sparging, then digested with acid persulfate and high-energy UV. Resultant CO_2 was reacted with buffered phenolphthalein and measured at 550 nm (Goulden and Brooksbank 1975; Bran+Luebbe Analyzing Technologies 1989). All procedures were run on a TrAAcs 800 automated analyzer (Bran+Luebbe Inc., Buffalo Grove, IL).

RESULTS AND DISCUSSION

Relatively high macroalgal species richness characterized each of the sites on the McKenzie River, with between 8 and 11 species observed per sample reach (Table 1). This compares with an average of 3.1 macroscopic algal species per reach, compiled from a survey of 1000 stream sites across North America

(Sheath and Cole 1992). In all McKenzie River sites, there were visually apparent tufts and crusts of algae that could easily be seen when wading the river. The most obvious photosynthetic organisms were large green tufts of the aquatic moss *Fontinalis* (probably *F. antipyretica*) and the foliose green alga *Prasiola mexicana*, both of which are large enough to be spotted from the riverbank. Several other species observed in the McKenzie, notably the cyanobacteria *Nostoc parmeliioides* and *N. verrucosum*, which have been frequently observed to co-occur with *Heribaudiella* elsewhere in the world (Holmes and Whitton 1975a, 1975b, Kann 1978, Wehr and Stein 1985). The apparent absence of *Cladophora glomerata* in the McKenzie is somewhat unusual for sites where *Heribaudiella* has been observed (Holmes and Whitton 1975a, 1975b, 1977b, Wehr and Stein 1985). Although sample reaches were sampled on different years, it is possible that temperature conditions on the sample dates (July through September) may have precluded the presence of *Cladophora* in the McKenzie River,

TABLE 1. Identification and percent cover estimates of common macroalgal species observed co-occurring with *Heribaudiella* in 3 sample reaches of the McKenzie River during summer and early autumn between 1997 and 1999 (numbers refer to sites shown on Figure 1; cover classes: 0 = absent; 1 = >0% to 1%; 2 = >1% to 10%; 3 = >10% to 25%; 4 = >25% to 50%; 5 = >50%).

Class / Division Species	1: Lost Creek trail	2: McKenzie Bridge	3: Ranger station
	August 1997	July 1998	September 1999
Cyanobacteria			
<i>Chamaesiphon incrustans</i>	2	0	1
<i>Nostoc parmelioides</i>	2	2	2
<i>N. verrucossum</i>	3	2	3
<i>Phormidium</i> cf. <i>autumnale</i>	1	2	3
Rhodophyta			
<i>Audouinella</i> cf. <i>hermannii</i>	0	1	1
Chlorophyta			
<i>Klebsormidium rivulare</i>	0	0	2
<i>Prasiola mexicana</i>	3	2	0
<i>Spirogyra</i> sp. (sterile)	2	1	1
<i>Ulothrix zonata</i>	0	0	2
<i>Zygnema</i> sp. (sterile)	1	1	1
Chrysophyta			
<i>Hydrurus foetidus</i>	0	0	2
Phaeophyta			
<i>Heribaudiella fluviatilis</i>	3	3	2
Total macroalgal species	8	8	11

as the late August temperature was rather cool (11°C). Nonetheless, this watershed does exhibit greater macroalgal biodiversity than other similar-sized rivers. Perhaps coincidentally, a new genus and species of red alga, *Rhododraparnadia oregonica*, was discovered in an adjacent stream about 7 km north of the McKenzie (Sheath et al. 1994).

The population of *Heribaudiella fluviatilis* from Oregon is quite typical of the species, which forms distinct, dark brown or reddish brown patches on several types of rock (sandstone, granite, and various metamorphic rocks), with colonies ranging from a few millimeters to greater than 5 cm in diameter (Fig. 2A). Colonies of this alga can be distinguished by their usually circular or at least regular outline, with definite margins and slightly raised (ca. 0.5–1.0 mm), but smooth, surface. Other dark patches on other rocks include aquatic lichens (e.g., *Verrucaria* sp.), which are nearly black in color and often have raised papillae, or encrusting cyanobacteria (e.g., *Chamaesiphon* spp.); they typically have indefinite margins and appear macroscopically as brown or reddish brown smudges. *Heribaudiella* can be distinguished with certainty microscopically from these other forms. As is typical of the species, the Oregon population possessed

the 2 definite growth forms: (1) a complex, multi-branched, prostrate array of narrow (ca. 7.0–8.5 [occasionally 10.0] µm diameter) filaments (Fig. 2B), and (2) a series of sparingly (dichotomously) branched and broader (ca. 11.0–13.0 [to 19 µm basally] diameter), erect filaments (Fig. 2C). Cells comprising vertical filaments contain many golden brown chloroplasts (Fig. 2D) and occasionally dark brown storage bodies known as physodes (Chadefaud 1950). The upright filaments often possess swollen, terminal unilocular sporangia (Fig. 2E), which produce zoospores and occasionally narrower, divided plurilocular sporangia (not seen in this population; see Svedelius 1930).

Ecological data for the McKenzie River (Lost Creek trail site; Table 2) suggest that conditions are similar to those where populations in

Fig. 2 (facing page). Photographs of *Heribaudiella fluviatilis* from the McKenzie River (A = macroscopic appearance of crusts on a rock [scale = 1 cm]; B = horizontal series of multiply branched filaments that form the crust [scale = 50 µm]; C = typical appearance of the vertical growth form in a series of erect filaments [scale = 10 µm]; D = detail of cells, showing multiple golden brown chloroplasts [scale = 10 µm]; E = detail of terminal unilocular sporangium [scale = 10 µm]).

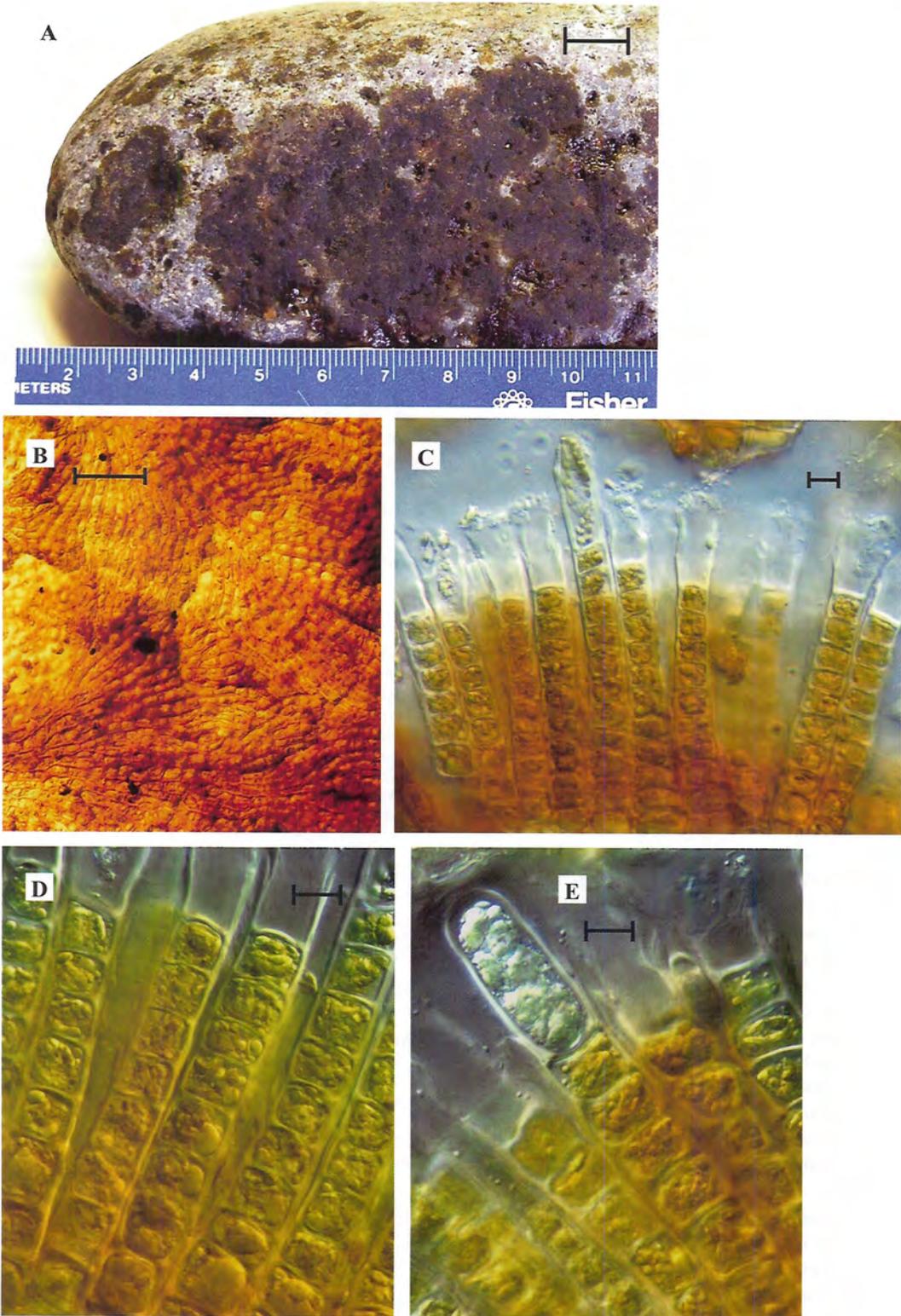


TABLE 2. Selected ecological properties of the McKenzie River, Lost Creek trail site, August 1997 (means based on 3 spatially separate measurements at the single study reach [exception: $n = 1$ for temperature]).

Variable (units)	Value
Mean depth (cm)	90.0
Mean width (m)	35.0
Temperature ($^{\circ}\text{C}$)	11.0
Current velocity ($\text{cm} \cdot \text{s}^{-1}$)	70.5
Inorganic-P ($\mu\text{g P} \cdot \text{L}^{-1}$)	65.2
NO_2^- ($\mu\text{g N} \cdot \text{L}^{-1}$)	2.0
NO_3^- ($\mu\text{g N} \cdot \text{L}^{-1}$)	5.9
NH_4^+ ($\mu\text{g N} \cdot \text{L}^{-1}$)	64.9
pH	7.8
Dissolved organic C ($\text{mg C} \cdot \text{L}^{-1}$)	1.8

British Columbia and the U.K. have been described (Holmes and Whitton 1977a, 1977b, Wehr and Stein 1985). Like most other *Heribaudiella* sites, the McKenzie is fairly broad and deep, with rapid current velocity. Dissolved phosphorus ($65.2 \mu\text{g} \cdot \text{L}^{-1}$) and NH_4^+ ($64.9 \mu\text{g N} \cdot \text{L}^{-1}$) levels in this river were higher than the averages recorded for other North American sites (British Columbia average $\approx 12 \mu\text{g P} \cdot \text{L}^{-1}$ and $17 \mu\text{g N} \cdot \text{L}^{-1}$), but similar or greater concentrations have been observed in sites from the U.K. (e.g., Holmes and Whitton 1975, 1977a, 1977b). Nutrient levels in the Oregon site may be influenced by soils, vegetation, or climate conditions that likely differ from the more northern British Columbia locations. High water clarity is another important but not easily quantified feature of this stream, consistent with other *Heribaudiella* sites. Thus far, few or no populations of this alga are known from sites that are silty or even slightly turbid. It is unclear what factor(s) may have led to the presence of this freshwater brown alga in the McKenzie River, but it is clearly a well-established and apparently vigorous population. It seems likely that additional populations of *Heribaudiella fluviatilis* will be discovered in other areas of North America with further study, but its means of dispersal is still unknown.

This collection of *Heribaudiella fluviatilis* is the 1st record of this genus and species (as well as any freshwater phaeophyte) for Oregon. It is also a range extension within North America of approximately 380 km south from the next nearest known population (Peshastin Creek,

WA; West 1990). This report on the McKenzie River and other algal studies in this watershed (e.g., Sheath et al. 1994) suggest that this region may be an area of greater and perhaps unusual algal biodiversity, and deserving of further careful study. A study of riparian plant communities within the McKenzie River region also reported exceptional species richness, although riparian corridors were very susceptible to invasions by exotic species (Planty-Tabacchi et al. 1996). Efforts to further describe and perhaps protect the aquatic biodiversity in parts of Oregon, therefore, seem warranted.

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