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Distribution and ecology of freshwater Ostracoda (Crustacea) collected from springs of Nevada, Idaho, and Oregon: a preliminary study

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DISTRIBUTION AND ECOLOGY OF FRESHWATER OSTRACODA (CRUSTACEA) COLLECTED FROM SPRINGS OF NEVADA, IDAHO, AND OREGON: A PRELIMINARY STUDY

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ABSTRACT.—Fourteen freshwater ostracod species collected from 24 springs in Nevada, Idaho, and Oregon between 1991 and 1994 were classified. Their ecology, based on major water parameters (i.e., temperature, dissolved oxygen, pH, conductivity), and biogeographical distribution in North America were studied. Among these 14 species, 9 (*Ilyocypris bradyi, I. gibba, Darwinula stevensoni, Candona candida, Heterocypris incongruens, Herpetocypris reptans, H. chevreuxi, Prionocypris canadensis, P. longiforma*) are new records for Nevada's ostracod fauna, while 3 (*H. reptans, P. canadensis,* and *Cypria turneri*) are new species for Oregon. *H. reptans, P. canadensis,* and *Heterocypris salina* are also recorded as new for the ostracod literature of Idaho. *Scottia pseudobrowniana,* collected from Nevada, is a new ostracod species for the United States. The occurrence of 5 Holarctic species in the northern Great Basin area may suggest a possible historical relationship with the European ostracod fauna.

Key words: Ostracoda, springs, distribution, ecology, new records, Scottia pseudobrowniana.

Ostracods, in general, can be found in most types of water including fresh, brackish, and saline, as well as their combinations. Because they are sensitive to changes in their aquatic environment, ostracods are useful as indicators of physical and chemical conditions. For example, seasonal variations in water temperature may affect their distribution, life span, and abundance (Külköylüoĝlu 1998).

Although ostracods are important in both biological and paleontological studies and previous studies indicate high and unique species richness and biogeographic distribution in the United States, modern investigations of species composition of freshwater ostracod faunas (particularly in the western United States) give comparatively incomplete listings. Tressler (1959) listed 193 species known to occur in North America. Most species in his list have been studied in specific regions, i.e., Ohio (Furtos 1933), Washington (Dobbin 1941), Illinois (Hoff 1942), Iowa (Danforth 1948), south central Texas (Wise 1961), and Gull Lake, Michigan (McGregor 1972). According to Pennak (1989), more than 300 freshwater ostracods are known from the United States. However, most recent works, particularly in western and central Minnesota, eastern South Dakota, and northern North Dakota, indicate a much higher number (Smith 1993). For example, in her study, Smith was able to record 26 species from 38 lakes.

Despite incomplete data or species listings, such studies contribute important information concerning relationship(s) between species occurrence/absence and both physical and ecological factors. Knowing the biogeographic distribution of a particular ostracod, for example, can reveal evidence of correlations with temperature (Forester 1991), ion composition, and historical events (Baltanás et al. 1990).

Geographic distributions of some taxa, including some subsurface ostracods, may be due to either passive or active dispersal processes (Danielopol et al. 1994). Individuals, generally eggs, can be carried passively by some insects (Bronstein 1947, Fryer 1953), snails (Sohn and Kornicker 1972), amphibians (Seidel 1989), fish (Kornicker and Sohn 1971, Victor et al. 1979, Vinyard 1979), birds (Löffler 1964, Proctor 1964, Frith 1967, De Deckker 1977, Scharf 1988), waterfowl (De Deckker 1983), and man, through accidental transportation (Bronstein 1947). Additionally, ostracods can extend their distribution actively by swimming.

The purpose of this preliminary study was to investigate the distribution, ecology, and diversity of freshwater ostracods by examining

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their relationships with selected parameters in springwaters.

MATERIALS AND METHODS

Samples were collected with a hand dip net from 24 springwaters (16 in Nevada, 5 in Idaho, and 3 in Oregon; Fig. 1) between 1991 and 1994. After water parameters were measured in the field, samples were fixed in 10% formalin and subsequently stored in glass jars in 70% ethanol. In the laboratory, species were separated from other materials with standard sieves (0.25-, 0.5-, 1.0-, 2.0-mm mesh sizes) under pressurized tap water. We dissected specimens in lactophenol; valves were then separated from the soft body, which was also dissected. Species were identified based on both soft body parts and valve morphology. Drawings were made with camera lucida. All materials were archived in the Department of Biology, University of Nevada, Reno.

TAXONOMY

In this study we followed the systematic key of Hartmann and Puri (1974), but other important studies (e.g., Sars 1926, Klie 1938, Bronstein 1947, Delorme 1970, Kempf 1997) were also useful during species description and identification. Two superfamilies, represented by 4 families and 10 genera, were found

Phylum or subphylum: CRUSTACEA Pennant, 1777
Class: OSTRACODA Latreille, 1806
Order: PODOCOPIDA Sars, 1866
- Superfamily: Darwinuloidea Brady and Norman, 1889
  - Family : Darwinulidae Brady and Norman, 1889
    - *Darwinula stevensoni* (Brady and Robertson, 1870)
- Superfamily: Cypridoidea Baird, 1845
  - Family: Ilyocyprididae Kaufmann, 1900
    - *Ilyocypris bradyi* Sars, 1890
    - *Ilyocypris gibba* (Ramdohr, 1808)
  - Family: Candonidae Kaufmann, 1900
    - Subfamily: Candoninae Kaufmann, 1900
      - Genus: *Candona* Baird, 1842
      - *Candona candida* (O.F. Müller, 1776)
    - Subfamily: Cyclocypridinae Kaufmann, 1900
      - Genus: *Cypria* Zenker, 1854
      - *Cypria turneri* Hoff, 1942
  - Family: Cyprididae Baird, 1845
    - Subfamily: Scottinae Bronstein, 1947
      - Genus: *Scottia* Brady and Norman, 1889
      - *Scottia pseudobrowniana* Kempf, 1971
    - Subfamily: Cyprinotinae Bronstein, 1947
      - Genus: *Heterocypris* Claus, 1892
      - *Heterocypris salina* (Brady, 1868)
      - *Heterocypris incongruens* (Ramdohr, 1808)
    - Subfamily: Herpetocypridinae Kaufmann, 1910
      - Genus: *Herpetocypris* Brady and Norman, 1889
      - *Herpetocypris chevreuxi* (Sars, 1896)
      - *Herpetocypris reptans* (Baird, 1835)
      - Genus: *Prionocypris* Brady and Norman, 1896
      - *Prionocypris canadensis* (Sars, 1926)
      - *Prionocypris* (*Strandesia*) *longiforma* (Dobbin, 1941)
    - Subfamily: Cypridinae Baird, 1845
      - Genus: *Cypris* Müller, 1776
      - *Cypris* sp.
    - Subfamily: Cypridopsinae Kaufmann, 1900
      - Genus: *Cavernocypris* Hartmann, 1964
      - *Cavernocypris subterranea* (Wolf, 1920)

ECOLOGY AND DISTRIBUTION

Darwinula stevensoni

MATERIAL.—10-24-92, St-13 (NV), 8♀. New record for Nevada.

DISTRIBUTION.—Atlanta-Georgia (Turner 1895, Furtos 1933); Illinois (Sharpe 1918, Hoff 1942, Tressler 1959); Lake Erie-Ohio, Massachusetts (Furtos 1933); Michigan (Furtos 1936, McGregor 1972); Texas, Kentucky, Tennessee (Cole 1966); Mississippi (McGregor 1969); Virginia (Elliot et al. 1966, Nichols and Ellison 1967); Florida, S. Carolina (McGregor 1972); Minnesota, S. Dakota, N. Dakota (Smith 1993); California (Külköylüoĝlu 1994).

ECOLOGY.—*Darwinula stevensoni* is a cosmopolitan (eurythermic) species (Bronstein 1947, Ranta 1979). Generally preferring low temperatures, the species can be found in waters with temperatures ranging between 10° and 35°C (Delorme 1991). Martens and Tudorance (1991) reported this species from

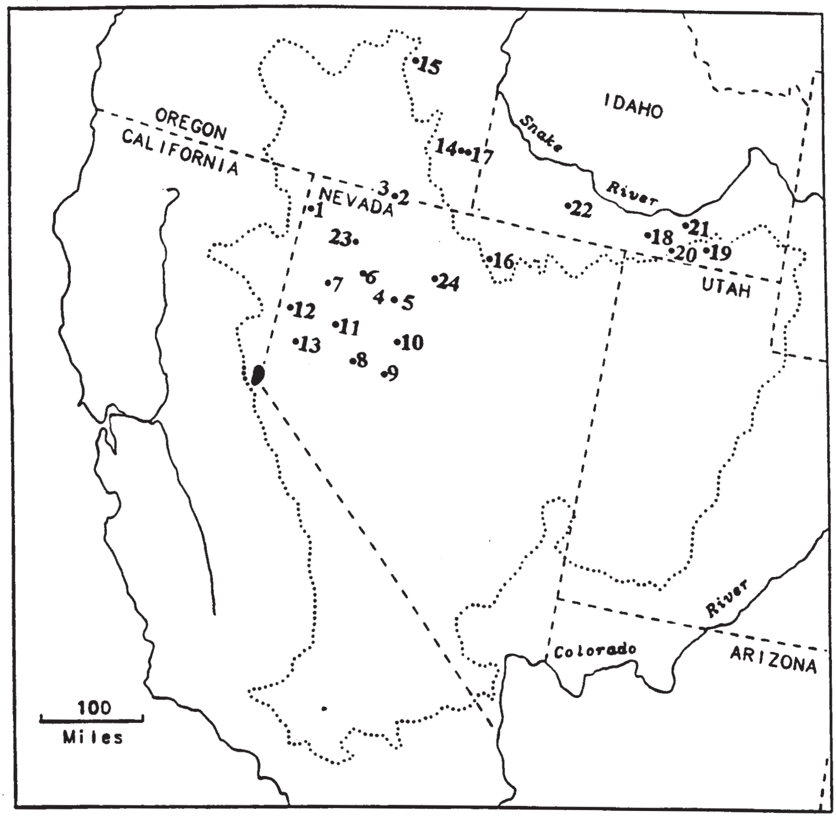

Fig. 1. Map showing 24 stations (springs) in 3 states; fine dotted line shows the Great Basin area.

water <2 m deep, with a pH range of 8.85–9.15, temperatures of 21.3° to 23.4°C, and conductivity (EC) between 300 and 400 μS cm^{-1}. However, a recent study (Smith 1993) showed that this range can be broader. In her study, Smith found *D. stevensoni* in waters with conductivity between 210 and 925 μS cm^{-1}. Salinity tolerance of this species varies from 800 mg L^{-1} (Neale 1964) to 2000–3000 mg L^{-1} (Hagerman 1967). However, the highest salinity reported with live specimens was 15,000 mg L^{-1} (Löffler 1961 in De Deckker 1981). On the other hand, this species was recovered from a depth of 12 m in Gull Lake, Michigan, where pH was between 7.5 and 8.5 (McGregor 1972). pH seems to be less important for this species' occurrence. It has been found in water with a pH as low as 6.0 (De Deckker 1981).

Darwinula stevensoni requires a high concentration of oxygen to aerate its eggs, and so it is found mostly in waters where DO level is relatively high. According to Delorme (1991), dissolved oxygen tolerance of this species is between 2 and 14 mg L^{-1}. Because of its lack of swimming setae, *D. stevensoni* is a benthic ostracod and can be found on muddy and sandy substrates with high DO. Also, it was found on *Phragmites* belt cores and marshes by Löffler (1990). Henderson (1990) collected the species from organic-rich substrates such as leaf litter. High population densities were reported from the boreal forest of the Canadian interior plains (Delorme 1970).

In this study we found this oxygen-sensitive species in a heavily grazed and trampled spring bottom comprising 50% silt, 30% sand, and 20% gravel and medium cobble. While conductivity was moderate (324 μS cm^{-1}), DO was relatively high (6.31 mg L^{-1}). It seems *D. stevensoni* prefers less saline but well-oxygenated waters. Some individuals, however, also may be found in high saline waters. Knowing the ecological and biological characteristics of this species can be useful in other disciplines such as paleontology, which uses the data to reconstruct past history and ecological changes in a particular region. For example, the fossil form of this species found from Pleistocene deposits in Illinois (Staplin 1963) suggests that water might have been relatively cooler and well oxygenated.

Ilyocypris bradyi

MATERIAL.—11-11-1992, St-2 (NV), 2♀; St-1 (NV), 1♀; 24-10-1992, St-13 (NV), 2♀. New record for Nevada.

DISTRIBUTION.—Colorado (Sharpe 1918); Lake Erie-Ohio (Furtos 1933); Illinois (Hoff 1942); Iowa (Danforth 1948); Wisconsin (Tressler 1959).

ECOLOGY.—*Ilyocypris bradyi,* a Holarctic species, inhabits the bottoms of pools, lakes, and ponds, but it also is common in low-velocity running waters and springs (Bronstein 1947). This species is indicative of moderate current action (Staplin 1963). According to Henderson (1990), *I. bradyi* prefers cooler waters such as springs and permanent streams, but it also occurs in temporary ponds and lowland marshes. Most recent studies showed that *I. bradyi* can be found in the benthos of waters where temperatures vary between 10° and 27°C (Delorme 1991). Delorme also states that DO tolerance of the species is high, between 3 and 20 mg L^{-1}. A study in an alkaline lake (9–13 meq L^{-1}) in Austria by Löffler (1990) found the species in water with a conductivity level of 1000–2800 μS cm^{-1} at 20°C. The specimens in the present study were collected in the heavily grazed, trampled, silty bottom (50–70%) of a spring.

It appears to us that *I. bradyi* can be found mostly in cooler waters (14–25°C), with low to moderate conductivity (134–324 μS cm^{-1}), and where DO level may vary from 4 to 6.3 mg L^{-1}. The species should be considered to be limited within a narrow range of pH values (7.3–8.26). These factors all support the contention that *I. bradyi* prefers relatively less saline alkaline waters.

Ilyocypris gibba

MATERIAL.—24-10-1992, St-13 (NV), 1♀.

DISTRIBUTION.—Colorado (Sharpe 1918, Furtos 1933); Ohio (Furtos 1933); Illinois (Hoff 1942); Iowa (Danforth 1948). New record for Nevada.

ECOLOGY.—Only 1 individual was identified. It was collected at a site where the bottom was grazed, trampled, and chopped up. *Ilyocypris gibba,* a cosmopolitan species, is usually found with its close relative *I. bradyi*. Hoff (1942) emphasized that *I. gibba* was abundant chiefly in running waters. Forty-one of his 44 collections were from streams, rivers, and pools. In the streambed he found a possible relationship between species occurrence and vegetation or algal masses.

Not only does *I. gibba* prefer the vegetated bottom of lotic waters, but it also lives on the sandy bottom of large and small lakes. It is possible to find this species in almost all types of water bodies—rivers, oxbows, canals, ponds, and lakes—because *I. gibba* has the advantage of being able to use the long swimming setae on its 2nd antennae (swimming setae are reduced in *I. bradyi*). In addition, it displays a wide range of tolerance to water quality parameters; for instance, its tolerance to total dissolved solids ranged from 0.09 to 6.5 (Delorme 1991). DO requirement of *I. gibba* seems to be narrower (3–14 mg L^{-1}) than *I. bradyi* (Delorme 1991). Like *I. bradyi, I. gibba* shows a wide range of temperature tolerance, between 10° and 30°C. However, this species' temperature tolerance can be much higher. Gülen (1977) was able to collect *I. gibba* from a hot spring where temperatures measured 38°–42°C with pH of 6.64. In his study Löffler (1990) pointed out that *I. gibba* was abundant on *Phragmites* belt cores and marshes where alkalinity was about 9–13 meq L^{-1}, and conductivity varied between 1000 and 2800 μS cm^{-1} at 20°C. Our results correspond with these studies. For example, we found this species in springwater with moderate EC value (324 μS cm^{-1}), where pH was relatively high (8.26 at 25°C) and DO was relatively high (6.31 mg L^{-1}). Data gained from previous studies as well as the present study suggest that DO and perhaps pH (but not temperature) are the 2 most important factors to which *I. gibba* is sensitive.

Candona candida

MATERIAL.—06-12-1991, St-1 (NV), 4♂ 5♀.

DISTRIBUTION.—Massachusetts (Cushman 1907, Sharpe 1918); Oregon (Dobbin 1941); Montana (Tressler 1947, 1959). New record for Nevada.

ECOLOGY.—*Candona candida,* one of the most common candonid species, can be found in shallow temporary ponds, ditches, lakes, waters left by rain or streams, and permanent waters with a muddy substrate. Bronstein (1947) reported this species from a deep lake (250 m) in the Soviet Union, but it was also collected from *Phragmites* marshes and belt cores of alkaline lakes (Benzie 1989, Löffler 1990). *Candona candida* tolerates low pH values, around 4.6, in peat bogs (Henderson 1990) and acidic moorland tarns (Fryer 1980). According to Delorme (1991), *C. candida* is common in waters where pH varies between 5.4 and 13. Delorme states that this species can resist up to 15 mg L^{-1} and 30°C on water bottoms. He also emphasized that *C. candida* was recovered from water with zero oxygen and zero temperature. All this offers evidence that temperature and DO ranges of this species are fairly broad, and thus it is not surprising to find *C. candida* in brackish waters. The present study reports *C. candida* from 4 cm deep in an 80% silt-bottomed spring where pH was 7.3, temperature was 20°C, DO was ~4 mg L^{-1}, and conductivity was low at 134 μS cm^{-1}. Staplin (1963) found some fossilized individuals of this species from silt deposits in Illinois. This may suggest that bottom type, rather than temperature and pH, is the most important factor for the occurrence of some ostracods.

REMARKS.—This is one of the most confusing species inasmuch as it shows variations on its valve structure. Our specimens also show some slight differences, indicating a subspecies. Holarctic distribution (?).

Cypria turneri

MATERIAL.—06-30-1993, St-15 (OR), 2♀.

DISTRIBUTION.—According to Hoff (1942), until his complete description of species from Illinois, *C. turneri* had been reported from different parts of the United States under the names *C. exsculpta* or *C. elegantula.* It was first reported from Alabama by Herrick (1887) as *C. exsculpta*; then several authors reported it from Ohio, Georgia, Delaware (Turner 1894), Illinois (Sharpe 1897, Kofoid 1908, Shelford 1913), and Maine (Procter 1933). Under the name *C. elegantula,* it has been known from Ohio (Furtos 1933), Washington, and Alaska (Dobbin 1941). The species has been known under the name *C. turneri* from Iowa (Danforth 1948), Tennessee, Mississippi, Virginia, S. Carolina, Wisconsin, Michigan, Utah (Tressler 1959, McGregor 1972), and Mirror Lake, New Hampshire (Strayer 1985, 1988). It is a new record for Oregon.

ECOLOGY.—*Cypria turneri* is one of the most abundant species in most permanent water bodies of the United States. It is possibly Nearctic under the name *C. turneri*. In 1897, Sharpe found this species in streams, although Hoff (1942) pointed out that he never collected it from running waters. It often can be found associated with water plants, algae, and grass (Hoff 1942), and feeds on detritus and small diatoms (Strayer 1985). An extensive study of the species by McGregor in Gull Lake, Michigan, in 1972 yielded data concerning its abundance. In Gull Lake abundance was essentially the same year-round from depths of a few millimeters to 32 m. A large population of the species was found to be restricted to oxygenated parts of the Gyttja, a soft, highly organic sediment, under 11-m-deep water of Mirror Lake in New Hampshire (Strayer 1988).

We found this species from a depth of 5 cm in a shallow spring located within a livestock exclosure where flow velocity inside the exclosure was reduced by abundant vegetation. Our result is consistent with previous studies and suggests that *C. turneri* can be seen in both limnic and lentic aquatic habitats, that it prefers cold (8.5°C) waters with high DO values (8.6 mg L^{-1}), but that it also may be found in supersaturated and relatively warmer waters (personal observation). We may conclude from this that oxygen dependency of the species, rather than other parameters, plays an important role in its occurrence.

Scottia pseudobrowniana

MATERIAL.—10-24-1992, St-13 (NV), 3♀ 2♂.

DISTRIBUTION.—New record for the USA.

DESCRIPTION.—Length of male is 0.70 mm, height 0.38 mm, and width 0.40. Females are similar to males in shape. Edges of valves are not tuberculated; left valve overlaps right at the anterodorsal side and exceeds it slightly at the posterior, which is not pointed in dorsal view (Fig. 2a). In dorsal view, left valve shows a projecting part on the right valve anteriorly. Dorsum is slightly curved. Viewed laterally (Fig. 2b), the posterior side shows distinctly more gibbosity than the anterior region in both valves. First antenna (Fig. 2c) is 6-segmented, and the 2nd antenna (Fig. 2d) is

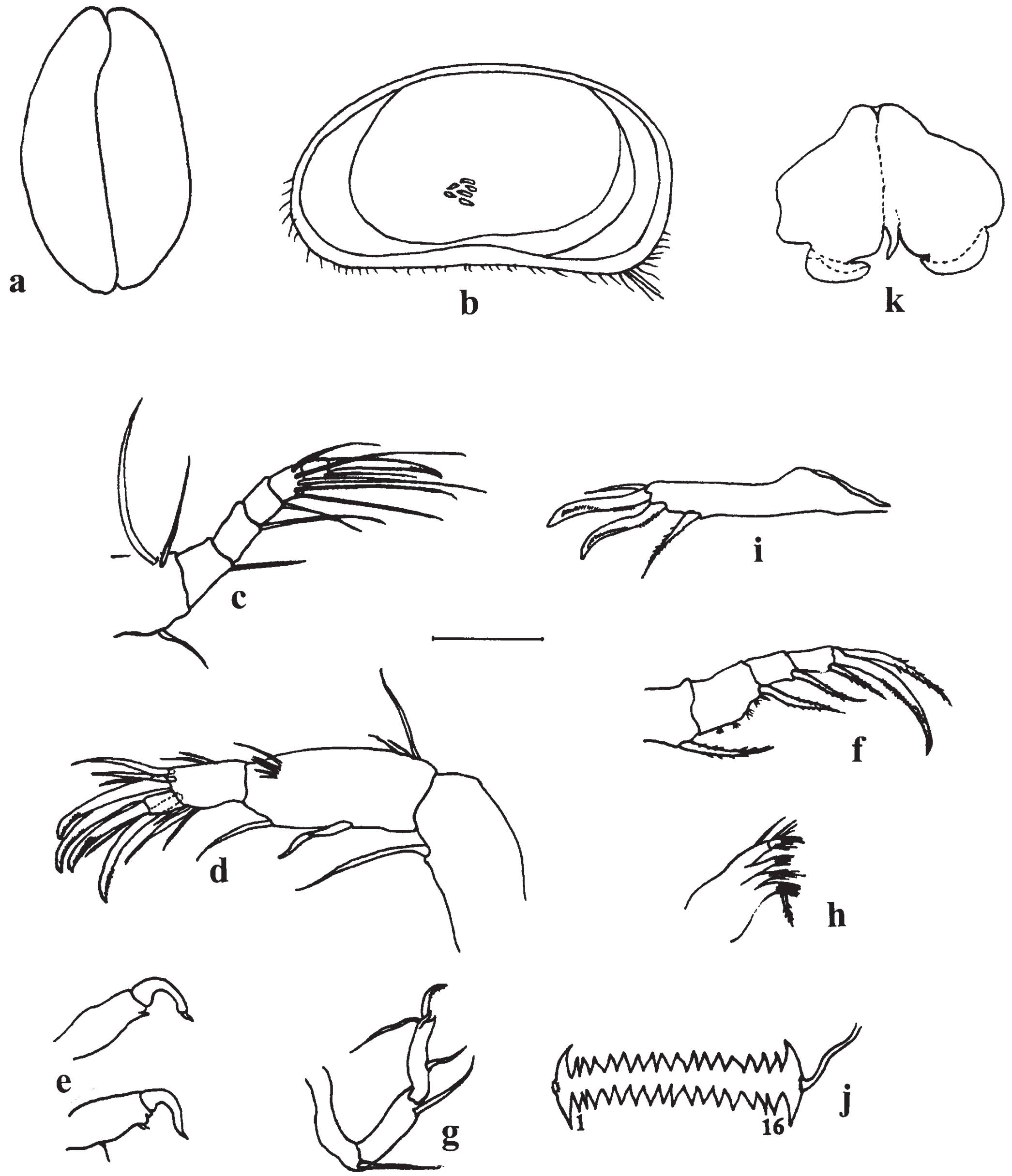

Fig. 2. *Scottia pseudobrowniana:* a, male seen from above; b, right valve, inner view; c, 1st antenna; d, 2nd antenna; e, palps of 1st thoracic leg; f, 2nd thoracic (walking) leg ending with 2 claws; g, 3rd thoracic (cleaning) leg; h, maxilla; i, furca; j, Zenker organ with 16 whorls; k, hemipenis. Scale bar: 200 μm for a and b; 100 μm for c, d, f, and g; 40 μm for e and h; 50 μm for i, j, and k.

4-segmented. Natatory setae of 2nd antenna are reduced and do not reach to the distal end of the penultimate segment. A pair of 1st thoracic legs are formed as prehensile palps in males (Fig. 2e). Second thoracic legs (Fig. 2f) are 5-segmented and end with 2 claws on the apical segment. This is one of the most important diagnostic structures of the genus. Figures 2g and 2h show 4-segmented 3rd thoracic (cleaning) leg and maxilla, respectively. Furca is well developed and ends with 2 strong claws (Fig. 2i). Zenker organ bears 16 whorls (Fig. 2j). Males also possess a complex hemipenis lobed at the basal region (Fig. 2k).

REMARKS.—Until the revision of the genus by Kempf (1971), live specimens of this genus were misidentified as *S. browniana,* which was first described from Pleistocene freshwater deposits of Clacton, England, by Jones (1850). However, Kempf showed that fossil forms (*S. browniana*) were congeneric with modern live specimens (*S. pseudobrowniana*), but they were not conspecific (Kempf 1971, 1994). The 1st known species of the genus *Scottia* from the United States was described under the name *S. browniana,* which was collected from Tennessee by Cole (1966). However, her description was based on illustrations and descriptions of Alm (1915), Klie (1938), and Bronstein (1947), which are now known to be possibly *S. pseudobrowniana* (Kempf 1971, 1994). On the other hand, in this study our description consists of both illustrations and descriptions from the literature including Kempf's revision (1971) and live specimens obtained from Dr. Huw I. Griffiths (England). As a result, we were able to distinguish the species *Scottia pseudobrowniana* Kempf 1971 from *S. browniana* (Jones 1850) Brady and Norman 1889. A detailed description of the species can be found in Kempf (1971, 1994).

ECOLOGY.—Live individuals of the genus *Scottia* were first described from pools in the Island of Bute, Scotland, by Brady and Norman (1889, 1896). Bronstein defined the species (as *S. browniana*) from springs of Russia in 1947 and noted that his collection site was surrounded by woody plants that prevented the springwater from receiving direct sunlight. He called the species a "crenobiont," implying a cold-springwater species. Similarly, Kempf (1971) stated that *S. pseudobrowniana* was a cold-spring freshwater ostracod that is also reported from cold freshwaters in northern Europe and Great Britain (Henderson 1990).

The genus *Scottia* is also known in the United States as a semiterrestrial species found primarily in groundwater discharge areas such as springs and seeps (Forester personal communication). It can be seen in fen wetlands walking around on *Chara* patches or in wetland soil (Smith personal communication). Because of its lack of swimming setae, this species is considered to be bottom dependent and is generally found with other bottom-dependent species such as *D. stevensoni, I. bradyi, H. reptans, I. gibba,* and *H. chevreuxi* (the last 2 are also known as active swimmers).

In the present study, *S. pseudobrowniana* was collected from a spring at 1273 m elevation, where the water was relatively warm (25°C). This, plus other water parameters such as DO of 6.31 mg L^{-1}, pH of 8.26, and EC of 324 μS cm^{-1}, indicates that alkaline waters are more preferred by this species. This study also extends the zoogeographic distribution of the species from the Palearctic to the Nearctic, thus a Holarctic distribution.

Heterocypris salina (=*Cyprinotus salinus)*

MATERIAL.—08-03-1993, St-18 (ID), 5♀; 08-05-1993, St-20 (ID), numerous ♀; 08-05-1993, St-19 (ID), 1♀. New record for Idaho.

DISTRIBUTION.—Texas (Tressler 1959); Arizona, Colorado, Nevada (Forester 1991).

ECOLOGY.—*Heterocypris salina,* a cosmopolitan species, is a typical halobiont (Bronstein 1947), but it is also common in coastal areas where it lives in brackish waters with salinities of 400–13,000 mg L^{-1} (Neale 1964). Ganning (1967) showed that its tolerance of salinity was very high, up to 20,000 mg L^{-1} (in Neale 1988). Similarly, current studies have found that this species can survive in saline waters, and Löffler (1990) suggested *H. salina* should be considered a "halophilic species," indicating tolerance of high saline (up to 25,000 mg L^{-1}) waters in Europe (De Deckker 1981).

In the western United States, *H. salina* commonly lives in springs and seeps, but it also is seen in streams, ponds, shallow parts of lakes, and salt marshes, from cooler to warmer waters (11°–>30°C) and from fresh to saline (750–>4000 μS cm^{-1}) waters (Forester 1991). Forester, who defined this species as "eurytopic," also reports the presence of *H. salina* from Zuni Salt Lake where conductivity is very high (>50,000 μS cm^{-1}). The species can be present at all times on muddy, sandy bottoms of permanent and temporary brackish water bodies. *Heterocypris salina* was abundant in station 20 where highest EC and temperature values were 1149 μS cm^{-1} and 29.5°C, respectively (lowest were 385 μS cm^{-1} and 11°C). On the other hand, pH values found in this study were 7.9–8.14, which may indicate some correlation between species occurrence and alkaline pH values.

Heterocypris incongruens

MATERIAL.—10-21-1992, St-12 (NV), 1♀; 11-11-1992, St-2 (NV), 4♀. New record for Nevada.

DISTRIBUTION.—Ohio (Turner 1895, Sharpe 1918, Furtos 1933); Florida (Sharpe 1897, 1918); Pennsylvania (Sharpe 1908); Oregon (Dobbin 1941); Illinois (Hoff 1942); Iowa (Danforth 1948); N. Carolina, Utah, Wisconsin, Michigan (Tressler 1959); Wyoming, Colorado (Forester 1991, Forester and Smith 1992); Arizona, Utah, New Mexico, Kansas (Forester and Smith 1992).

ECOLOGY.—*Heterocypris incongruens* is cosmopolitan. It can be found in almost any water type, limnic or lotic, temporary or permanent, small puddles, ponds, and ditches. Apparently, it shows no strict ecological requirements in fresh to saline waters with salinities up to 20,000 mg L^{-1} (De Deckker 1981). Forester (1991) emphasized that even though *H. incongruens* lives in seeps, ponds, marshes, and the edges of lakes, it is not found in high-volume-drainage springs. Moreover, it is found in waters from 6°C to 28°C. The occurrence of the species could be related to the calcium and carbonate level (more than 25–30%) in freshwaters with a range of salinity between 100 and 2500 $\mu S\ cm^{-1}$ (Forester 1991, Forester and Smith 1992). Due to its tolerance of high salinities, this species, like *H. salina,* can be called a "eurytopic species" (Forester 1991). *Heterocypris incongruens* in this study was collected from an unnamed, heavily grazed springwater impounded from the source (water parameters are given in Table 1).

Herpetocypris chevreuxi

MATERIAL.—07-21-1993, St-7 (NV), 2♀; 12-11-1992, St-4 (NV), 1♀; 10-24-1992, St-13 (NV), 9♀; 08-17-1993, St-8 (NV), numerous ♀; 07-15-1993, St-16 (NV), 12♀.

DISTRIBUTION.—Utah (Tressler 1959). New record for Nevada.

ECOLOGY.—This species was first raised from dried mud samples taken from Algeria in the aquarium by Sars (1896). Thirty years later Sars (1924) redescribed the species under the name *H. chevreuxi*. It is not common in the United States. Bronstein (1947) believed that *H. chevreuxi* could be found in both brackish waters and freshwaters. More detailed data can be obtained from the study by Baltanás (1992), who concludes that *H. chevreuxi* prefers stagnant waters but also occurs in slightly saline aquatic habitats including rivers. One study also showed that it was present in rice fields (Fores et al. 1986). Nevertheless, *H. chevreuxi* was reported from hot-water springs and swamps, canal waters, ponds, and small lakes in Turkey (Gülen 1977, 1985), and also from well-oxygenated waters covered by algae and water plants (personal observation). In Britain this species was plentiful over coarse substrates (Henderson 1990).

Like most other freshwater ostracods, little is known about its natural history; therefore, this present study may guide future researchers in understanding the ecological requirements of this species. Our results suggest this Holarctic species prefers less alkaline (pH 8.0 or more) and relatively cooler waters (15–24°C) with high DO (6.3–8 mg L^{-1}). Additionally, finding this species in waters with 80% silty bottoms may indicate habitat preferences.

Herpetocypris reptans

MATERIAL.—06-04-1993, St-14 (OR), 42♀; 07-27-1993, St-17 (OR), 1♀; 08-05-1993, St-22 (ID), 1♀; 08-17-1993, St-11 (NV), 1♀; 11-11-1992, St-3 (NV), numerous ♀; 10-21-1992, St-11 (NV), 2♀; 11-11-1992, St-2 (NV), numerous ♀ and juvenile; 11-11-1992, St-1 (NV), 2♀; 10-24-1992, St-13 (NV), 7♀; 07-07-1992, St-9 (NV), 5♀. New record for Nevada, Idaho, and Oregon.

DISTRIBUTION.—California (Sharpe 1918); Washington (Dobbin 1941).

ECOLOGY.—Known as a cosmopolitan species, *H. reptans* lives mostly on the muddy bottoms of lakes and ponds, and in streams with laminar flow. We believe that bottom type alone is not crucial for its occurrence, but according to Bronstein (1947), vegetation richness and types may be important. In fact, these suggestions coincide with one of the earliest experimental studies done under laboratory conditions by Benzie (1989). Benzie recorded that distribution of the species was affected by food supply on fine-grained sediments where *H. reptans* was abundant in *Eleocharis* (macrophyte) habitat (old *Eleocharis* and *Chara* were preferred as food). The paucity of the species found by Benzie was also related to predation. According to Benzie, there was a strongly negative correlation between presence of black

TABLE 1. Data collected from 24 stations. Species initials are as follows: (IB) *Ilyocypris bradyi*, (IG) *I. gibba*, (DS) *Darwinula stevensoni*, (CO) *Candona candida*, (CP) *Cypria turneri*, (HS) *Heterocypris salina*, (HI) *H. incongruens*, (HC) *Herpetocypris chevreuxi*, (HR) *H. reptans*, (CD) *Cavernocypris subterranea*, (CR) *Cypris* sp., (PC) *Prionocypris canadensis*, (PL) *P. longiforma*, (SB) *Scottia pseudobrowniana*. St. no. represents the number of the spring. Location for each spring is given in elevation in meters (El. [m]) and UTM coordinates of latitude (Lat.) and longitude (Long.). Water parameters measured include temperature (T°C); dissolved oxygen (DO), mg L^{-1}; electrical conductivity (EC), $\mu S\ cm^{-1}$; and pH.

St. no.	Lat.	Long.	El. (m)	T°C	DO	EC	pH	Initials of species
1	41.825	119.85	1667	19.5	3.8	134	7.30	IB, CO, HR, CR, PL
2	41.987	118.69	1595	17.5	6.4	312	7.80	IB, HI, HR, PL
3	41.987	118.70	1545	11.2	7.6	197	7.67	HR, PL
4	41.182	118.16	1273	5.7	7.6	556	8.02	HC, PL
5	41.315	118.51	1333	11.0	8.3	462	8.02	PL
6	41.315	118.50	1351	11.4	8.3	637	8.03	PL
7	41.091	119.15	1345	18.8	7.9	446	8.44	HC
8	40.322	118.14	1849	19.3	7.8	618	8.59	HC
9	40.213	117.82	1406	18.7	5.3	NA	7.92	HR
10	40.731	117.66	1764	11.3	7.1	495	7.99	PL
11	40.417	118.86	1491	19.9	5.2	450	7.70	HR
12	40.914	119.45	NA	NA	NA	NA	NA	HI, HR
13	40.051	119.39	1273	24.8	6.3	324	8.26	IB, IG, DS, HR, HC, SB
14	42.802	117.73	1291	17.6	6.5	401	8.01	HR, PC
15	44.037	118.45	1709	8.5	8.6	140	7.40	CP
16	41.472	116.53	1691	16.2	NA	231	7.60	HC, PC
17	42.791	117.60	1133	19.7	6.4	521	8.90	PR
18	42.335	113.40	1491	13.6	NA	385	7.90	HS, PC
19	42.484	112.06	1842	9.6	NA	528	7.73	CD
20	42.391	112.87	1485	29.5	NA	1149	7.95	HS
21	42.559	112.77	1667	11.0	NA	438	8.14	HS, PL
22	42.544	114.94	1188	20.9	NA	619	8.20	HR
23	41.595	118.85	1370	21.1	7.5	196	7.33	PL
24	41.446	117.08	1400	14.8	4.5	308	8.10	PL

mites (*Piona* sp.) and *H. reptans* abundance. When mites were present, the number of *H. reptans* individuals found was very low or vice versa.

Benzie's study indicates that abundance and occurrence of this species can be associated with presence of predators in the water. This species tolerates a wide range of salinity, from 1000 to 16,000 mg L^{-1} in European waters (De Deckker 1981). In this study conductivity was moderate to high (134–619 $\mu S\ cm^{-1}$), and pH values were 7.3–9.0. Also, it seems that *H. reptans* can be found in a broad range of DO values (3.8–7.6 mg L^{-1}; see Table 1). The occurrence of this species within a wide ranges of water parameters may indicate its high endurance and adaptation to various habitats. This may also explain why *H. reptans*, like *P. longiforma*, was among the most common species found in our study.

Prionocypris (Strandesia?) Canadensis

MATERIAL.—06-04-1993, St-14 (OR), numerous ♀; 08-03-1993, St-18 (ID), 6♀; 07-15-1993, St-16 (NV), 20♀. New record for Nevada, Idaho, and Oregon.

DISTRIBUTION.—Wyoming, Colorado (Forester 1991, Forester and Smith 1992).

ECOLOGY.—This historically Nearctic species was first identified from a small brook in Alberta, Canada, by Sars (1926) under the name *Prionocypris canadensis*. So far, it has not been reported from other parts of the world. One study showed that *P. canadensis* can live in permanent, high-volume-discharge springs, but not lacustrine environments (Forester 1991). It is generally restricted to dilute (75–1000 $\mu S\ cm^{-1}$) cold water (0–10°C), which is considered to be undersaturated relative to calcite formations (Forester and Smith 1992). Because of its cold-water preference, Forester (1991) called *P. canadensis* a "cryophilic or cryobiotic species." However, our study indicates that this restriction to low temperature by *P. canadensis* may not be as low as reported. For example, the lowest temperature we found in this study was 13.6°C, and the highest was 17.6°C. pH values seemed to be limited between 7.6 and 8.0 when conductivity measured 231, 385, and 401 from 3 stations, respectively. Even though our values, especially temperature values, are different from previous studies, we agree that *P. canadensis* prefers relatively cool waters with high DO levels (6.5 mg L^{-1} at station 14) and can be called a cryophilic species. In addition, it can be found in alkaline waters with pH values around 8.0 (and perhaps higher).

Prionocypris (Strandesia) longiforma

MATERIAL.—11-12-1992, St-6 (NV), 16♀ 8♂; 11-12-1992, St-5 (NV), 28♀ 11♂; 11-11-1992, St-2 (NV), numerous ♂ and ♀; 06-12-1991, St-1 (NV), numerous ♀ and ♂; 11-12-1992, St-4 (NV), 34♀ 8♂; 08-17-1993, St-10 (NV), 2♀ 2♂; 08-05-1993, St-19 (ID), 6♀ 21♂; 07-20-1994, St-24 (NV), 16♀ 7♂; 06-09-1994, St-23 (NV), 13♀ 6♂. New record for Nevada.

DISTRIBUTION.—Washington (Dobbin 1941).

ECOLOGY.—In 1941, Dobbin was the first to identify this species from the streams of Washington. So far, it is known only from the United States and thus may be considered a Nearctic species. The biology and ecology of this species are not well known. Like *H. reptans,* it is one of the most abundant species collected during this study. It was found in springs and streams where pH values ranged between 7.3 and 9.0 and water temperature was relatively cold (around 11°C). It was abundant on silty, sandy bottoms of springwaters with higher temperatures (21°C).

REMARKS.—According to Dobbin (1941), *P. longiforma* is different from its conspecific species *P. canadensis* based on length of the furcal setae. However, females of both species are morphologically very similar to each other. We think *P. longiforma* may be the bisexual form of *P. canadensis* (since *P. canadensis* is known as a parthenogenetic species). However, detailed comparison of the species is needed to support our view.

Cypris sp.

MATERIAL.—06-12-1991, St-2 (NV), 1♀.

REMARKS.—Only 1 female individual was found but could not be identified due to some suspicious structures on the valves and lack of additional specimens. All of the water parameters are given in Table 1 and may be helpful as a reference for future studies.

Cavernocypris subterranea

MATERIAL.—08-04-1993, St-19 (ID), 19♀ 6♂.

DISTRIBUTION.—Idaho, USA.

ECOLOGY.—*C. subterranea* is a crenobiont species inhabiting relatively slow-flowing cold springwaters. Its parthenogenetic populations can be found from rivers and alluvial bed sediments, caves, and littoral zones of mountain lakes (Marmonier et al. 1989).

REMARKS.—A full description of the 1st bisexual population of the species from Idaho can be found in Külköylüoĝlu and Vinyard (1998).

SUMMARY AND CONCLUSION

Among 14 freshwater ostracod species, *Scottia pseudobrowniana* was recorded from Nevada as a new species for the ostracod literature of the United States. Nine species are new for Nevada (*Ilyocypris bradyi, I. gibba, Darwinula stevensoni, Candona candida, Heterocypris incongruens, Herpetocypris reptans, H. chevreuxi, Prionocypris canadensis, P. longiforma*). Of these 9, *H. reptans* and *P. canadensis* are also new records for Oregon and Idaho. With the present study, distributions have been extended in the United States for *Heterocypris salina,* which was a new record for the ostracod literature of Idaho, and *Cypria turneri,* also the 1st record for Oregon. In addition, reporting 5 Holarctic species (*I. bradyi, C. turneri (exsculpta), H. chevreuxi, S. pseudobrowniana, Cavernocypris subterranea*) from the northern part of the Great Basin may suggest that many Palearctic species can be found in Nearctic regions, thus demonstrating a possible historical relationship between these 2 land masses. On the other hand, finding 6 cosmopolitan and 3 Nearctic ostracod species from 3 states (ID, NV, OR) also reveals that species richness of freshwater ostracods is greater and their distribution much broader than previously known. Consequently, we suggest that further studies are needed to extract additional information on freshwater ostracods in the United States.

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APPENDIX. Station numbers, names, and locations of stations (springs), and collection dates.

St-1	Mosquito Lake Spring, Mosquito Valley, Washoe Co., NV. Collected June 12, 1991.
St-2	Unnamed spring #1, Humboldt Bog Hot Valley, Humboldt Co., NV. Collected June 14, 1991.
St-3	Unnamed spring #2, Humboldt Albertson Basin, Humboldt Co., NV. Collected June 14, 1991.
St-4	Buck Brush Spring, Black Rock Valley, Humboldt Co., NV. Collected July 13, 1991.
St-5	Unnamed spring #1, Black Rock Valley, Jackson Canyon, Humboldt Co., NV. Collected July 14, 1991.
St-6	Unnamed spring #2, Black Rock Valley, Jackson Canyon, Humboldt Co., NV. Collected July 14, 1991.
St-7	Unnamed spring, 2 m W of Bronco Spring, Humboldt Co., NV. Collected August 7, 1991.
St-8	Unnamed spring, Spring Valley, Pershing Co., NV. Collected July 7, 1992.
St-9	Dago Spring, Buena Vista Valley, Pershing Co., NV. Collected July 7, 1992.
St-10	Clear Creek Spring, Grass Valley, Pershing Co., NV. Collected July 8, 1992.
St-11	Porter Spring, Humboldt Valley, Pershing Co., NV. Collected July 9, 1992.
St-12	Red Mountain Creek Spring #2, Black Rock Valley, Gerlach, Washoe Co., NV. Collected October 21, 1992.
St-13	Seven Mile Spring, Pyramid Valley, Washoe Co., NV. Collected October 24, 1992.
St-14	Crooked Creek Roadside Spring, Jordan Valley, Malheur Co., OR. Collected June 4, 1993.
St-15	Muffet Spring, Harney Valley, Malheur Co., OR. Collected June 30, 1993.
St-16	Buffalo Spring, Squaw Valley, Elko Co., NV. Collected July 15, 1993.
St-17	Owyhee Spring, Jordan Valley, Malheur Co., OR. Collected July 27, 1993.
St-18	McLenden Spring, Snake Valley, Oakley, Cassia Co., ID. Collected August 3, 1993.
St-19	Brush Creek Head Spring, Snake Valley, Bannock Co., ID. Collected August 4, 1993.
St-20	Indian Spring, Snake Valley, Pocatello, Power Co., ID. Collected August 5, 1993.
St-21	E Fork Creek Spring, Snake Valley, Power Co., ID. Collected August 5, 1993.
St-22	Unnamed spring in Salmon Falls Creek, Snake Valley, Twin Falls Co., ID. Collected August 5, 1993.
St-23	Unnamed spring, E of Crane Creek, Bog Hot Valley, Humboldt Co., NV. Collected June 9, 1994.
St-24	Layton Spring, Little Humboldt Valley, Humboldt Co., NV. Collected July 20, 1994.