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New records of Bathynellacea (Syncarida, Bathynellidae) in North America: three new species of the genus *Pacificabathynella* from Montana, USA

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Three new species of the genus *Pacificabathynella* Schminke and Noodt, 1988 are described from groundwater aquifers in glaciated North America (Montana, USA). This is the first time that this genus, known previously only from the state of California, has been documented in Montana. *Pacificabathynella* and *Paradoxibathynella* Serban, 2000 are the only genera that show sexual dimorphism in thoracopod VI. *Pacificabathynella kalispellensis* sp. nov. has several unique features: the setal formula of the antenna (0/2+exop/3/12/6/8/5); the setal formula of the maxilla (7/4/7/6); the presence of an epipod on thoracopod II; tufts of setulae and abundant setae on the basipod and endopod of thoracopods I to V; the epipod of thoracopod VIII female three times longer than the basipod; three smooth setae on the exopod of the female thoracopod VIII; eight spines on the endopod of the uropod and the endopod longer than the sympod, whereas the opposite is typical. *Pacificabathynella stanfordi* sp. nov. has several unique features: only five setae on the exopod of thoracopods II to VII, while six setae are common in the genus; only six setae on the second segment of the first pleopod; five spines on the endopod and seven setae on the exopod of the uropod. *Pacificabathynella ruthae* sp. nov. is the largest species and has several unique features: antennule equal in size to the antenna, whereas in the rest of the species of the genus the antenna is larger; the projection of the inner lobe of the male thoracopod VIII is bidentate and there are six spines on the endopod and nine setae on the exopod of the uropod. The three new species have slight differences in the pars molaris of the mandible and in thoracopod VIII of males, and there are other minor differences between the females and the species *Pacificabathynella sequoiae*. The new taxa, together with the new genus *Montanabathynella* described separately, represent a 30% increase in North American taxa. Considering the glaciated landscape and the fragmented nature of alluvial aquifer habitat, we believe that there is a profound lack of critical knowledge of the biogeography and biodiversity of syncarids in North America.

Keywords: Syncarida; Bathynellacea; taxonomy; biogeography; hyporheic corridor; *Pacificabathynella*; Montana State; USA; subterranean aquatic fauna

Introduction

The family Bathynellidae Grobben, 1904 in North America includes only four known species belonging to two genera: *Bathynella* Vejdovsky, 1882, with three species, (one

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in Colorado and two others in California) and *Pacificabathynella* Schminke and Noodt, 1988, with only one species (California). This family is widespread throughout the world, with 27 genera and 95 species (Camacho 2006) but is poorly known in North America. The current taxonomy of the genus *Bathynella* is not satisfactory: it includes more than 50 species and subspecies (Camacho 2006) distributed throughout the world, but few have been properly studied. The genus *Pacificabathynella* consists of a single described species, *P. sequoiae* Schminke and Noodt, 1988, from a gravelly bank of Red Wood Creek in Muir Wood, Mt Tamalpais State Park, San Francisco, CA, USA.

Schminke and Noodt (1988) proposed that the species *Bathynella yezoensis* Ueno, 1954, recorded from wells in Hokkaido (Japan), must belong to the genus *Pacificabathynella*, mainly because of the type of dimorphism seen in thoracopod VI of the male, which is similar to the dimorphism seen in *Pacificabathynella sequoiae*. In 1988, *Pacificabathynella* was the only known genus with this type of sexual dimorphism. However, Serban (2000) described a new genus from Japan, *Paradoxibathynella*, which has the same type of sexual dimorphism. He considered, after studying all the characters of the *Pacificabathynella yezoensis* [described by Ueno (1954)], that this species belonged in the *Paradoxibathynella* Serban, 2000 genus and not to *Pacificabathynella* [see Serban (2000) for a detailed discussion]. Serban (2000) created the new tribe Pacificabathynellini, which includes the two genera exhibiting sexual dimorphism on thoracopod VI.

The three new species described in this paper belong to the genus *Pacificabathynella* Table 1; they are all sexually dimorphic in thoracopod VI and their thoracopod VIII is similar to that of *Pacificabathynella sequoiae* Schminke and Noodt, (1988) (in addition to other more subtle characters).

With this and other recent discoveries from glaciated western Montana (i.e. Camacho et al. 2009), the true diversity of the group in North America begins to emerge. It is important to note that only a handful of samples from a restricted radius within a single state have produced four species and one genus new to science. Three of these new species belong to a unique genus first described near San Francisco on the west coast of North America, over 1700 km to the south-west.

Material and methods

The specimens studied were found in 13 well samples from two localities. *Pacificabathynella kalispellensis* sp. nov. was found in four groundwater well samples from two localities in Montana (USA): Kalispell Aquifer, Flathead River, Flathead County (St-SR- well, 31 May 1989; well station SR, 2 April 1989), and Nyack Aquifer, Middle Fork Flathead River, Flathead County (Chris B and Tadpole B wells, 30 April 2004). *Pacificabathynella stanfordi* sp. nov. was found in nine samples from two localities: Kalispell Aquifer, Flathead River, Flathead County (St-SR-well, 31 May 1989; SR well, 2 April 1989; Graham Channel up-well, 14 April 1989; Nyack Channel of Flathead river-down-well, 1 May 1989; Walters well, 31 March 1989; Graham Field west well, 16 July 1989), and Nyack Aquifer, Middle Fork Flathead River, Flathead County (Sargent North well, 6 November 2003; Great Bear well, 9 November 2003; Tadpole B well 30 April 2003). *Pacificabathynella ruthae* sp. nov. was found in five samples from one locality on the Nyack floodplain, Middle Fork Flathead River, Flathead County. (Great Bear well, 9 November 2003; Wally ER, Chris B, HA 12, and Wally C wells, 20

Table 1. Characteristics of the two genera of the tribe Pacificabathynellini Serban, 2000: *Pacificabathynella* Schminke and Noodt, 1988 and *Paradoxibathynella* Serban, 2000.

	Pacificabathynella	*Paradoxibathynella*
A.I: segments	7	7
A.II: segments	7	7
AI/AII	A.I << A.II/ A.I = A.II	A.I < A.II/ A.I = A.II
Md: teeth of the pars molaris	two dentated lobes	6 (5+1 big)
Epipod Th. I	absent	absent
Epipod Th. II	absent/present	present
Exopod of the Th I to VII	5–6 setae	5 setae
Sexual dimorphism on Th. VI	present	present
Th. VIII male		
lobes in the penial region	3	4
prominence in the basipod	present	absent
exopod	1-segmented	1-segmented
endopod	1-segmented	1-segmented
Th. VIII female		
coxa	1–2 plumose setae	3 smooth setae
basipod	1–2 setae	1 seta
epipod	present	present
exopod: apical seta	2	4
endopod: apical seta	1–2	2
Uropod: sympod	6–8 spines	4 spines
endopod	4–8 strong spines	4 strong spines
First pleopods: setae	1–6/1–7	1–8/1–9
Male Min.–Max. length	0.53–2.07	1.1–1.3
Female Min.–Max. length	0.51–1.78	0.8–1.38

Abbreviations: A.I, antennule; A.II, Antenna; Th., thoracopod.

February 2004). The exact localities and coordinates of the sampling sites from which the three new species of *Pacificabathynella* were obtained are listed in Table 2.

The material was collected from alluvial aquifers in two floodplains of the Flathead River system of north-western Montana, USA (Stanford and Ward 1988, 1994). Wells were installed with either a hollow auger drilling rig, or a direct-push well driver (Geoprobe). Sample depths ranged from 1 m below the land surface (depending on depth to the water table) to ≥ 12 m. Wells consisted of PVC pipes, slotted from completion depth until just below the soil horizon; they were completed with a bentonite seal and were capped (closed to the atmosphere) except during sampling. Sampling involved lowering a tube into the well and pumping groundwater from the well at a high discharge rate (> 60 l m^{-1}). Sediment, detritus and organisms pumped from the wells were collected using a plankton net (40-μm mesh size). Pumping continued for at least 3 minutes for the Nyack floodplain samples, or until clear water emerged from the well for the Flathead Aquifer samples (Ward et al. 1994).

Complete dissections of all anatomical parts of all type series were made and were kept as permanent preparations (special metal slides, glycerine gelatine stained with methylene blue as the mounting medium). Anatomical examinations were performed using an oil immersion lens (100 ×) of a Zeiss interference microscope. The descriptions are based on the type series. The material is deposited in the Museo Nacional de

Table 2. Localities of sampling sites, including coordinates, from where the three new species of the genus *Pacificabathynella* Schminke and Noodt, 1988, from Montana (USA), have been found.

Species	Locality	Site	Latitude	Longitude
P. kalispellensis sp. nov.	Nyack Aquifer	Chris B	48° 27′ 59″	113° 49′ 14″
	Nyack Aquifer	Tadpole B	48° 28′ 48″	113° 49′ 55″
	Kalispell Aquifer	St-SR Well	48° 24′ 0″	114° 23′ 42″
	Kalispell Aquifer	SR Well	48° 24′ 6″	114° 23′ 44″
P. stanfordi sp. nov.	Nyack Aquifer	Great Bear	48° 26′ 39″	113° 49′ 54″
	Nyack Aquifer	Sargent North	48° 28′ 39″	113° 49 2″
	Nyack Aquifer	Tadpole B	48° 28′ 48″	113° 49′ 55″
	Nyack Aquifer	Nyack Channel down	48° 27′ 15″	114° 48′ 30″
	Kalispell Aquifer	St-SR Well	48° 24′ 0″	114° 23′ 42″
	Kalispell Aquifer	SR Well	48° 24′ 6″	114° 23′ 44″
	Kalispell Aquifer	Graham-up	48° 31′ 12″	114° 21′ 42″
	Kalispell Aquifer	Graham-west	48° 31′ 18″	114° 22′ 36″
	Kalispell Aquifer	Walters well	48° 31′ 18′	111° 27′ 42″
P. ruthae sp. nov.	Nyack Aquifer	Chris B	48° 27′ 59″	113° 49′ 14″
	Nyack Aquifer	Great Bear	48° 26′ 39″	113° 49′ 54″
	Nyack Aquifer	HA12	48° 27′ 13″1	113° 48′ 24″
	Nyack Aquifer	Wally C	48° 27′ 47″	113° 48′ 58″
	Nyack Aquifer	Wally ER	48° 27′ 46′	113° 49′ 3″

Ciencias Naturales, Madrid (MNCN). Duplicate specimens of the three species are stored in the reference collection of the University of Montana, Flathead Lake Biological Station, Polson, MT, USA.

Abbreviations used: Th, thoracopod; A.I, Antennule; A.II, Antenna; Md, mandible.

Systematic account of the family Bathynellidae Grobben, 1905 and distribution in USA

The family Bathynellidae Grobben, 1905 consists of three subfamilies, Bathynellinae Grobben, 1905, Gallobathynellinae Serban, Coineau and Delamare Deboutteville, 1971 and Austrobathynellinae Delamare Deboutteville and Serban, 1973. Only the subfamily Bathynellinae is known in North America. To date only a few species have been described, four species belonging to two genera: *Bathynella riparia* Pennak and Ward, 1988, *Bathynella fraterna* Cho and Kim, 1997, *Bathynella germanitas* Cho and Kim, 1997, and *Pacificabathynella sequoiae* Schminke and Noodt, 1988. Many species have not yet been described in the literature: Noodt (1974) reported bathynellids from California; Pennak and Ward (1985) reported bathynellids being collected by colleagues in the states of Montana, Wyoming, Colorado, Kansas, Oklahoma, Indiana, Ohio and Georgia. *Bathynella fraterna* and *B. germanitas* occurred in gravel stream beds (2 km from the coast) in San Clemente Canyon Park, La Jolla (San Diego, CA) (Cho and Kim 1997); *B. riparia* occurs in the gravel bars along the South Fork, South Platte River (Colorado) and *P. sequoiae* occur in the gravelly bank of the Red Wood Creek, Muir Wood, Mt Tamalpais State Park (north of San Francisco). The three new species were collected from groundwater aquifers in Flathead County (Montana), tens to hundreds of meters from surface water.

Tribe **PACIFICABATHYNELLINI** Serban, 2000

Tribe diagnosis

Male Th. VIII: penial region constituted by a large number of lobes. Main axis of basipod forming angle of 25° with penial region. Th. VI with differentiated structure in both sexes: male endopod three-segmented with very strong, dilated middle segment and with distinctive appearance. Female Th. VIII with small plumose setae on laterointernal face of coxa.

Type genus: *Pacificabathynella* Schminke and Noodt, 1988.

Genera: *Pacificabathynella* Schminke and Noodt, 1988, *Paradoxibathynella* Serban, 2000.

Pacificabathynella Schminke and Noodt, 1988

Amended diagnosis

A.I and A.II seven-segmented. Md with two teeth on incisor process (pars incisiva), *processus incisivus accessorius* with one tooth and one seta-like tooth, pars molaris with two structures bidentate, parallel to main axis of teeth, most distal tooth very strong with apical denticles. Labrum with a small protuberance. Th. VI and VIII sexually dimorphic. Male Th. VI with three-segmented endopod, second segment broad and dilated with strong curved seta at outer margin; first segment also broader than usual. Female Th. VI with four-segmented endopod and setal formula 1+0/0+1/0+0/2(1). Male Th. VIII with several lobes around genital opening on coxa and with tooth-like protuberance, endopod and exopod one-segmented. Female Th. VIII bearing epipod; endopod and exopod one-segmented, both with two or three apical setae. Endopod of uropod with four to eight strong spines along inner margin. Furcal rami with five spines and conspicuous furcal organ dorsolaterally (Schminke and Noodt 1988).

Type species: *Pacificabathynella sequoiae* Schminke and Noodt, 1988.

Species: *P. sequoiae* Schminke and Noodt, 1988, *P. kalispellensis* sp. nov., *P. stanfordi* sp. nov., *P. ruthae* sp. nov.

Pacificabathynella kalispellensis sp. nov.
(Figures 1–3)

Material examined

Type locality. Flathead County, St-SR-well, 31 May 1989 (one male, holotype), Montana, USA. Others localities: Flathead County, well station SR, 2 April 1989 (two male and three female were collected; one female is the allotype); Flathead County, Middle Fork, Nyack, Chris B well, 20 February 2004 (two males and two females); Montana. Flathead County, Middle Fork, Nyack, Tadpole B well, 30 April 2004 (six females and one juvenile), Montana, USA (see Table 2). The details of the description are based on all specimens. The holotype is a male and the allotype is a female and the

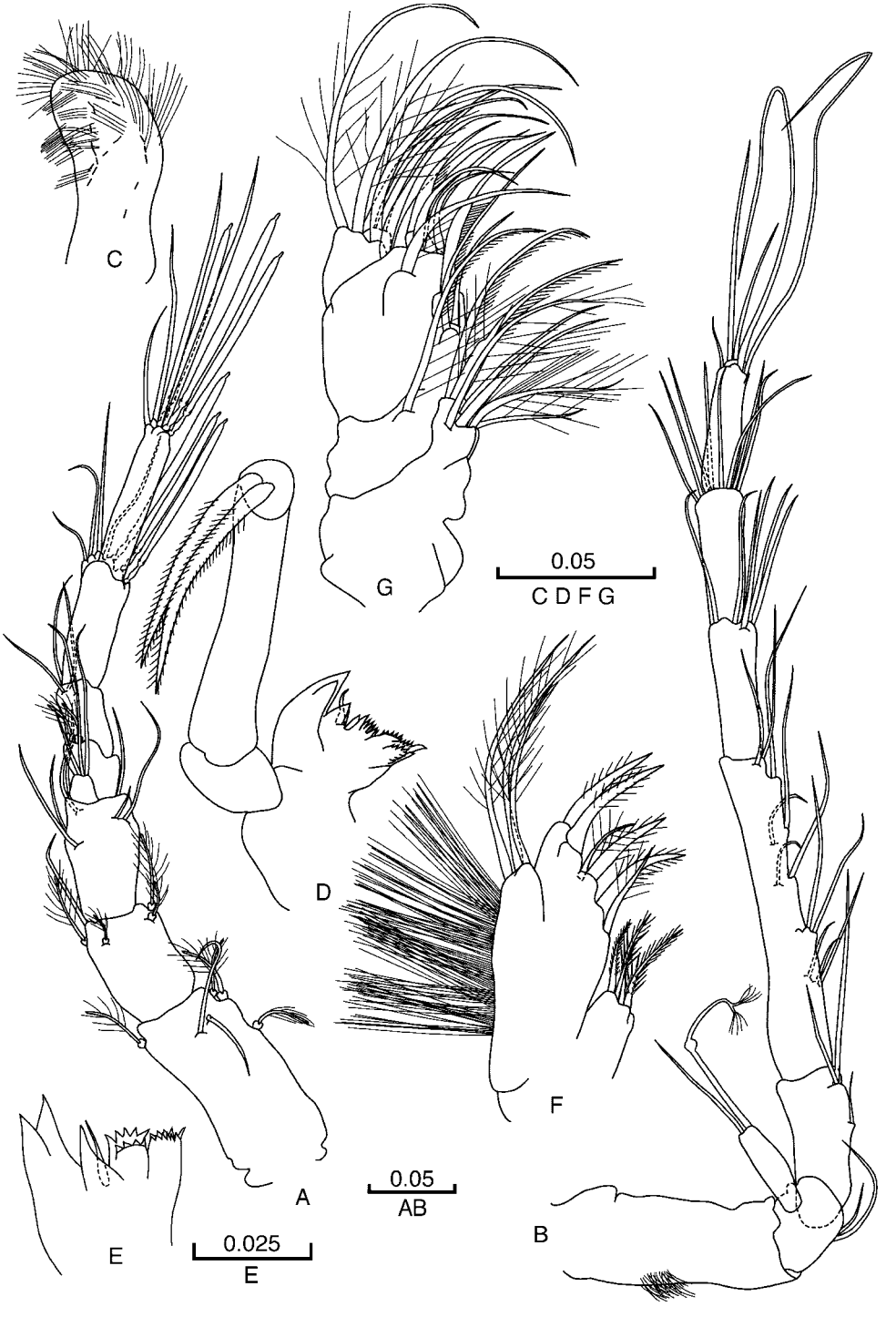

Figure 1. *Pacificabathynella kalispellensis* sp. nov., male holotype. (A) Antennule (dorsal view); (B) antenna (dorsal view); (C) paragnath; (D) mandible; (E) mandible, masticatory part; (F) maxillule and (G) maxilla (dorsal view). Scale bar in mm.

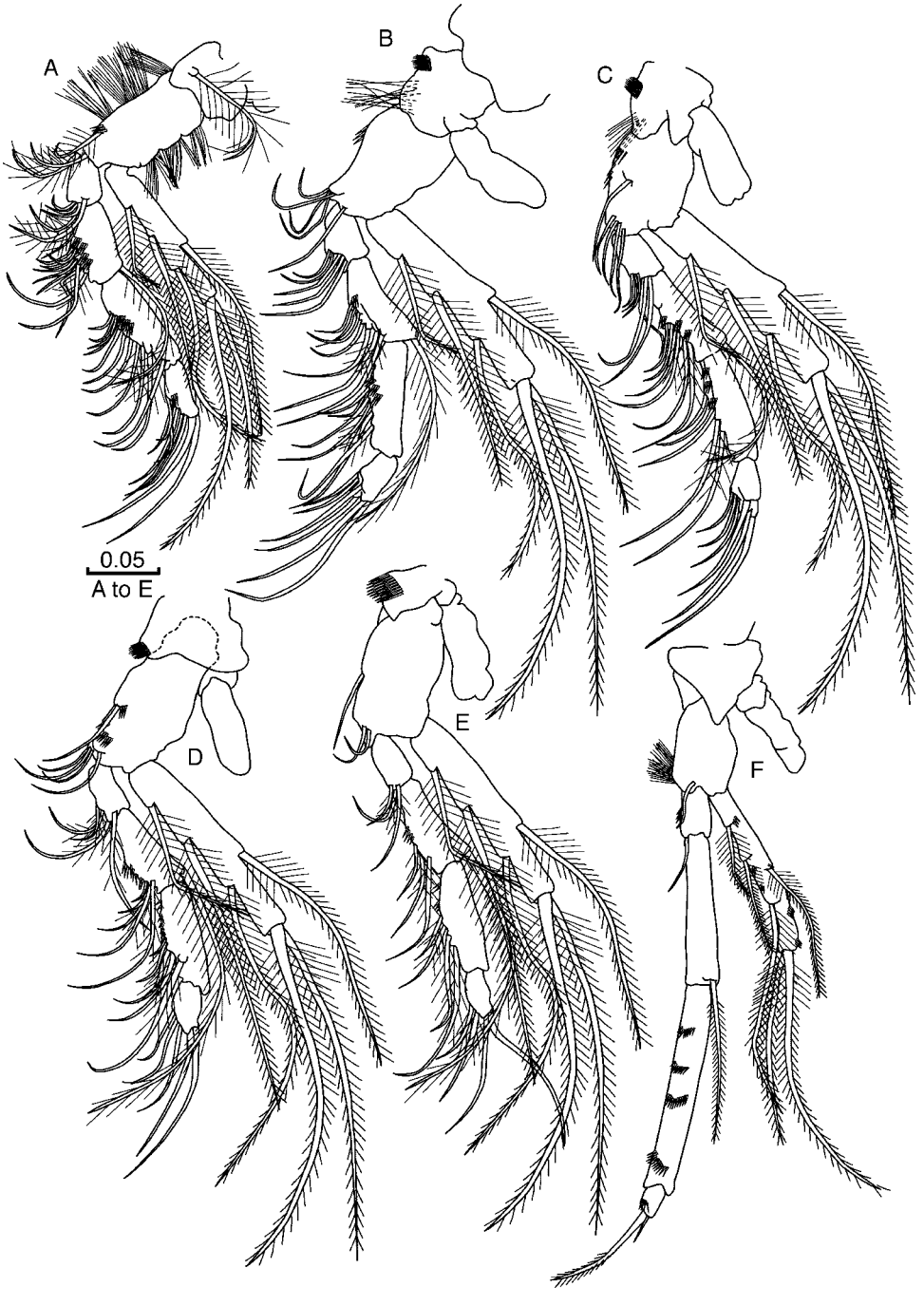

Figure 2. *Pacificabathynella kalispellensis* sp. nov., male holotype. (A) Thoracopod I; (B) thoracopod II; (C) thoracopod III; (D) thoracopod IV; (E) thoracopod V and (F) thoracopod VII. Scale bar in mm.

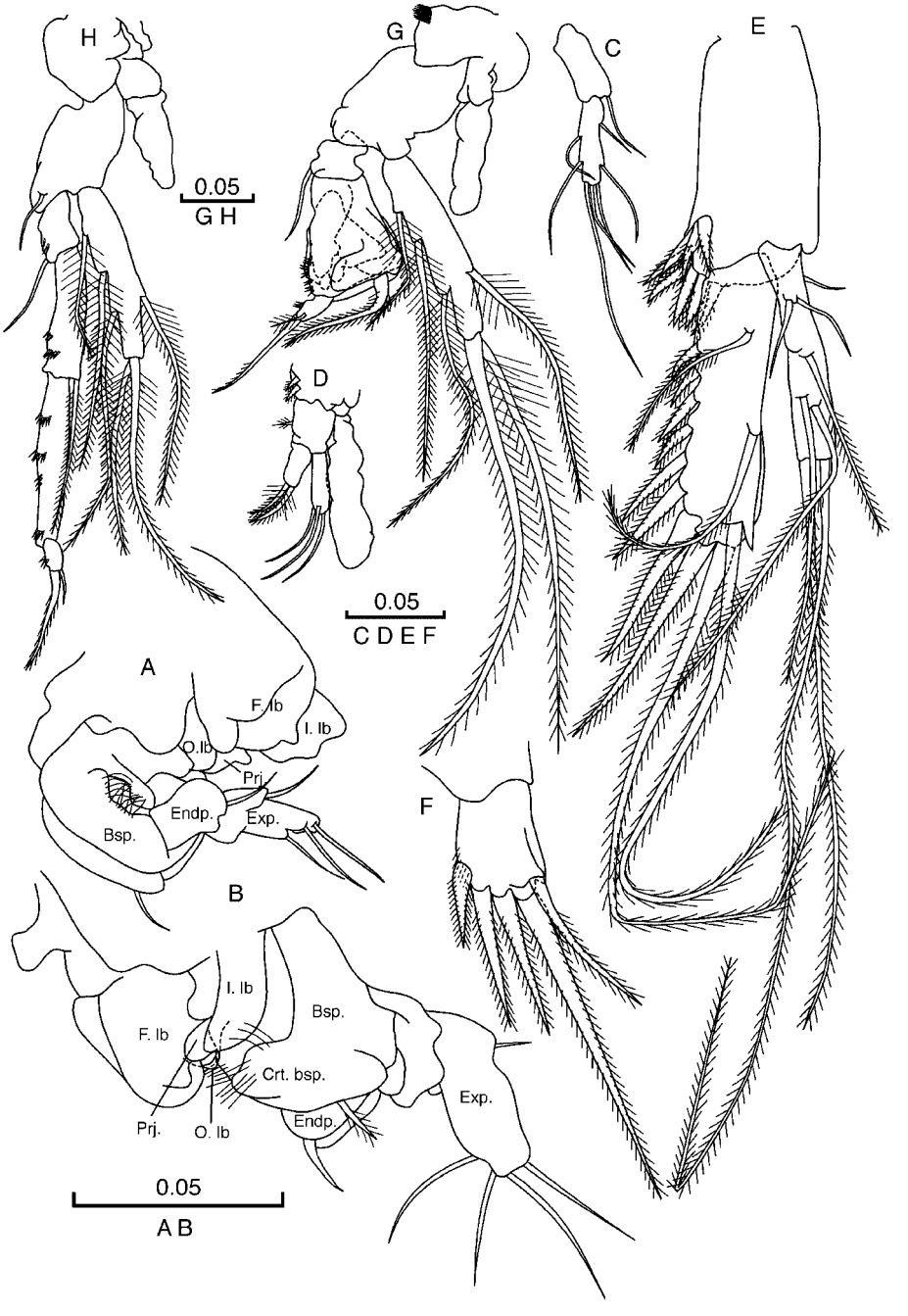

Figure 3. *Pacificabathynella kalispellensis* sp. nov., (A–C, E–G) male holotype. (A) thoracopod VIII (latero-external view); (B) thoracopod VIII (latero-internal view); (C) first pleopod; (D) thoracopod VIII female (frontal view); (E) uropod (latero-external view); (F) furcal rami (dorsal view); (G) thoracopod VI and (H) thoracopod VI female allotype. Scale bar in mm. Abbreviations: F. lb, frontal lobe; I. lb, inner lobe; O. lb, outer lobe; Prj, projection of inner lobe; Bsp, basipod; Crt. bsp, crest-like protruberance of basipod; Endp, endopod; Exp, exopod.

type series contains 14 additional specimens (four males and 10 females). (Holotype MNCN20.04/8090, Allotype MNCN20.04/8091 and type series MNCN20.04/8092.)

Description

Body. Total length of holotype (male) 1.01 mm and allotype (female) 1.41 mm. Largest male total length 1.47 mm, smallest 1.01 mm; largest female total length 1.44 mm, smallest 1.30 mm. For variability see Table 4. Body form not very elongated, almost cylindrical, approximately 12 times as long as wide. Pleotelson with one barbed dorsal seta on either side, shorter than furcal rami.

Antennule (Figure 1A). Seven segments; length of first three segments similar to other four segments; segments four and five smaller than others; segment four half length of segment five; setation as in Figure 1(A); three aesthetascs on sixth and seventh segments. A.I shorter than A.II, as long as the last five segments of A.II combined.

Antenna (Figure 1B). Almost 25% longer than A.I; first four segments almost twice as long as last three; three terminal segments similar in length; fourth segment very elongated, twice length of fifth segment, with 12 setae; setal formula: 0/2+exp/3+0/12+0/5+1/4+4/5; exopod with two terminal setae, one of these a bifurcated sensory seta; ventromedial seta absent.

Paragnath (Figure 1C). Large, with rounded distal part and very thick setulation on all surfaces in distal half.

Mandible (Figure 1D,E). Palp with three segments, terminal segment with two long barbed claws, second segment as long as terminal segment, more or less cylindrical without expansions. Incisor process (*pars incisiva*) with two teeth; *processus incisivus accessorius* with one tooth and one long seta-like tooth; pars molaris with two dentate structures, like two crowns (Figure 1E) parallel to main axis of teeth, the first with consistently strong denticles and the other with small denticles, except the most distal which is a strong tooth.

Maxillule (Figure 1F). Proximal endite with four setae; distal endite with six teeth, four with spines (denticles) and two more seta-like, with three plumose setae and tufts of long setules on outer margin.

Maxilla (Figure 1G). Four segments; setal formula 7, 4, 7, 6.

Thoracopods I to VII (Figures 2A–F, 3F,G). Sexual dimorphism present in Th. VI. Th. I (Figure 2A) smaller than others; Th. II (Figure 2B) to V (Figure 2E) similar in size and Th. VI (Figure 3G) and VII (Figure 2F) longer than others. Th. I without epipod; coxa with a long and strong plumose seta; basipod with three plumose setae. Exopod with one segment on all thoracopods, shorter than endopod in all cases; with six barbed setae, two terminal, one dorsal and three ventral. Endopod with four segments in all thoracopods, setal formulae (number of setae on basipod in brackets):

Th. I: (3) 6+0/9+1/11+0/7
Th. II: (5) 5+0/7+1/6+0/6

Table 3. Characters of the species of the genus *Pacificabathynella* Schminke and Noodt, 1988 found in North America. *Pacificabathynella sequoiae* Schminke and Noodt, 1988; *Pacificabathynella kalispellensis* sp. nov.; *Pacificabathynella stanfordi* sp. nov. and *Pacificabathynella ruthae* sp. nov.

	P. sequoiae	*P. kalispellensis* sp. nov.	*P. stanfordi* sp. nov.	*P. ruthae* sp. nov.
A.II: setal formula	0/2/2/2/0/3/5	0/2/3/12/6/8/5	0/2/2/2/0/4/5	0/2/2/2/0/4/5
A.I/A.II	A.I<A.II	A.I<A.II	A.I<A.II	A.I=A.II
Mx.II: setal formula	7/4/7/5	7/4/7/6	7/4/7/5	7/4/7/5
Epipod of Th. I	absent	absent	absent	absent
Epipod of Th. II	absent	present	absent	absent
Exopod of Th.I	5 setae	6 setae	5 setae	6 setae
Exopod of Th. II to VII	6 setae	6 setae	5 setae	6 setae
Th VIII female	exp.>>endp.	exp.>>endp.	exp.>endp	exp.>endp
Size of epipod	2 times bsp	3 times bsp	2 times bsp	1.5 times bsp
Setae coxa	2 plumose	2 plumose	1 plumose	1 plumose
Seta basipod	1 smooth	1 plumose	1 smooth	1 smooth
Number setae exp.	2 smooth	3 smooth	2 smooth	2 smooth
Number setae endp.	2 smooth	2 barbed	2 smooth	2 smooth

Th VIII male: Bsp.: setae	2	1		2
Exp.: long/width (setae)	3 times (5)	2 times (4)	2 times (5)	3 times (5)
Endopod: setae	1+1	1	1	1
Crt. Basipod	not pronounced	very pronounced	very pronounced	pronounced
Pleopod: setae	1/–	1/7	1/6	1/7
Uropod: Sympod: spines	8	8	6	6
Endp.: spines	4	8	5	6
Endp./symp.	Symp.>endp.	Symp.<endp.	Symp.>endp.	Symp.>endp.
Exp. setae	8	8	7	9
Exp./endp.	Exp.< endp.	Exp.< endp.	Exp.< endp.	Exp.< endp.
Furca: first spines /second	3 times longer	2.3 times longer	1.3 times longer	1.5 times longer
first spines/dorsal	7 times longer	2 times longer	2 times longer	2 times longer
size spines	DS<S1>S2=S3>S4	S1>DS>S2=S3>S4	S1>DS>S2>S3>S4	S1>DS>S2=S3>S4
Males: Min.–Max. length	1.32	0.95–1.42	0.53–1.02	1.57–2.07
Females: Min.–Max. length	1.27	0.84–1.46	0.51–0.94	1.45–1.78

Abbreviations: A.I, antennule; A.II, Antenna; bsp., basipod; Crt., crest of the basipod; endp., endopod; exp., exopod; segs., segments; DS, dorsal spine of the furca; S1, spine 1 of the furca; S2, spine 2 of the furca; S3, spine 3 of the furca; S5, spine 5 of the furca.

Th. III: (5) 5+0/7+1/5+0/6
Th. IV: (5) 4+0/5+1/5+0/5
Th. V: (3) 3+0/3+1/4+0/4
Th. VI: (0) 1+0/0+1/2(1)
Th. VII: (1) 1+0/0+1/0+0/2(1)

Thoracopod VI (Figure 3G) with aberrant structure, with only three segments in endopod: first segment broader than usual, second segment broad and dilated bearing on its outer margin strong medially curved seta, third segment small with two setae, one long and another shorter.

Coxa of Th. II–VI with oblique row of tiny spinules on inner margin; basipods of Th. I–III and Th. VII have tufts of long fine setules.

Male thoracopod VIII (Figure 3A,B). Longitudinal axis of coxa and basipod form 25° angle. Penial region with frontal lobe, inner lobe, outer lobe. Frontal lobe with lobules on distal end, almost completely covers outer and inner lobes. Inner lobe more or less similarly developed to frontal lobe, distal region divided into three areas with conical projection on internal side. Outer lobe smallest with two almost cylindrical lobules. Basipod very large, with distal, very well-developed, crest-like protuberance with rows of setules distally on inner side and with one lateral-distal barbed seta. Endopod one-segmented, small, half length of exopod, one distal seta. Exopod well developed with five setae.

First pleopods (Figure 3C). Two segments, first segment with one very long seta; second segment with seven setae.

Female thoracopod VIII of the allotype (Figure 3D). Coxa with two small, barbed lateral setae; very large epipod, three times length of basipod; endopod one-segmented, with two apical barbed setae of equal length; exopod slightly more slender, a little longer than endopod, with three apical smooth setae of similar length.

Female thoracopod VI of the allotype (Figure 3H). Exopod one-segmented and with six setae, as in other thoracopods; endopod four-segmented, setal formula 1+0/0+1/0+0/2(1). Number of setae on segments of endopod and basipod of thoracopods differs between female and male. Setal formulae of allotype (number of setae of basipod in brackets):

Th. I: (4) 8+0/8+1/11+0/7
Th. II: (8) 7+0/7+1/8+0/7
Th. III: (7) 7+0/8+1/7+0/7
Th. IV: (6) 6+0/7+1/7+0/6
Th. V: (6) 3+0/4+1/5+0/5
Th. VI: (1) 1+0/0+1/0+0/2(1)
Th. VII: (1) 1+0/0+1/0+0/2(1)

Uropods (Figure 3E). Sympod slightly shorter than endopod, 1.5 times longer than wide, with eight distal equal spines; endopod 30% longer than exopod, with eight

strong claws, distal two longest, most distal eight times length of two most basal, terminally with two very long setae and two shorter setae located dorsolaterally, all barbed; exopod with eight setae, two terminal, three medial and three basal. Endopod with spinous projection at the distal outer corner.

Furcal rami (Figure 3F). Almost square, bearing five spines; dorsal spine almost 50% length of second spine, second spine twice length of two medial spines, medial spines twice length of fifth spine.

Variability

The observed variability affects the number of setae of the two last segments of the antenna with six, seven or eight and four or five, respectively) and the numbers of setae of the different segments of the endopods of thoracopods I to IV on males and thoracopods I to V on females (see Table 5).

The setal formula on the males different from the holotype is:

Th. I: 6–8+0/8+1/8–9+0/6–7
Th. II: 6+0/6+1/6–8+0/6
Th. III: 6+0/6+1/6+0/5–6
Th. IV: 4–5+0/5–6+1/5+0/5

The setal formula on females different from the setal formula of the allotype is:

Th. I: 8–10+0/9–10+1/9–11+0/8
Th. II: 8+0/7+1/6+0/6–10
Th. III: 6+0/6–7+1/7+0/6–7
Th. IV: 5–6+0/5–6+1/6+0/5–6
Th. V: 3–4+0/4–5+1/4–5+0/5

Etymology

The species name is taken from the name of the nearby city of Kalispell and the aquifer containing this new species.

Remarks

Pacificabathynella kalispellensis sp. nov. is similar in size to *P. sequoiae*, and is the second largest of the four known species. It has a profusion of setae on the antenna and on the thoracopods (see Table 5 and Figures 1B, Figure 2A–E). The antenna is 25% longer than the antennule. This is the species with the highest number of unique characters within the genus. The setal formula of the antenna (Figure 1B) is unique to the genus (see Table 3) and to the family Bathynellidae; the fourth segment is very long and has many setae; segment five is well developed and has six setae, whereas normally in this family this segment lacks setae. The pars molaris of the mandible has more teeth than in other species. On the fourth segment of the maxilla there are six setae, whereas all the other species of the genus have only five. The epipod of thoracopod II (Figure 2B) is absent in other species. The setal formula of the endopod of the thoracopods is unique (see Table 5). The male thoracopod VIII is very large and massive and the crest of the

Table 4. Size in mm of the specimens of the new species *Pacificabathynella. kalispellensis* sp. nov., *P. stanfordi* sp. nov. and *P. ruthae* sp. nov. found in the populations of the different localities of Montana (USA).

Species	Sampling site Sampling point	Date	Male				Female			
			Max. size	Min. size	X size	Specimens number	Max. size	Min. size	X size	Specimens number
P. kalispellensis	St-SR Well	31/05/89	1.01	1.01	1.01	1	–	–	–	0
	SR Well	02/04/89	1.42	1.31	1.36	2	1.44	1.30	1.38	3
	Chris B		1.06	0.95	1.00	2	1.02	0.84	0.93	2
	Tadpole B	30/04/89	–	–	–	0	1.46	1.10	1.34	6
P. stanfordi	St-SR Well	31/05/89	0.71	0.66	0.68	2	0.62	0.62	0.62	1
	SR well	02/04/89	0.72	0.66	0.69	2	0.65	0.65	0.65	1
	Graham-up	14/04/89	0.82	0.53	0.72	4	0.81	0.58	0.71	5
	Channel down	01/05/89	0.82	0.71	0.76	6	0.78	0.71	0.75	6
	Walters well	31/03/89	1.02	0.66	0.78	10	0.81	0.56	0.72	6
	Graham-west	16/07/89	–	–	–	0	0.84	0.67	0.75	6
	Sargent North	06/11/03	–	–	–	0	0.78	0.51	0.70	6
	Great Bear	09/11/03	0.82	0.71	0.76	2	0.81	0.67	0.76	5
	Tadpole B	30/04/89	0.93	0.93	0.93	1	0.94	0.84	0.90	3
P. ruthae	Great Bear	09/11/03	1.74	1.74	1.74	1	1.69	1.45	1.58	4
	Nyack Aquifer	Feb- 2004	2.07	1.57	1.76	6	1.78	1.68	1.73	2

Max = maximun size; Min = minimum size and X = arithmetical mean.

Table 5. Setal formula and other characters of the thoracopods of species of the genus *Pacificabathynella* Noodt and Schminke, 1988, from North America.

	P. sequoiae	*P. kalispellensis* sp. nov.	*P. stanfordi* sp. nov.	*P. ruthae* sp. nov.
Th. I: endp. M	(3) 5+0/5+1/4+0/5	(3) 6–8+0/8–9+1/8–11+0/7–8	(3) 4–5+0/3–4+1/3–4+0/4	(3) 6+0/5–6+1/5–6+0/5
endp. F		(4) 8–10+0/9–1+1/9–11+0/8	(3) 4–5+0/3–4+1/3–4+0/4	(3) 5–6+0/5–6+1/5–6+0/5
Epipod	absent	absent	absent	absent
Exp.	5 setae	6 setae	5 setae	6 setae
Th. II: endp. M	(5) 4+0/4+1/4+0/5	(5) 5–6+0/6–7+1/6–8+0/6	(2) 2–3+0/2–3+1/2–3+0/4	(4) 4+0/4+1/4+0/5
endp. F		(8) 7–8+0/7+1/6–8+0/6–7–10	(2) 2–3+0/2–3+1/2–3+0/4	(5) 4–5+0/4–5+1/3–4+0/5
Epipod	absent	present	absent	absent
Exp.	6 setae	6 setae	5 setae	6 setae
Th. III: endp.M	(4) 4+0/4+1/3+0/5	(5) 5–6+0/6–7+1/5–6+0/5–6	(2) 2+0/2+1/2+0/4	(4) 3+0/3+1/2–3+0/5
endp. F		(7) 6–7+0/6–8+1/7+0/6–7	(2) 2+0/2+1/2+0/4	(4) 3+0/3+1/3+0/5
Epipod	present	present	present	present
Exp.	6 setae	6 setae	5 setae	6 setae
Th. IV: endp.M	(2) 3+0/3+1/3+0/4	(5) 4–5+0/5–6+1/5+0/5	(1) 2+0/2+1/1–2+0/3	(3) 2+0/2–3+1/2–3+0/4–5
endp. F		(6) 5–6+0/5–7+1/7+0/6–7	(1) 2+0/2+1/1–2+0/3	(4) 3+0/3+1/3+0/5
Epipod	present	present	present	present
Exp.	6 setae	6 setae	5 setae	6 setae
Th. V: endp.M	(1) 2+0/2+1/2+0/3	(3) 3+0/3+1/4+0/4	(1) 1+0/1+1/1–2+0/3	(1) 2+0/2–3+1/2+0/4
endp. F		(6) 3–4+0/4–5+1/4–5+0/5	(1) 1+0/1+1/1–2+0/3	(4) 2–3+0/2–3+1/2–3+0/5
Epipod	present	present	present	present
Exp.	6 setae	6 setae	5 setae	6 setae
Th. VI: endp.M	(1) transformed	(0) transformed	(0) transformed	(1) transformed
endp. F	(1) 1+0/0+1/0+0/2(1)	(1) 1+0/0+1/0+0/2(1)	(1) 1+0/0+1/0+0/2(1)	(1) 1+0/0+1/0+0/2(1).
Epipod	present	present	present	present
Exopod	6 setae	6 setae	5 setae	6 setae
Th. VII: endp. M	(1) 1+0/0+1/0+0/2(1)	(1) 1+0/0+1/0+0/2(1)	(0) 1+0/0+1/0+0/2(1)	(1) 1+0/0+1/0+0/2(1)
endp. F	(1) 1+0/0+1/0+0/2(1)	(1) 1+0/0+1/0+0/2(1)	(0) 1+0/0+1/0+0/2(1)	(1) 1+0/0+1/0+0/2(1)
Epipod	present	present	present	present
Exp.	6 setae	6 setae	5 setae	6 setae

The number of setae on the basipod appears in brackets. Abbreviations: Th., thoracopod; Endp., endopod; exp., exopod; f, female; m, male.

basipod (Figure 3B) is better developed than in the four other species of the genus, has setulae and only one plumose seta. The epipod of thoracopod VIII of the female is very large (Figure 3D), three times the length of the basipod; the exopod has three smooth setae (two is the norm) and the seta of the basipod is plumose. This species has the highest number of spines on the endopod of the uropod (eight) and the endopod of the uropod is longer than the sympod whereas the opposite is the norm in the genus.

Pacificabathynella kalispellensis sp. nov., despite being a species with many unique characters, is perhaps the species that has most in common, apart from size, with *P. sequoiae* (see Table 3). On the uropod, both species have eight spines on the sympod and eight setae on the exopod, although they differ in the endopod, the new species having twice the number of spines as *P. sequoia*. The furca is similar in both species, one spine is longer than the other, but the dorsal spine is longest in the new species, while in *P. sequoiae* it is very small; in the other two species all furcal spines are very similar. The oblique row of tiny spinules on the inner margin of the coxa of thoracopods II–VI is unique. Schminke and Noodt (1988) in the original description of *P. sequoiae* drew something similar in the coxa of thoracopod VII (figure 28, p. 296), but did not comment on the structure. Thoracopod VIII of the male is very different for both species.

Pacificabathynella stanfordi sp. nov.
(Figures 4, 5)

Material examined

Type locality. Flathead County, Graham Channel upstream-well, 14 April 1989 (four males and four females were collected), Montana, USA. Other localities from Montana: Flathead County, St-SR-well, 3 May 1989 (two males and one female); Flathead County, well station SR, 2 April 1989 (two males and three females were collected); Flathead County, Nyack Channel of Flathead river-down-well, 1 May 1989 (six males and six females); Flathead County, Walters well, 31 March 1989 (10 males, six females and two young); Flathead County, Graham Field west well, 16 July 1989 (six females); Flathead County, Sargent North well, 6 November 2003 (six females); Flathead County, Great Bear well, 9 November 2003 (two males and five females); Mt Flathead County, Middle Fork, Flathead R. Nyack aquifer, Tadpole B well, 30 April 2004 (three females and one male). The details of the new description are based on all specimens. The holotype is a male and the allotype is a female and the type series contains 63 additional specimens (26 males and 38 females). (Holotype MNCN20.04/8093, allotype MNCN20.04/8094 and type series MNCN20.04/8095.)

Description

Body. Total length of holotype (male) 0.77 mm and allotype (female) 0.60 mm. Largest male total length 0.82 mm, smallest 0.53 mm; largest female total length 0.81 mm, smallest 0.60 mm. For variability see Table 4. Body form not very elongated, almost cylindrical; approximately 13 times long as wide. Pleotelson with one barbed dorsal seta on either side, shorter than furcal rami.

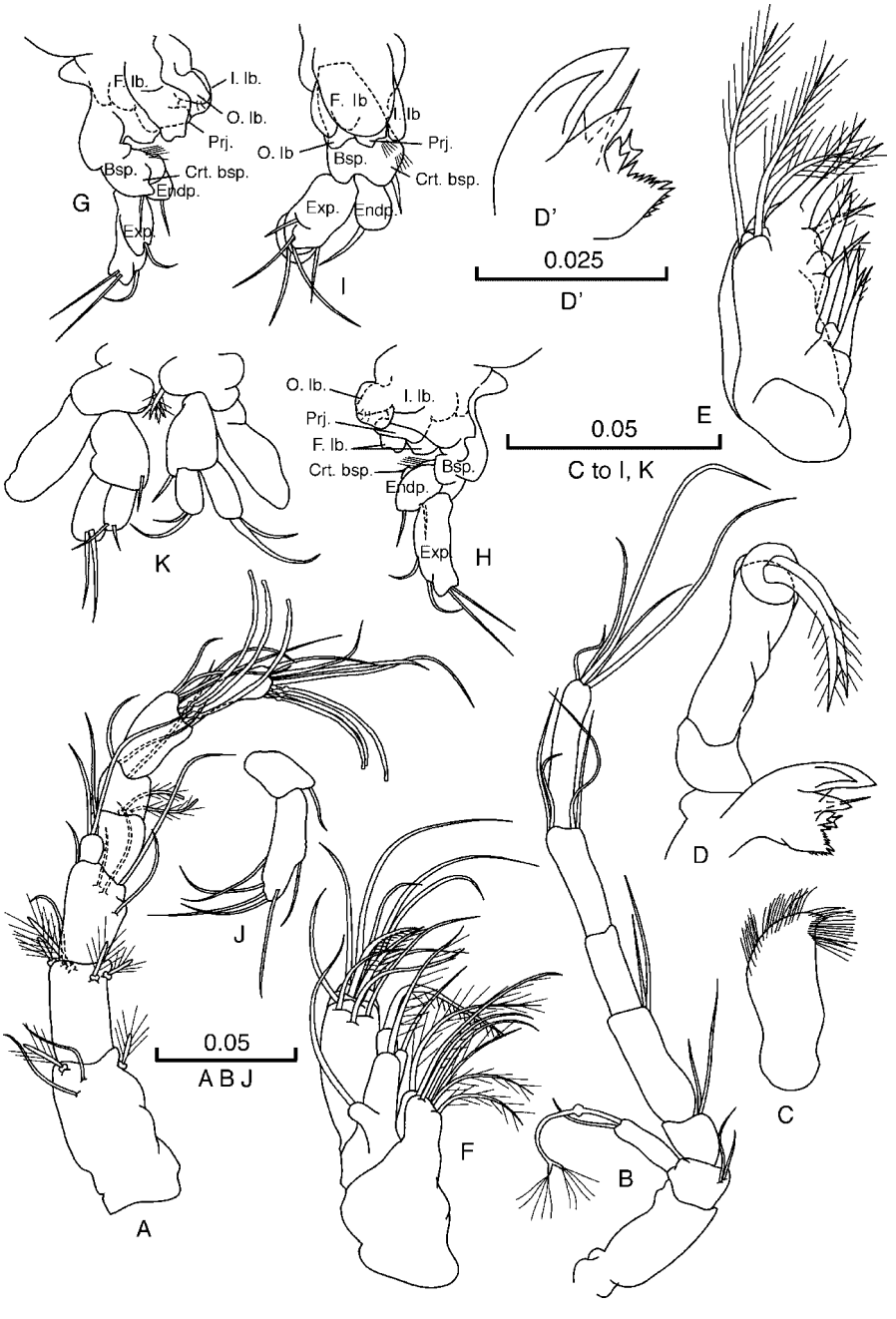

Figure 4. *Pacificabathynella stanfordi* sp. nov. (A–J) male holotype. (A) Antennule (dorsal view); (B) antenna (dorsal view); (C) paragnath; (D) mandible, (D′) mandible masticatory part; (E) maxillule (dorsal view); (F) maxilla (dorsal view); (G) thoracopod VIII (latero-external view); (H) thoracopod VIII (latero-internal view); (I) thoracopod VIII (frontal view); (J) first pleopod and (K) thoracopod VIII female (frontal view). Scale bar in mm. Abbreviations: F. lb, frontal lobe; I. lb, inner lobe; O. lb, outer lobe; Prj, projection of inner lobe; Bsp, basipod; Crt. bsp, crest-like protruberance of basipod; Endp, endopod; Exp, exopod.

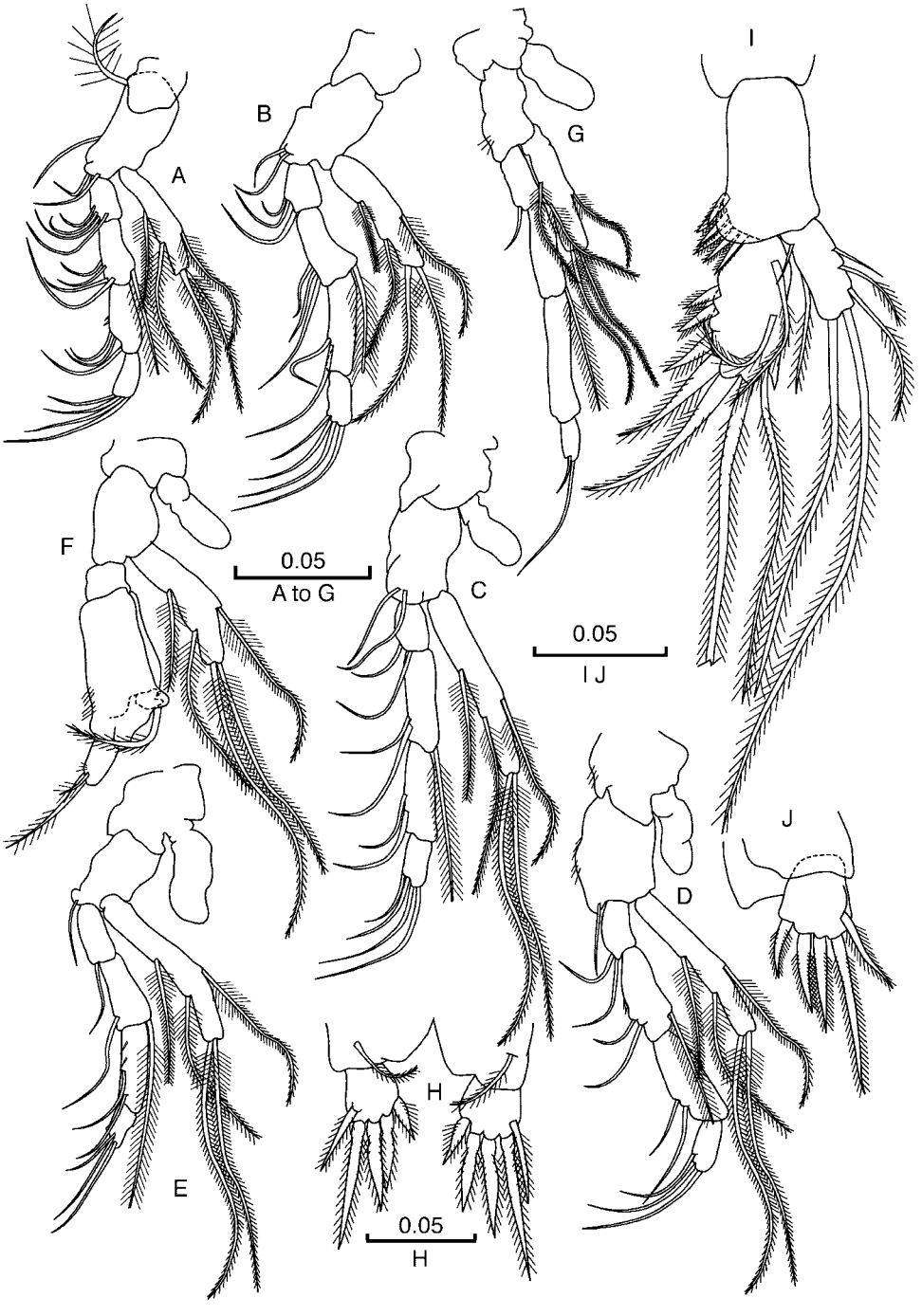

Figure 5. *Pacificabathynella stanfordi* sp. nov., male holotype. (A) Thoracopod I; (B) thoracopod II; (C) thoracopod III; (D) thoracopod IV; (E) thoracopod V; (F) thoracopod VI; (G) thoracopod VII; (H) telson and furcal ramis; (I) uropod (latero-external view) and (J) furcal rami (dorsal view). Scale bar in mm.

Antennule (Figure 4A). Seven segments; length of first three segments slightly longer than other four segments; segment five smaller than others, half length of segment four; setulation as in Figure 4(A); three aesthetascs of different length on segments six and seven. A.I slightly shorter than A.II.

Antenna (Figure 4B). Seven segments; length of first three segments half length of last four; setal formula: 0/2+exp/2+0/2+0/0+0/2+2/5; ventromedial seta of exopod absent, with two terminal setae, one a bifurcated sensory seta.

Paragnath (Figure 4C). Rounded with one distinctive tooth on distal part, very thick setulation at the distal end.

Mandible (Figure 4D,D′). Palp with three segments, terminal segment with two claws, not very long, with sparse setulation; second segment more or less cylindrical without expansions. Incisor process (*pars incisiva*) with two teeth; *processus incisivus accessorius* with one tooth, one long seta-like tooth; pars molaris with two structures dentate, the more distal with four teeth, other with small similar denticles located at edges, two most distal slightly larger.

Maxillule (Figure 4E). Proximal endite with four setae; distal endite with six teeth, four strong teeth with denticles, other two thin, setae-like; outer margin with three plumose setae.

Maxilla (Figure 4F). Four segments; setal formula 7, 4, 7, 5.

Thoracopods I to VII (Figure 5A–G). Sexual dimorphism present in Th. VI. Th. I (Figure 5A) a little smaller; Th. II-VII (Figure 5B–H) very similar in size. Th. I and II without epipod; coxa of Th. I with long, strong plumose seta, basipod with three setae. Exopod with one segment on all thoracopods, shorter than endopod in all cases; with five barbed setae, two terminal, one dorsal, two ventral. Endopod with four segments in all thoracopods, setal formulae (number of setae of basipod in brackets):

Th. I (Figure 5A): (3) 4+0/4+1/3+0/4
Th. II (Figure 5B): (2) 3+0/3+1/2+0/4
Th. III (Figure 5C): (2) 2+0/2+1/2+0/4
Th. IV (Figure 5D): (1) 2+0/2+1/2+0/3
Th. V (Figure 5E): (1) 1+0/1+1/2+0/3
Th. VI (Figure 5F): (0) 0+0/0+1/2(1)
Th. VII (Figure 5G): (0) 1+0/0+1/0+0/2(1)

Thoracopod VI (Figure 5F) with aberrant structure in all males, only three segments in endopod: first segment broader and shorter than usual, second segment broad, dilated, bearing on its outer margin strong seta curved medially, third segment small with two setae, one long, barbed, other short.

Male thoracopod VIII (Figure 4G–I). Longitudinal axis of coxa and basipod form angle of 25°. Penial region with frontal lobe, inner lobe, outer lobe. Frontal lobe has

two lobules, completely covers outer and inner lobes. Inner lobe has distal region divided into two areas with almost square projection on internal side. Outer lobe smallest, with conical aspect with fine setae. Basipod with distal, well-developed, crest-like protuberance with two rows of setules distally on inner side, one distal-lateral barbed seta. Endopod one-segmented, half length of exopod, one smooth distal seta. Exopod well developed with five setae.

First pleopods (Figure 4J). Two segments, first segment with one seta; second segment with six setae.

Female thoracopod VIII allotype (Figure 4K). Coxa with one small, barbed, lateral seta; large epipod, almost twice length of basipod; endopod one-segmented, with two apical setae of similar length; exopod a little longer than endopod, with two apical smooth setae of different lengths.

Female thoracopod VI allotype. Exopod one-segmented and with five setae, as in other thoracopods; endopod four-segmented, setal formula 1+0/0+1/0+0/2(1). Number of setae on segments of endopod and on basipod of thoracopods similar to male.

Uropods (Figure 5I). Sympod slightly longer than endopod, twice as long as wide, with six equal spines on distal end; endopod one-third longer than exopod, with five strong claws, two distal-most longest (five times length of most basal), with two very long terminal setae and with two shorter ones located dorsolaterally, all barbed; exopod with seven setae, two terminal, one subterminal, three medial and one basal. Endopod with spinous projection at distal outer corner (Figure 5I).

Furcal rami (Figure 5J,H). Almost square, bearing five spines; long dorsal spine almost half length of second spine, second spine 30% longer than third medial spine, third spine slightly longer than fourth, fourth almost twice length of fifth.

Variability

The variability that we have found is very small, in spite of the fact that we have studied many specimens from many different samples. The observed variability only affects the observed number of setae on the different segments of the endopods of thoracopods I to V on males and females (see Table 5):

The setal formula variation from the holotype is:

Th. I: 4–5+0/3–4+1/3–4+0/4
Th. II: 2–3+0/2–3+1/2–3+0/4
Th. III: 2+0/2+1/2+0/4
Th. IV: 2+0/2+1/1–2+0/3
Th. V: 1+0/1+1/1–2+0/3

Etymology

The species name is derived from Dr Jack Stanford, Director of the University of Montana's Flathead Lake Biological Station, and long-time pioneer in the study of hyporheic communities and floodplain aquifer ecosystems.

Remarks

Pacificabathynella stanfordi sp. nov. is the smallest known species of the genus (see Tables 3 and 4); the largest specimens are similar to small *P. kalispellensis* sp. nov. This species has the smallest number of setae on thoracopods and uropods within the genus (see Table 3). This is a unique species of the genus in that it has five setae on the exopod of thoracopods I to VII. Only six setae are present on the second segment of the first pleopod, while in the other known species the pleopod has seven setae. *Pacificabathynella stanfordi* sp. nov. has only five spines on the endopod and seven setae on the exopod of the uropods (Figure 2I). The setal formula of the endopod of the thoracopods is unique (see Table 5).

Perhaps the species that has more characters in common is *P. ruthae* sp. nov. (see Table 3), although the latter is a much larger species. On the uropod both species have six spines on the sympod; however, the endopod and exopod differ between the species, the new species having only five and seven spines respectively. The furca is similar in both species, and very different from the furca of *P. sequoiae*. One spine one is longer than the other, and is similar to the dorsal spines; all furcal spines are very similar. The male thoracopod VIII is very different in both species. The coxa of the female thoracopod VIII only has one seta as in *P. ruthae* sp. nov., and the epipod is bigger in *P. stanfordi* sp. nov.

Pacificabathynella ruthae sp. nov.
(Figures 6 to 8)

Material examined

Type locality. Flathead County, Middle Fork Flathead River, 2 February 2004, Wally ER, Chris B, HA-12, Wally C wells (six males and two females), Montana, USA; other locality: Flathead County, Great Bear well, 9 November, 2003 (one male and four females), Montana, USA (see Table 1). The details of the new description are based on all 13 specimens. The holotype is a male and the allotype is a female and the type series contains 11 additional specimens (six males and five females). (Holotype MNCN20.04/8096, allotype MNCN20.04/8097 and type series MNCN20.04/8098.)

Description

Body. Total length of holotype (male) 1.94 mm and allotype (female) 1.68 mm. Largest male total length 2.07 mm, smallest 1.57 mm; largest female total length 1.78 mm, smallest 1.45 mm (see Table 4). Body form not very elongated, almost cylindrical, approximately 13 times long as wide. Pleotelson with one barbed dorsal seta on either side, shorter than furcal rami.

Antennule (Figure 6A). Seven segments; length of first three segments similar to the other four segments; segments five and six similar in size and smaller than other segments; setulation as in Figure 6A; three aesthetascs on segments six and seven. A.I almost equal in length to A.II.

Antenna (Figure 6B). First four segments longer than terminal three; three terminal segments of similar length; setal formula: 0/2+exp/2+0/2+0/0+0/2+2/5; ventromedial seta of exopod absent, two terminal setae, one a bifurcated sensory seta.

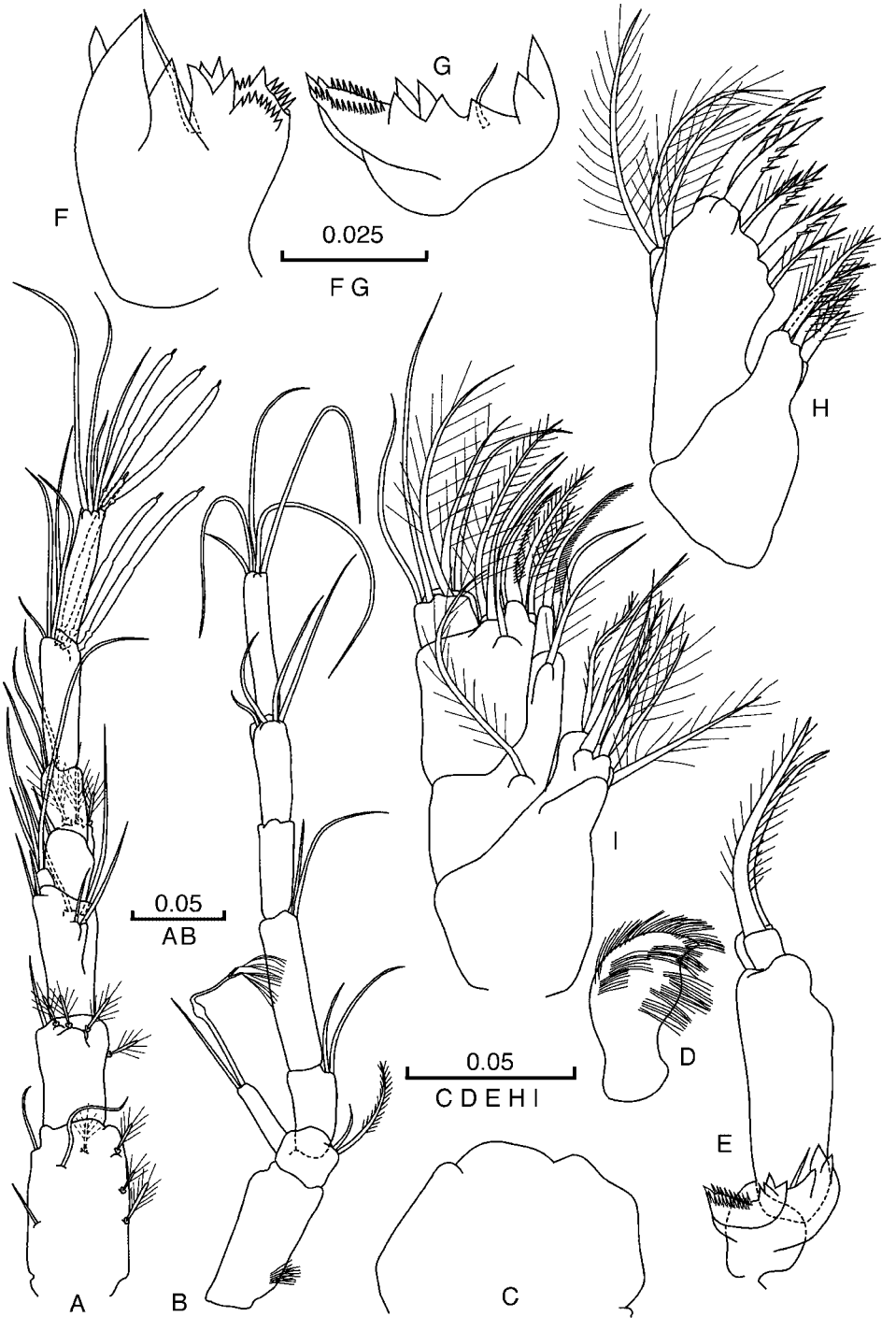

Figure 6. *Pacificabathynella ruthae* sp. nov., male holotype. (A) Antennule (dorsal view); (B) antenna (ventral view); (C) labrum; (D) paragnath (E) mandible; (F, G) mandible masticatory part; (H) maxillule (dorsal view) and (I) maxilla (dorsal view). Scale bar in mm.

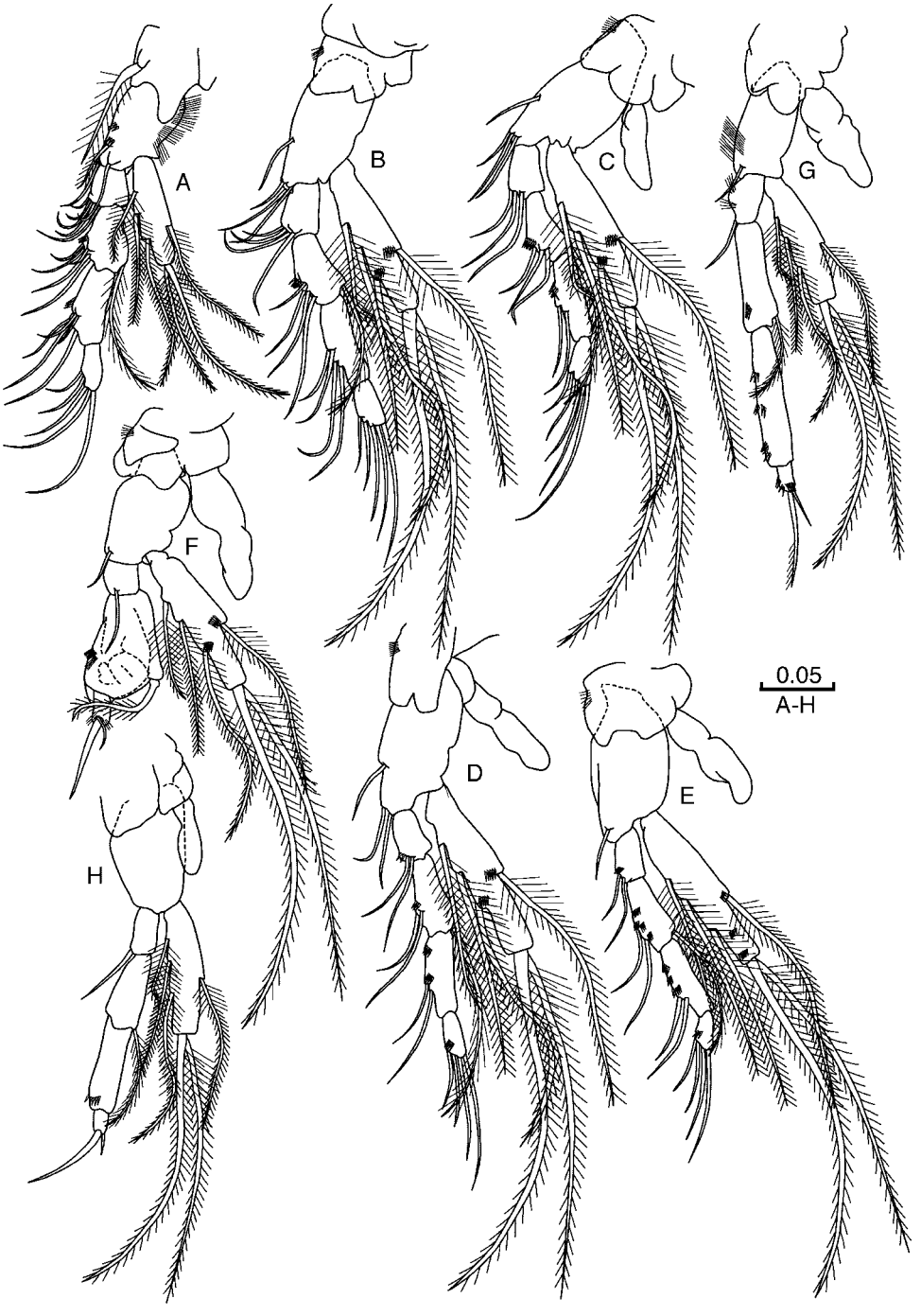

Figure 7. *Pacificabathynella ruthae* sp. nov., male holotype. (A) Thoracopod I; (B) thoracopod II; (C) thoracopod III; (D) thoracopod IV; (E) thoracopod V; (F) thoracopod VI; (G) thoracopod VII and (H) thoracopod VI female allotype. Scale bar in mm.

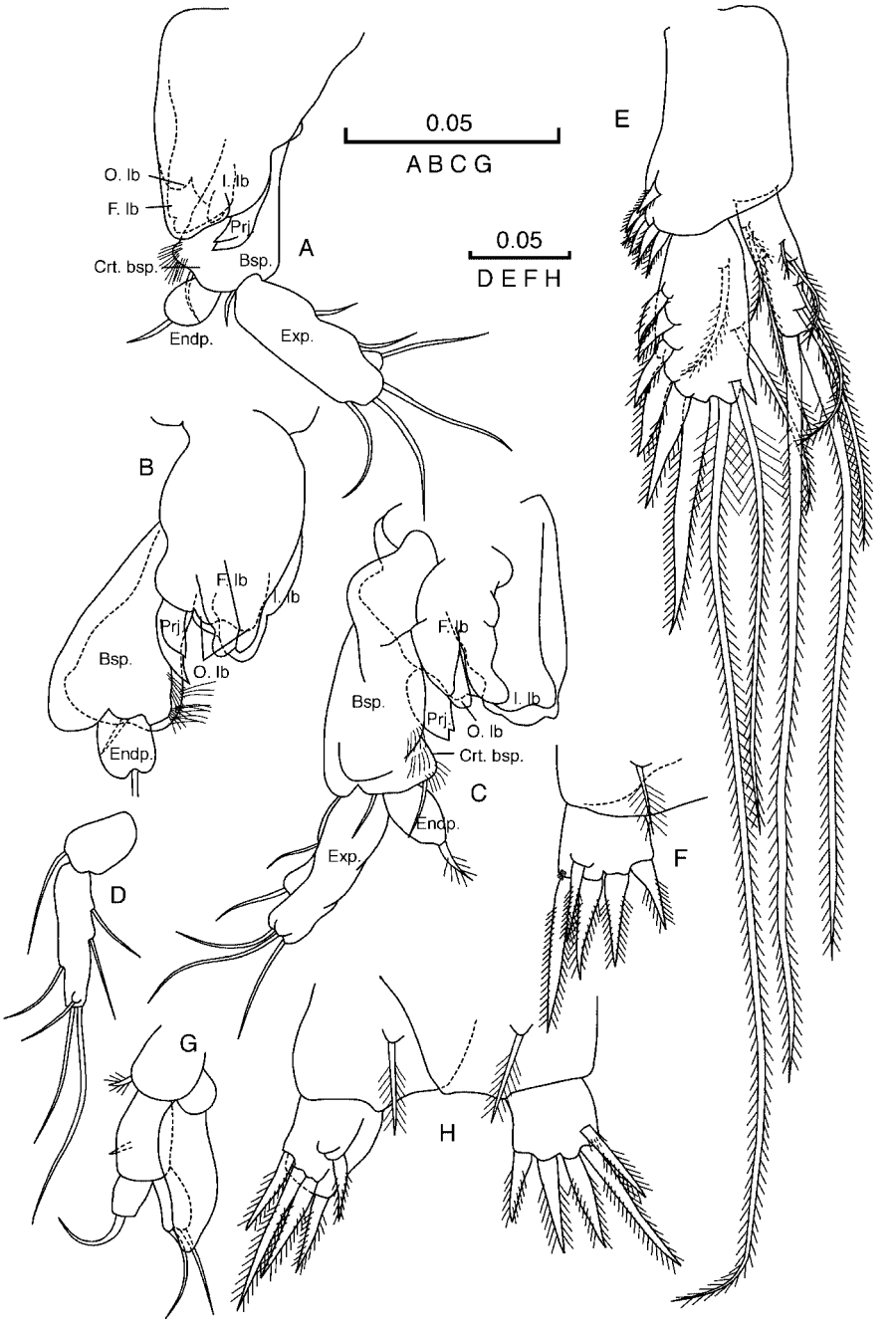

Figure 8. *Pacificabathynella ruthae* sp. nov., male holotype. (A) thoracopod VIII (latero-internal view); (B) thoracopod VIII (frontal view); (C) thoracopod VIII (latero-external view); (D) first pleopod; (E) uropod (latero-external view); (F) furcal rami (drsal view) and (G) thoracopod VIII female (frontal view). Scale bar in mm. Abbreviations: F. lb, frontal lobe; I. lb, inner lobe; O. lb, outer lobe; Prj, projection of inner lobe; Bsp, basipod; Crt. bsp, crest-like protruberance of basipod; Endp, endopod; Exp, exopod.

Labrum (Figure 6C). With median protusion.

Paragnath (Figure 6D). Large, subrectangular, with one tooth on distal part and with very thick setulation on entire surface of distal half.

Mandible (Figure 6E–G). Palp with three segments, terminal segment with two barbed similar claws, second segment more or less rectangular. Incisor process (*pars incisiva*) with two teeth; *processus incisivus accessorius* with one tooth, and one long seta-like tooth; pars molaris with two dentated structures (Figure 6F,G) parallel to main axis of teeth, first with four similar teeth, other with small similar teeth arranged in two rows, crown-like, most distal tooth is strong and longer than others.

Maxillule (Figure 6H). Proximal endite with four setae; distal endite with six teeth, four with spines (denticles), other two setae-like, with three plumose setae.

Maxilla (Figure 6I). Four segments; setal formula 7, 4, 7, 5.

Thoracopods I to VII (Figure 7A–H). Sexual dimorphism Th. VI, (Figure 7F,H). Th. I (Figure 7A) lightly smaller than others; Th. II (Figure 7B) to V (Figure 8B) similar in size to Th. VII (Figure 7G) and longer than others. Th. I and II without epipod; coxa of Th. I with long, strong plumose seta, basipod with three setae, one of these plumose. Exopod one- segment for all thoracopods, shorter than endopod in all cases; with six barbed setae, two terminal, one dorsal and three ventral. Endopod with four segments in all thoracopods, setal formulae (number of setae of basipod in brackets):

Th. I: (3) 6+0/5+1/5+0/5
Th. II: (4) 4+0/4+1/4+0/5
Th. III: (4) 3+0/3+1/2+0/5
Th. IV: (3) 2+0/3+1/2+0/4
Th. V: (1) 2+0/2+1/2+0/4
Th. VI: (1) 1+0/0+1/2(1)
Th. VII: (1) 1+0/0+1/0+0/2(1)

Thoracopod VI (Figure 7F) with only three segments in endopod: first segment broader than usual, second segment broad-dilated, bearing on its outer margin strong medially curved seta and third segment small with two setae, one long and another short. Basipods of Th. I and Th. VII have tufts of long and fine setules.

Male thoracopod VIII (Figure 8A–C). Longitudinal axis of coxa and basipod form angle of 25°. Penial region with frontal lobe, inner lobe, outer lobe. Frontal lobe with two very well-developed lobules that cover outer lobe and partially cover inner lobe. Well-developed inner lobe has distal region elongated with very large bidentated projection on internal side. Outer lobe similar to frontal lobe and with two almost square lobules. Basipod very large, with distal crest-like protuberance, three rows of setules distally on inner side, two smooth setae, one distal-lateral and another on external side. Endopod one-segmented, small, 33% of the exopod, with only one barbed distal seta. Exopod well developed with six setae.

First pleopods (Figure 8D). Two segments, first segment with one very long seta; second segment with six setae.

Female thoracopod VIII allotype (Figure 8G). Coxa with one, small, barbed lateral seta; very large epipod, twice length of basipod; basipod almost square, longer than endopod, with smooth seta; endopod one-segmented, with one smooth seta; exopod a little longer than endopod and with two apical smooth setae of similar length.

Female thoracopod VI allotype (Figure 7H). Exopod one segmented and with six setae, as in other thoracopods; endopod four-segmented, setal formula 1+0/0+1/0+0/2(1). Number of setae on segments of endopod and on basipod of thoracopods is different on female. Setal formulae of allotype (number of setae of basipod in brackets):

Th. I: (3) 6+0/6+1/6+0/5
Th. II: (5) 5+0/5+1/4+0/5
Th. III: (4) 3+0/3+1/3+0/5
Th. IV: (4) 3+0/3+1/3+0/5
Th. V: (4) 3+0/3+1/3+0/5
Th. VI: (1) 1+0/0+1/0+0/2(1)
Th. VII: (1) 1+0/0+1/0+0/2(1)

Uropods (Figure 8E). Sympod a little longer than endopod, almost twice as long as wide, with six equal spines on distal end; endopod 10% longer than exopod, with six strong claws, two most distal longest, twice length of penultimate, three times length of two most basal, with two very long terminal setae and with two shorter ones located dorsolaterally, all of which barbed; exopod with nine setae, two terminal, four medial, three basal.

Furcal rami (Figure 8F). Almost square, bearing five spines; a long dorsal spine, almost half length of second spine, second spine 30% longer than two equal length medial spines, medial spines 25% times longer than fifth.

Variability

The variability is very low between individuals and populations.

The observed variability only affects the numbers of setae on the different segments of the endopods of thoracopods I to V in males and females (see Table 5), which differ from the holotype and allotype as follows:

Males:
Th. I: 6+0/5–6+1/5–6+0/5
Th. II: 4+0/4+1/4+0/5
Th. III: 3+0/3+1/2–3+0/5
Th. IV: 2+0/2–3+1/2–3+0/4–5
Th. V: 2+0/2–3+1/2+0/4

Females:
Th. I: (3) 5–6+0/5–6+1/5–6+0/5
Th. II: (5) 4–5+0/4–5+1/3–4+0/5

Th. III: (4) 3+0/3+1/3+0/5
Th. IV: (4) 3+0/3+1/3+0/5
Th. V: (4) 2–3+0/2–3+1/2–3+0/5

Etymology

The species name is derived from Ruth Dalimata, wife of John Dalimata, who owns the land surrounding the Nyack well sites and has long been supportive of the research occurring on this large floodplain.

Remarks

Pacificabathynella ruthae sp. nov. is the largest known species of the genus (see Table 4); the largest specimens reach 2 mm. This is the only species of the genus in which the antennule is similar in length to the antenna. The female thoracopod VIII has the smallest epipod within the genus. Despite being the largest species of the genus it does not have more setae on thoracopods (see Table 5) and uropods (see Table 3) than other species. The endopod of the uropod has six spines (the others species have four, five or eight), the exopod has nine setae, while other species have only seven or eight setae.

The species that share the greatest number of similar characters are *P. stanfordi* .sp. nov. and *P. sequoiae*. *Pacificabathynella stanfordi* sp. nov. differs principally in the number of setae on the exopod of the thoracopods, having six (see Table 5), which is the norm in the genus, and the male thoracopod VIII is very different from that of the other species.

Discussion

Pacificabathynella Schminke and Noodt, 1988 and *Paradoxibathynella* Serban, 2000 are the only known Bathynellidae genera in the world that show sexual dimorphism in the endopod of thoracopod VI. The three new species described in this paper, in addition to *P. sequoiae*, all have the same type of dimorphism as the three species of *Paradoxibathynella* known at present: *Paradoxibathynella parayezoensis* Serban, 2000, *Paradoxibathynella kussharokoensis* Serban, 2000 and *Paradoxibathynella yezoensis* (Ueno, 1954). The transformations of thoracopod VI in the male are similar in both genera.

Table 1 shows the characteristics of both genera to facilitate comparison. The new species will undoubtedly belong to the genus *Pacificabathynella* following the series of characters that we analysed in detail here. Thoracopod VIII of the male of the new species has three lobes in the penial region with a protuberance (Prj. = projection of the inner lobe) as a tooth, meanwhile *Paradoxibathynella* has four lobes; the basipod has a crest-like protuberance, which is more or less developed in each of the new species, but which is lacking in *Paradoxibathynella*. The *pars molaris* of the mandible has two dentate structures in the three new species, while *Paradoxibathynella* has six teeth in this part of the mandible. The three species of *Paradoxibathynella* have an epipod on thoracopod II, whereas in the genus *Pacificabathynella* the absence of this feature is a common character in the genus, only *P. kalispellensis* sp. nov. having an epipod on thoractopod II. The three species of *Paradoxibathynella* have five setae on the exopod of thoracopods I to VII, while in the genus

Pacificabathynella this formula is only seen in *P. stanfordi* sp. nov. The coxa of the female thoracopod VIII has either one or two plumose setae on the new species, while *Paradoxibathynella* has three setae. The second segment of the first pleopod has six or seven setae in the new species, whereas there are eight or nine in the genus *Paradoxibathynella*. The sympod of the uropod of the new species has six to eight spines, while the genus *Paradoxibathynella* only has four spines; the new species have four to eight spines on the endopod, but in *Paradoxibathynella* only four are present. In general, *Paradoxibathynella* has fewer spines and setae than *Pacificabathynella*. Certainly the three new species, along with *P. sequoiae*, constitute the distinct North American genus *Pacificabathynella*.

Tables 3, 4 and 5 show the similarities and differences between the four species of the genus *Pacificabathynella*.

The largest species is *P. ruthae* sp. nov. and the smallest is *P. stanfordi* sp. nov.; these are the most similar of the four known species. *Pacificabathynella kalispellensis* sp. nov. is the most distinctive of the three Montana species (but similar in size to *P. sequoiae*).

The sexual dimorphism is similar in all species and is only exhibited in thoracopod six. In males there are only three segments on the endopod, with the second segment broadly dilated, bearing on its outer edge a strong and curved medial seta. The first segment is also broader than usual, the third segment is similar to the fourth segment of thoracopod VI of the female and thoracopod VII of the male and female. *Pacificabathynella ruthae* sp. nov. has an antennule similar in size to the antenna (the antenna usually being larger in this genus). The species with more setation on the thoracopods and more spines on the uropod is not the largest in terms of body size, being the medium-sized species *P. kalispellensis* sp. nov. (see Tables 3, 4 and 5), which also has a distinctive antenna.

Remarks on the biogeography of bathynellaceans in the Northern Rockies

We found three new species in the state of Montana, belonging to a genus that was previously only known from the state of California, extending the range of distribution of *Pacificabathynella* by over 1700 km. The three new parabathynellid taxa described here, in addition to the new genus *Montanabathynella* described separately (Camacho et al. 2009), represent a 31% increase in the number of syncarid taxa described for North America (13 species to date). These new taxa occur in a relatively young landscape significantly altered by Pleistocene glaciation: the Kalispell aquifer is within the limits of the Flathead Lobe of the Cordilleran Ice Sheet, while the Jocko Aquifer site represents quaternary alluvium deposited within the limits of Glacial Lake Missoula (Figure 9). We are not suggesting that western Montana is a biodiversity hotspot for bathynellaceans, which is unlikely given the glacial legacy of this region. Instead, we feel that these new taxa indicate the very limited sampling and taxonomic treatment of this group in North America, in addition to the effectiveness of sampling methods and the directed focus on sampling shallow alluvial groundwater fauna by the research group at the Flathead Lake Biological Station. Pumping groundwater from permanently installed, shallow, slotted wells at high discharge rates (> 1 litre/s) produces large numbers of groundwater fauna from most shallow alluvial aquifer sites, and at the Nyack aquifer, with wells located hundreds of meters from surface water, nearly 85% of the 40+ sampling wells consistently produced

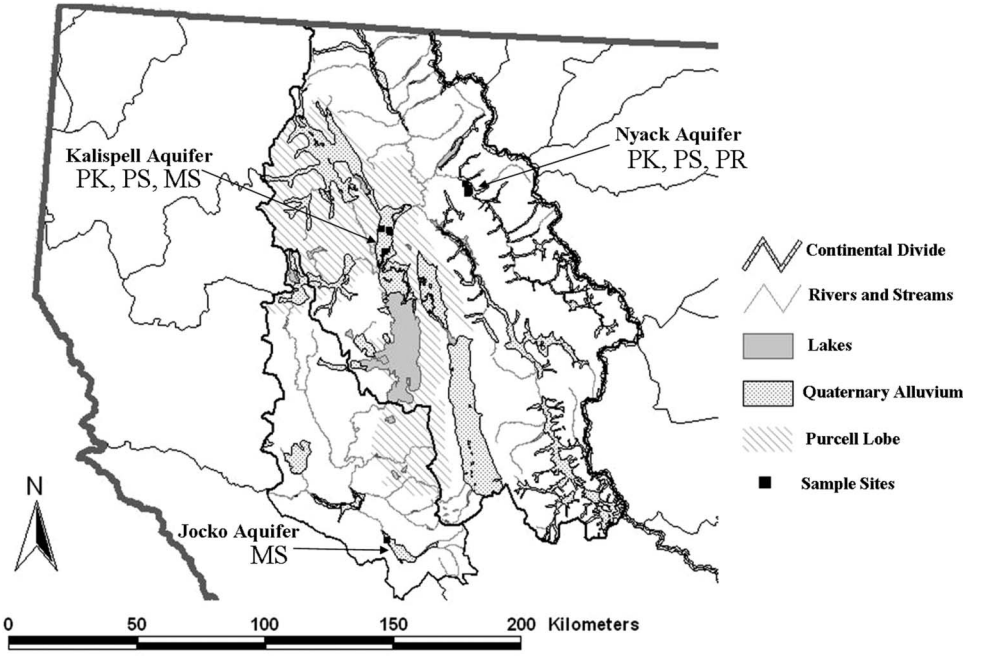

Figure 9. Map of the study area and sampling sites, Montana, USA. All sampling sites were within Quaternary alluvium deposits. The Kalispell aquifer is also within the limits of the Flathead Lobe of the Cordilleran Ice Sheet, while the Jocko Aquifer site is within the limits of Glacial Lake Missoula. Data sources: approximate boundary of the Cordilleran Ice Sheet redrawn from Booth et al. 2003; GIS basemaps, hydrography and surficial geology are from Montana NRIS (http://nris.mt.gov/).

bathynellaceans. We predict that with additional sampling of alluvial aquifers in both glaciated and unglaciated landscapes, the number of known taxa will increase many fold. Secondly, Figure 9 suggests an interesting research problem for bathynellaceans and groundwater fauna in general. Alluvial aquifers are essentially islands within the hyporheic continuum of the river network (*sensu* Ward and Palmer 1994; Stanford and Ward 1993). With increased future alteration of riverscapes, disruption of the river continuum and more intensive land use overlying shallow alluvial aquifers, we feel that there is a profound lack of critical knowledge on the degree of isolation between respective populations in nearby aquifers. How unique are these populations given that their biodiversity is still largely undocumented, and so how vulnerable will they be to anthropogenic land use? This important question should be addressed from a phylogeographic [(see Camacho et al. (2006) for an analogous example from a fractured rock system in Spain] and phylogenetic approach, combined with much more extensive sampling efforts.

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