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CRITICAL COMMENT. . .

Why Museums Matter: A Tale of Pinworms (Oxyuroidea: Heteroxynematidae) Among Pikas (*Ochotona princeps* and *O. collaris*) in the American West

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ABSTRACT: Permanent and well-supported museum or natural history collections provide a solid foundation for the process of systematics research through creation of an empirical record which validates our understanding of the biosphere. We explore the role of museums in ongoing studies of the complex helminth fauna characteristic of pikas (*Ochotona* spp.) in the American west. These studies address the taxonomy for pinworms of the Labiostomatinae and the problems associated with the absence of adequate type series and vouchers and with misidentifications in original descriptions. We demonstrate that the types for *Labiostomum* (*Labiostomum*) *coloradensis* are identical to some specimens in the syntype series representing *L.* (*Eugenuris*) *utahensis*, although the published descriptions are in disagreement. Both are identical to *L.* (*Eugenuris*) *talkeetnaeuris* and, as a consequence, are reduced as junior synonyms. Only 2 species of large pinworms, namely *L.* (*Labiostomum*) *rauschi* and *L.* (*Eugenuris*) *talkeetnaeuris*, are widely distributed in *Ochotona collaris* and *O. princeps*. Although this serves to clarify the taxonomy for species in these genera, prior records remain confused, as representative voucher specimens from all major surveys in North America were never submitted to museum collections. We strongly suggest that type and voucher series should not be held in private or personal collections, where such are eventually lost, discarded, or destroyed through neglect due to inattention and the absence of curation. The potential to accumulate meaningful baselines for assessment of environmental change is jeopardized if materials from survey and inventory are not routinely submitted to museum collections. The capacity of museum repositories, as a focus for systematics, ecology, and evolutionary studies and for the development of resources for biodiversity informatics, continues to be undervalued and poorly utilized by a cadre of scientists who are dependant on accurate and definitive information that transcends specific disciplines.

In biology and parasitology, confusion over issues of taxonomy and the host and geographic distributions of species are not uncommon. In resolving such challenges, natural history collections and the specimens held in such museum repositories are critical, whether these represent irreplaceable type series or the vouchers that document associations on varying temporal and spatial scales. Specimens, associated data, and permanent collections provide a solid foundation for the process of systematics research through creation of an empirical record, which validates our understanding of the biosphere. Increasingly, collections reside at the core for development of resources for biodiversity informatics, which embody a synoptic understanding or summary of knowledge about the identity, geographic distribution, ecology, phylogeny, population structure, and history of organismal diversity (Brooks and Hoberg, 2000; Wilson, 2000; Hoberg, 2002; Cook et al., 2005; Wandeler et al., 2007). Concurrently, collections serve as historical and environmental baselines with which to assess ecological perturbations and changing faunal structure, including invasive species and emerging diseases, emanating from such processes as global climate warming and other anthropogenic and natural phenomena (e.g., Hoberg et al., 2003; Brooks and Hoberg 2006, 2007; Hoberg et al., 2008).

Here, we explore a range of taxonomic (nomenclatural) and biogeographic questions about pinworms and the complex helminth fauna in the American pika (*Ochotona princeps* [Richardson]) and collared pika (*O. collaris* [Nelson]), which emphasize the critical nature of specimen-based collections. Taxonomic conclusions that emerge from these evaluations among the Labiostomatinae Akhtar, 1956 (Oxyuroidea: Heteroxynematidae Skriabin and Shikhobalova, 1948) provide a necessary framework for geographically fine-scale and detailed analyses of population structure and phylogeography for hosts and parasites across the intermountain west of North America (K. E. Galbreath, unpubl. obs.). Our primary focus, however, addresses why and how we choose, as a scientific community, to use specimens-based collections held in museum repositories, as well as the idea that a major cultural change is necessary.

Pikas are small lagomorphs that are distributed primarily in alpine–talus habitats and, in western North America, are represented by *O. collaris* at high latitudes and by *O. princeps* at boreal to temperate latitudes (Smith et al., 1990). These relatively obscure lagomorphs have received considerable attention as crucial bio-indicators of historical environmental structure across western North America during the late Pleistocene and Quaternary (Hafner, 1993; Hafner and Sullivan, 1995). An understanding of the intricate biogeographic history for pikas has also contributed to interest in documenting the complex nature of the parasite fauna associated with these lagomorphs, both in North America and more broadly in the Holarctic (e.g., Gvozdev, 1956, 1962; Gvozdev et al., 1970; Hoberg, 2005).

The pinworm fauna described from pikas is rich and complex. The Herteroxynematidae contains the Labiostomatinae, a putative monophyletic group of genera in lagomorph hosts that includes Ochotonidae and Leporidae; considered here based on the current taxonomy according to Petter and Quentin (1976), are *Dermatoxys* Schneider, 1866, *Labiostomum* (*Labiostomum*) Akhtar, 1941, *Labiostomum* (*Eugenuris*) (Schulz, 1948), and *Cephaluris* Akhtar, 1947. Since inception of the subfamily, proposals for considerable rearrangements have been entertained (reviewed in Akhtar, 1941, 1947, 1953, 1956; Inglis, 1959; See-

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see, 1973; Quentin, 1975; Grundmann and Lombardi, 1976). For example, *Pikaeuris* Akhtar, 1953 was reduced as a synonym of *Eugenuris* by Akhtar (1956), whereas the initially independent *Eugenuris* was synonymized with *Labiostomum* by Inglis (1959). Further, Gvozdev (1956, 1962) considered, incorrectly, that *Eugenuris* was a junior synonym of *Dermatoxys*.

Among this assemblage of hosts and parasites, multi-species infections in single hosts are not uncommon (Hobbs, 1980). This observation, in conjunction with the difficulty in distinguishing among closely related genera and species, particularly for *L.* (*Labiostomum*) and *L.* (*Eugenuris*), has led to a considerable number of divergent opinions about faunal diversity for pinworms in pikas (e.g., Akhtar, 1956, 1958; Inglis, 1959; Leiby, 1961; Seesee, 1973; Quentin, 1975; Hobbs, 1976; Grundmann and Lombardi, 1976). Additionally, assumptions about host-specificity and extreme geographic isolation for host populations further influenced ideas about biogeography and host associations for parasites in the American pika and the collared pika.

THE CAST OF PLAYERS—PINWORMS IN PIKAS

Specimens representing pinworms in *O. collaris* and *O. princeps*, from localities across western North America, were evaluated. We report taxonomic conclusions that will provide context for broader surveys and analyses of species diversity and the phylogeography of helminth faunas among populations of these host species (K. E. Galbreath and E. P. Hoberg, unpubl. obs.). This does not, however, presume to constitute a formal or synoptic taxonomic revision of this group of oxyurids.

Acronyms for specific museum or field collections include: USNPC (U.S. National Parasite Collection), BCP (Beringian Coevolution Project), and KEG (K. E. Galbreath). Where possible, the type specimens or series were examined, and attempts were made to locate catalogued museum materials and vouchers representing prior published field-studies dealing with pinworms in species of *Ochotona* from North America. Additional specimens were derived from geographically extensive field surveys represented by the BCP and those conducted by KEG for coevolutionary and phylogeographic studies of hosts and parasites (to be reported in detail elsewhere).

Nematodes were cleared in phenol-alcohol (80 parts melted phenol crystals and 20 parts absolute ethanol) and studied in temporary whole-mounts under differential interference contrast with a Zeiss Axiophot compound microscope (Carl Zeiss Incorporated, Thornwood, New York). Lip structure, considered by some to be diagnostic in this group at the species-level (e.g., Akhtar, 1956; Grundmann and Lombardi, 1976), was evaluated based on en face views from hand-cut specimens mounted in glycerine jelly. Photomicrographs were prepared using a Nikon DXM 1200F digital camera system (Nikon Instruments Incorporated, Melville, New York); line drawings were prepared using a drawing tube. The comparisons focus primarily on a series of structural attributes in males and females, with lesser emphasis on meristic data due to the limited numbers of specimens available in the respective type series; all measurements are reported in micrometers unless specified otherwise.

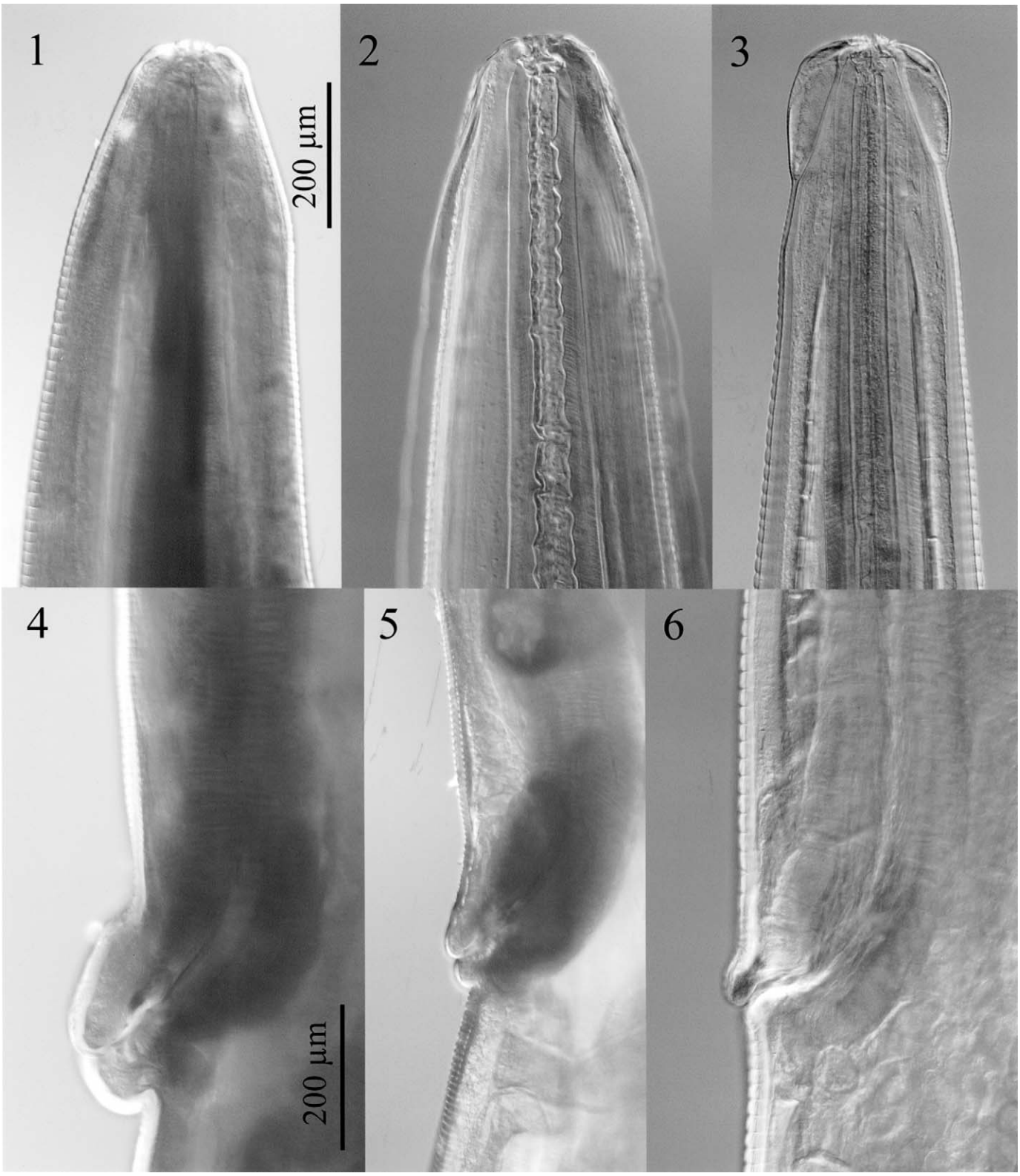
Type specimens examined: (1) *L. coloradensis* Leiby, 1961, holotype male and alloptype female in *O. princeps* from Colorado, under USNPC 39443, re-determined as *L.* (*E.*) *talkeetnaeuris*; (2) *E. utahensis* Grundmann and Lombardi, 1976, syntype males (6 specimens) and females (3 specimens) in *O. princeps* from Utah, under USNPC 73259, re-determined as *L.* (*E.*) *talkeetnaeuris*; (3) *L.* (*Eugenuris*) sp., from Grundmann's syntype females (2 specimens) for *E. utahensis*, re-determined under USNPC 101091.

Other specimens examined: (1) *L.* (*Labiostomum*) *rauschi* Akhtar, 1956 voucher specimens: USNPC 101096 (BCP 9737) in *O. collaris*, Lake Clark National Park, Alaska; USNPC 101097 (BCP 49536) in *O. collaris*, Yukon-Charley National Park, Alaska; USNPC 101093 (KEG 377) in *O. collaris* from Northwest Territories, Canada; USNPC 101095 (KEG 433) in *O. princeps* from Grande Cache, Alberta, Canada; USNPC 101092 (KEG 337) in *O. princeps* from Gifford-Pinchot National Forest, Washington State. (2) *D. veligera*, voucher females (2 specimens) in *O. collaris* from Alaska, under USNPC 26485, re-determined as *L.* (*L.*) *rauschi.* (3) *L.* (*Eugenuris*) *talkeetnaeuris* Akhtar, 1956 voucher specimens: USNPC 101103 (KEG 377) and 101102 (KEG 375) in *O. collaris* from Jawbone Lake, Northwest Territories, Canada; USNPC 101099 (BCP 9737) and 101104 (BCP 9635) in *O. collaris* from Lake Clark National Park, Alaska; USNPC 101100 (BCP 49518) and 101101 (BCP 49340) in *O. collaris* from Yukon-Charley National Park, Alaska; USNPC 101105 (KEG 488) in *O. princeps* from Mackenzie Pass, Oregon; and USNPC 101098 (BCP 7687) in *O. hyperborea* from Yttgran Island, Chutkhotka, Russia.

COMPARISONS AMONG SPECIMENS

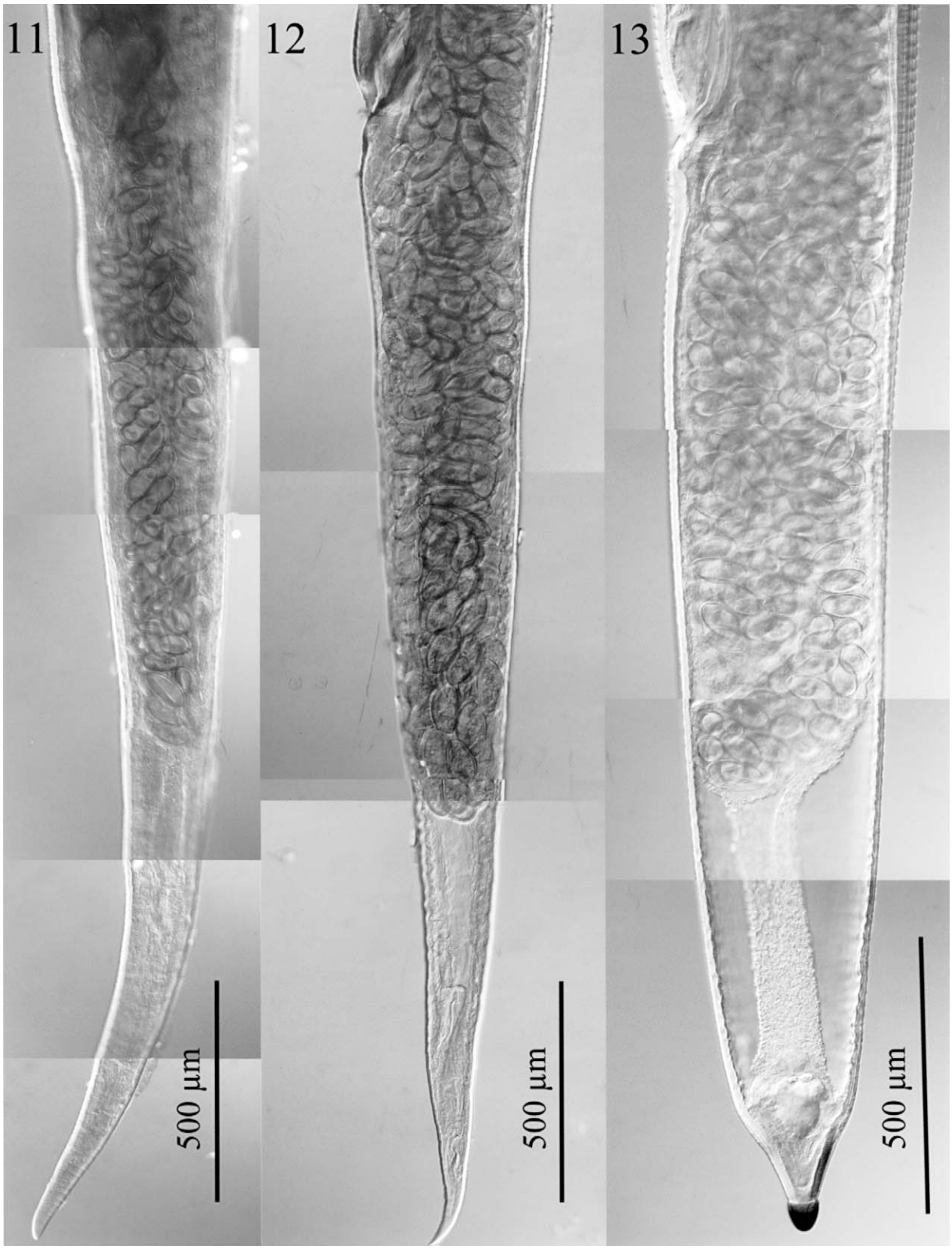
We examined and compared the types for *L.* (*L.*) *coloradensis* and *L.* (*E.*) *utahensis* and representative vouchers of *L.* (*E.*) *talkeetnaeuris* and *L.* (*L.*) *rauschi* during the current study (Figs. 1–22). Further, we compared these observations with the original descriptions attributable to respective species (Akhtar, 1956; Leiby, 1961; Grundmann and Lombardi, 1976). The type series for the latter 2 species, originally deposited by Akhtar (1956) in the collections of the Pakistan Zoological Survey, Karachi, Pakistan, were not immediately available.

Type specimens for *L.* (*Labiostomum*) *coloradensis*: Leiby (1961) apparently described this species based on 3 male and 8 female nematodes in *O. princeps* from Gunnison, Colorado, but only deposited 2 specimens in the USNPC. These ''type specimens,'' a presumptive male holotype and female allotype, were not clearly designated in the original description; other specimens were not deposited. The male was represented by a tail in ventral orientation, mounted permanently in glycerine jelly (Fig. 19). Length of the tail in this specimen is 597 (355 in the original description) and ventral crests initiate near 416 anterior to the cloaca. Caudal papillae include 6 pairs, and 2 massive median or double papillae form a ventral cushion on the posterior margin of the cloaca (Fig. 19). The anterior-most pair, or first, have prominent elongate bases, with tips turned ventrally along the margin of the cloaca. The third pair is bilobed in appearance, each with a prominent inflated base. The female allotype is large, about 19 mm in length and 356 in width at the vulva. The cephalic extremity lacks an inflation, and prominent cervical alae are present laterally (Fig. 1). The esophagus, including the bulb, is 1,249 in length. The prominent, beak-like vulva is situated at 8,979 from the cephalic ex-

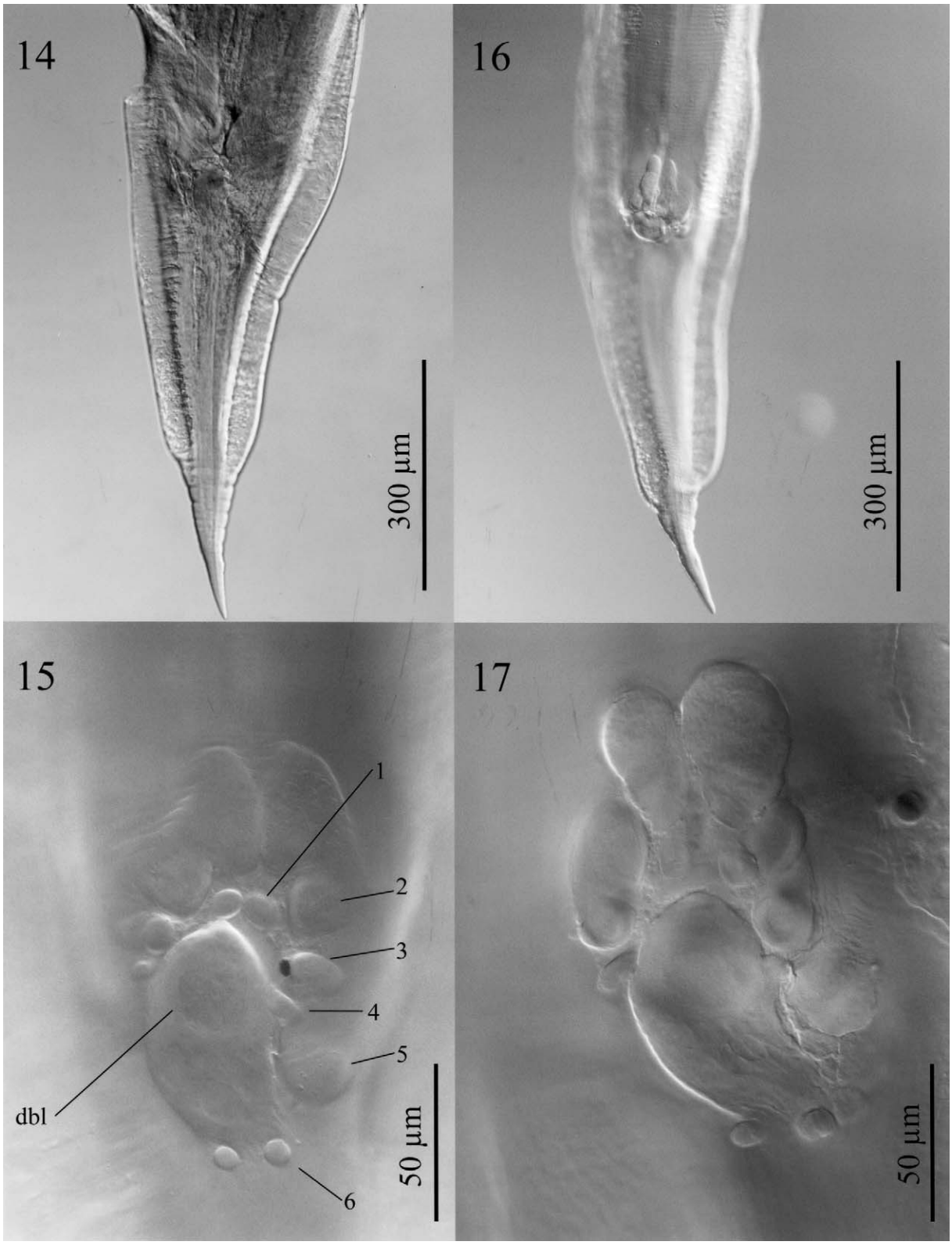


FIGURES 1–6. *Labiostomum* (*Eugenuris*) *talkeetnaeuris* and *L.* (*Labiostomum*) *rauschi* showing structure of the cephalic region (1–3) and vulva in female specimens (4–6); same scale bars for all figures. (**1**) Cephalic extremity, lateral view of allotype for *L.* (*L.*) *coloradensis*, USNPC 39443 in *O. princeps* showing tapering head without inflated capsule. (**2**) Cephalic extremity, dorsal view of voucher specimen of *L.* (*E.*) *talkeetnaeuris*, USNPC 101105 in *O. princeps*, showing tapering head with prominent cervical alae and without capsule. (**3**) Cephalic extremity of voucher specimen of *L.* (*L.*) *rauschi*, USNPC 101092 in *O. princeps*, showing well-developed capsule. (**4**) Vulva, lateral view in allotype for *L.* (*L.*) *coloradensis*, USNPC 39443, noting prominent beak-like structure. (**5**) Vulva, lateral view in syntype female of *L.* (*E.*) *utahensis*, USNPC 73259 in *O. princeps*, showing beak-like form and variation in size. (**6**) Vulva, lateral view in voucher specimen of *L.* (*L.*) *rauschi*, USNPC 101092, showing structure of small ventral flap.

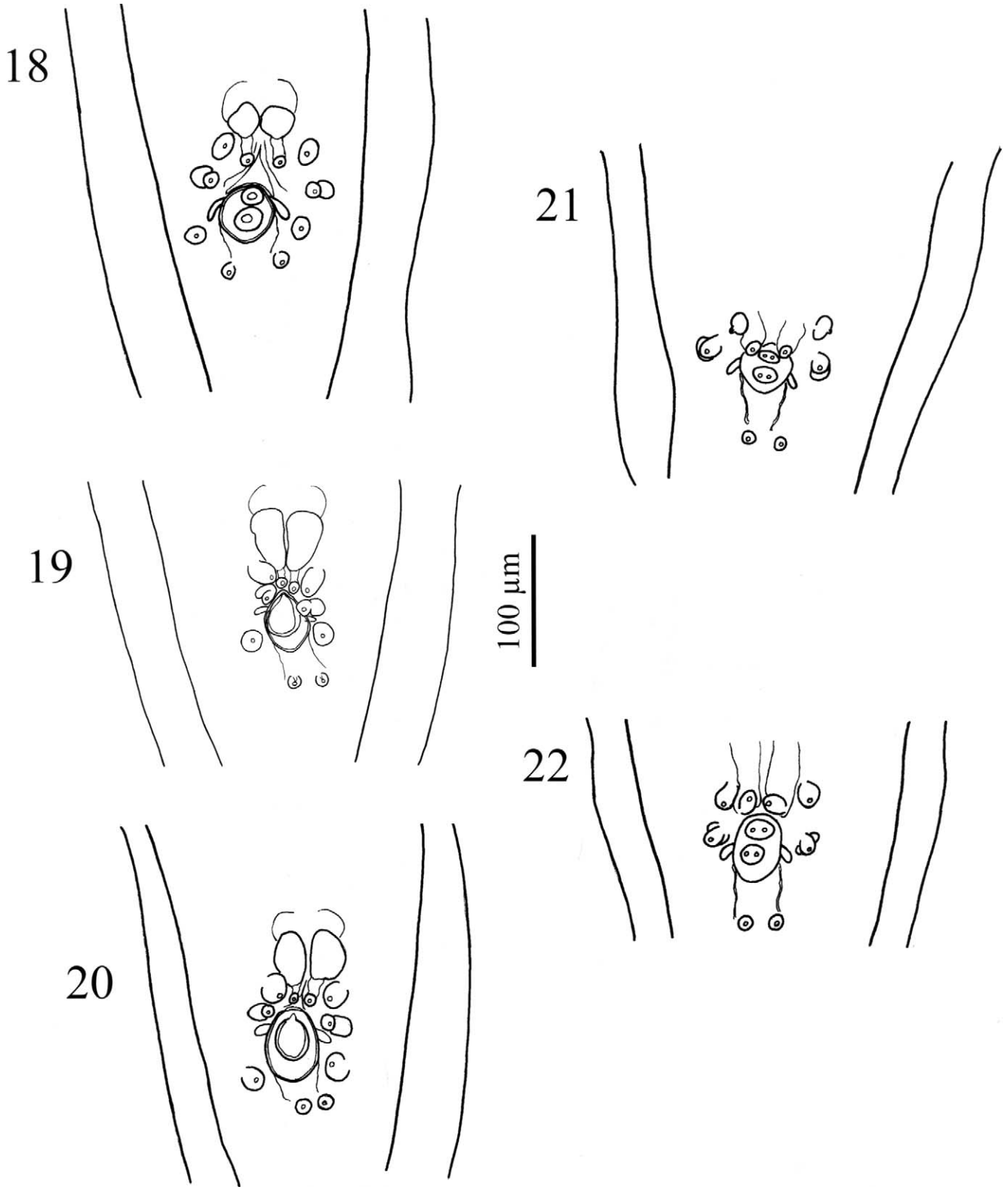
FIGURES 7–10. *Labiostomum* (*Eugenuris*) *talkeetnaeuris* and *L.* (*Labiostomum*) *rauschi* showing variation in structure of the vulva; same scale bars for all figures. (**7**) Vulva, lateral view in syntype female of *L.* (*E.*) *utahensis*, USNPC 73259 in *O. princeps*. (**8**) Vulva in lateral view of voucher of *L.* (*E.*) *talkeetnaeuris*, USNPC 101105 in *O. princeps*. (**9**) Vulva in lateral view of voucher of *L.* (*E.*) *talkeetnaeuris*, USNPC 101103 in *O. collaris*. (**10**) Vulva in latero-ventral view of voucher of *L.* (*L.*) *rauschi*, USNPC 101093 in *O. collaris*, noting prominent ventral flap.



FIGURES 11–13. *Labiostomum* (*Eugenuris*) *talkeetnaeuris* and *L.* (*Labiostomum*) *rauschi* showing structure of tail in female, in lateral view. (**11**) Allotype for *L.* (*L.*) *coloradensis*, USNPC 39443 in *O. princeps* showing elongate filiform tail. (**12**) Syntype female of *L.* (*E.*) *utahensis*, USNPC 73259 in *O. princeps*. (**13**) Voucher of *L.* (*L.*) *rauschi*, USNPC 101092 in *O. princeps* showing inflated tail.



FIGURES 14–17. *Labiostomum* (*Eugenuris*) *talkeetnaeuris* showing structure of male tail and distribution of caudal papillae. (**14**) Caudal extremity in syntype male of *L.* (*E.*) *utahensis*, USNPC 73259 in *O. princeps*. (**15**) Caudal papillae, ventral view, in syntype male of *L.* (*E.*) *utahensis* USNPC 73259 showing distribution of 6 paired papillae (1–6) and massive double papillae (dbl) on posterior margin of cloaca. (**16**) Caudal extremity of voucher specimen of *L.* (*E.*) *talkeetnaeuris* USNPC 101105 in *O. princeps*. (**17**) Caudal papillae, ventral view, in voucher specimen of *L.* (*E.*) *talkeetnaeuris* USNPC 101103 in *O. collaris*.



FIGURES 18–22. *Labiostomum* (*Eugenuris*) *talkeetnaeuris* and *L.* (*Labiostomum*) *rauschi* showing structure and distribution of caudal papillae in male specimens; drawn at same scale. Shown is ventral view at level of cloaca, bordered by body wall and lateral caudal alae. (**18**) Voucher specimen of *L.* (*E.*) *talkeetnaeuris*, USNPC 101103 in *O. collaris* showing 2 preanal pairs, 1 adanal pair with inflated bases, 3 postanal pairs, and massive double papillae forming ventral cushion on median line. (**19**) Holotype male for *L.* (*L.*) *coloradensis*, USNPC 39443 in *O. princeps*. (**20**) Syntype male of *L.* (*E.*) *utahensis*, USNPC 73259 in *O. princeps*. (**21**) Voucher specimen of *L.* (*L.*) *rauschi*, USNPC 101093 in *O. collaris*, showing 2 preanal pairs and 3 postanal pairs, and massive double papillae on midline forming ventral cushion posterior to cloaca. (**22**) Voucher specimen of *L.* (*L.*) *rauschi*, USNPC 101095 in *O. princeps*.

tremity (Fig. 4). The tail is elongate and filiform, 2,574 in length (Fig. 11). Eggs have a single operculum and measure 107–109 long and 52–57 wide. The range of diagnostic characters demonstrated in the male and female type specimens contrasts considerably from the original description presented by Leiby (1961) and is incompatible with species of *L.* (*Labiostomum*), according to Petter and Quentin (1976).

Type specimens for *L.* (*Eugenuris*) *utahensis*: Grundmann and Lombardi (1976) described this species based on 17 male and 15 female specimens in *O. princeps* from Utah; only 6 males and 5 females were deposited in the syntype series in the USNPC; specimens were not deposited in other museum collections. Among males, 6 specimens largely conform to the original description and include relatively large worms to near 11 mm in total length, with the tail being 575–615 long (Fig. 14). Caudal papillae include 6 pairs, and massive double papillae form a ventral cushion on the posterior margin of the cloaca (Figs. 15, 20). Ventral crests initiate at 588–594 anterior to the cloaca. Among females, 3 specimens conform to the original description and are represented by large worms, near 16–18 mm in total length, lacking a cephalic capsule but with an elongate filiform tail exceeding 2 mm in length (Fig. 12) and with a prominent beak-like vulva (Figs. 5, 7). The remaining 2 specimens (not shown), including a fully gravid female, are considerably smaller, 8.6 and 9.1 mm in total length and with a filiform tail 910 and 1,080 long; the vulva is smooth and lacking a prominent beak-like protuberance.

Voucher specimens for *L.* (*Eugenuris*) *talkeetnaeuris*: Akhtar (1956) described this species based on specimens collected by Robert L. Rausch in *O. collaris* from the Talkeetna Mountains, Alaska. Our specimens in *O. collaris* from the Northwest Territories and Alaska, those in *O. princeps* from Oregon, and those in *O. hyperboea* from Chukhotka conform to the original description (Figs. 2, 8, 9, 16, 17, 18). Male specimens are relatively large worms measuring about 9–10 mm in total length, with the tail 554–742 long (Fig. 16). Caudal papillae include 6 pairs, and massive double papillae form a cushion on the posterior margin of the cloaca (Figs. 17, 18). Ventral crests initiate at 693–861 anterior to the cloaca. Female specimens are represented by large worms, from 18–21 mm in total length, with prominent cervical alae but lacking a cephalic capsule (Fig. 2); an elongate filiform tail is 2,445–2,908 in length. The vulva is prominent and beak-like (Figs. 8, 9) and situated at 8,563–9,553 from the cephalic extremity. Eggs measure 96–111 long by 47–52 wide.

Voucher specimens for *L.* (*Labiostomum*) *rauschi*: Akhtar (1956) described this species based on specimens collected by Robert L. Rausch in *O. collaris* from the Talkeetna Mountains, Alaska. Our specimens in *O. collaris* from the Northwest Territories and Alaska, and those in *O. princeps* from Washington and Alberta, conform to the original description (Figs. 3, 6, 10, 13, 21, 22). Males and females have a prominent cephalic capsule (Fig. 3). Males are relatively large worms, measuring 10–11 mm in total length and with a tail 514–569 long. Caudal papillae include 5 pairs, and prominent double papillae form a ventral cushion on the posterior margin of the cloaca (Figs. 21, 22). Ventral crests initiate at 539–630 anterior to the cloaca. Among females, total length ranges from 16–20 mm, the tail is 1,831–2,336 long and inflated with a relatively blunt tip (Fig. 13), and the vulva with ventral flap is 8,959–9,256 from the cephalic extremity (Figs. 6, 10). Eggs measure 94–101 long by 44–49 wide.

TAXONOMIC CONCLUSIONS

The holotype and allotype for *L.* (*L.*) *coloradensis* were found to be identical to some specimens in the syntype series representing *L.* (*E.*) *utahensis*, although the figures and written descriptions of the 2 species do not agree (Leiby, 1961; Grundmann and Lombardi, 1976). Both lots of type specimens represent *L.* (*Eugenuris*), and neither is compatible with *L.* (*Labiostomum*) as demonstrated by comparisons to *L.* (*L.*) *rauschi*. Further, we examined ''unequivocal voucher specimens'' attributed to *L.* (*Eugenuris*) *talkeetnaeuris* in both *O. collaris* and *O. princeps* and found these to be identical with the type specimens for *L.* (*L.*) *coloradensis* and *L.* (*E.*) *utahensis*. Additionally, the syntypes deposited by Grundmann and Lombardi (1976) clearly contained 2 species, a large form (on which the description was based) that represents *L.* (*E.*) *utahensis* and a small form that remains undescribed (USNPC 101091).

The term 'unequivocal voucher' is introduced here for materials such as those representing *L.* (*E.*). *talkeetnaeuris* for which the original types, possibly still held in Pakistan, were simply not available. This concept relates to the idea that specimens referred to this species, from multiple and geographically widespread localities, were identical in all critical morphological details to those in the original description; genetic variation demonstrated among these parasites was further consistent with a single species (K. E. Galbreath and E. P. Hoberg., unpubl. obs.). Although not collected specifically from the type locality, all specimens examined by us were derived from the type host across a range of localities at high latitudes which geographically bracket the Talkeetna Mountains, where the original specimens were collected by R. L. Rausch. Consequently, we consider the identification to be unequivocal and feel that these current voucher specimens can serve as a basis for comparison.

Therefore, due to the identity of these 3 nominal species, *L.* (*L.*) *coloradensis* and *L.* (*E.*) *utahensis* are reduced as junior synonyms of *L.* (*E.*) *talkeetnaeuris* through application of priority (Article 23, ICZN, 1999). In this case, although the description by Leiby (1961) refers to a species of *L.* (*Labiostomum*) for *L. coloradensis*, it is the ''name bearing type specimens'' representing *L.* (*Eugenuris*) that determines the identity (Article 72, ICZN, 1999). Additionally, the large syntype specimens and description of *E. utahensis* provided by Grundmann and Lombardi (1976) apply to *L.* (*E.*) *talkeetnaeuris*, although the syntype series represents a composite; the small forms of *L.* (*Eugenuris*) sp. (USNPC 101091) are a putative, undescribed species that should be dealt with in a separate study.

CONCLUSIONS

Setting the stage—pinworm taxonomy: Understanding the diversity of the pinworms associated with species of pikas from North America has been plagued by a convergence in taxonomic problems: (1) confusion and inconsistency over a period of years in application of generic names for an array of species of oxyurids; (2) misidentifications involving type specimens and species descriptions based on composites; (3) inaccurate descriptions; (4) incomplete comparisons to establish identity of various species; and (5) absence of adequate type series or de-

position of representative voucher specimens to museum repositories to document the results of survey and inventory. Exploring this morass serves as a prime example of the importance of type and voucher specimens, and the role of museum repositories, which are the critical cornerstones for documenting species diversity and the history of faunal structure (Brooks and Hoberg, 2000; Hoberg, 2002).

A series of taxonomic decisions for *Labiostomum*, *Eugenuris*, and *Dermatoxys* served to confuse the understanding of generic diversity for oxyurids among Ochotonidae. Such taxonomic proposals, and whether or not these were rejected or accepted by various authors, had a considerable influence on the generic and species diversity that was eventually reported in various surveys of parasites among pikas. The discussion will be centered on *Labiostomum* and *Eugenuris* and, to a lesser extent, other genera of Labiostomatinae. Among other attributes, *L.* (*Labiostomum*) Akhtar, 1941 is characterized by an inflated cephalic bulb, a single preanal crest in males, and an inflation near the termination of the tail in females (also Quentin, 1975; Petter and Quentin, 1976) (Figs. 3, 13). In contrast, *L.* (*Eugenuris*) (Schulz, 1948) is characterized by the absence of an inflated cephalic bulb, but with a single preanal crest in males and a narrow, tapering, filiform tail in females (Akhtar, 1956) (Figs. 1, 2, 11, 12). Otherwise, the structure of the male caudal papillae is similar across species relegated to these subgenera, although interspecific differences remain important in species recognition (Inglis, 1959; Quentin, 1975) (Figs. 15–22). In contrast, *Cephaluris* is distinguished by the presence of a pair of cephalic shields, and *Dermatoxys* is distinct among this group of genera, based on the presence of 3 preanal crests (Akhtar, 1947; Petter and Quentin, 1976). In addition, *Labiostomum* and *Cephaluris* are specific among hosts of the Ochotonidae, whereas *Dermatoxys* is found among the Leporidae.

Leiby (1961) deposited 2 specimens, a male tail and an intact female, from among 3 males and 8 females mentioned as the type series for *L. coloradensis*; it is now certain that Leiby had representatives of 2 species referable to different subgenera, namely *L.* (*Labiostomum*) and *L.* (*Eugenuris*). Apparently, specimens representing both subgenera may have been included in the written description. The figures of the female were based on *L.* (*Labiostomum*) (the cephalic and caudal regions); the origin (specimen) of the figure for male caudal structures cannot now be assigned and does not represent the holotype. Although a putative species of *L.* (*Labiostomum*) was described, only specimens of *L.* (*Eugenuris*) were deposited in the USNPC and, thus, the types were misidentified. The type specimens, both the male holotype and female allotype, attributed to *L. coloradensis* do not agree with either the written description or measurements, and the published figures and scale bars are incorrect (Leiby, 1961) (Figs. 1, 2, 11, 19). There are no longer any representatives of true *L.* (*Labiostomum*) in these collections, but some aspects of the description suggest that Leiby's account is consistent with that of *L.* (*Labiostomum*) *rauschi.* At the time of the description, Leiby (1961) rejected the taxonomic decisions proposed by Inglis (1959) for the synonymy of *Labiostomum* and *Eugenuris*.

Grundmann and Lombardi (1976) described *E. utahensis* apparently based on 17 male and 15 female specimens; only 6 males and 5 females were deposited in the syntype series in the USNPC. Some, but not all, of the specimens in the type series, and the description are internally consistent, and this species was correctly referred to *Eugenuris*. At the time of the description, these authors apparently rejected the synonymy of *Dermatoxys* and *Eugenuris* proposed by Gvozdev (1956), or of *Eugenuris* and *Labiostomum* proposed by Inglis (1959), and appeared to be unaware of decisions for generic taxonomy outlined by Quentin (1975) and Petter and Quentin (1976). Specimens of *E. utahensis* were only compared to published descriptions of *E. talkeetnaeuris* Akhtar, 1956 and *E. schumakhovitschi* Schulz, 1948, but not to those for species of *Labiostomum*, including *L. coloradensis*, although the latter species was reported in the survey.

We conclude that the types for *L. coloradensis* and *E. utahensis* are identical, based on the current comparisons and, further, cannot be distinguished from unequivocal voucher specimens attributed to *L.* (*Eugenuris*) *talkeetnaeuris* in both *O. collaris* and *O. princeps*. Consequently, due to the identity of these 3 nominal species, *L.* (*L.*) *coloradensis* and *L.* (*E.*) *utahensis* are reduced as junior synonyms of *L.* (*E.*) *talkeetnaeuris.*

A final confounding variable for understanding parasite diversity in American and collared pikas is the common occurrence of mixed infections for multiple genera and species in single hosts (e.g., Akhtar, 1956, 1958; Hobbs, 1976, 1980). Further, assumptions about host-specificity and extreme geographic isolation for host populations contributed to concepts about species diversity, distribution, and associations of various species of pinworms in either *O. collaris* or *O. princeps* and suggested that the faunas should be strongly segregated or partitioned (e.g., Grundmann and Lombardi, 1976). Nematodes in the subgenera *L.* (*Labiostomum*) and *L.* (*Eugenuris*) are morphologically similar, leading to misidentifications if specimens are superficially examined. Such mixed infections have had consequences in taxonomy, as 3 species in 3 genera were originally based on composites. Hobbs (1976) discussed this problem for *C. coloradensis* Olson, 1949. We have explored the ramifications of this problem for newly recognized composites, involving multiple species represented in the original descriptions or type series for *L.* (*L.*) *coloradensis* and *L.* (*E.*) *utahensis*, as well as the resulting complications for nomenclature and for understanding the distribution and structure of biodiversity.

These conclusions may serve to resolve the identity of pinworms reported from pikas in prior surveys in western North America. We suggest that single species of *L.* (*Labiostomum*) and *L.* (*Eugenuris*), both representing large pinworms, are widely distributed in *O. collaris* and *O. princeps*. Thus, prior records in *O princeps* attributed to *L. coloradensis* are probably consistent with *L.* (*L.*) *rauschi*, whereas those for *E. utahensis* represent *L.* (*E.*) *talkeetnaeuris* (Barrett and Worley, 1970; Seesee, 1973; Grundmann and Lombardi, 1976; Hobbs, 1980); neither species had been recognized previously in *O. princeps*. Additionally, the occurrence of *L.* (*E.*) *talkeetnaeuris* in *O. hyperborea* from Chukhotka would represent both a new host and geographic record for this species in the Palearctic. These conclusions are not yet definitive and remain to be confirmed, although the identity of large pinworms in both subgenera appears unequivocal. Additional, currently undescribed diversity for species of small pinworms, in both subgenera among populations of *O. princeps*, has been demonstrated by integrated molecular and morphological studies (K. E. Galbreath and E. P. Hoberg, unpubl. obs.). Finally, the possibility of sorting out

prior records in North America is now limited by the absence of vouchers from earlier studies.

Since 1938, there have been 5 published studies (excluding explicit taxonomic diagnoses and descriptions) which, in part, have dealt with reports of pinworms among species of pikas, including *O. collaris* or *O. princeps* from North America. Identification of materials from many of these studies cannot now be confirmed reliably due to the absence of any voucher materials. Additionally, the type series for the North American species, *C. alaskensis*, *E. talkeetnaeuris*, and *L. rauschi* are not readily available, as specimens were originally deposited in various museum collections of the Pakistan Zoological Survey, Karachi, (Akhtar, 1956, 1958).

Barrett and Worley (1970) examined parasites in *O. princeps ventorum* Howell and reported *L. coloradensis* and *C. coloradensis*. Specimens of *Eugenuris* were not reported, and vouchers were not deposited concurrent with the study. Specimens were received posthumously from the D. Worley collections by the Harold W. Manter Laboratory, University of Nebraska, but critical material from pikas could not be located (S. L. Gardner, pers. comm.).

Seesee (1973) examined parasites in *O. princeps* from northern Idaho and reported *Labiostomum* sp. and *Dermatoxys* sp. In this study, *L. coloradensis* is not identified, but is included in a key for parasites in pikas. Seesee (1973) must have considered his specimens to be distinct from both *L. coloradensis* and *L. rauschi*, although papers by Leiby (1961) and Akhtar (1956) are cited. In 1973, following Gvozdev (1956, 1962), but not Inglis (1959), *Eugenuris* was considered a synonym of *Dermatoxys*, thus accounting for the report of the latter genus and also the reference to *D. talkeetnaeuris*. It appears possible that specimens reported as *Dermatoxys* sp. by Seesee (1973) in *O. princeps* represented *E. utahensis*, now referable to *L.* (*E.*) *talkeetnaeuris*.

Grundmann and Lombardi (1976) conducted surveys of subspecies of *O. princeps* in Utah and Nevada. *Eugenuris utahensis* (discussed above) was described and *L. coloradensis* was reported, but again, no vouchers of the latter were made available to any museums at the time of the study; materials from the collections of A. W. Grundmann are now held in the Harold W. Manter Laboratory (HWML), University of Nebraska, Lincoln, but specimens from pikas could not be located (S. L. Gardner, pers. comm.). The status of *Eugenuris* was addressed in their study, and the proposal by Inglis (1959) was rejected. In this case, specimens reported as *L. coloradensis* would probably represent *L.* (*L.*) *rauschi.*

Hobbs (1980) conducted surveys and comparative studies of the community ecology of pinworms in *O. princeps* and *O. collaris*, but representative vouchers were not deposited. *Eugenuris* sp. A., an apparently undescribed species, and *L. coloradensis* were reported as parasites in *O. princeps*; the former is referable to either *L.* (*E.*) *talkeetnaeuris* or to an undescribed species—if specimens represent the ''small form'' reported in the current study. Hobbs (1980) apparently did not see the work by Grundmann and Lombardi (1976). There is no basis for identification of *L. coloradensis* by Hobbs (1980), as Leiby (1961) is not in the literature cited; *E. talkeetnaeuris* and *L. rauschi* were reported in *O. collaris*.

Confusion over the identity of ''*L. coloradensis*,'' and the absence of voucher specimens in these prior studies, raises questions about the identity of specimens reported as *Labiostomum* or *Eugenuris* in *O. princeps*. Extensive new collections (site intensive and geographically extensive) across the geographic distribution of *O. princeps* from northwestern North America, and more-limited material in *O. collaris* from the Northwest Territories and Alaska (K. E. Galbreath and E. P. Hoberg, unpubl. obs.), have failed to reveal specimens that agree with the description of *L. coloradensis* provided by Leiby (1961). Specimens examined from either *O. collaris* or *O. princeps* were consistent with *L.* (*Labiostomum*) *rauschi* (not previously reported in the latter pika).

Considering other records of pinworms in pikas, Inglis (1959) speculated that specimens attributed to *Dermatoxys* sp. in *O. collaris* from Alaska by Philip (1938) represented a species of *Cephaluris*. Records for these specimens in the USNPC indicated identification as *D. veligera* by J. T. Lucker in 1937, although parasites of this genus are typically associated with Leporidae and not with Ochotonidae. Our examination of these specimens demonstrated the 2 female specimens to be *L.* (*Labiostomum*) *rauschi* (USNPC 26485.02), thus clarifying this formerly enigmatic record.

Significantly, these specimens deposited by Phillip (1938), and now redetermined as *L. rauschi*, represented the only voucher material for oxyurids or other nematodes submitted to the USNPC across a range of survey and ecological studies of parasites in *O. collaris* or *O. princeps* from North America (Barrett and Worley, 1970; Seesee, 1973; Grundmann and Lombardi, 1976; Hobbs, 1980). The only exceptions, where specimens were deposited, involved taxonomic descriptions. In this case, the types for *L. coloradensis* and *E. utahensis* were submitted (USNPC 39443, USNPC 73259) and some, but not all, specimens of *Cephaluris* represent the redescriptions of *C. alaskensis* and *C. coloradensis* by Hobbs (1976); no other materials representing pinworms from published field collections are currently in catalogued museum repositories.

Although the practice for submission of vouchers has become increasingly common, there remains no generalized requirement, on the part of all journals that publish the results of survey and inventory or, more specifically, ecological investigations, for the submission of definitively identified vouchers. Concurrently, not all molecular- and sequence-based investigations are accompanied by representative specimens that validate the identity of the organisms under examination. In the case that we have outlined, the absence of vouchers, in convergence with a dynamically changing taxonomy, considerably confused our understanding of geographic distribution and diversity for the oxyurid fauna in species of *Ochotona* from North America. This is but one small example of the degree of potential complexity that emerges from the absence of adequate type series or representative voucher specimens.

Pikas and pinworms provide a powerful example of why specimens and surveys are important and of why museum collections should serve a vital and central role in the exploration of diversity. Natural history collections are most useful when they provide a synoptic view of diversity. Such a view of diversity only emerges if museum repositories are supported and if a culture exists in science that values and contributes to the development of specimen-based collections having considerable scope and depth; or, put another way, we require collections that provide a detailed representation of the biosphere extending

hierarchically from higher taxa to populations. (Brooks and Hoberg, 2000, 2006, 2007; Hoberg, 2002). This point is further emphasized in the context of baselines for documenting faunal stability and change that are particularly significant now in a regime of accelerated ecological perturbation, including the cascading effects of climate warming (Hoberg et al., 2003; Brooks and Hoberg, 2007; Hoberg et al., 2008). Patterns for the distribution of pathogens and emergent diseases cannot be understood unless considered in an historical framework that can only be articulated from empirical data derived from geographically extensive inventories, with arrays of specimens represented in museum collections (Brooks and Hoberg, 2006; Hoberg and Brooks, 2008).

It is important that large or complete series of specimens be deposited, either as a basis for taxonomic description or as those that document host and geographic associations, from extensive and intensive survey and inventory and from ecological investigations exploring processes at varying temporal and spatial scales (Hoberg et al., 2003; Cook et al., 2005). Deposition of a single type specimen, or of a limited number of vouchers, is clearly insufficient. It is only through accumulation of synoptic, representative series that a species or host-parasite association is well characterized, and a foundation can then be established with which to assess morphological or molecular variation at both the interspecific and intraspecific levels. Further, it is essential that any molecular-based investigations, extending across the continuum from higher-level systematics to population structure within species and phylogeography, be soundly backed by definitively identified specimens that become the physical vouchers for explorations of the origins and distribution of organismal diversity. Such physical specimens can further be linked to gene products or frozen materials held in ultralow or liquid nitrogen storage.

We suggest, strongly, that type series or portions of type series should not be held in private or personal collections, where some specimens are eventually lost, discarded, or are destroyed through neglect due to inattention and the absence of curation. Separation of specimens from their original data for field collection represents a considerable challenge and, often, the context is lost for understanding patterns of diversity or life history. These aspects of large, orphaned collections pose a substantial curatorial burden on museums that are chronically underfunded and understaffed. The potential to accumulate meaningful baselines for assessment of environmental change is jeopardized if fully documented materials from survey and inventory are not routinely submitted to museum collections. It is the responsibility of museum repositories to provide for stewardship and long-term care of the critical type specimens on which our concepts of diversity are established, as specified in Article 72F of the International Code for Zoological Nomenclature (ICZN, 1999).

The capacity of museum repositories or natural history collections, as a focus for systematics and the development of resources for biodiversity informatics, continues to be undervalued and poorly utilized by a cadre of scientists who are dependant on accurate and definitive information that transcends specific disciplines (Hoberg, 2002). With global ecosystems in rapid transformation and perturbation, we risk loosing critical information about biodiversity and about the influence of accelerated ecological change that has consequences for human health, sustainability of food resources, conservation biology, and the integrity and continuity of natural systems.

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