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Four New Species of the Subgenus *Leptoferonia* Casey (Coleoptera, Carabidae, *Pterostichus* Bonelli) from California

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Four small, nearly eyeless species, *Pterostichus* (*Leptoferonia*) *blodgettensis, P.* (*Leptoferonia*) *pemphredo* (both with type locality Blodgett Experimental Forest, Eldorado Co. California), *P.* (*Leptoferonia*) *deino* (type locality Deer Creek Meadow, Tehama Co. California), and *P.* (*Leptoferonia*) *enyo*, (type locality, 12 mi west of Weaverville, Trinity Co. California) are described. These species are known from very few specimens but are highly distinctive in body form, male genitalic shape and in having extremely small eyes. These species represent three separate evolutionary events in *Leptoferonia* resulting in size and eye reduction.

Pterostichus Bonelli is one of the few groups of relatively large-sized carabid beetles in North America that needs significant revision. The classification of this genus has been subjected to bouts of lumping and splitting of generic and subgeneric taxa throughout its taxonomic history. Presently, there are approximately 75 recognized subgenera worldwide. In North America, the tribe Pterostichini includes 12 genera, of which two, *Abaris* Dejean and *Hybothecus* Chaudoir (= *Ophryogaster* Chaudoir), are more closely related to South American taxa and one, *Abax* Schuler, is a recent introduction from Europe. The remaining genera (excluding Loxandrini) are more or less closely related to *Pterostichus*, and many of them have been included in a larger concept of that genus by various authors. The relationships among the 21 North American and several Mexican subgenera of *Pterostichus*, and between these taxa and the numerous Palearctic subgenera is still unresolved. However, significant advances have been made in one part of *Pterostichus*, the *Hypherpes*-complex. Recent classifications have placed the taxa of this complex, which includes species placed by various authors in *Leptoferonia* Casey, *Anilliferonia* Van Dyke, and *Hypherpes* Chaudoir together in the single subgenus *Hypherpes.* Based on adult and larval morphology, which provide few obviously decisive grouping characters for the subgenera (Bousquet 1999), this was a reasonable solution. Exemplar DNA sequence analysis of taxa of the *Hypherpes*-complex using three gene loci showed that the three subgenera of *Pterostichus* (*Leptoferonia, Anilliferonia* and *Hypherpes*) do form a single clade relative to other North American and select Palearctic subgenera. *Leptoferonia* and *Hypherpes* are reciprocally monophyletic and *Anilliferonia* is monophyletic, exclusive of *Anilloferonia rothi* (Hatch), which is a member of *Leptoferonia* (K.Will and A.Gill, unpublished). Therefore, the species treated herein are described in *Leptoferonia*.

Recent publications on North American *Pterostichus* (Bousquet 1999) and descriptions of new species of the subgenus *Hypherpes* all point out that there are a great many new species to describe in *Hypherpes* s.str. (Kavanaugh and LaBonte 2006; LaBonte 2006). The last treatment of *Hypherpes,* exclusive of *Leptoferonia*, was done by Casey (1913, 1924). My examination of available specimens of *Leptoferonia* suggests that the more thorough study done by Hacker (1968)

leaves relatively few species to be described in that subgenus. Notwithstanding the quality of Hacker's treatment, study of recently collected specimens and specimens found in various collections revealed the presence of four highly distinctive new species of *Leptoferonia*. The purpose of this contribution is to describe and name these newly discovered taxa.

Materials and Methods

More than 600 adult specimens of *Leptoferonia* were examined for this study, and these represent all named species. Specimens pertinent to this study are deposited in the Essig Museum of Entomology Collection, University of California, Berkeley (EMEC) and the California Academy of Sciences, San Francisco (CAS). Specimen dissection protocols, taxonomic methods, and species recognition criteria follow Will (2002). Specimens and their dissected elements were examined using a dissecting microscope with magnification ranging from 25–100×. An ocular scale micrometer was used to take measurements. Total body length is the sum of the length of the elytra along the midline from basal margin to apex, plus length of pronotum from base to apices of anterior angles, plus head length from anterior margin of pronotum to base of mandibles. Habitus and genitalia images were taken using a Microptics XLT digital imaging system. Line drawings of male genitalia, female reproductive tract, and pronota were composed in standard image editing software by overlaying digital images and tracing them using a drawing tablet.

Taxonomic Treatment

***Pterostichus* (*Leptoferonia*) *blodgettensis* Will, sp. nov.**
Figures 1A, 2A, 3A–D, 4.

Types.— Holotype: Point mounted male, labeled: "38°54′45″N/120°39′26″W, USA: **California**: El Dorado Co., Blodgett Experimental Forest, Bacon Crk nr Loop Rd. 1250 m el., 3.xii.2004. Coll. K. & O.Will, Under rotten log." Deposited EMEC. Partially disarticulated and tissue used for DNA extraction. Template DNA labeled "kww368".

Description.— *Color*: rufous throughout. *Total body length*: 6.0 mm. *Ventral surface*: Prothoracic venter smooth, mesepimeron and lateral portion of the metasternum shallowly punctate, abdomen without punctuation. *Head*: Moderately broad, width of head at widest point 7/10 width of pronotum at widest point. Eye minute, 0.10 mm over greatest length, narrow oval form. Frontal impressions divergent. Antennae of average build, total length reaching slightly beyond base of pronotum, antennomeres 5–10 elongate form. *Pronotum* (Fig. 1A): Greatest width and length equal, widest well before midpoint, sides nearly parallel and slightly convergent to base and straight onto nearly rectangular hind angles. Anterior corners markedly produced. Median line clearly impressed and near full length of pronotum. Basal impressions shallow, inner linear and outer absent. Base smooth. Anterior lateral setae less than one quarter pronotum length from anterior margin, basal setae set in hind angles. *Elytra* (Fig. 2A): Form parallel-sided, base with border entire, humeral angle with prominent tooth, parascutellar setiferous punctures absent, parascutellar stria not connected to stria 1, angular base of stria 1 present, connected or not to stria 1, nine well-impressed striae, striae smooth throughout, margin at epiplura carinate with well defined bead for its entire length, no external plica. Umbilicate series of stria 8 with six setiferous punctures in anterior (basal) series, no punctures in medial series, six in posterior (apical) series and a single puncture near apex of stria 7. *Legs*: Average build, metatrochanter blunt, meta coxa with one seta near base and one near medial edge, tarsi moderately elongate, fifth tarsomere ventrally glabrous. Male protarsi slightly, symmetrically expanded, with ventral articulo-setae. *Sixth abdominal ventrite*: Male with two

seta, medial concavity and preapical, low thick ridge. *Aedeagus* (Fig. 3A–D): Meeting of ventral surface and right-lateral surface of median lobe with elevated carina, ventral surface concave with lightly sclerotized diagonal strip. Tip relatively short and bluntly rounded. Right paramere short, broadly rounded at apex. Internal sac without sclerotized spine. *Pygidial glands*: Reservoirs somewhat cordiform, no additional lobes on reservoir or efferent duct.

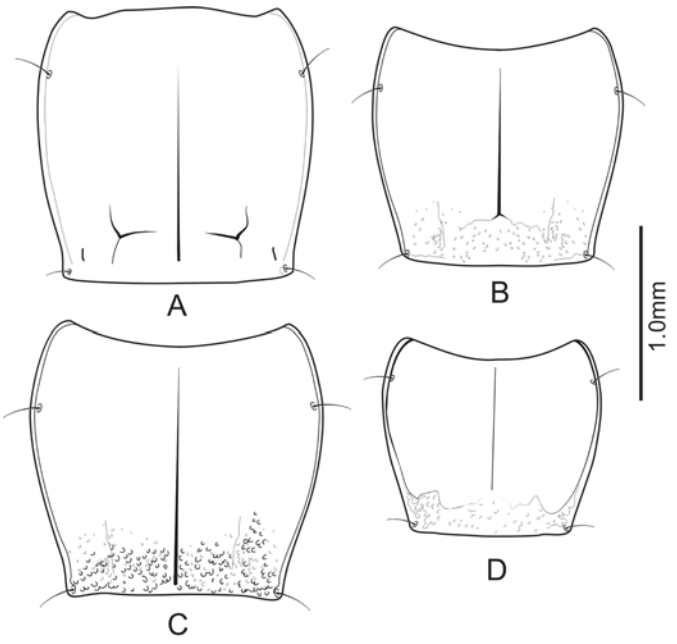

FIGURE 1. Pronota. A. *Pterostichus blodgettensis*; B. *P. pemphredo*; C. *P. deino*; D. *P. enyo*.

SPECIMENS EXAMINED.— Type specimen only.

DISTRIBUTION.— Known only from the type locality, Blodgett Experimental Forest, Eldorado Co. California (Fig. 4).

REMARKS.— I collected a single specimen under a deeply set, large rotten log in a shaded area near Bacon Creek. The soil was relatively moist, but not saturated. Microhabitat is the same as *P. pemphredo*, and although they were not collected together under a single log, they were under adjacent ones. Other species of *Leptoferonia* found in the area, but not under deep-set logs, include *P. inanis* Horn and *P. hatchi* (Hacker).

ETYMOLOGY.— Named after the type locality.

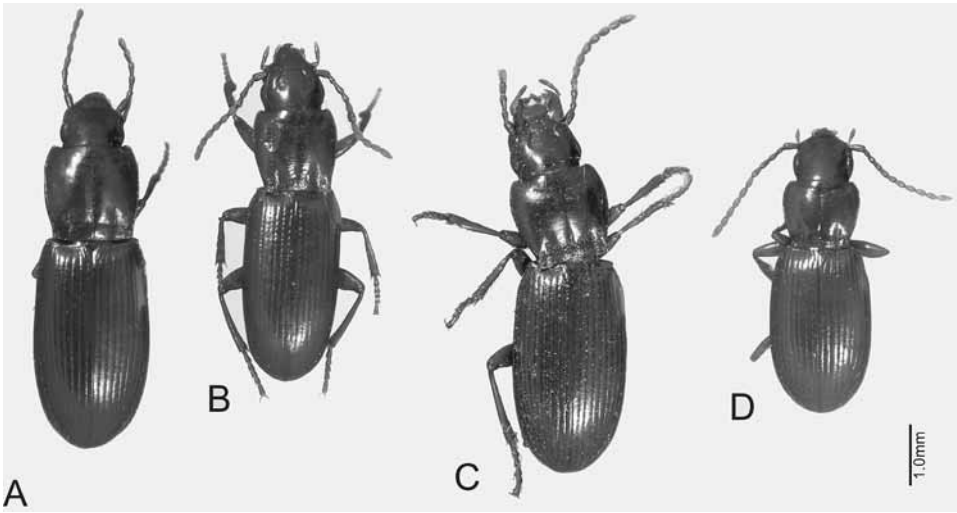

FIGURE 2. Images of habitus. A. *Pterostichus blodgettensis*; B. *P. pemphredo*; C. *P. deino*; D. *P. enyo*.

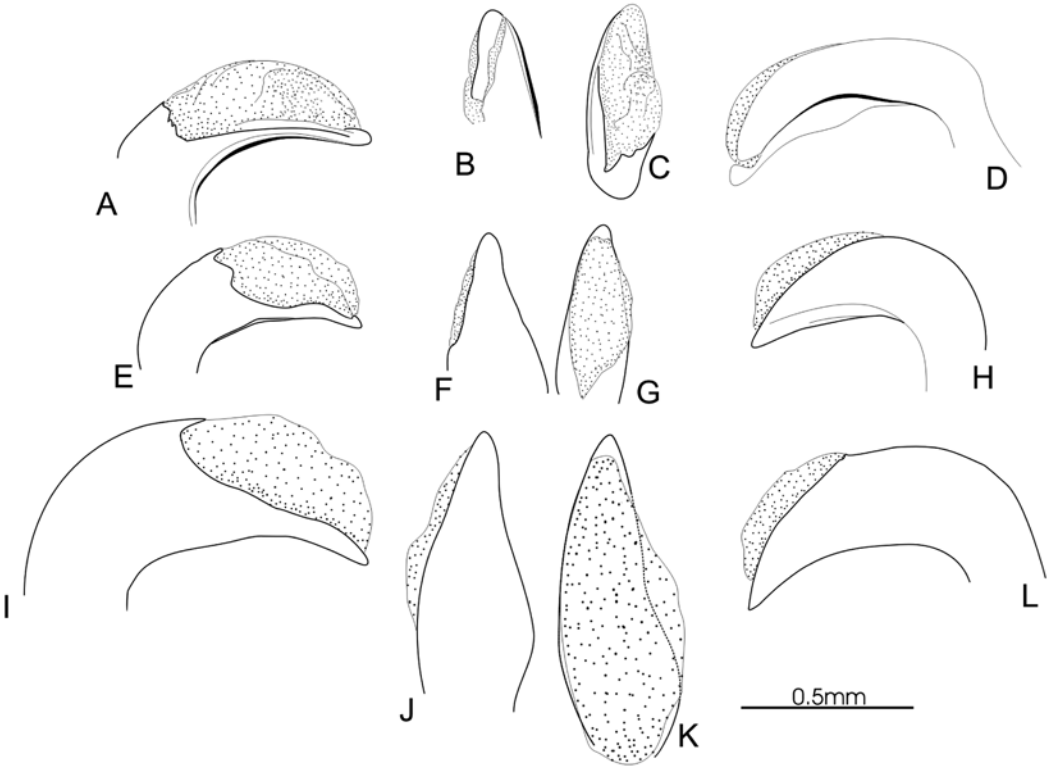

FIGURE 3. Median lobe of the aedeagus. A. left lateral view, B.ventral view of tip, C. dorsal view of tip, D. right lateral view for *Pterostichus blodgettensis*; E–H, same for *P. pemphredo*; I–L, same for *P. deino*.

***Pterostichus* (*Leptoferonia*) *pemphredo* Will, sp. nov.**
Figures 1B, 2B, 3E–H, 4, 5.

TYPES.— HOLOTYPE: Point mounted female, labeled: "38°54′45″N/120°39′26″W, USA: **California**: El Dorado Co., Blodgett Experimental Forest, Bacon Crk nr Loop Rd. 1250 m el., 5.vi.2004. Coll. K.Will, Under rotten log nr stream." Deposited EMEC. ALLOTYPE: Point mounted male, labeled: "CALF. El Dorado Co., Blodgett Forest, 13 mi. E. Georgetown, el. 4000–4500′; 29 May 1971, Robert Hislop. Univ. Calif. Insect Survey Specimen # 109722". Deposited EMEC. PARATYPES: Vial storage in EtOH 1 male, 1 female, both with same label data and deposition as holotype, both with genitalia dissected, male further disarticulated and tissue used for DNA extraction. Template DNA labeled "kww240". Deposited EMEC. 1 female, point mounted, with same label data and deposition as holotype. Deposited CAS.

DESCRIPTION.— *Color*: rufous throughout. *Total body length*: 5.8 mm (range of paratypes 5.6–5.8 mm). *Ventral surface*: Lateral portion of thorax and abdomen distinctly punctate. *Head*: Relatively broad, width of head at widest point ⅘ width of pronotum at widest point. Eye minute, 0.10 mm over greatest length, narrow oval form. Frontal impressions divergent posteriorly. Antennae relatively short and stout, total length not reaching base of pronotum, antennomeres 5–10 quadrate form. *Pronotum* (Fig. 1B): Greatest width slightly more than greatest length, widest well before midpoint, sides scarcely rounded and convergent to base where they are straight onto nearly rectangular hind angles. Anterior angles very slightly produced. Median line clearly impressed and near full length of pronotum. Basal impressions shallow, inner linear and broadly joined to outer that ends laterally at a low, rounded carina. Entire base lightly punctate. Anterior lateral setae

one quarter pronotum length from anterior margin, basal setae approximately width of puncture forward of base. *Elytra* (Fig. 2B): Form parallel-sided, base with border entire, humeral angle with prominent tooth, parascutellar setiferous punctures absent, angular base of stria 1 absent, nine well-impressed striae, striae distinctly punctate in basal two thirds, shallowly punctate to smooth in apical third, margin at epiplura rounded in apical two thirds, carinate in basal third, no external plica. Umbilicate series of stria 8 with five setiferous punctures in anterior (basal) series, no punctures in medial series, five in posterior (apical) series and a single puncture near apex of stria 7. *Legs*: Average build, metatrochanter bluntly pointed, more slender in male, meta coxa with single seta near base (one paratype female with extremely short, fine seta near median margin), tarsi stout, fifth tarsomere ventrally glabrous. Male protarsi slightly, symmetrically expanded, with ventral articulo-setae. *Sixth abdominal ventrite*: Female with four setae, male with two. Male apex unmodified. *Aedeagus* (Fig. 3E–H): Meeting of ventral surface and right-lateral surface of median lobe slightly carinate, ventral surface without lightly sclerotized strip. Tip relatively long and pointed. Right paramere short. Internal sac with large, sclerotized spine. *Female reproductive tract* (Fig. 5): Bursa cup-shaped; spermathecal duct very elongate, length about 16× of that of gonocoxite-1; spermatheca elongate, smooth; appended spermathecal gland elongate, subtended by ampulla and connected by duct near base of spermatheca; gonocoxite-1 with 1–2 apicolatera ensiform setae, gonocoxite-2 with 2–3 lateral and 1 dorsomedial ensiform setae and 2 nematiform setae in elongate subapical furrow. *Pygidial glands*: Simple, without modification of reservoir or efferent duct.

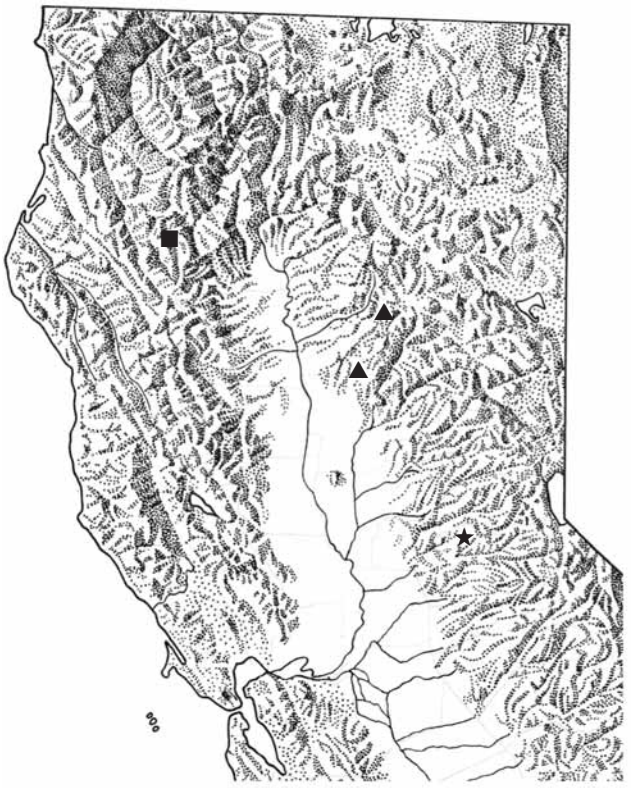

FIGURE 4. Northern California localities for *Pterostichus blodgettensis*, star; *P. pemphredo*, star; *P. deino*, triangle; D. *P. enyo*, square.

SPECIMENS EXAMINED.— Five individuals of type series.

DISTRIBUTION.— Known only from the type locality, Blodgett Experimental Forest, El Dorado Co., California (Fig. 4).

REMARKS.— I collected four specimens near Bacon Creek. The soil was moist, but not saturated. All four where found under deeply set, large rotten logs in shaded areas. Additionally, the field notes related to the specimen labeled 'Calif. Insect Survey Specimen # 109722' indicate that this specimen was found to be active under an old, rotten log in wet soil. Microhabitat is the same as *P. blodgetti*, and although they were not collected together under a single log, they were under adjacent ones. Other species of *Leptoferonia* found in the area, but not under deep-set logs, include *P. inanis* Horn and *P. hatchi* (Hacker).

ETYMOLOGY.— Named as a noun in apposition after *Pemphredo* ("Alarm"), one of the three Graeae, daughters of Phorcys and Ceto from Greek mythology. These sisters are said to share one eye among them. This is analogous to the three minute-eyed species of beetle described herein, which are named after the *Graeae*, as they scarcely have a single eye among them.

***Pterostichus* (*Leptoferonia*) *deino* Will, sp. nov.**

Fig. 1C, 2C, 3I–L, 4.

TYPES.— HOLOTYPE: Point mounted female, labeled: "Chico-Chester, Deer Ck. Meadow, Cal. 6-17-1956, P.S. Bartholemow// P.S. Bartholomew collection, Calif. Acad. Sci. Accession 1967". Deposited CAS. ALLOTYPE: Point mounted male, genitalia dissected in vial, labeled: "Chico El. 2200, Forest Ranch, Cal. 6-17-1956, P.S. Bartholomew// P.S. Bartholomew collection, Calif. Acad. Sci. Accession 1967". Deposited CAS.

DESCRIPTION.— *Color*: rufous throughout. *Total body length*: 6.0 mm (allotype 6.9 mm). *Ventral surface*: Lateral portion of thorax distinctly punctate, abdomen smooth. *Head*: Relatively broad, width of head at widest point ¾ width of pronotum at widest point. Eye minute, 1.0 mm over greatest length, narrow obovate form. Frontal impressions divergent. Antennae relatively short and somewhat stout, total length scarcely reaching base of pronotum, antennomeres 5–10 nearly quadrate form. *Pronotum*(Fig. 1C): Greatest width slightly more than greatest length, widest well before midpoint, sides scarcely rounded and convergent to base where they are straight onto rectangular hind angles. Anterior corners slightly produced. Median line clearly impressed and near full length of pronotum. Basal impressions shallow, inner broad, linear and joined to outer that ends laterally at a low, rounded carina. Entire base coarsely punctate. Anterior lateral setae slightly less than one third pronotum length from anterior margin, basal setae approximately half width of puncture forward of base. *Elytra* (Fig. 2C): Form parallel-sided, base with border entire, humeral angle with prominent tooth, parascutellar setiferous punctures absent, parascutellar stria connected to stria 1, angular base of stria 1 absent in holotype present in allotype, nine well-impressed striae, striae distinctly punctate in basal

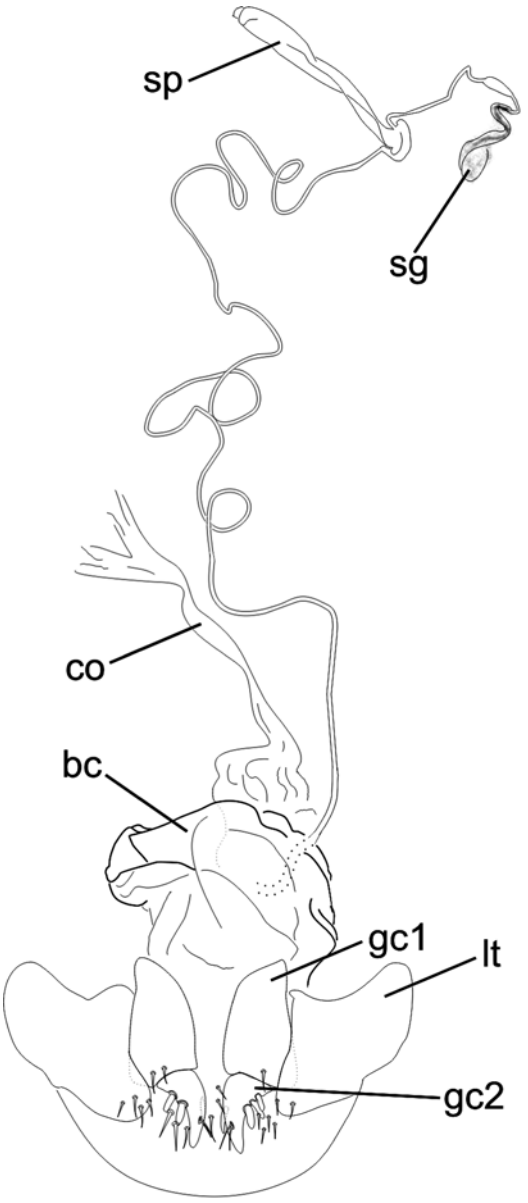

FIGURE 5. Female reproductive tract. *Pterostichus pemphredo*; bc, bursa copulatrix; co, common oviduct; gc1, gonocoxite-1; gc2, gonocoxite-2; lt, laterotergite IX; sg, appended spermathecal gland; sp, spermatheca.

two thirds, shallowly punctate in apical third, margin at epiplura rounded in apical two thirds, marginal bead scarcely apparent, carinate in basal third, no external plica. Umbilicate series of stria 8 with five setiferous punctures in anterior (basal) series, no punctures in medial series, five in posterior (apical) series and a single puncture near apex of stria 7. *Legs*: Average build, metatrochanter acutely pointed, more slender and with more attenuated apex in male, meta coxa seta near base and near median margin, pro- and mesotarsi stout, metatarsi more elongate, fifth tarsomere ventrally glabrous. Male protarsi slightly, symmetrically expanded, with ventral articulo-setae. *Sixth abdominal ventrite*: Female with four setae, male with two. Male apex unmodified. *Aedeagus* (Fig. 3I–L): Meeting of ventral surface and right-lateral surface of median lobe carinate, ventral surface without lightly sclerotized strip. Tip long, acuminate and pointed at apex. Right paramere short. Internal sac with large, broad sclerotized spine. Female reproductive tract not studied.

Specimens examined.— Two individuals of type series.

Distribution.— Known from the type locality, Deer Creek Meadow, Tehama Co. California, estimated coordinates 40°16′10″N/121°26′00″W, 1600 m el., and Forest Ranch, Butte Co. California, estimated coordinates 39°53′07″N, 121°40′27″W, 730 m el.

Etymology.— Named as a noun in apposition for *Deino* ("Dread") of Greek mythology. See further explanation under *P. pemphredo.*

Pterostichus (*Leptoferonia*) *enyo* Will, sp. nov.

Fig. 1D, 2D, 4.

Types.— Holotype: Point mounted female, labeled "USA: California: Trinity Co.: 12 mi. W. Weaverville, 2.3–6.8 mi N. on FR 421, 1700–2000 ft., V-29-96, litter nr. stream, L. Herman". Deposited AMNH.

Description .— *Color*: light rufous. *Total body length*: 4.3 mm. *Ventral surface*: Lateral portions of thorax and abdomen distinctly punctate. Punctures on metasternum and metepisternum irregular and confluent. Punctures on abdominal ventrites 1–3 shallow, sparse to absent on remaining ventrites. *Head*: Relatively broad, width of head about as wide as pronotum, head at widest point $^{8}/_{10}$ width of pronotum at widest point. Frontal impressions well defined and sharply divergent **posteriorly**. Eye minute, 0.14 mm over greatest length, nearly as broad as long, obovate form. Antennae relatively average build, total length reaching well beyond base of pronotum, antennomeres 5–10 longer than wide. *Pronotum* (Fig. 1D): Greatest width $^{4}/_{5}$ length, widest point well before midpoint, sides scarcely rounded and convergent to base and obtuse hind angles. Anterior angles very slightly produced. Median line clearly impressed and near full length of pronotum. Basal impressions shallow, inner linear, divergent posteriorly, outer impression absent, area laterad of inner impression flat and depressed to margin. Median area of base very slightly punctulate. Anterior lateral setae one quarter pronotum length from anterior margin, basal setae approximately width of puncture forward of base. *Elytra* (Fig. 2D): Form slightly rounded, little ventricose, base with border entire, humeral angle with small tooth, parascutellar setiferous punctures absent, parascutellar stria present and free of stria 1, angular base of stria 1 present, nine well-impressed striae, striae shallowly punctate in basal two thirds to smooth in apical third, margin at epiplura carinate throughout, no external plica. Umbilicate series of stria 8 with five setiferous punctures in anterior (basal) series, one in medial series, four in posterior (apical) series and two puncture near apex of stria 7. *Legs*: Gracile build, metatrochanter bluntly pointed, meta coxa with seta near base and lateral margin of apex, tarsi average form, fifth tarsomere ventrally glabrous. *Sixth abdominal ventrite*: Female with four setae. Male unknown. Reproductive structures not studied.

Specimens examined.— Single holotype.

Distribution.— Known only from the type locality,12 mi west of Weaverville, Trinity Co. Ca., estimated coordinates 40°48′53″N/123°07′29″W.

Remarks.— Type locality is an area of Oak, Madrone and Poison Oak. Significant effort to collect additional specimens of this species at the type locality has not succeeded. No other species of *Leptoferonia* are known from the immediate type locality; however, I have found *P. humilis* Casey a few miles west and *P. inanis* a few miles north and east of the type locality.

Etymology.— Named as a noun in apposition for *Enyo* ("Horror") of Greek mythology. See further explanation under *P. pemphredo.*

Discussion

These four species have similar, characteristic eye reduction. However, only *P. pemphredo* and *P. deino* appear to be closely related to each other and these two near *P. caligans* Horn. All three of these species have a similarly modified margin of the elytral epiplura and general elytral form. They all share a rather parallel-side form and have the elytral margin rounded in the apical two-thirds with the marginal bead scarcely apparent such that the edge is carinate only in the basal third. Other species of *Leptoferonia* have the margin at epiplura carinate throughout its length. *Pterostichus enyo* is most likely related to *P. humilis* and *P. trinitensis* based on the general body form and similar shape of the pronotum. *Pterostichus blodgettensis* is related to *P. hatchi* based in both morphological similarities, such as the carina and concavity on the ventral surface of the median lobe of the aedeagus, the body-form and pronotal shape, and also DNA sequence data (K.Will and A.Gill unpublished).

Based on the relationships of these species alone, it appears that smaller body size and eye reduction have occurred at least three separate times in *Leptoferonia.* In the species described herein, the eyes are minute (relatively largest in *P. enyo*) and probably of limited function, and body size range is 4.3–6.9 mm. Other species of *Leptoferonia* range in body size from 5.5 mm to 12 mm, with the vast majority of species and specimens falling into the range of 7–9 mm (Hacker 1968). The specific habitat is known for *P. pemphredo*, *P. blodgettensis* and *P. enyo*. Although the sample size is extremely small, the three species seem to be associated with a persistent groundwater source and a surface stream that generally persists, but may not have a flow in the summer during extremely dry years. Probably these beetles evolved a more subterranean habit and concomitant eye reduction in response to California's seasonal rainfall patterns and frequent local droughts.

It is remarkable that two of these undescribed species were collected at the University of California's Blodgett Experimental Forest and that these specimens were found within a few meters of headquarters and researcher cabins. Many different aspects of the Blodgett property have been studied intensively over the more than 70 years that the property has belonged to the University of California. This includes numerous trips by entomologists and students of entomology. However, only a single specimen of one species was found among all specimens examined from those previous collecting efforts. In part, this is likely due to the strongly seasonal and somewhat cryptic nature of the beetles' life history. The discovery of these small and special species of carabid beetle points to two important facts: first, that there remains a great undescribed diversity of life under our feet in California and second, that state-owned and other public lands are important havens for many of these yet-to-be-discovered species.

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