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A New Species of *Lepeophtheirus* (Copepoda; Caligidae) Parasitic on Three Kelpfish Species (Clinidae) from the Southern California Coast

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Abstract.—A new copepod species, *Lepeophtheirus schaadti* n. sp., is established based on female and male specimens obtained from the Giant Kelpfish, *Heterostichus rostratus* Girard, 1854, and Striped Kelpfish, *Gibbonsia metzi* Hubbs, 1927, captured at Inner Cabrillo Beach in southern California, U.S.A. In addition, comparisons with copepod specimens identified by Wilson (1935) as *L. parviventris* Wilson, 1905 from the Spotted Kelpfish, *Gibbonsia elegans* (Cooper, 1864), in Newport Bay, California, revealed they are conspecific with *L. schaadti* n. sp. The new species differs from its congeners by a combination of characters that include: female with a genital complex that is more than half the length of the cephalothoracic shield and with posterolateral lobes, an abdomen that is composed of one somite and is less than one-quarter the length of the genital complex, a maxillary dentiform process bearing a thin ridge on the inner tine and lacking a basal knob, no myxal process on the maxilliped, apically rounded tines on the sternal furca, the spine on the first exopodal segment of leg 3 inserted distally on the basal swelling, a 3-segmented leg 4 exopod, and a broad inner lobe of leg 5 that does not extend beyond the posterior margin of the genital complex; and male with three accessory claws on the antennal endopod and no myxal process on the maxilliped. *L. schaadti* n. sp. represents the first account of an ectoparasitic species from the Striped Kelpfish and Spotted Kelpfish, as well as the fourth ectoparasitic species reported from the Giant Kelpfish.

Members of the copepod family Caligidae Burmeister, 1835, commonly known as sea lice, are predominantly external parasites of marine fishes (Dojiri and Ho 2013). Among the 30 valid caligid genera, *Lepeophtheirus* von Nordmann, 1832 is one of the more speciose genera, with 121 valid species and 2 recognized subspecies (Boxshall and Walter 2016). *Lepeophtheirus* parasitizes marine teleosts worldwide, but is more diverse in temperate latitudes (Kabata 1979). One species, *Lepeophtheirus salmonis* (Krøyer, 1837) sensu lato, is the most pathogenic ectoparasite on farmed salmonids in the northern hemisphere (Johnson et al. 2004; Costello 2006). Presently, 17 species of *Lepeophtheirus* have been reported from 16 fish families along the California coast, from San Francisco Bay in the north to La Jolla in the south of the state (Table 1). Recent samples of Giant Kelpfish (*Heterostichus rostratus* Girard, 1854) and Striped Kelpfish (*Gibbonsia metzi* Hubbs, 1927) (Clinidae Swainson, 1839) collected within the Port of Los Angeles during Cabrillo Marine Aquarium's Inner Cabrillo Beach Survey (ICBS) were infected with an unidentified species of *Lepeophtheirus*. The ICBS is a long-term, tri-annual survey designed to monitor the abundance and diversity of the invertebrates and

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Table 1. Fish hosts and locality records for species of *Lepeophtheirus* reported from California, U.S.A.

Copepod species	Host family	Host species	Locality	Reference
<i>Lepeophtheirus</i> sp.	Kyphosidae	<i>Medialuna californiensis</i> (Steindachner, 1876)	Off La Jolla	Hobson (1971)
	Labridae	<i>Oxyjulius californica</i> (Günther, 1861)	Off La Jolla	Hobson (1971)
	Pomacentridae	<i>Hypsypops rubicundus</i> (Girard, 1854) (as <i>Hypsypops rubicunda</i>)	Off La Jolla	Hobson (1971)
	Sciaenidae	<i>Genyonemus lineatus</i> (Ayres, 1855)	Southern California	Love and Moser (1983)
	Sciaenidae	<i>Menticirrhus undulatus</i> (Girard, 1854)	Southern California	Love and Moser (1983)
	Scorpaenidae	<i>Sebastes paucispinis</i> Ayres, 1854	Southern California	Love and Moser (1983)
<i>Lepeophtheirus bifidus</i> Fraser, 1920	Paralichthyidae	<i>Paralichthys californicus</i> (Ayres, 1859)	Anaheim Bay	Ho (1972a)
	Pleuronectidae	<i>Pleuronichthys guttulatus</i> Girard, 1856 (as <i>Hypsopsetta guttulata</i>)	Anaheim Bay	Ho (1975)
<i>Lepeophtheirus bifurcatus</i> Wilson, 1905	Embiotocidae	<i>Cymatogaster aggregata</i> Gibbons, 1854	Southern California	Love and Moser (1983)
	Embiotocidae	<i>Phanerodon furcatus</i> Girard, 1854	Southern California	Love and Moser (1983)
	Paralichthyidae	<i>Paralichthys californicus</i> (Ayres, 1859)	Santa Monica Bay	Kalman (2006)
	Pleuronectidae	<i>Pleuronichthys verrucalis</i> Jordan & Gilbert, 1880	Santa Monica Bay	Kalman (2006)
<i>Lepeophtheirus brachyurus</i> Heller, 1865	Pleuronectidae	<i>Psettichthys melanosictus</i> Girard, 1854	San Francisco Bay	Wilson (1908)
<i>Lepeophtheirus constrictus</i> Wilson, 1908	Scorpaenidae	<i>Scorpaena guttata</i> Girard, 1854	Off La Jolla	Wilson (1908)
	Serranidae	<i>Paralabrax clathratus</i> (Girard, 1854)	Southern California	Love and Moser (1983)
	Serranidae	<i>Paralabrax maculatofasciatus</i> (Steindachner, 1868)	Off La Jolla	Wilson (1908)
<i>Lepeophtheirus longtabdominis</i> Shiino, 1960	Serranidae	<i>Paralabrax nebulifer</i> (Girard, 1854)	Southern California	Love and Moser (1983)
	Sciaenidae	<i>Atractoscion nobilis</i> (Ayres, 1860) (as <i>Cynoscion nobilis</i>)	Off La Jolla	Shiino (1960)
<i>Lepeophtheirus longipes</i> Wilson 1905	Polyprionidae	<i>Stereolepis gigas</i> Ayres, 1859	Off La Jolla	Wilson (1908)
	Scorpaenidae	<i>Sebastes serriceps</i> (Jordan & Gilbert, 1880)	Off La Jolla	Hobson (1971)
	Serranidae	<i>Paralabrax clathratus</i> (Girard, 1854)	Catalina Island	Wilson (1921)
<i>Lepeophtheirus nordmanni</i> (Milne Edwards, 1840)	Molidae	<i>Mola mola</i> (Linnaeus, 1758)	Santa Catalina Island	Wilson (1908)
			Southern California	Wilson (1908) ^a
			Monterey Bay	Wilson (1935)

Table 1. Continued.

Copepod species	Host family	Host species	Locality	Reference
<i>Lepeophtheirus parviventris</i> Wilson, 1905	Clinidae	<i>Heterostichus rostratus</i> Girard, 1854 ^b	Newport Bay	Wilson (1935) ^b
	Labridae	<i>Halichoeres semicinctus</i> (Ayres, 1859) (as <i>Iridio semicinctus</i>)	Southern California	Wilson (1924) ^c
<i>Lepeophtheirus parvus</i> Wilson, 1908	Scorpaenidae	<i>Sebastes rubrivinctus</i> (Jordan & Gilbert, 1880) (as <i>Sebastes rubrivinctus</i>)	Off Santa Barbara Island	Wilson (1908) ^c
	Urotrygonidae	<i>Urobatis halleri</i> (Cooper, 1863) (as <i>Urolophus halleri</i>)	California	Wilson (1924) ^d
	Embiotocidae	<i>Cymatogaster aggregata</i> Gibbons, 1854	Southern California	Love and Moser (1983)
	Embiotocidae	<i>Damalichthys vacca</i> (Girard, 1855)	Southern California	Love and Moser (1983)
<i>Lepeophtheirus paulus</i> Cressey, 1969	Labridae	<i>Semicossyphus pulcher</i> (Ayres, 1854) (as <i>Pimelometopon pulcher</i> and <i>P. pulchrum</i>)	Off San Diego	Wilson (1908); Shimo (1963)
	Scorpaenidae	<i>Sebastes serriceps</i> (Jordan & Gilbert, 1880) (as <i>Sebastes serriceps</i>)	Off La Jolla	Hobson (1971)
<i>Lepeophtheirus pravipes</i> Wilson, 1912	Hexagrammidae	<i>Ophiodon elongatus</i> Girard, 1854	Off San Diego	Shimo (1965) ^e
	Scorpaenidae	<i>Scorpaena guttata</i> Girard, 1854	Off Pacific Grove	Wilson (1935)
<i>Lepeophtheirus remiopsis</i> Dojiri, 1979	Batrachoididae	<i>Porichthys notatus</i> Girard, 1854	Off Huntington Beach	Dojiri (1979)
	Paralichthyidae	<i>Hippoglossina stomata</i> Eigenmann & Eigenmann, 1890	Off Huntington Beach	Dojiri (1979)
	Paralichthyidae	<i>Xysteuropsis liolepis</i> Jordan & Gilbert, 1880	Santa Monica Bay	Kalman (2006)
	Pleuronectidae	<i>Parophrys vetulus</i> Girard, 1854	Santa Monica Bay	Kalman (2006)
	Pleuronectidae	<i>Pleuronichthys verticalis</i> Jordan & Gilbert, 1880	Off Huntington Beach	Kalman (2006)
	Cottidae	<i>Chitonotus pugentensis</i> (Steindachner, 1876)	Santa Monica Bay	Dojiri (1979)
	Paralichthyidae	<i>Citharichthys stigmaeus</i> Jordan & Gilbert, 1882	Off Huntington Beach	Kalman (2006)
	Scorpaenidae	<i>Scorpaena guttata</i> Girard, 1854	Off Huntington Beach	Dojiri (1979)
			Santa Monica Bay	Kalman (2006)

Table 1. Continued.

Copepod species	Host family	Host species	Locality	Reference
<i>Lepeophtheirus salmonis oncorhynchi</i> Skern-Mauritzen, Torrissen and Glover, 2014	Salmonidae	<i>Oncorhynchus tshawytscha</i> (Walbaum, 1792)	Monterey Bay	Wilson (1908) ^f
<i>Lepeophtheirus spatha</i> Dojiri and Brantley, 1991	Paralichthyidae	<i>Paralichthys californicus</i> (Ayres, 1859)	Santa Monica Bay	Dojiri and Brantley (1991); Kalman (2006)
<i>Lepeophtheirus thompsoni</i> Baird, 1850	Sciaenidae	<i>Atractoscion nobilis</i> (Ayres, 1860) (as <i>Cynoscion nobilis</i>)	Off La Jolla	Wilson (1908)

^a Reported as *L. insignis*.

^b Specimens were reported as *L. parviventris*, but examination of these specimens revealed they are *L. schaadti* n. sp. Furthermore, the same specimens were reported from *Heterostichus rostratus*, but *Gibbonsia evides* (= *Gibbonsia elegans*) was handwritten on the vial label.

^c Specimens were reported as *L. parviventris*, but examination of these specimens revealed they are not conspecific with *L. parviventris*.

^d Reported from *U. halleri* held in an aquarium at the marine station of the University of Southern California, at Venice, California.

^e Reported as *L. trifidus*.

^f Reported as *L. salmonis*.

fishes living in subtidal eelgrass beds off Inner Cabrillo Beach. Subsequent examination of the unidentified *Lepeophtheirus* specimens revealed they were not conspecific with *Lepeophtheirus parviventris* Wilson, 1905, a species previously reported by Wilson (1935) from the Giant Kelpfish in Newport Bay, California. Indeed, the *Lepeophtheirus* specimens from Inner Cabrillo Beach, as well as those of Wilson (1935), represent an undescribed species, which is described in detail herein.

Materials and Methods

Nearly all copepod specimens of the new taxon were obtained from *Heterostichus rostratus* samples that were collected in beach seines at three stations along Inner Cabrillo Beach during the 2011–2014 ICBS. Only two copepod specimens were obtained from one individual of *Gibbonsia metzi* captured in a winter 2011 ICBS. Copepod samples were preserved in 70% ethanol upon removal from the host. Copepod specimens were later soaked in lactophenol prior to examination using an Olympus SZX10 dissection microscope and an Olympus BX53 compound microscope equipped with differential interference contrast optics. Selected specimens were also measured intact using an ocular micrometer and/or dissected and examined according to the wooden slide procedure of Humes and Gooding (1964). In the description, length measurements are provided first, followed by width measurements; all measurements given are expressed as the mean followed by the range in parentheses. Pencil drawings of the copepod body and appendages were made with the aid of a drawing tube. Drawings were subsequently inked in with Sakura Pigma Micron™ pens on 110 g/m² tracing paper, digitized with a CanoScan LiDE 500F scanner, and assembled into figure plates using Adobe Photoshop. Morphological terminology follows Huys and Boxshall (1991) and Dojiri and Ho (2013). Fish names and classifications conform to Page et al. (2013). Type material and voucher specimens of the new taxon are deposited at the Crustacea Department of the Natural History Museum of Los Angeles County (LACM), Los Angeles, California, U.S.A., and Cabrillo Marine Aquarium (CMA), San Pedro, California, U.S.A.

Type material and voucher specimens of *L. parviventris* deposited by Wilson (1905, 1908, 1924, 1935) in the National Museum of Natural History (USNM), Smithsonian Institution, Washington, D.C., were also examined for comparative purposes: syntypes comprising 22 females, 15 males, and 11 juveniles (USNM 42064), ex *Gadus macrocephalus* Tilesius, 1810 (*Gadidae* Rafinesque, 1810), Chignik Bay, Alaska, 1903; 2 females and 1 male (USNM 69798), ex skin of *Gibbonsia evides* (Jordan & Gilbert, 1883) (= *Gibbonsia elegans* (Cooper, 1864)) (as *Heterostichus rostratus*), Newport Bay, California, 1934; 5 females and 1 male (USNM 38566), ex *Sebastes rubrivinctus* (Jordan & Gilbert, 1880) (as *Sebastes rubrivinctus* (Jordan & Gilbert, 1880)) (*Scorpaenidae* Risso, 1827), Station 4417, off Santa Barbara Island, 29 fathoms, April 12, 1904; 1 female (USNM 53491), ex *Halichoeres semicinctus* (Ayres, 1859) (as *Iridio semicinctus* (Ayres, 1859)) (*Labridae* Cuvier, 1816), southern California, April 12, 1913.

Results

Lepeophtheirus schaadti n. sp. (Figs. 1–6)

Type material. Holotype female (LACM CR-2011-3), allotype male (LACM CR-2011-4), and 1 male and 2 female paratypes (CMA 2017.04.0002), ex *Heterostichus rostratus* (222 mm SL), Station 2 (33°42'38.3"N, 118°16'58.5"W), off Inner Cabrillo Beach, San Pedro, California, U.S.A., February 5, 2011.

Other material examined. From Station 1 (33°42'42.6"N, 118°16'59.1"W), off Inner Cabrillo Beach, San Pedro, California, U.S.A.: 10 females (7 with an unidentified species of *Udonella* Johnston, 1835 (*Monogenea*) attached to the genital complex) and 4 males (3 with *Udonella* sp.

attached to the genital complex) (CMA 2017.04.0006), ex *H. rostratus* (330 mm SL), October 10, 2014; 2 females (each with *Udonella* sp. attached to the genital complex and egg sacs) (CMA 2017.04.0005), ex *H. rostratus* (169 mm SL), October 11, 2014; 3 females (LACM MBPC 17851), ex *H. rostratus* (193 mm SL), October 11, 2014; 1 female and 1 male (LACM MBPC 17852), ex *H. rostratus* (197 mm SL), October 11, 2014. From Station 2 (33°42'38.3"N, 118°16'58.5"W), off Inner Cabrillo Beach, San Pedro, California, U.S.A.: 1 female and 1 male (CMA 2017.04.0014), ex *Gibbonsia metzi* (110 mm SL), February 5, 2011; 1 female (CMA 2017.04.0003), ex *H. rostratus* (170 mm SL), February 5, 2011; 1 female and 1 male (CMA 2017.04.0004), ex *H. rostratus* (120 mm SL), February 5, 2011; 1 female and 1 male (CMA 2017.04.0010), ex *H. rostratus* (86 mm SL), October 28, 2011; 1 female (CMA 2017.04.0011), ex *H. rostratus* (182 mm SL), October 28, 2011; 2 females and 2 males (CMA 2017.04.0012), ex *H. rostratus* (163 mm SL), October 28, 2011; 1 female and 2 males (CMA 2017.04.0013), ex *H. rostratus* (178 mm SL), October 28, 2011; 4 females (CMA 2017.04.0008), ex *H. rostratus* (200 mm SL), October 17, 2013; 1 female (CMA 2017.04.0009), ex *H. rostratus* (245 mm SL), October 17, 2013. From Station 3 (33°42'35.5"N, 118°16'51.3"W), off Inner Cabrillo Beach, San Pedro, California, U.S.A.: 1 female (dissected and mounted on glass slide) and 3 males (1 male partially dissected and mounted on glass slide) (CMA 2017.04.0007), ex *H. rostratus* (260 mm SL), June 10, 2013.

Description of adult female. Body (Figure 1A) 4.08 (3.85–4.25) mm long (excluding caudal setae) ($n=7$). Cephalothoracic shield subcircular, nearly as long as wide [2.19 (2.05–2.35) × 2.11 (1.98–2.33) mm], with well-developed paired frontal plates, posterior margin of thoracic zone extending beyond posterior limit of lateral zone, and hyaline membrane along frontal and lateral rims. Free fourth pedigerous somite about three times wider than long [209 (170–230) × 609 (560–645) μm] and indistinctly separated from genital complex. Genital complex large, more than half the length of cephalothoracic shield, marginally wider than long [1.41 (1.30–1.55) × 1.52 (1.38–1.78) mm], with nearly parallel lateral margins and protruded posterolateral corners. Abdomen (Fig. 1B) composed of 1 somite, 247 (220–280) × 416 (370–460) μm , widest anteriorly, and indistinctly separated from genital complex. Caudal ramus (Fig. 1C) slightly longer than wide [111 (105–120) × 99 (90–110) μm], with 6 plumose setae (seta I absent) and short row of setules along inner margin. Egg sacs (Fig. 1A) uniseriate.

Antennule (Fig. 1D) 2-segmented. Proximal segment longer than distal segment, bearing 1 tiny semispherical knob and 1 bifid process on posterodistal corner and 27 setae (25 hirsute, 2 naked) along anterior margin. Distal segment cylindrical, bearing 12 setae (2 setae near posterodistal corner share a common base) and 2 aesthetascs.

Antenna (Fig. 2A) 3-segmented, comprising coxa, basis and 1-segmented endopod incorporating distal claw. Coxa with long, apically rounded process on posterolateral corner. Basis stout, with corrugated surface on protruded, inner distal corner and 1 large, outer distal adhesion pad on dorsal surface. Endopod long, uncinata, bearing 2 naked setae.

Postantennal process (Fig. 2A) with small bump midway on anterior margin of basal section, pair of setulose papillae on base, 1 setulose papilla posterior to base, and recurved, apically rounded hook.

Mandible (Fig. 2B) modified into elongate stylet bearing distolateral hyaline membrane and 12 distomedial teeth (1 blunt, 11 sharp).

Maxillule (Fig. 2A) composed of trisetose papilla and bifid dentiform process. Sclerite anterior to papilla with posteriorly-directed triangular process. Tines on dentiform process subequal, with thin ridge on inner tine.

Postoral process (Fig. 2A) small, triangular.

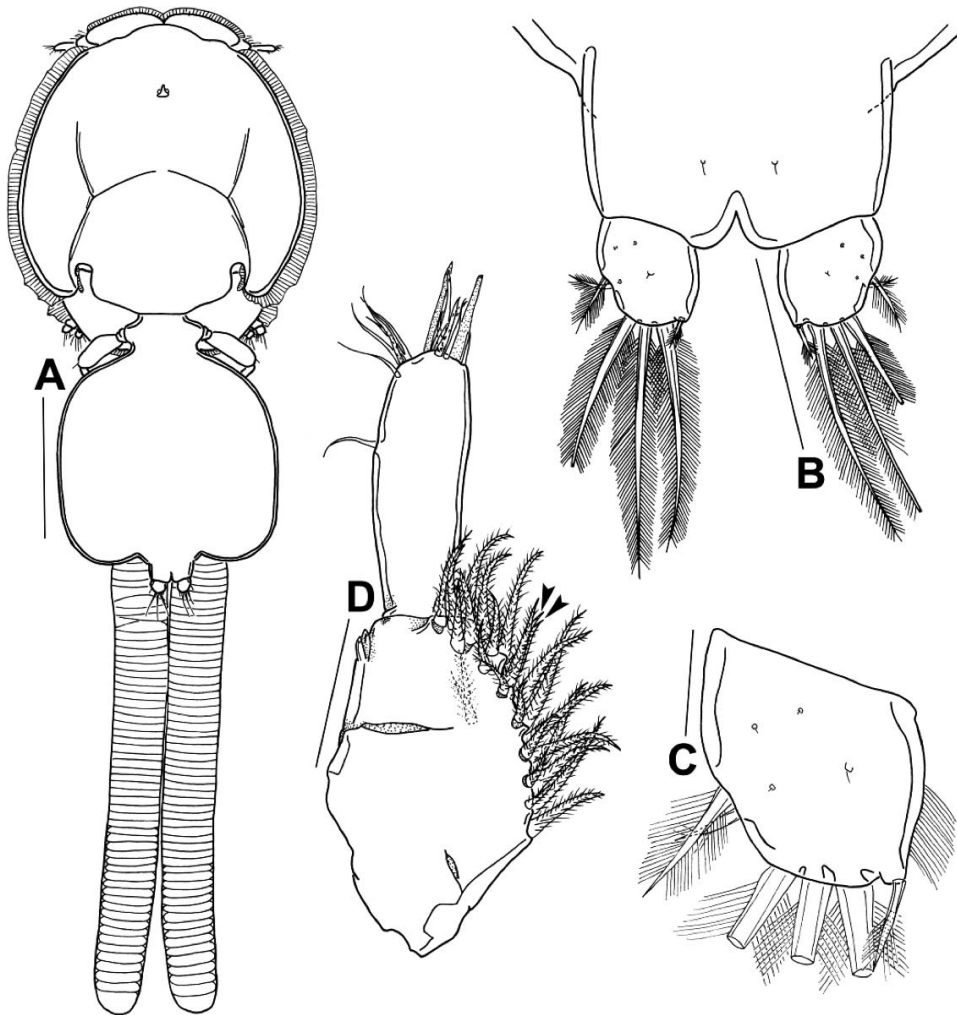


Fig 1. *Lepeophtheirus schaadti* n. sp., adult female. A) Habitus, dorsal; B) Abdomen and caudal rami, dorsal; C) Right caudal ramus, dorsal; D) Right antennule (arrowheads indicate naked setae on proximal segment), ventral. Scale bars: 1.00 mm for A; 200 μm for B; 50 μm for C; 100 μm for D.

Maxilla (Fig. 2C), brachiform, 2-segmented, composed of elongate, unarmed syncoxa and slender basis. Basis with large flabellum and long apical calamus and shorter apical canna; calamus furnished with finely serrated membranes; canna with finely serrated posterior margin.

Maxilliped (Fig. 2D) large, subchelate, 3-segmented, comprising long protopod (corpus) and subchela consisting of free endopodal segment (shaft) and claw. Protopod with 2 large patches of denticles near inner margin and small patch of denticles on distolateral corner. Shaft unarmed. Claw with long, naked basal seta and 2 thin ridges and fine striations distally.

Tines of sternal furca (Fig. 2E) longer than box, slightly divergent, and apically rounded; shallow T-shaped depression present, situated anterior to base of box.

Legs 1 to 3 (Figs. 3A–B and 4A) biramous; leg 4 (Fig. 4C) uniramous. Armature formula of legs 1–4 is shown in Table 2.

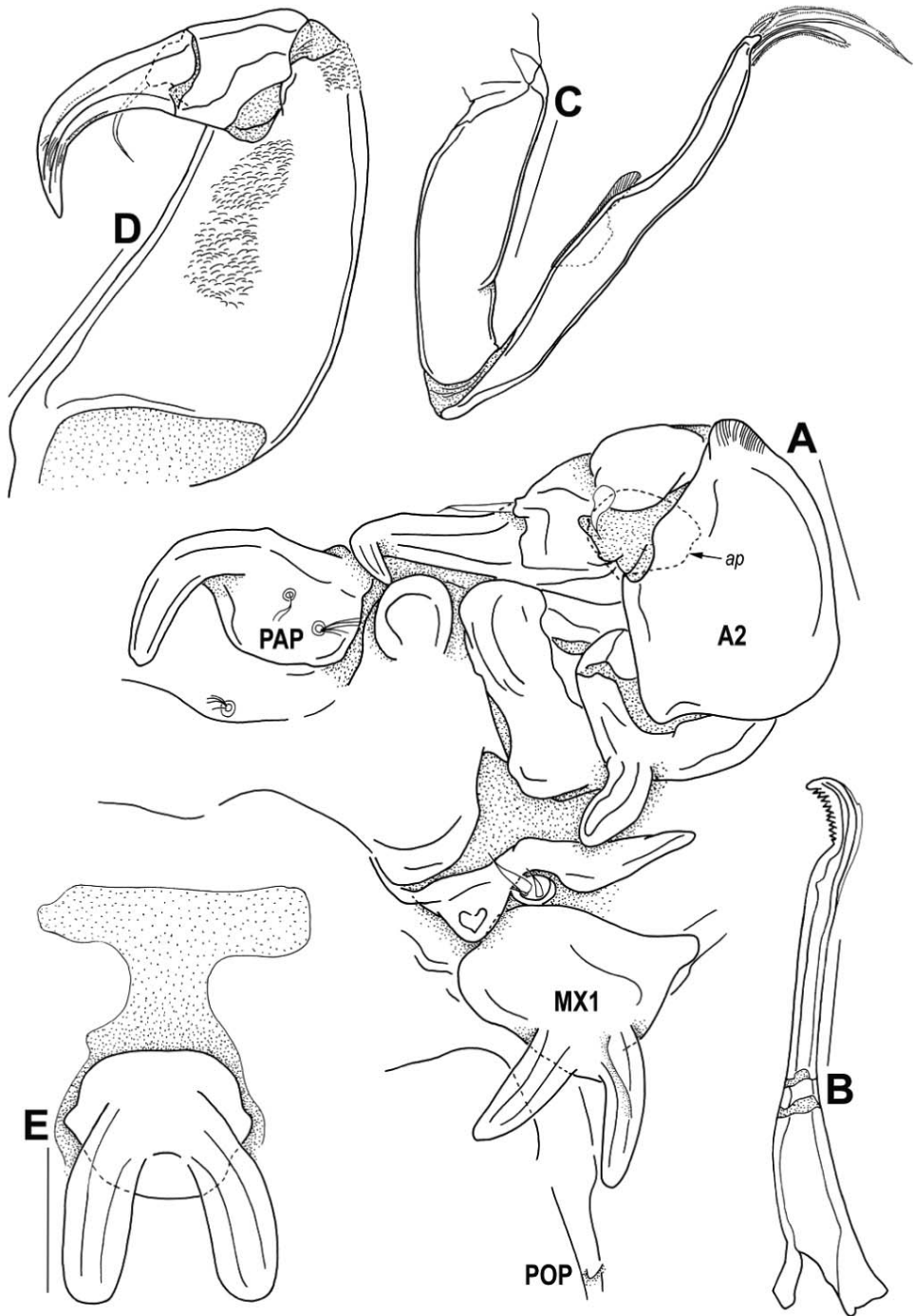


Fig 2. *Lepeophtheirus schaadti* n. sp., adult female. A) Right antenna (A2) (ap = adhesion pad), postantennal process (PAP), maxillule (MX1) and postoral process (POP), ventral; B) Left mandible, posterior; C) Right maxilla, anterior; D) Right maxilliped, anterior; E) Sternal furca, ventral. Scale bars: 100 μm for A, E; 50 μm for B; 150 μm for C, D.

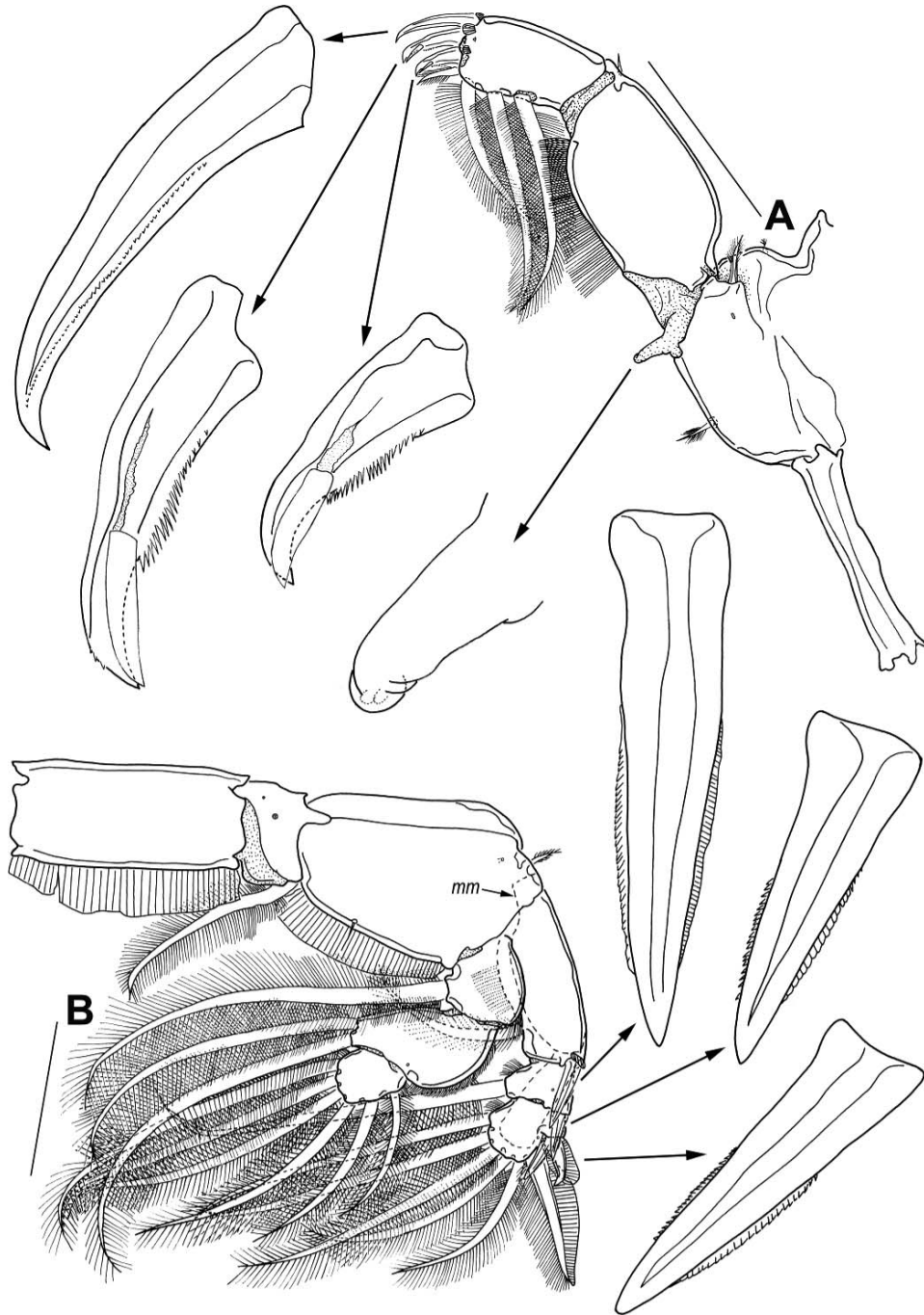


Fig 3. *Lepeophtheirus schaadti* n. sp., adult female. A) Right leg 1 with detail of endopod and apical spines on second exopodal segment, anterior; B) Left leg 2 (mm = marginal membrane) with detail of outer spine on first and second exopodal segments and proximalmost outer spine on third exopodal segment, anterior. Scale bars: 200 μm for A, B.

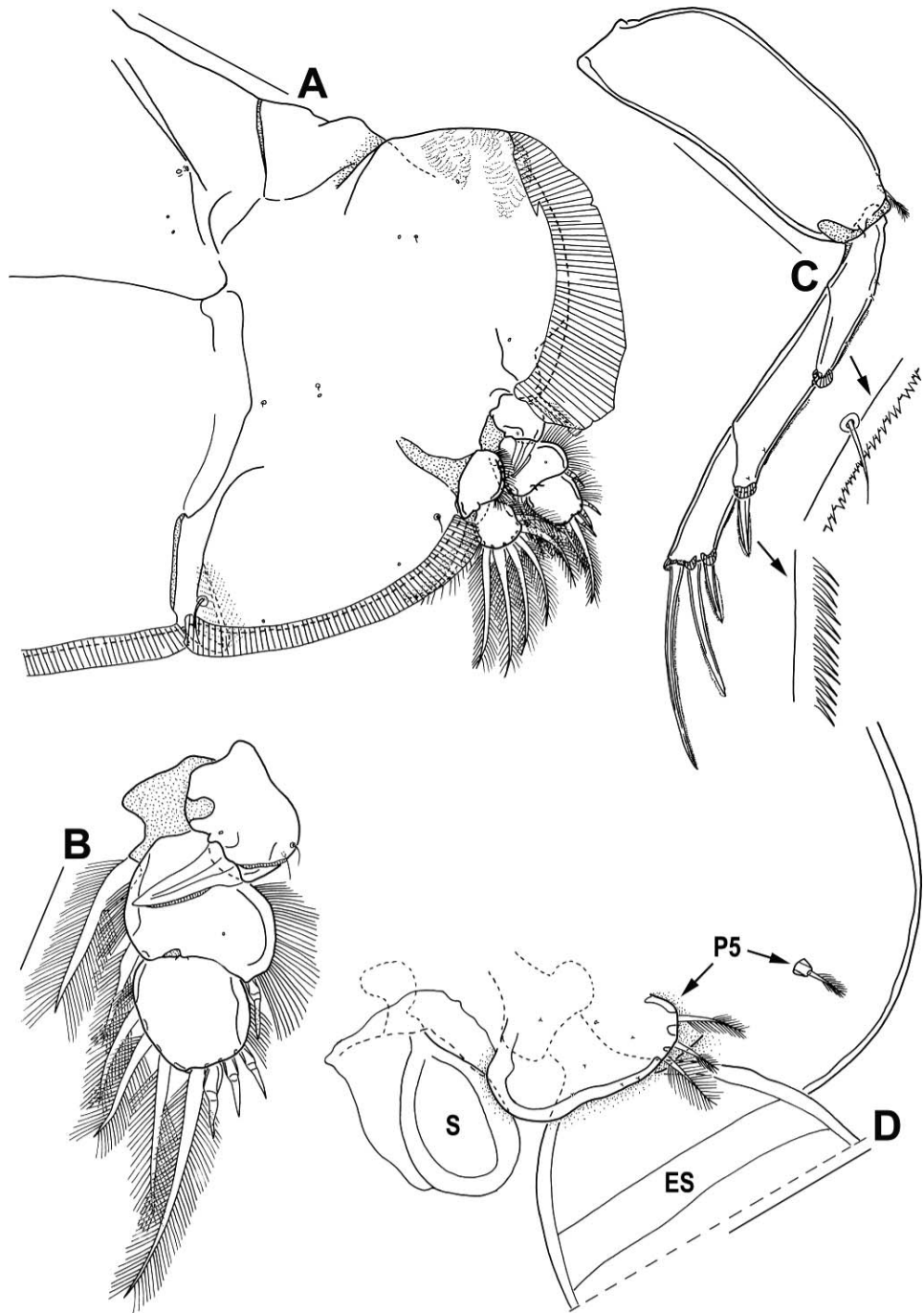


Fig 4. *Lepeophtheirus schaadti* n. sp., adult female. A) Left leg 3, ventral; B) Left leg 3 exopod, ventral; C) Left leg 4 with detail of serrations along outer margin of first exopodal segment and fine teeth along outer margin of spine on second exopodal segment, anterior; D) Left leg 5 (P5), spermatophore (S) and egg sac (ES), ventral. Scale bars: 200 μ m for A, C, D; 50 μ m for B.

Table 2. Armature on legs 1–4 (Roman numerals = spines; Arabic numerals = setae).

	Coxa	Basis	Exopod	Endopod
Leg 1*	0-0	1-1	I-0; 0,III + 1,3	vestigial
Leg 2	0-1	1-0	I-1; I-1; II,I,5	0-1; 0-2; 6
Leg 3*	0-1	1-0	I-1; I-1; II,I,4	0-1; 6
Leg 4*	0-0	1-0	I-0; I-0; II,I,0	absent

* Although the coxa and basis are fused to form a protopod in this leg, these segments are treated separately in this Table.

Leg 1 (Fig. 3A) intercoxal sclerite naked and elongate. Protopod with 1 outer and 1 inner plumose setae, 1 proximolateral setulose papilla, and 1 mid-lateral pore. First exopodal segment with 1 small, naked outer spine and inner row of setules. Second exopodal segment with 4 apical elements (3 spines, 1 seta), 3 inner plumose setae, tiny inflated process near apical margin, and pectinate membrane at base of each apical spine; outer apical spine with row of tiny denticles on anterior and posterior sides (denticles on posterior side not drawn); middle and inner apical spines each with serrations on anterior and posterior sides (serrations on posterior side not drawn) and an accessory process; apical seta plumose, shorter than outer apical spine. Endopod digitiform, bearing 2 elements apically.

Leg 2 (Fig. 3B) intercoxal sclerite subquadrate, with large hyaline membrane along distal margin. Coxa with 1 inner plumose seta and 2 pores on anterior surface. Basis with 1 outer short, plumose seta, 1 minute pore near outer margin, 1 inner sensillum, and large hyaline membrane along inner margin. Exopod 3-segmented, with large hyaline membrane covering dorsal surface of ramus. First segment with 1 inner plumose seta, inner row of setules, and pectinate membrane at base of large outer spine; latter with sclerotized flange along outer margin and fine serrations along inner margin. Second segment with 1 inner plumose seta, inner row of setules, 1 outer serrate spine, and 1 minute pore on anterior surface. Third segment with inner row of setules, 5 inner plumose setae, 3 outer spines, and 1 minute pore near lateral margin; proximal outer spine with serrated margins; middle outer spine with hyaline membrane along both margins; outer distal spine with hyaline membrane along outer margin and row of setules along inner margin. Endopod 3-segmented. First segment with 1 inner plumose seta and row of setules on distolateral corner. Second segment with 2 inner plumose setae, row of setules along inner and outer margins, and 1 minute pore on anterior surface. Third segment with 6 plumose setae and short row of setules along proximolateral and proximomedial margins.

Leg 3 (Fig. 4A) protopod large, modified to form apron, with 1 outer plumose seta situated near base of exopod, 1 inner plumose seta near large intercoxal sclerite, 1 proximolateral corrugated pad on dorsal surface, 3 marginal membranes, minute pores scattered on ventral surface, and 2 unequal sensilla along posterior margin. Exopod (Fig. 4B) 3-segmented. First segment with 1 inner plumose seta, 1 apical spine reflexed over second segment and furnished with sclerotized flange along outer margin, and 1 minute pore, several sensilla and sclerotized flange on outer basal swelling. Second segment with 1 outer naked spine, 1 inner plumose seta, 1 minute pore, and setules along lateral and medial margins. Third segment with 4 plumose setae, 3 naked spines, and setules along proximal margins. Endopod 2-segmented. First segment with 1 inner plumose seta and outer row of setules. Second segment with 6 plumose setae and setules along outer and inner margins.

Leg 4 (Fig. 4C) protopod with 1 distolateral plumose seta. First exopodal segment with pectinate membrane at base of small, outer naked spine and serrations and several sensilla

along outer margin. Second exopodal segment similar to first segment but with much larger outer spine furnished with pectinate margins. Third exopodal segment with 3 apical pectinate spines, pectinate membrane at base of each spine, and tiny serrations along outer margin; spines progressively increase in length from outer to inner apical margin.

Leg 5 (Fig. 4D) vestigial, comprised of small setiferous papilla and broad trisetose lobe on posteroventral surface of genital complex.

Leg 6 (not figured) rudimentary, represented by unarmed genital operculum at gonopore opening.

Description of adult male. Body (Fig. 5A) 2.64 (2.53–2.78) mm long (excluding caudal setae) (n=4). Cephalothoracic shield slightly longer than wide [$1.73 (1.65–1.83) \times 1.62 (1.58–1.65)$ mm], ornamented as in female. Free fourth pedigerous somite wider than long [$170 (160–180) \times 406 (385–420)$ μm]. Genital complex wider than long [$448 (420–470) \times 514 (490–540)$ μm]. Abdomen composed of 1 somite, $210 (210–210) \times 268 (260–275)$ μm , narrowed at junction with genital complex. Caudal ramus longer than wide [$120 (110–130) \times 110 (100–115)$ μm], armed as in female.

All limbs as in female, except for the following. Antennule (Fig. 5B) with 29 setae (27 hirsute, 2 naked) on proximal segment. Antenna (Fig. 5C–E) 3-segmented, comprising coxa, basis, and 1-segmented endopod incorporating distal claw. Coxa with large corrugated pad along outer margin on posterior side and fine striations on inner distal margin on anterior side. Basis with 1 large and 1 small corrugated pad on posterior side and 3 unequal corrugated pads on anterior side. Endopod forming robust terminal claw with sclerotized flange on posterior side and bearing 2 naked setae and 3 accessory claws. Maxillule (Fig. 5F) with hyaline digitiform process medial to bifid dentiform process. Postoral process (Fig. 5F) elongate and corrugated. Maxilliped (Fig. 6A) lacking small patch of denticles on distolateral corner of protopod and fine apical striations on claw. Weakly sclerotized adhesion pad (Fig. 6B) present, situated anterior to sternal furca. Leg 5 (Fig. 6C) lobate, bearing 2 plumose and 2 unipinnate setae. Leg 6 (Fig. 6C) forming genital operculum, armed distally with 1 pinnate and 2 plumose setae.

Variability. Female specimen from *H. rostratus* captured at Station 3 without row of setules along inner margin of caudal rami (Fig. 1B) and with one apically bifurcate seta on distal endopodal segment of right leg 3 (Fig. 6D).

Attachment site. Body surface.

Prevalence and mean intensity. From a total of 655 Giant Kelpfish that were inspected for *Lepeophtherius* infections between June 2011 and February 2013, 233 *L. schaadti* n. sp. were removed from 86 fish (prevalence = 13.1%; mean intensity = 2.71). By contrast, from a total of 2716 Striped Kelpfish captured within the same time period at Inner Cabrillo Beach, only two *L. schaadti* n. sp. were recovered from one fish (prevalence = 0.04%; mean intensity = 2).

Etymology. This species is named in honor of Mike Schaadt, the Director of the Cabrillo Marine Aquarium.

Remarks. Examination of Wilson's (1908, 1924) *Lepeophtherius* specimens from the Flag Rockfish, *Sebastes rubrivinctus*, and Rock Wrasse, *Halichoeres semicinctus*, captured in California waters revealed they are not conspecific with *L. parviventris*. More importantly, examination of Wilson's (1935) *Lepeophtherius* specimens from Newport Bay, California, revealed they are conspecific with *L. schaadti* n. sp. and the host was the Spotted Kelpfish, *Gibbonsia elegans*, rather than the Giant Kelpfish, as indicated on the vial label.

L. schaadti n. sp. resembles *L. elegans* Gusev, 1951, *L. hexagrammi* Gusev, 1951, and *L. hospitalis* Fraser, 1920 by having in the female a genital complex that is at least half the length of the cephalothoracic shield (including frontal plates) and with small, rounded posterolateral lobes, a 1-segmented abdomen that is less than one-quarter the length of the genital complex, a

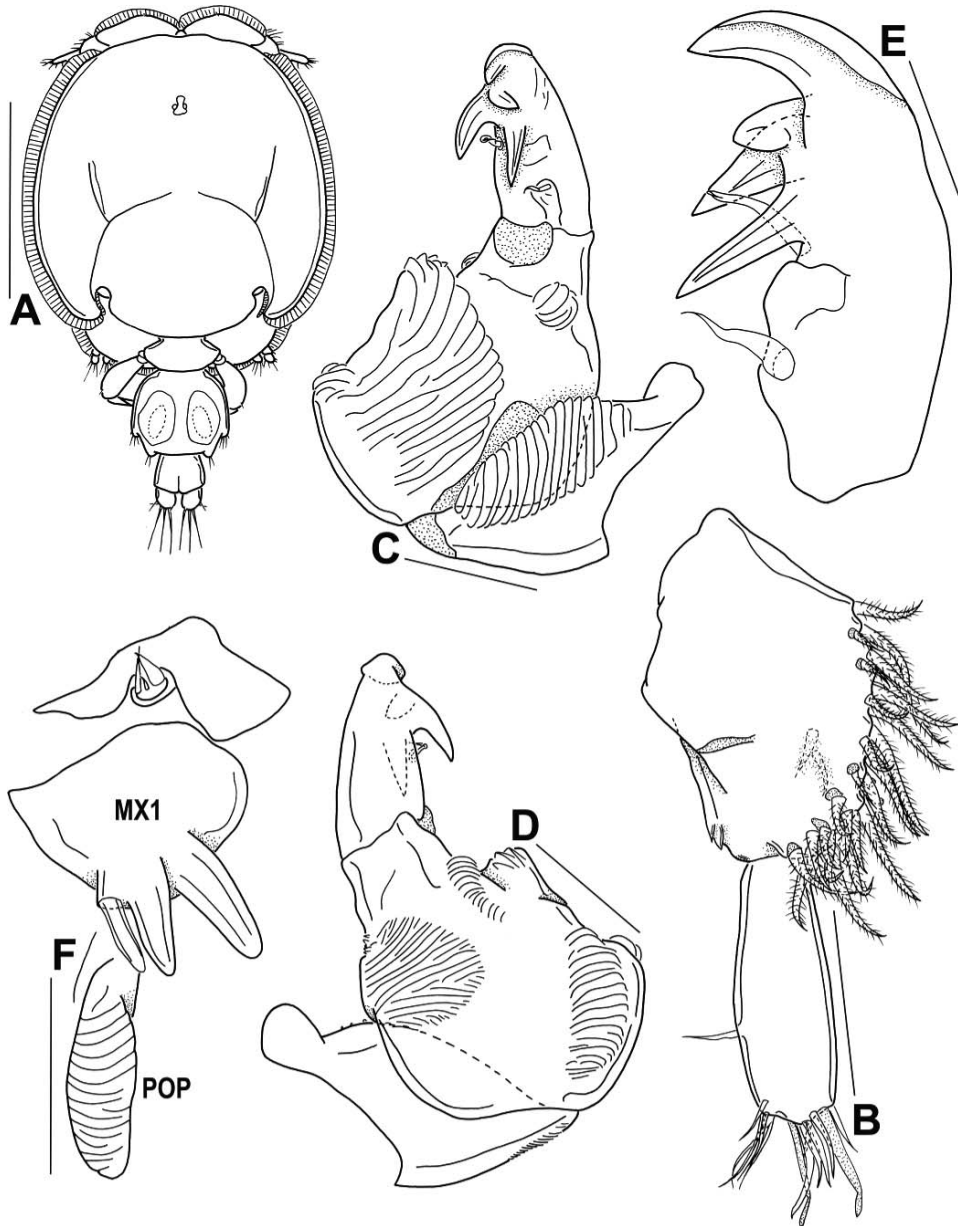


Fig 5. *Lepeophtheirus schaadti* n. sp., adult male. A) Habitus, dorsal; B) Left antennule, ventral; C) Left antenna, posteromedial; D) Left antenna, anterolateral; E) Distal endopodal segment of left antenna, posterior; F) Left maxillule (MX1) and postoral process (POP), ventral. Scale bars: 1.00 mm for A; 100 μ m for B, C, D, F; 50 μ m for E.

maxillule with two large tines on the dentiform process, a maxilliped without a myxal process, a pair of non-bifid tines on the sternal furca, the spine on the first exopodal segment of leg 3 inserted distally on the basal swelling, a 3-segmented leg 4 exopod, and the inner lobe of leg 5 not protruding beyond the posterior margin of the genital complex.

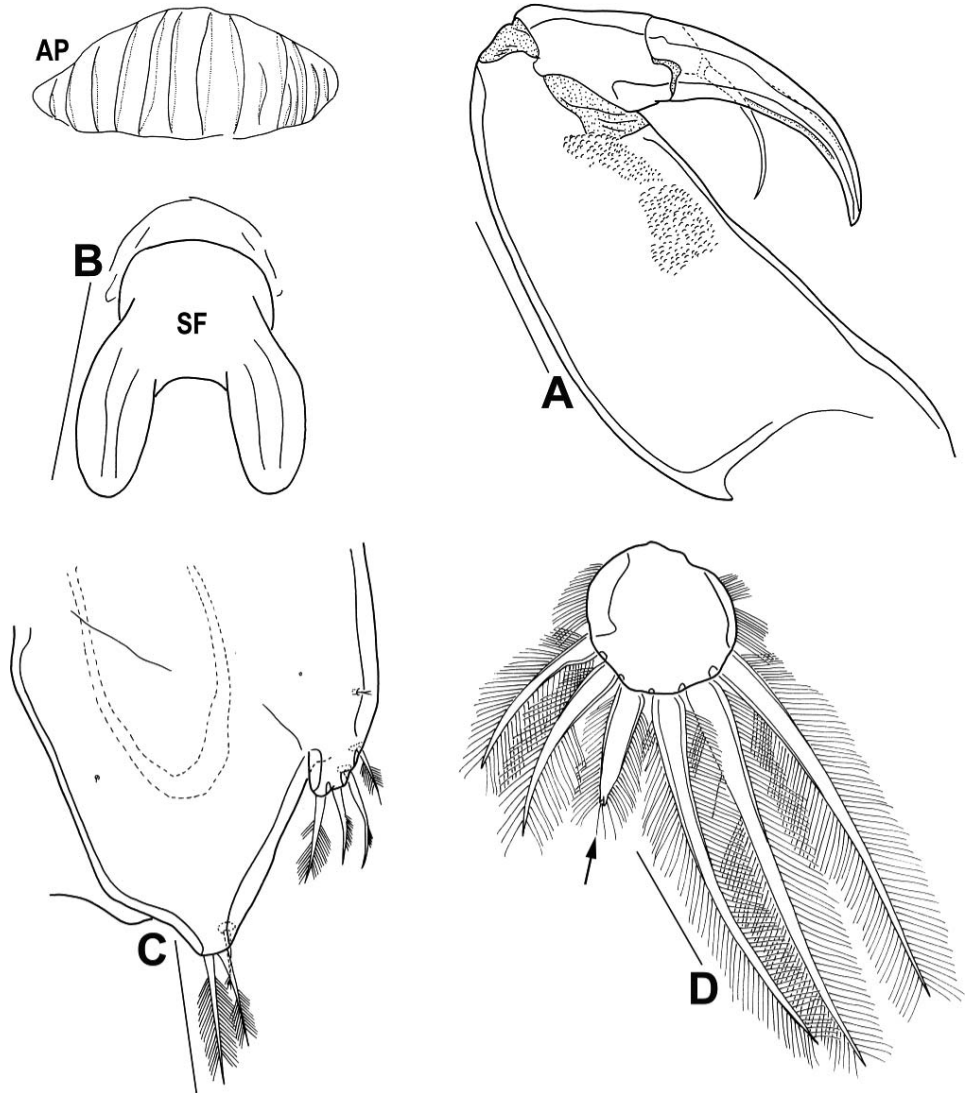


Fig 6. *Lepeophtheirus schaadti* n. sp., adult male (A–C) and adult female (D). A) Left maxilliped, anterior; B) Sternal furca (SF) and adhesion pad (AP), ventral; C) Left legs 5 (P5) and 6 (P6), ventral; D) Distal endopodal segment of right leg 3 (arrow indicates abnormal seta), ventral. Scale bars: 100 μm for A, B, C; 50 μm for D.

L. elegans can be distinguished from *L. schaadti* n. sp. by having a smooth inner distal corner on the basis of the female antenna, pointed tines and no ridge on the inner tine of the dentiform process of the female maxillule, no denticles on the outer distal corner of the protopod of the female maxilliped, pointed tines on the female sternal furca, a subtriangular inner lobe on the female leg 5, no accessory claws on the endopod of the male antenna, and a large, cone-shaped myxal process on the protopod of the male maxilliped.

L. hexagrammi can be differentiated from *L. schaadti* n. sp. by the presence of a smooth inner distal corner on the basis of the female antenna, a broader and less recurved hook on the postantennal process of both sexes, both an outer basal knob and a ridge on both tines on the

dentiform process of the female maxillule, more tapered tines on the female sternal furca, one accessory claw on the endopod of the male antenna, and a large, cone-shaped myxal process on the protopod of the male maxilliped.

L. hospitalis can be discerned from *L. schaadti* n. sp. by having a pointed and less recurved hook on the postantennal process of both sexes, a basal semispherical knob on the dentiform process of the maxillule of both sexes, broad flanges on the pointed tines of the female sternal furca, a subtriangular inner lobe on the female leg 5, and two accessory claws on the endopod of the male antenna.

Discussion and Conclusions

The discovery of *L. schaadti* n. sp. represents the first account of an ectoparasitic species from the Striped Kelpfish and Spotted Kelpfish, as well as the fourth ectoparasitic species reported from the Giant Kelpfish. The copepods *Chondracanthus heterostichi* Ho, 1972 and *C. horridus* Heller, 1865 (Chondracanthidae Milne Edwards, 1840) and the leech *Heptacyclus cabrilloi* Burreson, Kalman Passarelli & Kim, 2012 (Piscicolidae Johnston, 1865) were previously recorded from the Giant Kelpfish (Wilson 1935; Ho 1972b; Burreson et al. 2012). It must be noted, however, that Wilson's record of *C. horridus* on the Giant Kelpfish requires verification, as *C. horridus* was originally described from the Black Goby, *Gobius niger* Linnaeus, 1758 (as *Gobius jozo* Linnaeus, 1758) (Gobiidae Cuvier, 1816), from the Mediterranean Sea (Heller 1865).

In this study, 13.1% of the Giant Kelpfish were infected with *L. schaadti* n. sp. as compared to only 0.04% of the Striped Kelpfish. These disparate infection levels suggest that the Giant Kelpfish is a more common host of *L. schaadti* n. sp. at Inner Cabrillo Beach. It remains to be determined how common *L. schaadti* n. sp. is throughout the geographical range of its kelpfish hosts, including the Spotted Kelpfish.

From 2011 to 2014, 20 individuals of *L. schaadti* n. sp. were infected with the hyperparasitic monogene *Udonella* sp. (Udonellidae Taschenberg, 1879). Nearly all *Udonella* specimens were attached to the external surface of the copepod's genital complex, with a few on the cephalothorax and egg sacs. In California, *Udonella caligorum* Johnston, 1835 has been reported from the copepods *Trebius caudatus* Krøyer, 1838 and *T. latifurcatus* Wilson, 1921 (Trebiidae Wilson, 1905) parasitic on the Bat Ray, *Myliobatis californica* Gill, 1865 (Myliobatidae Bonaparte, 1835); on the Curlfin Sole, *Pleuronichthys decurrens* Jordan & Gilbert, 1881 (Pleuronectidae Rafinesque, 1815); and on the isopod *Elthusa vulgaris* (Stimpson, 1857) (as *Lironeca vulgaris* Stimpson, 1857) (Cymothoidae Leach, 1818) parasitic on the Sand Sole, *Psettichthys melanostictus* Girard, 1854 (Pleuronectidae) (Love and Moser, 1983). Identification of the *Udonella* material is currently underway and will be dealt with in detail elsewhere.

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Literature Cited

- Boxshall, G. and T.C. Walter. 2016. *Lepeophtheirus* von Nordmann, 1832. In World of Copepods database. (T.C. Walter and G. Boxshall, eds.). Accessed through World Register of Marine Species. Available from <http://www.marinespecies.org/copepoda/aphia.php?p=taxdetails&id=13558> (accessed February 9, 2017).

- Burreson, E.M., J. Kalman Passarelli, and B. Kim. 2012. A new species of marine leech (Hirudinida: Piscicolidae) from giant kelpfish, *Heterostichus rostratus* Girard, in Southern California. *J. Parasitol.* 98:788–790.
- Costello, M.J. 2006. Ecology of sea lice parasitic on farmed and wild fish. *Trends Parasitol.*, 22:475–483.
- Cressey, R.F. 1969. Five new parasitic copepods from California inshore fish. *Proc. Biol. Soc. Wash.*, 82:409–428.
- Dojiri, M. 1979. Two new species of *Lepeophtheirus* (Copepoda: Caligidae) parasitic on fishes from southern California waters. *Parasitology*, 78:251–262.
- and R.A. Brantley. 1991. *Lepeophtheirus spatha*, a new species of copepod (Siphonostomatoida: Caligidae) parasitic on the California halibut from Santa Monica Bay, California. *Proc. Biol. Soc. Wash.*, 104:727–735.
- and J.-S. Ho. 2013. Systematics of the Caligidae, copepods parasitic on marine fishes. *Crustaceana Monographs*, 18:1–448.
- Heller, C. 1865. Crustaceen. Reise der Oösterreichischen Fregatte Novara um die Erde in den Jahren 1857, 1858, 1859. *Zoologie*, 2:1–280.
- Ho, J.-S. 1972a. Copepod parasites of California halibut, *Paralichthys californicus* (Ayres), in Anaheim Bay, California. *J. Parasitol.*, 58:993–998.
- . 1972b. Four new parasitic copepods of the family Chondracanthidae from California inshore fishes. *Proc. Biol. Soc. Wash.*, 85:523–540.
- . 1975. Parasitic Crustacea. Pp. 69–72 in *The Marine Resources of Anaheim Bay*. (E.D. Lane and C.W. Hill, eds). California Department of Fish and Game, Fish Bulletin 165, 195 pp.
- Hobson, E. 1971. Cleaning symbiosis among California inshore fishes. *Fish. Bull., U.S.*, 69:491–523.
- Humes, A.G. and R.U. Gooding. 1964. A method for studying the external anatomy of copepods. *Crustaceana*, 6:238–240.
- Huys, R. and G.A. Boxshall. 1991. Copepod evolution. The Ray Society, London, 468 pp.
- Johnson, S.C., J.W. Treasurer, S. Bravo, K. Nagasawa, and Z. Kabata. 2004. A review of the impact of parasitic copepods on marine aquaculture. *Zool. Stud.*, 43:229–243.
- Kabata, Z. 1979. Parasitic Copepoda of British fishes. The Ray Society, London, 468 pp.
- Kalman, J.E. 2006. Ectoparasites of demersal marine fishes in Santa Monica Bay, California, U.S.A., with 31 new host records and three range extensions. *Comp. Parasitol.*, 73:201–213.
- Love, M.S. and M. Moser. 1983. A checklist of parasites of California, Oregon, and Washington marine and estuarine fishes. NOAA Technical Report NMFS SSRF-777, 576 pp.
- Page, L.M., H. Espinosa-Pérez, L.T. Findley, C.R. Gilbert, R.N. Lea, N.E. Mandrak, R.L. Mayden, and J.S. Nelson. 2013. Common and scientific names of fishes from the United States, Canada, and Mexico, 7th Edition. American Fisheries Society Special Publication 34, 243pp.
- Shiino, S.M. 1960. Parasitic copepods of fishes from the Eastern Pacific. *Rep. Fac. Fish. Pref. Univ. Mie*, 3:527–541.
- . 1963. Parasitic copepods of the Eastern Pacific fishes. 1. Records of the known species. *Rep. Fac. Fish. Pref. Univ. Mie*, 4:335–347.
- . 1965. Parasitic copepods of the Eastern Pacific fishes. 8. *Lepeophtheirus*. *Rep. Fac. Fish. Pref. Univ. Mie*, 5:441–454.
- Wilson, C.B. 1905. North American parasitic copepods belonging to the family Caligidae, Part I. The Caliginae. *Proc. U. S. Nat. Mus.*, 28:479–672.
- . 1908. North American parasitic copepods: A list of those found upon the fishes of the Pacific coast, with descriptions, of new genera and species. *Proc. U. S. Nat. Mus.*, 35:431–481.
- . 1921. New species and a new genus of parasitic copepods. *Proc. U. S. Nat. Mus.*, 59:1–17.
- . 1924. New North American parasitic copepods, new hosts, and notes on copepod nomenclature. *Proc. U. S. Nat. Mus.*, 64:1–22.
- . 1935. Parasitic copepods from the Pacific coast. *Am. Midl. Nat.*, 16:776–797.