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NEW RECORDS ON ACANTHOCEPHALANS FROM CALIFORNIA SEA LIONS *ZALOPHUS CALIFORNIANUS* (PINNIPEDIA, OTARIIDAE) FROM CALIFORNIA, USA

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New Records on Acanthocephalans from California Sea Lions *Zalophus californianus* (Pinnipedia, Otariidae) from California, USA. Lisitsyna, O. I. Kudlai, O., Spraker, T. R., Kuzmina, T. A. — To increase the currently limited knowledge addressing acanthocephalans parasitizing California sea lions (*Zalophus californianus*), 33 animals including pups, juvenile and adult males and females from the Marine Mammal Center (TMMC), Sausalito, California, USA were examined. Totally, 2,268 specimens of acanthocephalans representing five species from the genera *Andracantha* (*A. phalacrocoracis* and *Andracantha* sp.), *Corynosoma* (*C. strumosum* and *C. obtuscens*) and *Profilicollis* (*P. altmani*) were found. *Profilicollis altmani* and *A. phalacrocoracis*, predominantly parasitize fish-eating birds; they were registered in *Z. californianus* for the first time. Prevalence and intensity of California sea lion infection and transmission of acanthocephalans in these hosts of different age groups were analyzed and discussed. We provide brief morphological descriptions of the five species of acanthocephalan found in California sea lions.

Key words: Acanthocephala, *Andracantha, Corynosoma, Profilicollis,* California sea lions.

Introduction

California sea lion (*Zalophus californianus* Lesson, 1828) is one of the most abundant and recognized pinniped species in the North Pacific ranging along the Pacific coast of North America from British Columbia, Canada to Baja California, Mexico (Carretta et al., 2007). The population of California sea lions has been growing steadily since their protection under the Marine Mammal Protection Act of 1972 from approximately 50,000 to 340,000 individuals in the last 40 years (Carretta et al., 2007; McClatchie et al., 2016).

Research on the biology and ecology of California sea lions has been conducted at the National Marine Mammal Laboratory, NOAA, Seattle, Washington, for over four decades (Laake et al., 2016). However, not many studies on helminths parasitizing California sea lions have been performed and published (Lincicom, 1943; Dailey, 1969; Dailey & Hill, 1970; Lyons et al., 1997, 2001, 2005; Kuzmina & Kuzmin, 2015). To date, eleven helminth species including five species of nematodes from the genera *Acanthocheilonema* Cobbold, 1870, *Anisakis* Dujardin, 1845, *Contracaecum* Mozgovoi et Shakhmatova, 1971, *Parafilaroides* Dougherty, 1946 and *Uncinaria* Frölich, 1789; one species of cestodes from the genus *Diphyllobothrium* Cobbold, 1858; three species of trematodes from the genera *Pricetrema* Ciurea, 1933, *Stictodora* Looss, 1899 and *Zalophotrema* Stunkard et Alvey, 1929; and two species of acanthocephalans from the genus *Corynosoma* Lühe, 1904 have been reported from California sea lions (Lincicome, 1943; Van Cleave, 1953 a, b; Delyamure, 1955; Dailey & Hill, 1970; Dailey & Brownell, 1972). Acanthocephalans were found in California sea lions twice; the first report documenting acanthocephalans from California sea lions was published by Lincicome (1943), who reported two species, *Corynosoma osmeri* Fujita, 1921 and *C. obtuscens* Lincicome, 1943, from four dead California sea lions from the San Diego Zoo. Later, *C. osmeri* was synonymized with *Corynosoma strumosum* (Rudolphi, 1802) (Van Cleave, 1953 a; Golvan, 1959). Dailey and Hill (1970) examined 14 dead *Z. californianus* collected from southern and central California and found *C. obtuscens* in one of the sea lions. Since then, acanthocephalans have not been reported in California sea lions, but these two findings have been mentioned in several revisions on parasites of marine mammals (Van Cleave, 1953 a, b; Delyamure, 1955; Petrochenko, 1958; Dailey & Brownell, 1972; Felix, 2013). Thus, the knowledge addressing acanthocephalans from California sea lions was still limited to these two species.

The aim of our work was to study the species diversity of acanthocephalans parasitizing California sea lions of different age groups. We also performed morphological studies of the species found and provide their brief morphological descriptions herein. Distribution of the acanthocephalans in California sea lions of different ages and possible transmission routes of these acanthocephalan species are also discussed.

Material and methods

This study was carried out in February–March 2012, 2015 and 2016 at The Marine Mammal Center (TMMC), Sausalito, California, USA. Thirty-three California sea lions of three age groups (22 pups 8–10 month old, 4 yearlings 1.8 year old and 7 adult animals 3–16 years old) were studied. All these animals were found stranded on the Pacific coast near San Francisco (37°46´ N; 122°25´ W), picked up and brought to TMMC for rehabilitation. They have been kept in TMMC for several days to several weeks, and eventually died. The causes of their death were starvation, trauma or domoic acid intoxication (Silvagni et al., 2005). The ages of these animals were approximated by the clinical veterinarians at TMMC based on the overall body size and size of the teeth.

Gastrointestinal tracts of these California sea lions were examined following methodology described by Bowman and Lynn (1995). Acanthocephalans were collected manually, washed with saline, and placed in Petri dishes containing tap water for approximately 1–2 hours to ensure evagination of the proboscis. Later, all acanthocephalans were fixed and stored in 70 % ethanol.

Specimens intended for morphological analysis were mounted in Berlese's medium and examined under light microscope Zeiss Axio Imager M1. Specimens were identified on the basis of their morphology using descriptions by Perry (1942), Lincicome (1943), Van Cleave (1953 a), Petrochenko (1958), Golvan (1959). Photomicrographs were made from a representative specimen of each species with a digital camera mounted on Zeiss Axio Imager M1 microscope. All measurements are in micrometers unless otherwise stated. Trunk length does not include proboscis, neck or bursa. Mature and immature males were distinguished by the presence or absence of sperm, mature and immature females — by the presence or absence of eggs.

Results

Twenty-four of 33 California sea lions of all ages were found to be infected with acanthocephalans; prevalence of 73 % (table 1). Intensity of infection varied from 1 to 1,226 specimens per host (average 94.5; mediana 19.5). Only one 9-month old pup (10 % of the pups of this age group) was found to be infected with one specimen of *C. strumosum*; no other helminths were found in sea lions of this age group. Acanthocephalans were found in all yearlings and adult sea lions (prevalence 100 %).

A total of 2,268 specimens of acanthocephalans representing five species from three genera of the family Polymorphidae Meyer, 1931: *Andracantha phalacrocoracis* (Yamaguti, 1939) Schmidt, 1975, *Andracantha* sp., *Corynosoma strumosum* (Rudolphi, 1802), *C. obtuscens* Lincicome, 1943 and *Profilicollis altmani* (Perry, 1942), were collected. Prevalence and intensity of infections with separate species of acanthocephalans varied widely between sea lions of different age groups (table 1). *Corynosoma strumosum* and *C. obtuscens* dominated in the acanthocephalan community, while *P. altmani*, *A. phalacrocoracis* and *Andracan-*

Table 1. Prevalence and intensity of infection in California sea lions of different age groups with five species of acanthocephalans

Age group (No of animals)	Totally		*Andracantha* sp.		*Andracantha phalacrocoracis*		*Corynosoma strumosum*		*Corynosoma obtuscens*		*Profilicollis altmani*	
	P, %	I	P, %	I	P, %	I	P, %	I	P, %	I	P, %	I
Pups 8–9 months old (n = 10)	10	1	—	—	—	—	10	1	—	—	—	—
Pups 10 months old (n = 12)	100	1–269	9.1	3	—	—	54.5	1–10	100	1–268	18.2	3–14
Yearlings of 1.8 years old (n = 4)	100	19–1,226	25	9	25	1	75	4–24	100	15–1,201	—	—
Adults of 3–16 years old (n = 7)	100	14–112	14.3	1	—	—	100	1–12	85.7	2–111	—	—

Note. Abbreviations: P — prevalence; I — intensity of infection.

tha sp., the typical parasites of fish-eating birds, were registered only in young animals: two pups and one yearling.

Short morphological descriptions of the five acanthocephalan species found in this study and information on their hosts and geographic distribution are provided below. The main measurements of the specimens studied including males and females are presented in table 2.

Family Polymorphidae Meyer, 1931
Andracantha Schmidt, 1975
Andracantha phalacrocoracis (Yamaguti, 1939) Schmidt, 1975

Description (figs 1, D; 2, D, K; table 2)

General. Relatively small acanthocephalans. Trunk with discoid widening and two fields of spines in anterior part. Anterior field of spines broadest on ventral surface, narrow dorsally. Posterior field of spines broadest ventrally. Maximum width of bare zone between fields of spines 150. In anterior field of spines, length of spines decreasing from apical (38–49), to basal (29–31). In posterior field of spines, length of spines increasing from apical (32–37) to median (39–41) and decreasing posteriorly (28). Ventral spines almost reaching posterior end of trunk. Genital spines absent. Proboscis almost cylindrical, with dilatation in posterior third, with 18 longitudinal rows of 11 hooks in each. First 7 hooks large, with strong roots directed posteriorly. Next 4 hooks spiniform, without roots. Proboscis receptacle double-walled, with cerebral ganglion in its anterior third. Neck distinct. Lemnisci sacciform, attached in neck, not reaching level of proboscis receptacle bottom.

Remarks. *Andracantha phalacrocoracis* is a common parasite of fish-eating birds. It was initially described by Yamaguti (1939) from pelagic cormorants (*Phalacrocoracis pelagicus* Pallas) from Shikoku Islands, Japan. This species was also reported from black-legged kittiwakes *Rissa tridactyla* (Linnaeus), slaty-backed gull (*Larus schistisagus* Steineger), black-throated loon (*Gavia arctica* Linnaeus), hooded crow *Corvus cornix* (Linnaeus), carrion crow *Corvus corone* (Linnaeus) and *P. pelagicus* from the Far East from Chukotka to the Prymorye, Russia (Khokhlova, 1986), from *P. pelagicus* and bald eagles (*Haliaeetus leucocephalus* Linnaeus, 1766) from Alaska (Schmidt, 1975; Richardson & Cole, 1997), from the great cormorant *Phalacrocorax carbo* (Blumenbach) from South Moravia, Poland, on their seasonal migrations (Okulewicz, 2014; Moravec & Scholz, 2016).

Intermediate hosts for *A. phalacrocoracis* are unknown. However, several species from the genus *Andracantha* are known to use amphipods as their intermediate hosts (Atrashkevich, 2008). Fishes from three families, Nototheniidae, Bathydraconidae and Channichthyidae, were reported as the paratenic hosts for these acanthocephalans (Rocka, 2006; Laskowski et al., 2008; Laskowski & Zdzitowiecki, 2009).

Table 2. Morphological features of Acanthocephala specimens found in California sea lions (*Zalophus californianus*). All measurements are in micrometers unless otherwise stated

Characters	*Andracantha* sp.		*Andracantha phalacrocoracis*	*Corynosoma strumosum*		*C. obtuscens*		*Profilicollis altmani*	
	males (n = 4)	females (n = 5)	female (n = 1)	males (n = 7)	females (n = 7)	males (n = 10)	females (n = 12)	males (n = 4)	females (n = 4)
Total body length, mm	2.70–3.76 (3.1)	2.80–3.88 (3.4)	3.15	3.71–4.92 (4.3)	4.20–6.24 (4.9)	2.46–3.10 (2.8)	2.50–3.55 (3.1)	6.17–7.83 (7.1)	8.42–11.70 (9.2)
Maximal body width, mm	1.15–1.40 (1.3)	1.50–1.59 (1.5)	1.02	0.93–1.60 (1.1)	1.13–1.70 (1.3)	0.93–1.30 (1.1)	1.28–1.50 (1.4)	1.37–1.48 (1.414)	1.41–2.00 (1.7)
Length of spines (anterior)	29–40 (36.3)	22–29 (25.3)	48	31–38 (34.4)	29–34 (31.3)	31–36 (33.5)	30–37 (34.4)	23–30 (27)	23–37 (27.6)
Length of spines (posterior)	24–43 (36)	27–29 (28.3)	25	23–36 (28.8)	34–44 (37.4)	31–44 (38.6)	30–38 (34.3)	22–25 (23.3)	23–32 (28.2)
Genital spines	absent	present	absent	present	present or absent	present	present	absent	absent
Length of proboscis	791–875 (833)	767–916 (819.7)	650	474–620 (526.3)	490–660 (559)	450–560 (514.3)	550–670 (624.5)	450–547 (487)	500–600 (746)
Width of proboscis	300–337 (318.5)	410–538 (456)	380	260–302 (275.9)	270–347 (300.4)	204–249 (230.2)	202–280 (254.6)	560–744 (641)	680–810 (746)
Number of hooks rows	16–17 (16.3)	15–16 (15.8)	18	17–19 (18.1)	17–19 (17.9)	17–19 (17.7)	18–19 (18.1)	25–26 (25.3)	25–30 (27.4)
Number of hooks per row	13–15 (13.7)	10–13 (11.5)	11	10–11 (10.7)	10–12 (10.6)	11–14 (12.5)	13–14 (13.4)	11–12 (11.4)	11–14 (12.4)
Number of rooted hooks	7–90 (8.5)	6–8 (6.9)	6–7	6–7 (6.4)	6–7 (6.4)	8–10 (9.4)	9–11 (9.8)	3–4 (3.4)	3–4 (3.2)
Number of spiniform hooks	4–6 (5.2)	4–5 (4.7)	4–5	4–5 (4.4)	4–5 (4.4)	2–4 (2.87)	3–4 (3.4)	8–9 (8.8)	8–10 (9. 2)
Length of blades of largest hook	90–103 (98.7)	103–125 (115)	85–90	54–72 (60.9)	55–68 (63.3)	40–50 (44.8)	48–57 (51.9)	40–44 (41.2)	44–50 (44.8)
Length of roots of largest hook	86–102 (94)	90–130 (108)	85–88	66–84 (72.6)	69–87 (78.4)	43–52 (45.6)	48–54 (52)	40–52 (44.5)	41–63 (51.8)
Length of blades of spiniform hooks	51–72 (63.3)	119–142 (128.2)	48–63	31–46 (38.2)	34–42 (37.7)	24–31 (27)	23–38 (30.3)	39–56 (50.1)	50–58 (54.4)
Testes, length	385–700 (575)	–	–	214–460 (316)	–	225–470 (358.2)	–	500–700 (620)	
Testes, width	162–400 (307.3)	–		150–400 (251.6)	–	289–520 (370.4)	–	500–706 (607)	
Eggs	–	absent	absent	–	absent	–	98–113 (105.1) × 30–40 (35.5)	–	absent
Gonopore	terminal	terminal	subterminal	terminal	subterminal	subterminal	subterminal	terminal	terminal

Andracantha sp.

Description (figs 1, E; 2, A, B, C, H, J; table 2).

General. Relatively small acanthocephalans. Trunk with discoid widening and two fields of spines in anterior part. Anterior field of spines broadest on ventral surface, narrow dorsally (fig. 2, A, C). Posterior field of spines broadest ventrally. Bare zone between fields of spines widest ventrally (265–488), often narrowing and ending near dorsal surface. In anterior field of spines, length of spines decreasing from apical (28–43), to basal (24–29). In posterior field of spines, length of spines increasing from apical (22–29) to median (35–43) and decreasing posteriorly (23–33). Posterior end of females with genital spines, posterior end of males without spines (fig. 2, A, C). Proboscis almost cylindrical, with dilatation in posterior third, with 15–17 longitudinal rows of 10–15 hooks in each (fig. 2, B, J). First 6–9 hooks large, with strong roots directed posteriorly. Next 4–6 hooks spiniform, without roots. Proboscis receptacle double-walled, with cerebral ganglion in its anterior third. Neck distinct. Lemnisci sacciform, 828–920 long, attached in neck, not reaching level of proboscis receptacle bottom.

Remarks. The genus *Andracantha* now comprises nine valid species (Schmidt, 1975; Amin, 2013; Presswell et al., 2017). The specimens found in the present study closely resemble *Andracantha baylisi* (Zdzitowiecki, 1986) based on the shape and size of the body and hooks, arrangement of the tegumental spines and location of the gonopore in females. However, they differ from *A. baylisi* in the armature of the proboscis (15–16 rows of 10–13 hooks each in females and 15–17 rows of 13 hooks each in males *vs* 16 rows of 10–11 hooks in both sexes in *A. baylisi*), the presence of bare zone between two fields of spines in the anterior part of the trunk, and a peculiar system of muscles in the posterior part of the female trunk (Zdzitowiecki, 1985, 1986, 1989). A complex system of foretrunk muscles was described in the species of the genera *Andracantha* and *Corynosoma* (Aznar et al., 2006); however these muscles in the area of female genital system were not studied. In our specimens of *Andracantha* sp., the muscles which support female genital system (fig. 2, H), possibly, act as ligaments.

Due to the presence of only immature individuals of both sexes in our material, a formal description of this putative new species was impossible, and requires examination of the mature specimens.

Corynosoma Lühe, 1904
Corynosoma strumosum (Rudolphi, 1802)

Description (figs , 1, A; 2, E; table 2).

General. Small acanthocephalans, males and females similar in size and shape, females slightly larger. Trunk 3,800–6,240 × 933–1,600. Trunk anterior part widened in the form of ellipsoidal swelling, with small spines extended ventrally more than dorsally. Length of spines increasing from apical (32–38) to median (44–61) and decreasing posteriorly (25–36). Trunk posterior part narrowest at middle, slightly dilated at posterior end. Genital spines present or absent. Proboscis 450–620 × 260–290, almost cylindrical, with widening in its posterior third. Proboscis with 17–19 longitudinal rows of 10–11 hooks each. First 6–7 hooks large, with simple roots directed posteriorly. Next 1–2 hooks transitional, with small roots in the shape of an inverted Y (fig. 2, E). Proximal 3–4 hooks spiniform, with simple roots directed anteriorly. Largest hooks are 6th or 7th. Proboscis receptacle double-walled. Lemnisci broad, leaf-shaped, shorter than proboscis receptacle. Neck truncated cone, 211–620 long, often retracted into foretrunk. Reproductive system in narrow posterior part of trunk.

Remarks. *Corynosoma strumosum* was initially described by Rudolphi (1802) from harbor seal (*Phoca vitulina* Linnaeus). This species was also reported in various marine mammals, terrestrial carnivores and aquatic birds throughout the Arctic, Pacific and At-

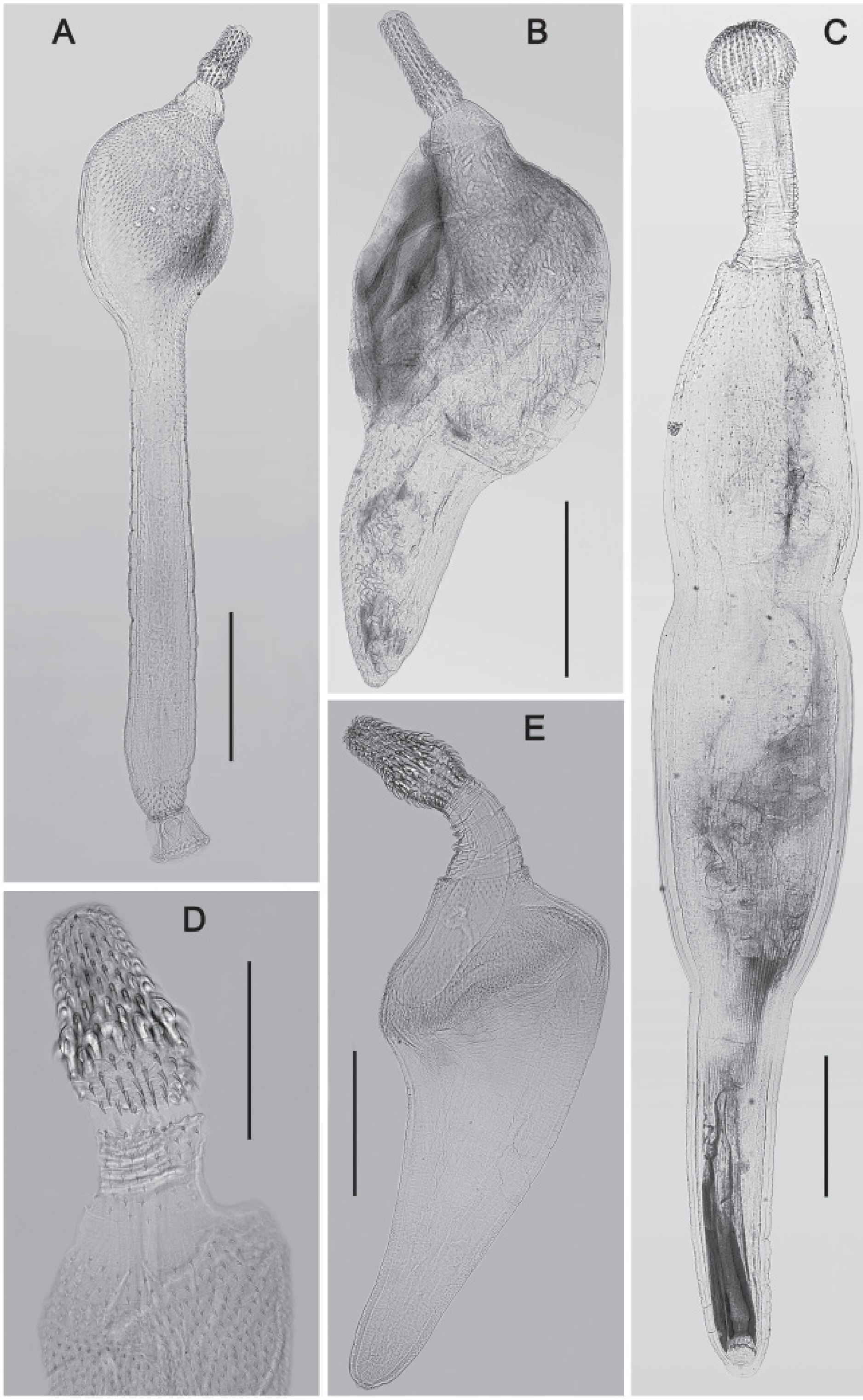

Fig. 1. Acanthocephalan species from California sea lions (*Zalophus californianus*): A — *Corynosoma strumosum*, total view of adult male; B — *Corynosoma obtuscens*, total view of female; C — *Profilicollis altmani*, total view of immature male; D — *Andracantha phalacrocoracis,* anterior part of female; E — *Andrcantha* sp., total view of immature female. Scale bars: A, B, C, E — 1 mm, D — 500 μm.

lantic Oceans, and in the Caspian Sea (Delyamure, 1955; Dailey & Brownell, 1972; Shults, 1982; Yurakhno, 1998; Nickol et al., 2002; Ionita et al., 2008; Amin et al., 2011). Morphologically, our specimens of *C. strumosum* are consistent with the original description of the species. Amphipods are known to be intermediate hosts for *C. strumosum* (Petrochenko, 1958; Atrashkevich, 2008); more than 30 species of fishes and a few reptiles, and experimentally infected amphibians and reptiles have been reported as paratenic hosts (Dubinin, 1949; Moles, 1982; Skorobrechova et al., 2012).

Corynosoma obtuscens Lincicome, 1943

Description (figs 1, B; 2, F; table 2).

General. Small acanthocephalans. Trunk with dilatation in its anterior part. Spine field extends to 609–976 dorsally, and to posterior end of trunk ventrally, in males with bare zone between ventral and genital spines. Length of somatic spines increasing from anterior (17–37) to posterior (36–44). Genital spines present, 41–49 long. Proboscis almost cylindrical, with widening in its posterior quarter. Proboscis with 17–19 longitudinal rows of 11–14 hooks each. First 9–11 hooks large, with simple roots directed posteriorly. Next 1–2 hooks transitional with small roots in shape of inverted Y (fig. 2, F). Next 2–3 hooks spiniform, with simple roots directed anteriorly or without roots. Largest hooks 9th and 10th. Proboscis receptacle double-walled. Neck 145–261 long. Lemnisci 505–901 long, attached in neck and extending to level of proboscis receptacle bottom or slightly posterior to it. Gonopore subterminal in both sexes.

Remarks. *Corynosoma obtuscens* is a common parasite of sea lions (Lincicome, 1943; Van Cleave, 1953 a, b). The species was described by Lincicome (1943) from *Z. californianus* from the San Diego Zoo, California, USA. It was also registered in northern fur seals (*Callorhinus ursinus* Linnaeus) and South American sea lions (*Otaria byronia* Péron) from the California coast, in the Gulf of Mexico, off the coast of South America and in Alaska (Van Cleve, 1953 a, b), and from domestic dogs in Peru (Cabrera et al., 1999). Juvenile specimens were also registered in sea otter (*Enhydra lutris* Linnaeus) (Ward & Winter, 1952). Domestic dogs were successfully infected experimentally with cystacanths collected from fish (Castro & Martínez, 2004). Our material corresponds to the original description provided by Lincicome (1943). Intermediate hosts for *C. obtuscens* are unknown. Several species of fishes (paratenic hosts) off the Pacific coast of South America were found to be infected with cystacanths of *C. obtuscens* with prevalence up to 60 % (Tantaleán & Huiza, 1994; Tantaleán et al., 2005; Chero et al., 2014).

Profilicollis Meyer, 1931
Profilicollis altmani (Perry, 1942)

Description (figs 1, C; 2, G; table 2).

General. Acanthocephalans of medium size. Trunk with two extensions in its anterior part; posterior part cylindrical. Spines extend to middle of anterior extension, arranged in irregular longitudinal rows. Length of spines decreasing from apical (30) to basal (22–23). Genital spines absent. Proboscis spherical, with 25–30 longitudinal rows of 11–13 hooks each (fig. 2, G). First 3–4 hooks thicker than others, with simple roots directed posteriorly. Next hooks spiniform, with root processes directed anteriorly or without processes. Neck 900–1,620 × 370–480 long. Proboscis receptacle double–walled, attached at proboscis base, extended through neck to trunk, with maximum width in its posterior part. Cerebral ganglion oval, 220 × 89. Lemnisci sacciform, attached to neck, extend to bottom of proboscis receptacle or slightly posterior.

Remarks. Specimens collected from *Z. californianus* in our study correspond to the original description of *P. altmani* provided by Perry (1942), but differ in the number

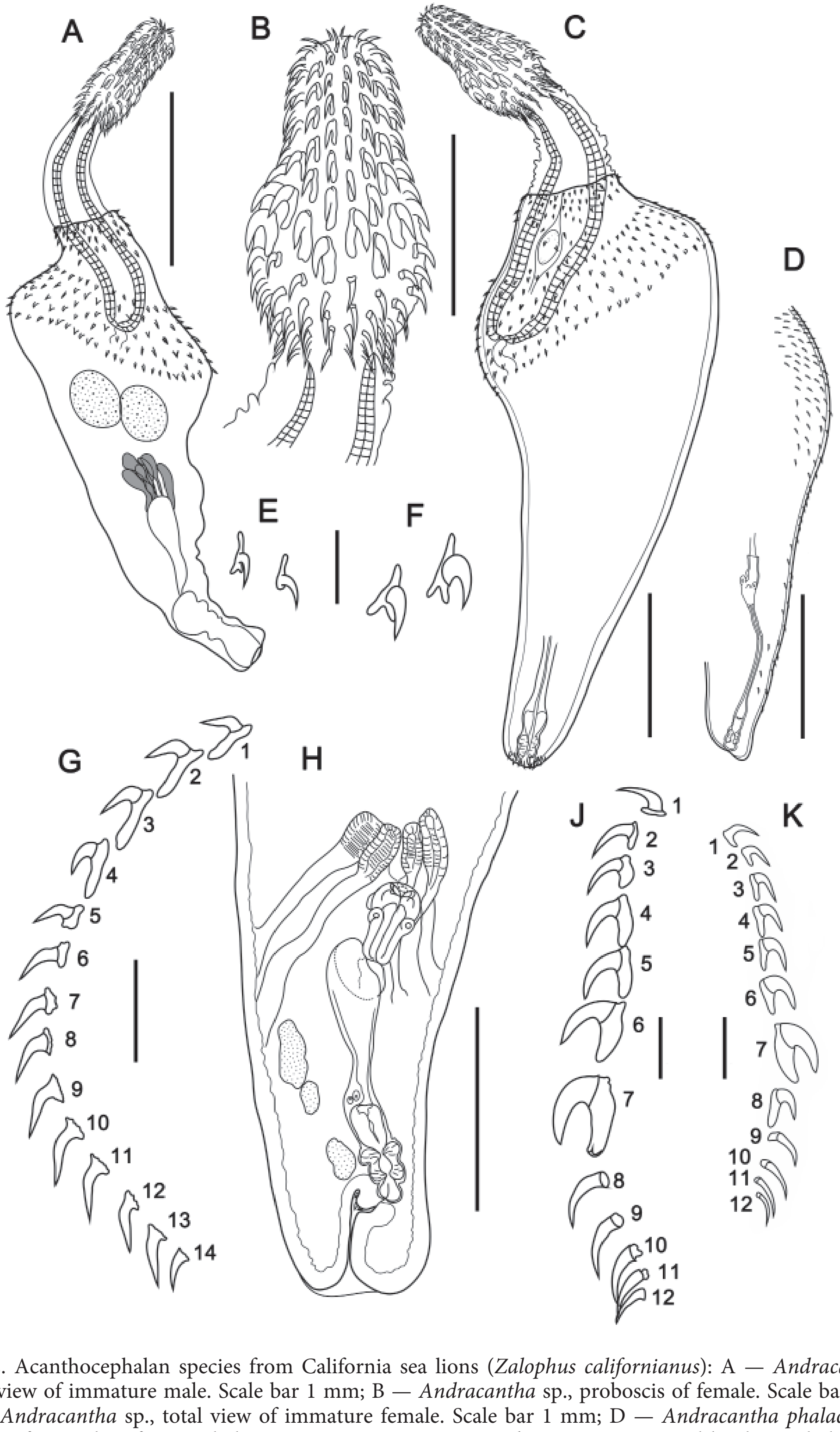

Fig. 2. Acanthocephalan species from California sea lions (*Zalophus californianus*): A — *Andracantha* sp., total view of immature male. Scale bar 1 mm; B — *Andracantha* sp., proboscis of female. Scale bar 500 µm; C — *Andracantha* sp., total view of immature female. Scale bar 1 mm; D — *Andracantha phalacrocoracis*, spines of ventral surface. Scale bar 1 mm; E — *Corynosoma obtuscens*, transitional hooks. Scale bar 50 µm; F — *Corynosoma strumosum*, transitional hooks. Scale bar 50 µm; G — *Profilicollis altmani*, longitudinal row of hooks. Scale bar 100 µm; H — *Andracantha* sp., posterior part of female. Scale bar 500 µm; J — *Andracantha* sp., longitudinal row of hooks. Scale bar 100 µm; K — *Andracantha phalacrocoracis*, longitudinal row of hooks. Scale bar 100 µm.

of hooks in the longitudinal rows (11–13 hooks *vs* 9–12 hooks). The wide variability in the number of hooks (13–17) was also found in specimens of *P. bullocki*, a synonym of *P. altmani* by Amin (2013) collected from birds, *Larus dominucanus* Lichtenstein, *L. pipixcan* Wagler, *Podiceps occipitalis* Garnot, *Numenius phaeopus* Linnaeus, in South America (Riquelme et al., 2006). We assume that the variability in the number of hooks in a row is typical for this species.

Profilicollis altmani was described from surf scoters (*Melanitta perspicillata* Linnaeus) and *M. deglandi stejnegeri* (Ridgway) in North America (Perry, 1942). This species was also reported in gulls (*Chroicocephalus maculipennis* Lichtenstein), *Larus dominicanus*, *L. pipixcan*, and *Leucophaeus modestus* von Tschudi), grebe (*Podiceps occipitalis*) and whimbrels (*Numenius phaeopus*) from the Pacific and Atlantic Oceans (Van Cleave, 1947; Bourgeois & Threlfall, 1982; Riquelme et al., 2006; Goulding & Cohen, 2014; Rodríguez et al., 2016), as well as in a sea otter *E. lutris* in California (Near et al., 1998; Mayer et al., 2003). Juvenile worms were found in the intestines of the Peruvian grunt (*Anisotremus scapularis* Tschudi) from the coastal zone of Chorrillos, Peru (Chero et al., 2014). Paratenic hosts were not reported. Crabs of the genera *Emerita* Scopoli and *Blepharipoda* Randall serve as the intermediate hosts for *P. altmani* (Tantaleán et al., 2002; Mayer et al., 2003; Royal et al., 2004; Smith, 2007).

Discussion

This study advances our knowledge on species diversity of acanthocephalans from California sea lions, and specifies new host and locality for *P. altmani*, which predominantly parasitizes fish-eating birds. Similarly, species of the genus *Andracantha* known as parasites of fish-eating birds were not reported in *Z. californianus* before. Thereby, the data obtained in our study widens the species composition of the acanthocephalans parasitizing California sea lions to five species.

Comparison of infections of California sea lions of different age groups with acanthocephalans revealed specific patterns associated with the transmission of these helminths through the food-webs. According to our observations, sea lion pups were infected with acanthocephalans more than with others groups of helminths. Moreover, acanthocephalans were found to be the first group of helminths which infect California sea lion pups (Kuzmina et al., 2017). Apparently, when 8–10 months old pups start feeding independently in shallow coastal waters, crustaceans, the intermediate hosts of acanthocephalans, compose significant part of their diet. Pups examined in our study evidently had at least several successful feedings with crustaceans and became infected with cystacanths. Prevalence of California sea lion infection with acanthocephalans increases with their age and reaches 100 % in yearlings and adults.

In our study, *P. altmani* was found only in two 10-month old pups. This may be due to the lack of ability to paratenic parasitism in *P. altmani*, as well as the restriction of their intermediate hosts (crabs from the genera *Emerita* and *Blepharipoda*) to shoal water areas where the pups predominantly feed. Thus, in our opinion, adult California sea lions are not infected by *P. altmani* because they predominantly do not feed in shallow coastal waters. The sources of California sea lion infections with *C. strumosum*, *C. obtuscens* and *Andracantha* spp. are both crustaceans, as the intermediate hosts, and fishes as the paratenic hosts; thus these acanthocephalans successfully infect pups as well as adult sea lions. Moreover, the intensity of infection with these species in California sea lions increases with their age.

In our study, only immature specimens of *Andracantha* spp. and *P. altmani* were found. Immature specimens of *Andracantha* sp. were observed in the South American sea lion *Otaria flavescens* (Shaw) in central California (Hernández-Orts et al., 2013). High intensity of *P. altmani* was observed in the sea otter *E. lutris* in California (Near et al., 1998; Mayer et al., 2003); however, authors did not mention if any mature parasites were present. These acanthocephalans are obligate parasites of fish-eating birds (Van Cleave, 1947; Bourgeois & Threlfall, 1982; Zdzitowiecki, 1985, 1986, 1989; Riquelme et al., 2006; Goulding & Cohen, 2014); thus we assume that California sea lion is an accidental host for these species.

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References

Amin, O. M. 2013. Classification of the Acanthocephala. *Folia Parasitologica*, 60, 273–305.

Amin, O. M., Richard, A. H., Halajian, A., El-Naggar, A. M. 2011. The morphology of an unique population of *Corynosoma strumosum* (Acanthocephala, Polymorphidae) from the Caspian seal, *Pusa caspica*, in the land-locked Caspian Sea using SEM, with special notes on histopathology. *Acta Parasitologica*, 56, 438–445.

Atrashkevich, G. I. 2008. Spiny-headed worms genus of *Corynosoma* Lűhe, 1904 (Acanthocephala: Polymorphidae) in the Okhotsk sea and parasitic system with dominant species of *C. strumosum* (Rudolphi, 1819). *In*: Proceedings of the IV Congress of the Russian Society of Parasitologists, Russian Academy of Sciences, 20–25, October, 2008, Zoological Institute RAS, St. Petersburg "Parasitology in XXI century — problems, methods, solutions", 1, 38–42 [In Russian.]

Aznar, F. J., Perez-Ponce de Leon, G., Raga, J. A. 2006. Status of *Corynosoma* (Acanthocephala; Polymorphidae) based on anatomical, ecological and phylogenetic evidence with the erection of *Pseudocorynosoma* n. gen. *Journal of Parasitology*, 92, 548–564.

Bourgeois, C. E., Threlfall, W. 1982. Metazoan parasites of three species of scoter (Anatidae). *Canadian Journal of Zoology,* 60, 2253–2257.

Bowman, D. D., Lynn, R. C. 1995. *Parasitology for Veterinarians*. 6th edn. W. B. Saunders Company, Philadelphia, 1–430.

Cabrera, R., Rojas, R., Davalos, M. 1999. *Corynosoma obtuscens* Lincicome, 1943 (Acanthocephala: Polymorphidae) in *Canis familiaris* de la Ciudad de Chincha, Peru. *Parasitología al día*, 23, 59–62.

Carretta, J. V., Forney, K. A., Lowry, M. S., Barlow, J., Baker, J., Hanson, B., Muto, M. M. 2007. *U.S. Pacific Marine Mammal Stock Assessments: 2007*. US Department of Commerce, NOAA Technical Memorandum, NMFS–SWFSC–414.

Castro, M., Martínez, R. 2004. Proceso del desarrollo de *Corynosoma obtuscens* (Acanthocephala: Polymorphidae) en *Canis familiaris* y su posible implicancia en slud publica. *Parasitología Latinoamericana*, 59, 26–30.

Chero, J., Iannacone, J., Cruces, C., Sáez, G., Alvariño, L. 2014. Community of metazoan parasites of corvine drum *Cilus gilberti* (Abbott, 1899) (Pisciformes: Sciaenidae) in the coastal zone of Chorrillos, Lima, Peru. *Neotropical Helminthology*, 8, 163–182.

Dailey, M. D. 1969. *Stictodora ubelakeri* a new species of heterophyid trematode from the California sea lion (*Zalophus californianus*). *Bulletin* of the *Southern California Academy* of *Sciences*, 68, 82–85.

Dailey, M. D., Brownell, R. L. J. 1972. A checklist of mammal parasites. *In*: Ridgeway, S. H., Springfield, C. C. T., eds. *Mammals of the Sea: Biology and Medicine*, 528–589.

Dailey, M. D, Hill, B. L. 1970. A survey of metazoan parasites infesting the California (*Zalophus californianus*) and Steller (*Eumetopias jubatus*) sea lion. *Bulletin* of the *Southern California Academy* of *Sciences*, 69, 126–132.

Delyamure, S. L. 1955. Helminthofauna of marine mammals (ecology and phylogeny). Izdatelstvo AN USSR, Moscow, 1–518 [In Russian.]

Dubinin, V. B. 1949. Experimental studies on the life-cycles of some parasitic worms of animals in the Volga delta. *Parazitologischeskiï Sbornik.* Zoologischeskiï Institut Akademiï Nauk SSSR, Leningrad, 11, 156–160 [In Russian.]

Felix, J. R. 2013. *Reported Incidences of Parasitic Infections in Marine Mammals from 1892 to 1978*. Zea E-Books. Book 20, 1–153.

Golvan Y. J. 1959. Acanthocéphales du genre *Corynosoma* Lühe, 1904 parasites de mammifères d'Alaska et de Midway. *Annales de Parasitologie Humaine et Comparee*, 34, 288–321.

Goulding ,T. C., Cohen, C. S. 2014. Phylogeography of a marine acanthocephalan: lack of cryptic diversity in a cosmopolitan parasite of mole crabs. *Journal of Biogeography*, 41, 965–976.

Hernández-Orts, J. S., Montero, F. E., Juan-Garcıa A., Garcıa, N. A., Crespo, E. A., Raga, J. A., Aznar, F. J. 2013. Intestinal helminth fauna of the South American sea lion *Otaria flavescens* and fur seal *Arctocephalus australis* from northern Patagonia, Argentina. *Journal of Helminthology*, 87, 336–347.

Ionita, M., Varela, M. G., Lyons, E. T., Spraker, T. R., Tolliver, S. C. 2008. Hookworms (*Uncinaria lucasi*) and acanthocephalans (*Corynosoma* spp. and *Bolbosoma* spp.) found in dead northern fur seals (*Callorhinus ursinus*) on St. Paul Island, Alaska in 2007. *Parasitology Research*, 103, 1025–1029.

Khokhlova, I. G. 1986. Acanthocephala of terrestrial vertebrates of the USSR. Nauka, Moscow, 1–275 [In Russian.]

Kuzmina, T. A., Kuzmin, Y. 2015. Description of *Uncinaria lyonsi* n. sp. (Nematoda: Ancylostomatidae) from the California sea lion *Zalophus californianus* Lesson (Carnivora: Otariidae). *Systematic Parasitology*, 90, 165–176.

Kuzmina, T., Spraker, T., Lyons, E., Lisitsyna, O. 2017. Gastrointestinal parasites in California sea lions (*Zalophus californianus*): biodiversity and age-related alterations in parasite community. *In:* Akimov, I. A., ed. *Abstracts of the XVI Conference of the Ukrainian Scientific Society of Parasitologists (Lviv, 18–21 September, 2017).* Kyiv, 105.

Laake, J. L., Melin, S. R., Orr, A. J., Greig,D. J., Prager, K. C., DeLong, R. L., Harris, J. D. 2016. California sea lion sex- and age-specific morphometry. *U.S. Dep. Commer., NOAA Tech. Memo*. NMFS–AFSC–312.

Laskowski, Z., Jeżewski, W., Zdzitowiecki, K. 2008. Cystacanths of Acanthocephala in notothenioid fish from the Beagle Channel (sub-Antarctica). *Systematic Parasitology*, 70, 107–117.

Laskowski, Z., Zdzitowiecki, K. 2009. Occurrence of acanthocephalans in notothenioid fishes in the Beagle Channel (Magellanic sub-region, sub-Antarctic). *Polish Polar Research*, 30, 179–186.

Lincicome, D. R. 1943. Acanthocephala of the genus *Corynosoma* from the California sea lion. *Journal of Parasitology*, 29, 102–106.

Lyons, E. T., DeLong, R. L., Melin, S. R., Tolliver, S. C. 1997. Uncinariasis in northern fur seal and California sea lion pups from California. *Journal of wildlife diseases*, 33(4):848–852.https://www.ncbi.nlm.nih.gov/pubmed/11390084

Lyons, E. T., Melin, S. R., DeLong, R. L., Orr, A. J., Gulland, F. M., Tolliver, S. C. 2001. Current prevalence of adult *Uncinaria* spp. in northern fur seal (*Callorhinus ursinus*) and California sea lion (*Zalophus californianus*) pups on San Miguel Island, California, with notes on the biology of these hookworms. *Veterinary Parasitology*, 97, 309–318.

Lyons, E. T., DeLong ,R. L., Spraker, T. R., Melin, S. R., Laake, J. L., Tolliver, S. C. 2005. Seasonal prevalence and intensity of hookworms (*Uncinaria* spp.) in California sea lion (*Zalophus californianus*) pups born in 2002 on San Miguel Island, California. *Parasitology Research*, 96, 127–132.

Mayer, K. A., Dailey, M. D., Miller, M. A. 2003. Helminth parasites of the southern sea otter *Enhydra lutris nereis* in central California: abundance, distribution, and pathology. *Diseases of Aquatic Organisms*, 53, 77–88.

McClatchie, S., Field, J., Thompson, A. R., Gerrodette, T., Lowry, M., Fiedler, P. C., Watson, W., Nieto, K. M., Vetter, R. D. 2016. Food limitation of sea lion pups and the decline of forage off central and southern California. *Royal Society Open Science*, 3: 150628

Moravec, F., Scholz, T. 2016. Helminth parasites of the lesser great cormorant *Phalacrocorax carbo sinensis* from two nesting regions in the Czech Republic. *Folia Parasitologica*, 63, 022.

Moles, A. 1982. Parasite-host records of Alaskan fisheries. *In:* National Atmospheric and Oceanic Agency, Washington, D. C. *National Marine Fisheries Special Scientific Report* No. 760, 1–41.

Near, J. T., Garey, J. R., Nadler, S. A. 1998. Phylogenetic relationships of the acanthocephala inferred from 18S ribosomal DNA sequences. *Molecular Phylogenetics and Evolution*, 10, 287–298.

Nickol, B. B., Helle, E., Valtonen, E. T. 2002. *Corynosoma magdaleni* in gray seals from the Gulf of Bothnia, with emended descriptions of *Corynosoma strumosum* and *Corynosoma magdaleni*. *Journal of Parasitology*, 88, 1222–1229.

Okulewicz, A. 2014. Helminths in migrating and wintering birds recorded in Poland. *Annals of Parasitology*, 60 (1), 19–24.

Perry M. L. 1942. A new species of the acanthocephalan genus *Filicollis*. *Journal of Parasitology*, 28, 385–388.

Petrochenko, V. I. 1958. Acanthocephala of Domestic and Wild Animals. Izdatelstvo NAS of USSR Moscow,, 1–458 [In Russian.]

Presswell, B., García-Varela, M., Smales, L. R. 2017. Morphological and molecular characterization of two new species of Andracantha (Acanthocephala: Polymorphidae) from New Zealand shags (Phalacrocoracidae) and penguins (Spheniscidae) with a key to the species. *Journal of Helminthology*. https://doi.org/10.1017/S0022149X17001067

Richardson, D. J., Cole, R. A. 1997. Acanthocephala of the bald eagle (*Haliaeetus leucocephalus*) in North America. *Journal of Parasitology*, 83 (3), 540-541.

Riquelme, C., George-Nascimento, M., Balboa, L. 2006. Morfometrìa y fecundidad de *Profilicollis bullocki* Mateo, Córdova & Guzmán 1982 (Acanthocephala: Polymorphidae) en especies simpdtricás de Aves costeras de Chile. *Revista chilena de historia natural,* 79, 465–474.

Rocka, A. 2006. Helminths of Antarctic fishes: life cycle biology, specificity and geographical distribution. *Acta Parasitologica*, 51, 26–35.

Rodríguez, S. M., D'Elía, G., Valdivia, N. 2016. The phylogeny and life cycle of two species of *Profilicollis* (Acanthocephala: Polymorphidae) in marine hosts off the Pacific coast of Chile. *Journal of Helminthology*, 26, 1–8.

Royal, L., Murray, D., Richard, D. 2004. Acanthocephala cystacanth infections in sand crabs from Bodea Bay, California. *California Fish and Game*, 90, 36–41.

Rudolphi, C. A. 1802. Fortsetzung der Beobachtungen uber die Eingeweidewurmer. *Archiv fur Zoologie und Zootomie von Wiedemanns*, 2, 1–67.

Schmidt, G. D. 1975. *Andracantha*, a new genus of Acanthocephala (Polymorphidae) from fish-eating birds with descriptions of three species. *Journal of Parasitology*, 61 (4), 615-620.
Shults, L. M. 1982. Helminths of the spotted seal, *Phoca largha,* from the Bering Sea. *Journal of Wildlife Diseases*, 18, 59–62.
Silvagni, P. A., Lowenstine, L. J., Spraker, T. R., Lipscomb, T. P., Gulland, F. M. 2005. Pathology of domoic acid toxicity in California sea lions (*Zalophus californianus*). *Veterinary Pathology*, 42, 184–191.
Skorobrechova, E. M., Nikishin, V. P., Lisitsyna, O. I. 2012. Structure of capsule around acanthocephalan *Corynosoma strumosum* from uncommon paratenic hosts — lizards of two species. *Parasitology Research*, 108, 459–467.
Smith, N. F. 2007. Associations between shorebirds abudance and parasites in the sand crab, *Emerita analoga*, along the California coast. *Journal of Parasitology*, 93, 265–273.
Tantaleán, M., Cárdenas, J., Güere, R. 2002. *Profilicollis altmani* (Perrry, 1942) Van Cleave, 1947 (Acanthocephala) in Peru. With notes on the experimental infection of terrestrial mammals. *Revista Peruana de Biología*, 9, 49–51.
Tantaleán, M., Huiza, A. 1994. Sinopsis de los parásitos de peces marinos de la costa peruana. *Biotempo*, 1, 53–101.
Tantaleán, M., Sánchez, L., Gómez, L., Huiza, A. 2005. Acantocéfalos del Perú. *Revista Peruana de Biología*, 12, 83–92.
Van Cleave, H. J. 1947. Analysis of distinctions between the acanthocephalan genera *Filicollis* and *Polymorphus*, with description of a new species of *Polymorphus*. *Transactions of the American Microscopical Society*, 66, 302–313.
Van Cleave, H. J. 1953 a. A preliminary analysis of the acanthocephalan genus *Corynosoma* in Mammals of North America. *Journal of Parasitology*, 39, 1–13.
Van Cleave, H. J. 1953 b. *Acanthocephala of North American mammals*. Illinois biological monographs, 23, 1–179.
Ward, H. L., Winter, H. A. 1952. Juvenile Acanthocephala from the yellowfin croaker, *Umbrina roncador*, with description of a new species of the genus *Arhythmorhynchus*. *Transactions of the American Microscopical Society*, 71, 154–156.
Yamaguti, S. 1939. Studies on the helminth fauna of Japan, part 29. Acanthocephala, II. *Japanese Journal Zoo1ogy*, 8, 317–351.
Yurakhno, M. V. 1998. Diseases and Parasites. *In:* Sokolov, V. E, Aristov, A. A., Lisitzina, T. U., eds. *Northern fur seal: systematic, morphology, ecology, behavior.* Nauka, Moscow, 810–899 [In Russian.]
Zdzitowiecki, K. 1985. Acanthocephalans of birds from South Shetlands (Antarctic). *Acta Parasitologica Polonica*, 30, 11–24.
Zdzitowiecki, K. 1986. Redescription of *Corynosoma tunitae* (Weiss, 1914) and description of *C. baylisi* sp. n. (Acanthocephala, Polymorphidae), parasites of piscivorous birds. *Acta Parasitologica Polonica*, 31, 117–123.
Zdzitowiecki, K. 1989. New data on the morphology and distribution of two acanthocephalans, *Andracantha baylisi* (Zszitowiecki, 1986) comb. n. and *Corynosoma australe* Johnston, 1937. *Acta Parasitologica Polonica*, 34, 167–172.

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