RESEARCH NOTES

Occurrence and Morphological Comparisons of *Campula oblonga* (Digenea: Campulidae), Including a Report from an Atypical Host, the Thresher Shark, *Alopias vulpinus*

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ABSTRACT: New host records for *Campula oblonga* Cobbold, 1858 from the common dolphin, *Delphinus delphis* L., and from the thresher shark, *Alopias vulpinus* (Bonnaterre), are reported herein. Campulids have not been reported previously from a host that was not a marine mammal. The excellent condition and small size of the gravid specimen and the diet and natural history of the thresher shark lead us to conclude that the digene was acquired from the consumption of infected fish. Specimens of *C. oblonga* from these 2 hosts and from harbor porpoises, *Phocoena phocoena* (L.), and from Dall's porpoises, *Phocoenoides dalli* (True), are compared, and a wide variation in ranges and values for characters is noted. The synonymy of *Campula folium* Ozaki, 1935 with *C. oblonga* is further supported by the apparent effect of the host on the size of the trematodes. Due to the degree of variation in measurements and the numerous factors that may impact these values, we recommend the use of qualitative morphologic characters for the identification of *C. oblonga*.

The family Campulidae Odhner, 1926 was established for the genera previously contained in the subfamily Brachycladiinae Odhner, 1905 of the family Fasciolidae Railliet, 1895. Campulid trematodes are regarded as parasites of marine mammals, and in particular, members of the genus *Campula* Cobbold, 1858 are known from the smaller cetaceans of the families Delphidae and Phocoenidae. Cobbold (1858) described *Campula oblonga* from the bile ducts of a harbor porpoise, *Delphinus phocaena* (=*Phocoena phocoena* (Linnaeus)) collected in the Firth of Forth, Scotland (lat. 56°N, long. 3°E). Since then, *C. oblonga* has been reported from harbor porpoises in the North Pacific (Ching and Robinson, 1959) and the North Atlantic (Price, 1932; Smith and Threlfall, 1973; Brattey and Stenson, 1995), and from Dall's porpoises, *Phocoenoides dalli* (True) in the Pacific (Yamaguti, 1951; Dailey, 1971; Migaki et al., 1971; Dailey and Walker, 1978; Conlogue et al., 1985). We report herein new host records for *C. oblonga*.

Specimens of *C. oblonga* (U.S. National Parasite Collection, USNPC 83337) were collected from the bile ducts of a common dolphin, *Delphinus delphis* L., at Bedeque Bay, Prince Edward Island, Canada (lat. 46°23′N, long. 63°50′W). This is the first report of this digene from a dolphin. Other species of *Campula* known to infect the common dolphin are *Campula rochebruni* (Poirier, 1886), *Campula delphini* (Poirier, 1886), and *Campula palliata* (Looss, 1885) in European and Pacific waters (Price, 1932; Ridgway and Dailey, 1972; Arvy, 1982). Without comment, Yamaguti (1958, 1971) placed the latter 2 species in the genus *Lecithodesmus* Braun, 1902, but subsequent workers have not accepted the allocations.

A thresher shark, *Alopias vulpinus* (Bonnaterre), was live entrapped and subsequently killed in a herring weir on 20 September 1989 at Dark Harbor, Grand Manan (lat. 44°45′, long.

66°50′W). We report the presence of a single mature specimen of *C. oblonga* (New Brunswick Museum, NBM 720) in the liver. This is the first report of an adult campulid in an elasmobranch; campulids have not been previously reported from a host that was not a marine mammal.

The general appearance of the digene from the thresher shark is consistent with that of *C. oblonga*. The parasite was in excellent condition, with the characteristic covering of dense cuticular spines maintained throughout. The single pair of anterior diverticula of the intestinal ceca lacks lateral processes, although the posterior portion of the ceca demonstrates lateral and medial processes, as is typical for *C. oblonga*. The testes are lobed. Both the cirrus and the metraterm are unarmed. Vitellaria extend anteriad almost to the posterior edge of the oral sucker.

The measurements of the digene are given in Table I, with those from other hosts provided for comparison. In the original description for *C. oblonga*, Cobbold (1858) provided measurements for the body length and width only, 3.2–6.4 mm and 1.7 mm, respectively; his data are not included. The specimen from the shark is small, approximately half the length of those from the cetaceans. However, it does equal the minimal length in the range reported by Cobbold (1858), and lengths of the eggs do overlap other reported values. As demonstrated within Table I, measurements for *C. oblonga* vary even among cetacean hosts. Ozaki (1935) differentiated *Campula folium* Ozaki, 1935, collected from *Neophocaena phocaenoides* (G. Cuvier), from *C. oblonga* based on the length of the body and size of testes. The range of values given in Table I encompasses those given for *C. folium* and further supports the synonymy of this species with *C. oblonga* proposed by Yamaguti (1942). With regard to the degree of variation in measurements and the numerous factors that may impact these values, we recommend that due consideration be given to qualitative morphologic characters for identification of *C. oblonga* rather than reliance on differences in size.

In addition to the effect on the dimensions of *C. oblonga*, species of host also has an apparent impact on the number of eggs produced by the digenes. The specimen from the thresher shark was gravid, with approximately 45 eggs within the uterus. In the uteri in those from the common dolphin, the eggs were tightly packed within the uterus and easily numbered over 200. Among specimens from the harbor porpoise, the number of eggs varied. Digenes collected from that host at Woods Hole had a minimum of 120 eggs to over 260. A specimen (USNPC 74674) collected from a harbor porpoise in the waters off of the Oregon coast contained over 300 eggs within its uterus.

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TABLE I. Measurements of *Campula oblonga* from the thresher shark, *Alopias vulpinus*, and from three species of cetaceans.*

Location	*Alopias vulpinus* Dark Harbor, Grand Manan, Canada	*Delphinus delphis* Bedeque Bay, Prince Edward Island, Canada	*Phocaenoides dalli*† Sea of Japan	*Phocoena phocoena*‡ Woods Hole, Massachusetts	*Phocoena phocoena*§ Hooper Bay, Alaska	*Phocoena phocoena*‖ Cordova, Alaska	*Phocoena phocoena*# Grays Harbor County, Washington
No. of specimens	1	3	7	4¶	10	10	10
Body							
Length (mm)	3.24	7.50–8.65 (8.11)	7.50–9.00	4.00–7.00	5.44–6.38 (5.96)	5.79–8.24 (7.19)	6.61–7.78 (7.29)
Width (mm)	1.13	1.43–1.48 (1.45)	2.00–2.50	1.00–3.00	1.48–1.80 (1.61)	1.45–2.39 (2.00)	1.80–2.28 (2.11)
Oral sucker							
Length	190	473–517 (495)	270–350	310–340**	253–275 (267)	264–308 (288)	286–330 (307)
Width	230	528–561 (545)	350–400		264–297 (286)	242–308 (285)	297–319 (307)
Pharynx							
Length	284	231–286 (264)	350–400	310–360	319–374 (345)	275–385 (350)	319–396 (359)
Width	131	154–264 (213)	200–250	170–220	165–209 (187)	165–209 (190)	165–209 (191)
Acetabulum							
Length	290	517–550 (532)	460–550**	430–465**	407–462 (431)	352–451 (409)	385–473 (429)
Width	310	506–528 (517)			407–462 (435)	363–440 (398)	396–462 (424)
Ovary							
Length	105	220–396 (297)	360–480	186–372	275–341 (309)	242–418 (348)	286–429 (372)
Width	150	396–407 (403)	520–600	310–527	286–385 (349)	253–484 (372)	308–506 (410)
Anterior testis							
Length	225	759–1,254 (983)	1,300–1,950††	620–770	726–847 (787)	704–1,045 (923)	737–1,001 (894)
Width	525	737–1,034 (906)	1,400–1,750††	770–990	858–1,078 (968)	814–1,474 (1,154)	968–1,320 (1,122)
Posterior testis							
Length	320	1,122–1,485 (1,360)		620–1,000	803–1,133 (943)	814–1,375 (1,144)	946–1,298 (1,142)
Width	485	748–935 (829)		770–1,200	792–1,078 (908)	836–1,386 (1,136)	891–1,221 (1,082)
Eggs							
Length	67–93 (80)	84–95 (90)	66–87	90–97	79–95 (89)	87–95 (91)	79–95 (86)
Width	31–39 (35)	40–46 (43)	44–54	45	40–54 (45)	44–51 (47)	41–49 (45)

* When available, means are given in parentheses; all values are in µm unless noted otherwise.
† Yamaguti (1951).
‡ Price (1932).
§ Collected by R. L. Rausch, 6 June 1957 (lat. 61°31'N, 166°05'W).
‖ Collected by F. H. Fay, 10 June 1972 (ca. lat. 61°N, 146°W).
Collected by M. L. Johnson, 28 June 1964 (ca. lat. 47°N, 124°W).
¶ Represents best estimate. Price (1932) does not state number of specimens measured but does provide the accession number of the specimens from the U.S. National Parasite Collection (USNPC no. 8415). This accession series includes 4 whole mounts and sections of another 3 trematodes.
** Measurements given as diameter.
†† Range includes measurements from both testes.

Although the number of eggs present can be affected by the maturity of the digene, the considerably fewer eggs within the specimen from the shark most likely are a result of the effect of an atypical host on the reproductive capability of the campulid.

The distributions of the 3 cetaceans (Watson, 1981) that are hosts for *C. oblonga* all overlap to some extent that of the thresher shark. *Phocoena phocoena* frequents the cooler waters of the northern Atlantic and northern Pacific, whereas *P. dalli* is found only in the northern Pacific. The common dolphin, *D. delphis,* is found worldwide in tropical and warm temperate waters, extending only somewhat into the more northern reaches. Thresher sharks are distributed worldwide in temperate and tropical seas, including the Atlantic coast of North America from the Gulf of St. Lawrence to Florida (Robins and Ray, 1986). They are considered pelagic, although thresher sharks have been reported close to shore (Lineaweaver and Backus, 1984), and their young may be found inshore and in shallow bays (Compagno, 1984). Thus, the geographic distributions for the cetaceans and the elasmobranch are broadly sympatric.

Although the life cycle of *C. oblonga* has not been determined, Deliamure (1955) proposed that the transmission of digenes to marine mammals occurred from the ingestion of infected fishes. The food habits of the 3 cetaceans and the thresher shark are all strikingly similar, comprised to a large extent of fishes. Harbor porpoise feed mostly on the small schooling fishes, including herring *Clupea harengus* L., mackerel *Scomber scombrus* L., and whiting *Merlangius merlangus* (L.), and sometimes squids and crustaceans (Watson, 1981). Squid is considered the primary prey of *P. dalli,* although fishes such as Pacific hake *Merluccius productus* (Ayres), capelin *Mallotus villosus* (Müller), and herring may also comprise a large portion of the diet (Watson, 1981; Brattey and Stenson, 1995). The common dolphin may feed on squid, but they generally pursue schools of migrating fishes. In the Pacific, they feed largely on anchovies *Engraulis* spp.; in the Atlantic, generally sardines *Sardinella* spp., herrings, and bottom-dwelling crabs (Watson, 1981). The thresher shark possesses a small mouth and teeth and feeds on only moderately sized prey. Primary prey of the thresher shark includes herring, mackerel, shads, and pilchards; other small fishes, squids, octopi, and pelagic crustaceans may also be consumed (Compagno, 1984; Steel, 1985). No reliable accounts of these sharks feeding on marine mammals are available, even though Bannister (1989) tells of "early reports" of 6 thresher sharks attacking a small school of dolphins, and Lineaweaver and Backus (1984) tell of a persistent fable involving the attack on a whale by a thresher shark and a swordfish. Compagno (1984) indicates that seabirds may be consumed, although rarely. This probably refers to the account reiterated by Lineaweaver and Backus (1984) of a thresher shark killing and eating a loon in Dublin Bay; however, the authors also state that the shark is not known to feed on prey other than small fishes.

The presence of a specimen of *C. oblonga* within the liver of a thresher shark is highly unusual, but the infection is proposed to have been acquired from the consumption of either an infected fish or a marine mammal. Because both the food habits and the geographical distributions of the typical hosts overlap with those of *A. vulpinus,* the possibility exists of a thresher shark ingesting fish infected with the metacercaria of *C. oblon-*

ga. If the digene was acquired from the consumption of a marine mammal by the shark, the size of the specimen should have been larger. In addition, the digestive process and migration up the bile duct would have been expected to have had a negative impact on the condition of the worm. The excellent condition and size of the worm argues against this scenario. Consideration of the anatomy and natural history of the shark also precludes the possibility of such an event. The unusually small size of the specimen and the small number of eggs illustrate the effect of an atypical host, although the maturity of the parasite and the presence of eggs indicate that the digene not only was capable of establishing itself with this host but was able to persist and mature.

We conclude then, that the thresher shark became infected from the ingestion of prey infected with the metacercaria, and the digene developed and matured within the shark. This remarkable record is an indication of the importance of guild associations (phylogenetically disparate hosts exploiting a common prey resource) in driving the potential for host-switching or colonization by parasites (see Hoberg, 1987).

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Toxoplasma gondii in Vancouver Island Cougars (*Felis concolor vancouverensis*): Serology and Oocyst Shedding

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ABSTRACT: One of 12 necropsied cougars (*Felis concolor vancouverensis*) from Vancouver Island, British Columbia, Canada, shed *Toxoplasma gondii* oocysts confirmed by mouse bioassay. Eleven of the 12 cougars (92%) had antibodies to *T. gondii* by the modified agglutination test with titers of <1:25 (1 cougar), 1:50 (8 cougars), and 1:500 (3 cougars). One additional cougar fecal sample collected from the Victoria watershed environment also contained *T. gondii* oocysts. In 1995, the largest reported outbreak of human toxoplasmosis was linked to municipal drinking water in Victoria, British Columbia. This study supports the initial hypothesis at the time of the outbreak that not only domestic cats, but also cougars, pose a risk to Victoria's water supply.

Felidae are the only hosts that excrete *Toxoplasma gondii* oocysts (Jewell et al., 1972; Miller et al., 1972). The role of large wild cats, including cougars (*Felis concolor*), in the epidemiology of *T. gondii* is unknown. Under experimental conditions, wild cats shed only a few oocysts compared with domestic cats (*Felis domesticus*). In 1 study, only 1 of 6 bobcats (*Lynx* sp.) initially free of *T. gondii* excreted oocysts after being fed many tissue cysts, and only a few oocysts were shed by a cougar fed *T. gondii* tissue cysts (Miller et al., 1972). We report for the first time the shedding of *T. gondii* oocysts by 2 naturally infected cougars (*Felis concolor vancouverensis*).

In the spring of 1995, the first reported human outbreak of toxoplasmosis associated with municipal drinking water was identified in Victoria on Vancouver Island, British Columbia, Canada (Bell et al., 1995; Bowie et al., 1997). An epidemiological investigation by the British Columbia Centre for Disease Control resulted in the hypothesis that water from 1 of 2 main reservoirs serving the Greater Victoria area was the source of the outbreak. It was suspected that feces of infected domestic or feral cats, or cougars, entered the reservoir or 1 of its contributor streams, resulting in contamination of the water supply with *T. gondii* oocysts. Both domestic cats and cougars (the only felids found on Vancouver Island) were frequently observed in the watershed.

Between April and August 1996, 12 cougars that were killed by conservation officers on Vancouver Island were necropsied within 12 hr of death. Only 1 of the 12 cougars was from within the Victoria watershed. The conservation officers estimated an age for each cougar based on animal size and teeth characteristics. Of the 12 cougars necropsied, 7 were males and 5 were females; 5 were 1 to 1.5-yr-old, and 7 were ≥2-yr-old. At necropsy, feces were collected from the rectum and colon, and blood was collected from the heart. Blood was centrifuged within 6 hr of collection and serum was stored at −20 C. Feces (20–50 g) were preserved in 2% H_2SO_4 and stored at 4 C. A fresh fecal sample we believed to be of cougar origin based on scat characteristics (Murie, 1974) was also collected from the Victoria watershed environment in August 1996.

All samples were sent for *T. gondii* examination to the United States Department of Agriculture Parasite Biology and Epidemiology Laboratory, Beltsville, Maryland. Sera were examined for anti-*T. gondii* antibodies with the modified direct agglutination test (MAT) using formalin-fixed whole tachyzoites as previously described (Dubey and Desmonts, 1987). For MAT, sera were diluted 1:25, 1:50, and 1:500. Results of 1:25 were selected as the threshold titer for determining seropositive status. Feces were emulsified in water, filtered through gauze, and centrifuged at 1,200 *g* for 10 min. The supernatant was discarded, and the sediment was mixed with 5–10 volumes of sucrose solution (specific gravity 1.18) in a 50-ml tube. After centrifugation, a drop from the meniscus was examined microscopically for coccidian oocysts. If oocysts were not found, 5 ml of the float from the top layer was mixed with 45 ml of water, centrifuged for 10 min, and the sediment was suspended in 10 ml of 2% H_2SO_4. When oocysts were detected micro-