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Prevalence and anatomic site of *Crassicauda* sp. infection, and its use in species identification, in kogiid whales from the mid-Atlantic United States

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ABSTRACT

The parasitic nematode *Crassicauda* sp. was initially described in kogiid whales from specimens collected within cervical tissues, uncommon sites of infection for this parasite. *Crassicauda* sp. has only been reported in *Kogia breviceps* to date, but no study has yet investigated a large sample of both kogiid species. A 15 yr record of 104 kogiid strandings (*K. sima*, $n = 40$; *K. breviceps*, $n = 64$) in North Carolina and Virginia, U.S.A. was used to determine the prevalence of *Crassicauda* sp. across species, within species across sex, and within sex across length and life history categories. *Crassicauda* sp. was confirmed to be a species-specific parasite among kogiids infecting only *K. breviceps* (prevalence = 45%). Within *K. breviceps*, prevalence was similar (45%) in both immature and mature males, but increased from 10% in immature to 76% in mature females. This study confirmed the cervico-thoracic distribution of the parasite, and identified a novel site of

infection in a previously undescribed exocrine gland associated with the pigmented "false gill slit." The species-specific nature of *Crassicauda* sp. infection, the exocrine gland, and the distinct features of the false gill slit pigmentation associated with the gland, are all useful characters to identify kogiid species in the field.

Key words: *Kogia*, *Crassicauda*, marine mammal, parasite, nematode, kogiid species identification, infection, prevalence.

The genus *Crassicauda* contains species of large parasitic nematodes that can reach several meters in length and that are specific to both mysticete and odontocete cetaceans (e.g., Baylis 1922; Skrjabin 1934, 1949; Delyamure 1955; Dollfus 1966; Yablokov 1974; Lambertsen 1985, 1986). Crassicaudids infect the urogenital system of mysticetes and odontocetes and the cranial pterygoid sinuses of delphinids, and has been documented to contribute to morbidity and mortality (e.g., Lambertsen 1985, 1986; Geraci and St. Aubin 1987). Crassicaudids have been directly linked to reproductive failure and erosion of the pterygoid bone in odontocetes (Ridgway 1972, Dailey and Stroud 1978, Geraci *et al.* 1978, Perrin and Powers 1980, Gibson *et al.* 1998, Pascual *et al.* 2000), and have been implicated as the primary cause of renal failure in several species of cetaceans from both suborders (Lambertsen *et al.* 1986, 1992; Gibson *et al.* 1998; Sotiraki *et al.* 2000; Oliveira *et al.* 2011).

Johnston and Mawson (1939) were the first to describe a crassicaudid infection in kogiid whales. The pygmy sperm whale (*Kogia breviceps*) specimens utilized in their study included one adult of unknown sex stranded in Queensland in 1933, and a cow/calf pair stranded in South Australia in 1937. Both adult kogiids were reported to be infected with *Crassicauda*, however,

the authors only provided a description of the 370 cm fragment of female worm dissected from the South Australian adult female. These authors described and named *Crassicauda magna* from this anterior fragment of a worm, which was reported to be "lying in a narrow tunnel entwined in the connective tissue" of the neck, an unusual anatomic site for this genus of nematodes. The authors made no mention of the location of infection in the other adult or of the infection status of the calf.

In 1966 Dollfus described a new species of *Crassicauda*, *C. duguyi*, occurring in "the subcutaneous musculature in the neck" of a *K. breviceps* specimen (sex unknown) stranded in southwestern France. This description was based upon a posterior fragment of a male worm. Unable to identify this specimen as *C. magna*, as described by Johnston and Mawson (1939), this author instead compared the posterior fragment to available descriptions of other known spiculated forms of the genus. Dollfus (1966) found all previously described forms to be incompatible with his specimen and therefore erected and described in detail the new species *C. duguyi*. Recent work by Jabbar et al. (2015), which provides new information on the heads and tails of males of these parasitic nematodes from Australian *K. breviceps*, suggests that both of these *Crassicauda* species are synonymous.

Since the two hallmark studies of Johnston and Mawson (1939) and Dollfus (1966), several surveys of cetacean parasites have been published that have included reports of *Crassicauda* spp. in kogiid whales. Abollo et al. (1998) investigated the macroparasites of stranded cetaceans along the Atlantic coast of Spain, and provided the first record of any crassicaudid in kogiids in the temperate waters of the northeast Atlantic Ocean.

These researchers reported a single species, which they identified as *C. magna*, infecting the "neck musculature" of a 258 cm *K. breviceps* stranded in Galicia, Spain. The next survey to include information on *Crassicauda* infection in kogiid whales was that by Mignucci-Giannoni *et al.* (1998), which examined metazoan parasites of cetaceans in the Caribbean Sea. Three of the 47 cetaceans investigated were *K. breviceps*. Fragments of *Crassicauda cf. duguyi* Dollfus, 1966, were reported to be collected from the "neck musculature" of one of the pygmy sperm whales. These authors considered this report to be a new geographic record for *C. duguyi*. Cardona-Maldonado and Mignucci-Giannoni (1999) later added more details on this individual *K. breviceps*, which was a 281 cm pregnant female (NEPST 527), stranded in Barceloneta, Puerto Rico.

Carvalho *et al.* (2010) investigated metazoan parasites of cetaceans stranded off the northeastern coast of Brazil between 2004 and 2009. Seven of the 82 cetacean carcasses examined were kogiids (three *K. sima* and four *K. breviceps*). The researchers reported *Crassicauda* spp. as occurring in the "muscle, pleura, and penis" of a single male *K. breviceps*. Specifically, fragments of crassicaudids were found encysted in the diaphragm muscle, suprascapular muscles, and penis. Carvalho *et al.* (2010) also reported the prevalence of *Crassicauda* spp. in their study. Prevalence is a commonly used descriptive statistic in epidemiology, requiring only presence-absence data, rather than the enumeration of individual parasites infecting a host (intensity) or the probability of cases within a specified period of time (incidence) (Bush *et al.* 1997). Prevalence represents the percentage of a population infected by a particular disease, or in this case, a parasite, without regard

as to how or when it was acquired, or where it was located in the host (Bush *et al.* 1997). Carvalho *et al.* (2010) reported an overall prevalence of *Crassicauda* spp. as 1.2%, *i.e.*, one infected *K. breviceps* out of 82 total individual cetaceans in their study. Prevalence recalculated for the sample of seven kogiids would be 14.3%, and for the four identified *K. breviceps* would be 25%.

Despite their known pathogenic effects in other cetaceans, other than these few records, there exist no other known detailed reports of crassicaudid infection in kogiid whales to the best of our knowledge. From a historical perspective, it is important to note that both proposed crassicaudid species, *C. magna* and *C. duguyi*, were described prior to Handley's (1966) delineation of kogiids into two separate species, the pygmy sperm whale (*K. breviceps*) and the dwarf sperm whale (*K. sima*). Although crassicaudid infection has only been reported in *K. breviceps* to date, the published helminthological surveys noted above include only 21 kogiid specimens—14 *K. breviceps* and seven *K. sima*. No study has explicitly investigated a large sample of kogiids to determine whether *Crassicauda* sp. is a species-specific parasite within the Family Kogiidae.

We conducted a retrospective investigation utilizing over one hundred historic stranding records of kogiids in North Carolina and Virginia from 1998 through 2013. Our goals were to (1) determine the prevalence of *Crassicauda* sp. infection in *K. sima* and *K. breviceps*, (2) analyze prevalence data in relation to host sex, total body length, and reproductive status, and (3) describe the anatomical site(s) of *Crassicauda* sp. infection within its kogiid host. An emergent finding of this study was the identification of two previously unrecognized anatomic

features that appear to be diagnostic of *K. breviceps*.

METHODS AND MATERIALS

This study represents a retrospective analysis of the prevalence of nematode parasites, from the genus *Crassicauda*, in both species of kogiid whales, *Kogia sima* and *K. breviceps*, stranded from 1998 to 2013 in Virginia and North Carolina, U.S.A. These two kogiid species are very similar in their shark-like appearance—both possess a pointed snout, an underslung jaw, and a pigmentation pattern that mimics a gill slit (Caldwell and Caldwell 1989). *K. sima* is smaller, ranging in size from 2.2 m to 2.4 m when fully mature, whereas *K. breviceps* can reach lengths up to 3.3 m (Barros and Duffield 2003). Sexually immature specimens at intermediate lengths are difficult to identify to species without the use of genetics (Chivers *et al.* 2005, Viricel 2012). Thus, to be included in this study, kogiid specimens had to (1) have their species identification confirmed by morphometric and/or genetic data, (2) be in fresh to moderate condition (Smithsonian Institution codes 1-3) (Geraci and Lounsbury 1993), and (3) have undergone an internal exam or necropsy. Of the 147 kogiids that stranded during the study period, 104 individuals met these criteria and were utilized in the study (*K. sima*, $n = 40$; *K. breviceps*, $n = 64$) (Table 1). For each of these individuals, digital and hardcopy data sheets and necropsy reports were reviewed. When available, all photographic records of each specimen were also carefully reviewed. Animals were considered positive for infection if crassicaudids were observed grossly and/or histologically. When crassicaudids were present, details regarding their anatomic position(s) within the host were determined. Because these descriptions were highly variable in anatomical detail, sites of infection were binned,

based upon body regions. For example, if the parasite was described in the muscle or connective tissues of the neck, its location was identified as "cervical." Similarly, regardless of the tissue type, any parasite described in the thoracic region was scored as "thoracic." For two specific anatomic features, vascular retia and "gill slit gland" (described below), descriptions were sufficiently consistent to be used as a category of infection site.

The statistical approach used to describe parasite infection in this study was prevalence (number of infected individuals divided by the total number of individuals sampled). Prevalence was first calculated for all kogiid individuals across the entire 15 yr study period, and then for each species. Within species, prevalence was calculated for both sexes, and within each sex, across individuals of different body size. For this analysis, total body lengths were binned into 30 cm intervals. Prevalence of *Crassicauda* sp. infection was also calculated in relation to sexual maturity of the specimen. For most animals in the data set ($n = 95$) reproductive status was explicitly reported. In cases where this information was not determined ($n = 9$), published measurements for estimated total body length at attainment of sexual maturity, for each species, were used to assign status. To be conservative, specimens were only identified as mature if they were larger than the published upper size estimate. Male *K. sima* in this study that were longer than 197.5 cm total body length were considered sexually mature based upon estimated sexual maturity between 197.0 and 197.5 cm (Plön 2004). Female *K. sima* were considered sexually mature at 215 cm (Plön 2004). Male *K. breviceps* from South Africa have been documented to attain sexual maturity between total body

lengths of 241-242 cm, based upon histological examination of the testis (Plön 2004). Thus, male *K. breviceps* from this study lacking information regarding their reproductive status were scored to be sexually mature at lengths above 242 cm. Female *K. breviceps* in this study were considered mature if they were found to be either lactating, pregnant, and/or with a dependent calf. In instances where females were not reported to be reproductively active, they were considered mature at a total body length of 262 cm or greater (Plön 2004).

The 95% confidence intervals were calculated using the Score Interval (Agresti and Coull 1998) for *Crassicauda* sp. prevalence in each species. Chi-square tests were used to investigate whether differences in prevalence existed between sexes within each species, and within each sex, across immature vs. mature individuals. Statistical analyses were performed using a commercial software package (JMP Pro 11.0, SAS Institute Inc., Cary, NC). Specimens included in this study underwent standard marine mammal necropsy protocols, which were not conducted from a helminthological standpoint; therefore, the prevalence of *Crassicauda* sp. infection may be underestimated.

RESULTS

Prevalence of Crassicauda sp. Infection

Of the total sample of 104 kogiids stranded along the coasts of Virginia and North Carolina from 1998 to 2013, 31% ($n = 32$) were infected with *Crassicauda* sp. The infection, though, was species specific. None of the 40 *Kogia sima* in the study were infected with *Crassicauda* sp. (prevalence = 0%, 95% CI = 0%-8.8%) (Fig. 1a). In contrast, 32 of the 64 *K. breviceps* individuals were infected, yielding a species prevalence of 50% (95% CI = 38.1-61.9%) (Fig. 1b). In all but 3 yr of the study

(1999, 2000, 2001), crassicaudids were reported in stranded *K. breviceps*.

In *K. breviceps*, prevalence of infection was similar in males ($n = 15/33 = 45\%$) and females ($n = 17/31 = 55\%$). Prevalence did, though, vary between sexes with regard to both total body length (Fig. 2) and reproductive status (Table 2). None of the dependent calves (*i.e.*, those that stranded with a mature female), all of which were female in this study population, were observed to be infected with *Crassicauda* sp. Crassicaudid infection was observed in independent male *K. breviceps* as small as 201 cm in length. In males, there was no clear relationship between host length and *Crassicauda* sp. prevalence, which ranged from 33% to 80% among different size classes (Fig. 2a). Further, prevalence of infection did not differ between mature and immature males (see Table 2). In contrast, there was a monotonic increase in the prevalence of infection among females with increasing total body length (Fig. 2b). There was also a significantly higher prevalence of *Crassicauda* sp. infection in mature (76%) vs. immature females (10%) (Pearson's chi-square test, $P = 0.0005$) (Table 2). Of infected mature females, all but one, where reproductive status was known, were reproductively active. The prevalence of *Crassicauda* sp. infection in mature females (76%) was also higher than that of mature males (45%) (Pearson's chi-square test, $P = 0.0393$).

Site of Infection

In 31 of 32 (97%) *K. breviceps* infected with *Crassicauda* sp., the parasite was described in the tissues of the cervico-thoracic region (Table 3). In only one instance did an examiner report observing *Crassicauda* sp. in the female reproductive

tract (3%, $n = 1/32$). Crassicaudids were observed in the blubber, fasciae, and epaxial musculature of the cervical (66%, $n = 21/32$), cervical or thoracic (28%, $n = 9/32$), and thoracic regions (3%, $n = 1/32$). For those individuals with infection noted in the cervico-thoracic region ($n = 31$), infection was noted specifically within the cervical retia (7%, $n = 2/31$), or both the cervical and thoracic retia (7%, $n = 2/31$), all vascular structures that feed the central nervous system. There was a marked (32%, $n = 10/31$) association with an as-of-yet-undescribed exocrine gland (see below) located in the whale's neck region, which lies deep to the ventral base of the "false gill slit" pigmentation mark.

Emergent Results

An emergent result of this study was the identification of an exocrine gland, often noted as the "gill slit" gland in necropsy reports, as a feature apparently unique to *K. breviceps*. This exocrine gland was specifically reported in 39% ($n = 25$) of all *K. breviceps* in the study, but was never reported in *K. sima*. We have subsequently investigated an additional 12 *K. breviceps* and 13 *K. sima*, and through detailed gross dissections, have confirmed that this gland is present only in *K. breviceps*.

The photographic review of all stranded individuals utilized in this study also revealed a distinct difference in the "false gill slit" pigmentation pattern across these two kogiid species, which to the best of our knowledge, has not been previously reported. In both species of *Kogia*, the dorso-cranial tip of the "false gill slit" marks the opening of the external auditory meatus, as reported by Hubbs (1951) and Yamada (1954). However, *K. breviceps* possesses a dark pigmentation pattern that

extends the ventral portion of the "false gill slit" mark cranially to form a "bracket" between the eye and pectoral flipper (Fig. 3a, 4a). At the cranial tip of the ventral arm of the bracket lies the external opening of the duct leading into the "gill slit" gland. Both the ventro-cranial extension of the false gill slit marking and the exocrine gland are lacking in *K. sima* (Fig. 3b, 4b). The ventral margin of the "false gill slit" pigmentation in *K. sima* extends ventro-caudally and terminates at the level of the insertion of the pectoral flipper.

DISCUSSION

Prevalence of Crassicauda sp. Infection

This study represents the first systematic review of *Crassicauda* sp. across a large sample size of both *Kogia sima* and *K. breviceps*. Although kogiids are some of the most commonly stranded pelagic cetaceans along the U.S. mid-Atlantic coast (Byrd *et al.* 2014), most aspects of their basic biology and ecology remain unknown. This information deficit is, in part, due to their deep diving habits and offshore distribution (Caldwell and Caldwell 1989, Barros and Duffield 2003, reviewed by Piscitelli *et al.* 2010). Much of what is known about kogiids is based upon investigations of stranded specimens. In this geographic region, both species share a high degree of dietary overlap, suggesting similarities in habitat usage (Staudinger *et al.* 2014). Given their shared deep-diving lifestyle and similar diet, it is plausible that both kogiid species may be exposed to, and serve as hosts for, crassicaudids. Within this study, though, *Crassicauda* sp. infection was found to be species-specific, infecting 50% of *K. breviceps* and zero *K. sima*. In all but three years of the 15 yr study period, *Crassicauda* sp. infection was observed in stranded *K. breviceps* (Fig. 1a). The

successive, annual prevalence of infection observed in this study indicates *Crassicauda* sp. is a common parasite of *K. breviceps* in the U.S. mid-Atlantic region.

Overall prevalence of infection differed across sexes in regard to both total body length and reproductive status. None of the dependent calves, all of which were female, were observed to be infected with *Crassicauda* sp. This result suggests that either vertical transmission of *Crassicauda* sp., from cow to calf, does not occur, or that the early life history stage of the parasite was undetectable during gross necropsies of these young whales. In males, there was no consistent relationship between total body length and *Crassicauda* sp. infection, and prevalence was similar among immature and mature individuals. In females, however, there was a marked increase in prevalence of infection with an increase in total body length, and all but one of the infected females was reproductively mature.

A variety of factors may contribute to the different patterns of infection across ontogeny among male and female *K. breviceps*. A hallmark characteristic of parasites is their ability to exploit food webs to complete their often complex life cycles (Lafferty *et al.* 2008). Dailey (1979) postulated that the parasites of cetaceans can be used as a tool to identify intraspecific variations within and among populations, as indicators of differences in migration and feeding habits. Male *K. breviceps* could be feeding on infected intermediate or paratenic prey species earlier in life than females. This hypothesis is supported by the finding that the smallest positive male in this study was 201 cm in length, while the smallest positive female was 231.5 cm in length. All dependent calves in this study were female, and this bias may also suggest

that a difference exists in the age of weaning across sexes in *K. breviceps*. If such a variation in feeding pattern does exist, it may explain earlier onset of infection in smaller, and presumably younger, males observed in this study. This hypothesis could be tested by comparing the diets of male and female *K. breviceps* across an ontogenetic sample of stranded individuals. To determine whether *Crassicauda* sp. is transmitted through the food web, known prey species of *K. breviceps* could be examined to determine presence/absence of *Crassicauda* sp., using approaches similar to those of McClelland *et al.* (1990), who identified larval stages of anisakine nematodes in various fish species near Sable Island, Nova Scotia. Alternatively, tissues of known prey species of *K. breviceps* could be examined using PCR to detect a crassicaudid genetic signal, using approaches similar to those of Stacy *et al.* (2010), who detected spirochiid trematodes within gastropod tissues to identify that parasite's intermediate hosts.

The significantly higher prevalence of *Crassicauda* sp. infection observed in mature females versus mature males could indicate differential vulnerability to infection based upon female investment in reproduction. All but one infected female *K. breviceps* was reproductively mature, and all but one of these females was reproductively active. Across the entire study sample of mature females (infected and uninfected), only one was reported as reproductively quiescent; all others were either lactating, pregnant, with a dependent calf, or a combination of the three (95%, $n = 20/21$). Once reproductively mature, females remain reproductively active throughout their life (Plön 2004). The largest two females in the study (KLC 078, 316 cm; ASF 028, 312 cm) were both lactating and had evidence of recent

parturition. Perhaps the successive high maternal investment and reproductive output, which are energetically expensive and require immunological alteration to allow for maternal fetal tolerance (Kay *et al.* 2014), may limit an adult female's ability to mount an effective immune response to *Crassicauda* sp. infection. Alternatively, *Crassicauda* sp. infection could result in a hyperinflammatory disease state triggered by overstimulation of the immune response during pregnancy (Kay *et al.* 2014). Unfortunately, testing these hypotheses on stranded *K. breviceps* would require the ability to meaningfully assess and interpret an individual's immune status prior to the stranding event, which is challenging given that the stranding event can profoundly impact such metrics.

Alternatively, the feeding patterns of reproductively mature females may differ from those of males and lead to increased exposure. Staudinger *et al.* (2014) demonstrated a high degree of dietary overlap between male and female kogiids (Pianka Index = 0.81), but this sample included immature and mature specimens of both kogiid species. This hypothesis could be tested with a more focused analysis that compared diets of mature male and female *K. breviceps*.

Site of Crassicauda sp. Infection

The site of *Crassicauda* sp. infection in *K. breviceps* investigated in this study differed from the urogenital and pterygoid sinus infections reported in other species of cetaceans (*e.g.*, Baylis 1922; Skrjabin 1934, 1949; Delyamure 1955; Dollfus 1966; Yablokov 1974; Lambertsen 1985, 1986). The results instead confirmed the unusual, primarily cervico-thoracic distribution reported by earlier authors (*e.g.*, Johnston and Mawson 1939, Dollfus 1966). As in earlier studies,

the parasite was described in the muscles and connective tissues of these body regions. Novel sites of infection noted in a number of specimens in this study were the cervical and thoracic vascular retia, which are thought to control blood pressure and volume during breath-hold dives (McFarland *et al.* 1979; Howard 1983; Vogl and Fisher 1981, 1982; Costidis and Rommel 2012), and the previously undescribed "gill slit" exocrine gland. The results of this study demonstrated that this bilateral gland opens to the surface of the body, as a small pinhole duct, at the ventral terminus of the "false gill slit" pigmentation. This gland was briefly noted by Hubbs (1951) who identified it as a characteristic of the genus *Kogia*. The results of this study strongly suggest that the "gill slit" gland is an anatomical feature unique to *K. breviceps*. While this gland is a site of *Crassicauda* sp. infection, its morphology has not been carefully described and its function is unknown. Future studies of this enigmatic exocrine gland are warranted. The species-specific nature of both the "gill slit" gland and the associated "false gill slit" pigmentation pattern highlight their use for species identification of kogiids in the field, a task that can be very difficult, even for experienced responders.

The novel site of infection, association with vascular retia, and the known pathogenicity of *Crassicauda* sp. infection in other cetaceans, suggest that this parasite may contribute to morbidity and mortality in *K. breviceps*. How these parasites may compromise these vascular structures, and other structures within *K. breviceps*, is not currently known. More thorough gross and histological investigations are warranted to further understand the role of *Crassicauda* sp. infection in the health of its kogiid host.

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Figure 1. Individual (a) *Kogia sima* and (b) *K. breviceps*

strandings and *Crassicauda* prevalence across all years of the study.

Figure 2. Prevalence of *Crassicauda* infection in *Kogia breviceps* (a) males and (b) females of different total body lengths.

Figure 3. Species-specific differences in the "false gill slit" pigmentation pattern among (a) *Kogia sima* and (b) *K. breviceps*.

Figure 4. Schematic illustration displaying species-specific differences in the "false gill slit" pigmentation pattern between (a) *Kogia sima* and (b) *K. breviceps*. These illustrations were adapted from Hubbs (1951) and Yamada (1954), who described variations in pigmentation patterns among *K. breviceps*.

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Table 1. *Kogia* specimens utilized in this study.

Species	Life history category
<i>Kogia sima</i>	Immature
Females (n = 4)	123.0–197.0 cm
Males (n = 10)	112.5–218.0 cm
	Mature
Females (n = 14)	207.0–242.0 cm
Males (n = 12)	197.5–243.0 cm
<i>Kogia breviceps</i>	Immature
Females (n = 10)	116.0–235.0 cm
Males (n = 11)	193.0–242.0 cm
	Mature
Females (n = 21)	237.0–316.0 cm
Males (n = 22)	245.0–331.0 cm

Table 2. Prevalence of *Crassicauda* in *Kogia breviceps*, by life history category ($n = 64$).

	Negative	Positive infection	Prevalence
Immature males ($n = 11$)	6	5	45%
Mature males ($n = 22$)	12	10	45%
Immature females ($n = 10$)	9	1	10%
Mature females ($n = 21$) ^a	5	16	76%
Quiescent ($n = 1$)	0	1	100%
Lactating only ($n = 5$)	0	5	100%
Pregnant and lactating ($n = 8$)	2	6	75%
Lactating and dependent calf ($n = 5$)	2	3	60%
Pregnant, lactating, and dependent calf ($n = 2$)	1	1	50%

^a For one individual (KMS 340) detailed information on reproductive status was not available.

Table 3. Description of general site of *Crassicauda* infection as described in necropsy reports for *Kogia breviceps* in this study ($n = 32$).

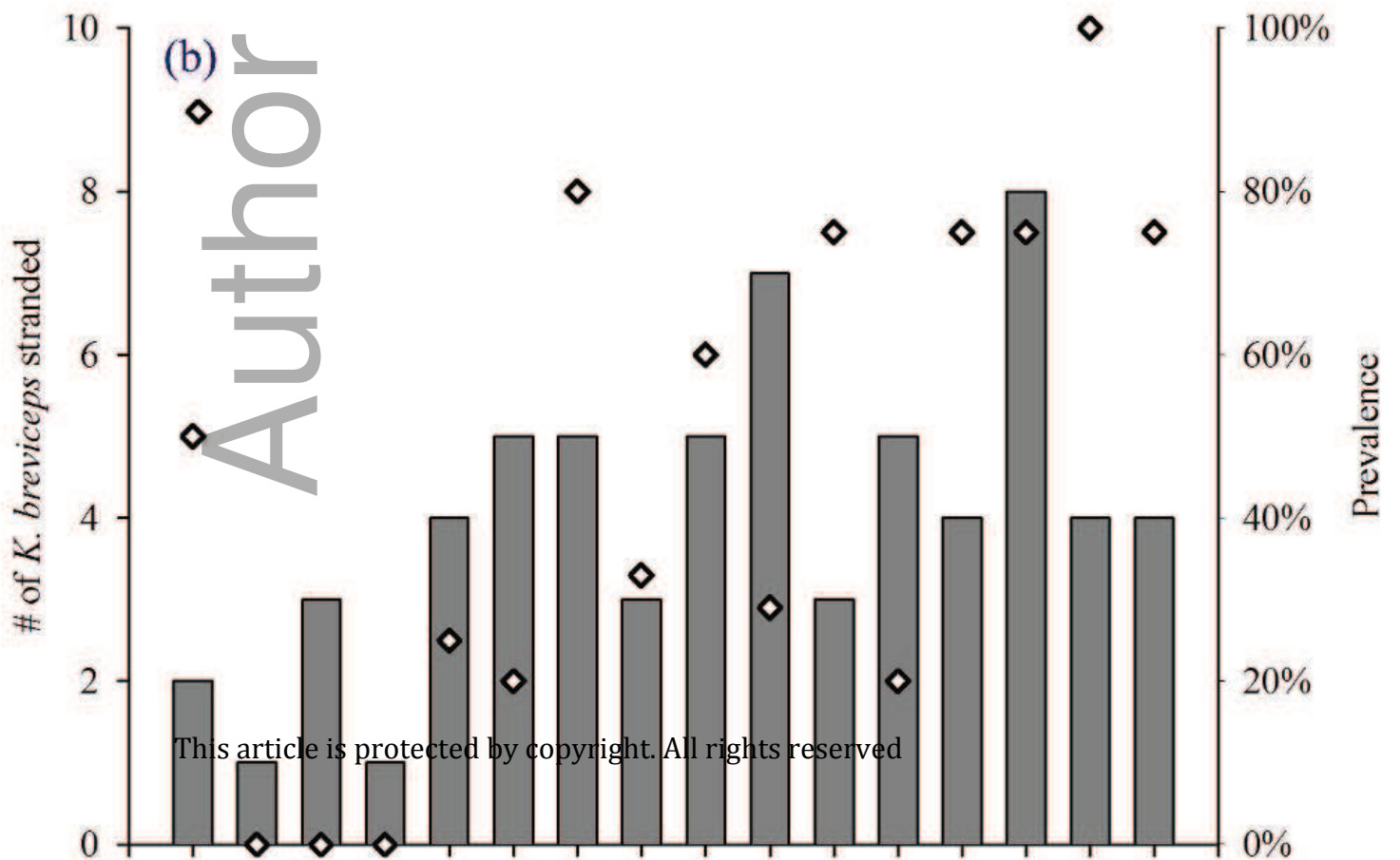
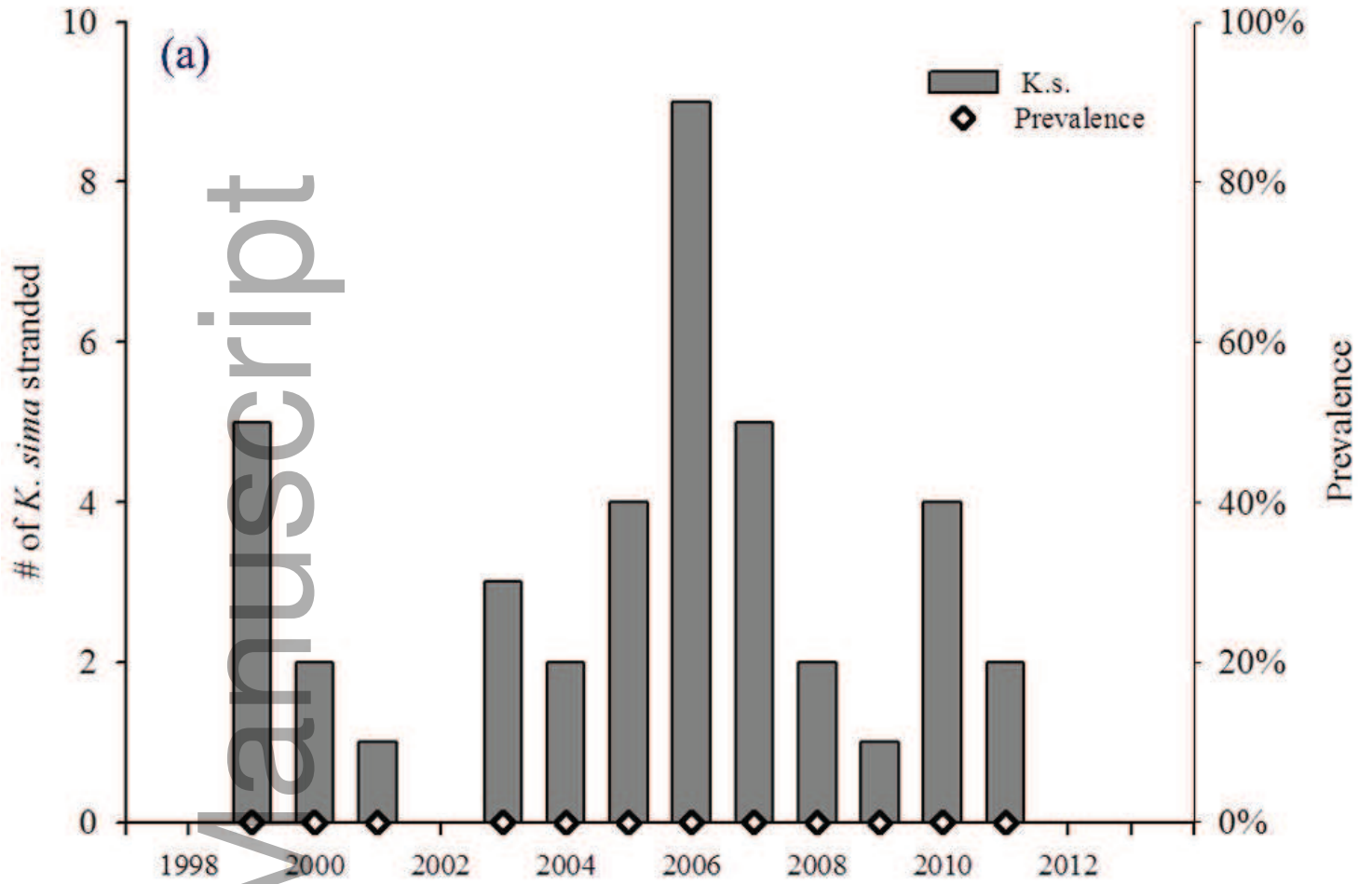
ID	Length (cm)	Sex	Reproductive status	Site of infection
TKB 002	201.0	M	Immature	C, CR
VAQS 20131076	220.0	M	Immature	C, Gsg
BRF 132	224.0	M	Immature	Gsg
REL 039	232.0	M	Immature	C, Gsg, T
NCARI 024	242.0	M	Immature	C, Gsg, T

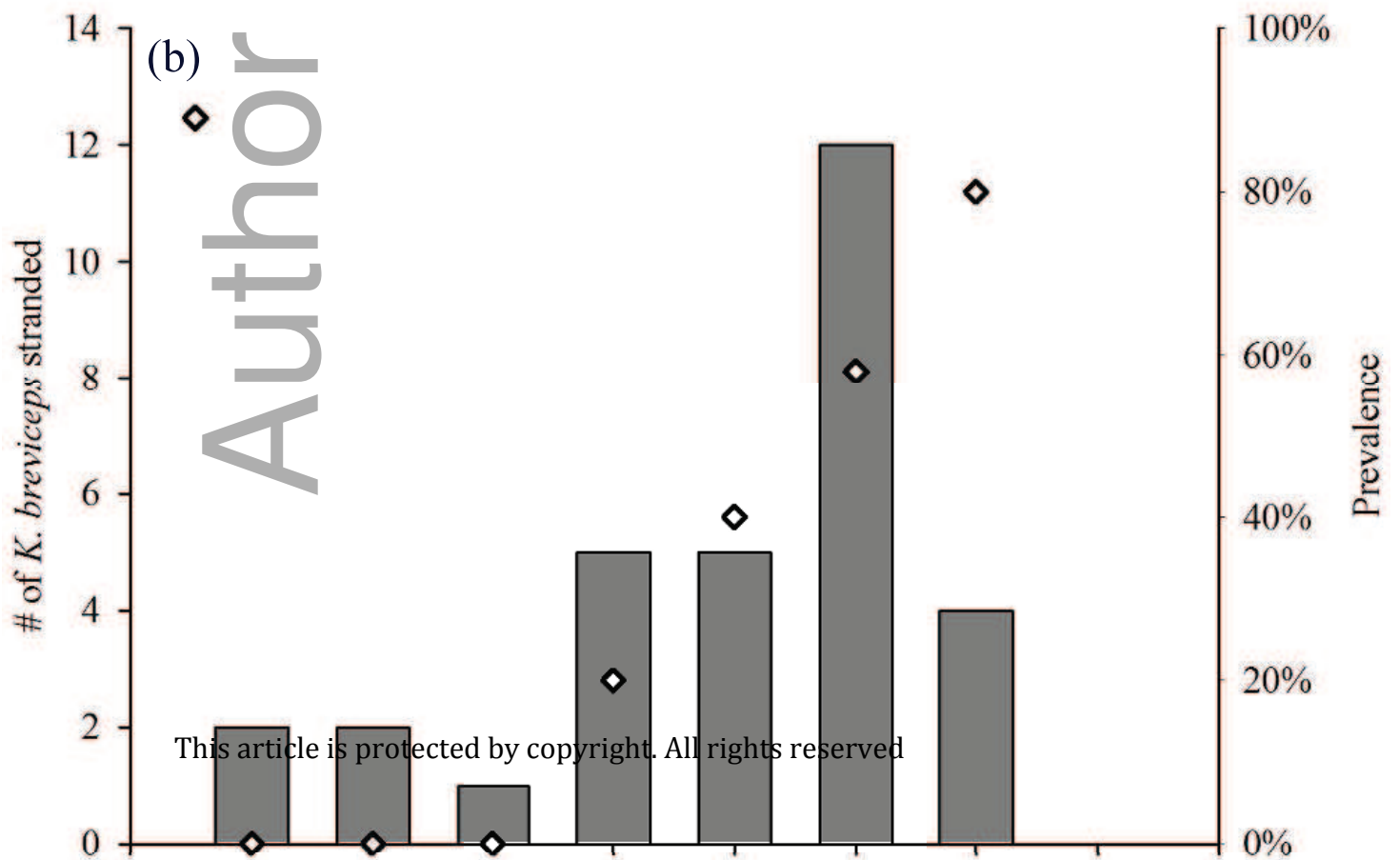
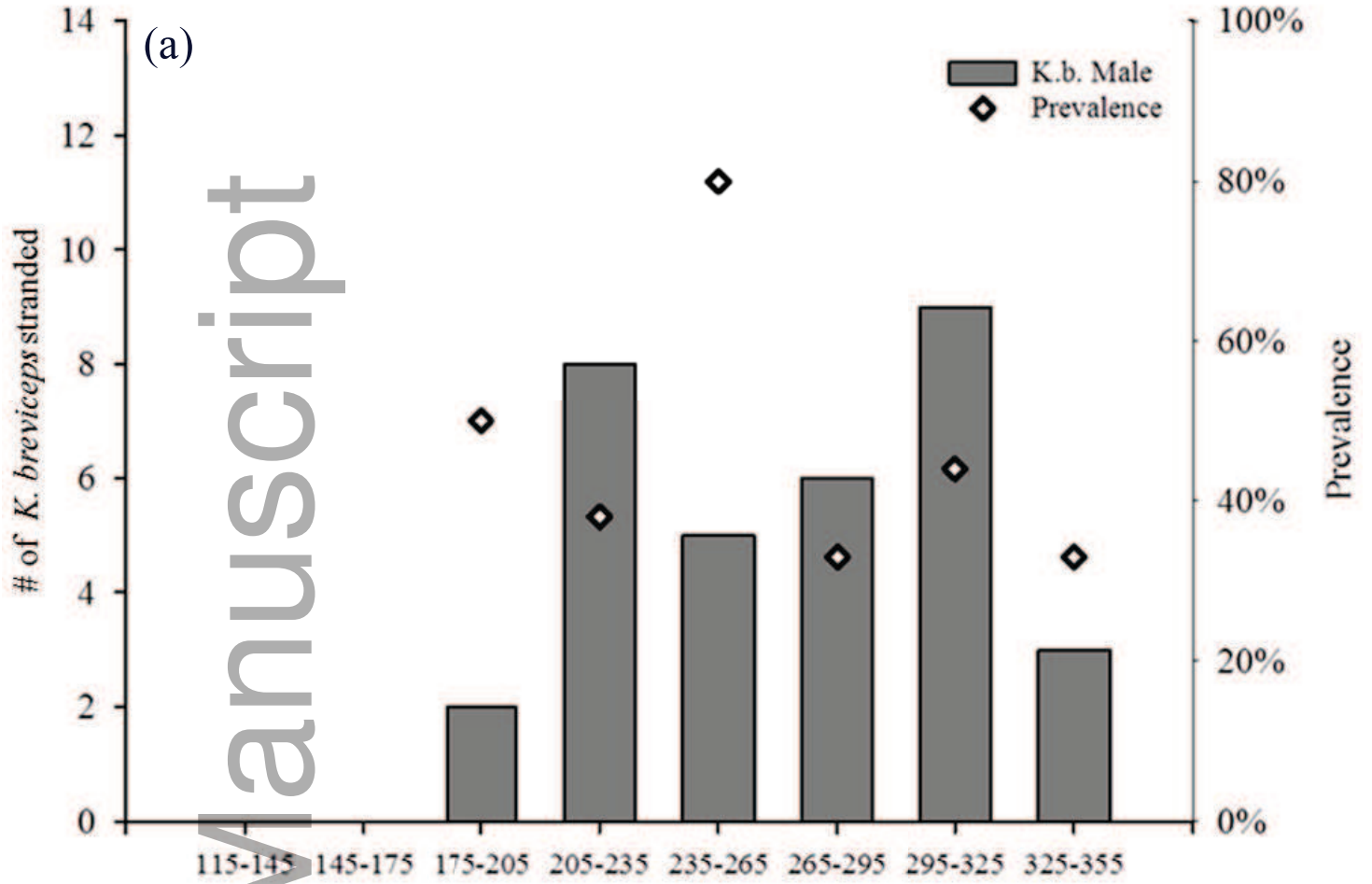
VGT 280	245.0	M	Mature	C
VGT 221	250.0	M	Mature	C
KLC 106	261.0	M	Mature	C, CR, T, TR
KMS 429	283.0	M	Mature	C
KMS 373	292.0	M	Mature	C
REL 028	296.5	M	Mature	C
VGT 254	305.0	M	Mature	C
WAM 644	307.0	M	Mature	C, Gsg
BRF 025	324.0	M	Mature	C
SWT 009	328.5	M	Mature	C, Gsg, T
CAHA 081	231.5	F	Immature	T
KLC 135	252.5	F	Mature	C
VGT 279	255.0	F	Mature	C, Gsg, T
MLC 003	262.0	F	Mature	C
BRF 092	267.0	F	Mature	C, Gsg
KMS 427	267.0	F	Mature	C, Gsg
KMS 340	268.0	F	Mature	C
VAQS 20071081	275.0	F	Mature	C, T
WAM 652	280.0	F	Mature	C, CR
KLC 113	286.0	F	Mature	C, CR, T, TR
VAQS 20111073	286.4	F	Mature	C, T
VAQS 20131386	289.8	F	Mature	C, T
KMS 332	293.0	F	Mature	C
KMS 361	293.0	F	Mature	C, Gsg
NCARI 012	296.0	F	Mature	C
ASF 028	312.0	F	Mature	R
KLC 078	316.0	F	Mature	C

Note: C = cervical region, CR = cervical vascular rete, Gsg = "gill slit" exocrine gland, T = thoracic region, TR = thoracic

vascular rete, R = reproductive tract and this is the only individual noted with this site of infection.

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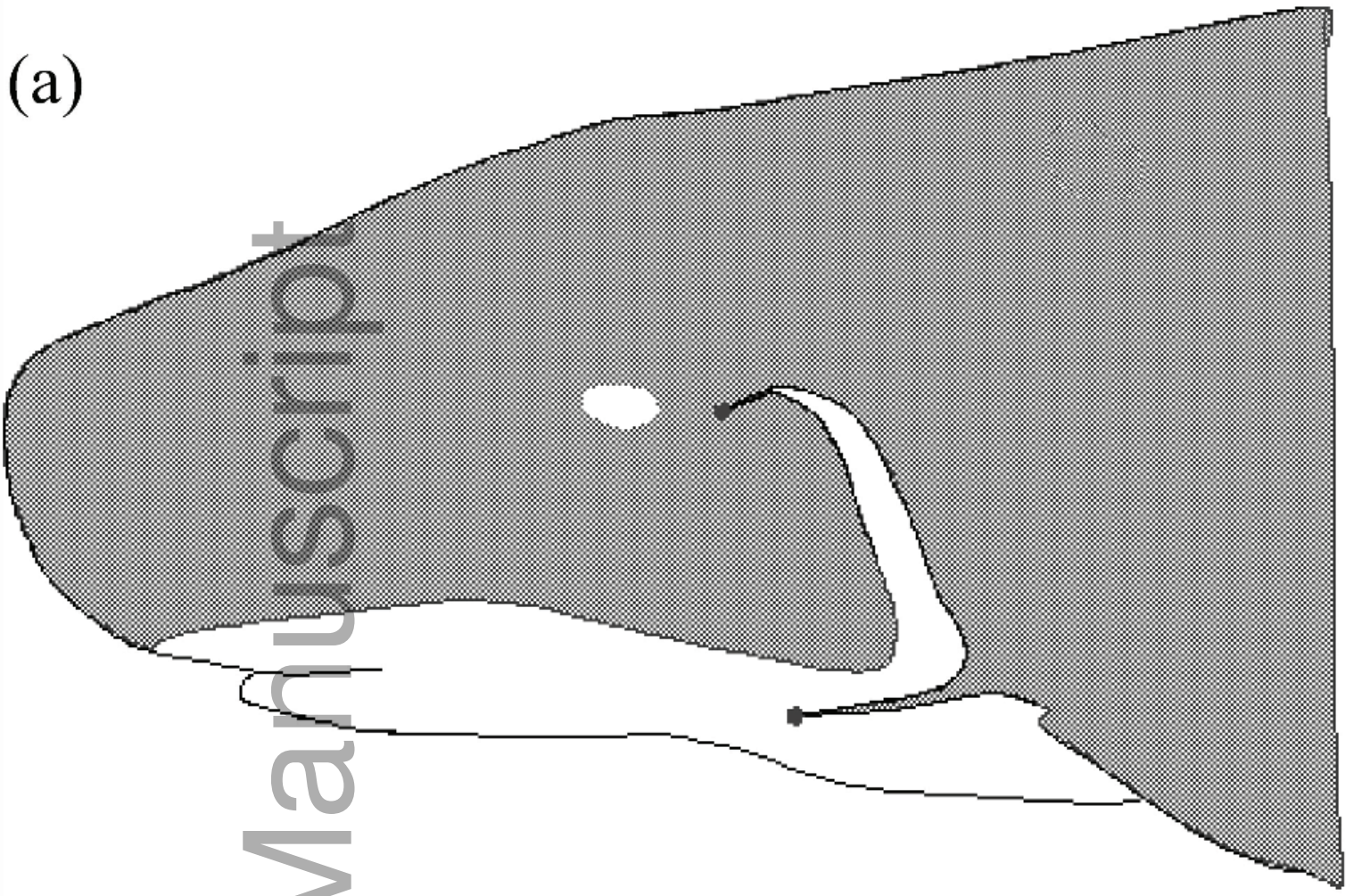


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(a)



(b)

