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Selected parasites of silver kob (*Argyrosomus inodorus*) (Actinopterygii: Sciaenidae) from northern Namibia

The present study reports five metazoan parasites recorded from silver kob (*Argyrosomus inodorus*). Five fish were collected monthly ($n=55$) for 11 months in 2017–2018 (excluding July 2017) using conventional angling gear in Toscanini, Mile 108 and Henties Bay, northern Namibia. Fish were examined individually for ecto- and endo-parasites. Photomicrographs, drawings and measurements of parasites were made using a camera lucida and calibrated eyepiece of an Olympus (BX50) compound microscope and/or a Zeiss (Discovery V8) camera calibrated on a Leica dissecting microscope. Amongst species found, monogeneans including *Diplectanum sciaenae* van Beneden & Hesse, 1863, two species of *Calceostoma* van Beneden, 1858, one species of *Sciaenacotyle* Mamaev, 1989 and one acanthocephalan *Corynosoma australe* Johnston, 1937 were found and are reported here. This is the first study of parasites found from silver kob of the Atlantic Ocean. Silver kob has potential to be used as a mariculture species. In addition to mariculture, information obtained from this study may also be used as a baseline for stock structure and biological tagging.

Significance:

- Silver kob has potential to be used as a mariculture species. Information obtained from this study will therefore form awareness to future mariculture silver kob farmers in terms of parasites that can infest and infect silver kob, hence making it possible to apply specific prevention and control measures. In addition to mariculture, results obtained from this study may be used as a baseline for biological tagging for stock structure assessment using parasites.

Introduction

Silver kob, *Argyrosomus inodorus* Griffiths & Heemstra, 1995, Actinopterygii, Perciformes, Sciaenidae, commonly known as kabeljou in southern Africa, has a short history of culture in southern Africa.^{1,2} Its congeners, *A. hololepidotus* Lacepède, 1801 (Madagascar meagre), *A. japonicus* Temminck & Schlegel, 1843 (dusty kob/mulloway) and *A. regius* Asso, 1801 (meagre) have been cultured successfully for many years throughout the world, including in South Africa.^{3–10} The Namibian marine aquaculture (mariculture) is dominated by shellfish (oyster and abalone). There is need to diversify the sector to ensure wide specialisation and make it more economically viable (stable). There are ongoing investigations into the aquaculture of some important finfish species (of which kob is one species of interest). Studies are looking into the captive propagation, larval rearing, feeding and disease (including parasites) aspects of the kob species. Currently in Namibia, silver kob is one of the most important species caught by shore anglers and ski-boat anglers in water shallower than 20 m.¹¹

Characteristics of silver kob – such as its robust growth, ability to spawn in captivity as well as its market value – make it one of the fish species suitable for mariculture.^{5,6,12} However, various diseases, including parasitic infections, pose a threat to fish cultivation, to the success of mariculture, as well as to the people that depend on it for a basic income. In many instances, fish health is not prioritised until extreme impacts are observed, which means the opportunity to manage and control parasites and diseases at the source is missed. Most farmers tend to react to large outbreaks rather than preventing or managing infections, most likely because of insufficient information on the ecology of pathogenic parasites, their prevention and control.¹³ The diseases and specific identity of the parasites that are infecting cultured fish are rarely known and very few parasite species, classified only to their genera, are recorded.¹⁴

External and internal clinical signs triggered by pathogens depend on the host species, fish age and stage of the disease.¹⁵ Parasites generally do not kill their hosts, but some severely stress fish to the point of biological and economical concern.¹⁶ High intensities of ecto-parasites cause excess mucus secretion, loose scales, dermis injuries such as haemorrhages, open sores, ulcers exposing connective and muscle tissues, and osmotic problems affecting respiratory functions.¹⁶ Consequently, damaged skin and gills make the fish host more susceptible to secondary infections, possibly from viruses, bacteria and other microorganisms that may also contribute to mortalities.¹⁷ Martins et al.¹⁸ and Kotob et al.¹⁹ reviewed impacts of different secondary infections, also called co-infections, on fish species.

In the wild, parasites have been used as a biotic force capable of determining the biodiversity of fish communities.²⁰ Parasites can regulate the population size of some fish species based on their susceptibility. If the host is the predator, parasite infestation causes lack of appetite, thereafter increasing the number of prey and, as most prey are herbivores, further decreasing the plant community. In addition, parasites can indirectly modify the functional importance of the host species by altering the host's phenotype (morphology, colouration and behaviour) which may influence the availability and scarcity of resources for other species. This could make the host, or part of the host's body, available as a resource to other organisms.²⁰

The culture of kob is being considered in Namibia and therefore parasites that infect it are being investigated.

Known parasites of kob

Diplectanum Diesing, 1858

Diplectanum, a genus of monopisthocotylean monogeneans, is the largest genus in the Diplectanidae and consists of over 80 species.^{21,22} In nature, species of *Diplectanum* are not highly pathogenic parasites; under adverse conditions, however, they can multiply and have detrimental effects on their hosts.⁹ There have been several reports associating monogeneans with increased fish mortalities in aquaculture, mostly because cultured fish are grown in high densities and handling procedures result in fish stress.

Calceostoma van Beneden, 1858

Species in the genus *Calceostoma* have been reported from the gills and skin of fish all over the world, including Australia and southern Africa.^{3,21} The genus comprises eight species of which only two described were available for use in the present study: *Calceostoma herculeana* Euzet & Vala, 1975 and *Calceostoma glandulosum* Johnston & Tieggs, 1922, synonym *Calceostoma calceostoma* Wagener, 1857 by Williams³. They are not highly pathogenic in nature, but can cause haemorrhages if they intensify in a mariculture set-up.

Sciaenacotyle Mamaev, 1989

Mycrocotylids are recognisable by their possession of large numbers of clamps that are relatively simple and lack accessory sclerites.⁵ To date, the genus *Sciaenacotyle* consists of only two documented species: *Sciaenacotyle panceri* Sonsino, 1891 and *Sciaenacotyle sciaenacola* Murray, 1932. There have been reports of these blood-feeding species affecting the gills of sciaenids shi drum (*Umbrina cirrosa* Linnaeus, 1758) in Tunisia²³, congeners meagre, *Argyrosomus regius* in Sardinia⁶ and mullet, *Argyrosomus japonicus* in Australia⁷. They are predominantly characterised by the nature of the genital armature. Their lengths may vary depending on the state of the contraction of the body during fixation or observation and the size of the host, as parasites on larger hosts grow faster than those infesting smaller hosts.⁵ In addition, temperature may also impact length and clamp size.

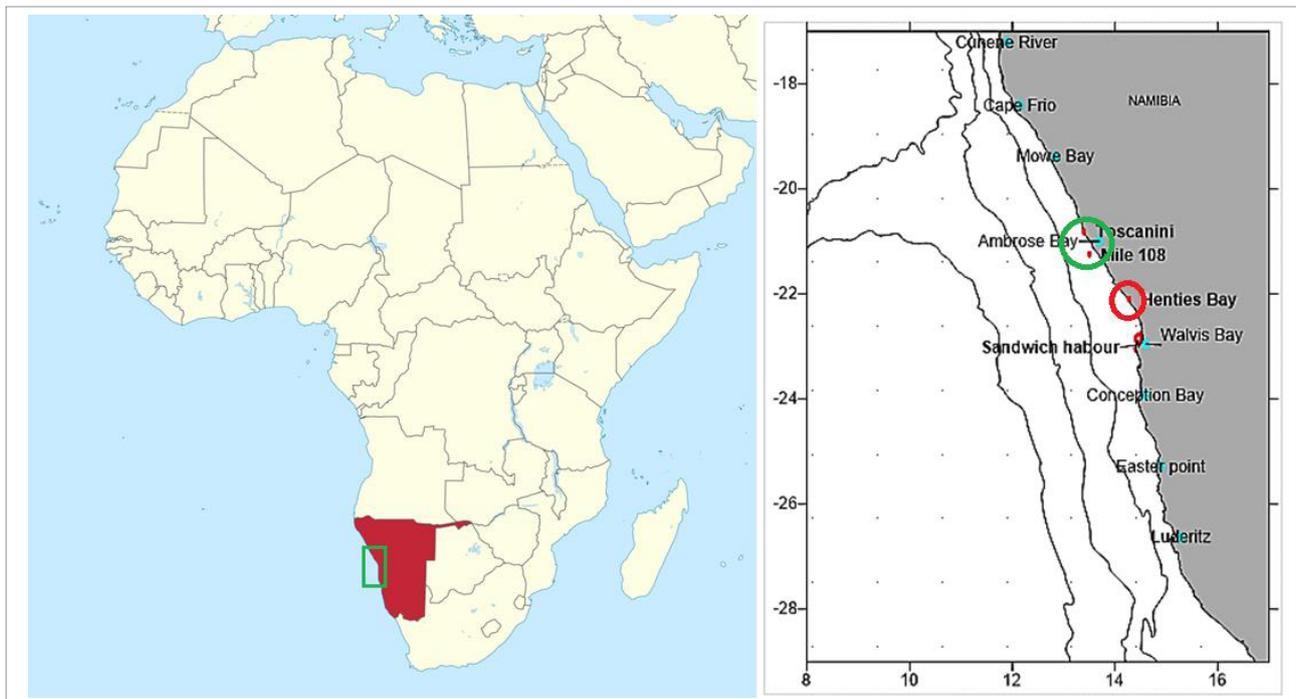
The parasites collected during the current study slightly differ from these two *Sciaenacotyle* species and are briefly described here.

Corynosoma Lühe, 1904

Acanthocephala is a phylum that is closely associated with the Cestoda phylum.²⁴ They are an integral component of the parasite fauna of pinnipeds. *Corynosoma* Lühe, 1904 consist of numerous species that use cetaceans and fish as intermediate hosts, and pinnipeds and fish-eating birds as definitive hosts.²⁴⁻²⁶ Acanthocephalans are characterised by a thorny anterior termed 'proboscis' that serves as an attachment organ and 'drills' firmly into the walls of the intestine and stomach of the host. The proboscis drilling causes damage and changes to the tissues, exposing the tissues to other secondary infections and increasing the host's susceptibility to diseases and infection.²⁷ Acanthocephalans lack a mouth and digestive tract. They absorb their nutrients directly through their body surface. Adult acanthocephalans usually live in the lumen of the digestive tract only, but sometimes they bore through the walls of the digestive tract and come to lie in the abdominal cavity.²⁸

Parasites have also been used as biological tags in stock identification in marine fish according to the principle explained by MacKenzie et al.²⁹ Fish become infected or infested with a particular parasite only when they come within the endemic area of that parasite – the endemic area being the geographical region in which transmission of the parasite can take place. If infected fish are found outside the endemic area, it is inferred that these fish had been within that area at some time in their past history. Parasite communities differ substantially among fish hosts even in the same geographical area.³⁰ Parasites, especially monogeneans, are host specific, and this specificity can be so strict that one parasite species may be restricted to only one fish species or genus.¹⁷ The information on the life span of the parasite in that particular host will allow the researcher to estimate the maximum time since the fish could have become infected, that is, the maximum time since it left the endemic area.

Information on parasites infecting silver kob is scarce. Stewart²¹ and Christison et al.³¹ also reported on *Calceostoma* sp. and *Diplectanum* sp. from the gills of *A. inodorus* in South Africa. Kotungondo has found species of the monogenean *Sciaenacotyle panceri* Sonsino, 1891 on the gills of the Namibian silver kob, *Argyrosomus inodorus* (Kotungondo BCC 2014, written communication, November 24). To the best of our knowledge, there is no previous documented study on parasites of silver



Source: Map on the left: [https://commons.wikimedia.org/wiki/File:Namibia_in_Africa_\(-mini_map_-rivers\).svg](https://commons.wikimedia.org/wiki/File:Namibia_in_Africa_(-mini_map_-rivers).svg)

Figure 1: Sampling area (Toscanini and Mile 108 on the Namibian coast) of silver kob indicated by the green circle and secondary sampling area indicated by the red circle.

kob in Namibia, although there have been a few reports on parasites from its congeners globally. We report on metazoan parasites from silver kob caught in northern Namibia.

Materials and methods

A total of 55 silver kob were collected over 11 months (June 2017, and August 2017 to May 2018), with 5 fish sampled and examined each month. Of these, 49 silver kob were caught using conventional angling gear at Toscanini and Mile 108, both sites within the Skeleton Coast Park, at about 20°50'S, 13°25'E and 21°49'S, 13°25'E, respectively (Figure 1). Six silver kob were caught by local anglers in Henties Bay (22.1°S and 14.3°E) (Figure 1).

Fish were sacrificed by a single cut through the spinal cord. The skin, fins, eyes and gastrointestinal organs were examined for parasites according to the procedure of Noga³². All parasites were identified and counted. In total, 28 species were identified³³, but for the present study only 5 species are listed and described. Whole mount preparations were made for monogeneans using glycerine ammonium picrate solution on microscope slides and some were preserved in vials with 70% ethanol. Nail varnish was used to seal the whole mounts.

Photomicrographs, drawings and measurements of parasites were made using a camera lucida and calibrated eyepiece of an Olympus (BX50) compound microscope or a Zeiss (Discovery V8) camera calibrated on a Leica dissecting microscope. All measurements are in micrometres (μm) unless otherwise indicated. In the descriptions, the initial number is the mean measurement followed by the minimum and maximum measurements (range) in parentheses and finally the number of specimens measured for that particular category ($n=x$).

For scanning electron microscopy, specimens were dehydrated through a series of ethanol (70, 80, 90, 100, and 100%) for 1 h each, followed by immersion in hexamethyldisilazane. After complete evaporation of hexamethyldisilazane, the specimens were sputter coated with gold-palladium in a Polaron SC7640 sputter coater. Specimens were then kept in a fume cupboard so that no dust fell on them while waiting for evaporation of hexamethyldisilazane. The specimens were examined using a LEO VP 1540 microscope at 10 kV.

Ethics approval

The study was approved by the University of Namibia's Research and Publication Committee.

Results

During this study, we analysed five helminths identified from silver kob (*A. inodorus*). Some effects of these parasites on their hosts were obvious and profound (damage causing secondary infections, decreased fish quality, reduced growth, etc.) (Table 1).

Table 1: Five parasite species found on Namibian silver kob collected from Toscanini, Mile 108 and Henties Bay from June 2017 to May 2018 and their possible pathogenicity

Class	Genus/Order	Species	Pathogenicity
Ecto-parasites			
Monogenea	<i>Diplectanum</i> Diesing, 1858	<i>D. sciaenae</i> van Beneden & Hesse, 1863	Not pathogenic but can have effects on fish quality. Could also act as vectors of viruses and bacteria.
	<i>Calceostoma</i> van Beneden, 1858	<i>C. glandulosum</i> Johnston & Tiegs, 1922	
	<i>Sciaenacotyle</i> Mamaev, 1989	<i>Sciaenacotyle</i> sp.	
Endo-parasites			
Monogenea	<i>Calceostoma</i> van Beneden, 1858	<i>Calceostoma</i> sp.	Unknown
Palaeacanthocephala	<i>Corynosoma</i> Lühe, 1904	<i>C. australe</i> Johnston, 1937	Damage to fish host, causes secondary infections

Monogeneans

Diplectanum sciaenae van Beneden and Hesse, 1863

Host: *Argyrosomus inodorus* Griffiths and Heemstra, 1995

Site: Skin, gills

Locality: Henties Bay, Mile 108 and Toscanini, Namibia

Description:

Eight whole-mount adult specimens were measured (Diplectanidae; *Diplectanum sciaenae*; Figure 2). Long and slender with total body length measuring 735 μm (436–943) ($n=8$) and mid-body width of 185 μm (117–250) ($n=8$) (Figure 2a). The haptor (Figure 2b), which measured 252 μm (198–310) ($n=8$) total length, consists of a lip-shaped median bar (Figure 2c), which measured 107 μm (97–134) ($n=8$) total length, 23 μm (20–27) ($n=8$) maximum width (i) and 15 μm (12–17) ($n=8$) minimum width (ii) at centre. The haptor has two transverse bars (Figure 2d) on either side of the median bar with total length of 95 μm (81–122) ($n=8$) that mostly meet midway from each side of the median bar, but do not overlap each other. In rare cases, the transverse bars were shifted 1/4th from the median bars toward the ends. At the end of each transverse bar lies a pair of curved-in hamuli consisting of a ventral (Figure 2e) and dorsal (Figure 2f) hamulus. The ventral hamulus has a long deep root and a short superficial root with the following dimensions: length (i) 70 μm (64–74) ($n=8$); length (ii) 65 μm (59–67) ($n=8$); length (iii) 37 μm (35–40) ($n=8$), length (iv) 28 μm (25–33) ($n=8$). The dorsal hamulus has a long deep-root and a poorly developed superficial root: length (i) 62 μm (55–65) ($n=8$) and length (ii) 57 μm (52–60) ($n=8$). Just below the median bar, the squamodiscs (Figure 2b) measure 161 μm (124–222) ($n=8$) total length and 140 μm (109–187) ($n=8$) maximum width with 36 μm (32–38) ($n=8$) concentric divergent rows.

The male copulatory organ (MCO) (Figure 2g) is small with 55 μm (50–76) ($n=8$) total length. The MCO widens at the base and has a spiral end encircling the tip end. The sclerotised canal (Figure 2h) at the conspicuous prostatic reservoir measures 29 μm (26–40) ($n=8$) total length and 9 μm (6–12) ($n=8$) maximum width. The sclerotised canal is sharply curved as described for *D. sciaenae* previously.^{8,9}

Calceostoma glandulosum Johnston and Tiegs, 1922

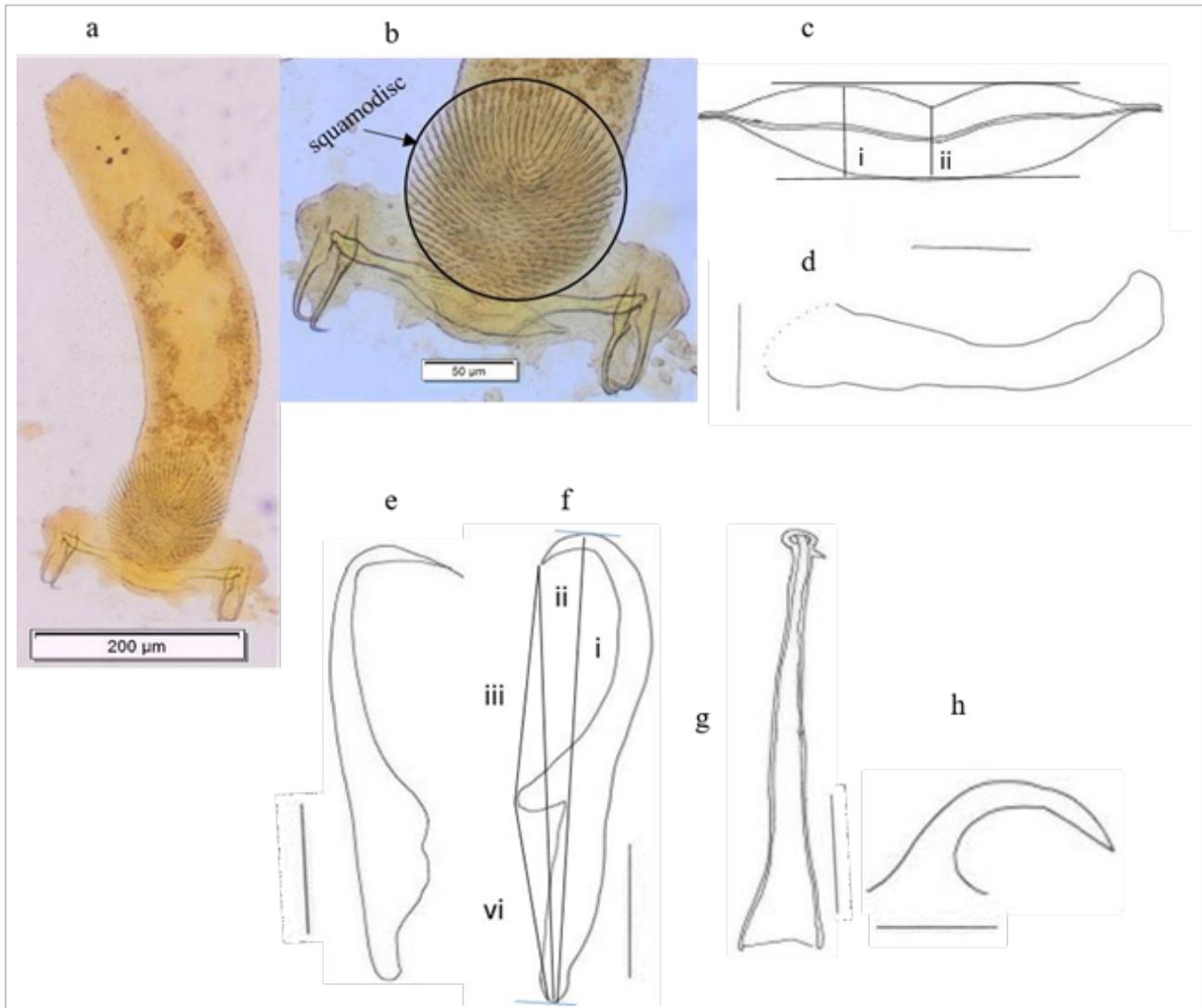
Host: *Argyrosomus inodorus* Griffiths and Heemstra, 1995

Site: Gills, skin

Locality: Henties Bay, Mile 108 and Toscanini, Namibia

Description:

Four whole-mount adult specimens were measured. Body elongated, total body length measures 6250 μm (4200–8000) ($n=4$) and maximum body width 1000 μm (900–1100) (Figure 3). Hood-like lappet (Figure 3e) with irregular margins at anterior end measuring 1225 μm (200–1900) ($n=4$) maximum width. Two pairs of small conspicuous eyespots just anterior to the pharynx. The pharynx (Figure 3e) measures 290 μm (234–322) ($n=4$) total length and 271 μm (227–342) ($n=4$) maximum width. The haptor consists of a median bar with t-shaped



Scale bars: 20 μm (c–h)

Figure 2: *Diplectanum sciaenae* van Beneden & Hesse, 1863 from the gills of silver kob. (a) *Diplectanum sciaenae* whole mount. (b) Haptor with squamodiscs and hamuli. (c) Median bar (lengths (i) and (ii)). (d) Transverse bar. (e) Ventral bar/hamulus. (f) Dorsal bar/hamulus with measurements (lengths i–iv). (g) Male copulatory organ. (h) Sclerotised canal.

posterior end and a paddle-shaped anterior end, which is associated with a pair of hamuli (Figure 3a–c). The haptor measures 225 μm (220–233) ($n=4$) and 50 μm (44–53) ($n=4$) anterior end ‘T’ width. The hamulus (Figure 3c) measures 200 μm (188–213) ($n=4$). The MCO (Figure 3d) has a total length (i) of 189 μm (179–195) ($n=4$); length (ii) of 165 μm (159–171) ($n=4$) and width of 24 μm (21–26) ($n=4$).

***Calceostoma* sp.**

Host: *Argyrosomus inodorus* Griffiths and Heemstra, 1995

Site: Stomach

Locality: Henties Bay, Mile 108 and Toscanini, Namibia

Description:

These species were found in nine *A. inodorus* hosts throughout the study and from all three study areas. Each host had either one or two *Calceostoma* sp. parasites. They were mostly found attached at the threshold walls of the stomach rather than in the middle of the stomach itself. Three whole-mount specimens were measured. Body slimmer and darker in colour compared to *C. glandulosum*. Total body length 4633 μm (2900–6900) ($n=3$) and 567 μm (400–800) ($n=3$) maximum body width (Figure 4). Lappet not hood-like but less developed (2000 μm) ($n=1$). This could be an adaptation mechanism to allow it to attach

properly to the host stomach walls. Pharynx (see Figure 3e) length 303 μm (294–312) ($n=2$) and 276 μm (261–292) ($n=2$) pharynx maximum width. The median bar (Figure 4e) measures 147 μm (133–172) ($n=3$) length, 36 μm (33–39) ($n=3$) anterior end ‘V’ width and 144 μm (129–159) ($n=3$) hamulus length, slightly curved in at the tips (Figure 4c). The MCO (Figure 4b) has a coiled anterior end and a thin posterior end and measures 184 μm (173–202) ($n=3$) length (i), 139 μm (125–153) ($n=3$) length (ii) and 13 μm (12–13) ($n=3$) width.

***Sciaenacotyle* sp. Mamaev, 1989**

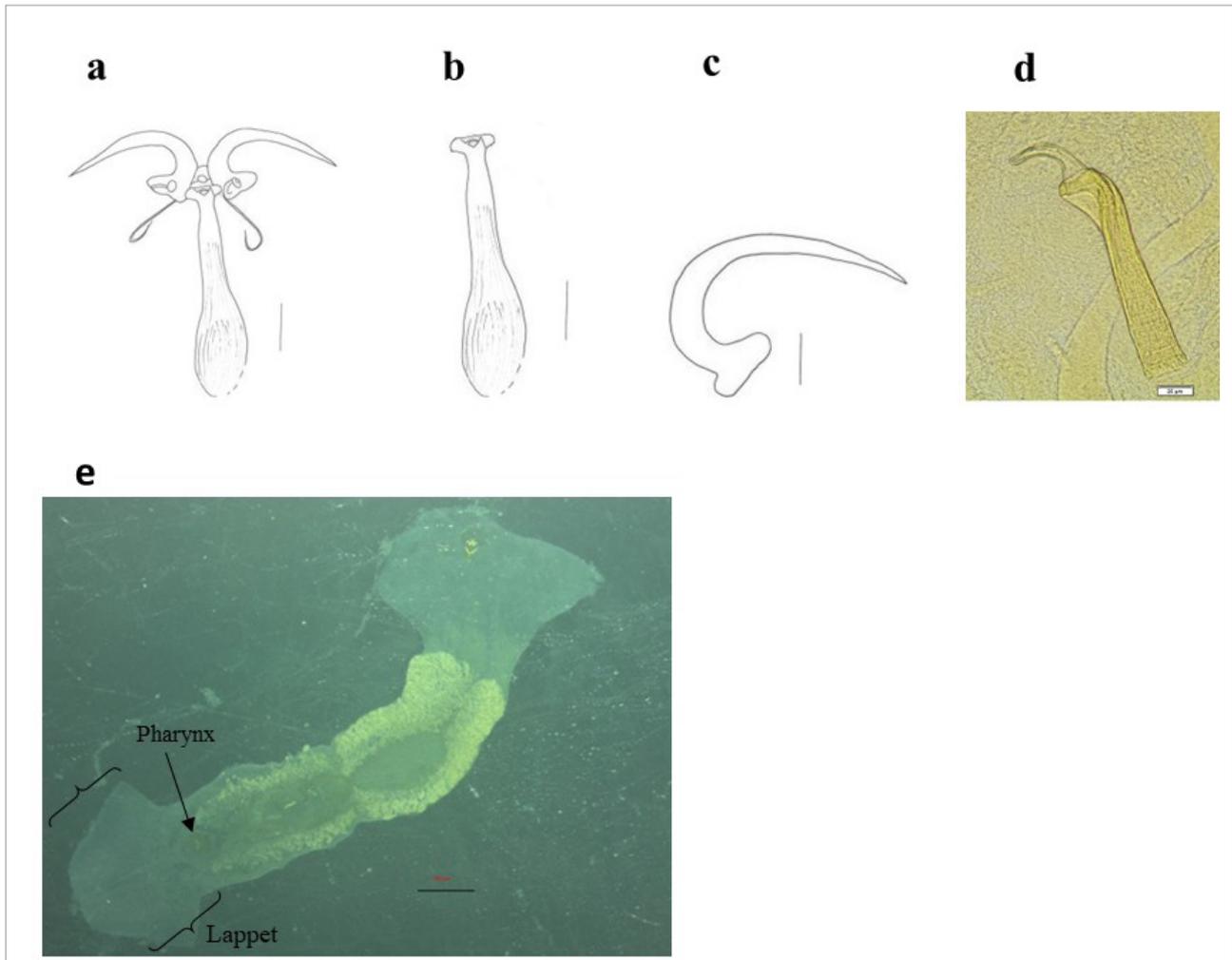
Host: *Argyrosomus inodorus* Griffiths and Heemstra, 1995

Site: Gills

Locality: Henties Bay, Mile 108 and Toscanini, Namibia

Description:

Thirteen whole-mount specimens were measured. Elongated body measures 8123 μm (4000–11 400) ($n=13$) total body length and 1208 μm (500–1800) ($n=13$) maximum body width (Figure 5). Possesses a triangular posterior haver that occupies about a third of the total body with numerous clamps (Figure 5f). The haver measures 4000 μm (1600–5400) ($n=13$). The genital atrium (Figure 5a) opens ventrally, is formed by two globular muscular masses, and consists of



Scale bars: 20 μm (a–d); 2.5 mm (e)

Figure 3: *Calceostoma glandulosum* Johnston & Tiegs, 1922 collected from gills of silver kob. (a) Haptor with median bar and hamuli. (b) Median bar. (c) Hamulus. (d) Male copulatory organ. (e) Whole mount.

two symmetrical continuous genital hamuliform spine rows (instead of three as described in the other two *Sciaenacotyle* species), parallel to each other (Figure 5a). These spinal rows of the genital atrium (Figure 5a and 5c) interchange where they bend anteriorly with the longer outer spinal row coiling outwards at the anterior end and the shorter spinal row coiling inwards at the anterior end as they continue in a parallel manner. The genital hamuliform spines of the outer spiral rows increase toward the end of the row (Figure 5b). The hamuliform spine counts were 139 (131–154) ($n=5$) in total number and measure length at posterior end 11 μm (6–16) ($n=5$) (Figure 5d); mid-length 21 μm (14–28) ($n=5$) (Figure 5c) and length at anterior end 8 μm (3–11) ($n=5$) (Figure 5b). Spines at the anterior end slightly curved compared to the spines at the posterior end, which are straight and also sharper. Spines at the middle of the row have a hook that is curved and a blade that is curved at almost 90° (Figure 5c).

Acanthocephalan

Corynosoma australe Johnston, 1937

Host: *Argyrosomus inodorus* Griffiths and Heemstra, 1995

Site: Body cavity

Locality: Henties Bay, Mile 108 and Toscanini, Namibia

Description:

The measurements of *C. australe* in this study are not described separately for female and male individuals due to the small number of specimens measured, but, generally, males had more and longer genital

spines than females. Measurements were done in relation to Sardella et al.²⁵ Six whole-mount specimens were measured (3 males, 3 females). Total body length 3331 μm (2867–3647) ($n=5$) and maximum body width 1076 μm (943–1211) ($n=6$) (Figure 6). Females possessed a relatively wider maximum body width than males. The spiny proboscis measures 556 μm (356–712) ($n=6$) total length and 269 μm (238–290) ($n=6$) maximum width. Proboscis receptacle 1194 μm (936–1339) ($n=5$) total length and 276 μm (227–331) ($n=5$) width. The neck, wider than long, total length 258 μm (236–273) ($n=5$) and maximum neck width 424 μm (400–448) ($n=5$). Trunk length measures 2448 μm (2063–2617) ($n=5$) and is relatively longer in males than in females. The genital spines have a length of 32 μm (18–45) ($n=6$) and mid-width of 14 μm (7–21) ($n=6$). Only one of the three males had testes visible enough to make accurate measurement: right testes length 117 μm ; right testes width 85 μm ; left testes length 112 μm ; and left testes width 88 μm .

Discussion

We have reported five parasite species from silver kob (*A. inodorus*): *Diplectanum sciaenae*, *Calceostoma glandulosum*, *Calceostoma* sp., *Sciaenacotyle* sp. and *Corynosoma australe*.

The morphological characteristics and measurements of *D. sciaenae* correspond with those described previously^{9,34} (Table 2). Diplectanids have been reported several times in aquaculture from all over the world, with increasing mortality in sciaenids, but they are not highly pathogenic parasites in nature.⁹

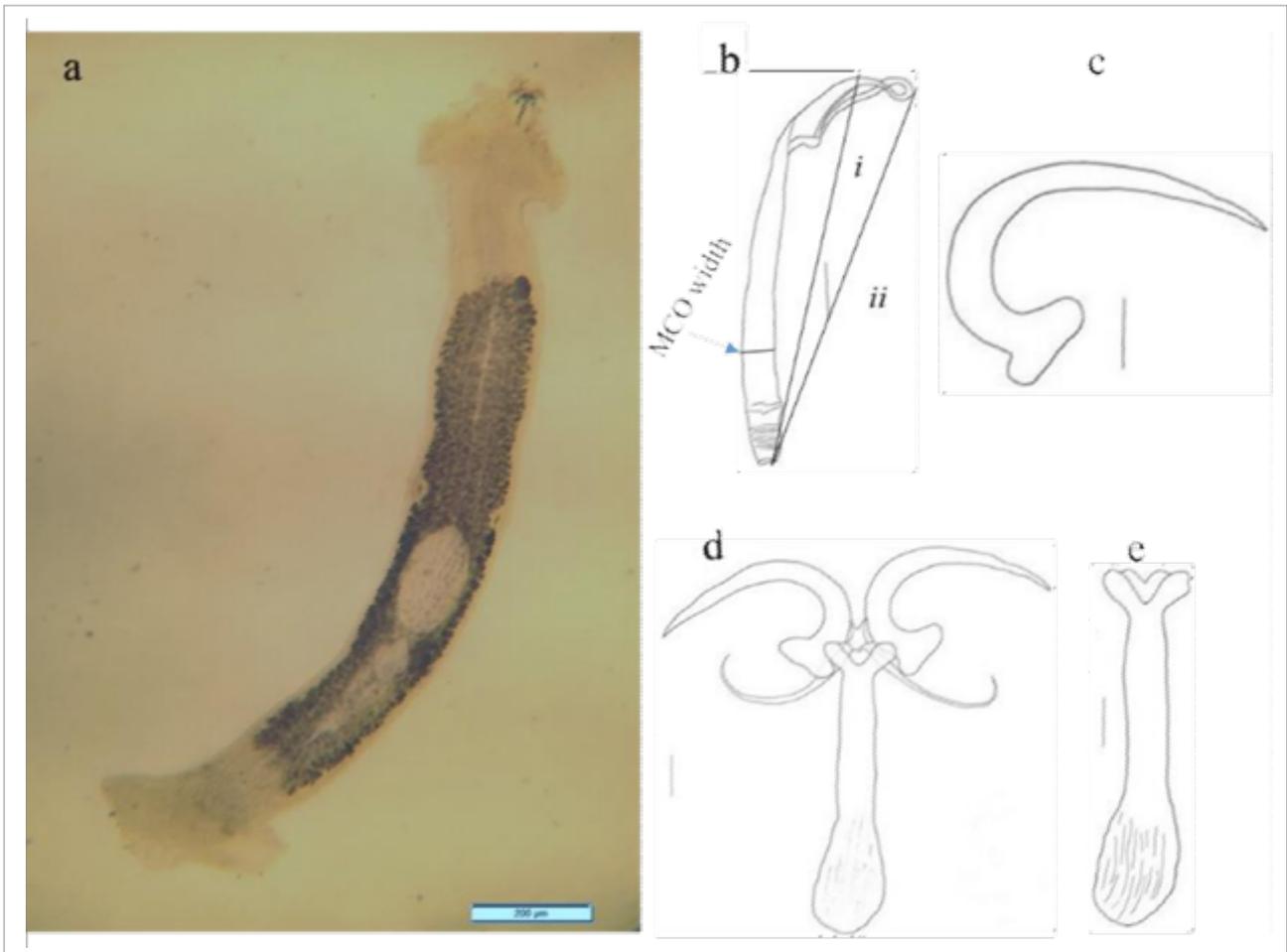
Table 2: Measurements (μm) of *Diplectanum* Diesing, 1858 species from *Argyrosomus hololepidotus*, *Argyrosomus regius* and *Argyrosomus inodorus*

Character	<i>D. oliveri</i> ^a	<i>D. glandulosum</i> ^a	<i>D. dollfus</i> ^b	<i>D. bocqueti</i> ^b	<i>D. sciaenae</i> ^b	<i>D. sciaenae</i> ^c
Host	<i>A. hololepidotus</i>	<i>A. hololepidotus</i>	<i>A. regius</i>	<i>A. regius</i>	<i>A. regius</i>	<i>A. inodorus</i>
Body length	909 – 1139	499 – 640	660 – 1370	800 – 1230	500 – 1160	751 (436–1066)
Body width	166 – 224	128 – 154	160 – 370	240 – 370	140 – 400	165 (79–250)
Haptor width	224 – 275	243 – 269	230 – 480	120 – 400	260 – 380	252 (198–310)
Penis length	166 – 179	51 – 66	57 – 78	90 – 123	51 – 94	63 (49–76)
Canal length	–	–	–	–	–	29 (26–40)
Canal width	–	–	–	–	–	9 (5–12)
Squamodisc length	–	–	–	–	–	173(124–222)
Squamodisc width	166 – 189	99 – 106	144 – 160	120 – 160	144 – 170	148 (109–187)
Concentric rows	–	–	32 – 38	26 – 32	31 – 41	35 (32–38)
Median bar length	128 – 158	117 – 153	108 – 159	102 – 132	95 – 150	107 (97–134)
Median bar width	–	–	–	–	–	23 (19–27)
Median bar 1/2 width	–	–	–	–	–	15 (12–17)
Transverse bar length	96 – 110	90 – 117	92 – 146	88 – 100	88 – 100	94 (81–122)
Ventral hamulus (a)	67 – 77	72 – 77	87– 94	58 – 67	69 – 79	70 (64–74)
Ventral hamulus (b)	–	65 – 69	78 – 86	52 – 63	63 – 73	65 (59–67)
Ventral hamulus (c)	32 – 34	34	43 – 50	27 – 32	33 – 41	37 (34–40)
Ventral hamulus (d)	30 – 32	30 – 32	33 – 39	25 – 32	26 – 35	28 (25–33)
Dorsal hamulus (a)	66 – 70	64 – 67	83 – 89	57 – 62	62 – 68	62 (55–65)
Dorsal hamulus (b)	61 – 64	59 – 64	62 – 135	51 – 56	59 – 64	57 (52–60)

^aWilliams³; ^bOliver²⁴; ^cpresent study

Table 3: Measurements (μm) of *Calceostoma glandulosum* Johnston & Tiegs, 1922, *Calceostoma calceostoma* Wagener, 1857 and *Calceostoma* sp. from *Argyrosomus hololepidotus*, *Argyrosomus regius* and *Argyrosomus inodorus*

Character	<i>C. glandulosum</i>	<i>C. calceostoma</i>	<i>C. calceostoma</i>	<i>C. glandulosum</i>	<i>Calceostoma</i> sp.
Host	<i>A. hololepidotus</i> (Western Australia)	<i>A. regius</i> (Tunis)	<i>A. regius</i> (Gulf of Gascoigne)	<i>A. inodorus</i> (northern Namibia)	<i>A. inodorus</i> (northern Namibia)
Total length	2724 (1848–4176)	3295 (2875–4002)	6302	6250 (4200–8000)	46332900–6900
Max body width	748 (592–960)	632 (598–644)	759–1012	1000 (900–1100)	566 (400–800)
Lappet max width	794 (504–1296)	776 (644–897)	943	1225 (200–1900)	2000
Pharynx length	210 (157–272)	202 (179–216)	273 (255–291)	289 (236–322)	303 (293–312)
Pharynx width	168 (132–208)	164 (156–179)	–	270 (226–342)	276 (260–292)
Median length	238 (243–236)	178 (154–207)	239 (230–251)	225 (219–233)	146 (132–172)
Median max width	–	–	–	50 (44–53)	36 (32–39)
Hamulus length	129 (112–139)	94 (71–106)	135 (124–147)	199 (188–213)	143. (128–159)
Penis length (a)	182	134 (124–152)	189 (179–209)	188 (178–195)	183 (172–202)
Penis length (b)	–	–	–	165 (159–171)	138 (124–153)
Penis width	23	14 (12–14)	19 (14–23)	24 (21–26)	12 (11–13)
Study	Williams ³	Williams ³	Williams ³	This study	This study



Scale bars: 20 μm (a–d). 2.5 mm (e)

Figure 4: *Calceostoma* sp. collected from stomach of silver kob. (a) Whole mount. (b) Male copulatory organ. (c) Hamulus. (d) Haptor with median bar and hamuli. (e) Median bar.

Calceostoma glandulosum in the present study was longer and wider than described by Williams³ (Table 3). The reason could be due to stretching of the parasites during mounting on the slides, as monogeneans were fixed without coverslip pressure. Williams³ also found that *Calceostoma calceostoma* in *Argyrosomus regius* from Tunis differed in size (were smaller) compared to *Calceostoma calceostoma* Wagener, 1857 in *Argyrosomus regius* from the Gulf of Gascogne. This means that *Calceostoma* species may vary according to their geographical distribution with different physical and chemical environmental parameters.

A calceostomatid *Calceostoma* sp., possessing morphological characteristics almost similar to an undescribed *Calceostoma* sp. found by Stewart²¹ from the gills of *Argyrosomus inodorus*, was found in the stomach of *A. inodorus*. Stomach dactylogyrid monogeneans such as *Enterogyrus* Paperna, 1963 have been documented on freshwater fish by Bayoumy and El-Monem³⁵ and others, but they possess different haptor and copulatory characteristics that enable them to adapt to the internal environment of their fish hosts. This is the first case of a calceostomatid in the gastrointestinal organs of marine species and more studies are necessary to understand the differences and/or similarities between these two species as well as their parasitic behaviours and pathogenic characteristics.

It could be assumed that because these *A. inodorus* feed on small pelagic fish (mostly sardine based on their gut content), the monogenean parasites could have survived from the gills of sardine (*Sardinops* sp.) into the stomach of *A. inodorus* during ingestion. To test this hypothesis, the inspection of sardine gills is required to confirm whether *Calceostoma* sp. infest the gills of sardine. Only one or two individual *Calceostoma* sp.

were found in every infected *A. inodorus* host. These may have been individuals that 'luckily' managed to survive the new environment of the stomach, despite being morphologically adapted to live and reproduce on the gills. The life cycle of a monogenean involves a free-living ciliated larva, called oncomiracidium.^{34,36} Chances are that a few parasites of *Calceostoma* sp. accumulated from the aquatic environment when fish were feeding and very few individuals managed to survive at the

Table 4: Measurements (μm) of *Sciaenacotyle* sp. from *Argyrosomus inodorus* from northern Namibia

Character	Mean	Minimum	Maximum
Body length	8123	4000	11 400
Body width	1208	500	1800
Tail length	4000	1600	5400
Genital spine rows	2	2	2
No. of hamuliform spines			
Row 1	139	131	154
Row 2	154	148	163
Length at posterior end	11	6	16
Mid-length	21	14	28
Length at anterior end	8	3	11

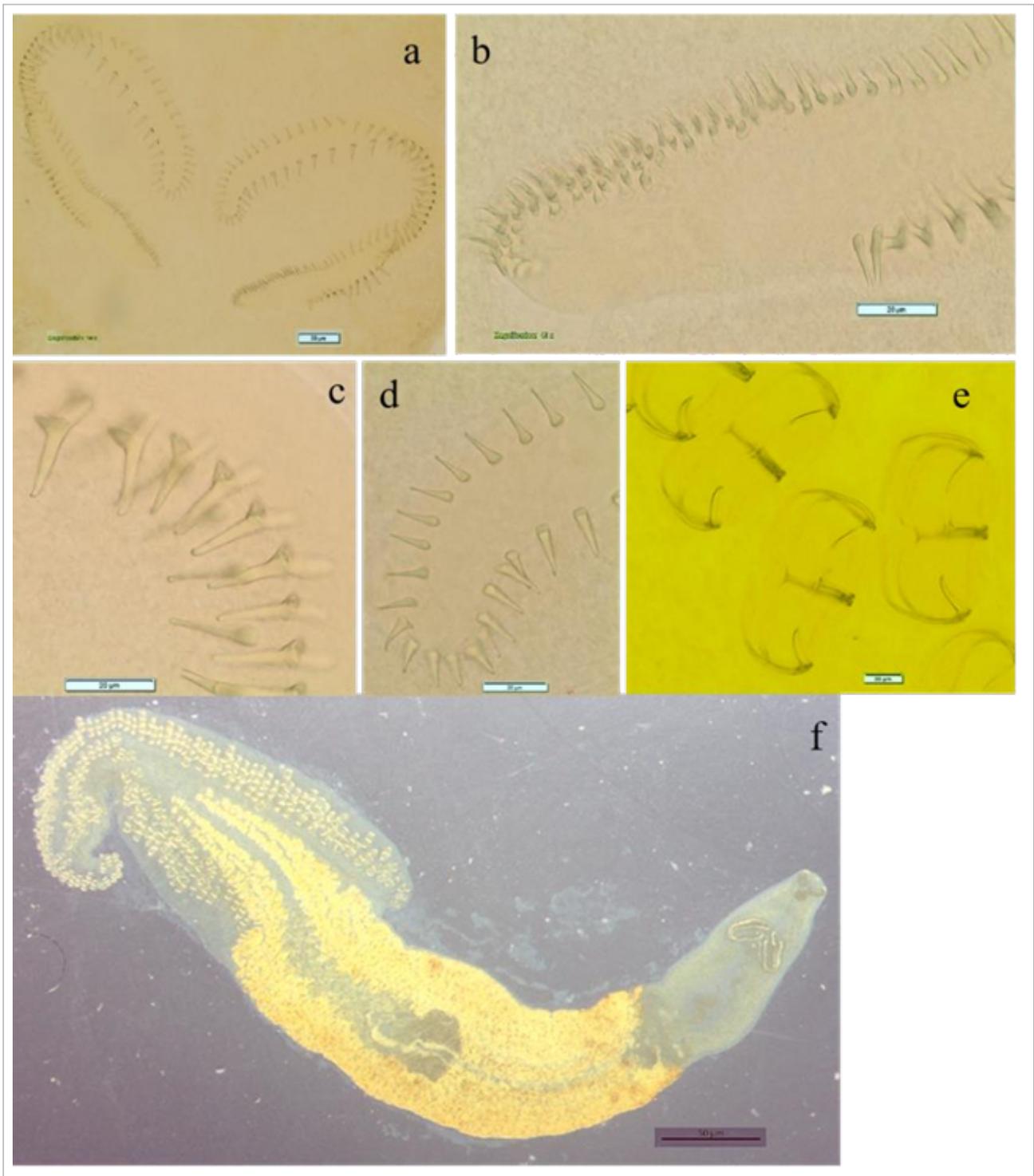


Figure 5: *Sciaenacotyle* sp. collected from the gills of silver kob. (a) Genital atrium. (b) Genital anterior end hamuliform spines. (c) Genital mid hamuliform spines. (d) Genital posterior end hamuliform spines. (e) Clamps. (f) Whole mount.

threshold of the stomach walls, where all these parasites were recovered. More studies, including molecular work on *Calceostoma* species from the gills, previously described³³, and *Calceostoma* sp. from the stomach, are therefore required to supplement the similarities described in this study, explain the survival of this parasite and understand the unusual adaptive mechanism of this gill monogenean parasite, which allows it to survive in the stomach of its *A. inodorus* host.

The microcotylid *Sciaenacotyle* sp. in the present study differed in makeup of their genital atrium from the other two *Sciaenacotyle* species, *S. sciaenicola*⁵ and *S. pancer*^{6,23}, previously described. The two species

possess a genital atrium consisting of three genital spine rows. However, the microcotylid in the present study possessed a genital atrium consisting of two genital spine rows. In addition, *Sciaenacotyle* sp. has more genital spines with a smaller minimum length than those described for the two previously described species (Table 4).

Sardella et al.²⁵ showed that adult *C. australe* differed in size from different hosts (seal *Arctocephalus australis* and fish hosts *Corynoscion quatuorcupa*). *Corynosoma australe* from the present study were larger than those formerly described.¹⁴ They also possessed longer proboscis, neck and truck lengths (Table 5).

Table 5: Measurements (μm) of *Corynosoma australe* Johnston, 1937 from *Arctocephalus australis*, *Cynoscion guatucupa* and *Arygosomus inodorus*

Host	<i>A. australis</i> ^a	<i>C. guatucupa</i> ^a	<i>A. inodorus</i> ^b
Body L (length)	4200–5500	2560–3180	3331 (2867–3647)
Body W (width)	1300–1620	760–1140	1076 (943–1211)
Proboscis L	580–740	580–740	556 (356–712)
Proboscis W	210–250	180–280	269 (238–290)
Neck L	160–260	19–270	258 (236–273)
Neck max W	360–500	260–420	424 (400–448)
Trunk L	3420–4660	1640–2180	2448 (2063–2617)
Genital spines L	25–48	31–48	32 (24–39)
Genital spines W	8.0–29	8.0–27	14 (9–17)
Proboscis receptacle L	740–1040	860–1300	1194 (936–1390)
Proboscis receptacle W	140–200	140–280	276 (227–331)
Right testes L	440–700	100–140	117
Right testes W	260–420	80–120	85
Left testes L	400–660	110–140	112
Left testes W	280–420	80–120	88

^aSardella et al.²⁵; ^bpresent study

This is the first descriptive study of parasites of *A. inodorus* in Namibia. More studies are required to complement the findings. The presence of parasites from *A. inodorus* hosts highlights the need for further surveillance of the health of fish, especially when used in an aquaculture set-up.⁵

Results from this study are also a significant tool towards stock identification, which is a key component for the management of economically important fish species. They will contribute to and improve the understanding of the vulnerability of unequally exploited subpopulations within the *A. inodorus* species range and thus help with the implementation of sustainable fisheries practices.³⁷ Biological tags used for stock identification is significant research given the rise in global fisheries as more species are being targeted and commercially exploited to keep up with the increasing demand.³⁸ Many natural tags have been used in population structure studies but parasites as biological tags have gained wide acceptance in recent decades as they can provide a reliable guide to understanding the biology of the hosts.³⁹ Parasites as biological tags for stock identification have not been used in Namibia, but they have been used successfully in South Africa to identify between two hake species (*Merluccius capensis* Castelnau, 1861 and *Merluccius paradoxus* Franca, 1960)⁴⁰ and recently for sardine species (*Sardinops sagax* Jenyns, 1842)⁴¹. This study will significantly add to that resource and create a threshold for more studies on *A. inodorus* and other marine fish species.

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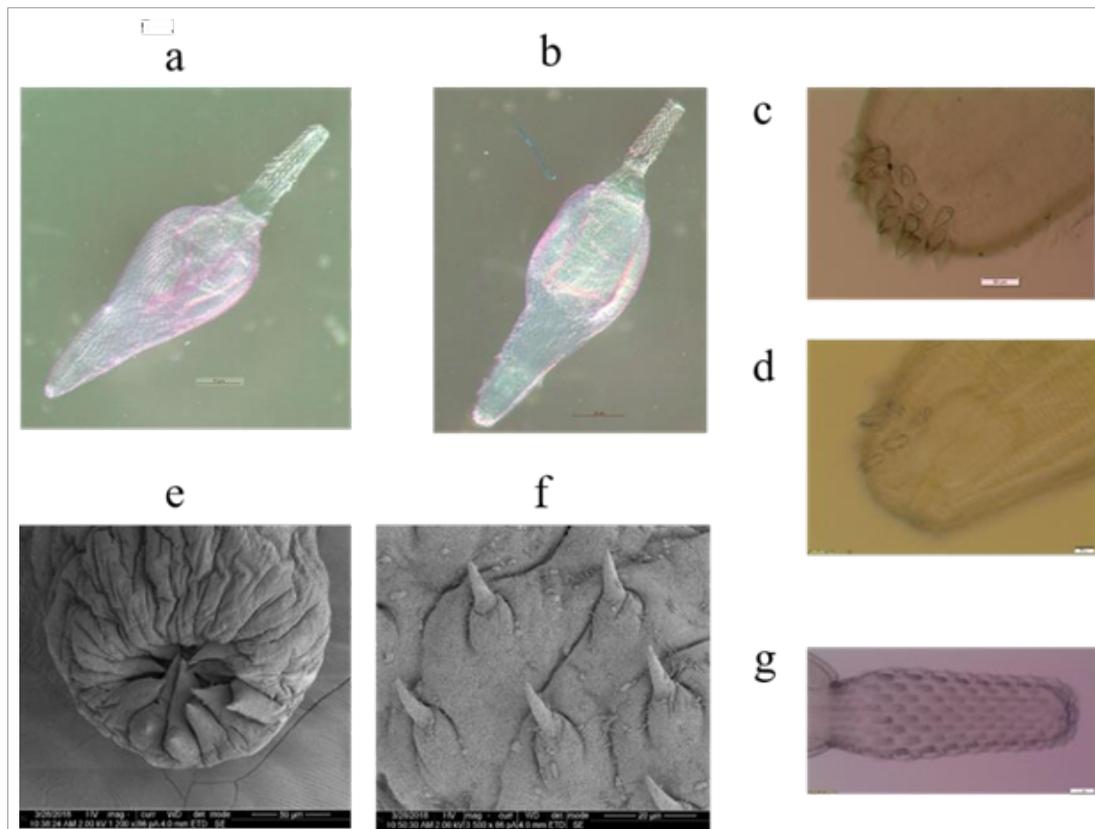


Figure 6: *Corynosoma australe* Johnston, 1937 collected from the body cavity of silver kob. (a) Female and (b) male. (c) Male and (d) female genital spines of adult *C. australe*. (e) Scanning electron micrograph (SEM) of spines at the folded in neck of *C. australe*. (f) SEM of spines. (g) Proboscis of adult *C. australe*, notice hooks.



Competing interests

We have no competing interests to declare.

Authors' contributions

A.M.A.: Methodology, data collection, data analysis, writing – the initial draft, writing – revisions. A.H.: Student supervision, project leadership, validation. M.J.W.: Student supervision, project leadership, validation. M.T.: Student supervision, methodology, data collection. R.H.: Validation. W.L.-P.: Student supervision, funding acquisition, validation.

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