ECTO- AND ENDO-PARASITES OF SILVER KOB (*ARGYROSOMUS INODORUS*) FROM NORTHERN NAMIBIA (21° - 24°S)

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ANNETTE MEGAMENO AMAKALI

(201150336)

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MAIN SUPERVISOR: Dr. Margit Wilhelm

CO-SUPERVISOR: Mr Martin Tjipute

Abstract

The silver kob (*Argyrosomus inodorus*) has been identified as a candidate species for finfish culture due to its outstanding qualities. There is little information available on the health of this species, especially parasite infestation that can pose a threat to fish cultivation and therefore to the success of mariculture. This study was thus designed to provide information on parasites that are affecting this species. Silver kob were collected monthly (2017–2018 for 11 months) using conventional fishing gear (n = 55) in Toscanini, Mile 108 and Henties Bay, northern Namibia (21° - 24°S). Fish were examined for ecto- and endo-parasites. Drawings and measurements of parasites were made using a camera lucida and calibrated eyepiece of an Olympus BX50 binocular microscope and/or a Zeiss (Discovery V8) camera calibrated on a Leica dissecting microscope. Parasite organ specificity was determined. Parasite prevalence, mean intensity and mean abundance were analysed by season of capture, fish length and fish sex. Chi-square tests were used to determine differences in mean abundance by season, host sex and host length. Twenty-eight species from 17 parasite genera were found, including monogeneans (five *Diplectanum* spp., *Sinodiplectanotrema* sp., four *Calceostoma* spp., *Neocalceosoma* sp. and *Sciaenacotyle* sp.), digeneans (*Helicometra* sp., three *Helicometrina* sp., and *Stephanostomum* sp.), cestode larvae (*Callitetrarhynchus* sp., a Tetraphyllidean plerocercoid), a nematode (*Anisakis* sp.), a palaeacanthocephalan (*Corynosoma australe*), copepods (*Caligus* sp., *Sciaenophilus* sp., *Lernanthropus* sp., two *Brachiella* spp.) and an unknown parasite. More ecto-parasites were organ specific than endo-parasites. *Corynosoma australe* and *Calceostoma* spp. were significantly more abundant during the cold season (June-November) (X^2 = 31.56, p <0.001 and X^2 = 3.10, p value = 0.048,

respectively), and *Diplectanum* spp. were significantly more abundant during the warm season (December-May) ($X^2 = 24.44$, $p < 0.001$). With the exception of digeneans, larger sized fish (TL > 47.3 cm) showed the highest prevalence and mean abundance of parasites compared to smaller sized fish (TL ≤ 35.8 cm). *Calceostoma* spp. and *Helicometrina* spp. showed a significant decrease in mean abundance with increasing host length ($X^2 = 28.22$, $p < 0.01$ and $X^2 = 5.77$, $p = 0.03$, respectively). *Corynosoma australe* and *Diplectanum* spp. showed a significant increase ($X^2 = 20.2$, $p < 0.01$ and $X^2 = 41.1$, $p < 0.001$) in mean abundances with increasing host length. No fish sex preference was observed for parasite infections in silver kob. Macroscopically, most fish showed no visible symptoms of the parasite infestations. In severe intensities however, lesions of the fins and skin, and signs of haemorrhages were observed. This is the first study of ecto- and endo-parasites of Namibian silver kob *A. inodorus*. Molecular work and studies including Scanning Electron Microscopy (SEM), histopathology, Health Assessment Index (HAI) and descriptive studies should be done to supplement the findings, identify all the parasites to their species level and determine the nature of infections of the parasites on the fish host.

List of Publication(s)/Conference(s) proceedings

1. **Identification of ecto- and endo-parasites of Mariculture potential candidate, silver kob (*Argyrosomus inodorus*) in Namibia. Preliminary results**

   Authors: Amakali AM; Wilhelm MR; Tjipute M

   Conference: 2nd ARC (Annual research conference) 28-29 September 2017.

   Conference, At University of Namibia, Sam Nujoma Campus. Henties Bay, Namibia

2. **Ecto- and endo-parasites of the potential mariculture species, silver kob (*Argyrosomus inodorus*) (Actinopterygii: Sciaenidae) in Namibia**

   Authors: Amakali AM; Wilhelm MR; Tjipute M; Halajian A; Luus-Powell WJ

   Conference: Conference: 47th PARSA (Parasitological Society of Southern Africa) 16-18 September 2018 (**Best Senior Presenter**).

   Conference, At Tshipise Forever Resort, Limpopo Province, South Africa

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List of Abbreviations and/or Acronyms

FAO – Food and Agriculture Organization

GAP – Glycerin Ammonium Picrate

HAI – Health Assessment Index

MA – Mean Abundance

MI – Mean Intensity

NIF – Number of fish

NP – Number of parasites

P – Prevalence

SCP – Skeleton Coast Park

SEM – Scanning Electron Microscopy

SST – Sea Surface Temperature

TL – Total Length

WCRA/NWCRA – West Coast Recreational Area/ National West Coast Recreational Area

WHO – World Health Organization

WoRMS – World Register of Marine Species

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Dedication

I dedicate this thesis and degree to my parents, Mr Gabriel and Mrs Victoria Amakali and my 6 siblings; Fillemon, Martin, Alina, Helena, Vickta and Sofia Amakali.

Declarations

I, Annette M. Amakali, hereby declare that this study is my own work and is a true reflection of my research, and that this work, or any part thereof has not been submitted for a degree at any other institution.

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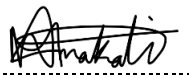
Annette M Amakali		08 April 2019
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Chapter 1: Introduction

1.1. General introduction

Fish provide an excellent source of quality protein, providing important food security and economic growth (Scholz 1999; Khalil *et al*. 2014; Moffitt & Cajas-Cano 2014). Increasing human population growth has led to increased regional and global demand for fish (Schoonbee 2006), a situation that is leading to overfishing to the extent that catches per unit effort are diminishing (FAO 2016). A great expectation is therefore placed on aquaculture to make up for the losses and supply the ever-growing demand for fish (FAO 2016). According to the World Aquaculture Society (WAS 2006), the future of a successful aquaculture sector must be based on the increase of scientific and technical developments, sustainable practices and diversification of cultured species.

Aquaculture, both fresh water and marine, has been increasing in Namibia as a means to provide food to cater for the growing population and hence to reduce poverty, generate foreign investment and earnings and also increase the rate of employment (Tjipute 2011). A number of conditions at the Namibian coast make it conducive for the development of mariculture. Mariculture is defined as a "specialized branch of aquaculture involving the cultivation of marine organisms for food and other products in the open ocean, an enclosed section of the ocean, or in tanks, ponds or raceways which are filled with seawater" (Khan 2011). These conditions include the vast unpopulated coastline, abundant natural living resources, including finfish, which comprise of a large pool of potential mariculture species in the rich Benguela Current, unpolluted water and political support (Tjipute

2011). Mariculture is mostly a private-investor driven initiative and concentrates on oyster and abalone culture at the coastal towns; Swakopmund, Walvis Bay and Lüderitz. Silver kob, *Argyrosomus inodorus* (Griffiths & Heemstra, 1995), is being investigated as a potential culture fish species in order to diversify the mariculture industry since there is currently no culture of marine finfish in Namibia. This will thereafter increase fish production and fish availability for human consumption in Namibia and supplement the already (commonly) consumed fish species (hake and horse mackerel) from the marine ecosystem, simultaneously allowing their stock to recover.

1.2 Problem statement

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 (Mumba 2014). Fish parasite infections arise from poor aquaculture management, high-density conditions, and increased fish stress. The interaction among these pathogens, hosts and their environment results in the development of fish diseases (Labella *et al.* 2011). In addition to the economic losses caused by parasites, some of the parasites are zoonotic. This means that they can be transmitted to humans through the consumption of infected fish that is either undercooked or consumed raw (Mumba 2014). The World Health Organization (WHO) estimated that more than 18 million people globally are infected by parasites (WHO 1995) and many more are at risk of being infected (FAO 2006).

Health-related threats due to fish disease are present in people who consume aquaculture products, especially in cases of zoonotic pathogens. Cost of production is increased because of the investment lost in dead fish, the cost of treatment, and decreased growth

during convalescence. Parasites are ever-present, primarily surviving in a dynamic equilibrium with their hosts and they are often overlooked (Iwanowicz 2011; Justine *et al*. 2012). Labella *et al.* (2011) highlighted that in order to apply measures to control parasites and diseases limiting the production of marine fish, studies involving virulence factors of pathogenic organisms, aspects of the fish biology and immunology, and a better understanding of environmental conditions affecting fish cultures are a prerequisite. As Namibia is a developing country striving for the development of a successful mariculture industry, it is imperative to have knowledge on parasites that may affect marine fish. Despite this, there are no published data on the parasites of silver kob *Argyrosomus inodorus* in Namibia, currently under investigation for its potential as a mariculture species. Since silver kob is currently not farmed in Namibia, wild-caught fish were used for this study.

Silver kob is one of the potential fish species for mariculture due to its robust growth, ability to spawn in captivity as well as its market value (Hayward *et al*. 2007; Merella *et al*. 2009; Tjipute 2011). The culture of silver kob and its congeners have been practiced successfully for many years throughout the world, including South Africa (Williams 1989; Grab 2005; Hayward *et al*. 2007; Merella *et al*. 2009; Hutson *et al*. 2011; Oliva *et al*. 2015; Andree *et al*. 2015; Costa *et al*. 2017). For this reason, this study aimed to investigate parasites that could influence the culture production of silver kob in Namibia.

1.3 Literature review

1.3.1 Importance of marine shore-angling in Namibia

Strong wind-driven upwelling resulting in a nutrient-rich Benguela current make the fishing grounds off Namibia one of the most productive in the world (Goodisan 1991). This creates room for fishing activities in the marine ecosystem, which can be either commercial or recreational (Holtzhausen 2001).

The recreational sector of the Namibian marine fishery consists of local shore anglers and ski-boat anglers; whose aim is not to sell their catches. Some anglers catch fish to provide an everyday meal for their families and some are tourists having quality time with friends and family on the beach and catch fish for a barbeque. Angling may also be competitive (on shore and from a light-tackle boat) as well as sports angling (Goodisan 1991; Holtzhausen *et al.* 2001).

On the smaller scale of commercial sectors, local shore anglers on the shores of Henties Bay and a few ski-boats operating out of Swakopmund sell their catches to local people as well as local restaurants and hotels. In addition, commercial line-boat fleets from Walvis Bay also catch fish, mostly old and large silver kob and snoek (Holtzhausen & Kirchner 2004; Kirchner and Stage 2005; Heymans & Sumaila 2007). The latter catches are exported to South Africa, Mauritius and the island of Reunion (Holtzhausen *et al.* 2001).

1.3.2 Silver kob *Argyrosomus inodorus*

Silver kob (Figure 1), Class: Actinopterygii, Order: Perciformes, Suborder: Percoidei, Family: Sciaenidae (drum/croaker), are also known as kabeljou in southern Africa (Griffiths 1995; 1997). They dwell in brackish water environments, marine habitats and in oceanic bentho-pelagic zone biomes with suitable temperatures ranging between 12°C and 14°C. In Namibia, silver kob is restricted to a depth of 1-20 m, seemingly due to anoxic conditions beyond this depth (Griffiths 1995). They are usually found from northern Namibia to the Kei River on the east coast of South Africa with high abundance off central to northern Namibia (Griffiths & Heemstra 1995). Silver kob grows to a maximum length of 145 cm and a mass of 36.3 kg (Griffiths & Heemstra 1995). The Namibian silver kob stock is considered discrete from the South African kob stock as it grows faster and can attain 40 cm in about two years (Kirchner & Voges 1999; Batty *et al*. 2005). In Namibia, silver kob is the most important species of line fisheries and is exploited by rock and surf anglers, and ski-boat anglers in water shallower than 20 m depth (Holtzhausen *et al.* 2001).

Growth of the silver kob depends on genotype, food supply and water quality (Payne *et al.* 2001). Males grow 10-20% faster than females in South African waters (Griffiths 1996; 1997). Silver kob reaches sexual maturity at about 30 cm total length (1.5 years) and spawn between September and March, with peaks in January and February (Griffiths & Heemstra 1995). Spawners migrate southwards at the beginning of austral summer, against the current, to Sandwich Harbour (23°S) and Moeb Bay (25°S), their main spawning grounds in Namibia (Figure 2).

Figure 1: Silver kob (*Argyrosomus inodorus*) sampled from Henties Bay, Namibia, in November 2017. Photo: A. Amakali

After spawning, silver kob larvae drift northwards with the current to the nursery area in the West Coast Recreational Area (WCRA) and move towards the north Skeleton Coast Park (SCP) as juveniles at about two years old (Figure 2). Spawners return to the SCP waters, moving with the current offshore at the end of their spawning season (Holtzhausen *et al*. 2001; Kirchner & Holtzhausen 2001). Juveniles mainly feed on shrimps and prawns, and adults feed on a variety of small fish and squid (Batty *et al*. 2005).

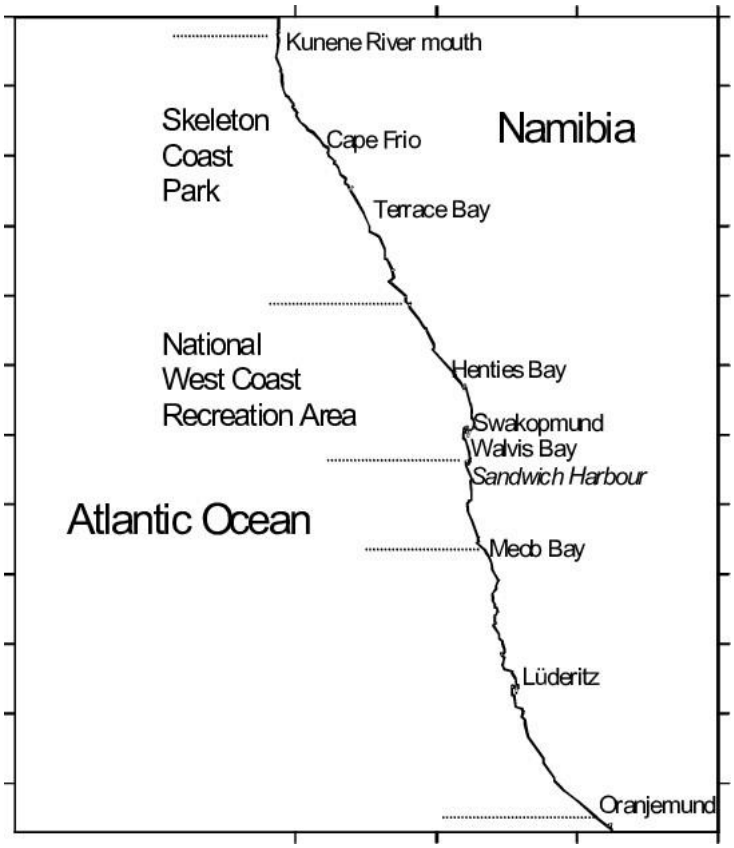

Figure 2: National West Coast Recreational Area (NWCRA) and Skeleton Coast Park (SCP) where *Argyrosomus inodorus* migrate annually to spawn. Source: Kirchner & Stage (2005).

During every annual spawning migration, silver kob falls prey to large predators such as pelagic sharks, as well as shore anglers at Terrace Bay, Torra Bay, Horingbaai, Mile 72, Jakkalsputs and others as the silver kob feed in the shallow bays. The migratory silver kob may also face seal colonies of Mowe Bay, Torra Bay, Toscanini and Cape Cross, although the seals prefer small pelagic shoaling fish such as sardine and horse mackerel. The abundance of silver kob decreases even more as they face ski boats between Henties Bay and Swakopmund before reaching safety at Sandwich Harbour which is closed to anglers

from 25 January to 15 April each year specifically to offer protection to kob spawners (Batty *et al*. 2005).

Silver kob numbers declined in the late 1990s as was shown by a decrease in catches despite increased efforts (Holtzhausen *et al.* 2001; Kirchner & Holtzhausen 2001; Holtzhausen & Kirchner 2004; Kirchner & Stage 2005). The daily bag limit per angler was consequently reduced, the minimum size limits were re-introduced and a daily limit that may be retained over a certain maximum size limit was introduced in December 2001 (Holtzhausen & Kirchner 2004; Heymans & Sumaila 2007).

1.3.3 Fish parasites

A parasite is an organism that lives in or on another larger organism of a different species, referred to as host species, upon which it depends for food and/or shelter (Rohde & Rhode 2005). Parasites are most often small, short-lived, and commonly hidden within organisms during their parasitic phase, especially endo-parasites. Their effects on their hosts may be obvious and profound, or subtler (Rohde & Rhode 2005). Typically, they attract attention only when they cause pathology and disease (effects on host behaviour, decreased fish growth, reduced host total body weight, decreased fecundity, increased mortality), or somehow degrade biological products, thus reducing production yields and economic benefits with consequently increasing healthcare costs (Marcogliese 2002; Stewart 2005; Hutson *et al.* 2011; Iwanowicz 2011; Khalil *et al*. 2014). Merella *et al.* 2009 reported an outbreak of *Sciaenacotyle panceri* on cage-reared meagre (*Argyrosomus regius*) from the

western Mediterrenian Sea, after the fish started showing non-specific disease signs such as lethargy, emaciation, gill anaemia and mortality.

It is important to distinguish between ecto-parasites and endo-parasites in finfish, defined by which organs of the fish they infest, external or internal organs, respectively (Poulin 2004). The main differences between ecto- and endo-parasites are fourfold: Firstly, endo-parasitic helminthsliving in the gastrointestinal tract have complex life cycles involving at least two host species, and are acquired by fish hosts via ingestion (Poulin 2004). Ecto-parasitic metazoans (mainly copepods and monogeneans), on the other hand, have direct life cycles and infest fish via free-swimming infective larvae (Poulin 2004). Secondly, the species richness of ecto-parasites per host is typically greater than that of endo-parasites. Monogeneans and copepods living on the external surfaces of fish are exposed to strong water currents that make robust attachment structures and copulation organs necessary. Thirdly, endo-parasites often occur at much higher abundances than ecto-parasites (Poulin 2004), as they are acquired from a daily diet of the fish and are not exposed to external environmental changes. Endo--arasites are also affected by changes in the immune response of fish (AYDOĞDU et al. 2015) which plays an important protective role for the fish host (Rubio-Godoy 2007). Lastly, ecto-parasites are subjected to water quality variations that influence their well-being (Poulin 2004).

When fish die due to parasitic infections, it can often be associated with changes in parasite densities and community composition (Iwanowicz 2011). Frequently, the damage associated with these dead fish is relative to the rate of parasite infestation, i.e. the state of the fish being invaded by parasites (Bruno *et al.* 2013). A lightly infected fish will show

few signs of parasite presence, while a heavily infected fish may become physiologically harmed and die (Iwanowicz 2011; Mumba 2014).

External and internal clinical signs triggered by pathogens depend on host species, fish age and stage of the disease (Labella *et al.* 2011). Parasites generally do not kill their hosts, but some severely stress the affected fish to the point of biological and economical concern (Bruno *et al.* 2013). 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 (Bruno *et al.* 2013). 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 (Rohde & Rhode 2005). Martins *et al.* (2015) and Kotob *et al.* (2016) reviewed impacts of different secondary infections, also called co-infections, on fish species.

Parasites use nutrition from the fish they invade. However, the severity of diseases and the resulting mortality is greater in cultured fish than in wild fish (Scholz 1999; Ternengo *et al.* 2010; Labella *et al.* 2011). In the wild, fish can get enough nutrition for their own needs and the needs of the infections. Sufficient intake of readily and naturally available nutrients also satisfies the pathogens and hence decreases fish stress while simultaneously increasing the fish resistance to disease (Bruno *et al.* 2013). In farmed fish, however, natural nutrients or feeds are not always readily available. In addition, feed is not usually increased, nor altered, with the presence of demanding pathogens or parasites in the fish (Scholz 1999). This may lead to an increased number of parasites that cause stress to the

fish, giving rise to diseases and further leading to pathological changes, decrease of fitness and reduction of market value of the fish (Scholz 1999).

Among the hosts, marine vertebrates are mostly large, long lived, tremendously vagile and gregarious, with generalised broad diets. Silver kob is no exception. This generalised feeding mechanism allows for prey switching and dietary overlap, thereafter creating a highly diversified host diet in comparison with terrestrial environments. As juveniles, silver kob feed on shrimps and squids and eventually add small pelagic fish such as sardine to their diet as they grow older therefore diversifying their dietary intake (Griffiths 1996; Kirchner & Voges 1999; Schoonbee 2006).

Silver kob migrate annually from northern Namibia to central Namibia to spawn (Kirchner & Stage 2005). This spawning migration can further destroy the local character of parasite faunas (Marcogliese 2002). As parasites are exposed to different areas with different physican and chemical environment, their morphological and ecological features could be altered.

1.3.4 Importance of studying fish parasites

Food-borne parasitic infections have been identified as one of the most significant public health problems (Khalil *et al.* 2014). Reducing cooking time or consuming raw and uncooked food are some of the major factors that contribute to these zoonotic infections. The reason for this is a lack of fundamental knowledge on parasitic infections that could be a precursor to infectious diseases in humans (Park *et al.* 2009).

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 (Iwanowicz 2011). 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 (Woo & Gregory 2014).

In the wild, parasites have been used as a biotic force capable of determining the biodiversity of fish communities. Poulin (1999a) explains three ways in which parasites can affect the community of organisms among which they live. Firstly, if different fish species have different susceptibilities to parasites of the same species, parasites can regulate the population size of some fish species more than others and hence are functionally important in the fish community structuring (Poulin 1999a; Marcogliese 2002). For example, Soares *et al.* (2012) found *Amyloodinium ocellatum* Brown, 1931 from *A. regius*, reared in a polyculture with gillhead seabream (*Sparus aurata* Linnaeus, 1758), where *A. regius* showed more resistance to parasites than *S. aurata*. The population

size of *A. regius* was therefore less diminished compared to that of *S. aurata*. In addition, parasites usually have more harmful effects on the competitively superior species, thus cancelling out its advantage and promoting its coexistence with related species (Poulin 1999a). Secondly, the functional importance of fish species can be directly decreased by a parasite via pathological effects. Parasites weaken their hosts, therefore playing a functional role in the community of free-living organisms. If the host is the predator in the community, parasite infestation causes lack of appetite, thereafter increasing the number of prey (Poulin 1999a). Furthermore, most prey species are herbivores. Therefore, an increase in the prey population will cause a decrease in the plant community. If the parasitic host is prey, they become more vulnerable and hence decrease in number, increasing the plant community. Finally, 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 (Poulin 1999a).

Poulin (2004) assumed that there should be a positive, interspecific relationship between parasite species richness and host geographic range. The main characteristic likely to affect the rate of parasite colonisation is host body size. Larger hosts provide more space and other resources for parasites and may be able to support richer parasite faunas. Larger hosts are also likely to be older than smaller hosts of the same species, hence has had linger time and exposure to parasitic infestations and infections over time. Large-bodied hosts are also long-lived and they tend to occur at lower population densities (Poulin 2004; Iwanowicz 2011). Poulin (2004) therefore concluded that parasite species richness should

be higher in larger bodied, long-lived host species with dense populations, broad geographical ranges and broad diets. Understanding the roles of parasites in the environment may therefore help to understand changes in a given fish population or ecosystem (Iwanowicz 2011).

1.3.5 Parasites as biological tags

The use of parasites as tags to track, or identify stocks and to assess the population structure of marine organisms have been widely used in many parts of the world (MacKenzie *et al*. 2005). Parasites as biological tags have been used in stock identification in marine fish according to the principle explained by MacKenzie *et al.* (2005). 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 geographic 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 geographic area (Marcogliese 2002). 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 (Rohde & Rohde 2005). For example, Cichlid monogeneans, including the endo-parasitic *Enterogyrus cichlidarum* were found to be specific to fresh-water fish species *Oreochromis niloticus* and *O. mossambicus* (Natividad et al. 1986; Bondad-Reantaso & Arthur 1990) in Southeast Asia. This means that the geographic distribution of one monogenean species may mirror the geographic distribution of their host species. 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. The more parasites with different endemic areas can be used, the more information can be obtained about the past movements of the fish populations (MacKenzie & Abaunza 1998).

Stock identification is a key component for the management of economically important fish species. It improves the understanding of the vulnerability of unequally exploited subpopulations within a species range and thus helps with the implementation of sustainable fisheries practices (Klapper *et al.* 2016). Biological tags used for stock identification is a very significant research given the rise in global fisheries as more species are being targeted and commercially exploited to keep up with the increasing demand (Catalano *et al.* 2014). Before a fishery on a stock can be efficiently managed, and policies implemented for future sustainability, the stocks need to be correctly identified. 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 (MacKenzie *et al*. 2005). MacKenzie *et al*. (2005) described 17 studies that has used parasites as biological tags for stock identification of small pelagic fish. They showed that the most frequently used tag parasites have been larval nematodes, particularly those of the genus *Anisakis*, while digenean metacercariae, cestode plerocercoids, juvenile acanthocephalans and parasitic crustaceans have also been used effectively. 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 paradoxuc* Franca, 1960) (Botha 1986) and recently for sardine species (*Sardinops sagax* Jenyns, 1842) (Reed *et al.* 2012).

Describing the parasite community of silver kob from northern Namibia could serve as a baseline for identifying parasitic candidate biological tags. These parasites could be used for stock identification, stock separation and assessment, and possible to understand migration patterns for silver kob in the future since they have not been used on silver kob Namibia so far. There are however, studies on parasites of Namibian hake stock, as well as snoek (*Centropomus undecimalis* Bloch, 1792) that are currently being conducted.

1.3.6 Parasites of *Argyrosomus*

Studies on dusky kob, *Argyrosomus japonicus* Temminck and Schlegel, 1843, conducted in South Africa indicate a variety of parasites, such as the endo-parasite *Neoechinorhynchus dorsovaginatus* Amin & Christison, 2005. Amin and Christison (2005) observed the mean intensity of endo-parasite *N. dorsovaginatus* _ to be greater in spring (November) than in summer (February) and most parasites were found in gravid females (with eggs) and male adults. Mean intensity refers to the mean of the number of individuals of a particular parasite species per infected host in a sample (Rózsa *et al*. 2000). In other studies, a species of Nematoda (*Philometra* sp. Costa, 1845) (Moravec *et al*. 2007) and *Amyloodinium ocellatum* Brown, 1931 was found on meagre, *Argyrosomus regius* Asso, 1801, in Portugal (Soares *et al.* 2012). Soares *et al*. (2012) recorded parasites from *A. regius*, reared in a polyculture with gillhead seabream (*Sparus aurata* Linnaeus, 1758), where *A. regius* showed more resistance to parasites than *S.*

aurata. This was the first record of this parasite from farmed *A. regius*, meaning that the pathogen was transmitted from *S. aurata* to *A. regius*. Other parasites including a nematode *Anisakis* sp.; monogeneans *Benedenia sciaenae* (Van Beneden, 1852) Odhner, 1905, *Diplectanum* spp., *Sciaenacotyle panceri* Sonsino, 1891 and *Calceostoma* spp.; copepods *Lernanthropus* sp.; and a digenean trematode *Helicometrina* sp. were also found on congeners *Argyrosomus japonicus*, *Argyrosomus regius* and *Argyrosomus hololepidotus* Lacepède, 1801 (Williams 1989; Grab 2005; Hayward *et al*. 2007; Merella *et al*. 2009; Hutson *et al*. 2011; Oliva *et al*. 2015; Andree *et al*. 2015; Costa *et al*. 2017). Kensley (1970) documented a copepod *Caligus mortis* Kensley, 1970 from intertidal pool fish hosts from Rocky Point, Torra Bay, Namibia, which was described by Dojiri (1989) and more recently re-described by Grobler *et al*. (2002). Bray and Reimer (2004) also discovered and described two *Stephanostomum* spp. (*S. kovalevae* Parukhin, 1968 and *S. beukelaardori* sp.) from cape monk (*Lophius vomerinus*) off Swakopmund, Namibia.

Information on marine fish parasites in Namibia is scarce. Kotungondo (2014) (unpublished data) has found species of the monogenean *Sciaenacotyle panceri* on the gills, copepod families (*Caligus* spp.) on the gills and a nematode in the gastrointestinal tract of the Namibia silver kob (*Argyrosomus inodorus*). Parasites were found to be more abundant on the gills than in the gastro-intestinal tract, with higher mean abundances in female than male in fish. Mean abundance refers to the mean of the number of individuals of a particular parasite species per host examined (Rózsa *et al*. 2000). In addition, parasites were more abundant in August and September than in June, July and October and more abundant in fish with sizes ranging between 35 and 55 cm than in smaller fish. None of the parasite species found by Kotungondo (2014) have been described, and no *A. inodorus*

hosts have been sampled for parasites in the summer months. The present study aimed to address this gap.

1.4 Objectives

The objectives of this study were to:

1. Identify the external and internal helminth parasite species of Namibian silver kob using morphological features
2. Determine parasite organ specificity in Namibian silver kob
3. Determine the prevalence, mean intensity and mean abundance of the parasite genera found on Namibian silver kob by season of capture
4. Determine the influence of host body size and host sex on the prevalence, mean abundance and mean intensity of Namibian silver kob

Chapter 2: Materials and Methods

2.1 Study area

A total of 55 silver kob were collected over 11 months (from June 2017 to May 2018), where five fish were examined each month, except for in July 2017. A sample size of five fish per month was used since most studies on wild marine fish used ≤10 samples. For example, Williams (1989) carried out a study using 5 fish (*Argyrosomus hololepidotus*). Silver kob were caught using the hook and line fishing method in Toscanini (n = 24) and Mile 108 (n = 24), both sites within the Skeleton Coast Park, at about 21°49' S and 13°25' E (Figure 3). Some silver kob were collected in Henties Bay (n = 7) (Figure 3), caught by local anglers.

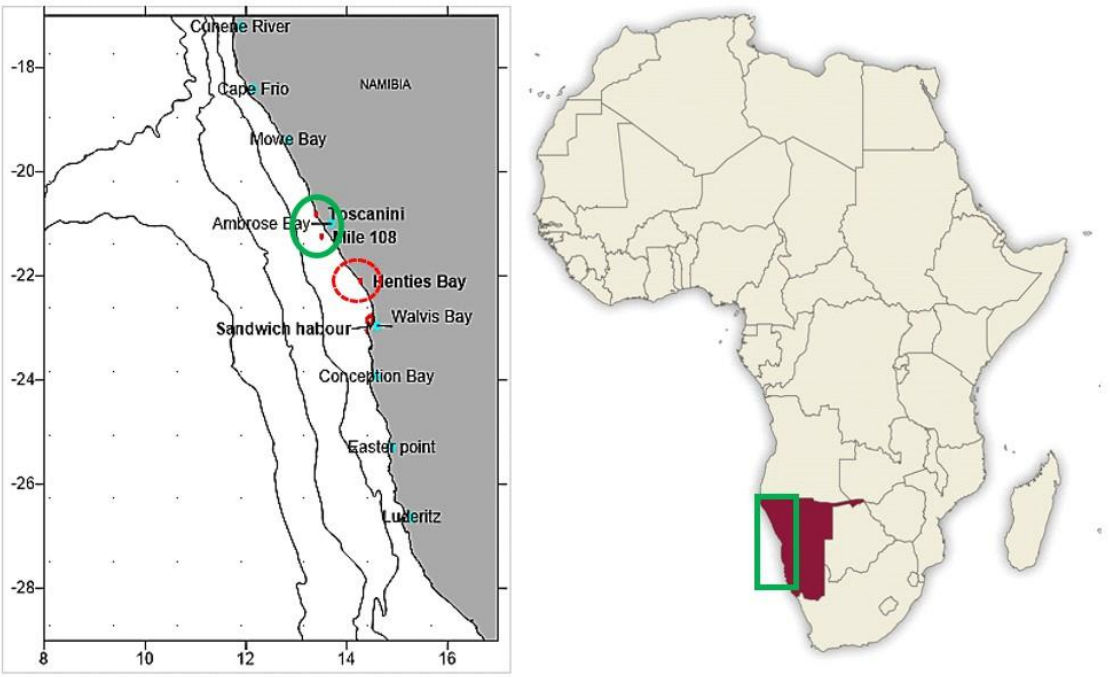

Figure 3: The main sampling area (Toscanini and Mile 108) of silver kob (*Argyrosomus inodorus*) indicated by the green solid circle and secondary sampling area, Henties Bay, indicated by the red dashed circle (Map on the right: https://www.info-namibia.com/images/information/geography/Africa.jpg).

During fish collection, fish were taken out from the water, straight to the tank on the hook. This was done in order to minimize contact and prevent loss of ecto-parasites. Fish were kept alive and transported in a tank with bubbled oxygen to the University of Namibia, Henties Bay laboratory (Figure 3, red dashed circle). Upon arrival, fish were transferred to bigger aerated tanks, where they were held until examination, in order to reduce fish stress and to maintain external parasites. The water supplied to the holding tanks was extracted during high tides, using perforated pipes laid under the sand. The sand acted as a filter medium. The fish were kept in a static flow-through tank system that was disinfected prior to introducing the fish into the tank. The water in the tanks was kept at an average temperature of 20°C. Fish were examined initially within one week and from September 2017 onwards, within 48 hours of capture. The period between fish collection and examination was reduced to possible minimum time because fish stress from the sudden change of environments (from open marine environment to enclosed tank environment) and they don't feed. This causes them to be more vulnerable and susceptible and consequently causing the parasites to intensify. Two fish were therefore caught at once and examined until the monthly five fish were examined as it took at least 8 hours to examine a single fish host.

2.2 Laboratory procedure

During examination fish were held by the opercula to handle them as gently as possible and also to minimize contact, and thus preventing loss of ecto-parasites. For parasite examination, fish were euthanized by a single cut through the spinal cord (Noga 2010; Blahoua 2016). Every fish was weighed to the nearest 0.1 kg using a weighing scale

(Mettler Toledo SB8001), and the fish total length (TL) was measured on a measuring board to the nearest 0.1 cm.

First observations of external visible parasites were made. Mucus smears were then collected from the skin and scales by taking a scalpel and gently scraping along the side of the body and the scales. The smears were placed in petri dishes adding filtered sea water to prevent the smears from drying and to keep the parasites alive. The fins were cut off and placed in separate petri dishes for examination. The eyes were carefully cut out and placed in a petri dish for examination. The tip of a pair of fine scissors was inserted into the gill chamber. The scissors were gently opened, lifting the operculum until the gill arches were seen. The gills were cut and transferred into a petri dish for examination. The opercula were examined for macroscopic parasites. The eyes were carefully cut out and placed in a petri dish. The liquid was removed and filtered sea water was added for microscopic examination.

A longitudinal incision was made along the ventral midline from the anal opening to the pelvic fin and then to the gill chamber using a pair of fine scissors. The incision was extended from the posterior peritoneal cavity into the pericardial sac to expose the gastrointestinal organs. The sex of the fish was determined. The gastrointestinal organs were removed, placed in separate labelled petri dishes and examined for endo-parasites using clean implements to avoid transfer of parasites from one site to another (Noga 2010). The different fish organs, were examined for parasites with the aid of a Motic SFC11 stereo microscope and cuts of liver, spleen, heart and flesh/tissue placed onto separate microscope slides were examined for parasites with a Motic B1 Series compound microscope.

Different parasites were fixed and preserved differently as follows: whole mount preparations were made for monogeneans using a glycerin ammonium picrate (GAP) solution on microscope slides and some were preserved in vials with 70% ethanol. Nail vanish was used to seal the whole mounts on the microscope slides. Digeneans were relaxed on slides with a warm 70% ethanol and preserved in 70% ethanol after relaxation. Staining of digeneans was made with lignin pink and a GAP solution. Nematodes (after relaxation in hot water) and copepods were preserved in 70% ethanol in accordance with methods described by Justine *et al.* (2012), and cleared on a slide with lactophenol.

All parasites were counted per species on each individual host at each specific site in the host's body and identified to the nearest species or genus level as far as possible using text books and scientific articles specific to each parasite species (e.g. Kabata 1982; Hogans & Trudeau 1989; Williams 1989; Kabata 1992; Meenakshi *et al.* 1993; Johnson *et al.* 2004; Jones *et al.* 2005; Hayward *et al.* 2007; Al-Zubaidy 2011).

2.3 Data analysis

Parasite prevalence (the proportion of infected hosts), mean intensity (the mean of the number of individuals of a particular parasite species per infected host in a sample) and mean abundance (the mean of the number of individuals of a particular parasite species per host examined) were calculated according to the formulae described by Bush *et al.* (1997) as follows:

$$\text{Prevalence (P \%)} = \frac{Number\ of\ infected\ fish}{Total\ number\ fish\ examined} \times 100\% \quad (1)$$

$$\text{Mean intensity (MI)} = \frac{total\ number\ of\ specific\ parasite\ species}{number\ of\ infected\ individuals} \quad (2)$$

$$\text{Mean abundance (MA)} = \frac{\boldsymbol{Total\ number\ of\ specific\ parasite\ species}}{\boldsymbol{Total\ number\ of\ fish\ examined}} \quad (3)$$

Chapter 3: Identification of external and internal helminth parasites of *Argyrosomus inodorus* in Namibia

3.1 Introduction

Silver kob (*Argyrosomus inodorus*) is the most important line fish species in Namibia and it is exploited by rock and surf anglers, and ski-boat anglers (Holtzhausen *et al*. 2001). Silver kob is considered a potential species for mariculture due to its robust growth, ability to spawn in captivity as well as its market value and acceptance (Hayward *et al*. 2007; Merella *et al*. 2009; Tjipute 2011). Parasites that could affect the production and growth of silver kob in a mariculture set-up are therefore being investigated, as parasites are one of the main factors that pose health, social and economic threats to mariculture species.

The capacity to correctly identify parasitic agents of fishes is essential for finfish aquaculture and maintenance of bio-security. If a parasite species causing a disease is not accurately identified, it may be difficult to develop control and treatment methods and assess risk factors (Hutson *et al*. 2011). So far there are no published records on parasites of silver kob in Namibia. This gap is therefore addressed in this chapter.

3.2 Objective

To identify the external and internal helminth parasite species of Namibian silver kob using morphological features.

3.3 Methods

Parasites were identified by morphological examination of whole mounted or cleared preserved specimens. Published records, keys in scientific papers and parasite diversity books assisted in identification, with distinctive characters being used to classify parasites to genus and species (e.g. Kabata 1982; Hogans & Trudeau 1989; Williams 1989; Kabata 1992; Meenakshi *et al.* 1993; Johnson *et al*. 2004; Jones *et al.* 2005; Hayward *et al.* 2007; Al-Zubaidy 2011).

Photographs, 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.

Parasite species that could be identified using books and articles specific to each parasite, were described to verify their identification (e.g. *Diplectanum* spp., *Calceostoma* spp., *Sciaenacotyle* sp., *Caligus* sp., *Helicometra* sp., *Helicometrina* spp., *Stephanostoma* sp., *Corynosoma australe*, *Anisakis* sp.). The other parasites (monogeneans; *Neocalceostoma* sp. and *Sinodiplectanotrema* sp., and copepods; *Sciaenophilus* sp., *Lernanthropus* sp. and two *Brachiella* spp. were only listed, but not described due to a lack of information on their descriptions in the literature.

All measurements are in micrometres (µm) unless indicated otherwise. In the descriptions, the initial number is the mean measurement followed by the minimum and maximum measurement (range) and the number (n) of specimens measured for that particular category in parentheses. General measurements for *Diplectanum* spp. and *Calceostoma* spp. were done according to lines a to d indicated on Figures 4 and 5.

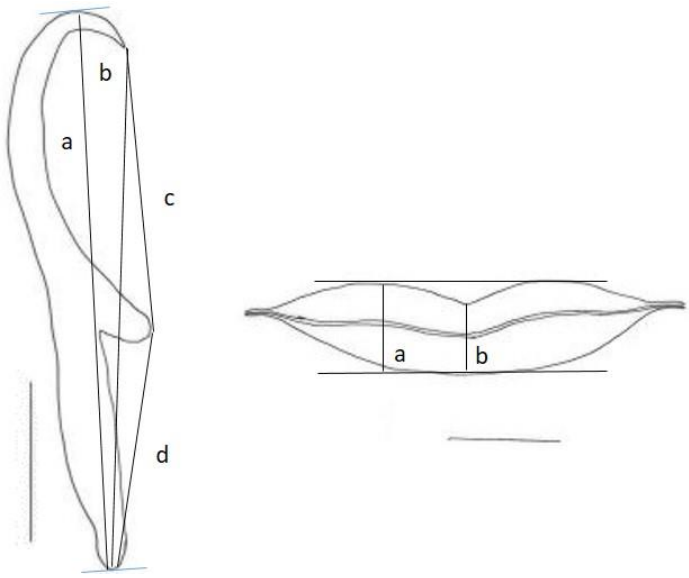

Figure 4: *Diplectanum* spp. (A) Ventral and dorsal hamuli measurements (dorsal hamuli only a & b). (B) Median bar maximum width a, and minimum width b.

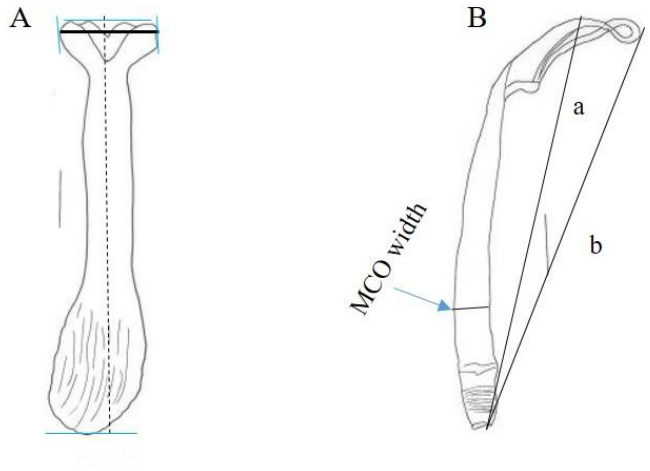

Figure 5: *Calceostoma* spp. measurements. (A) Median bar total length (dashed line), as well as the “V” and "T" shape width (Solid lined). (B) MCO measurements, a and b, and width.

3.4 Results

A total of 28 parasite species of 17 genera (Table 1) were recorded from silver kob, of which 18 species were ecto-parasites and 10 were endo-parasites. Of the 18 external parasite species, 16 were collected from the gills, of which 10 species were identified as monogeneans, four as copepods, one as a digenean trematode larvae (normally known as an endo-parasite) and one parasite was unknown. The other two of the 18 external parasites were collected from the skin and fins, and the opercula. Of the 10 monogeneans collected from the gills, five belonged to the family Diplectanidae, three belonged to Calceostomidae, one Mycrocotylidae, and one Neocalceostomoide. Of the 10 internal parasite species, one was identified as a monogenean (normally known as an ecto-parasite), five as digeneans (of which three were from the genus *Helicometrina* and one from *Helicometra* and one from *Stephanostoma*), one cestode larva, one cestode plerocercoid, one nematode, and one Palaeacanthocephala.

Table 1: Twenty-eight parasite species found on Namibian silver kob collected from Toscanini, Mile 108 and Henties Bay from June 2017 to May 2018 and their possible pathegenicities.

Class	Genus/Order	Species	Pathogenicity
Ecto-parasites			
Monogenea	*Diplectanum* *Diplectanum* *Diplectanum* *Diplectanum* *Diplectanum* *Calceostoma* *Calceostoma* *Calceostoma* *Sciaenacotyle* *Neocalceostoma* *Sinodiplectanotrema*	*D. sciaenae* *D. dollfusi* *D.* sp. 1 *D.* sp. 2 *D.* sp. 3 *C. glandulosum* *C.* sp. 1 *C.* sp. 3 *S.* sp. *N.* sp. *S.* sp.	Not pathogenic but can have effect on fish quality. Could also act as vectors of viruses and bacteria.
Trematoda (Subclass: Digenea)	*Stephanostomum*	*S.* sp.	Fish stress at high abundances could lead to fish mortality
Copepoda	*Caligus* *Lernanthropus* *Sciaenophilus* *Brachiella* *Brachiella* Unknown	*C.* sp. *L.* sp. *S.* sp. *B.* sp. 1 *B.* sp. 2 Unknown	Could be vectors for viruses, bacteria and protozoans. Have effects on fish welfare and fecudity
Endo-parasites			
Monogenea	*Calceostoma*	*C.* sp. 2	Unknown
Trematoda (Subclass: Digenea)	*Helicometra* *Helicometrina* *Helicometrina* *Helicometrina* *Stephanostomum*	*H.* sp. *H. labrisomi* *H. nimia* *H.* sp. *S.* sp.	Could be pathogenic at high abundances
Cestoda	*Callitetrarhynchus* Tetraphyllidea	*C.* sp. (plerocercoid)	Damage to fish host (fish quality is affected) Unknown
Nematoda	*Anisakis*	*A.* sp.	High abundance can affect fish quality
Palaeacanthocephala	*Corynosoma*	*C australe*	Damage to fish host, causes secondary infections

3.4.1 External parasites of Namibian silver kob (*Argyrosomus inodorus*)

3.4.1.1 Monogeneans

Throughout the study, monogeneans from the genus *Diplectanum* dominated in numbers. Five species are described in the current study; *Diplectanum sciaenae, Diplectanum dollfusi* Oliver, 1980, *Diplectanum* sp. 1, *Diplectanum* sp. 2 (believed to be *Diplectanum simile* Bychowsky, 1957) and *Diplectanum* sp. 3 (believed to be *Diplectanum sciaenae* with the squamodiscs absent). *Diplectanum* sp. 1, 2 and 3 had all other features of *Diplectanum*, but lacked the attachment armature, two squamodiscs (also see appendix 1. e.). They were, nonetheless, believed to be diplectanids as some have what seemed like developing squamodiscs, which were only visible before mounting of the slides. They are therefore identified as such.

In addition to *Calceostoma glandulosum* Johnston & Tiegs, 1922, another species of *Calceostoma* was found and differed in the structure of their haptoral morphology (shape of median bar and hamuli) and male copulatory organs. This species was also found on silver kob *A. inodorus* by Stewart (2005) in South Africa.

Another monogenean species, possessing a whole different male copulatory organ, was found but could not be fully described due to an insufficient number of specimens found. Its distinctive features are highlighted.

I. *Diplectanum* spp.

Class: Monogenea van Beneden, 1858

Subclass: Monopisthocotylea Bychowsky, 1937

Order: Dactylogyrodea Bychowsky, 1937

Family: Diplectanidae Monticelli, 1903

Genus: *Diplectanum* Diesing, 1858

Diplectanum Diesing, 1858, a genus of monopisthocotylea monogeneans is the largest genus in the family Diplectanidae and consists of over 80 species (Stewart 2005; Gibson & Bray 2010). The systematics of *Diplectanum* relies mostly on characters of the posterior attachment organ (haptor) and distal regions of the reproductive system (Petrov *et al*. 2017). The posterior attachment organ comprises two main components: the typical attaching armature of *Diplectanum;* a pair of attachment squamodiscs (dorsal and ventral) covered by rows of interlocked rodlets (ossicles) and a set of hamuli and connecting bars consisting of a supporting apparatus of the haptor (Petrov *et al*. 2017).

In nature, *Diplectanum* spp. are not highly pathogenic parasites; under adverse conditions, however, they can multiply and have detrimental effects on their hosts (Andree *et al*. 2015). 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.

Terminologies used in this study may differ in different publications since some terminologies seemed to have changed over time. The median bar is sometimes referred to as ventral bar, dorsal hamulus as dorsal anchor, the ventral hamulus as ventral anchor, the superficial root as inner root, the deep-root as outer root, and the male copulatory organ as penis.

***Diplectanum sciaenae* Van Beneden & Hesse, 1863**

Host: *Argyrosomus inodorus* Griffiths & Heemstra, 1995

Site: Skin, gills

Locality: Henties Bay, Mile 108 and Toscanini, Namibia

Specimens studied: Eight whole-mount adult specimens measured

Description

Long and slender with total body length measured 735 µm (436–943) and mid body width of 185 µm (117–250) (Figure 6A). The haptor (Figure 6B), which measured 252 µm (198–310) total length, consisted of a lip-shaped median bar (Figure 6B & C), which measured 107 µm (97–134) total length, 23 µm (20–27) maximum width (a) and 15 µm (12–17) minimum width (b). Just below the median bar, the squamodiscs measured 161 µm (124–222) total length and 140 µm (109–187) maximum width with 36 µm (32-38) concentric divergent rows. The haptor also consisted of two transverse bars (Figure 6B & D) on either side of the median bar with total length of 95 µm (81–122), which mostly met midway from each side of the median bar, but did not intersect. In rare cases the transverse bars were shifted to $\frac{1}{4}$ of the median bars toward the ends. At the end of each transverse bar lied a pair of curved-in hamuli consisting of a dorsal hamulus (Figure 6E) and a ventral hamulus (Figure 6F). The dorsal hamulus had a long deep-root and a poorly developed superficial root: length (a) 62 µm (55–65) and length (b) 57 µm (52–60) (see Figure 4). The ventral hamulus had a long deep root and a short superficial root with the following

dimensions: length (a) 70 µm (64–74); length (b) 65 µm (59–67); length (c) 37 µm (35–40), length (d) 28 µm (25–33) (see Figure 4).

The male copulatory organ (MCO) (Figure 4G) was small with 55 µm (50–76) total length. The MCO widened at the base and had a spiral end encircling the tip end. The sclerotized canal (Figure 6H) at the conspicuous prostatic reservoir measured 29 µm (26–40) total length and 9 µm (6–12) maximum width. The sclerotized canal was sharply curved as described for *D. sciaenae* by Oliver (1980) and Andree *et al*. (2015).

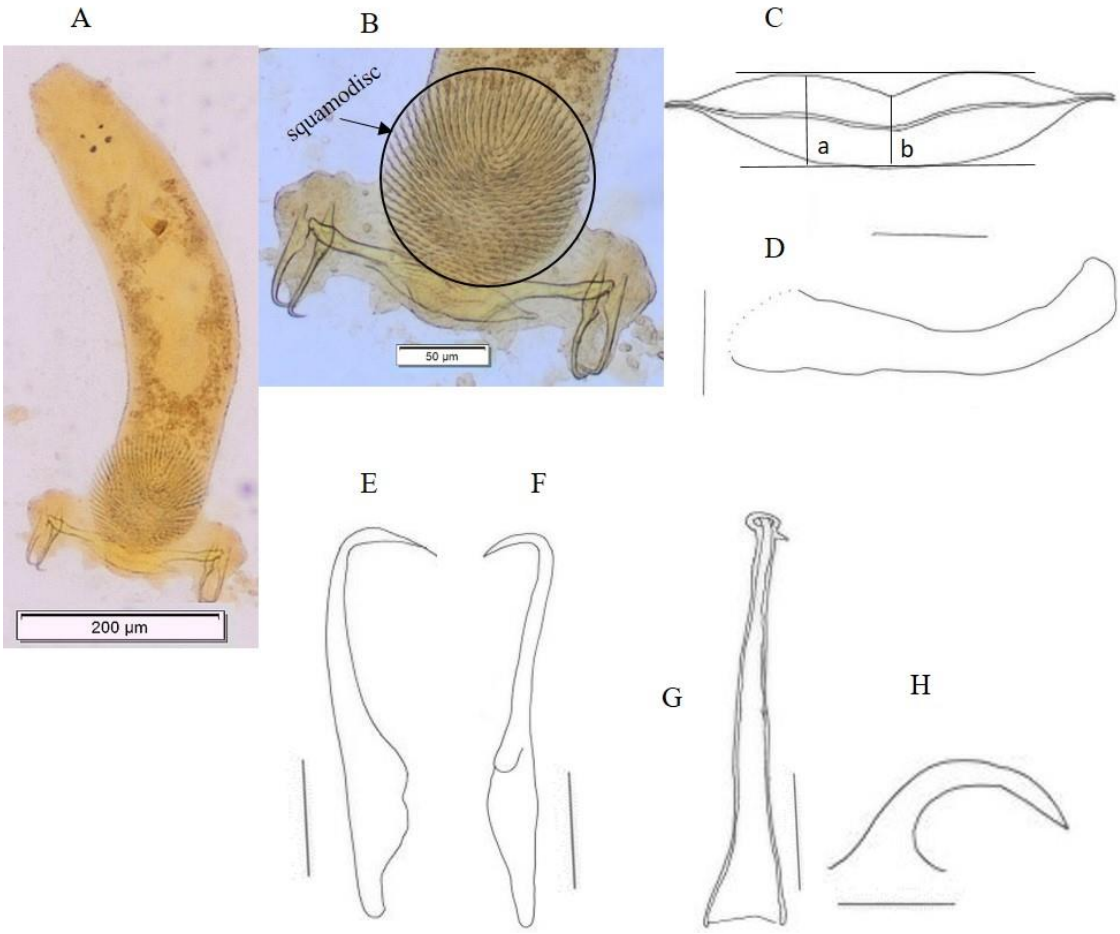

Figure 6: *Diplectanum sciaenae* from the gills of silver kob. (A) *Diplectanum sciaenae* whole mount. (B) Haptor with squamodiscs and hamuli. (C) Median bar (Lengths (a) and (b)). (D) Transverse bar. (E) Dorsal hamulus. (F)Ventral hamulus. (G) Male copulatory organ (MCO). (H) Sclerotized canal. Scale bars: 20 µm (C-H).

***Diplectanum dollfusi* Oliver, 1980 (squamodiscs absent)**

Host: *Argyrosomus inodorus* Griffiths & Heemstra, 1995

Site: Skin, gills

Locality: Henties Bay, Mile 108 and Toscanini, Namibia

Specimens studied: Four whole-mount adult specimens measured

Description:

Body length measured 875 µm (805–925; n = 3) and 156 µm (123–180; n = 3) mid body width. The haptor (Figure 7A) total width measured 251 µm (233–269; n = 2). The median bar (Figure 7A) measured 102 µm (91–127; n = 4) total length, 22 µm (20–26; n = 4) maximum width and 15 µm (13–18; n = 4) minimum width. The transverse bar lied towards the end of the median bar and slightly heading out (Figure 7A), measured 94 µm (87–114; n = 4). Dorsal hamulus (Figure 7B) measured; length (a) 61 µm (57–66; n = 4) and length (b) 55 µm (51–61; n = 4) (Figure 4). The ventral hamulus (Figure 7C) measured: length (a) 66 µm (62–73; n = 4); length (b) 60 µm (56–68; n = 4); length (c) 34 µm (31–37; n = 4) and length (d) 27 µm (25–31; n = 4) (see Figure 4). The hamuli were considerably curved.

The MCO (Figure 7D) widened at the base, has a spiral end and measured 55 µm (50–66; n = 4). The spike-shaped sclerotized canal measured 29 µm (24–39; n = 4) total length and 7 µm (5–9; n = 3) maximum width (Figure 7E). In some cases, the sclerotized canal was slightly curved.

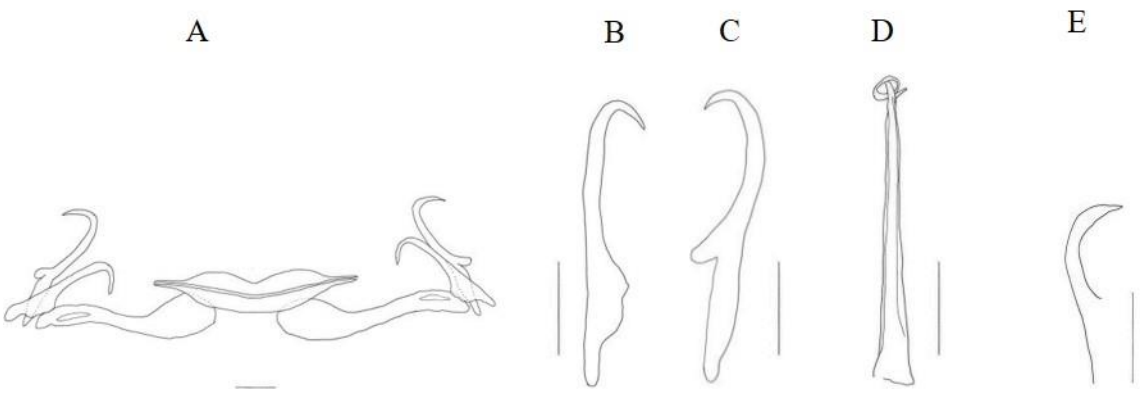

Figure 7: *Diplectanum dollfusi* collected from the gills of silver kob. (A) Haptor (median bar, transverse bar and two pairs of hamuli). (B) Dorsal hamulus. (C) Ventral hamulus respectively. (D) Male copulatory organ. (E) Sclerotized canal. Scale bars: (A) 20 µm, (B-D) 20 µm

***Diplectanum* sp. 1**

Host: *Argyrosomus inodorus* Griffiths & Heemstra, 1995

Site: Skin, gills

Locality: Henties Bay, Mile 108 and Toscanini, Namibia

Specimens studied: Four whole-mount adult specimens measured

Description:

Body wider than other *Diplectanum* species with total length 876 µm (777–950; n = 4) and body width 330 µm (237–383; n = 4) (Figure 8A). Haptor width measured 325 µm (309–338; n = 4). Median bar (Figure 8B) lower "lip" curved in at an angle (not smooth). Median bar measured 104 µm (101–107; n = 4) total length, 21 µm (19–24; n = 4) maximum width and 13 µm (13–14; n = 4) minimum width. Transverse bar pointing

outwards and measured 91 µm (88–94; n = 4). Hamuli curved or angled to almost 90°. Ventral hamulus length (a) 67 µm (65–69; n = 4); length (b) 61 µm (59–63; n = 4); length (c) 35 µm (33–37; n = 4); length (d) 26 µm (26–27; n = 4) (see Figure 4). Dorsal hamulus length (a) 59 µm (58–61; n = 4) and length (b) 56 µm (54–57; n = 4) (see Figure 4). Reduced squamodisc situated at the posterior centre 152 µm (118–191; n = 4) length and 131 µm (107–157; n = 4) width with 38 µm (36–39; n = 4) concentric divergent rows.

The male copulatory organ measured 51 µm (50–54; n = 4). The sclerotized canal curves in at a much greater angle than that of *D. sciaenae* and measured 31 µm (30–32; n = 4) total length and 8 µm (6–9; n = 4) maximum width.

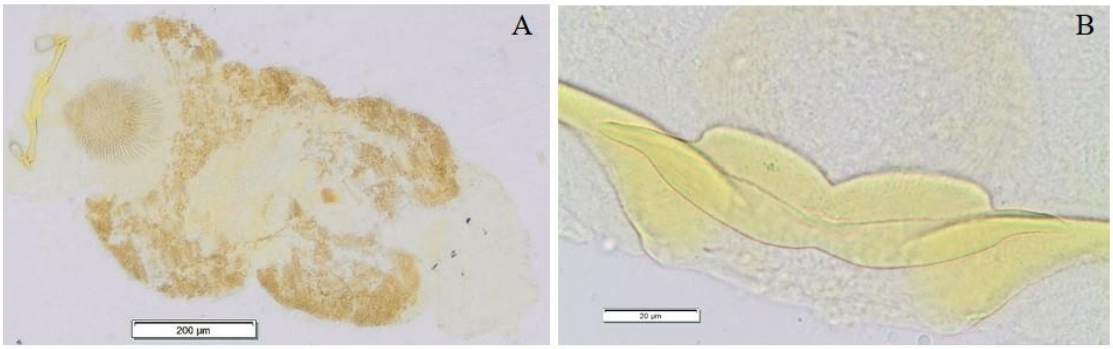

Figure 8: *Diplectanum* sp. 1 collected from silver kob. (A) Whole mount. (B) Median bar.

***Diplectanum* sp. 2** (squamodiscs absent)

Host: *Argyrosomus inodorus* Griffiths & Heemstra, 1995

Site: Skin, gills

Locality: Henties Bay, Mile 108 and Toscanini, Namibia

Specimens studied: seven whole-mount adult specimens measured

Description:

Body elongated (Figure 9A) measured 1309 µm (1141–1597; n = 7) total length and 299 µm (165–368; n = 7) mid body width. Haptor (Figure 9B) measured 236 µm (223–254; n = 4). Median bar (Figure 9C) longer and slimmer than those of other *Diplectanum* species measured 112 µm (105–124; n = 7) total length, 18 µm (16–22; n = 7) maximum width and 8 µm (6–10; n = 7) minimum width (see Figure 4). Transverse bar measured 73 µm (47–96; n = 7) total length. The superficial root on ventral hamulus raised to almost 90°. Ventral hamulus (Figure 9D) measured: length (a) 58 µm (55–62; n = 7); length (b) 53 µm (50–58; n = 7); length (c) 29 µm (27–34; n = 7); length (d) 25 µm (24–27; n = 7) (see Figure 4). In some instances lengths (c) and (d) almost equal. Dorsal hamulus (Figure 9E) measured: length (a) 56 µm (53–60; n = 7) and length (b) 51 µm (49–53; n = 7) (see Figure 4). Hamuli had quite a sharp curve. This species was also characterised by only one pair of conspicuous eyespots.

Long, ridged male copulatory organ (Figure 9F) measured 106 µm (54–137; n = 7) total length. Funnel-shaped sclerotized canal (Figure 9G) sometimes slightly curved, measured

44 µm (28–51; n = 7) total length and 13 µm (5–19; n = 7) maximum width. This species was similar to *D. simile* in the morphology of its haptor, but had a longer male copulatory organ than that of *D. simile* described by Oliver (1980).

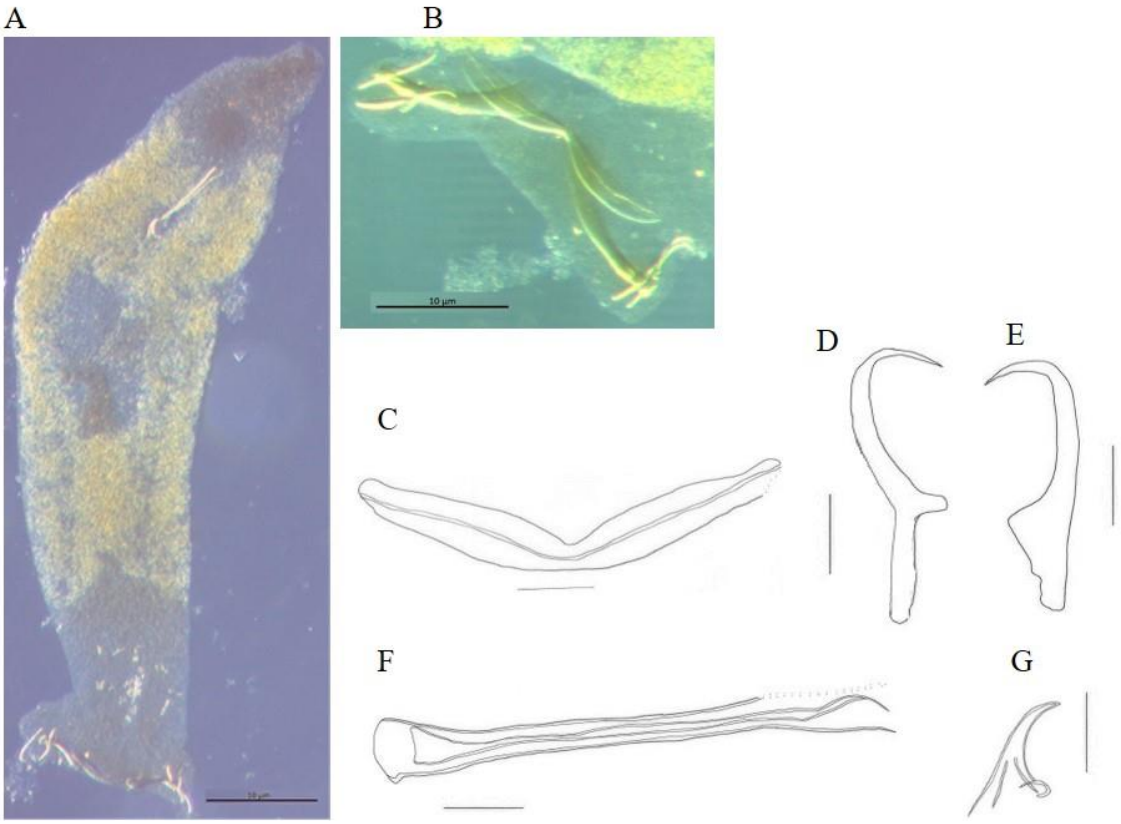

Figure 9: *Diplectanum* sp. 2 collected from the gills of silver kob. (A) Whole mount. (B) Haptor. (C) Median bar. (D) Ventral hamulus. (E) Dorsal hamulus. (F) Male copulatory organ. (G) Sclerotized canal. Scale bars: (A & B) 10 µm. (C-G) 20 µm.

***Diplectanum* sp. 3 (*D. sciaenae* Van Beneden & Hesse, 1863)** (squamodiscs absent)

Host: *Argyrosomus inodorus* Griffiths & Heemstra, 1995

Site: Skin, gills

Locality: Henties Bay, Mile 108 and Toscanini, Namibia

Specimens studied: Eight whole-mount adult specimens measured

Description:

Total body length 915 µm (748–1066; n = 5) and 146 µm (79–229; n = 4) mid width. Haptor width 260 µm (238–296; n = 4). Lip-shaped median bar measured 104 µm (97–110; n = 8) length, 21 µm (19–24; n = 8) maximum width and 14 µm (12–16; n = 8) minimum width. The transverse bar measured 91 µm (82–96; n = 8) total length. Curved hamuli consisted of ventral hamulus: length (a) 66 µm (64–68; n = 8); length (b) 61 µm (60–63; n = 8); length (c) 35 µm (34–37; n = 8); length (d) 26 µm (25–27; n = 8); and dorsal hamulus length (a) 59 µm (58–61; n = 8) and length (b) 55 µm (54–56; n = 8) (see Figure 4).

The male copulatory organ measured 55 µm (49–67; n = 8). The sharply curved sclerotized canal had a total length measured 30 µm (27–34; n = 8) and maximum width measured 8 µm (5–12; n = 8).

II. *Calceostoma* spp.

Class: Monogenea van Beneden, 1858

Subclass: Polyonchoinea Bychowsky, 1937

Order Dactylogyridea Bychowsky, 1937

Family: Calceostomatidae Parona & Perugia, 1890

Genus: *Calceostoma* van Beneden, 1852

Species in the genus *Calceostoma* have been reported from the gills and skin of fish all over the world including Australia and southern Africa (Williams 1989; Stewart 2005). The genus comprises eight species of which only two are described; *Calceostoma herculanea* Euzet & Vala, 1975 and *Calceostoma glandulosum* Johnston & Tiegs, 1922, synonym *Calceostoma calceostoma* Williams, 1989 (see appendix 1. j.). Three *Calceostoma* species are described from the gills of silver kob.

***Calceostoma glandulosum* Johnston & Tiegs, 1922**

Host: *Argyrosomus inodorus* Griffiths & Heemstra, 1995

Site: Gills, skin

Locality: Henties Bay, Mile 108 and Toscanini, Namibia

Specimens studied: Four whole-mount adult specimens measured

Description:

Body elongate, total body length measured 6250 µm (4200–8000; n = 4) and maximum body width 1000 µm (900–1100; n = 4) (Figure 10). Hood-like lappet (Figure 10E) with irregular margins at anterior end measured 1225 µm (200–1900; n = 4) maximum width. Two pairs of small conspicuous eyespots just anterior to the pharynx. The pharynx (Figure 10E) measured 290 µm (234–322; n = 4) total length and 271 µm (227–342; n = 4) maximum width. The haptor consisted of a median bar with a T-shaped anterior end and a paddle-shaped posterior end, which was associated with a pair of hamuli (Figure 10A-C). The median bar measured 225 µm (220–233; n = 4) total length and 50 µm (44–53; n = 4) anterior end "T" width. The hamulus (Figure 10C) measured 200 µm (188–213; n = 4) total length. The male copulatory organ (Figure 10D) had a total length (a), 189 µm (179–195; n = 4); length (b), 165 µm (159–171; n = 4) and 24 µm (21–26; n = 4) width (see Figure 5).

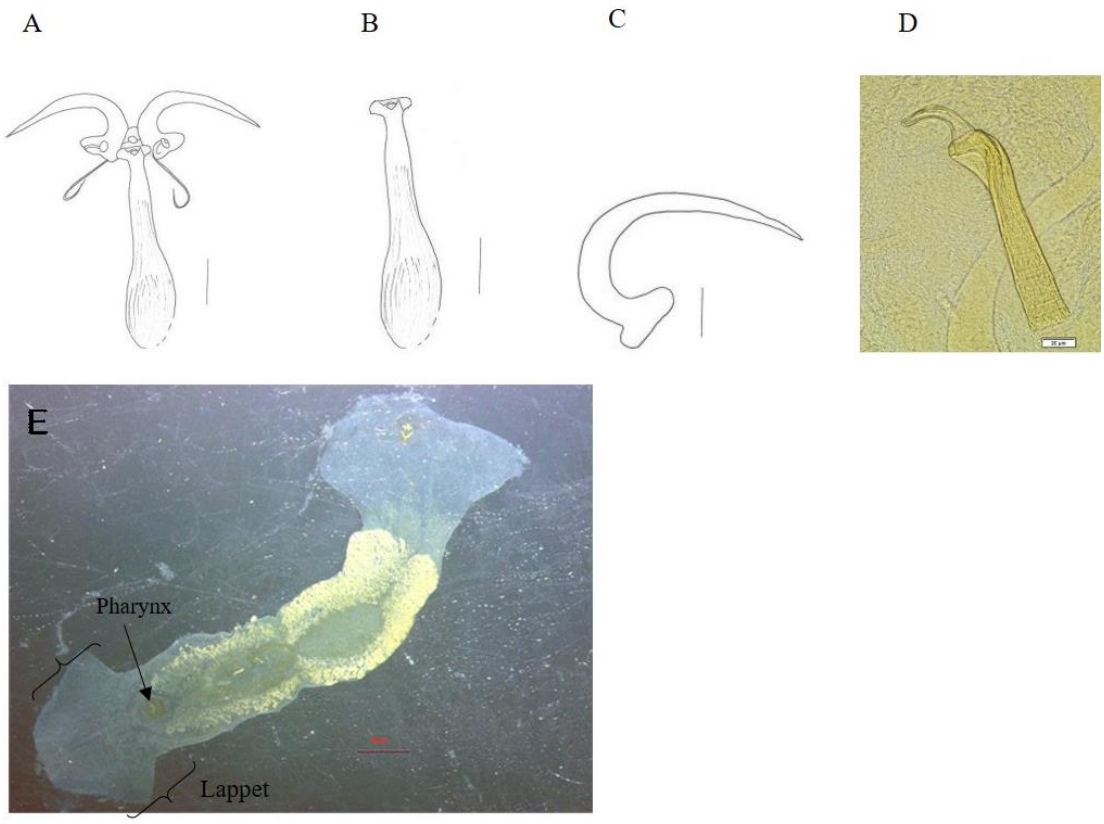

Figure 10: *Calceostoma glandulosum* collected from gills of silver kob. (A) Haptor with median bar and hamuli. (B) Median bar. (C) Hamulus. (D) Male copulatory organ. (E) Whole mount. Scale bars: (A-D) 20 µm, (E) 2.5 mm.

***Calceostoma* sp. 1**

Host: *Argyrosomus inodorus* Griffiths & Heemstra, 1995

Site: Gills, skin

Locality: Henties Bay, Mile 108 and Toscanini, Namibia

Specimens studied: Twelve whole-mount adult specimens measured

Description:

Total body length 5242 µm (2100–7000; n = 12) and 808 µm (400–1200; n = 12) maximum body width (Figure 11). Lappet maximum width measured 1324 µm (520–2000; n = 9). Pharynx length 175 µm (153–236; n = 9) and 188 µm (128–273; n = 9) maximum pharynx width. The median bar (Figure 11B) measured 138 µm (119–154; n = 12) total length, 40 µm (34–46; n = 12) width. Anterior end "V" rather than "T" shaped. The hamulus (Figure 11C) measured 145 µm (131–156; n = 12) length. The male copulatory organ length (a) 160 µm (114–187; n = 12); length (b) 131 µm (93–158; n = 12) and 12 µm (9–23; n = 12) MCO width (Figure 5).

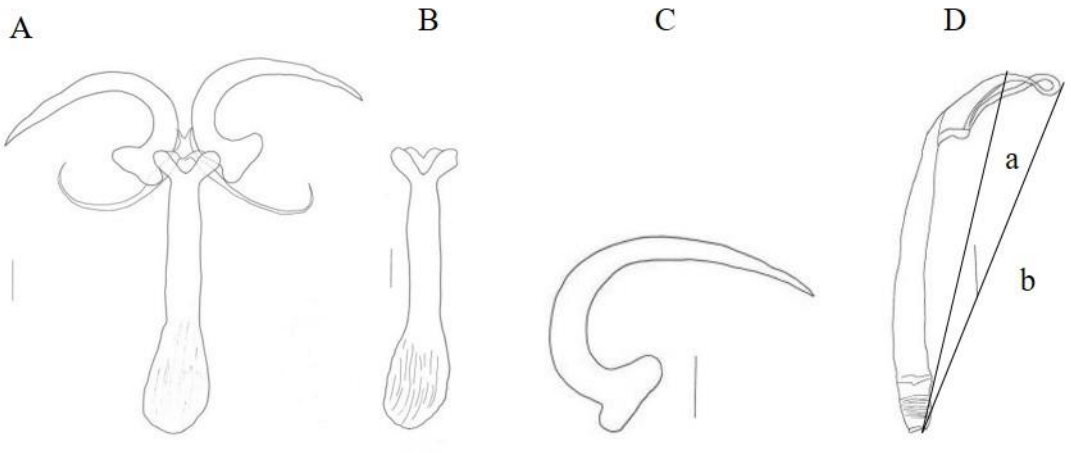

Figure 11: *Calceostoma* sp. 1 collected from silver kob. (A) Haptor with median bar and hamuli. (B) Median bar. (C) Hamulus. (D) Male copulatory organ. Scale bars: (A, B) 20 µm, (C, D) 20 µm.

***Calceostoma* sp. 3**

Host: *Argyrosomus inodorus* Griffiths & Heemstra, 1995

Site: Gills

Locality: Henties Bay, Namibia

Specimens studied: One adult whole-mount specimen measured

Description:

Only one individual was found throughout the study and its distinctive features are briefly described (Figure 12). Body length 2800 µm and 200 µm maximum body width. Pharynx measured 115 µm length and 133 µm maximum width. The median bar (Figure 12B) had a thinner posterior end than those of other *Calceostoma* species and measured 101 µm in

length and 40 µm anterior end (“V”) length. The hamulus (Figure 12A, C) measured 214 µm total length. Male copulatory organ (Figure 12D) 63 µm total length (a) 51 µm length (b) and 7 µm width (see Figure 5).

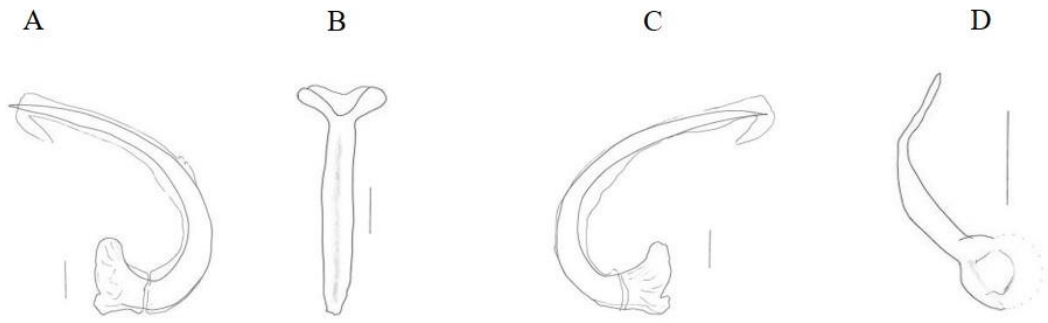

Figure 12: *Calceostoma* sp. 3 collected from silver kob. (A) Hamulus. (B) Median bar. (C) Hamulus. (D) Male copulatory organ. Scale bars: (A-C) 20 µm, (D) 20 µm.

III. *Sciaenacotyle* sp.

Class: Monogenea Van Beneden, 1958

Subclass: Polyopisthocotylea Bray, 2001

Order: Mazocraeidea Price, 1936

Family: Mycrocotylidae Taschenberg, 1879

Genus: *Sciaenacotyle* Mamaev, 1989. Syn. *Mycrocotyle* Van Beneden & Hesse, 1862

Mycrocotylids are recognisable by their possession of large numbers of clamps that are relatively simple and lack accessory sclerites (Hayward *et al*. 2007). Up 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) (Ktari 1970) in Tunisia, congeners meagre, *Argyrosomus regius* (Merella *et al*. 2009) in Sardinia and mulloway, *Argyrosomus japonicus* (Hutson *et al*. 2011) in Australia. 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 on the size of the host, as parasites on larger hosts grow faster than those infesting smaller hosts (Hayward *et al*. 2007). In addition, temperature may also impact length and clamp size. The parasites collected during the current study slightly differ from these two described species and are briefly described here.

***Sciaenacotyle* sp**.

Host: *Argyrosomus inodorus* Griffiths & Heemstra, 1995

Site: Gills

Locality: Henties Bay, Mile 108 and Toscanini, Namibia

Specimens studied: Thirteen whole-mounts of adult and juvenile specimens measured

Description:

Elongated body measured 8123 µm (4000–11400; n = 13), total body length and 1208 µm (500–1800; n = 13) maximum body width (Figure 13). Possessed a triangular posterior haver that occupied about a third of the total body coated by numerous clamps on the outer lining (Figure 11F). The haver measured 4000 µm (1600–5400; n = 13). The genital atrium (Figure 11A) opened ventrally, was formed by two globular muscular masses, and consisted of one pair of symmetrical continuous genital hamuliform spine rows (instead of two as described for the other two *Sciaenacotyle* species), parallel to each other (Figure 13A). These spinal rows of the genital atrium (Figures 13A and C) interchanged, where they bent anteriorly with the longer outer spinal row coiling inwards at the anterior end and the shorter spinal row coiling outwards at the anterior end as they continued in a parallel manner. The number of genital hamuliform spines of the outer spiral rows increased toward the end of the row (Figure 13B). The hamuliform spine counted 139 (131–154; n = 5) in total number and measured 8 µm (3–11; n = 5) length at anterior end (Figure 13B), mid length 21 µm (14–28; n = 5) (Figure 13C) and 11 µm (6–10; n = 5)

length at posterior end (Figure 13D). Spines at the anterior end slightly curved compared to the spines at the posterior end that were straight and also sharper. Spines at the middle of the row had a hook that was curved and a blade that was curved at almost 90° (Figure 13C).

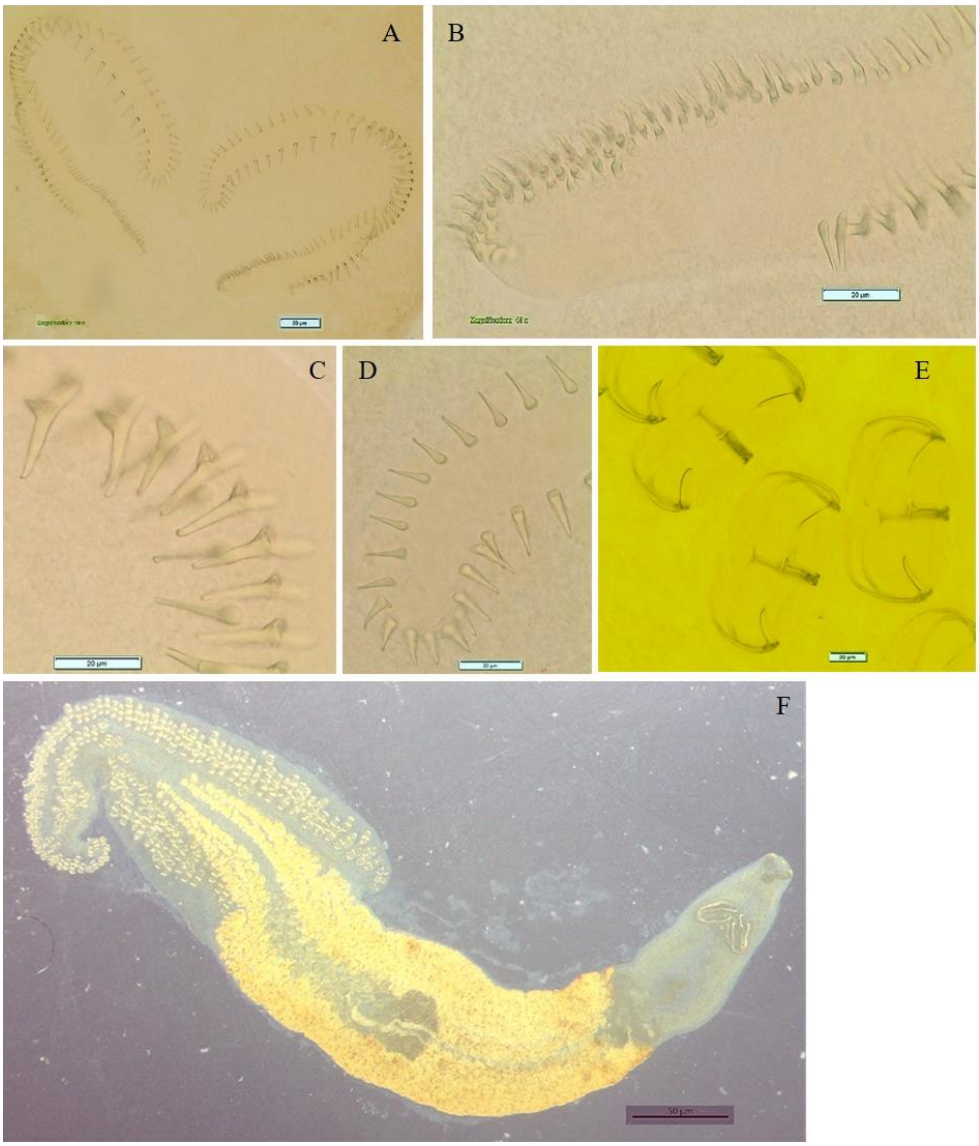

Figure 13: *Sciaenacotyle* sp. collected from the gills of silver kob. (A) Genital atrium. (B) Genital anterior end hamuliform spines. (C) Genital mid hamuliform spines. (D) Genital posterior end hamuliform spines. (E) Clamps. (F) Whole mount.

IV. Other monogeneans

Species from the genera *Neocalceostoma* Tripathi, 1959 and *Sinodiplectanotrema* Zhang in Zhang, Yang & Liu, 2001 were also found on *A. inodorus* in the present study. These monogeneans rarely occurred and the numbers obtained were insufficient for comparisons and hence descriptions. In addition, there are not many studies that have found these parasite species and/or described them. Thus they are only listed here (Figure 14).

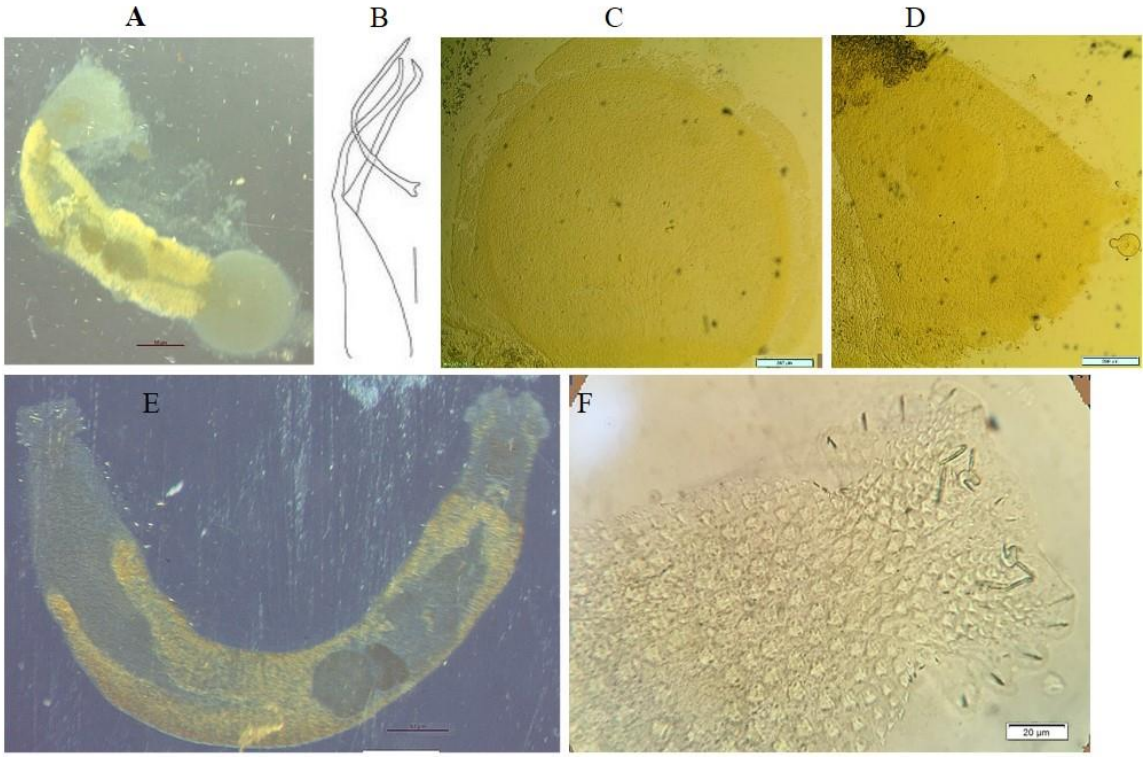

Figure 14: *Neocalceostoma* sp. (A) whole mount. (B) Male copulatory organ of *Neocalceostoma* sp. (C) Disc-like posterior end with two barely visible hamuliform of *Neocalceostoma* sp. (D) *Neocalceostoma* sp. posterior end. (E) *Sinodiplectanotrema* sp. whole mount. (F) *Sinodiplectanotrema* sp. posterior end. Scale bar: (B) 20 µm.

3.4.1.2 Digeneans

Two cysts of the digenean trematode *Stephanostomum* sp. Looss, 1899 metacercariae were collected from the gills of *Argyrosomus inodorus*. These two cysts were only found in January 2018, of which one had a single *Stephanostomum* larval individual and another cyst had "twin" larvae inside it. Encysted metacercaria of *Stephanostomum* have been described in the fin, skin, muscle, gill, pericardium and spleen of fish species including *S. baccatum* and *S. tenue* (Gibson, 1996, Ngamniyom *et al.* 2017). This is the first report of this digenean trematode on the gills of *A. inodorus*.

3.4.1.3 Copepods

Copepods are a group of crustaceans. Their lifecycle involves a series of nauplius and copepodid stages (Hogans & Trudeau 1989). The time it takes to complete the lifecycle depends on water temperature. High temperatures reduces the time it takes to complete the lifecycle compared to low temperatures. Copepods have been reported on both cultured and wild marine fin fish (Johnson *et al*. 2004). The species could be a vector for viruses, bacteria and protozoans, and is responsible for most disease outbreaks in cultured systems, having the potential to affect growth, fecundity and survival of their host (Johnson *et al*. 2004).

I. *Caligus* sp.

Class: Hexanauplia Oakley, Wolfe, Lindgren & Zaharof, 2013

Subclass: Copepoda Edwards, 1840

Order: Siphonostomatoida Thorell, 1859

Family: Caligidae Burmeister, 1834

Genus: *Caligus* Muller, 1785

Caligus is a genus of crustaceans (sea lice) of the family Caligidae (Johnson *et al*. 2004). A total of 429 species are currently accommodated in this genus (WoRMS 2018). Members of the family Caligidae are the most commonly reported parasitic copepods on marine and brackish water fish all over the world. Caligids have a direct lifecycle that consists of two free-living planktonic nauplius stages, one free-swimming infectious copepodid stage, 4-6 attached chalimus stages, 1-2 pre-adult stages and one adult stage (Hogans & Trudeau 1989; Johnson *et al.* 2004). The anterior part of the body is broad and bears jointed appendages whereas the posterior part ends in a fork or furca (caudal rami). During this study, three stages of the species were collected (Figure 14), but only the adult stage is described (Figure 15).

***Caligus* sp.**

Host: *Argyrosomus inodorus* Griffiths & Heemstra, 1995

Site: Skin, fins

Locality: Mile 108 and Toscanini, Namibia

Specimens studied: One whole-mount specimens studied. No measurements taken

Description:

The *Caligus* parasite had a close resemblance to *Caligus elongatus* von Nordmann, 1832 described by Parker (1969) and Kabata (1992) (Figure 15). Slender body with abdomen longer than wide, oval-shaped genital segment approximately half the length of the abdomen (Figure 15A). Abdomen was not segmented (Figure 15A and I). The strongly developed and elongate tines of the sternal furca were fork-shaped and had two sharp spines (Figure 15B). The naked distolateral setae of the first legs were bifurcate (Figure 15C). The coxobasic (containing coxal and base) segment, endopod and exopod of the second leg and their plumule and naked setae were also shown (Figure 15D). The second antennae of the species in the present study (Figure 15H) presented a much shorter and less sharper end than those described from Parker (1969), Hogans & Trudeau (1989) and Kabata (1992).

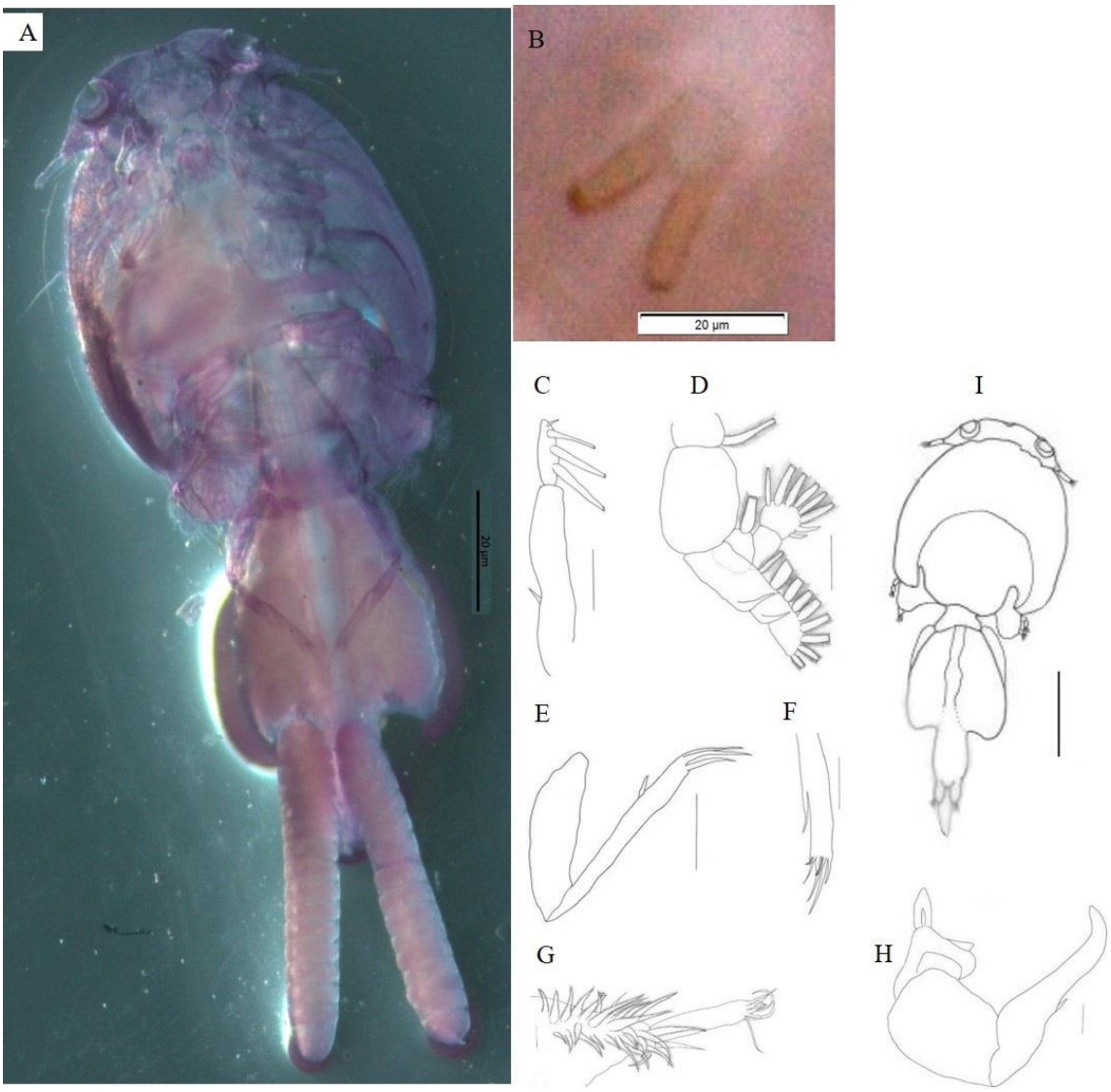

Figure 15: *Caligus* sp. collected from the skin and fins of silver kob. (A) Whole mount. (B) Sternal furca. (C) First swimming leg. (D) Second swimming leg. (E) Maxilla. (F) End of fourth swimming leg. (G) First antenna (antennule). (H) Second antenna. (I) Whole mount drawing. Scale bars: (C-F) 200 µm, (G&H) 50 µm, and (I) 2.5 mm

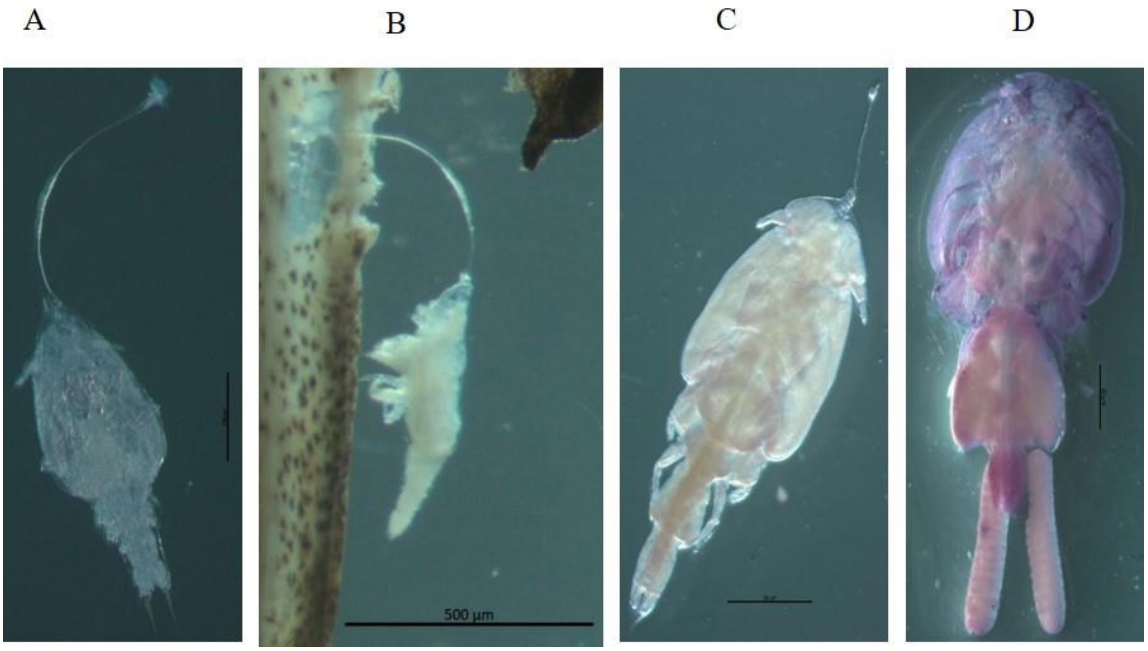

Figure 16: *Caligus* sp. different life stages. (A) Stage 7 detached from a fin and (B) attached on a fin. (C) Towards stage 8. (D) Adult stage. Scale bars: (A-C) 500 µm, (D) 2.5 mm

II. Other copepods:

Five other copepod species were found (Figure 17), including species from *Sciaenophilus* van Beneden, 1852 genus (Figure 17A and B), *Lernanthropus* de Blainville, 1822 genus (Figure 17C and D), two *Brachiella* Cuvier, 1830 species (Figure 17E and F) and an unknown copepod (not displayed). There are very few studies that have found these parasite species and described them, therefore they are only listed below.

Figure 17: Copepod collected from the gills of silver kob. *Sciaenophilus* sp., (A) ventral and (B) lateral view. *Lernanthropus* sp., (C) male and (D) female. Notice the egg sacks. (E) *Brachiella* sp. 1 and (F) *Brachiella* sp. 2, notice the egg sacks. Scale bars: (A-F) 2.5 mm

3.4.2 Internal parasites of Namibian silver kob (*Argyrosomus inodorus*)

3.4.2.1 Monogeneans

***Calceostoma* sp. 2**

Host: *Argyrosomus inodorus* Griffiths & Heemstra, 1995

Site: Stomach

Locality: Henties Bay, Mile 108 and Toscanini, Namibia

Specimens studied: Three whole-mount specimens measured

Description:

Calceostoma sp. 2 (Figure 18) was morphologically almost similar to *Calceostoma* sp. 1 (Figure 11). Distinctive characteristics for *Calceostoma* sp. 2 included: Body slimmer and darker in colour than *Calceostoma* sp. 1. Total body length 4633 µm (2900–6900; n = 3) and 567 µm (400–800; n = 3) maximum body width (Figure 18A). Lappet not hood-like but less developed than *Calceostoma* sp. 2 (2000 µm; n = 1). This could be an adaptation mechanism to allow it to attach properly to the host stomach walls. Pharynx length 303 µm (294–312; n = 2) and 276 µm (261–292; n = 2) pharynx maximum width. The Haptor (Figures 18B) consisted of a median bar (Figure 18C) which measured 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 18D). The male copulatory organ (Figure 18E) had a coiled anterior end and a thin posterior end and measured 184 µm (173–202; n = 3) length (a), 139 µm (125–153; n = 3) length (b) and 13 µm (12–13; n = 3) width (see Figure 5).

Unlike *Calceostoma* sp. 1 which was found on the gills of silver kob, *Calceostoma* sp. 2 were mostly found attached at the threshold walls of the stomach rather than in the middle of the stomach itself.

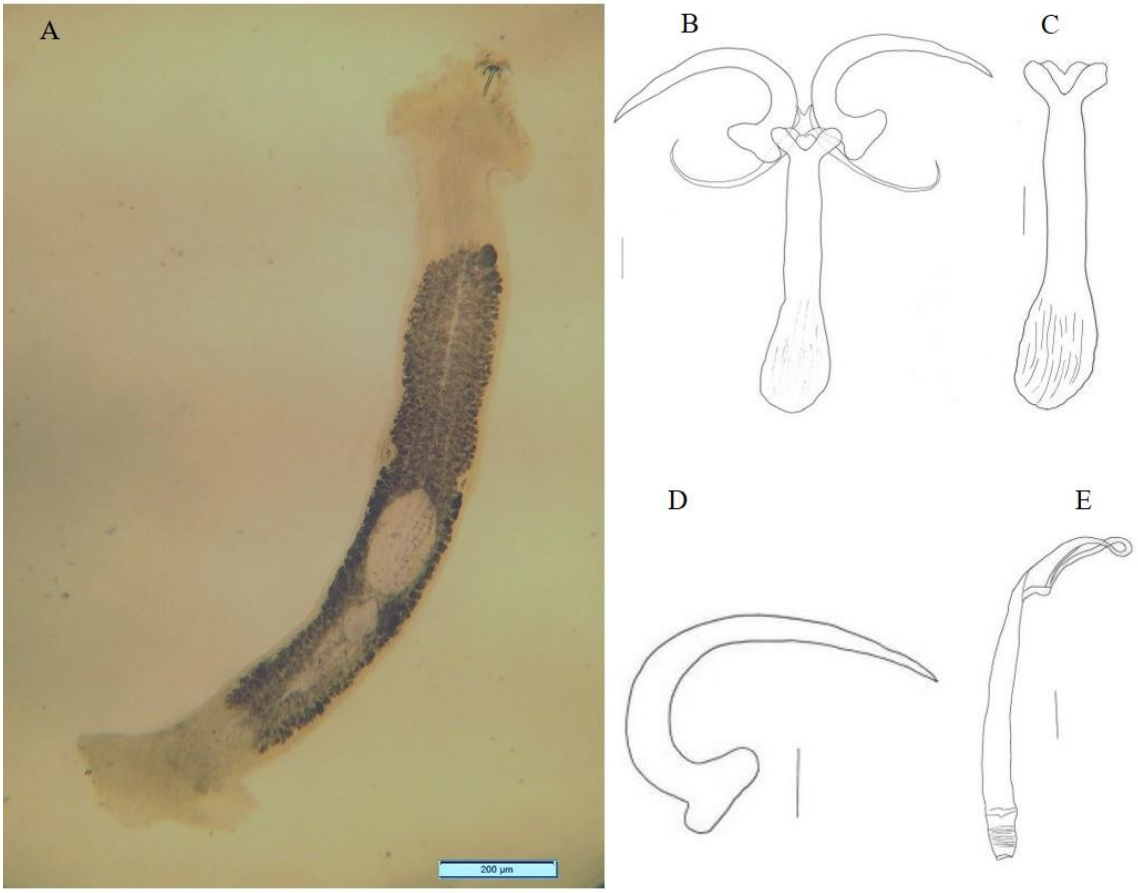

Figure 18: *Calceostoma* sp. 2 collected from the stomach of silver kob. (A) Whole mount. (B) Male copulatory organ. (C) Hamulus. (D) Haptor with median bar and hamuli. (E) Median bar. Scale bar: (B-E) 20 µm

3.4.2.2 Digeneans

The digenean trematode represents the largest group of parasites and comprises approximately 18 000 families (Bannai 2017). They have been reported and described throughout a broad geographical range from multiple fish hosts across broad taxonomic ranks. *Helicometra* sp. and *Helicometrina* spp. described in the current study are opecoelids. The opecoelid *Helicometra* Odhner, 1902 is one of the largest genera and has undergone several taxonomic reorganisations along with the creation of numerous, and often confusing, synonymous taxa (Blend & Dronen 2015). *Helicometra* has a wide distribution and has been reported from marine fish along the Pacific, California, southern Chile, Atlantic, Brazil, coasts of America and South Africa (Bannai 2017).

The Acanthocolpid digenean *Stephanostomum* (Lühe 1906), a large genus and getting larger, parasitise a wide range of teleost fish (Bray & Cribb 2004; Bray & Reimer 2004; Al-Zubaidy 2011). Two species of *Stephanostomum*, *S. kovalevae* Parukhin, 1968 and *S. beukelaardori* Bray & Reimer, 2004 were found off Swakopmund and off Walvis Bay, Namibia respectively (Bray & Reimer 2004).

The general life cycle of digenean trematodes involves multiple hosts. Development of rediae and cercariae takes place in the marine snails and crustaceans. Small fish serve as second intermediate host and adult trematodes develop in big fish and mammals that feed on infected small fish, serving as definitive or final hosts. The trematodes are generally associated with two suckers; an oral sucker that opens into the gut, and the ventral sucker that is used for attachment.

I. *Helicometra* sp.

Class: Trematoda Rudolphi, 1808

Subclass: Digenea Carus, 1863

Order: Plagiorchiida Gibson, 2001

Family: Opecoelidae Ozaki, 1925

Genus: *Helicometra* Odhner, 1902

***Helicometra* sp.**

Host: *Argyrosomus inodorus* Griffiths & Heemstra, 1995

Site: Stomach, intestines

Locality: Henties Bay, Mile 108 and Toscanini, Namibia

Specimens studied: Two whole-mount specimens measured

Description:

The morphological characteristics of *Helicometra* sp. resemble those of *Helicometra gibsoni* Meenakshi, Madhavi and Swarnkumari, 1993. Oval-shaped aspinose body measured 3900 µm (3200-4600; n = 2) total length, 900 µm (800-1000; n = 2) body width. Terminal oral sucker that measured 292 µm (287-296; n = 2) length and 305 µm (302-

307; n = 2) width. Ventral sucker larger than oral sucker measured 467 µm (461-473; n = 2) length and 441 µm (400-482; n = 2) width. Pharynx tubular and measured 113 µm length and 121 µm width. *Helicometra* sp. was also characterised by tandem and lobed testes and the uterus was coiled spirally between the ovary and the ventral sucker.

II. *Helicometrina* spp.

Class: Trematoda Rudolphi, 1808

Subclass: Digenea Carus, 1863

Order: Plagiorchiida La Rue, 1957

Family: Opecoelidae Ozaki, 1925

Genus: *Helicometrina* Odhner, 1902

Host: *Argyrosomus inodorus* Griffiths & Heemstra, 1995

Site: Stomach, intestines, pyloric caeca

Locality: Northern Benguela, Namibia

Specimens studied: Five adult whole-mount specimens measured

***Helicometrina labrisomi* Oliva *et al*., 2015**

Description:

Elongated body with total body length of 5250 µm (5200–5300; n = 2) and maximum body width of 2900 µm (for both) (Figure 19A). Oesophagus short, and muscular pharynx that was wider than long, measured 159 µm (146–171; n = 2) length and 172 µm (148–196; n = 2) width. Oral suckers measured 420 µm (404–430; n = 2) length by 403 µm (386–419; n = 2) width. The ventral sucker had a length of 605 µm (593–618; n = 2). They possessed nine smooth oval testes that were symmetrical, four on one side and five testes on another side. Uterus with 3–4 loops.

***Helicometrina nimia* Linton, 1910**

Description:

This one specimen of *H. nimia* was different from the other of the genus and there were no other specimens to make comparisons, but the distinctive features are highlighted (Figure 19B). It had a total elongated body length of 3 500 µm and maximum body width of 1 000 µm. The terminal oral sucker measured 319 µm total length by 327 µm width and the ventral sucker 573 µm by 582 µm total length by width respectively. Short oesophagus and unlike *Helicometrina labrisomi*, the muscular pharynx was longer than wide, measured 187 µm total length by 142 µm total width. The uterus had six loops

instead of three or four. It also had nine testes, smooth, oval and symmetrical of which five were aligned on one side and four on the other.

Figure 19: Species of the genus *Helicometrina* found in the stomach, intestine and pyloric caeca of silver kob. (A) *Helicometrina labrisomi* in lignin pink. (B) *Helicometrina nimia* in GAP solution.

***Helicometrina* sp. 1**

Description:

Two individuals of *Helicometrina* sp. 1 were separated from *H. nimia* as they possessed four instead of nine testes which were lobed rather than smooth. They were smaller than *H. labrisomi* (Figure 19A), measured 2,450 µm (2000–2900; n = 2) total body length and 1,250 µm (1000–1500; n = 2) maximum body width. The terminal oral sucker was 247

µm (245–248; n = 2) long and 253 µm (247–259; n = 2) wide. Ventral sucker measured 498 µm (495–501; n = 2) total length and 508 µm (498–518; n = 2) total width. The uterus had 5-6 loops.

III. *Stephanostomum* sp.

Class: Trematoda Rudolphi, 1808

Subclass: Digenea Carus, 1863

Order: Opisthorichiida Lühe, 1906

Family: Acanthocolpidae Lühe, 1906

Genus: *Stephanostomum* Looss, 1899

***Stephanostomum* sp.**

Host: *Argyrosomus inodorus* Griffiths & Heemstra, 1995

Site: Stomach, intestines

Locality: Henties Bay, Mile 108 and Toscanini, Namibia

Specimens studied: Two whole-mount specimens measured

Most specimens of *Stephanostomum* sp. could not be measured due to ventral flexing of the fixed body (Figure 20A). The description here is therefore based on only two specimens.

Description:

Elongated body with a narrow anterior and widened at ventral sucker (Figure 20). Total body length measured 2900 µm (2500–3400; n = 2) and 383 µm (366–400; n = 2) maximum body width. Oral sucker terminal, surrounded by spines and much wider than long with total length 104 µm (94–113; n = 2) and width 209 µm (160–258; n = 2). Oval-shaped ventral sucker with total length 253 µm (231–286; n = 2) and width 253 µm (226–229; n = 2). Eggs measured 88 µm (73–103; n = 2) length and 34 µm (28–43; n = 2) width.

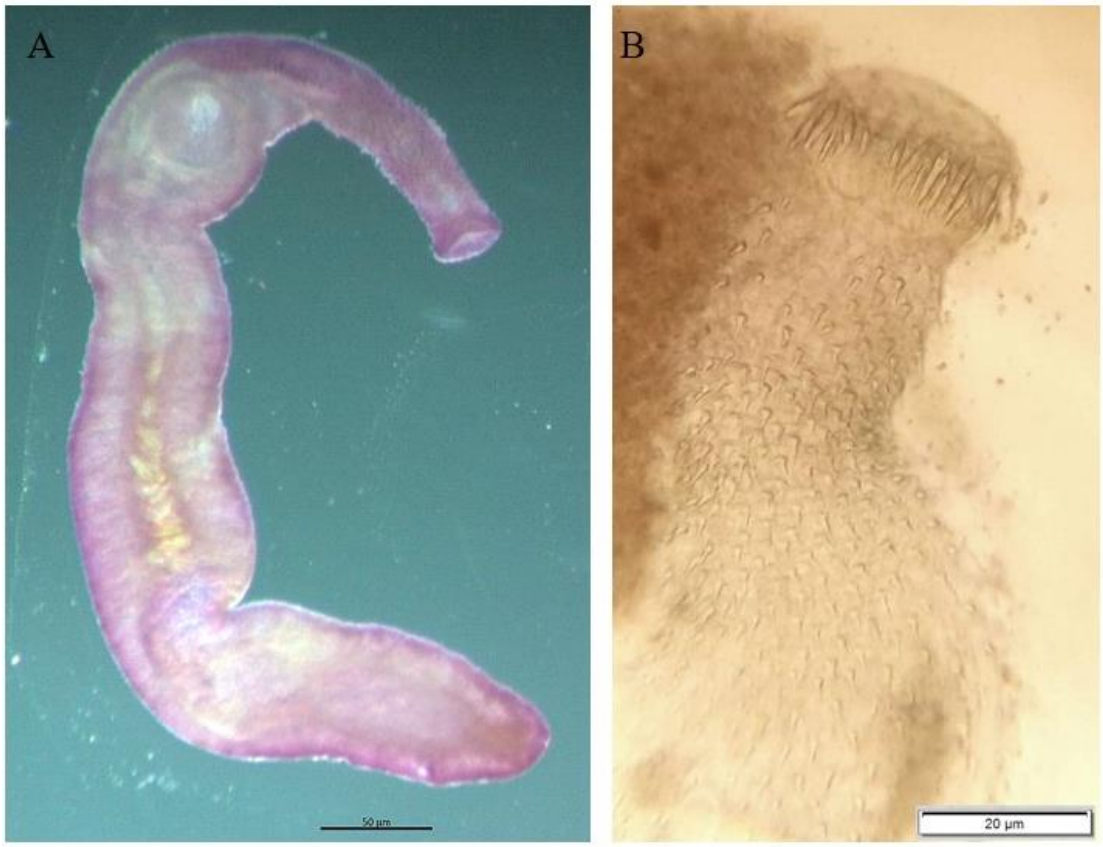

Figure 20: *Stephanostomum* sp. found in the stomach and intestines of silver kob. (A) Whole mount stained in lignin pink. (B) Anterior end of unstained specimen.

3.4.2.3 Cestodes

I. *Callitetrarhynchus* sp.

Class: Rhabditophora Ehlers, 1985

Order: Trypanorhyncha Bray, 2001

Family: Lacistorhynchidae Guiart, 1937

Genus: *Callitetrarhynchus* Pintner, 1931

Host: *Argyrosomus inodorus* Griffiths & Heemstra, 1995

Site: Stomach

Locality: Mile 108, Namibia

Specimens studied: Specimen damaged. No measurements taken.

Callitetrarhynchus sp. were found in the stomach of two silver kob hosts, one in January and one in February 2018. The larvae possessed a pair of bothridia. All were encysted but the one mounted was in the early stage (Figure 21A), while the one that was found in February was in the late stage (Figure 21B). The stages were determined based on the development of the bothridia and state of the tentacles. The specimens are assumed to be *C. gracilis* (Rudolphi, 1819) Pintner, 1931, but the samples were damaged and characteristic features of the tentacles and bulbs could not be elucidated. Larval *Callitetrarhynchus* sp. have been recorded from other fish hosts such as the red grouper (*Epinephelus morio* Valenciennes, 1828, Pisces: Sarranidae) in southern Mexico (Moravec *et al*. 1997) and hake (*Merluccius gayi peruanus* Ginsburg, 1954) in Peru (Chero *et al*. 2014). More study is needed to clearly describe, classify and supplement the findings in the current study.

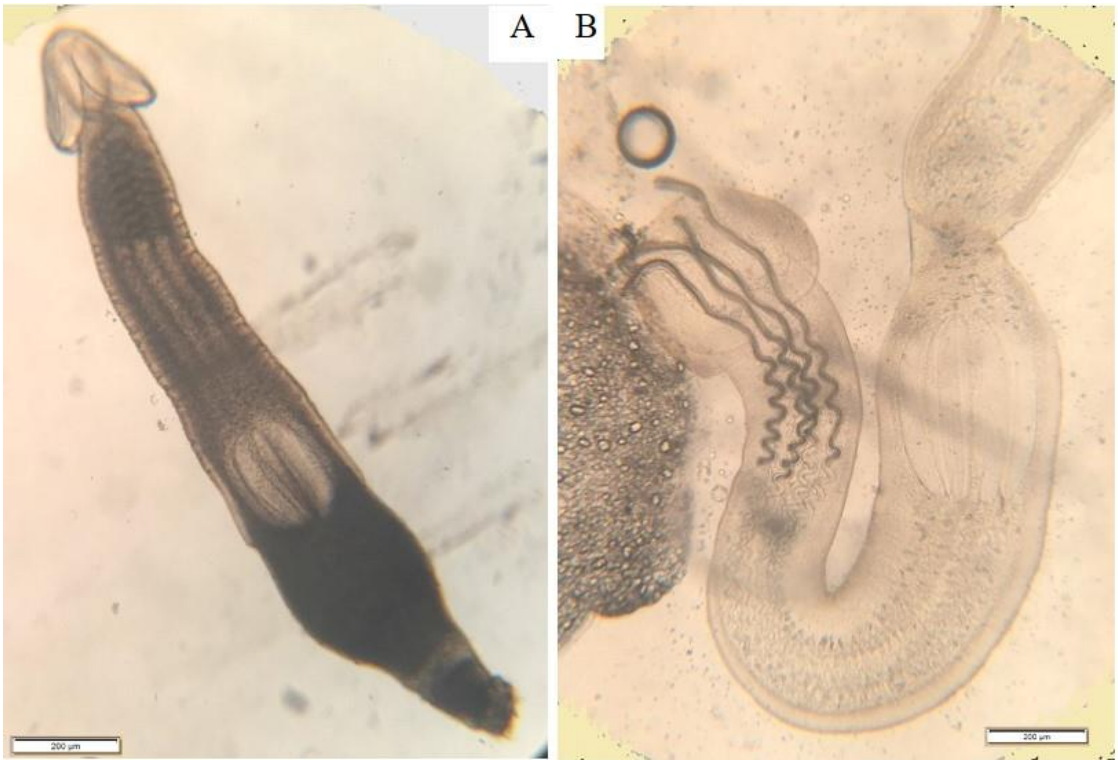

Figure 21: *Callitetrarhynchus* sp. larvae found encysted in the stomach of silver kob. (A) Early larval stage. (B) Late larval stage, notice the tentacles suspended.

II. Order Tetraphyllidea

Class: Rhabditophora Ehlers, 1985

Order: Tetraphyllidea Bray, 2001

Host: *Argyrosomus inodorus* Griffiths & Heemstra, 1995

Site: Stomach

Locality: Mile 108 and Toscanini, Namibia

Specimens studied: Specimens damages. No specimens measured

Tetraphyllidean plerocercoids (metacestodes) were found on very rare occasions in the stomach of silver kob (Figure 22). They have a lanceolate body, and a scolex with an epical sucker and four sessile monocular bothridia. The bothridia have free posterior edges and an accessory sucker at their anterior end. There have been occasional reports of these metacestodes in marine fish, and especially in marine mammals. They are rarely described in detail and the ecological significance of their infection remains unclear (Agustí *et al*. 2005).

Figure 22: Tetraphyllidean plerocercoids (metacestodes) found in the stomach of silver kob.

3.4.2.4 Nematodes

Class: Chromadorea De Ley & Blaxter, 2004

Order: Rhabditida Chitwood, 1933

Family: Anisakidae Railliet & Henry, 1912

Genus: *Anisakis* Dujardin, 1845

***I.* *Anisakis* sp.**

Host: *Argyrosomus inodorus* Griffiths & Heemstra, 1995

Site: abdominal cavity, stomach

Locality: Henties Bay, Mile 108 and Toscanini, Namibia

Specimens studied: Seven whole-mount larval specimens measured

Anisakis is a common parasite in marine fish, including finfish (Molina-García & Sanz 2002). The most common species is *Anisakis simplex* Rudolphi, 1809 and has been reported all over the world in different marine fish species including sciaenids, predominantly collected from the visceral organs and even the muscles of the fish (Molina-García & Sanz 2002; Hutson *et al*. 2011). Their occurrence can cause a deterioration of fish quality and can be of great concern to human health if ingested in raw or undercooked fish (Deardorff & Kent 1989). Their lifecycle involves crustaceans as

transport hosts, fish as intermediate hosts and marine mammals such as seals and whales as final or definitive hosts (Molina-García & Sanz 2002).

Throughout all months of this study, *Anisakis* larvae were collected from silver kob hosts (Figure 23). It is difficult to identify the larvae to species level, but they have been differentiated from other Anisakidae genera mainly due to the absence of intestinal ceca and the shape and position of the ventriculus, in accordance with Anderson *et al*. (2009). Their total body length measured 2,371 µm (1900–3300; n = 7) and maximum body width 300 µm (200–500; n = 7).

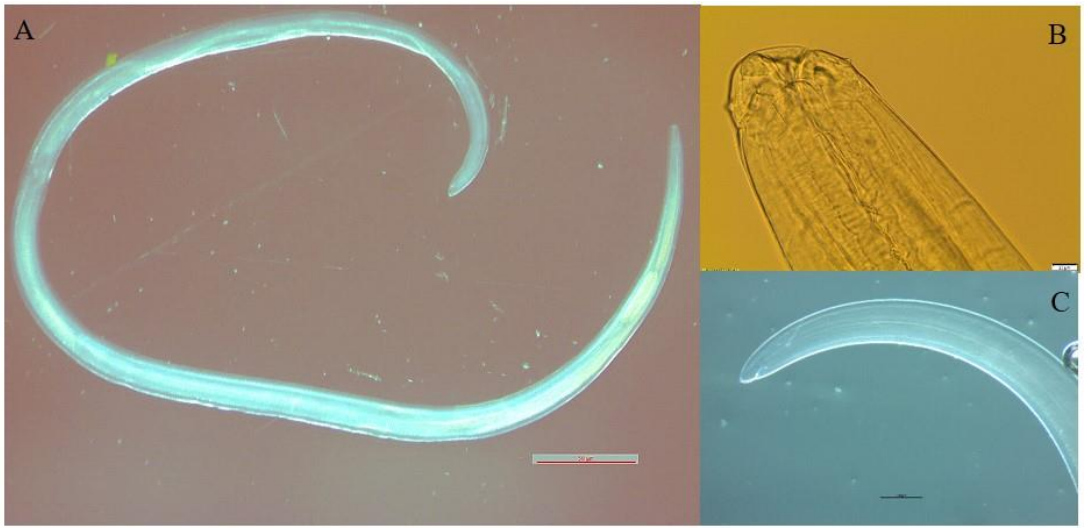

Figure 23: *Anisakis* sp. collected from the abdominal cavity and stomach of silver kob. (A) Whole mount. (B) Anterior end. (C) Posterior end. Scale bar: (A & C) 50 µm. (B) 20 µm.

3.2.4.5 Acanthocephala

Class: Palaeacanthocephala Meyer, 1931

Order: Polymorphida Petrochenko, 1956

Family: Polymorphidae Meyer, 1931

Genus: *Corynosoma* Lühe, 1904

Acanthocephala is a phylum that is closely associated with the Cestoda phylum (Amin 2013). 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 (Sardella *et al*. 2005; Ionita *et al*. 2008; Amin 2013).

Acanthocephalans are characterised by a thorny anterior termed "proboscis" that serves as an attachment organ and "drills" firmly into the walls of the intestines 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 (Silva *et al*. 2014). 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 (Hayunga 1991).

***Corynosoma australe* Johnston, 1937**

Host: *Argyrosomus inodorus* Griffiths & Heemstra, 1995

Site: Abdominal cavity

Locality: Henties Bay, Mile 108 and Toscanini, Namibia

Specimens studied: Six whole-mount specimens measured (three males, three females)

The measurements of *Corynosoma australe* in this study were not described separately for females and males 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*. (2005) (also see Appendix 1. n.).

It is noteworthy that these *Corynosoma australe* were all found in the abdominal cavity of *A. inodorus* and none of them were attached. Some of them were encysted with short, possibly still developing, proboscises. The proboscis receptacle retained its normal length as well as the proboscis end which was rather flat. Others were not encysted but their proboscis had still not evaginated (termed cystacanths rather than juveniles).

Description:

Total body length 3,331 µm (2867–3647; n = 5) and maximum body width 1,076 µm (943–1211; n = 6) (Figure 24). Females possessed a relatively wider maximum body width than males. The spiny proboscis measured 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, and measured 258 µm (236–273; n = 5) in total length and had a maximum neck width of 424 µm (400–448; n = 5). Trunk length measured 2,448 µm (2063–2617; n = 5) and was relatively longer in males and females. The genital spines had 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 measurement: right testes length 117 µm; right testes width, 85 µm; left testes length 112 µm and left testes width 88 µm.

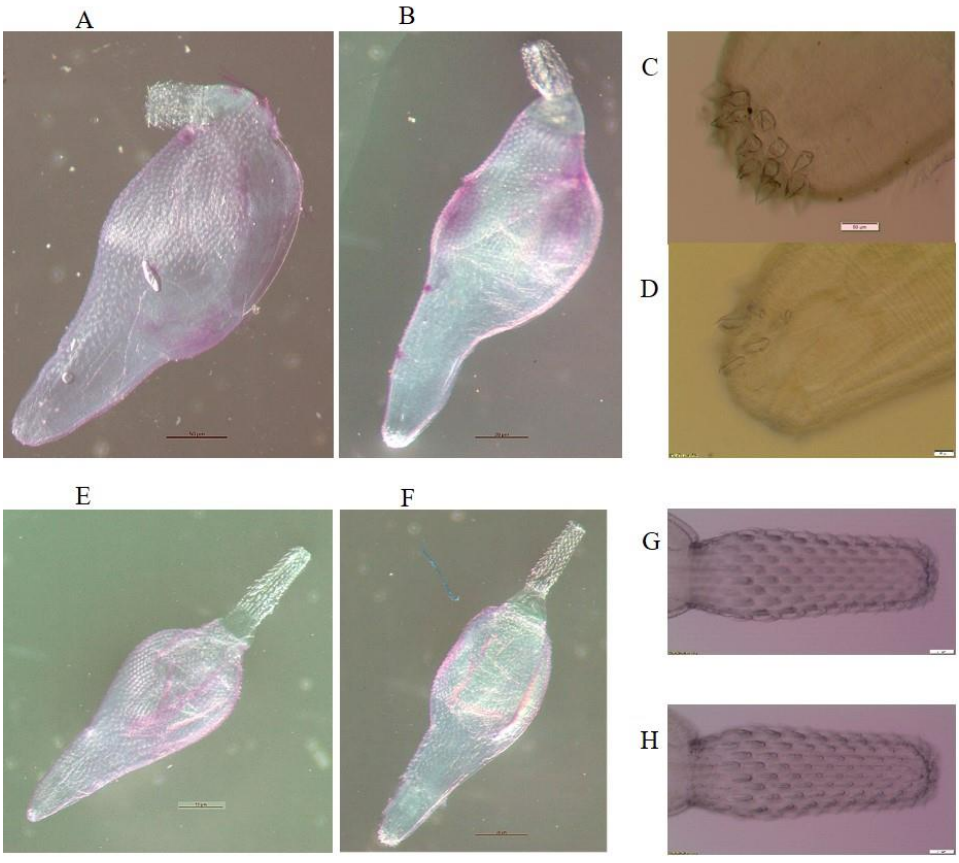

Figure 24: Palaeacanthocephalan *Corynosoma australe* collected from the abdominal cavity of silver kob. (A) Female and (B) male developing a proboscis. (C) Male and (D) female genital spines of adult *Corynosoma australe*. (E) Adult female and (F) male *Corynosoma australe*. (G) Proboscis of adult *Corynosoma australe*, notice hooks and (H) hook arrangemet.

3.4.3 Granulomas

In addition to parasites, white empty nodules were found in the gills, abdominal cavity, liver and musculature of some silver kob examined (Figure 25). An increased number of these nodules showed conspicuous paleness of the liver and softened musculature of the host flesh.

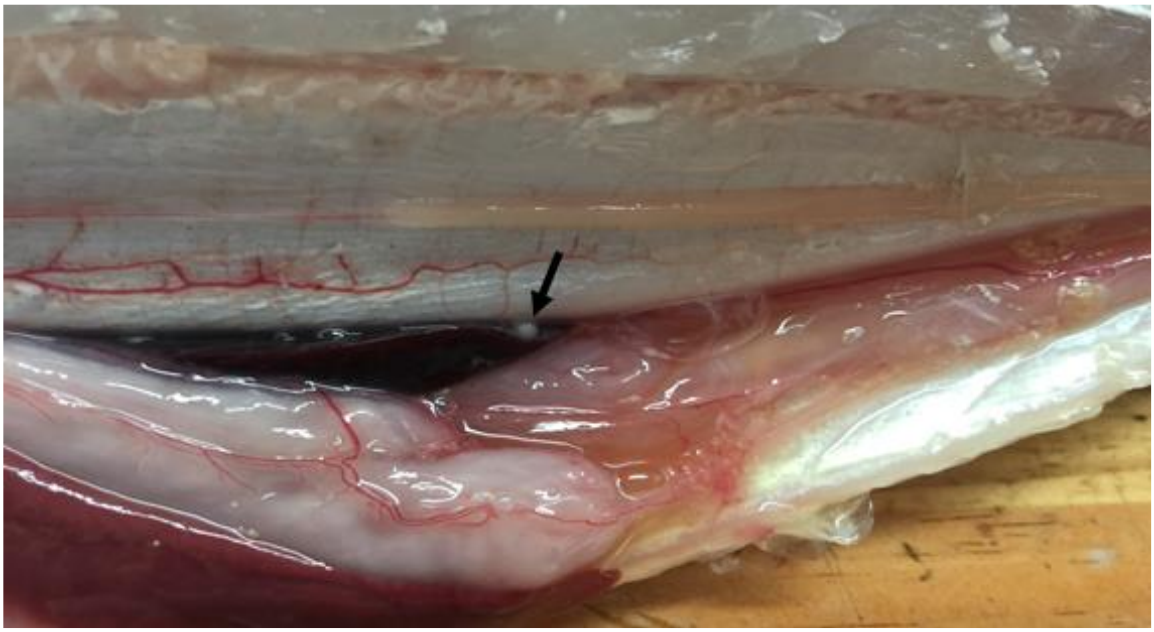

Figure 25. White empty nodule in the abdominal cavity of silver kob.

3.5 Discussion

Twenty-eight parasite species from 17 genera were identified from silver kob (*A. inodorus*) over 11 months. Of these 28 species, 18 species were external parasites (64%), and 10 species were internal parasites (36%). In total, 4652 parasite individuals were collected throughout the study of which only 1725 (37%) were external parasites and 2927 were internal parasites (63%). Thus, although external organs were most species rich,

internal organs were numerous. These results concur with results from Aloo-Obudho *et al.* (2004) who also observed parasite species richness in external organs and richer parasite communities in internal organs. The reason for the richer communities of internal parasites found in the present study could be that internal parasites are acquired from the daily diet of silver kob, feeding on shrimps, prawns and small crustaceans, and are acquired in large numbers because of their small sizes (Poulin 2004). They are easily acquired and hardly lost because they are protected from external factors by the gastrointestinal tract which they inhabit. On the contrary, external parasites are exposed to the external environmental factors such as variations in the marine water quality that influence and challenge their attachment and well-being (Poulin 2004). In addition, external parasites, for instance monogeneans, have a shorter lifespan than internal parasites that includes only one host. This means that they decrease and increase in numbers at faster rates than internal parasites.

Granuloma nodules found in the gills, abdominal cavity, liver and musculature of Namibian *A. inodorus* could be signs of a certain bacterium granuloma similar to those described by Paperna 1987, Labella *et al.* (2011), Katharios *et al*. (2011) and Costa *et al*. (2017) in cultured meagre (*A. regius*) from sea-cages and inland facilities. Little is known about the cause of the granulomas, but infectious agents and metabolic disorders have been suspected as contributing factors (Paperna 1987; Katharios *et al*. 2011). There have been several reports of this bacterial pathogen causing diseases in humans and it may therefore be considered as a zoonotic agent (Labella *et al*. 2011). Katharios *et al*. (2011) described the disease as associated with low but constant mortalities, that varied seasonally (Labella *et al*. 2011), and the infected fish showed visible symptoms of reduced

growth and eroded fins, haemorrhagic areas, and resulted in an unacceptably low and/or demolished market value. Noticeable erosion of the fins and devaluation of the flesh have been observed in some fish examined in the present study. This needs to be considered when considering mariculture of *A. inodorus*.

Parasites, such as some diplectanids and calceostomids, could not be identified to species level due to differences in morphology and measurements which caused uncertainties. This could because it is difficult to take 100% accurate measurements that lead to the differences. It could also be due to differences in geographical areas in which the hosts inhabited, which have different environmental conditions, hence might have an effect on the morphology of the parasites. Nonetheless, molecular work is required to supplement the findings and identify them to species level. There was a lack of information on some parasites that could help identify the specimens to species level. Some specimens, such as for Cestodes were damaged in the process of removal, and it was difficult to identify them further to their species level

In conclusion, silver kob is subject to many external parasite species than internal parasite species especially monogeneans (*Diplectanum* spp. and *Calceostoma* spp.). Different parasites have different effects on fish hosts and could cause deterioration of fish quality, secondary infections and in severe cases (high abundances), lead to fish mortalities. For example, Monogeneans and nematodes are not pathogenic, but can diminish economic value of fish. Digeneans could be pathogenic in high abundances, depending on the intensity of infestation (parasite load). Copepods could be carriers for bacteria and viruses. Other parasites (monogeneans and digeneans) could also act as vectors of viruses and bacteria. Acanthocephalans cause damage that could cause secondary infections. These

parasites therefore, need to be taken into consideration in a mariculture set-up in order to apply effective measures to prevent, detect and control parasite out-breaks.

Chapter 4: Parasite organ specificity in Namibian silver kob (*Argyrosomus inodorus*)

4.1 Introduction

The organ specificity of parasites is often studied, but it is usually limited to certain host organs or parasite species. For example Williams (1989) only studied gill monogeneans from *Argyrosomus hololepidotus*, Bray and Reimer (2004) studied two *Stephanostomum* spp. (*S. kovalevae* and *S. beukelaardori*) from intestines of *Lophius vomerinus*, Khanum *et al.* (2011) only studied gastrointestinal helminths from *Macrognathus aculeatus*, and Kotungondo (2014) (unpublished data) only focused on gill and gastrointestinal parasites of *Argyrosomus inodorus*. So far, there are no published records on organ specificity of external and internal parasites of Namibian *A. inodorus*. This gap is addressed in this chapter.

4.2 Objective

To determine parasite organ specificity in Namibian silver kob.

4.3 Methods

Parasites were recorded according to their organ of infestation. Parasites found infesting one specific organ on silver kob throughout the study were said to be organ specific. Parasites found infesting more than one organ on silver were nor organ specific. The percentage organ specificity was calculated as follows:

$$(S\ \%) = \frac{Number\ of\ organ\ specific\ parasites\ species}{Total\ number\ of\ parasite\ species} \times 100\% \quad (4)$$

4.4 Results

Seventeen parasite genera were identified on silver kob (Table 2). Most parasite genera were associated with the gills. Of the 17 parasite genera, 10 (59%) were specific to one organ each. This includes *Sciaenacotyle* sp. (gills), *Neocalceostoma* sp. (gills), *Helicometra* sp. (stomach), Tetraphyllidean plerocercoid (stomach), *Callitetrarhynchus* sp. (stomach), *Corynosoma australe* (abdominal cavity) *Lernanthropus* sp. (gills), *Sciaenophilus* sp. (opercula) *Brachiella* spp. (gills) and the unknown parasite (gills). Of the 10 external parasite genera, six (60%) were organ specific and of the seven internal parasite genera, four (57 %) were organ specific.

Interestingly, some (usually known to be) external parasites were found in the gastrointestinal tract and vise vesa. For example, a gill monogenean from the genus *Calceostoma* was also discovered in the stomach of silver kob (Chapter 3). Another digenean trematode *Stephanostomum* was recovered from three locations, two gastrointestinal organs (the intestines and the stomach) and from an external organ (the gills), where they were found encysted (larvae). In addition, species of the digenean trematode *Helicometrina* inhabited three different gastrointestinal organs (the intestines, the pyloric caeca and the stomach).

Cestode larvae were 100% organ specific, associated with the stomach only and *Corynosoma australe* were found associated with the abdominal cavity only (Table 2).

Table 2: Site of infestation of 17 external (E) and internal (I) parasite genera found in silver kob from June 2017 to May 2018.

Parasite class	Parasite genus/Order	Site of infestation	E/I	Organ specific
Monogenea	*Calceostoma* spp.	Gills, Skin, Stomach	E&I	No
	Sciaenacotyle sp.	Gills	E	Yes
	Diplectanum spp.	Gills, Skin	E	No
	Sinodiplectanotrema sp.	Skin, Fins	E	No
	Neocalceostoma sp.	Gills	E	Yes
Digenea	*Helicometra* sp.	Stomach	I	Yes
	Helicometrina spp.	Intestines, Pyloric caeca, Stomach	I	No
	Stephanostomum sp.	Intestines, Stomach, Gills	E&I	No
Cestoda	Tetraphyllidean plerocercoid	Stomach	I	Yes
	Callitetrarhynchus sp.	Stomach	I	Yes
Nematoda	*Anisakis* sp.	Body cavity, Stomach	I	No
palaeacantho cephala	*Corynosoma australe*	Body cavity	I	Yes
Copepoda	*Lernanthropus* sp.	Gills	E	Yes
	Caligus sp.	Skin, Fins	E	No
	Sciaenophilus sp.	Operculum	E	Yes
	Brachiella spp.	Gills	E	Yes
	Unknown	Gills	E	Yes

4.5 Discussion

A high percentage of external parasites were organ specific compared to internal parasites Table 2. The reason for this could be to reduce their chances of getting detached in the process of relocating to other organs for better feeding areas (Poulin 2000), so once they are attached they spend their life span on one site. External parasites are free-living in the aquatic environment until they come across a perfect, available and infective form to firmly attach to and inhabit (Poulin 2000; Sobecka 2012). When they do, they hold on tight to the skin and/or fins.

Gill parasites attach to the host as a result of the gaseous exchange between water and the gills. As the water passes through the gills during the gaseous exchange process, the gills accumulate most free-living parasites in the water. This could explain why gills accommodate more parasite species compared to all other host organs. This results concur with results from Kotungondo (2014) (unpublished data) who also found parasites of silver kob from Namibia more abundant on the gills than in the gastro-intestinal tract

Gill parasites have caused mass mortalities in cultured fish over the years and still continue to cause failures in aquaculture (both freshwater and marine aquaculture). The buccal and gill chambers have been greatly inhabited by parasites, especially monogeneans (Kearn 1994). This could be due to direct accessibility and vulnerability of their surface to parasites, which results from their morphological characteristics and purposes. In addition, these chambers provide large, comparatively flat areas of epidermis for attachment and feeding as well as for easy location of a mate (Blahoua *et al.* 2016). Furthermore, environmental water currents are not as strong in the gills as they would be on the skin of a fast moving fish, although the gill aeration current for gaseous exchange is continuous.

Internal parasites are not exposed to external forces and environmental variations, and it is thus easy to move from one organ to another organ within the gastrointestinal tract. This could explain why internal parasites were less organ specific compared to external parasites. Endo-parasites are also affected by changes in the immune response of fish (AYDOĞDU *et al.* 2015) which plays an important protective role for the fish host (Rubio-Godoy 2007). Rubio-Godoy (2007) further explained that some immune defence are activated when the parasites are in abundance. Some parasites, especially those which were found less abundant, example cestodes, could have less tolorence to these immune responses, while it's probably not too harsh for other parasites such as *Helicometrina* spp.

Monogenean parasites are usually host-specific (Rohde & Rohde 2005) and organ-specific as they have a specific haptoral make-up and copulatory organ that is suitable for the organ (internal or external) that they inhabit (Mandeng *et al*. 2015). However, a monogenean, *Calceostoma* sp. 2, was found in the stomach of *A. inodorus,* which was morphologically almost similar to a gill monogenean *Calceostoma* sp. 1 (Chapter 3). Stomach dactylogyrid monogeneans such as *Cichlidogyrus* Paperna, 1960 and *Enterogyrus* Paperna, 1963 have been documented on freshwater fish by Bayoumy & El-Monem (2012), Mandeng *et al*. (2015) and others, but they possessed different haptoral and copulatory characteristics that enable them to adapt to the internal environment of their fish hosts. There has not been any case of monogenean parasites in the gastrointestinal organs of *A. inodorus,* so these findings require more samples and further studies for clarification of their features.

Meanwhile, the following was hypothesised: since these monogenean parasites only infested fish with total length > 35 cm, and since these large *A. inodorus* feed on small pelagic fish (mostly sardine), the monogenean parasites could have survived while being

transferred from the gills of sardine into the stomach of *A. inodorus* during ingestion. To test this hypothesis, the inspection of sardine gills is required to confirm whether gills of sardine are infected with *Calceostoma* sp. 1. Only ≤ two individual *Calceostoma* sp. 2 per infected host was found in the stomach of *A. inodorus*. 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 lifecycle of a monogenean involves a free-living ciliated larva, called oncomiracidium (Whittington *et al*. 1999; Bayoumy & El-Monem 2012). Chances could be that few parasites of *Calceostoma* sp. 1 have been accumulated from the aquatic environment when fish were feeding and very few individuals managed to survive at the threshold of the stomach walls, where all of these parasites were recovered. More studies, including molecular work on *Calceostoma* sp. 1 and *Calceostoma* sp. 2 are therefore required to suppliment 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.

Hayunga (1991), Sardella *et al*. (2005), Ionita *et al*. (2008) and Amin (2013) explained the lifecycle of an acanthocephalan, which *sensu stricto* ends in the lumen of the digestive tract of mostly pinnipeds and fish-eating birds, but some species represent exceptions (Silva *et al*. 2013). In some instances, adult acanthocephalans bore through the walls of the digestive tract and came to lie in the host abdominal cavity (Florkin 2012). In the present study, all *Corynosoma australe* were found lying in the abdominal cavity of *A. inodorus*. *Argyrosomus inodorus* is a definitive host for *Corynosoma australe* and they only bore thought the stomach walls to live in the abdominal cavity to complete its

lifecycle. Silva *et al*. (2014) suggested that parasite's migratory processes can be influenced by daily and seasonal sequences such as availability of the food, host's food intake, intestinal flow, nutritional composition of the food, as well as intra- or inter-specific relationships (such as crowding effect).

A digenean trematode *Stephanostomum* was recovered from three locations, two gastrointestinal organs (the intestines and the stomach) and from an external organ (the gills), where they were found encysted (larvae). Encysted metacercaria of *Stephanostomum* have been described in the fin, skin, muscle, gill, pericardium and spleen of fish species including *S. baccatum* and *S. tenue* (Gibson, 1996, Ngamniyom *et al.* 2017). They devalue the flesh of the fish and cause hinder gaseous exchange in the gills when in abundance as it can cause excessive mucous secretion (Reda *et al.* 2010), limiting the surface area for gaseous exchange (Blazer & Gratzek 1985). Blazer & Gratzek (1985) observed the most consistent sign of infection as flared opercula with protruding gills.

Different species of the digenean trematode *Helicometrina* inhabited three different gastrointestinal organs (the intestines, the pyloric caeca and the stomach). Adult digeneans in fish are primarily parasites of the digestive tract (Constenla *et al.* 2011). Gibson (1996), Constenla *et al.* (2011) and Hutson *et al.* 2011 among others, stated from their studies that digeneans inhibit mostly the three organs, most especially the intestines and pyloric caeca to complete their lifecycles.

Cestodes were all observed to be 100% organ specific, invading only the stomach of silver kob. This results are consistent with Mackiewicz (1988) who stated that cestodes are generally organ specific. By lacking a gut, cestodes, unlike nematodes and trematodes, are unable to exploit diverse environments such as liver, heart or circulatory system and thus

move to the intestinal tract—the environment of unlimited and superabundant food resources (Mackiewicz 1988). Hutson *et al.* 2011 also found cestodes including *Callitetrarhynchus gracilis* and Tetraphyllidea specifically inhabiting the intestinal tract of King George Whiting *Sillaginodes punctatus* Cuvier, 1829.

In conclusion, there was a total of 59% organ specificity of which majority was observed in ecto-parasites than endo-parasites. All copepods were organ specific except *Caligus* sp. which infested the skin and fins. All cestodes were organ specific. Parasite organ specificity is important when considering application of prevention and/or control measures and treatments in a mariculture culture set up. Gastrointestinal parasites might be easier to control in a mariculture set up compared to ecto-parasites by controlling the feed given since they are acquired through a daily diet. This could be done by feeding once-frozen feed or removing the gut of small pelagic fish (e.g. sardine) before feeding it to cultured silver kob. Ecto-parasites, especially monogeneans can be controlled effectively by regular freshwater baths (Stewart 2005).

Chapter 5: Seasonal variation in prevalence, mean abundance and mean intensity of Namibian silver kob parasites

5.1 Introduction

Marine fish parasitology is a rapidly developing field of marine science (Aloo-Obudho *et al.* 2004). This is due to the growing importance of mariculture. In addition, concerns on pollution effects on fish health and a generally increasing interest in marine environmental biology is also one of the main triggers of parasites studied on marine species.

Studies on helminth parasites of marine fish species are scarce in Namibia. The seasonal abundance of helminth parasites has been found to be influenced by various factors such as changes in the immune response of fish at different temperatures, and the feeding habits of the host fish (Aydoğdu *et al.* 2015).

This chapter determines the seasonal variation in prevalence (the proportion of infected hosts), mean abundance (the mean of the number of individuals of a particular parasite species per host examined) and mean intensity (the mean of the number of individuals of a particular parasite species per infected host in a sample) of helminth parasites found on silver kob in Namibia.

5.2 Objective

To determine the seasonal variation in the prevalence, mean intensity and mean abundance of all parasite genera found on Namibian silver kob.

5.3 Methods

Parasites were sorted according to their months of capture. The months of the year were divided into the cold season (June to November) and the warm season (December to May) according to sea surface temperature (SST) recorded in northern Namibia by Bartholomae and van der Plas (2007).

Calceostoma spp., *Diplectanum* spp. and *Helicometrina* spp. were recorded and counted as individual genera during initial examination. Further work on the few preserved specimens resulted in identifying more species of the genus than initially recorded, but not all parasite individuals were preserved because they were numerous and therefore only some (considered enough then) were preserved and the rest were only counted. For this reason, their prevalence, mean intensity and mean abundance by season were calculated for the parasites at genus level (Table 2). However, *Calceostoma* sp. 2 (from the stomach) was recorded separately from the other *Calceostoma* species found on the gills.

The seven most abundant (mean abundance > 1) parasite genera (*Calceostoma* spp., *Sciaenacotyle* sp., *Diplectanum* spp., *Helicometrina* spp., *Stephanostomum* sp., *Anisakis* sp. and *Corynosoma australe*) were used for describing parasite abundance by warm and cold season graphically. Parasite prevalence and mean abundance were plotted per warm and cold season and compared using Chi-square tests.

5.4 Results

5.4.1 Overall prevalence, mean intensity and mean abundance

With all months combined, the nematode *Anisakis* sp. had the highest prevalence (80%) of all parasite genera (Table 3). Cestode larvae *Callitetrarhynchus* sp. had the lowest prevalence (2%). Mean intensity was recorded highest for the acanthocephalan *Corynosoma australe* (66 parasites per infected host) and lowest in *Sinodiplectanotrema* sp., *Neocalceostoma* sp., *Calceostoma* sp. 1, *Helicometra* sp. and *Brachiella* spp. (1 parasite per infected host). Mean abundance was highest for *Corynosoma australe* (43 parasites per host) and lowest for *Neocalceostoma* sp., *Callitetrarhynchus* sp. and *Brachiella* spp. (0.04 parasites per host).

Table 3: Prevalence %, P%, mean intensity, MI, (parasites per infected fish individual) and mean abundance, MA, (parasites per fish individual) of 18 parasite genera found in silver kob from June 2017 to May 2018.

Parasite class	Parasite genus/Order	P%	MI	MA
Monogenea	*Calceostoma* spp.	56	8	4.69
	Sciaenocotyle sp.	56	3	1.95
	Diplectanum spp.	64	35	22.45
	Sinodiplectanotrema sp.	7	1	0.07
	Neocalceosoma sp.	4	1	0.04
	Calceostoma sp. 1	13	1	0.16
Digenea	*Helicometra* sp.	9	1	0.13
	Helicometrina spp.	56	9	4.91
	Stephanostomum sp.	22	8	1.67
Cestoda	Tetraphyllidean plerocercoid	7	2	0.11
	Callitetrarhynchus sp.	2	2	0.04
Nematoda	*Anisakis* sp.	80	5	4.38
Palaeacanthocephala	*Corynosoma australe*	64	66	42.80
Copepoda	*Lernanthropus* sp.	13	3	0.38
	Caligus sp.	18	4	0.69
	Sciaenophilus sp.	5	5	0.27
	Brachiella spp.	4	1	0.04
	Unknown	4	21	0.75

5.4.2 Overall seasonality

Out of a total of 4,652 parasite individuals collected throughout the study, 2,347 (50.5%) were collected during the cold season (June-November 2017) and 2,305 (49.5%) were collected during the warm season (December 2017-May 2018) (Table 4), but these percentages did not differ significantly (x^2 test, $P > 0.05$). Sixteen of the 17 parasite genera

were collected during the warm season (94%), and 14 of the 17 genera were collected during the cold season (82%).

The cold season was associated with the highest total number of parasite individuals per *A. inodorus* host, with 1,770 individuals of *Corynosoma australe*, which was the most abundant parasite species during the cold season (Table 4). Mean intensity for all parasite species combined was higher in the warm season (8.5 parasites per infected host individual) than in the cold season (7.7 parasites per infected host individual). *Neocalceostoma* sp., *Callitetrarhynchus* sp., *Sciaenophilus* sp., and the unknown copepod were only recorded in the warm season. The two *Brachiella* species occurred only in the cold season. There was no significant difference in overall *A. inodorus* parasite mean abundance between the warm and cold season (x^2 test, $P > 0.05$).

The highest prevalence was recorded from *Anisakis* sp. (84%) during the cold season while the least prevalent parasite species were *Sinodiplectanotrema* sp., *Helicometra* sp. and Tetraphyllidean plerocercoid recorded during the cold season (4%).

Table 4: Total number of individual parasites found (Total), number of fish infected, prevalence % (P%, proposition of infected hosts), mean intensity (MI, number parasites per infected fish) and mean abundance (MA, number of parasites per fish exained) of parasite species infesting silver kob separated by the cold season (June to November 2017, n = 25) and the warm season (December 2017 to May 2018, n = 30). Count, number of parasite genera present in the season. Sum, total number of parasite individuals.

Parasites		Cold season (June to November)					Warm season (December to May)				
Parasite class	**Parasite genus/family**	**Total**	**No. infected fish**	**P%**	**MI**	**MA**	**Total**	**Fish infected**	**P%**	**MI**	**MA**
Monogenea	*Calceostoma* spp.	185	14	56.0	13	7.40	73	17	56.7	4	2.43
	Sciaenacotyle sp.	20	10	40.0	2	0.80	88	21	70.0	4	2.93
	Diplectanum spp.	124	15	60.0	8	4.96	1112	20	66.7	56	37.07
	Sinodiplectanotrema sp.	1	1	4.0	1	0.04	3	3	10.0	1	0.10
	Neocalceosoma sp.						2	2	6.7	1	0.07
	Calceostoma sp. 2	4	3	12.0	1	0.16	5	4	13.3	1	0.17
Digenea	*Helicometra* sp.	1	1	4.0	1	0.04	6	4	13.3	2	0.20
	Helicometrina spp.	101	11	44.0	9	4.04	169	20	66.7	8	5.63
	Stephanostomum sp.	6	2	8.0	3	0.24	86	10	33.3	9	2.87
Cestoda	Tetraphyllidean plerocercoid	2	1	4.0	2	0.08	4	3	10.0	1	0.13
	Callitetrarhynchus sp.						2	2	6.7	1	0.07
Nematoda	*Anisakis* sp.	102	21	84.0	5	4.08	139	23	76.7	6	4.63
Palaeacanthocephala	*Corynosoma australe*	1770	19	76.0	93	70.80	530	16	53.3	33	17.67
Copepoda	*Lernanthropus* sp.	5	2	8.0	3	0.20	16	5	16.7	3	0.53
	Caligus sp.	24	7	28.0	3	0.96	14	3	10.0	5	0.47
	Sciaenophilus sp.						15	3	10.0	5	0.50
	Brachiella spp.	2	2	8.0	1	0.04					
	Unknown						41	2	6.7	21	1.37
	Count	14					17				
	Sum	2347		436	146	93.8	2305		527	161	76.83
	Average	124		22.9	7.7	4.94	121		27.7	8.5	4.04

5.4.3 The most abundant parasites' seasonality

Endo-parasite *Corynosoma australe* showed the highest prevalence, mean intensity and mean abundance during the cold season (x2 test, P <<0.05) (Figure 26). For the ecto-parasites, *Calceostoma* spp. mean abundance was significantly higher during the cold season than during the warm season (x2 test, P <<0.05) (Figure 26C, Table 5). Ecto-parasite *Diplectanum* spp. showed a significantly higher mean abundance in the warm season than cold season (x2 test, P < 0.05) (Figure 26C, Table 5). No significant differences in mean abundance between warm and cold were observed for any other parasite genera (Tables 5).

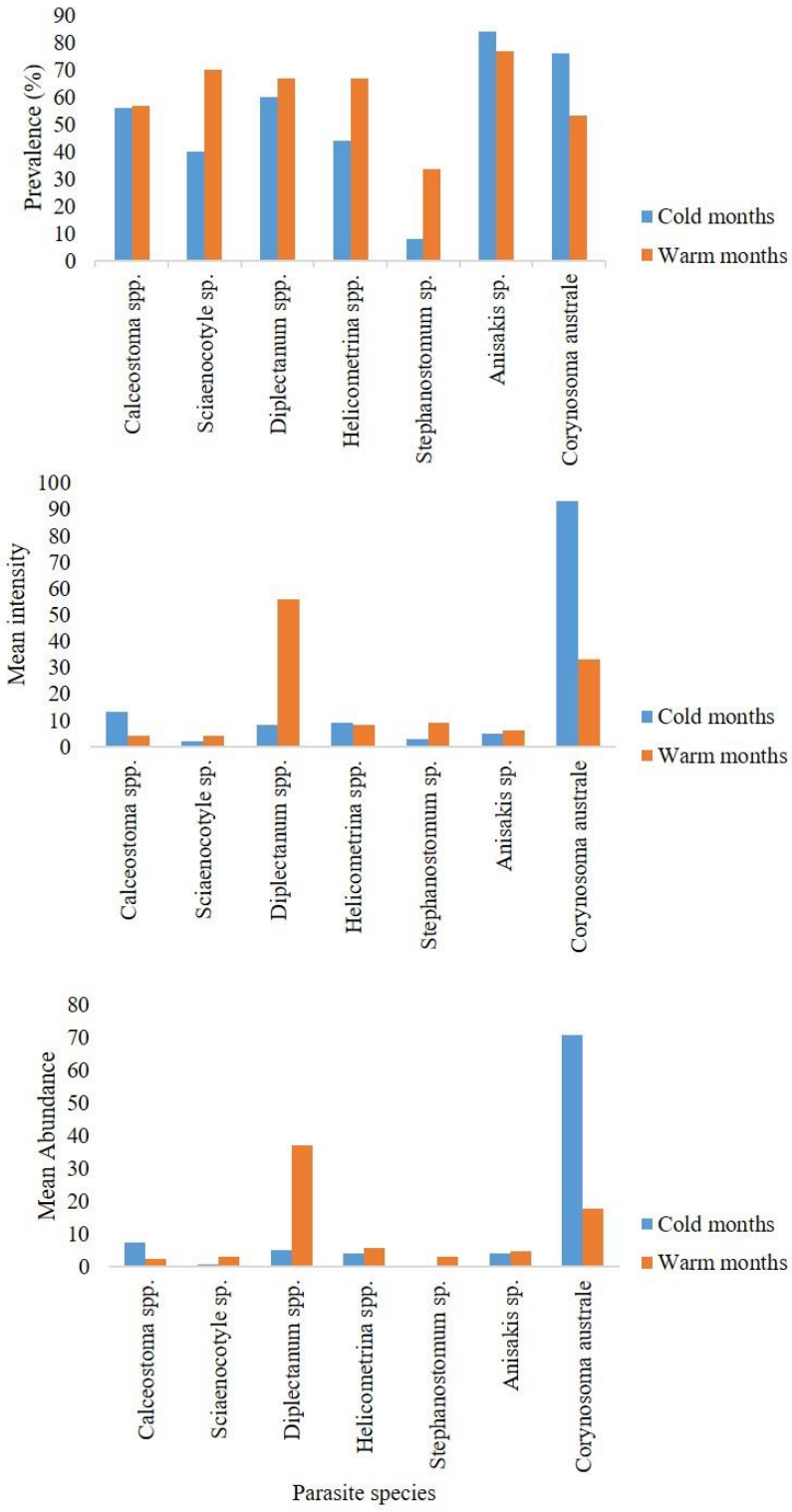

Figure 26: (A) Prevalence, (B) mean intensity and (C) mean abundance of seven of the most abundant parasites species of silver kob during the cold season (June-November 2017) (bars) and the warm season (December 2017-May 2018) (line).

Table 5: Chi-square test results, testing differences in mean abundance between the cold season (June - November 2017) and the warm season (December 2017 - May 2018) of seven parasite genera on silver kob. * indicates significant differences at the 5% level.

Parasite species	Chi-value	P-value
Calceostoma spp.	3.10	0.048*
Sciaenacotyle sp.	1.27	0.187
Diplectanum spp.	24.44	<<0.001*
Helicometrina spp.	0.40	0.516
Stephanostomum sp.	2.35	0.080
Anisakis sp.	0.11	1.132
Corynosoma australe	31.56	<<0.001*

5.5 Discussion

Parasites tend to be more active and intensify more rapidly with increasing temperature, and the abundance of monogeneans (ecto-parasites) could be controlled by temperature (Poulin 1999b). Since external parasites are directly exposed to the marine environment they are also subject to the variations in the physical and chemical environmental parameters. Warm temperatures also increase the primary productivity (planktons) in the marine environment, which means that there will be more nutrition for primary consumers (crustaceans), secondary consumers (small fish) and tertiary consumers (piscivorous fish) (Poulin 1999b, Poulin 2004). This also means that hosts have enough nutrition to maintain their own body need and the needs of the parasites. In addition, ecto-parasites have a direct lifecycle which includes only one fish host (Poulin 2004) and do not need different hosts to complete their lifecycles. It is therefore easier for them to multiply within a short period of time on the host (Poulin 2004; Reed *et al.* 2009; Whittington & Kearn 2011). This

explains the significantly higher abundance of *Diplectanum* spp. in the warm seasonthan in the cold season.

During January-February, the warm Angolan water starts pushing southwards bringing warm, saline water and sometimes tropical fish species from mid-Angola into Namibia (Kirchner & Stage 2005), which may introduce new parasite species to the Namibian water ecosystem. This could possibly be the reason why some parasites such as *Neocalceostoma* sp., *Callitetrarhynchus* sp., *Sciaenophilus* sp. and the unknown copepod were only observed on *A. inodorus* during the warm season and not during the cold season. Galaviz-Silve *et al.* (2016) found that the months of highest temperatures (May to September) were positively correlated with monogenean (*Clavunculus unguis* and *Acolpenteron ureteroecetes*, *Syncleithrium fusiformis*, *Haplocleidus furcatus*, *Clavunculus bifurcatus* and *Urocleidus principalis*) parasite abundance in the largemouth bass *Micropterus salmoides* Lacepède, 1802 from Nuevo León, Mexico. In addition, Kotungondo (2014) (unpublished data) also found parasites generally more abundant in August and September than in June, July and October in silver kob, in Namibia.

There are no studies explaining the effects of temperature on the abundance of *Calceostoma* spp. The present study found *Calceostoma* spp. significantly most abundant during the cold season than in the warm season. These fascinating results are different from those of the rest of the monogeneans and more studies are needed to understand the findings.

Different acanthocephalans present different seasonal parasite prevalence, mean intensity and mean abundance. Zdzitowiecki (1986) examined three common fish parasite species; *Aspersentis austrinus* Van Cleave, 1929, *Metacanthocephalus johnstoni* Zdzitowiecki,

1983 and *Metacanthocephalus dalmori* Zdzitowiecki, 1983 from host fish species *Notothenia coriiceps neglecta* Nybelin, 1951. *Aspersentis austrinus* was found most abundant during the winter season and *M. johnstoni* was most abundant during the summer season. Acanthocephalans hence react differently to changes in environmental parameters, especially temperatures. More studies are required to elucidate how temperature influences the abundance of *Corynosoma australe*.

Kennedy (1970) explained based on laboratory experiments, that high water temperature reduces the success of acanthocephalans. The increased feeding by fish in the summer offsets a lower rate of parasite establishment. This could explain why the acanthocephalan *Corynosoma australe* was significantly more abundant in the cold season than the warm season. Differences in parasite prevalence, mean intensity and mean abundance between seasons may be used to determine the dietary preference and routine for the host (Silva *et al*. 2013). Food preference could result in the crowded pattern of occurrence of the parasites within the host trophic level, *sensu lato* secondary and definitive hosts. It is therefore important to study the seasonal diet composition of *A. inodorus* in order to understand the seasonal differences in mean abundance for *Corynosoma australe* in *A. inodorus*.

The rest of the parasites showed no significant difference in abundance between the cold and warm season. The reason for that could be that the marine environment is broad and temperature variations in the warm season and the cold season in the up-welling northern Benguela current waters are not sufficient to warrant differences in some parasites as would otherwise be expected in higher latitudes and down-welling areas. Also, endo-parasites are not affected by temperatures variations as much as ecto-parasites are because

endo-parasites, unlike ecto-parasites, are not directly exposed to the external environment. This could be the reason why seasonal abundances of most endo-parasites, unlike end-parasites, were not influenced by the warm and cold temperatures.

In conclution, different parasites seemed to have different reactions and sensitivity to seasonal changes. Of all parasites, monogenean *Calceostoma* spp. and paleacanthocephala *Corynosoma australe* were significatly most abundant during the cold season than the warm season. The rest of the parasites where most abundant during the warm season. It is therefore imperative to know the physiology associated with these parasites in relation to seasonal influence.

Chapter 6: Influence of host body size and host sex on prevalence, mean intensity and mean abundance of parasites of Namibian silver kob (*A. inodorus*)

6.1 Introduction

Host body size has been found to be one of the main factors that influence parasite infestation levels on fish hosts (Polyanski 1961; Poulin 2004; Labella *et al*. 2011; Carvallho *et al*. 2015). Poulin (2004) explained that bigger fish have a larger surface area for parasite infestation (Poulin 2004). Additionally, bigger fish also have longer lives and therefore accumulate parasites throughout their lifespan.

The influence of host sex on parasite infestation varies in different studies on different host species and difference parasites. Duneau and Ebert (2012) explained that parasite prevalence and disease expression is often different between males and females, which is mainly attributed to sex-specific differences in host traits, such as immune responses. It was suggested that differences in many traits between host sexes, such as morphology and hormone levels, can impose selection on parasites, which can eventually lead to parasite adaptations specific to the host sex more commonly encountered, or to differential expression of parasite traits depending on which host sex they find themselves in.

Some studies, for example Dias *et al*. (2004) and Ferreira (2008) on marine catfish *Sciades proops* (Valenciennes, 1840) reported that male and female hosts showed no significant differences with respect to intensities and prevalence of parasitism. Although there have been some studies on the parasitic fauna of congeners of *A. inodorus*, no work on

Namibian *A. inodorus* parasite infestation in relation to host size and host sex has been published. In this chapter, this gap is addressed.

6.2 Objective

To determine the influence/effects of host size and host sex on the prevalence, mean abundance and mean intensity of parasites on the Namibian silver kob.

6.3 Methods

To relate parasite prevalence, mean intensity and mean abundance to host size, *A. inodorus* host total lengths (TL) were divided into three length classes of 11.5 cm class width ($\frac{(Max\ length - Min\ length)}{Number\ of\ classes}$). Small size class (TL < 35.8), medium size class (35.8 ≤ TL < 47.3) and large size class (TL ≥ 47.3). Chi-square tests were performed to test for differences in parasite mean abundance between host size classes of the seven most abundant parasite genera (*Calceostoma* spp., *Sciaenacotyle* sp., *Diplectanum* spp., *Helicometrina* spp., *Stephanostomum* sp., *Anisakis* sp. and *Corynosoma australe*).

To determine sex dependency, parasite prevalence, mean intensity and mean abundance were calculated by host sex for all parasite genera. Chi-square tests were performed to determine the significant differences in mean abundance of the seven most abundant parasites and between male hosts and female hosts. Mean abundance and standard deviation (±) were plotted for each length class for the parasites that showed a significant difference were plotted.

6.4 Results

6.4.1 Overall host size dependency

Hosts of the medium size class were subject to most parasite species, with 100% (17 of 17) of the collected parasite genera present in this size class (Table 6). Hosts of the small size class only had 53% (9 of 17) of the parasite genera present. Hosts of the large size class showed the highest overall prevalence (30%) and the highest individual species prevalence of 90% (*Corynosoma australe*). The lowest average prevalence was recorded in hosts of the small size class (26%). The average mean intensity was highest in hosts of the middle size class (10 parasites per infected host), with highest mean intensity recorded from *Corynosoma australe* (84 parasites per infected host). Hosts of the small size class had the lowest average mean parasite intensity (5 parasites per infected host). Average mean abundance was highest in hosts of the large size class (5.4 parasites per host) and lowest in hosts of the small size class (3.1 parasites per host) (Table 6).

Table 6: Prevalence (%, proportion of infected fish), mean intensity (parasites per infected fish host) and mean abundance (parasites per fish host) of 17 parasite genera of silver kob at three host size class: Small size classes (S) (TL < 35.8, n = 5), medium size class (M) (35.8 ≤ TL< 47.3, n = 40) and large size class (L) (TL ≥ 47.3, n = 10).

Parasite	Prevalence			Mean intensity			Mean abundance		
	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3
Calceostoma spp.	80	58	40	27	6	6	21.60	3.20	2.20
Sciaenacotyle sp.	60	55	60	1	3	5	0.80	1.83	3.10
Diplectanum spp.	60	60	80	8	31	59	5.00	18.40	47.50
Sinodiplectanotrema sp.	0	10	0	0	1	0	0	0.10	0
Neocalceosoma sp.	0	5	0	0	1	0	0	0.05	0
Calceostoma sp. 2	20	13	10	1	1	1	0.20	0.18	0.10
Helicometra sp.	0	5	30	0	2	1	0	0.08	0.40
Helicometrina sp.	80	50	70	14	9	5	11.40	4.45	3.50
Stephanostomum sp.	20	20	30	7	9	4	1.40	1.80	0.30
Tetraphyllidean Plerocercoid	0	8	10	0	1	2	0	0.10	0.20
Callitetrarynchus sp.	0	3	10	0	1	1	0	0.03	0.10
Anisakis sp.	60	83	80	4	5	9	2.60	3.85	7.40
Corynosoma australe	60	58	90	22	84	34	13.00	48.00	30.00
Lernanthropus sp.	20	13	10	1	3	3	0.20	0.43	0.30
Caligus sp.	0	23	10	0	3	10	0	0.70	1.00
Sciaenophilus sp.	0	5	5	0	5	5	0	0.25	0.50
Brachiella spp.	0	3	0	0	1	0	0	0.05	0
Unknown	0	5	0	0	21	0	0	1.03	0
Average	25.6	26.5	29.7	4.7	10.4	8.1	3.1	4.7	5.4

6.4.2 Most abundant parasite size dependency

Calceostoma spp. and *Helicometrina* spp. showed a significant decrease in mean number of parasites per host with increasing host size (x^2-test statistic = 28.22 and 5.55, P< < 0.01, respectively, Table 7, Figure 27A & B). *Diplectanum* spp. showed a significant increase in number of parasites per host with increasing host size, p-value approaching 0 (x^2-test statistic = 41.1, P << 0.001, Table 7, Figure 27D). *Corynosoma australe* showed a significantly higher mean abundance for the medium size class than the other classes (X^2-test statistic = 20.0, P < <0.01, Table 7, Figure 27C). All other parasite species showed no

significant difference in numbers of parasites per host with host length classes ($P > 0.05$, Table 7).

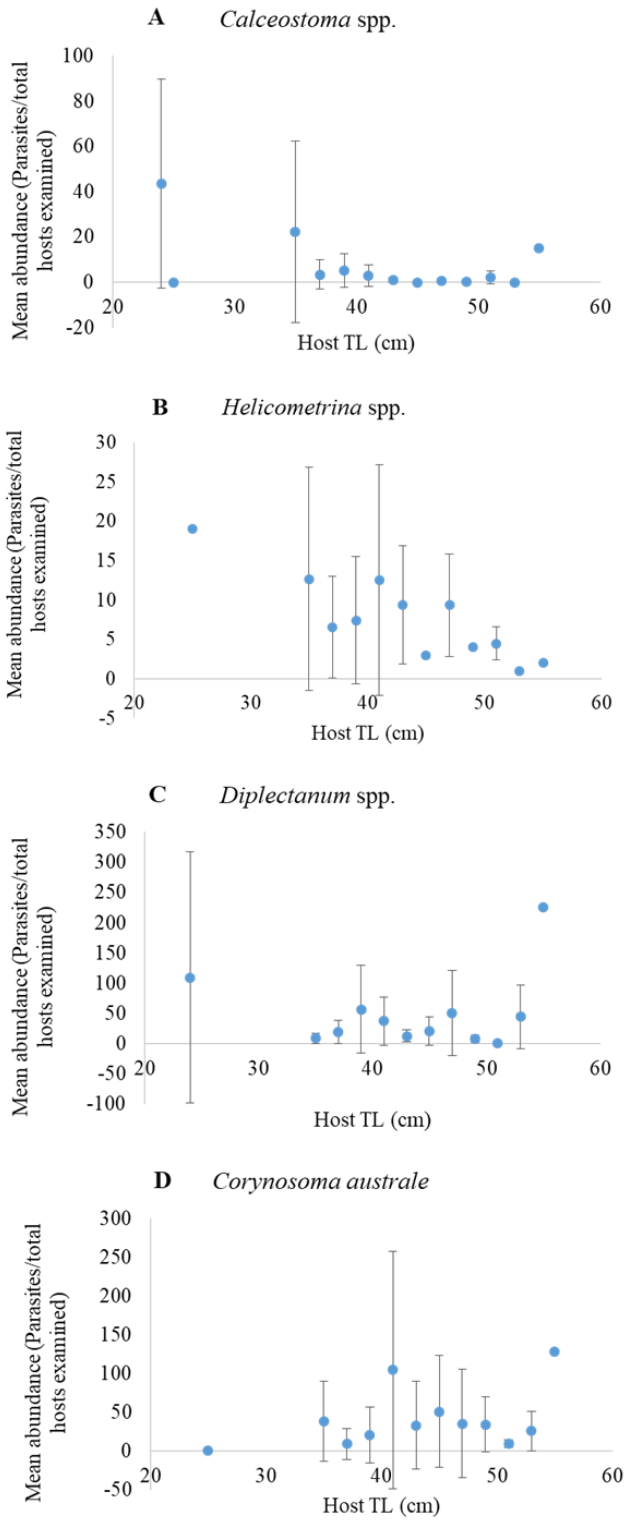

Figure 27: Mean and standard deviations of parasite abundance collected from silver kob per host total length (cm). *Calceostoma* spp. (A), *Helicometrina* spp. (B), *Corynosoma australe* (C) and *Diplectanum* spp. (D).

Table 7: X^2-test statistics and p-value comparing mean abundance by host size class, Small size class (S) (TL < 35.8), medium size class (M) (35.8 ≤ TL< 47.3) and large size class (L) (TL ≥ 47.3), of silver kob collected from June 2017 to May 2018. "*" indicates significant differences at the 5% level.

Parasite species	**Mean Abundance**			Chi-value	P-value
	Class (S)	Class (M)	Class (L)		
Calceostoma spp.	21.6	3.2	2.2	28.22	<<0.01*
Sciaenacotyle sp.	0.8	1.83	3.1	1	0.30
Diplectanum spp.	5.0	18.4	47.5	41.1	<<0.001*
Helicometrina spp.	11.40	4.45	3.5	5.77	0.03*
Stephanostomum sp.	1.40	1.80	0.30	0.09	0.48
Anisakis sp.	2.60	3.85	7.40	2.66	0.13
Corynosoma australe	13.0	48.0	30.0	20.2	<<0.01*

6.4.3 Host sex dependency

All 17 parasite genera were found in male silver kob hosts (100%). Of the 17 genera, only 10 (58%) were found in female silver kob hosts. Female hosts generally had a higher prevalence than male hosts (43.4% and 26.9%, respectively), a higher mean intensity (11 and 9 parasites per infected host, respectively), and a higher mean abundance (5.0 and 4.6 parasites per host, respectively) (Table 8), but no significant differences in mean abundance by sex for any of the individual seven most abundant species (x^2-test, $P > 0.05$) (Table 9).

Table 8: Overall prevalence (%), mean intensity (fish per infected fish host) and mean abundance (fish per fish host) of parasite genera found on male (n = 41) and female (n = 14) silver kob from June 2017 to May 2018.

Parasites	Prevalence %		Mean Intensity		Mean Abundance	
	Female	Male	Female	Male	Female	Male
Calceostoma spp.	64	54	5	10	3.29	5.17
Sciaenacotyle sp.	71	51	3	4	2.07	1.93
Diplectanum spp.	64	63	43	32	27.5	20.76
Sinodiplectanotrema sp.	7	7	1	1	0.07	0.07
Neocalceosoma sp.	0	5	0	1	0	0.05
Calceostoma sp. 1	14	12	2	1	0.21	0.15
Helicometra sp.	0	12	0	1	0	0.17
Helicometrina spp.	57	56	5	10	2.71	5.66
Stephanostomum sp.	29	17	5	10	1.42	1.76
Tetraphyllidean plerocercoid	0	10	0	2	0	0.15
Callitetrarhynchus sp.	0	5	0	1	0	0.04
Anisakis sp.	86	78	5	6	4.57	4.32
Corynosoma australe	57	66	78	62	44.43	40.9
Lernanthropus sp.	21	10	3	3	0.64	0.29
Caligus sp.	0	24	0	3	0	0.93
Sciaenophilus sp.	0	7	0	5	0	0.37
Brachiella spp.	0	5	0	1	0	0.05
Unknown	7	2	40	1	2.8	0.02
Average	**26.5**	**26.9**	**11**	**9**	**5.0**	**4.6**

Table 9: X^2-test statistics and P-values comparing differences in parasite abundance in silver kob between male and female hosts.

Parasite species	X^2	P-value
Calceostoma spp.	0.423	0.497
Sciaenacotyle sp.	0.005	5.685
Diplectanum spp.	0.941	0.257
Helicometrina spp.	0.628	0.368
Stephanostomum sp.	0.036	2.055
Anisakis sp.	0.038	2.010
Corynosoma australe	0.146	0.970

6.5 Discussion

Parasite abundance increased significantly with increasing *A. inodorus* size class for only external parasite *Diplectanum* spp. (a monogenean), and was highest in medium-hosts for the endo-parasite *Corynosoma australe* (a palaeacanthocephalan). As the fish grows, the amount of food it consumes, which includes the larval stages of the parasites, increases (Aloo-Obudho *et al*. 2004). Poulin (1999b) and Aloo-Obudho *et al*. (2004) showed that parasite intensity increased with increasing host size because large/adult fish hosts can get enough nutrition for their own needs and the needs of the infection (Poulin 2004), so they will survive longer with parasites present than juvenile fish. Large fish generally have a large surface area for parasitic infections and more potential attachment and settlement sites. This explains the increase in abundance of external parasite *Diplectanum* spp. with host size. Large silver kob are also long-lived with broad geographic areas as they migrate from West Coast Recreational Area to Sandwich Harbour to spawn every year and have broad diets. This means that they can progressively accumulate parasites over time (Dias *et al*. 2004). It is therefore not known why the external parasite *Calceostoma* spp. should significantly decrease in mean abundance with increasing *A. inodorus* host size.

Possibilities could be that small fish have a softer skin hence enabling easy attachment to the host as opposed to larger fish skin. Further study is needed on the lifecycle of this interesting parasite genus.

As silver kob grow greater than 30 cm from juveniles to adults (Kirchner & Voges 1999), they change their diet from only shrimps, prawns and small crustaceans, to incorporating small pelagic fish such as sardine (Batty *et al*. 2005). This diversity in diet composition exposes large fish to a higher potential of parasitic infestation through the ingestion of a variety of intermediate hosts (Sasal *et al*. 1999). Khanum et al. (2011) also reported that the degree of gastrointestinal parasitism was obviously related to the food habit and age of the fishes. This explains the increase in mean abundance of the internal parasite *Corynosoma australe*, and in addition, *Anisakis* sp. and cestodes (Tetraphyllidean plerocercoid and *Callitetrarhynchus* sp.) from small to medium host size classes as the parasites move from the ingested prey to *A. inodorus* intermediate hosts.

Parasites such as digenean trematodes (e.g. *Helicometrina*) and acanthocephalans (*Corynosoma australe*) need a final host, mainly a seal or fish-eating bird to complete their life cycles (Al-Zubaidy 2011, Chapter 3). Since fur seals prefer horse mackerel and sardine to silver kob, most trematodes are unable to complete their lifecycles and are therefore likely to die in large *A. inodorus* hosts. This may partially explain the decrease in mean abundance of *Helicometrina* with increasing host size.

There were no significant differences in parasite abundance between female and male *A. inodorus*. The reason could be that both female and male fish sampled in the present study lived in the same environment, had more or less the same size and were exposed to the same diet, and parasites therefore had equal probability to infections. Ferreira (2008)

believes that male and female hosts *Aluterus monoceros* (Linnaeus, 1758), have the same behaviour in relation to food habits and thus have the same chances of parasite infestation. Findings from the present study are, however, different from the results presented by Kotungondo (2014), who found parasites abundance significantly higher in female hosts than in male hosts in 2014 on *A. inodorus* from the same sampling area. Kotungondo (2014) sampled larger fish (ranging between 35 and 74.7 cm TL) than those in the present study (24.3-58.8 cm TL), for which sex-specific differences in feeding behaviour may be more pronounced. Aloo-Obudho *et al.* (2004) stated the main reason for the differences in parasitic load with sex is thought to be physiological. However, endoparasites have been reported to infest the two sexes differentially because male and female fish often have different feeding habits (Rohde, 1993). More studies are therefore needed to make conclusions on the relationship of *A. inodorus* host sex and parasite abundances based on their feeding habits.

Parasite reduction experiments carried out by Newey *et al*. (2005) concluded that parasites can have a negative impact on host reproduction by reducing fecundity through a mechanism still not yet known. There have been different reports and conclusions on the association of host sex with parasite infestation. Esch *et al*. (1988) stated that host sex could be a decisive and influential factor to parasite infestation, and this could be due to different diet compositions of male and female hosts as well as differences in behaviour and physiological resistance between male and female hosts (Fernández 1985). Studies by Dias *et al*. (2004) and Ferreira (2008) on marine catfish *Sciades proops* (Valenciennes, 1840) however, reported that male and female hosts showed no significant differences

with respect to intensities and frequencies of parasitism, which is similar to *A. inodorus* in the present study.

In conclusion, all parasites showed an increase in abundance with increasing silver kob host body size except for *Calceostoma* spp. and *Helicometrina* spp., which showed a significant decrease with increasing host body size. None of the parasites seemed to be significantly influenced by silver kob host sex.

Chapter 7: Conclusions and recommendations

7.1 Conclusions

This is the first descriptive study of parasites of Namibian silver kob (*A. inodorus*). Namibian silver kob is subject to a variety of parasitic infections. A total of 4652 parasite individuals were found on silver kob, which included 28 parasite species from 17 genera. Of these 17 genera, ten were specific to one organ. With the exception of digeneans, large-sized hosts (TL > 47.3 cm) showed the highest prevalence and mean abundance of parasites compared to small hosts (TL ≤ 35.8 cm). *Calceostoma* spp. and *Helicometrina* spp. showed a significant decrease in mean abundance with increasing host length. *Corynosoma australe* and *Diplectanum* spp. showed a significant increase in mean abundances with increasing host length. *Corynosoma australe* and *Calceostoma* spp. were significantly more abundant during the cold season (June-November) than during the warm season, and *Diplectanum* spp. were significantly more abundant during the warm season (December-May) than during the cold season. No fish sex preference was observed for parasite infections in silver kob.

In previous parasite studies done on congeners of *Argyrosomus*, fish were reared in either cages or tanks. In the present study, however, wild silver kob (*A. inodorus*) were inspected. This might have had an influence on the parasitic fauna recorded, considering the open and dynamic marine environment in which silver kob live, and most importantly their life history that involves migrating from the West Coast Recreational Area to Sandwich Harbour for spawning and returning every year (Batty *et al.* 2005). Fish

spawning migrations can alter and/or destroy the local character of parasite fauna (Marcogliese 2002). Hosts may acquire new parasitic infections or lose some parasites between the different areas they pass through, which are subject to different physical and chemical environmental parameters, during their migration as explained by Poulin (2004). For these reasons, results from the present study will not be exactly the same in a mariculture set-up, also because of the the enclosed environment that increases easier for external parasite transmission within the set-up. The present study is therefore an awareness to potential mariculture farmers on parasites that could affect silver kob and their abundances in relation to season, host size and host sex.

7.2 Recommendations

This was the first study to examine ecto- and endo-parasite fauna on all host organs of Namibian silver kob and thus serves as a baseline for future studies. Species of *Diplectanum*, *Sciaenacotyle*, *Calceostoma* and *Caligus* were described. More descriptive studies and studies that will loy/use Scanning Electron Microscopy (SEM), histopathology, Health Assessment Index (HAI) and molecular work following this, to supplement the findings, identify the parasites to their species level and determine the nature of damages to the fish host that are caused by these parasites are needed. In addition, further studies are needed to fully understand the behaviour and lifecycles associated with these parasites, which may influence productivity of the silver kob host. This would help in determining ways to prevent and control parasite epidemics, if necessary, in a mariculture set-up. Also more studied, especially on cultured silver kob when possible, are required to supplement these findings.

Factors that influence the composition of the parasite fauna found in fish hosts may include host nutrition, host size, lifespan of the host, the mobility of the host, stock density, as well as physical and chemical parameters of the aquatic habitat in which they live (Polyanski 1961; Poulin 2004; Labella *et al*. 2011; Carvallho *et al*. 2015). The feeding habit of the fish host is one of the factors that have the most influence on the variety of endo-parasite species in the host. *A. inodorus* are piscivorous fish, and are therefore prone to harbouring internal parasite species as they feed on already infected organisms that serve as intermediate hosts of various parasitic groups, such as digenean trematodes, acanthocephalans and nematodes. Change in their diet over time (as they change their diet from feeding on shrimps and squids as juveniles to incorporating small pelagic fish as adults) may also influence the parasites they acquire, as well as their prevalence and abundances. I therefore recommend a study on the feeding habits of silver kob and a study of parasites that can infest its prey (e.g. sardine) to supplement my findings.

A monogenean *Calceostoma* sp. 2 was found in the stomach of silver kob. This monogenean had almost similar characteristics to a gill monogenean *Calceostoma* sp. 1. Usually, stomach monogeneans possess different specialised haptoral and copulatory characteristics that allowed them to adapt to the internal environment. It is therefore concluded that they belong to the same species without molecular comparisons. Further studies, including molecular work and SEM, are recommended to compare the similarities between the two *Calceostoma* species and to explain the findings of the present study. In addition, histopathology should also be incorporated in future studies to compare the damage done to the gills and those done to the stomach walls by *Calceostoma* spp. I also

recommend a study that will investigate sardine gills for *Calceostoma* species to confirm whether it is subject to *Calceostoma* sp. 2 identified in the present study.

Calceostoma spp. from the gills, unlike other monogeneans, possessed unique characteristics. Firstly, they were more abundant in the cold season than in the warm season, and secondly, their abundances decreased with increasing host size. A study focusing on the life cycle and temperature preferences of *Calceostoma* spp. is recommended to understand and further explain the seasonal behaviour of this parasite species and why it is influenced by host size.

A difference in parasite prevalence, mean intensity and mean abundance between parasites was found on silver kob caught from Toscanini, Mile 108, and Henties Bay throughout the present study (see Appendix 1.1). I therefore recommend a study in which the parasite fauna of silver kob are compared by area of study using equal number of host individuals collected fish at similar times/seasons from different areas. I also recommend sampling larger spawning fish from Sandwich Harbour for a more complete size specificity and sex specificity study.

The Acanthocephalan *Corynosoma australe* was significantly more abundant during the cold season than during the warm season. Other studies found that Acanthocephalans differ in abundance seasonally. Literature relates this seasonal difference in abundance to diet plasticity and uniformity for the host during different seasons (Silva *et al*. 2013). A study that would look at the annual/seasonal diet composition for silver kob in Namibia is therefore recommended to understand the seasonal differences in *Corynosoma australe* abundance in the present study.

External parasites are influenced by the size of the host, as well as the degree of specialisation of the means of attachment and availability of infective forms in certain population host groups (Poulin 2000). In the present study, most parasites increased with increasing host size, except for *Calceostoma* spp. which decreased with increasing host size. It is possible that their haptoral make-up might not be specialized for easy attachment on matured host bodies. A study that would focus on host-size relationships, using the same number of *A. inodorus* hosts for each size class is again recommended for clarity.

During the present study some parasite specimens lost structural visibility with time, especially when they were not preserved properly or not kept in a cool place. I therefore recommend that parasites be worked on after one week at most, while all morphological structures are still fresh and visible.

Finally, I recommend an analysis of the water for parasites that may have fallen off during transportation of fish from the area of capture to the laboratory.

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Appendices

Appendix 1 (Raw data)

1.1: Record of ecto-parasites found on silver kob from June 2017 to May 2018. Abbreviations: Total length (TL), unknown copepod (Unn), *Brachiella* sp. 1 (*Br* sp. 1), *Brachiella* sp. 2 (*Br* sp. 2), *Sciaenophilus* sp. (*Sph* sp.), *Caligus* sp. (*Cal* sp.), *Lernanthropus* sp. (*Lern* sp.), *Neocalceostoma* sp. (*Neo* sp.), *Diplectanum* spp. (*Dip* spp.), *Sinodiplectanotrema* sp. (*Sino* sp.), *Calceostoma* spp. (*Cal* spp.), *Sciaenacotyle* sp. (*Scot* sp.).

Month	**Location**	**Fish No.**	**Species**	**TL (cm)**	**Mass**	**Sex**	**Ecto**	**Unn**	***Br* sp. 1**	***Br* sp. 2**	***Sph* sp.**	***Cal*.sp.**	***Lern* sp.**	***Neo* sp.**	***Dip* spp.**	***Sino* sp.**	***Cal* spp.**	***Scot* sp.**
Jun	Toscanini	1	*A. inodorus*	46.3	919.0	M	**6**					2			3	1		
Jun	Toscanini	2	*A. inodorus*	42.0	617.3	M	**19**					3			16			
Jun	Toscanini	3	*A. inodorus*	41.7	609.6	M	**23**					2	3		18			
Jun	Toscanini	4	*A. inodorus*	37.8	458.7	M	**26**			1		7					18	
Jun	Toscanini	5	*A. inodorus*	38.6	427.7	M	**14**					2			10		2	
Aug	Toscanini	1	*A. inodorus*	40.7	705.1	M	**8**					5			3			
Aug	Toscanini	2	*A. inodorus*	41.3	621.7	M	**16**										16	

Aug	Toscanini	3	*A. inodorus*	49.4	950.5	M	**3**								2			1
Aug	Toscanini	4	*A. inodorus*	42.6	749.5	M	**33**		1						29		2	1
Aug	Toscanini	5	*A. inodorus*	47.8	756.2	M	**3**								3			
Sep	Toscanini	1	*A. inodorus*	40.7	871.1	M	**19**					3	2		12		2	
Sep	Toscanini	2	*A. inodorus*	46.5	804.8	F	**4**										1	3
Sept	Toscanini	3	*A. inodorus*	51.4	1190.1	M	**6**										4	2
Sep	Toscanini	4	*A. inodorus*	43.6	611.7	F	**20**								5		10	5
Sep	Toscanini	5	*A. inodorus*	34.1	343.8	M	**8**								3		5	
Oct	Toscanini	1	*A. inodorus*	35.2	440.7	M	**94**										94	
Oct	Toscanini	2	*A. inodorus*	40.3	640.0	F	**4**										3	1
Oct	Toscanini	3	*A. inodorus*	39.3	575.7	M	**4**										3	1
Oct	Toscanini	4	*A. inodorus*	38.9	485.3	M	**22**										22	
Oct	Toscanini	5	*A. inodorus*	35.9	456.0	M	**3**										3	
Nov	Henties Bay	1	*A. inodorus*	43.1	799.5	F	**15**								12			3
Nov	Henties Bay	2	*A. inodorus*	37.9	554.2	F	**3**								2			1
Nov	Henties Bay	3	*A. inodorus*	38.0	544.3	F	**0**											
Nov	Henties Bay	4	*A. inodorus*	43.4	703.2	F	**5**								5			
Nov	Henties Bay	5	*A. inodorus*	50.0	1228.1	M	**3**								1			2

Dec	Henties Bay	1	*A. inodorus*	43.7	835.0	F	**10**								7	1	1	1
Dec	Toscanini	2	*A. inodorus*	37.1	493.8	M	**61**								52	1	3	5
Dec	Toscanini	3	*A. inodorus*	39.0	560.8	M	**266**						2		245		17	2
Dec	Toscanini	4	*A. inodorus*	39.3	567.4	M	**58**								49		6	3
Dec	Toscanini	5	*A. inodorus*	35.0	527.9	M	**24**								21		2	1
Jan	Mile 108	1	*A. inodorus*	48.3	1218.3	M	**34**				5	10						19
Jan	Mile 108	2	*A. inodorus*	38.8	580.9	F	**11**										5	6
Jan	Mile 109	3	*A. inodorus*	40.6	626.9	M	**2**										1	1
Jan	Mile 108	4	*A. inodorus*	36.0	551.4	M	**10**							1				9
Jan	Mile 108	5	*A. inodorus*	36.5	471.1	M	**0**											
Feb	Mile 108	1	*A. inodorus*	39.0	619.9	M	**24**				5	3			16			
Feb	Mile 108	2	*A. inodorus*	38.0	598.9	M	**5**				5							
Feb	Mile 108	3	*A. inodorus*	24.3	130	M	**2**											2
Feb	Mile 108	4	*A. inodorus*	40.5	665	M	**13**							1				12
Feb	Mile 108	5	*A. inodorus*	43.0	765.3	M	**3**										2	1
Mar	Mille 108	1	*A. inodorus*	38.8	700.3	M	**8**	1							4			3
Mar	Mile 108	2	*A. inodorus*	38.5	576	M	**27**					1			15	1	2	8
Mar	Mile 108	3	*A. inodorus*	36.4	464.1	F	**4**								2			2

Mar	Mile 108	4	*A. inodorus*	58.8	1820.2	F	**250**						3		226		15	6
Mar	Mile 108	5	*A. inodorus*	36.8	517	F	**43**	40									3	
Apr	Mile 108	1	*A. inodorus*	41.3	624.6	F	**131**						5		125		1	
Apr	Mile 108	2	*A. inodorus*	40.2	550	M	**12**								9		3	
Apr	Mile 108	3	*A. inodorus*	41.4	712.6	M	**60**								56		2	2
Apr	Mile 108	4	*A. inodorus*	52.8	1545.2	M	**81**								81			
Apr	Mile 108	5	*A. inodorus*	45.0	859.7	M	**6**								4			2
May	Mile 108	1	*A. inodorus*	52.9	1460	M	**7**								7			
May	Mile 108	2	*A. inodorus*	49.6	1078	M	**13**								12		1	
May	Heties Bay	3	*A. inodorus*	35.0	440	F	**10**						1		1		7	1
May	Mile 108	4	*A. inodorus*	47.6	1028	M	**146**								143		2	1
May	Mile 108	5	*A. inodorus*	44.0	858	M	**43**						5		37			1
NIF							55	2	1	1	3	10	7	2	35	4	31	31
NP							1725	41	1	1	15	38	21	2	1236	4	258	108
MI							31	21	1	1	5	4	3	1	35	1	8	3
MA							31.4	0.7	0.02	0.02	0.3	0.7	0.4	0.04	22.5	0.07	4.7	2.0
P %							100	4	2	2	6	18	13	4	64	7	56	56

1.2. Record of endo-parasites found on silver kob from June 2017 to May 2018. Abbreviations: Total length (TL), *Corynosoma australe* (*Cor*. Sp.), *Calceostoma* sp. 1 (*Cal* sp. 1), Tetraphyllidean plerocercoid (Tetra.), *Callitetrarhynchus* sp. (*Call*. sp.), *Helicometra* sp. (*H.tra* sp.), *Helicometrina* spp. (*H.trina* spp.), *Stephanostomum* sp. (*Steph*. sp.), *Anisakis* sp (*Anis* sp.), Number of infected fish (NIF), total number of parasites (NP).

Month	**Location**	**Fish No.**	**Species**	**TL (cm)**	**Mass**	**Sex**	**Endo**	**Cyst**	***Cor*. sp.**	***Cal* sp. 1**	**Tetra.**	***Call*. sp.**	***H.tra* sp.**	***H.trina* spp.**	***Steph* sp.**	***Anis sp.***
Jun	Toscanini	1	*A. inodorus*	46.3	919.0	M	**16**	9								7
Jun	Toscanini	2	*A. inodorus*	42.0	617.3	M	**43**		36							7
Jun	Toscanini	3	*A. inodorus*	41.7	609.6	M	**48**	3						41		4
Jun	Toscanini	4	*A. inodorus*	37.8	458.7	M	**78**		55					16		7
Jun	Toscanini	5	*A. inodorus*	38.6	427.7	M	**39**		28	1				8		2
Aug	Toscanini	1	*A. inodorus*	40.7	705.1	M	**140**		140							
Aug	Toscanini	2	*A. inodorus*	41.3	621.7	M	**207**		200							7
Aug	Toscanini	3	*A. inodorus*	49.4	950.5	M	**83**		74							9

Aug	Toscanini	4	*A. inodorus*	42.6	749.5	M	**32**		30							2
Aug	Toscanini	5	*A. inodorus*	47.8	756.2	M	**6**		1		2			3		
Sep	Toscanini	1	*A. inodorus*	40.7	871.1	M	**504**		494	1				2		7
Sep	Toscanini	2	*A. inodorus*	46.5	804.8	F	**157**		140					9		8
Sep	Toscanini	3	*A. inodorus*	51.4	1190.1	M	**19**		13					6		
Sep	Toscanini	4	*A. inodorus*	43.6	611.7	F	**158**		157							1
Sep	Toscanini	5	*A. inodorus*	34.1	343.8	M	**59**		46					5		8
Oct	Toscanini	1	*A. inodorus*	35.2	440.7	M	**11**		11							
Oct	Toscanini	2	*A. inodorus*	40.3	640.0	F	**96**		87					6		3
Oct	Toscanini	3	*A. inodorus*	39.3	575.7	M	**121**		118							3
Oct	Toscanini	4	*A. inodorus*	38.9	485.3	M	**6**									6
Oct	Toscanini	5	*A. inodorus*	35.9	456.0	M	**130**		125							5
Nov	Henties Bay	1	*A. inodorus*	43.1	799.5	F	**18**		9					2	1	6
Nov	Henties Bay	2	*A. inodorus*	37.9	554.2	F	**2**	1								1
Nov	Henties Bay	3	*A. inodorus*	38.0	544.3	F	**5**			2						3

Nov	Henties Bay	4	*A. inodorus*	43.4	703.2	F	**1**									1
Nov	Henties Bay	5	*A. inodorus*	50.0	1228.1	M	**32**	12	6				1	3	5	5
Dec	Henties Bay	1	*A. inodorus*	43.7	835.0	F	**24**							9	10	5
Dec	Toscanini	2	*A. inodorus*	37.1	493.8	M	**25**		4	2					11	8
Dec	Toscanini	3	*A. inodorus*	39.0	560.8	M	**114**		47				1	21	35	10
Dec	Toscanini	4	*A. inodorus*	39.3	567.4	M	**20**		7	1					9	3
Dec	Toscanini	5	*A. inodorus*	35.0	527.9	M	**39**			1				29	7	2
Jan	Mile 108	1	*A. inodorus*	48.3	1218.3	M	**11**		4			1	2		1	3
Jan	Mile 108	2	*A. inodorus*	38.8	580.9	F	**5**									5
Jan	Mile 109	3	*A. inodorus*	40.6	626.9	M	**3**						2			1
Jan	Mile 108	4	*A. inodorus*	36.0	551.4	M	**11**	2						5	3	1
Jan	Mile 108	5	*A. inodorus*	36.5	471.1	M	**3**							2		1
Feb	Mile 108	1	*A. inodorus*	39.0	619.9	M	**2**							2		
Feb	Mile 108	2	*A. inodorus*	38.0	598.9	M	**2**					1			1	
Feb	Mile 108	3	*A. inodorus*	24.3	130	M	**19**							19		

Feb	Mile 108	4	*A. inodorus*	40.5	665	M	**0**									
Feb	Mile 108	5	*A. inodorus*	43.0	765.3	M	**25**							17		8
Mar	Mille 108	1	*A. inodorus*	38.8	700.3	M	**28**		21		2			5		
Mar	Mile 108	2	*A. inodorus*	38.5	576	M	**8**		4		1			1		2
Mar	Mile 108	3	*A. inodorus*	36.4	464.1	F	**7**		4					3		
Mar	Mile 108	4	*A. inodorus*	58.8	1820.2	F	**165**		128	1				2	7	27
Mar	Mile 108	5	*A. inodorus*	36.8	517	F	**3**								2	1
Apr	Mile 108	1	*A. inodorus*	41.3	624.6	F	**92**		89					3		
Apr	Mile 108	2	*A. inodorus*	40.2	550	M	**43**		23					14		6
Apr	Mile 108	3	*A. inodorus*	41.4	712.6	M	**31**		12					9		10
Apr	Mile 108	4	*A. inodorus*	52.8	1545.2	M	**12**		8				1	1		2
Apr	Mile 108	5	*A. inodorus*	45.0	859.7	M	**107**		102		1			3		1
May	Mile 108	1	*A. inodorus*	52.9	1460	M	**56**		44							12
May	Mile 108	2	*A. inodorus*	49.6	1078	M	**37**		25					4		8
May	Heties Bay	3	*A. inodorus*	35.0	440	F	**21**	6	8					4		3

May	Mile 108	4	*A. inodorus*	47.6	1028	M	**24**							16		8
May	Mile 108	5	*A. inodorus*	44.0	858	M	**12**									12
NIF							55	6	35	7	4	2	5	31	12	44
NP							2960	33	2300	9	6	2	7	270	92	241
MI							54	6	66	1	2	1	1	9	8	5
MA							53.8	0.6	41.8	0.1	0.1	0.04	0.1	4.9	1.7	4.4
P %							100	11	64	13	7.3	3.6	9.2	56	21	80

Appendix 1.3: Measurement results for different parasites.

Diplectanum sciaenae

Specimen Code	Dsp2a	Dsp2b	Dsp2c	Dsp2d	Dsp2e	Dsp2f	Dsp2g	Dsp2i	Mean	Min	Max
Host	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*			
Characteristics											
body length	569	931	754	658	717	943	436	872	735	436	943
body width	122	250	205	162	184	246	117	195	185	117	250
Haptor width	232	310	258	234	236	274	198	276	252	198	310
Penis length	51	76	50	51	51	56	51	50	55	50	76
Canal Length	29	40	27	26	26	32	26	26	29	26	40
Canal Width	11	12	8	8	7	10	6	7	9	6	12
Squamodisc length	124	222	167	164	163	172	127	152	161	124	222
Squamodisc width	116	187	144	136	141	139	109	145	140	109	187
No. of concentric rows	36	36	32	36	37	37	38	36	36	32	38
Median bar length	108	134	101	97	100	118	100	99	107	97	134
Median bar width	24	27	21	20	22	26	23	20	23	20	27
Median Bar 1/2 width	16	14	16	16	15	17	16	12	15	12	17
transverse bar length	95	122	81	88	86	103	84	91	94	81	122
Ventral hamulus (a)	72	74	66	71	71	74	69	64	70	64	74
Ventral hamulus (b)	67	66	62	66	66	67	63	59	65	59	67
Ventral hamulus (a)	38	36	35	40	38	39	36	35	37	35	40
Ventral hamulus (D)	30	33	27	26	28	29	25	25	28	25	33
Dorsal hamulus (a)	62	64	61	63	65	65	62	55	62	55	65
Ventral hamulus (b)	59	59	55	58	60	58	54	52	57	52	60

a. *Diplectanum sciaenae* (squamodiscs absent)

Specimen Code	Dsp1b	Dsp1c	Dsp1d	Dsp1t	Dsp1u	Dsp1p(A)	Dsp1q(A)	Dsp1r	Mean	Min	Max
Host	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*			
Characteristics											
body length	1018	1066	912	748	830	-	-	-	915	748	1066
body width	131	79	229	145	-	-	-	-	146	79	229
Haptor width	296	256	238	250	-	-	-	-	260	238	296
Penis length	51	49	67	57	54	55	50	55	55	49	67
Canal Length	31	27	34	30	28	27	31	33	30	27	34
Canal Width	6	9	12	9	7	5	8	6	8	5	12
Squamodisc length	-	-	-	-	-	-	-	-	-	0	0
Squamodisc width	-	-	-	-	-	-	-	-	-	0	0
No. of concentric rows	-	-	-	-	-	-	-	-	-	0	0
Median bar length	105	97	110	102	107	101	102	106	104	97	110
Median bar width	20	20	24	19	20	22	23	22	21	19	24
Median Bar 1/2 width	13	14	15	13	14	14	16	12	14	12	16
transverse bar length	93	82	94	89	94	93	96	91	91	82	96
Ventral hamulus (a)	66	64	66	66	65	68	67	66	66	64	68
Ventral hamulus (b)	62	60	61	60	60	62	63	61	61	60	63
Ventral hamulus (a)	35	35	36	34	36	36	37	35	35	34	37
Ventral hamulus (D)	27	26	25	26	25	25	26	26	26	25	27
Dorsal hamulus (a)	58	58	61	59	59	59	59	58	59	58	61
Ventral hamulus (b)	54	54	56	55	54	55	54	55	55	54	56

b. *Diplectanum dollfusi*

Specimen Code	Dsp1a	Dsp1j	Dsp1s	Dsp1e	Mean	Min	Max
Host	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*			
Characteristics							
body length	-	925	805	896	875	805	925
body width	-	165	123	180	156	123	180
Haptor width	-	233	-	269	251	233	269
Penis length	-	66	51	50	55	50	66
Canal Length	39	24	25	27	29	24	39
Canal Width	-	9	5	6	7	5	9
Squamodisc length	-	-	-	-	-	0	0
Squamodisc width	-	-	-	-	-	0	0
No. of concentric rows	-	-	-	-	-	0	0
Median bar length	127	93	96	91	102	91	127
Median bar width	26	22	20	20	22	20	26
Median Bar 1/2 width	18	13	16	13	15	13	18
transverse bar length	114	88	88	87	94	87	114
Ventral hamulus (a)	73	65	62	64	66	62	73
Ventral hamulus (b)	68	58	56	59	60	56	68
Ventral hamulus (c)	37	34	31	34	34	31	37
Ventral hamulus (D)	31	27	25	25	27	25	31
Dorsal hamulus (a)	66	59	60	57	61	57	66
Ventral hamulus (b)	61	55	51	53	55	51	61

c. *Diplectanum* sp. 1

Specimen Code	Dsp2h	Dsp2j(A)	Dsp2k(B)	Dsp2l	Mean	Min	Max
Host	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*			
Characteristics							
body length	950	777	862	917	876	777	950
body width	356	383	346	237	330	237	383
Haptor width	338	309	325	329	325	309	338
Penis length	50	50	52	54	51	50	54
Canal Length	31	30	30	32	31	30	32
Canal Width	9	8	8	6	8	6	9
Squamodisc length	178	118	121	191	152	118	191
Squamodisc width	147	115	107	157	131	107	157
No. of concentric rows	37	36	38	39	38	36	39
Median bar length	107	106	103	101	104	101	107
Median bar width	24	22	19	22	21	19	24
Median Bar 1/2 width	14	13	12	14	13	12	14
transverse bar length	91	94	90	88	91	88	94
Ventral hamulus (a)	65	68	66	69	67	65	69
Ventral hamulus (b)	59	62	59	63	61	59	63
Ventral hamulus (c)	33	36	34	37	35	33	37
Ventral hamulus (d)	26	27	26	27	26	26	27
Dorsal hamulus (a)	58	61	58	60	59	58	61
Ventral hamulus (b)	54	57	56	55	56	54	57

d. *Diplectanum* sp. 2

Specimen Code	Dsp1f	Dsp1g"	Dsp1k	Dsp1l	Dsp1m(A)	Dsp1h*	Dsp1n (B)	Mean	Min	Max
Host	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*			
Characteristics										
body length	1141	1181	1337	1225	1597	1218	1468	1309	1141	1597
body width	265	292	313	165	346	368	344	299	165	368
Haptor width	254	223	244	225	-	-	-	236	223	254
Penis length	112	115	110	117	137	117	122	119	110	137
Canal Length	46	47	51	46	51	46	51	48	46	51
Canal Width	13	14	19	15	14	14	14	15	13	19
Squamodisc length	-	-	-	-	-	-	-	-	0	0
Squamodisc width	-	-	-	-	-	-	-	-	0	0
No. of concentric rows	-	-	-	-	-	-	-	-	0	0
Median bar length	111	110	105	114	124	106	113	112	105	124
Median bar width	20	17	17	19	22	16	18	18	16	22
Median Bar 1/2 width	7	7	6	6	10	8	8	8	6	10
transverse bar length	69	68	72	70	89	47	96	73	47	96
Ventral hamulus (a)	55	56	57	56	62	57	61	58	55	62
Ventral hamulus (b)	50	51	52	53	58	53	57	53	50	58
Ventral hamulus (c)	27	28	27	29	34	29	32	29	27	34
Ventral hamulus (d)	24	27	26	25	25	25	27	25	24	27
Dorsal hamulus (a)	54	53	57	55	60	56	58	56	53	60
orsal hamulus (b)	50	49	52	50	53	52	53	51	49	53

e. Comparisons to other *Diplectanum* species documented.

Character	*D. oliveri*	*D. glandulosum*	*D. dollfusi*	*D. bocqueti*	*D. sciaenae*	*D. sciaenae*	*D. dollfusi*	*D.* sp. 1	*D.* sp. 2
body length	909 - 1139	499 - 640	660 – 1370	800 - 1230	500 -1160	751 (436-1066)	875 (805-925)	876 (777-950)	1309 (1141-1597)
body width	166 - 224	128 - 154	160 – 370	240 - 370	140 - 400	165 (79-250)	156 (123-165)	330 (237-383)	299 (165-368)
Haptor width	224 - 275	243 - 269	230 – 480	120 - 400	260 - 380	252 (198-310)	251 (233-269	325 (309-338)	236 (223-254)
Penis length	166 - 179	51 - 66	57 – 78	90 - 123	51 - 94	63 (49-76)	55 (50-66)	51 (50-54)	119 (110-137)
Canal Length	-	-	-	-	-	29 (26-40)	29 (24-39)	31 (30-32)	48 (46-51)
Canal Width	-	-	-	-	-	9 (5-12)	7 (5-9)	8 (6-9)	15 (13-19)
Squamodisc length	-	-	-	-	-	173(124-222)	-	152 (118-191)	-
Squamodisc width	166 - 189	99 - 106	144 – 160	120 -160	144 - 170	148 (109-187)	-	131 (107-157)	-
No. of concentric rows	-	-	32 – 38	26 - 32	31 - 41	35 (32-38)	-	38 (36-39)	-
Median bar length	128 - 158	117 - 153	108 – 159	102 – 132	95 - 150	107 (97-134)	102 (93-127)	104 (101-107)	112 (105-124
Median bar width	-	-	-	-	-	23 (19-27)	22 (20-26)	21 (19-24)	18 (16-22)
Median Bar 1/2 width	-	-	-	-	-	15 (12-17)	15 (13-18)	13 (12-14)	8 (6-10)
transverse bar length	96 - 110	90 - 117	92 – 146	88 – 100	88 - 100	94 (81-122)	94 (88-114)	91 (88-94)	73 (47-96)
Ventral hamulus (a)	67 - 77	72 - 77	87- 94	58 – 67	69 - 79	70 (64-74)	66 (62-73)	67 (65-69)	58 (55-62)
Ventral hamulus (b)	-	65 - 69	78 – 86	52 – 63	63 - 73	65 (59-67)	60 (56-68)	61 (59-63)	53 (50-58)
Ventral hamulus (c)	32 - 34	34	43 – 50	27 – 32	33 - 41	37 (34-40)	34 (31-37)	35 (33-37)	29 (27-34)
Ventral hamulus (d)	30 - 32	30 - 32	33 – 39	25 – 32	26 - 35	28 (25-33)	27 (25-31)	26 (26-27)	25 (24-27)
Dorsal hamulus (a)	66 - 70	64 - 67	83 – 89	57 – 62	62 - 68	62 (55-65)	61 (59-66)	59 (58-61)	56 (53-60)
Dorsal hamulus (b)	61 - 64	59 - 64	62 – 135	51 – 56	59 - 64	57 (52-60)	55 (51-61)	56 (54-57)	51 (49-53)
Author	Williams (1989)	Williams (1989)	Oliver (1980)	Oliver (1980)	Oliver (1980)	This paper	This paper	This paper	This paper
Geographical area	Western Australia	Western Australia	Golf of Gascogne	Golf of Gascogne	Golf of Gascogne	Northen Namibia	Northen Namibia	Northen Namibia	Northen Namibia
Host	*A. hololepidotus*	*A. hololepidotus*	*A. regius*	*A. regius*	*A. regius*	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*
No. of speciment	7	8	-	-	-	16	4	4	7

f. Calceostoma glandulosum

Specimen Code	C. 1	C. 8	C. 15	C. 17	Mean	Min	Max
Host	*A. inodorus*	A. inodorus	A. inodorus	A. inodorus			
Characteristics							
Body Length	8000	7500	5300	4200	6250.00	4200.00	8000.00
Body Width	1100	1000	900	1000	1000.00	900.00	1100.00
Lappet Max w	1900	200	1500	1300	1225.00	200.00	1900.00
Pharynx L	311.34	289.52	236.99	321.66	289.88	236.99	321.66
pharynx W	342.31	266.88	246.09	226.71	270.50	226.71	342.31
Hamuli L1	203.72	207.75	192.7	188.38	198.14	188.38	207.75
Hamuli L2	207.2	213.05	194.6	189.89	201.19	189.89	213.05
Median bar L	233.11	219.55	227.08	220.43	225.04	219.55	233.11
"T" L	52.94	52.48	50.76	44.38	50.14	44.38	52.94
MCO LA	195.38	185.94	195.31	178.54	188.79	178.54	195.38
MCO LB	165.25	164.52	171.23	159.14	165.04	159.14	171.23
MCO W	25.52	24.81	25.53	21.14	24.25	21.14	25.53

g. Calceostoma sp. 1

Specimen Code	C. 12	C.13	C. 20	Mean	Min	Max
Host	*A. inodorus*	*A. inodorus*	*A. inodorus*			
Characteristics						
Body Length	6900	2900	4100	4633.33	2900.00	6900.00
Body Width	800	400	500	566.67	400.00	800.00
lappet max W	2000	-	-	2000.00	2000.00	2000.00
Pharynx L	293.91	-	312.33	303.12	293.91	312.33
Pharynx W	260.6	-	292.23	276.42	260.60	292.23
Hamuli L1	158.68	154.65	134.26	149.20	134.26	158.68
Hamuli L2	157.43	149.11	128.67	145.07	128.67	157.43
Median bar L	172.28	135.31	132.92	146.84	132.92	172.28
"T" L	38.98	37.54	32.74	36.42	32.74	38.98
MCO LA	201.63	172.66	176.25	183.51	172.66	201.63
MCO LB	152.63	124.64	139.43	138.90	124.64	152.63
MCO W	13.2	12.9	11.77	12.62	11.77	13.20

h. *Calceostoma* sp. 2

Specimen Code	C. 2	C. 3 (A)	C. 4 (B)	C. 5 (C)	C. 6	C. 7	C. 9	C.10	C. 11	C. 14	C. 16	C. 19	Mean	Min	Max
Host	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*			
Characteristics															
Body Length	3500	5800	5100	6100	4800	2100	4000	6300	6000	6300	7000	5900	5241.67	2100.00	7000
Body Width	700	1200	900	800	900	400	500	900	900	900	1000	600	808.33	400.00	1200
lappet max W	1494.43	2000	1700	1470.06	1162.97	519.65	868.03	-	-	-	1400	1300	1323.90	519.65	2000
Pharynx L	158.36	170.02	191.42	172.16	168.71	-	156.29	-	152.97	-	236.04	166.01	174.66	152.97	236
Pharynx W	162.35	213.64	195.31	147.83	233.45	-	176.76	-	128.86	-	273.33	160.07	187.96	128.86	273
Hamuli L1	131.51	142.85	147.62	146.16	136.67	144.06	150.4	140.09	154.92	148.39	146.59	145.22	144.54	131.51	154
Hamuli L2	130.65	142.89	151.03	149.13	133.35	146. 63	146.94	146.65	155.92	148.84	144.9	148.56	145.35	130.65	156
Median bar L	140.02	140.39	141.33	153.61	136.4	119.28	122.6	125.89	149.36	147.31	148.32	129.53	137.84	119.28	154
"T" L	38.25	35.79	45.75	42.47	39.71	35.1	34.35	37.05	41.85	44.41	45.34	37.14	39.77	34.35	46
MCO LA	161.91	172.78	166.4	168.92	171.25	113.96	126.97	125.83	185.2	181.41	186.86	155.43	159.74	113.96	187
MCO LB	132.26	141.45	136.64	139.47	135.89	93.02	107.53	104.87	148.49	148.31	157.64	122.76	130.69	93.02	157.64
MCO W	11.52	13.44	13.22	12.25	10.64	9.12	10.68	10.72	12.27	12.65	12.81	10	11.61	9.12	13.44

i. *Calceostoma* sp. 3

Specimen Code	C. 18
Host	*A. inodorus*
Characteristics	
Body Length	2800
Body Width	200
lappet max W	816.43
Pharynx L	114.72
Pharynx W	132.94
Hamuli L1	214.33
Hamuli L2	214.39
Median bar L	100.79
"T" L	39.77
MCO LA	63.44
MCO LB	51
MCO W	7.02

j. Comparisons to other *Calceostoma* species documented

Character	*C. glandulosum*	*C. calceostoma*	*C. calceostoma*	*C. herculanea*	*C. glandulosum*	*C.* sp. 1	*C. sp. 3*	*C.* sp. 2
Total length	1,848-4,176	2,875-4,002	6,302	2,500-3,500	6,250 (4,200-8,000)	5,241.67 (2,100-7,000)	2,800	4,633.33 (2,900-6,900)
Max body width	592-960	598-644	759-1,012	400-500	1,000 (900-1,100)	808.33 (400-1,200)	200	566.67 (400-800)
lappet Max width	504-1296	644-897	943	600	1,225 (200-1,900)	1,323.90 (519.65-2,000)	816.43	2,000
Pharynx length	157-272	179-216	255-291	100	289.88 (236.99-321.66)	174.66 (152.97-236.04)	114.72	303.12 (293.91-312.33)
Pharynx width	132-208	156-179	-	-	270.50 (226.71-342.31)	187.96 (128.86-273.33)	132.94	276.42 (260.60-292.23)
Median length	243-236	154-207	251-230	50-65	225.04 (219.55-233.11)	137.84 (119.28-153.61)	100.79	146.84 (132.92-172.28)
Median Max width	-	-	-	-	50.14 (44.38-52.94)	39.77 (34.35-45.75)	39.77	36.42 (32.74-38.98)
Hamulus length	112-139	71-106	124-147	45-50	199.66 (188.38-213.05)	144.93 (130.65-155.92)	214.36	143.80 (128.67-158.68)
Penis length a	182	124-152	179-209	-	188.79 (178.54-195.38)	159.74 (113.96-186.86)	63.44	183.51 (172.66-201.63)
Penis length b	-	-	-	-	165.04 (159.14-171.23)	130.69 (93.02-157.64)	51	138.90 (124.64-152.63)
Penis width	23	12-14.	14-23	-	24.25 (21.25-25.53)	11.61 (9.12-13.44)	7.02	12.62 (11.77-13.20)
Author	Williams 1989	Williams 1989	Williams (1989)	Euzet & Vala (1975)	This paper	This paper	This paper	This paper
Geographical area	Western australia	Tunis	Gulf of Gascogne	Morocco	Northen Namibia	Northen Namibia	Northen Namibia	Northen Namibia
Host	*A. hololepidotus*	*A. regius*	*A. regius*	*Umbrina canariencis*	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*
No. of speciment	8	4	4	-	4	3	1	3

k. *Sciaenacotyle* sp.

Specimen Code	Sc.1	Sc. 2	Sc. 3	Sc. 4	Sc. 5	Sc. 6	Sc. 7	Sc. 8	Sc. 9	Sc. 10	Sc. 11	Sc. 12	Sc. 13
Host	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*
Characteristics													
Body length	7,500	7,100	8,200	11,400	9,200	9,500	6,900	9,000	8,200	4,000	10,000	8,800	5,800
Body width	1,100	1,000	1,200	1,500	1,300	1,200	1,000	1,100	900	500	1,800	1,600	1,500
tail length	4,900	3,500	4,800	5,400	4,000	3,400	2,900	4,400	5,000	1,600	4,800	4,500	2,800
Genital spine rows	2	2	2	2	2	2	2	2	2	2	2	2	2
No. of hamuliform spine	131	138	139	154	133	-	-	-	-	-	-	-	-
No. of hamuliform spine	148	158	153	163	149	-	-	-	-	-	-	-	-
length at a	10-15.0	9.0-15	6.0-11	10.0-14	7.0-16	-	-	-	-	-	-		
leghth at b	16-28	14-28	15-22	15-31	17-26	-	-	-	-	-	-	-	-
length at c	6.0-11	5.0-11	6.0-11	5.0-11	3.0-8	-	-	-	-	-	-		

l. *Helicometra* sp.

Specimen Code	Hr-1	Hr-2
Host	*A. inodorus*	*A. inodorus*
Characteristics		
Body length	3,200	4,600
Maximum body width	1,000	800
Oral sucker length	287	296
Oral sucker width	302	307
Ventral sucker length	473	461
Ventral sucker width	482	399
Pharynx length		113
Pharynx width		121

m. *Helicometrina* spp.

Specimen Code	H-1	H-2	H-3	H-4	H-5	Mean	Min	Max
Host	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*	*A. inodorus*			
Characteristics								
Body length	1000	5300	5200	2900	2000	3280	1000	5300
Maximum body width	1000	2900	2900	1500	1000	1860	1000	2900
Oral sucker length	319	430	409	245	248	330	245	430
Oral sucker width	327	419	386	247	259	328	247	419
Ventral sucker length	573	593	618	495	501	556	495	618
Ventral sucker width	582	634	656	498	518	578	498	656
Pharynx length	187	171	146	-	-	168	146	187
Pharynx width	142	196	148	-	-	162	142	196

n. Comparisons to other *Corynosoma* species documented

Character	*C. australe*	*C. australe*	*C. australe*
Body L	4200-5500	2560-3180	3331 (2867-3647)
Body W	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)
Truck 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)
R. testes L	440-700	100-140	117
R. testes W	260-420	80-120	85
L. testes L	400-660	110-140	112
L. testes W	280-420	80-120	88
Author	Sardella et al, 2005	Sardella et al, 2005	Present study
Geographical area	Argentinian water	Argentinian water	Northern Namibia
Host	*Arctocephalus australis*	*Cynoscion guatucupa*	*A. inodorus*
No. of speciment	22	12	6

o. *Stephanostomum* sp.

Specimen Code	St-1	St-2		Mean
Host	*A. inodorus*	*A. inodorus*		
Characteristics				
Body length	3,400	2,500		2,950
Maximum body width	400	366		383
Oral sucker length	94.48	112.98		104
Oral sucker width	160	257.97		209
Ventral sucker length	285.71	231.17		258
Ventral sucker width	276.71	228.81		253
eggs length	73.11-103.22	84.71-92.61		88.4 (73.1-103)
eggs width	30.06-42.40	27.53-34.18		33.5 (27.5-43.40)

p. *Anisakis* sp.

Specimen Code	A-1	A-2	A-3	A-4	A-5	A-6	A-7
Host	*A.inodorus*	*A.inodorus*	*A.inodorus*	*A.inodorus*	*A.inodorus*	*A.inodorus*	*A.inodorus*
Characteristics							
Body L	3,300	2,200	1,900	2,400	2,300	2,400	2,100
Body W	500	300	200	300	300	300	200

Appendix 2.

2.1. X^2 test, testing the differences in mean abundance between the cold season (June – November 2017) and the warm season (December 2017 – May 2018) of the three most abundant ecto-parasite found on silver kob.

	Calceostoma spp			*Sciaenacotyle* sp.			*Diplectanum* spp		
	Observed	Expected	Chi value	Observed	Expected	Chi value	Observed	Expected	Chi value
Cold months	7.4	4.7	1.55106	0.8	1.9	0.63684	4.97	20.985	12.2221
Warm months	2	4.7	1.55106	3	1.9	0.63684	37	20.985	12.2221
		Chi vlaue	3.10213			1.27368			24.4441
		p-value	0.04802			0.18698			4E-07

2.2. X^2 test, testing the differences in mean abundance between the cold season (June – November 2017) and the warm season (December 2017 – May 2018) of the four most abundant endo-parasite found on silver kob.

	Helicometrina spp.			Stephanostomum sp.			Anisakis sp.			Corynosoma australe		
	Observed	Expected	Chi value	Observed	Expected	Chi value	Observed	Expected	Chi value	Observed	Expected	Chi value
Cold months	4	5	0.2	0.24	1.62	1.17556	4	4.5	0.05556	71	44.5	15.7809
Warm months	6	5	0.2	3	1.62	1.17556	5	4.5	0.05556	18	44.5	15.7809
		Chi vlaue	0.4			2.35111			0.11111			31.5618
		p-value	0.51644			0.0803			1.13215			9.9E-09

Appendix 3.

3.1. X^2 test, comparing mean abundance of the three most abundant ecto-parasite found on silver kob in relation to host size.

	Calceostoma spp.			*Sciaenacotyle* sp.			*Diplectanum* spp.		
	Observed	Expected	Chi value	Observed	Expected	Chi value	Observed	Expected	Chi value
SMALL	22	9	18.77777778	1	2	0.5	5	23.6667	14.7230047
MEDIUM	3	9	4	2	2	0	18	23.6667	1.35680751
LARGE	2	9	5.444444444	3	2	0.5	48	23.6667	25.0187793
		Chi vlaue	28.22222222			1			41.0985915
		p-value	3.72042E-07			0.30327			5.9501E-10

3.2. X^2 test, comparing mean abundance of the four most abundant endo-parasite found on silver kob in relation to host size.

	Helicometrina spp.			*Stephanostomum* sp.			*Anisakis* sp.			*Corynosoma australe*		
	Observed	Expected	Chi value	Observed	Expected	Chi value	Observed	Expected	Chi value	Observed	Expected	Chi value
SMALL	11.4	6.45	3.79883721	1.4	1.5	0.00667	2.6	4.63333	0.8923261	13	30.3333	9.904761905
MEDIUM	4.45	6.45	0.62015504	1.8	1.5	0.06	3.9	4.63333	0.1160671	48	30.3333	10.28937729
LARGE	3.5	6.45	1.34922481	1.3	1.5	0.02667	7.4	4.63333	1.6520384	30	30.3333	0.003663004
		Chi vlaue	5.76821705			0.09333			2.6604317			20.1978022
		p-value	0.0279523			0.4772			0.1322101			2.05624E-05

Appendix 4

4.1. X^2 test, comparing mean abundance of the three most abundant ecto-parasite found on silver kob in relation to host sex.

	Calceostoma spp			*Sciaenacotyle* sp.			*Diplectanum* spp		
	Observed	Expected	Chi value	Observed	Expected	Chi value	Observed	Expected	Chi value
Male	5.17	4.225	0.21137	1.93	2	0.00245	20.76	24.13	0.47065
Female	3.28	4.225	0.21137	2.07	2	0.00245	27.5	24.13	0.47065
		Chi vlaue	0.42273			0.0049			0.94131
		p-value	0.49669			5.68523			0.25683

4.1. X^2 test, comparing mean abundance of the four most abundant endo-parasite found on silver kob in relation to host sex.

	Helicometrina spp.			Stephanostomum sp.			Anisakis sp.			Corynosoma australe		
	Observed	Expected	Chi value	Observed	Expected	Chi value	Observed	Expected	Chi value	Observed	Expected	Chi value
Male	5.66	4.475	0.31379	1.76	1.59	0.01818	4	4.285	0.01896	40.9	42.665	0.07302
Female	3.29	4.475	0.31379	1.42	1.59	0.01818	4.57	4.285	0.01896	44.43	42.665	0.07302
		Chi vlaue	0.62759			0.03635			0.03791			0.14603
		p-value	0.36795			2.05471			2.01045			0.97046