A Snapshot of Parasite Occurrence in Yellow Tail Snappers (*Ocyurus chrysurus*) in South Water Caye Marine Reserve

Joaquin D. Magana[1]
Karen L. Link[1]
Dylana Nicholas[1]

Abstract

Yellow Tail Snapper (Ocyurus chrysurus) is one of the most consumed fishes in the country of Belize. To prevent its population from becoming threatened, as seen for other snappers in the area, it is important to keep track of its abundance and health. An ongoing monitoring system needs to be set up as part of a strategy to manage fish populations. This system should include investigating parasites of this fish. Uncontrolled parasite proliferation can be detrimental to both the host and the environment. There are no updated studies regarding the identity and prevalence of parasites of this fish in Belizean waters. This study aims to contribute to the creation of a body of data that documents the identity, types, and abundance of parasites of Yellow Tail Snappers found in Belize. In order to assess the current situation of parasites on Yellow Tail Snappers, a quantitative analysis of ectoparasites and endoparasites on the body of forty O. chrysurus individuals was conducted within the South Water Caye Marine Reserve, Belize. The specimens were collected from a local fisher and examined both internally and externally. Organs were removed from each individual, and their tissues were examined for the presence of observable parasites. The results showed a relatively healthy population of fishes, with 75% of the fishes having at least one observed parasite. The most abundant parasite was Cymothoa exigua found in the oral cavity of 50% of the samples. Isopods were also found in the gills, and digeneans and other helminths were found in the stomach and gut of many samples. Statistical analysis was done on the forty fish obtained from four sites (ten individuals from each site) from the Reserve. The results suggested that there was no correlation among the sites and the overall incidence of parasites was low. Together, the 4 sites can potentially represent the abundance of macroscopic parasites in O. chrysurus found in the General Use Zone of the South Water Caye Marine Reserve.

Keywords: *Ocyurus chrysurus*, parasites, Yellow Tail Snappers, Belize, South Water Caye Marine Reserve

Introduction

It is estimated that close to 50% of Belize's population lives near the coast and over 190, 000 are dependent on tourism and fishing (Oceana, 2020). A large fraction of the country's population is accustomed to consuming various marine products such as fish, conch, seaweed, and several different invertebrates (Oceana, 2020). Unfortunately, according to the 2022 Mesoamerican Reef Report (McField *et al.*, 2022) the "Critical Commercial fish biomass" (composed of larger fish species such as snapper and grouper) has

1 University of Belize
Corresponding Authors: Joaquin D. Magana, Faculty of Science and Technology, University of Belize, Hummingbird Avenue, Belmopan, Belize. email: jmagana@ub.edu.bz.

declined over the past two years causing the Reef Health Index (RHI) to fall from fair to poor in the region. The presence of marine protected areas, such as the South Water Caye Marine Reserve, contributes to the conservation of fish populations; however, more active involvement seems to be needed as these populations continue to be on the decline (Belize Fisheries Department, 2018). Currently, like many of the other seafood, the snapper fishery in Belize is not systematically assessed (Oceana, 2020) as compared to the lobster and conch fisheries. The abundance data for studied fish species like the snapper are often bundled together and reported as one group. The cause of the fish decline is therefore not clear and may be due to a reduction of several or just one of the more abundant species (Oceana, 2020). Yellow Tail Snappers (*O. chrysurus)* are a smaller species of snapper measuring about 14 inches and weight 2 to 3 pounds, in the past twenty years, they have been more abundant than the larger snapper species like the *Lutjanus campechanus* or commonly known as red snapper (Oceana, 2020). However, with the decline of snappers in general, there has been an increase in fishing of this species, hence it's important to also monitor the populations of this snapper (Begossi *et al.*, 2011). Belize supports a variety of marine habitats, including mangrove forests, seagrass meadows, and coral reefs. A wide variety of finfish species, which are significant both ecologically and commercially, are supported by these environments (Cooper *et al.*, 2009). Belize has recently developed a management plan to help sustain finfish species, as with the others, which will require monitoring of populations of finfish to ensure healthy ecosystems and sustainable fishery extraction (United Nations Conference on Trade and Development, 2022). Additional management plans can include keeping track of their growth and reproduction as well as their general health. This includes looking at any disease and parasite infestation that may be threatening the species.

It is not uncommon to find parasites residing on or in marine organisms (Rohde, 1984). Parasitism, like many other symbiotic relations, is a natural part of any healthy ecosystem and is considered to be important for biodiversity and production (Hudson *et al.*, 2006). Parasites exist in a close interspecific relationship with another organism (the host). The parasite benefits from and is dependent on, the host at the expense of the host (Gunn, 2012). Although they do not normally directly kill the host, parasites can weaken it by destroying its tissues, reducing its blood, and diverting its nutrients, causing the host to be highly stressed (Misganaw and Getu, 2016). Continued stress can eventually result in the host's death (Gunderson, 2008). Due to their mode of interaction, the presence of parasites is often seen in a negative light; however, parasitism begins to be problematic only when their populations cause a decline in the host population (Ebert *et al.*, 2000). This in turn can have other indirect impacts on the environment with which the host interacts (Dunn *et al.*, 2012). Another concern regarding parasites is their potential impact on human health, for example, if eaten raw or improperly prepared, seafood containing parasites may result in the transferal of the parasite to the human consumer and cause diseases associated with microbial origin (Institute of Medicine (US) Committee on Evaluation of the Safety of Fishery Products, 1991). This has been seen most often with parasitic worms which can cause problems such as anisakiasis, diphyllobothriasis, tapeworms, and roundworms (Burrows, 2013). It should be noted, however, that when cooked properly, these organisms generally pose a limited threat to humans. Most parasites are host specific and only affect a specific species of organisms or close relatives of the species. This is due to the evolutionary adaptions needed for the parasite to live, which varies among the host species (Gunn, 2012). Nevertheless, because of their importance both within the marine environment and within the lives of those that depend on food, finance, or both, fishes are a critical organism to study to determine the potential risk for the transfer of pathogens from fish to humans (Klimpel *et al*., 2019).

Parasites are smaller than their host, and one single parasite does not often significantly affect the health of a fish (Barber, 2005). An otherwise healthy host will often compensate for the presence of the parasite by increasing its consumption of nutrients to replace what is consumed by the parasite (Barber, 2005). However, if a single host is infested by multiple parasites, it may not be able to sufficiently counter the demands on its body (Gunn, 2012). Parasite quantity within aquatic organisms can also act as an indicator regarding the ecology and movement of marine animals and the conditions of their habitats (Nachev and Sures, 2016). The aquatic environment allows for the easy dispersal and reproduction of many parasitic animals (Cavalcanti *et al.*, 2011). When compared to other vertebrates, fishes tend to have more parasites due to their environment and their proximity to one another (Leung, 2014). Parasite communities can be used to identify the cohabitation of fish species (Leung, 2014). Parasites can affect fish mortality by reducing the growth rate and meat quality while eliciting changes in behavioral patterns, thereby making the host more susceptible to more pathogens (Lim, 1992).

O. chrysurus belongs to the family Lutjanidae and is the only member of the genus *Ocyurus* (Greek for "quick tail"). It can be identified by its streamlined body, deeply forked tail, and the yellow lateral band that extends from its snout to its tail which is entirely yellow with scattered yellow spots above the band (figure 1). This yellow color is the origin of its namesake a "yellow tail snapper." It can be found in coastal waters near coral reefs in the Western Atlantic and extending to the Gulf of Mexico. This fish typically ranges between 15-40 cm in length and 4kg in weight (Luna, 2017). It possesses a two-phase recruitment process; juveniles have high post-settlement mortality and are relatively sedentary, staying mainly in mangrove habitats, while adults form large schools within coral reefs (Zajovits, 2021). It is a generalist carnivore; consuming smaller animals such as fishes and invertebrates (Luna, 2017). Unlike other snappers, yellow tails have been seen feeding both at night and opportunistically during the day (Longley and Hildebrand, 1941; reported in Zajovits, 2021). It is a commercially important species that numerous countries have farmed for recreational sport fishing, aquarium displays, and as a source of food (Luna, 2017). Despite this, there is still a significant lack of data relating to critical life-history parameters such as reproduction, growth rate, school movement, and age (Branch *et al.,* 2011). The most common parasite of *O. chrysurus* is the isopod *Cymothoa exigua*, known as the "tongue eating louse". *O. chrysurus* is also often inhabited by numerous parasitic worms. This paper will focus on initiating documentation of parasitic occurrences in Yellow Tail Snappers.

Methods

The southern waters of Belize are home to many fishing communities which inhabit the nearby islands and coast (Oceana, 2020). Along the coast, it ranges from the town of Dangriga in the Stann Creek District to Punta Gorda in the Toledo District and encompasses the lagoons of Placencia, extending outwards to the islands offshore of Toledo and Stann Creek (Remote Sensing Solutions Gmbh, 2016). Fishing is often a major source of income and food for populations in this area (Oceana, 2020). The South Water Caye Marine Reserve (SWCMR) was established in 1996 by the fisheries department and is the second-largest marine reserve in Belize (Wildtracks, 2009). It is one of seven protected areas that form the Belize barrier reef, which has been designated as a World Heritage Site by UNESCO (Wildtracks, 2009). SWCMR is located in the southern waters of Belize within the Mesoamerican reef between the town of Dangriga and the village of Placencia (Wildlife Conservation Society, 2008). It was formed due to its rich biodiversity of flora and fauna to preserve the wildlife in the nearby waters (Wildlife Conservation Society, 2008). The Reserve consists of three zones: the Preservation, Conservation, and General Use Zones, including numerous islands. Zones are classified based on allowed use (Wildlife Conservation Society, 2008). The General Use Zone is designated for recreational use, research, and fishing, the Conservation Zone only allows recreational use, no extractive activity; and the Preservation Zone allows no activities at all (Wildlife Conservation Society, 2008). Part of the goal of zoning is to protect spawning sites for many aquatic animals (Wildlife Conservation Society, 2008). This allows the General Use Zone to often have higher fish populations than outside the reserve hence many fisherfolks can benefit from this plan (Wildlife Conservation Society, 2008). The fish samples were taken from four sites located in the General Use Zone of the SWCMR, as seen on the map (Figure 2) (Wildlife Conservation Society, 2008).

Figure 1: Ocyurus chrysurus (yellow tail snapper) (Photo credit Jeanne Solis).

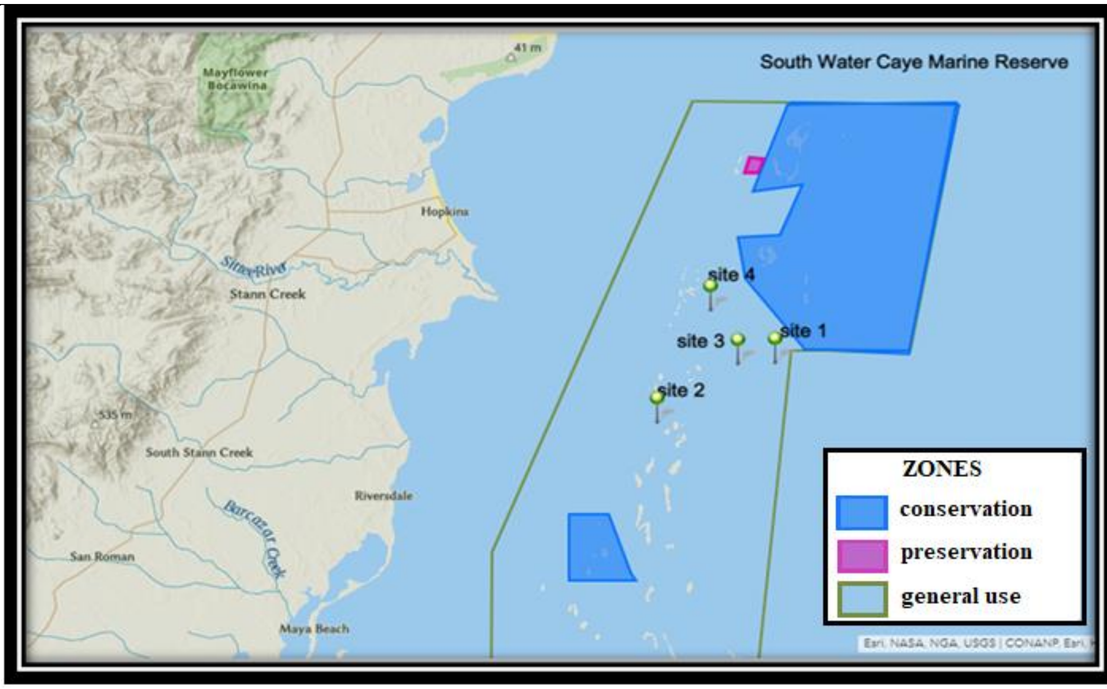

Figure 2: Sample sites in the SWCMR. Sites were in the General Use Zone which is designated for recreational use, research and fishing. In the Conservation Zone, only recreational use is allowed, no extractive activity. No activities are allowed in the preservation zone (Map credit Dylana Nicholas).

Fish samples and location coordinates were collected with the assistance of a local fisherman from the Dangriga market. At each of the four sample sites, 10 samples were collected and reserved for analysis. This resulted in a total of 40 samples. Sample collection was done at fortnight intervals, spanning a two-month period from February to April 2022. The fish samples were taken to the University of Belize and the Stann Creek Ecumenical Junior College laboratories for examination.

The methodology used for parasite identification was based on the work of Klimpel *et al.* (2019). Primary morphometric data including total length, standard length, and total weight were recorded. A macroscopic examination of the outer surface of the fish (body surface, eyes, gills, nostrils, anus, and mouth cavity) was conducted and any visible signs of ectoparasites were recorded. The gills and operculum were removed and examined, then the tunic fibrosa bulbi of the fish eyes were punctured and the eye fluid was collected and inspected. Each fish was dissected by cutting laterally from the anus to the isthmus. When isopods were encountered, their location was noted, then they were removed using tweezers and the abundance in the individual fish was recorded. The internal organs were removed and each was examined with both a stereoscope and a microscope for the presence of parasites.

Images were taken to document various parasites observed. Parasites were classified based on type, location in the fish body, and the fish sample site. An ANOVA was done to determine whether there were any statistical differences in parasite abundance between all four sites. The fish were divided into two groups based on their distance from the mainland. Sites two and four were labeled as West (these were a little closer to the coast), and sites one and three were labeled East (these were a little further from the mainland). It was speculated that fisherfolk would likely prefer sites that were closer to the coast as further trips would be more costly in terms of fuel. If yields were not as great, then they would venture further out. With this in mind, a T-test was done to determine if there were any statistical differences between parasite quantity and the two sample groups.

Results

For the surveyed sample population of *O. chrysurus,* the total weight ranged from 109.1 g to 374.6 g with an average weight of 181.1 g. Total length ranged from 22 cm to 32 cm with an average of 25.7 cm. Sex distribution showed a 14% difference with 43% being male and 57% female. Using a cut-off length at maturity of 25 cm, 38 % of samples were classified as juveniles. Figure 3 summarizes the sex and maturity of the total population of yellow tail snappers collected.

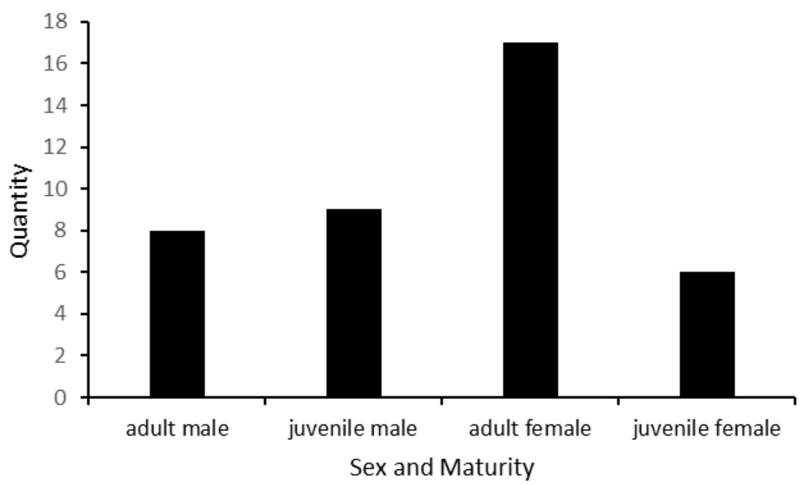

Figure 3: Sex and maturity of Ocyurus chrysurus sample population: 20% were adult males, 22.5% were juvenile males, 42.5% were adult females, and 15% were juvenile females.

Parasites found on fish were classified as ectoparasites or endoparasites based on their location on the body. Ectoparasites are found on the external surface, while endoparasites are found within the host's cavities or in internal organs (Klimpel *et. al.,* 2019). A total of 84 individual multicellular parasites were observed distributed among the 40 individuals of *O. chrysurus* samples. The only ectoparasite observed was the *Cirolanid isopod* found on fish 3, site 2 (figure 4 A). The Cirolanid isopod was also detected along the body surface of 3 other individuals (~8%). Endoparasites were not detected in the internal body cavity, liver, gonads, or kidneys of any of the fish samples. Twelve isopods were found in the gills of four fishes from site 3 (Figure 4 B). However, over 50% of the fish samples had *Cymothoa exigua* (an Isopod) in their oral cavities (Figure 4 C). Fishes from sites 3 and 4 were at the higher end of the results with 90% and 100% infestation of *C. exigua* respectively, while site 1 had 60% and site 2 had 20%. *C. exigua* were encountered as male-female pairs in a majority of the cases (60%) with the male further in the oral cavity near the gills. Isopods were also found in the gills of 5 fishes (~13%), with the majority (4) being from the sample of fishes from site 3. Other than *C. exigua*, the most common parasite was digeneans (flukes) found within the stomach, pyloric caeca, and gut. A total of 40% of the samples had digeneans. Several unidentified helminths were also seen in several fish samples' stomachs and guts. A total of 20% of the fish had a helminth infestation other than digenean. Two *O. chrysurus* individuals (representing 5% of the sample) had both digenean and another helminth.

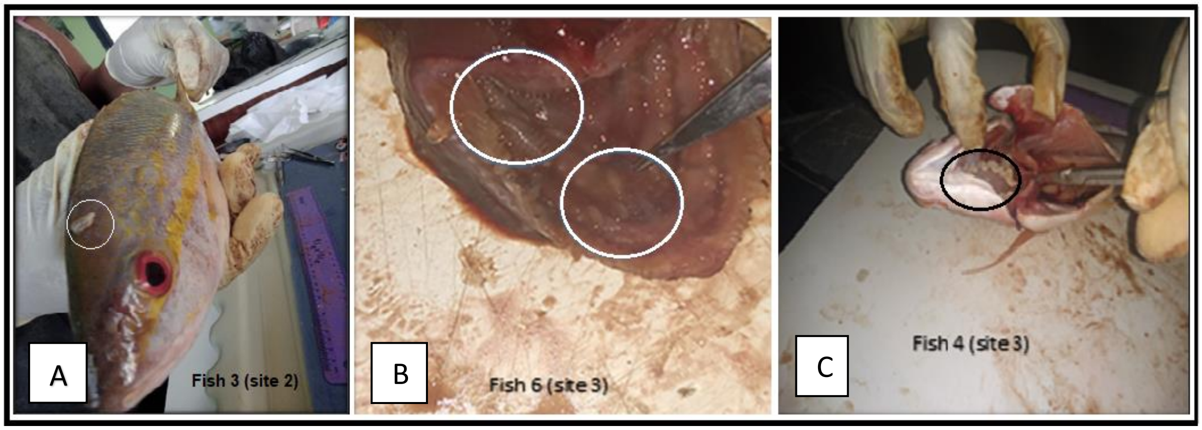

Figure 4: isopod parasite found on the surface of a fish (A) (photo credits: Jeanne Solis), isopods found in the gills of a fish (B), Cymothoa exigua attached to the mouth of fish (C) (photo credits: Cynthia Villagran).

Figure 5 displays images of the most abundant examples of the digeneans, unidentified segmented worms and another helminth observed under the microscope at 40x. Figure 5 A shows an example of a digenean found in the gut. It was also found in the pyloric caeca and the stomach of different individuals. A total of nine fishes were infected with digeneans. Figure 5 B shows a segmented worm found in the pyloric caeca of a fish. A total of thirteen unidentified segmented worms were found in eleven fishes. Figure 5 C shows an unidentified helminth found in the gut of a fish. A total of nine unidentified helminths were found in eight fishes.

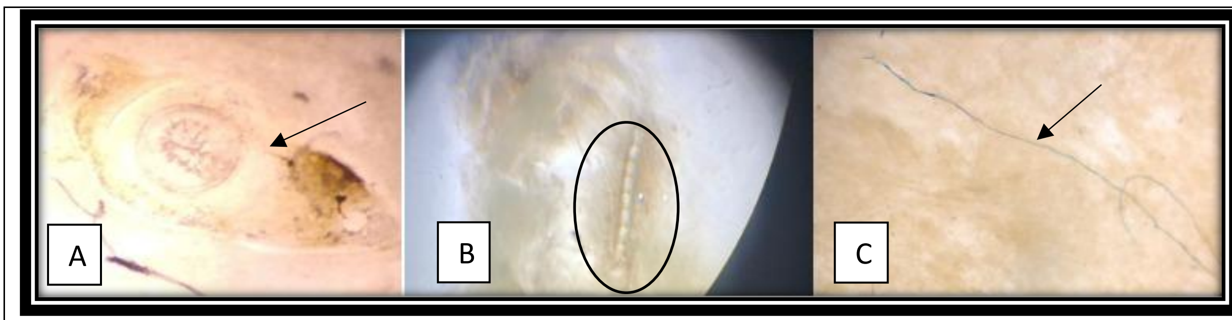

Figure 5: Parasitic worms found in O. chrysurus: digeneans found in the gut of fish 8 from site 1 (A), segmented worm found in the pyloric caeca of fish 6 from site 1 (B), unidentified helminth found in the gut of fish 1 from site 1 (C). Magnification 40x. (Photo credits: Jeanne Solis).

The parasites can be divided into two common types: isopods and helminths. The isopods were found the surface, mouth, and gills; the helminths in the digestive system. Table 1 shows the abundance of the various types of parasites identified, grouped by anatomical location in which they were found in the fish. Grouping all isopods, there was a total of 38 individuals. *C. exigua* was the most abundant isopod with a total of 22. *C. exigua* (58% of total isopods) found in the mouths of the infested fishes. The majority of the other isopods, 12 individuals (32% of total isopods), were found in fish gills. A total of 14 individual digeneans were identified. Digeneans are from a class of trematodes in the Platyhelminthes phylum.

Table 1: Overview of parasites observed based on type and anatomical location.

Organ	Types of Parasites	Quantity
mouth	*C. exigua*	22
	C. isopod	1
Body surface	*C. isopod*	3
gills	Unidentified isopods	12
stomach	Blue unidentified worm	8
	digenea	4
	helminth	6
pyloric caeca	digenea	7
gut	digenea	3
	unidentified segmented worm	7
	helminth	3

There was no statistical difference in parasite quantity amongst the 4 sites as shown by the one-way ANOVA test ($F=2.228$, $p=0.133$).

There were no statistical differences in parasite quantity when sites were grouped by cardinal points. Sites 2 and 4 were grouped as West and sites 1 and 3 were grouped and labeled as East. A T-test showed no statistical difference between the two groups ($F=2.720$, $p=0.119$).

Figure 6 shows the overall quantity of parasites found in each of the four locations. Site 3 was noted to have the most total parasite from all four sites, followed by site 4, site 1, and then site 2.

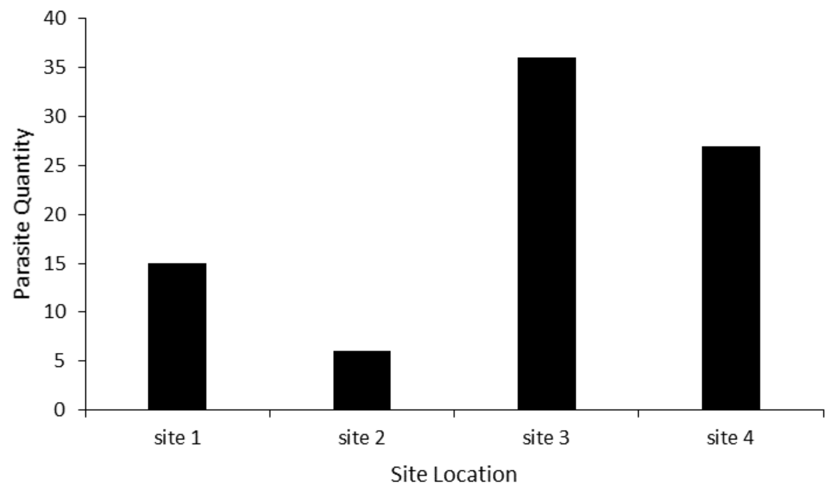

Figure 6: Overall quantity of parasites by site location

Discussion

Aquatic parasitic infections are pretty common within marine ecosystems, especially when there are diverse environments where all the requirements for transmission between parasite and host are met (Tinsley, 2005). Parasite prevalence is thought to play an important role in controlling both the host population and its evolution (Ill, 2015). Since many fish parasites rely on multiple hosts throughout their life cycle, the diversity and prevalence of parasites can be an indicator of the general health condition of the fish populations and the ecosystem as a whole (Ill, 2015). In a broad 2012 study of various tropical marine fish, species diversity of parasites vs diversity of fish hosts was found to be approximately 10:1 (Justine *et al.*, 2012). Diversity overall is considered important; higher diversity in an ecosystem's populations can have a "dilution" effect on disease and infestations, including a decrease in the abundance of parasitic infestations (Civitello, 2015). This effect is different from the prevalence of parasitic infestations in general. Monoxenous (single host) parasites tend to be able to resist environmental changes more than heteroxenous (multiple hosts) parasites since they are dependent on a diversity of hosts (Dzikowski, 2003). A recent study in Puget Sound in the U.S. showed that there was a decrease in parasite abundance in fish that could be linked to a change in climate and an increase in sea surface temperature of about 38% for every 1^{o}C (Wood, 2023). This suggests that monitoring parasites in local marine waters may be used as one indicator in a monitoring system of an ecosystem's condition.

Prevalence, abundance, and diversity of parasites compared along with associated environmental conditions over time can be monitored and evaluated for correlation in any given site. This small study has begun the compilation of parasitic information for *O. chrysurus in* SWCMR which can potentially be used in this manner. This study found that the most abundant macroparasites in the area for *O. chrysurus* were helminths and crustaceans. Some of the major groups of parasites found in fish are similar to those found in most animals and include protists, various helminths, and crustaceans (Petty *et al.,* 2022). The parasites observed were broadly grouped into two categories - endoparasites and ectoparasites. The majority of different parasites identified were endoparasitic helminths and copepods that occupied different locations in the digestive tract. Helminths were found mainly in the stomach and intestines, while crustaceans were mainly found in the oral cavity. Endoparasites can normally be found in nearly every internal organ within a host fish species (Leung, 2014), but examination of tissues did not result in the discovery of any macroparasite.

Various species of helminths are known to infect fish. Fish like snappers are even more susceptible to infestation because they are predators that feed on crustaceans and small fish that are often intermediate hosts to different species of helminths (Hossen *et al*., 2021). A study of helminth parasites of red snapper, *Lutjanas campehanus*, in the neighboring waters of Veracruz, Mexico, showed a 100% prevalence of helminth infestation in a sample of 52 individual fish specimens (Mendoza *et al.,* 2014). There is also a bit of diversity in the type of helminths. A study focusing on the diversity of helminths infesting *O. chrysurus* in the same area showed 19 species of helminths with 47% of these species being digeneans; two monogeans showed the highest prevalence, with *Euryhalitrema torquecirrus* being 69% and *Microcotyloides incisa* being 53% (Mendoza *et al*., 2014). An updated list of parasites found in snapper from the Caribbean, Gulf of Mexico, and the Mexican Pacific done by Avila *et al*., (2022) recorded 171 helminths distributed amongst numerous species of snapper. Of the total individual helminths, 80 were digeneans, followed by 42 nematodes, 27 monogeneans, 11 cestodes, and 11 acanthocephalans. The common digeneans found were *Stephanostomum casum*, *Hamacreadium mutabile*, *Helicometrina nimia*, and *Siphodera vinaledwardsii*. In this study of the SWCNR, 55% of the fish had a helminth infestation, which is a little lower than that obtained in the Vera Cruz studies for red and yellow snappers (Mendoza *et al*., 2014; Montoya-Mendoza *et al*., 2014) but, like the latter study, digeneans were seen to be the most common helminth. As a group, digeneans were the second most abundant parasite found with a prevalence of 40%. Several unidentified helminths were seen in the stomach and the gut of several fish samples with two *O. chrysurus* individuals having both digenean and another helminth. For better characterization of the diversity of the helminths, more time would need to be spent in trying to classify the various helminth found.

Digeneans are heteroxenous flatworms that usually require a mollusk as an intermediate host (Paperna, 1996). They are a very large group of endoparasites in aquatic systems and likely play a significant role in the ecosystems in which they occur (Orelis-Ribeiro *et al*., 2014) There are two major types – blood flukes and didymozoida. Blood flukes are slender and spiny, while didymozoida are threadlike and tend to occur in body cavities or cysts (Paperna, 1996). Helminth infections within the intestinal tract can cause occlusion of the gut or affect the structure of the intestinal epithelium through feeding (Wakelin, 1996). Infestation by these parasites can affect the fish's behavior, metabolism, fecundity, survival, and body condition (Rohde, 1984). However, the presence of a parasite does not always result in measurable harm to the fish host. A study done by Lagrue and Poulin (2015) studied the condition of several fishes with and without parasites. The fish condition was based on a commonly accepted index - the ratio of body mass to length. The greater the ratio, the better condition the fish was assumed to be in. The study showed no correlation between parasite load and fish body condition when parasite mass was excluded, suggesting that the presence of the helminth had no significant effect on the fish condition. The fish samples from SWCMR ranged in total length size from 22 cm to 32 cm with an average of 25.7 cm. These are smaller than what is commonly encountered for *O. chrysurus*, which according to FishBase 2015 updated data, is commonly 40 cm in total length, with the average size at maturity being 23.8. Further analysis would need to be done to see what factors may be affecting the average size of these fish in the area.

The crustacean *C. exigua* was the most prevalent and abundant parasite found in the samples. *C. exigua* is known to target snapper species primarily. The parasitic louse *C. exigua* was found in more than half of the total population of *O. chrysurus*. Both male and female parasites were found within the fish's mouths, with some females also found to be carrying fertilized eggs. The parasite's life cycle starts when it first enters the host in the juvenile stage as a male; it may then transforms into a female as time progresses (Alvarez and Flores, 1996). In adults, the female attaches to the tongue, completely replacing it, while the male attaches to the branchial cavity (Alvarez and Flores, 1996). This parasite substitutes the tongue completely and allows the host to feed normally (Alvarez and Flores, 1996). Infection of the parasite *C. exigua* occurs in high frequency due to the characteristics of the host species, which allows for more favorable encounters between the host and the juvenile isopods. The characteristics include their habitat range (demersal habitats) and whether they are schooling species. The findings of this study can be due to numerous reasons such as fish species and the dates on which the research was conducted. According to Brusca (1978),

There are two main groups of ectoparasites for fishes; monogeneans and crustaceans. Crustaceans are a large and diverse group, including copepods, isopods, and branchiurans (Feist and Longshaw, 2008). Many infections involving crustaceans are limited or only localized where feeding and attachment are necessary

(Feist and Longshaw, 2008). However, those areas can facilitate entry for damaging bacteria and fungi (Feist and Longshaw, 2008).

The differences in parasite quantity at the various site can be due to numerous reasons such as habitat area, population dynamics, and environmental factors. As shown in Figure 2, the fishing location ranged within the general use zone of the SWCMR, with sites 1 and 4 closest to the conservation zone, followed by sites 3 and site 2 being the furthest. Figure 5 illustrates that site 3 was the most abundant in parasites, followed by sites 4 and 1, with site 2 showing the least number of parasites. This could be because the fishes caught from sites 1, 3, and 4 were so close to the protected area of the reserve. A study done by Wood *et al.*, (2013) found that parasitism in various organisms increased among populations in protected areas versus unprotected areas. They concluded that fishing could reduce parasite abundance due to its decline in the availability of host and habitat. McCallum *et al.*, (2005) found that higher host densities in protected areas supported higher parasitic levels when looking at the influence of parasites on marine protected areas.

Statistical significance indicates the presence of an effect, while practical significance relays information regarding the magnitude of the effect (Frost, 2019). In other words, even though there was no proof of a statistical difference among parasite activity within the different sites, it does not mean there was no significance overall. Even though parasite infection rates were higher in sites 3 and 4, there were no statistical differences between these two and the other sites nor between the East and West groups. This can be due to the magnitude of the sample size and/or the period in which the samples were taken. A larger sample size can more accurately show the entire group's behavior (Kalla, 2009). The period in which this study was conducted could also play a role in the quantity of parasites found within the sites. A study by Shearer and Ezenwa (2020) researched the effect of rainfall as a driver of seasonality in parasitism. They concluded that rainfall can have a positive effect on parasite survival and movement within the environment. This study was conducted during the dry season, which may have limited the quantity of parasites found at the various sites.

When analysis of parasite quantity based on gender was done, it showed that females held the majority of parasites compared to males. Cable and Van Oosterhout (2007) studied how sex-specific differences, such as behavior and biology, and shoaling, affect parasite transmission in guppies. This research showed parasite transmission may be affected by several sex-specific differences, and the rate of transmission was determined by how long these fishes were in contact with one another. Females were seen to have the most parasites, and since they shoaled more frequently than males, the infection rate was 4 times higher than the ones in the males. A similar study done by Karvonen and Lindstrom (2018) looked at gender-specific parasitism in two species of gobies. They found that females had a higher infection rate and were easily infected, suggesting a difference in exposure or males having a higher resistance to the parasites. Overall, parasite quantity can depend on numerous factors, many of which were not tested for in this research.

Conclusion

In summary, Ocyurus chrysurus is known to have very few parasites and was found with a relatively low parasitic relationship compared to similar studies done by Mendoza *et. al.,* (2014) and Ruiz and Madrid (1992). The majority of the parasites found (*Cymothoa exigua*) were located within the mouth of the fishes, followed by isopods on the gills and body surface and various worms and digeneans within the digestive system. No differences were seen concerning parasites and site location. One limitation of this study was the lack of advanced parasitic knowledge to identify better all parasites found. Recommendations to better this study; compare parasite richness of the same species in different locations and during different periods to see if there are any relations between parasites and different environmental factors. Another recommendation is to broaden this study to other species and sites, which will allow us to be well-versed in better management strategies and food safety for ourselves and the community.

Conflicts of Interest

The authors declare no conflicts of interest.

Acknowledgments

The authors thank faculty member, Mr. Rolando Caballero, from the Science Department under the Faculty of Science and Technology at the University of Belize for his contribution to the facilitation of the biology laboratory as well as the Stann Creek Ecumenical Junior College for allowing the use of their laboratory during Covid 19 pandemic.

Funding

No direct funding supported this study.

References

Alvarez, F. and Flores, M. (1996). *Cymothoa exigua* (Isopoda: Cymothoidae) parasitizing snapper Lurjanus peru (Pisces: Lutjanidae) in Manzanillo, Colima, Mexico. *Journal of Tropical Biology*, 44 (3), 391-394. Retrieved from https://revistas.ucr.ac.cr/index.php/rbt/article/view/22152

Avila, F. E. J., Prieto G. L., Jiménez, S. L. C., Medina, G. R. M. and Moralez, S. F. N (2022). Updated list of helminth parasites of snappers (Lutjanidae) from the Caribbean, Gulf of Mexico, and Mexican Pacific. Thalassa. https://doi.org/10.1007/s41208-022-00411-x

Barber, L. (2005). Parasites grow larger in faster growing fish hosts. International Journal for Parasitology. Volume 35, Issue 2, February 2005, Pages 137-143. https://doi.org/10.1016/j.ijpara.2004.11.010

Begossi, A., Salivonchyk, S.V., Araujo, L.G., Andreoli, T.B., Clauzet, M., Martinelli, C.M., Ferreira, A.G., Oliveira, L.E. and Silvano, R.A. (2011) Ethnobiology of snappers (Lutjanidae): target species and suggestions for management. J. Ethnobiol Ethnomed. 7:11. doi: 10.1186/1746-4269-7-11. PMID: 21410969; PMCID: PMC3068939

Belize Fisheries Department (2018). South Water Caye Marine Reserve – Management Plan 2019-2023 https://rris.biopama.org/sites/default/files/2021 02/SWCMR%20Management%20Plan%202019-2023.pdf

Branch, T. A., Jensen, O. P., Ricard, D., Ye, Y. and Hilborn, R. (2011). Contrasting global trends in marine fishery status obtained from catches and from stock assessments. Conservation Biology. doi: 10.1111/j.1523-1739.2011.01687.x

Brusca, R.C. (1978). Studies on the cymothoid fish symbionts of the eastern Pacific (Crustacea: Cymothoidae). II Systematics and biology of *Lironeca vulgaris* Stimpson 1857. *Occaa. Pap Allan Hancock Found. New Series.* No. 2. p. 1-19

Burrows, J. (2013). Illness-Causing Fish Parasites (Worms). Retrieved September 17, 2020, from http://www.bccdc.ca/resourcegallery/Documents/Educational%20Materials/EH/FPS/Fish/illnesscausingfishparasitesjan 13.pdf

Cable, J. and Van Oosterhout. (2007). The role of innate and acquired resistance in two natural populations of guppies (*Poecilia reticulata*) infected with the ectoparasite *Gyrodactylus turnbulli*. Biological Journal of the Linnean Society (90). pp. 647-655. ISSN 1095-8312

Collins, M. R. (1984). Hatschekia O. (Copepoda, Caligoida) from Yellowtail Snapper (*Ocyurus chrysurus*) in the Florida Keys. Journal of Wildlife Diseases, 20(1), 63–64. https://doi.org/https://doi.org/10.7589/0090-3558-20.1.63

Cavalcanti, Elizete., Takemoto, Ricardo., Alves, Leucio. And Chellappa, Sathyabama. (2011). First record of endoparasite Philometra sp. (Nematoda: Philometridae) in lane snapper *Lutjanus synagris* from the coast of Rio Grande do Norte, Brazil. Marine Biodiversity Records. 3.10.1017/S1755267210000862

Civitello, D.J.; Cohen, J., Hiba, F. and Rohr, J.R. (2015) Biodiversity inhibits parasites: Broad evidence for the dilution effect. *PNAS*. 112(28). https://doi.org/10.1073/pnas.1506279112

Cooper, E., Burke, L. and Bood, N. (2009). Coastal Capital: Belize The Economic Contribution of Belize's Coral Reefs and Mangroves. Retrieved September 17, 2020, from http://pdf.wri.org/coastal_capital_belize_brochure.pdf

Dunn, A.M., Torchin, M.E., Hatcher, M.J., Kotanen, P.M., Blumenthal, D.M., Byers, J.E., Coon, C.A.C., Frankel, V.M., Holt, R.D., Hufbauer, R.A., Kanarek, A.R., Schierenbeck, K.A., Wolfe, L.M. and Perkins, S.E. (2012), Indirect effects of parasites in invasions. Funct Ecol, 26: 1262-1274. https://doi.org/10.1111/j.1365-2435.2012.02041.x

Dzikowski, R., Paperna, I. and Diamant, A. (2003). Use of Fish Parasite Species Richness Indices in Analyszing Anthropoengically Impacted Costal marine Ecosystems. Helgoland Marine Research. 57 : 220-227. https://doi.org/10.1007/s10152-003-0138-2

Ebert, D., Lipsitch, M. and Mangin, K. L. (2000). The Effect of Parasites on Host Population Density and Extinction: Experimental Epidemiology with Daphnia and Six Microparasites. Grenfell, B.T. (Ed.) The American Naturalist. 156(5), 459–477. https://doi.org/10.1086/303404

Feist, S. W. and Longshaw, M. (2008). Histopathology of fish parasite infections - importance for populations. Journal of Fish Biology, 73(9), 2143–2160. https://doi.org/10.1111/j.1095-8649.2008.02060.x

Frost, J (2019). Practical vs. Statistical significance. Retrieved September 17, 2020, from https://statisticsbyjim.com/hypothesis-testing/practical-statistical-significance

Froese, R., and Pauly. D. Editors. (2023). *Ocyurus chrysurus* in FishBase. World Wide Web electronic publication. www.fishbase.org, (page last updated 2015)

Gunderson, J. (2008). Parasites of Freshwater Fish. Retrieved September 17, 2020, fromhttp://www.seagrant.umn.edu/fisheries/parasites

Gunn, A. and Pitt, S.J. (2012). Parasitology: An integrated approach. John Wiley & Sons, Ltd.

Hossen, M. S.; Wassens, S. and Shamsi, S. (2021) Occurrence and Abundance of Zoonotic Nematodes in Snapper *Chrysophrys auratus*, a Popular Table Fish from Australian and New Zealand Waters. *Food and Waterborne Parasitology*. https://doi.org/10.1016/j.fawpar.2021.e00120

Hudson, P. J., Dobson, A. P., and Lafferty, K.D. (2006). Is a Healthy Ecosystem One That Is Rich in Parasites? Trends in Ecology & Evolution. 21(7) 381-386 https://doi.org/10.1016/j.tree.2006.04.007

Institute of Medicine (US) Committee on Evaluation of the Safety of Fishery Products, Seafood Safety. Washington (DC): National Academies Press (US) (1991). 3, Microbiological and Parasitic Exposure and Health Effects. Ahmed, F.E. (Ed.) Available from: https://www.ncbi.nlm.nih.gov/books/NBK235727/

Ill, Gonzalo. (2015) Parasites as Health Indicators in Wild Fish Populations. Journal of Aquaculture and Marine Biology. 3(1): 00055. DOI: 10.15406/jamb.2015.03.00055

Justine, J.L.; Beveridge, I.; Boxshall, G.A.; Bray, R.A.; Miller, T.L.; Moravec, F.; Trilles, J.P. and Whittington ID. An annotated list of fish parasites (Isopoda, Copepoda, Monogenea, Digenea, Cestoda, Nematoda) collected from Snappers and Bream (Lutjanidae, Nemipteridae, Caesionidae) in New Caledonia confirms high parasite biodiversity on coral reef fish. Aquat Biosyst. 2012 Sep 4; 8(1):22. doi: 10.1186/2046-9063-8-22. PMID: 22947621; PMCID: PMC3507714

Kalla, S (Jun 18, 2009). Statistical Significance and Sample Size. https://explorable.com/statistical-significance-sample-size

Karvonen, A. and Lindström, K. (2018). Spatiotemporal and gender-specific parasitism in two species of gobiid fish. Ecology and evolution, 8(12), 6114–6123. https://doi.org/10.1002/ece3.4151

Klimpel, S., Kuhn, T., Münster Julian, Dörge Dorian D., Klapper, R., and Kochmann, J. (2019). Parasites of marine fish and cephalopods: A practical guide. Springer Cham. https://doi.org/10.1007/978-3-030-16220-7

Lagrue, C., and Poulin, R. (2015). Measuring fish body condition with or without parasites: Does it matter? Journal of Fish Biology, 87(4), 836–847. https://doi.org/10.1111/jfb.12749

Leung, Tommy L. F. (2014). Fish as parasites: an insight into evolutionary convergence in adaptations for parasitism. Journal of Zoology. Volume 294, Issue 1, September 2014. Pages 1-12. https://doi.org/10.1111/jzo.12148.

Lim, L. H. (1992). Fish parasites in integrated farming systems in peninsular Malaysia. In 959183296746580269 T. K. Mukherjee (Author), Integrated livestock-fish production systems: Proceedings... 16-20 December 1991. Kuala Lumpur: Inst. Of Advanced Studies, Univ. Of Malaya.

Longley, W.H. and S.F. Hildebrand, (1941). Systematic catalogue of the fishes of Tortugas, Florida with observations on color, habits, and local distribution. Pap. Tortugas Lab., Carnegie Institution of Washington 34(publ. 535):1-331, pls. 1-34

Luna, S. (2017). Ocyurus chrysurus. FishBase. Retrieved from https://www.fishbase.se/summary/Ocyurus-chrysurus.html

Mendoza, M.J, Badillo, M. L. J. Badillo, and M, Maldonado, S.G (2014) Helminths of *Ocyurus chrysurus* from coastal reefs in Veracruz, Mexico, Revista Mexicana de Biodiversidad, Volume 85, Issue 3, Pages 957-960, ISSN 1870-3453, https://doi.org/10.7550/rmb.43343

McField, M. Soto, N. Craig, A. Giro, I. Drysdale, C. Guerrero, M. Rueda, P. Kramer, S. Canty, and I. Muñiz (2022). 2022 Mesoamerican Reef Report Card. Healthy Reefs Initiative. www.healthyreefs.or

Montoya-Mendoza, J., Jiménez-Badillo, M.; Salgado-Maldonado, G., and Mendoza-Franco, E. (2014). Helminth Parasites of the Red Snapper, *Lutjanus campechanus* (Perciformes: Lutjanidae) from the Reef Santiaguillo, Veracruz, Mexico. The Journal of parasitology. 100. 10.1645/13-429.1

McCallum, H, Gerber, L, and Jani, A. (2005). Does infectious disease influence the efficacy of Marine Protected Areas? A theoretical framework. Journal of Applied Ecology, 42(4), 688–698. https://doi.org/10.1111/j.1365-2664.2005.01043.x

Misganaw, K. and Getu, A. (2016). Review on Major Parasitic Crustacean in Fish. Fish Aquac J 7:175.

Nachev, Milen and Sures, Bernd. (2016). Environmental parasitology: Parasites as accumulation bioindicators in the marine environment. Journal of Sea Research. Volume 113, July 2016, Pages 45-50. https://doi.org/10.1016/j.seares.2015.06.005

Oceana. (2020). State of Belize Fisheries Report. https://belize.oceana.org/wp-content/uploads/sites/15/State_of_Belize_Fisheries_Report_2020.pdf

Orelis-Riveiro, R., Arias, C.R.; Halanych, K. M.; Cribb, T.H., and Bullard, S. A. (2014) Chapter One - Diversity and Ancestry of Flatworms Infecting Blood of Nontetrapod Craniates "Fishes." Advances in Parasitology. 85. P1-64

Paperna, I. (1996). Parasites, infections, and diseases of fishes in Africa: an Update. CIFA Technical Paper. (31). FAO, Rome. http://www.fao.org/3/v9661e/V9551E00.htm#TOC

Petty, B.D., Francis-Floyd, R., Yaang, R.P.E. (2022). Parasitic Diseases of Fish. MSD Veterinary Manual. https://www.msdvetmanual.com/exotic-and-laboratory-animals/aquarium-fish/parasitic-diseases-of-fish

Remote Sensing Solutions GmbH. (2016). Establishing the baseline for seagrass and mangrove area cover in five Marine and Coastal Priority Protected Areas within the Meso-American Reef area - South Water Caye Marine Reserve, Belize. Retrieved from: https://fondosam.org/nopublic/library marfund/Sanctuary/Phase_II/Project_Deliverables/Seagrass_and_mangrove_area_cover_in_the_five_protected_areas_of_the_project/Baseline_Measurement/3.%20Baseline%20measurement%20South%20Water%20Caye.pdf

Rohde, K. (1984). Ecology of marine parasites. Helgoländer Meeresunters. 37, 5-33. Department of Zoology, University of N e w England; Armidale, N.S. IV., Australia

Ruiz-L, A. and Madrid-V, J. (1992). Studies on the biology of the parasitic isopod *Cymothoa exigua* Schioedte and Meinert, 1884 and its relationship with the snapper *Lutjanus peru*

(Pisces: Lutjanidae) Nichols and Murphy, 1922, from commercial catch in Michoacan. Ciencias Marinas, 18(1), 19–34. https://doi.org/10.7773/cm.v18i1.885

Shearer, C, L, Ezenwa, V, O. (2020). Rainfall as a driver of seasonality in parasitism, International Journal for Parasitology: Parasites and Wildlife, Volume 12, Pages 8-12, ISSN 2213-2244, https://doi.org/10.1016/j.ijppaw.2020.04.004

Tinsley, Richard C. (2005) 'Parasitism and hostile environments, in Frédéric Thomas, François Renaud, and Jean-François Guegan (eds), Parasitism and Ecosystems (Oxford, 2005; online ed. Oxford Academic, 1 Sept. 2007), https://doi.org/10.1093/acprof:oso/9780198529873.003.0007, accessed 23 Mar. 2023

United Nations Conference on Trade and Development (2022). Towards a Climate Resilient Multispecies Finfish Management Plan for Belize. DOI: https://doi.org/10.18356/9789210013666

Wakelin, Derek. (1996). Helminths: Pathogenesis and Defenses. In: Baron S, editor. Medical Microbiology. 4th edition. Galveston (TX): University of Texas Medical Branch at Galveston; Chapter 87. Available from: https://www.ncbi.nlm.nih.gov/books/NBK8191/

Wildlife Conservation Society. (2008). Wild places south water caye marine reserve. WCS Belize. Retrieved from https://belize.wcs.org/Wild-Places/South-Water-Caye-Marine-Reserve.aspx

Wildtracks. (2009). Management Plan – South Water Caye Marine Reserve World Heritage Site. Retrieved from: https://rris.biopama.org/sites/default/files/2021- 02/SWCMR Management Plan 2019-

2023.pdf02/South%20Water%20Caye%20Management%20Plan%202010%20-%202015.pdf

Wood, C. L., Micheli, F., Fernández, M., Gelcich, S., Castilla, J. C., & Carvajal, J. (2013). Marine protected areas facilitate parasite populations among four fished host species of central Chile. Journal of Animal Ecology, 82(6), 1276–1287. https://doi.org/10.1111/1365-2656.12104

Wood, C. L, Welicky, R. L.; Preisser, W. C.; Leslie, K.L.; Mastick, N.; Correigh, G.; Maslenikov, K. P.; Tornabene, L.; Kinsella, J. M.; Essington, T. E. (2023) A Reconstruction of Parasite Burden Reveals One Centruy of Climate Associated Parasite Decline. PNAS 120(3). https://doi.org/10.1073/pnas.2211903120

Zajovits, S. (2021). Caribbean Yellowtail Snapper Ocyurus chrysurus: Filling in critical gaps in research for life history and novel aging validation utilizing (thesis)