UNIVERSITI PUTRA MALAYSIA

THE EFFECT OF DIFFERENT HOOK TYPES ON CATCH EFFECTIVENESS, INJURIES, AND SURVIVAL RATES OF THE TILAPIA OREOCHROMIS SP. IN RECREATIONAL FISHING

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The Effect of Different Hook Types on Catch Effectiveness, Injuries, and Survival Rates of the Tilapia *Oreochromis* sp. in Recreational Fishing

By

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ABSTRACT

Recreational fishing is one of the most sought-after activities by the public. A growing number of specialist and conservation-minded anglers demonstrated certain tools and strategies to reduce the negative impacts of angling in catch-and-release fisheries. Physical damage of fish in recreational fishing activities tend to be influenced by hook type. Therefore, present study was aimed to investigated the type of hook that suitable to catch the tilapia *Oreochromis* sp. as well as evaluate the injuries and survival rates after catch-and-release. The sampling was conducted at recreational pond, UPM Bintulu Campus. Three set of fishing rods with two types of hooks (circle hook and octopus hook) was used in this study. The catch efficiency, injuries level and survival rates of both hooks that were used were highlighted. A total of 41 and 22 fish were successfully caught using circle hooks and octopus hooks, respectively. Specifically, 39 out of 41 and 9 out of 22 of the fishes caught was tilapia. The hooking location (non-critical area) of octopus hook and circle hook on the tilapia approximately 100 % and 81.8 %, respectively. While there were only 15.38 % of hook located at the critical area of tilapia when using the circle hook and none for octopus hook. All fish caught in the critical area, i.e., the gills, die after the circle hook is hooked in that area. This may relate with shape of the circle hook whereas the length of the gape shorter than octopus's hook. The moment of fish captured the bait, the hook easily enters to deeper area of the mouth which led to severe damage to the fish. It was recommended to use octopus hook in recreational fishing in order to reduce the mortality rate after the fish released back to the water.

ABSTRAK

Memancing rekreasi adalah salah satu aktiviti yang paling dicari oleh orang ramai. Semakin ramai pemancing yang pakar dan berjiwa pemuliharaan menunjukkan alat dan strategi tertentu untuk mengurangkan impak negatif memancing dalam perikanan tangkap-dan-lepas. Kecederaan fizikal ikan dalam aktiviti memancing rekreasi cenderung dipengaruhi oleh jenis mata kail. Oleh itu, kajian ini bertujuan untuk mengkaji jenis mata kail yang sesuai untuk menangkap ikan tilapia hitam, *Oreochromis* sp. serta menilai kecederaan dan kadar kelangsungan hidup selepas tangkap-dan-lepas. Persampelan dijalankan di kolam rekreasi, UPM Kampus Bintulu. Tiga set pancing dengan dua jenis mata kail (mata kail bulat dan mata kail sotong) digunakan dalam kajian ini. Kecekapan tangkapan, tahap kecederaan dan kadar kelangsungan hidup oleh kedua-dua mata kail yang digunakan telah ditonjolkan. Sebanyak 41 dan 22 ekor ikan berjaya ditangkap menggunakan mata kail bulat dan mata kail sotong, masing-masing. Secara khusus, 39 daripada 41 dan 9 daripada 22 ikan yang ditangkap adalah tilapia hitam. Lokasi mata kail (kawasan tidak kritikal) mata kail sotong dan mata kail bulat pada ikan tilapia hitam masing-masing adalah 100 % dan 81.8 %. Manakala hanya terdapat 15.38 % mata kail yang terletak di kawasan kritikal ikan tilapia hitam apabila menggunakan mata kail bulat dan tiada untuk mata kail sotong. Semua ikan yang dipancing di kawasan kritikal, iaitu insang, mati selepas mata kail bulat sangkut di kawasan tersebut. Ini mungkin berkaitan dengan bentuk mata kail bulat dimana panjang *gape* lebih pendek daripada mata kail sotong. Pada saat ikan memakan umpan, mata kail mudah masuk ke bahagian mulut ikan lebih dalam yang mengakibatkan kecederaan yang parah pada ikan. Adalah disyorkan untuk menggunakan mata kail sotong dalam memancing rekreasi untuk mengurangkan kadar kematian selepas ikan dilepaskan semula ke dalam air.

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APPROVAL SHEETS

I certify that this research project report entitled "The effect of different hook sizes on catch effectiveness, injuries, and survival rates of the tilapia *Oreochromis* sp. in recreational fishing" has been examined and approved as a partial fulfillment of the requirement for the degree of Bachelor of Science (Honors) Aquaculture in the Faculty of Agricultural and Forestry Sciences, Universiti Putra Malaysia Bintulu Sarawak Campus.

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LIST OF ABBREVIATIONS

Abbreviations	Meaning
C&R	Catch-and-released
C&K	Catch-and-keep
CPUE	Catch per unit effort
EAA	European Anglers Alliance
GBIF	Global Biodiversity Information Facility
&	And
%	Percentage
°, ', "	Degrees, minutes and seconds
mm	Millimeters
cm	Centimeters
n	Number of individuals
g	Gram
<,>	Less than, more than
P value	Statistically significant
N	North, or Y. S, South or - (minus)
E	East, or X. W, West or - (minus)

1.0 INTRODUCTION

Recreational fishing is highly popular all around the world, and it is one of the main activities widely applied for recreation as well in fish stocking other than commercial vessels and aquaculture. While recreational fishing has traditionally been operated by either catch-and-keep (C&K) or catch-and-release (C&R). It is grown in popularity in many developed countries, as well as in developing and emerging economies (Brownscombe *et al.* 2017). Catch-and-release is one of the conservation and management method which based on the assumption toward mortality and injuries or sublethal disruptions are temporary. Yet, a widen amount of evidence indicates that not all fish could survive in the fishing activity. Mortality rates vary greatly based on ecological circumstances, fishermen etiquette, types of gear, and species-specific stress reactions (Trahan *et al.* 2021).

Anatomical hooking location has been identified as the one most important determinant of fish survival across C&R studies, with fish hooked in vital areas which are the stomach, oesophagus, and gills that caused serious bleeding to mortality than fish hooked in non-critical positions (Alós *et al.* 2008 & Trahan *et al.* 2021). A range of aspects, including lure/bait type, gear type, and fishermen experience, might influence hooking location. Organic baits, for example, have deeper hooking positions than artificial lure, meanwhile smaller baits produce deeper hooking positions compared to larger baits (Trahan *et al.* 2021). In order to reduce the death of fish (deeply hooked and bleeding) that are fished by C&R and improve the welfare of the fish, then the selection of the right gear and bait should be applied (Weltersbach *et al.* 2019).

Physical harm in recreationally angled fish has also been demonstrated to be influenced by hook type and hook number. Circle hooks, for example, produce shallower hooking positions than J hooks. When compared to treble hooks, several studies have demonstrated that utilising one hooks on lures reduces mortality, less injury and fatality (DuBois and Dubielzig 2004 & Trahan *et al.* 2021). The research on the consequences of the usage of a single hook-on solid plastic fishing lures is still limited whereas it is frequently employed by anglers when hunting freshwater gamefish. When examining impacts on recreationally angled fish, types of hooks and number also can affect handling time and the requirement to utilise specialised hook removal tools such as pliers rather than bare hands (Trahan *et al.* 2021). Barbless hooks have also been widespread practise (sometimes optional, sometimes mandatory) in various countries, as studies show that they prevent injuries during C&R angling events (Trahan *et al.* 2021).

Few previous studies that looked at the influence of hook size in determining catch rates, survival rates, and anatomical hooking location. According to Gilman *et al* (2017) because of the effects on species, adjusting hook sizes can help achieve the goal of catch effectiveness on target. Deep-hooking was the most crucial element determining mortality of fish caught and released. Although just a several studies have looked into the relation between hook size and the possibility of deep-hooking in fishery leisure, the findings imply that the probability of deep-hooking is connected with hook size (Alós *et al.* 2008, Kapusta and Czarkowski 2022 & Meyer *et al.* 2022).

Many selectivity experiments show that small hooks capture more fish than huge hooks. Barbless hooks are a good technique to reduce the time of unhooking, pressure, and hooking injury in freshwater fisheries when it comes to hook type (Grixti *et al.* 2007). Meka (2004) report that the matched tendencies, but also found that barbless hooks lower *Oncorhynchus mykiss* catch efficiency. Other studies found no significant differences in death or hooking damage between barbed and barbless hooks, but did find a decrease in catch per unit effort. Barbless hooks reduce unhooking time, which is a good predictor of fatality rate. Barbless hooks took substantially less time to unhook, hence the authors concluded that they provided just a minor gain at the trade-off of lower catch rates (Alós *et al.* 2008).

The problem faced in recreational fishing is that anglers mostly underestimate the situation of what happens to the tilapia that have been fished using C&R method. Angler attitude and behaviour, which can have a significant impact on fish condition after release, are critical to the long-term viability of C&R angling. It is possible that the tilapia will suffer external or internal injuries (or both), or that it will be infected with another disease or not through the wound. The survival of the fish was also not identified after it was released back into its habitat. Anglers should keep in mind that releasing fish is essentially conservation-oriented, with the goal of allowing the fish to survive. So, anglers should practice good C&R methods according to the rules and laws. Thus, the objectives of this study are to:

1. Identified the appropriate hook types for catching tilapia *Oreochromis* sp.
2. Determined the injuries and survival rates of tilapia *Oreochromis* sp. after C&R.

2.0 LITERATURE REVIEW

2.1 Recreational fishing (C&R)

Recreational angling is one form of recreational fishing. Angling is defined as line fishing employing the hooking method, according to a report released by the European Anglers Alliance (EAA) in 2004. Recreational angling can be defined as the action of catching or attempting to catch fish for non-commercial purposes using a rod and line, pole, or hand-held line. According to the EAA Definition (2004), recreational fishers and anglers do not sell the fish they catch. Because of the low-impact, highly selective catching gear employed and the high survival rate of the fish released, recreational angling is a relatively sustainable type of fishing when compared to other types of fishing, like capture fisheries. Recreational fishing creates greater value than commercial fishing in many countries. The recreational angling segment contributes by far the most to the recreational fishing sector's total socio-economic value (Tisdell 2003).

Catch-and-release fishing helps native fish populations by allowing more fish to stay in the ecosystem and spawn. As a result of this method, an increasing number of anglers are able to enjoy fishing and catch fish. Releasing native fish caught in a national park will assist to ensure that future generations will be able to enjoy this recreational opportunity. Anglers that participate in catch-and-release fishing promptly return native fish (unharmed) to the water where they were caught. Catch-and-release procedures produce high survival rates and successfully take practise when done correctly (Alic *et al.* 2021 & Bartholomew and Bohnsack 2005).

Disadvantages of C&R fishing is that it hurt the fish physically (Donaldson *et al.* 2008). Many caught fish are so damaged physically as their stomach, tongue, or throats are ripped by the hook. According to Noble *et al* (2012), fish that are not handled properly and with respect also at a minimum end up with deformities (ripped lips from aggressively removing hooks from their mouth). They cannot survive after release, which will ultimately die and rot and eventually taint in the water (Donaldson *et al.* 2008).

2.2 Angler's behaviours and attitude

Nguyen *et al* (2013) reported that the potentially critical role of recreational fishermen in freshwater species conservation necessitates paying special attention to recreational anglers' attitudes and activities. Anglers come from a variety of socioeconomic origins, seek a variety of fishing experiences, and vary in their fishing enthusiasm and devotion. Anglers have a variety of reasons, ranging from catching trophy fish to simply enjoying the outdoors. Anglers' views and preferences toward management, as well as their readiness to participate in finding answers to conservation difficulties, vary just as much as their motivations (Golden *et al.* 2019). Nguyen *et al* (2013) has stated that identifying these disparities across anglers and the reasons behind them should help better management and balance stakeholder interests. Angler specialisation (skills, equipment, and setting) has long been used to describe a spectrum of general to specialised angler behaviour, which can influence angler preferences and attitudes toward alternative management model (Beardmore *et al.* 2013).

2.3 Anatomical hook location

According to Mauldin *et al.* (2023), anatomical hook location refers to the orientation of a particular fish's body that is used when describing the anatomy of the hook hooked on the fish. Reeves and Bruesewitz (2007) have mentioned that hooking mortality is frequently influenced by a number of factors, including fish species, ambient circumstances, population variance, gear selection, and the anatomical placement of hook wounds. James *et al.* (2007) has stated that anatomical hooking location plays a significant role in spotted seatrout C&R mortality. The depth of the hooking point within the oral cavity increased the mortality rates of spotted seatrout captured on hook and line. Fish hooked externally and, in the mouth, exhibited a significantly lower mortality rate than those trapped in the gills and oesophagus. Fish hooked externally and, in the mouth, had fatality rates that were over seven times higher than those of fish hooked in the gills and oesophagus. James (2006) mentioned in his study that anatomical hooking positions were established for the four body parts of the mouth, gills, oesophagus, and external (Figure 2.1) where the position of hook wounds or anatomical hooking location is one of the most obvious reasons of hooking fatality. James (2006) mention that Diodati and Richards (1996) has stated that striped bass hooked in the head, jaws, fins, and torso died 5.8 % of the time, whereas those caught in the eyes, gills, and oesophagus died 24 % of the time. They also discovered that striped bass hooked anterior to the pharynx died at a rate of 5.3 %, whereas those hooked in or posterior to the pharynx died at a rate of 25.9 %. James (2006) also indicated that Lukacovic and Uphoff (2002) found that the depth of anatomical hooking position increased mortality in striped bass. Fish hooked in the lip, mouth, or gills had an 8.2 % mortality rate, while fish hooked posterior to the gills had a 54 % mortality rate. Millard *et al* (2003) found that striped bass hooked both anterior and posterior to the gills had greater fatality rates. Fish hooked anterior to the gills died 27 % of the time, while fish hooked posterior to the gills died 69 % of the time.

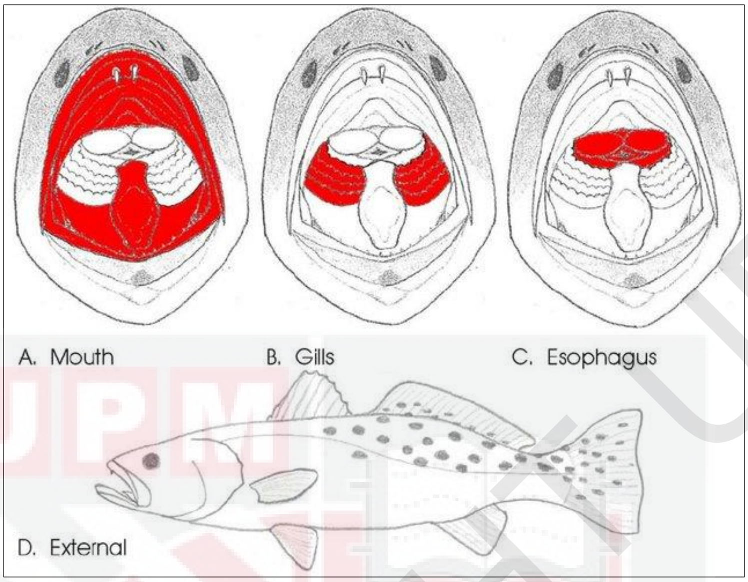

Figure 2.1. Fish hooked in the mouth (A), gills (B), and oesophagus (C) and external hooking refers to fish hooked outside the mouth cavity (D) (James 2006).

2.4 Injuries

Barbs are found on the majority of fishing hooks. Barbs are added to the hook to make it more "sticky." This implies that once the tip has pierced the fish's flesh, the barb is engineered to form a second point that is tough to remove. The barb helps to keep fighting fish stuck to the hook by making it sticky. When anglers remove the hook, barbs cause injury to the fish. They may cause more flesh damage (Inchingolo *et al.* 2010). The quick change in pressure causes the fish's gills to collapse and their swim bladders to rupture once they are out of the water. Other internal injuries that fish might suffer include ruptured blood arteries or enlarged stomachs that protrude from their mouths, in addition to ruptured swim bladders. Even when fish are caught and released, they are frequently killed by injury (Reeves and Bruesewitz 2007). The protective layer on fish's bodies is disturbed when they are grabbed and handled by human. When fish are thrown back into the water, they are more exposed to predators. Anglers frequently attempt to retrieve hooks swallowed by fish by forcing their fingers or even a pair of pliers down the fish's throat. This technique rips off the hook as well as a portion of the fish's throat and guts. Many C&R fish suffer from severe physiological distress and are more likely to die (Cooke and Sneddon 2007 & Davie and Kopf 2006).

2.5 Hook

Basic knowledge on recreational fishing is to understand every instrument used before anglers to start fishing. One of the main instruments is fishing hook. There are five main parts about any fishing hook (Figure 2.2). The eye, shank, bend, point, and barb are the main components (Edappazham *et al.* 2008 & Kaminsky and Schwipps 2020). 1) The eye is the point at which the angler attaches the fishing line or leader. It's what connects the line to the hook. 2) The shank, which is the hook's longest section, provides much of its strength and act as a backbone. The shanks of some hooks, such as circle hooks, are very short, whereas the shanks of others, such as Aberdeen hooks, are longer. 3) The bend is the hook's curve that contributes the torque required to drive the tip into the fish. The point of some hooks, such as the circle hook, is offset from the shank due to a twisting movement in the bend. 4) The tip, or the sharp end of the hook is what burrows into a fish's lip and keeps it secure during the struggle. Lastly, 5) a barb is a secondary point that is offset from the main point. It's made to keep bait and the lip of a fish firmly linked to the hook. Barbs can be troublesome because they are designed to be "sticky." They have a habit of sticking the hook to the fish's lips, the angler's shirt, the angler's thumb, and other places. Barbs are not found on all hooks; a few hooks are sold barbless which eliminates the damage and stickiness caused by barbs but makes it a bit tougher to keep the fish hooked for the entire fight (Edappazham *et al.* 2008 & Kaminsky and Schwipps 2020). According to Amarasinghe *et al.* (2011), depending on the species they are after, hook sizes used by hook-and-line fishermen can range from 8 mm to 22 mm. In their investigation, hook sizes 8 mm, 9 mm, 10 mm, and 11 mm successfully caught an adequate quantity of *Caranx ignobilis* per 100 hooks. In the modified approach used in the present study, the length frequency distribution of fish in each hook size was used as the number of fish per 100 hooks.

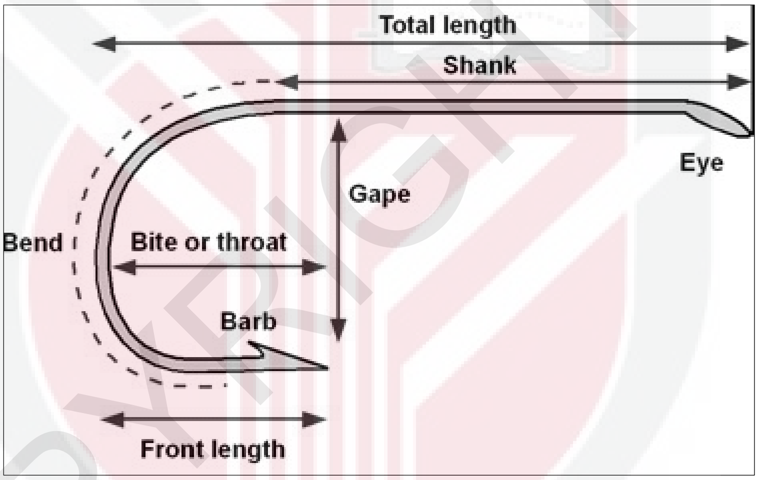

Figure 2.2. Parts of a hook (Amarasinghe *et al.* 2011).

2.6 Hook's type (Circle hook & Octopus hook)

Circle hooks are growing in popularity among recreational and commercial fishermen for their effectiveness and reliable hook set. A circle hook has an eye and shank in a similar fashion to an octopus hook, but a rounder, wider bend and an alarmingly-angled point that sits at a 90-degree angle to the shank, pointing at it rather than parallel to it. A circle hook is designed to only hook a fish in the lip area and nowhere else

(Beverly 2010). The circle hook is a great choice for conservation-minded angler in C&R fishing technique. This is because the unique shape and way it hooks the fish ensures they're nearly always lip-hooked and easy to release. This is an especially important consideration when fishing for large game fish (Brownscombe *et al.* 2017). Other than that, Cooke *et al.* (2003) mentioned that the contrary to many other hook types, circle hooks do not need a strong draw to set the hook since they employ the line's force to rotate the hook so that it hooks on the jaw area.

Octopus hook is between circle hook and J-hooks. Octopus hooks are short-shank hooks that feature a round shank and bend, but they don't have the same dramatic bend as circle hooks (Figure 2.3). When a natural presentation requires a small hook weight and size, octopus hooks are frequently employed for bait fishing (Reeves and Staples 2011). Although they resemble circle hooks, they must be fixed like a J-hook. These hooks are a little easier than a regular bait hook due to their design. They're ideal for little baits and are extremely durable. For live bait fishing, the octopus hook and the circle hook are the two most preferred hook types. These hooks feature a large gap between them and the angler's bait to better fit it. This makes them ideal for tilapia fishing. The durability and strength of the octopus hook have long been known (Waters 2020).

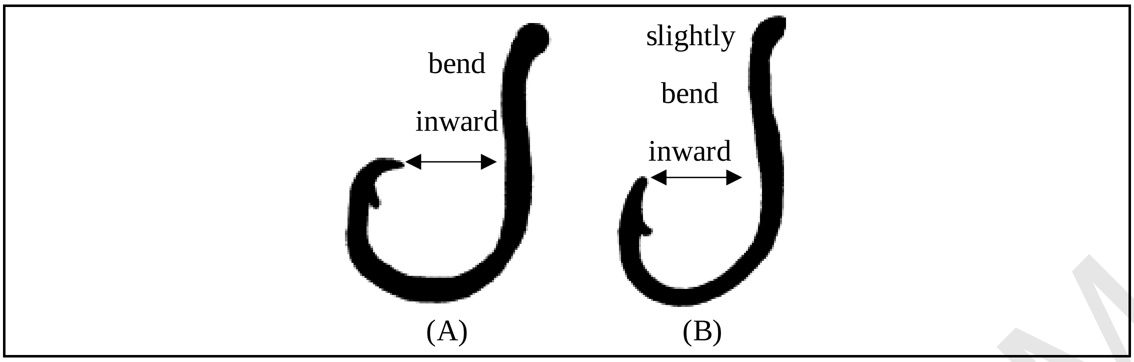

Figure 2.3. (A) Octopus hook (Cooke *et al.* 2003) and (B) Circle hook (Cooke *et al.* 2003).

2.7 Catch effectiveness

Using an octopus hook and circle hook to catch the tilapia and determining the efficacy of the catch. After determining the efficacy of fishing, it is vital to measure its effectiveness in order to ensure and understand how to build better fishing (Herrmann *et al.* 2018). According to Appelman (2015), the catch per unit effort (CPUE) is an indirect measure of the abundance of a target species in fisheries and conservation biology, in this case tilapia. Changes in CPUE are interpreted as changes in the true abundance of the targeted species. Overexploitation is indicated by a declining CPUE, whereas stable CPUE suggests sustainable harvesting (Kantoussan *et al.* 2014).

2.8 Survival rates

According to controlled research, most fish released after hook capture, survive (Thorstad *et al.* 2003). It is mentioned that some of the fish died as a result of being hauled out of the water for a pre-release image, and some of them had been caught multiple times each. But the survival rates are also greater since most fish were captured using lures rather than live bait. Besides, hook position had an effect on survival rates, with fish hooked in the mouth generally surviving and those hooked in the gills or gut surviving at a lower rate. These studies show that C&R fishing is effective, as the majority of fish released live (Bartholomew and Bohnsack 2005). There are several other ways to improve survival rates, such as (1) to hook and land the fish as quickly as possible, leave the fish in the water while removing the hook, and release the fish quickly, and (2) angler's also can wet their hands or gloves before handling the fish to help the fish retain its protective slime, (3) refrain from holding fish in a vertical position when inspecting or photographing them because internal organs are displaced and stress is increased in this unnatural position, and (4) if the hook is difficult to remove by hand, use long-nosed pliers or a hook-removal tool but do not tear additional tissue by removing the hook (Taylor 2003).

2.9 Tilapia, *Oreochromis* sp.

Tilapia is a common name for almost a hundred species of Cichlid fish. The Bali Safari Marine Park (2022) has stated that the Levant, which comprises Israel, Palestine, Lebanon, Syria, and Jordan, is home to the tilapia. They are most frequently found living in brackish water, but they can also be found in shallow streams, ponds, rivers, and lakes. They now occupy a wide range of fresh and brackish tropical and subtropical regions beyond their natural home. Tilapia are therefore listed as one of the "100 of the World's Worst Alien Invasive Species" by the Global Invasive Species Database (2022).

Tilapia's shape resembles sunfish or crappie, but it can still be distinguished because of the Cichlid fish family's distinctive interrupted lateral line. They have lengthy dorsal fins and a deep, compressed body. The dorsal fins anterior section has several spines. The pelvis and anal fins both have spines. Fry, fingerlings, and occasionally adults all have broad vertical bars running the length of their sides (Osman *et al.* 2017).

According to Prabu (2019), tilapia has historically been an important catch fish in Africa and is becoming increasingly important in aquaculture around the world. The group is made up of the genera Oreochromis, Sarotherodon, and Tilapia, which are all significant in aquaculture (Figure 2.4). These three genera are distinguished by a number of traits, but reproductive behaviour may be the most significant. All tilapia species make nests, and fertilized eggs are watched over by a brood parent inside the nest. Both Sarotherodon and Oreochromis species are mouth brooders. Only females of the Oreochromis species engage in mouth brooding, whereas males or both male and female of the Sarotherodon species perform this behaviour (McConnel 2009).

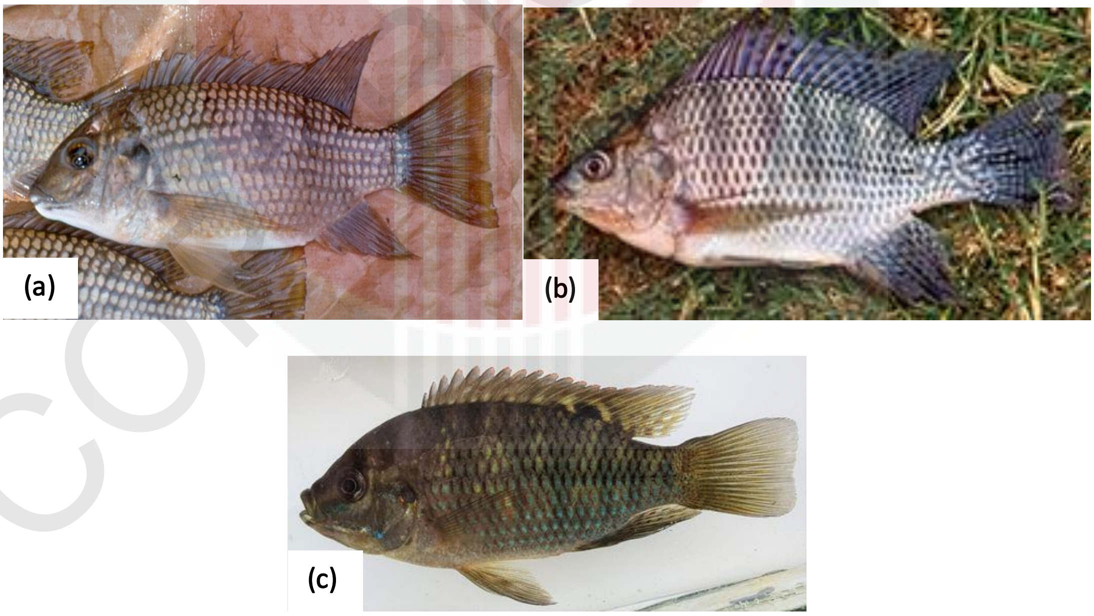

Figure 2.4. (a) *Sarotherodon melanotheron* (FishBase), (b) *Oreochromis niloticus* (FishBase) and (c) *Tilapia sparrmanii* (GBIF).

3.0 MATERIALS AND METHODS

3.1 Study area

The study was carried out at recreational pond in the UPM Bintulu Campus (UPMKB), starting from July until November 2022. *Oreochromis* sp. is a freshwater fish species that commonly captured by the angler at UPMKB, therefore it makes UPMKB the suitable site to carry out this project. Furthermore, the recreational pond was connected with the small rivers in UPMKB that derived from the upstream with approximately 900 meters long as shown in the Figure 3.1 (N 3° 12' 20.412'' and E 113° 5' 41.712'').

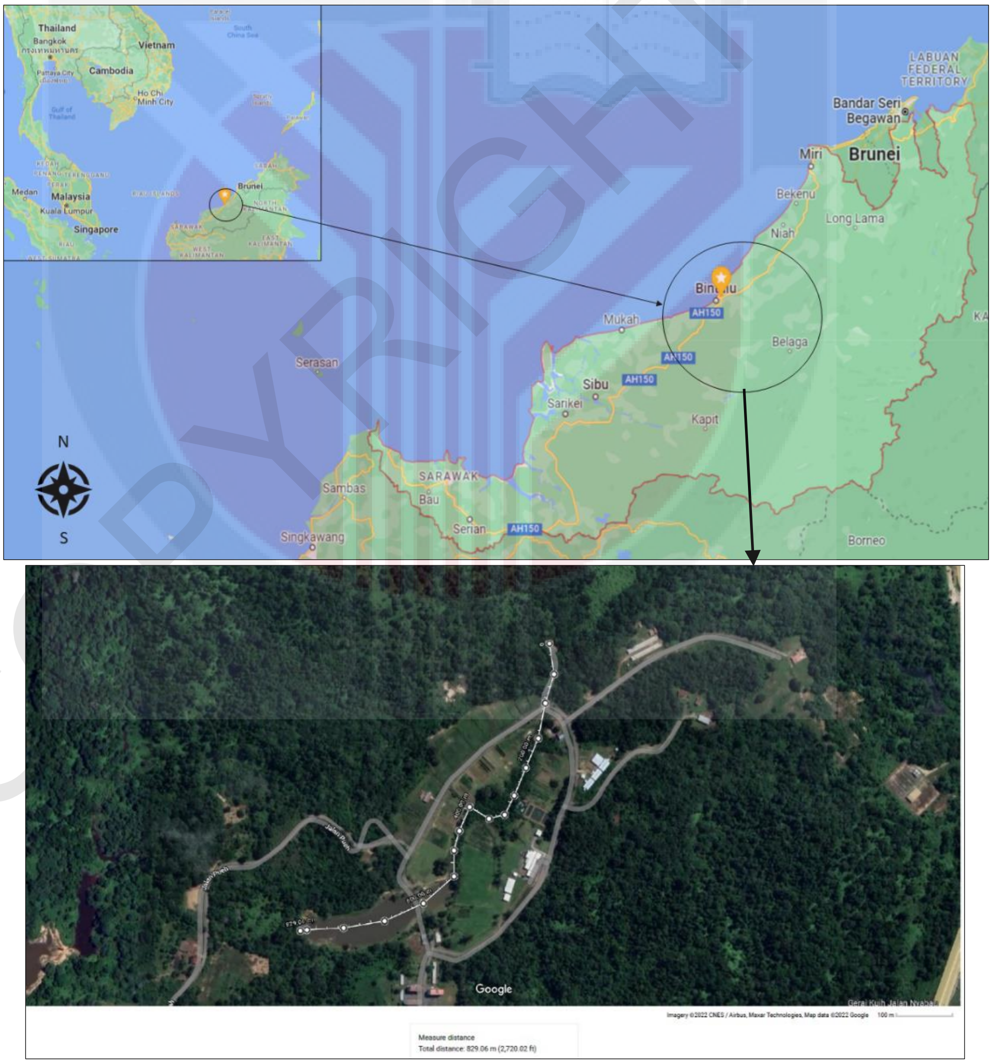

Figure 3.1. Sampling area.

3.2 Sampling procedure

The sampling process was conducted on a daytime period. Rod and line were used with different type of hooks. The type of bait that were used are worms, bread, and chicken liver. Each specimen caught was placed on the tray for the process of removing hook from the mouth of the fish. Wet towel was used to hold the fish. After hook removal, fish weight and length were measured by using weighing scale and measuring board, respectively. The fish then was kept in the stainless-steel quarantine cage net to undergo temporarily quarantined for 24 hours, for the observation of the injury status and survival rate of the fish. The number of fish caught was recorded and sorted according to hook types that previously used during the sampling. Two cm mesh size cage with 30 cm diameter at the centre were used as a quarantine cage (Figure 3.2). Quarantined fish was released back to the water right after 24 hours duration (before being photographed).

Figure 3.2 Stainless steel quarantine cage net.

3.3 Fishing gears

Bottom-line technique was applied from riverbank during a daytime. Different type of hook was used (circle hook – EXORI Fishing size 4 & octopus hook – EXORI Fishing size 4). Three fishing rods (Solid King SK 260) with line (AGASS Lynon Line) were worn with a set of hooks and sinker (size ¼). The hook sizes for the circle hook and octopus hook to be worn are approximately the same. Each hook was fastened to a different swivel (Rolling Swivel W/ Germany – A Snap, size 6) to facilitate the conversion of the set of hooks with the fishing rod.

3.4 Hook removal

The fish immediately transferred to the tray, where the hook removal procedure was carried out. Hook location on the fish mouth was recorded in which divided into two hooking locations namely non-critical and critical. The non-critical hooking location refer to injuries at outer lip and inner-upper lower jaw of the fish, while critical hooking location refer to injuries at gill and gullet. Apart from that, the number of fish that "self-released" were recorded. According to Trahan *et al.* (2021), self-released can be defined as the hook comes out of the fish without any assistance from the angler.

3.5 Data analysis

Simple proportion were used to portray the percentage of injuries, catch effectiveness, and the survival rate of the fish caused by different types of hooks. The two-sample T-test was used to compared the significant differences between percentage of weight and length for hook types. The test was used to compared the significant differences among among individual's weight and length. Statistically significant differences required that *p* values less than 0.05.

4.0 RESULTS

In total, 63 of fish were caught in this study. This finding encompasses 10 genera and six families. Family Anabantidae, Bagridae, Channidae, Cichlidae and Clariidae was represented by one species each namely *Anabas testudineus*, *Hemibagrus nemurus*, *Channa striata*, *Oreochromis* sp. and *Clarias macrocephalus*, respectively. For the family Cyprinidae, it was represented by six species namely *Cyclocheilichthys apogon*, *Barbonymus altus*, *Barbonymus gonionotus*, *Hampala macrolepidota*, *Puntius sealei*, and *Rasbora sarawakensis*.

4.1 The hooking location of fish caught

The total number of fish caught using the circle hook are 41 individuals, while the octopus hook was 22 individuals. All individuals or 100 % of the fish caught using octopus hooks experienced non-critical injuries, which are 62.5 % located at the outer lip and 37.5 % located at inner jaw of fish. Meanwhile, for circle hook, there are 36.4 % of hooks located at outer lip and 45.4 % at the inner jaw, which represented of non-critical hook location. In addition, for the critical hooking location, 18.2 % of hooks located at gill area of fish died during quarantine. There is no hook reached at the gullet of fish during the sampling periods.

The dominant fish caught at UPMKB's Recreational Pond is tilapia, *Oreochromis* sp.. There are nine out of 22 individuals (40.9 %) of tilapia were caught using octopus hooks, and 39 out of 41 individuals (95.1 %) caught using circle hooks. Apart from *Oreochromis* sp., others fish species that was caught using octopus hook like *C. macrocephalus, C. striata, B. altus, B. gonionotus, H. macrolepidota, H. nemurus, P. sealei,* and *R. sarawakensis*. All of these fish grouped in the non-critical hooking location. Meanwhile, for the circle hook, one other species apart from tilapia were recorded namely *C. apogon* which grouped in non-critical hooking location.

Table 4.1. The proportion of injuries on the fish species caught.

Family	Species	No. of individual, n	Self-released, n (%)	Non-critical hooking location, n (%)		Critical hooking location, n (%)		IUCN Status
				Outer lip	Inner-Upper lower jaw	Gill	Gullet	
Fish caught using Octopus hook								
BAGRIDAE	*Hemibagrus nemurus* (Valenciennes, 1840)	2	-	2 (100)	-	-	-	LC
CHANNIDAE	*Channa striata* (Bloch, 1793)	3	1 (33.33)	2 (100)	-	-	-	LC
CICHLIDAE	*Oreochromis* Günther, 1889	9	1 (11.11)	5 (62.5)	3 (37.5)	-	-	LC
CLARIIDAE	*Clarias macrocephalus* Günther, 1864	2	-	2 (100)	-	-	-	DD
CYPRINIDAE	*Barbonymus altus* (Günther, 1868)	1	-	1 (100)	-	-	-	LC
	Barbonymus gonionotus (Bleeker, 1849)	1	-	1 (100)	-	-	-	LC
	Hampala macrolepidota Kuhl & Van Hasselt, 1823	2	-	2 (100)	-	-	-	LC
	Puntius sealei (Herre, 1933)	1	-	-	1 (100)	-	-	LC
	Rasbora sarawakensis Brittan, 1951	1	-	1 (100)	-	-	-	LC
		22	**2**	**16**	**4**	**0**	**0**	
Fish caught using Circle hook								
ANABANTIDAE	*Anabas testudineus* (Bloch, 1792)	1	1 (100)	-	-	-	-	LC
CICHLIDAE	*Oreochromis* Günther, 1889	39	6 (15.38)	12 (36.4)	15 (45.4)	6 (18.2)	-	LC
CYPRINIDAE	*Cyclocheilichthys apogon* (Valenciennes, 1842)	1	-	-	1 (100)	-	-	LC
		41	**7**	**12**	**16**	**6**	**0**	

4.2 Percentage of level of hooking location on tilapia

The percentage of hook locations were shown in Table 4.2. For the octopus hook, the hooking location at the outer lip is higher (62.5%) compared to the inner-upper lower jaw (37.5%) and there was no hook reached into the gill and gullet. For the circle hook, the percentage of the hook location in the inner-upper lower jaw is higher (45.4%) compared to the location of the hook at the outer lip (36.4%) and gill (18.2%), also there are no fish was caught where the hook stuck in the gullet.

Table 4.2. Percentage of different hook location relative to hook type used.

	Non-critical hooking location		**Critical hooking location**	
	Outer lip (%)	**Inner-Upper lower jaw (%)**	**Gill (%)**	**Gullet (%)**
Octopus hook	62.5	37.5	0	0
Circle hook	36.4	45.4	18.2	0

4.3 Species composition

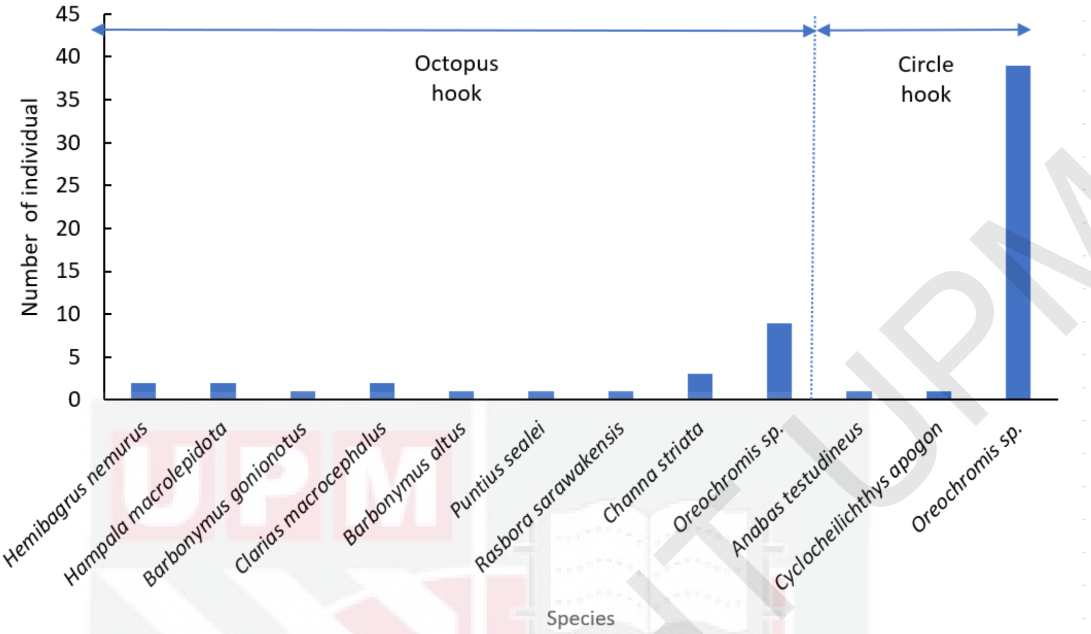

Figure 4.1. The species and number of fish caught.

There are 11 species of fish caught and dominated by *Oreochromis* sp. (Figure 4.1). There are few tilapias that was caught (n = 9) using octopus hook as compared to fish caught using circle hooks (n = 39). Tilapia is the dominant species that inhabits the recreational pond. Low number of fish species that was caught like *A. testudineus, B. altus, B. gonionotus, C. apogon, P. sealei,* and *R. sarawakensis* in the pond.

4.4 Survival rate of tilapia

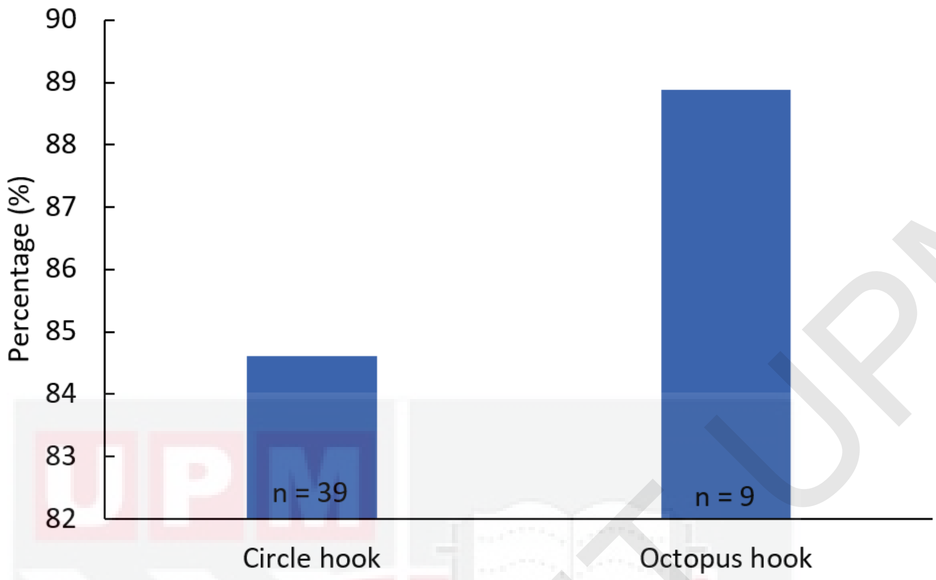

Figure 4.2. The survival rate of *Oreochromis* sp. according to different hook types.

The 88.89 % survival rate of tilapia obtained by using octopus hook with nine individuals caught. Meanwhile, six out of 39 individuals of tilapia died which indicated 15.38 % mortality rate caught using circle hook during the sampling.

4.5 Average total length and weight of tilapia

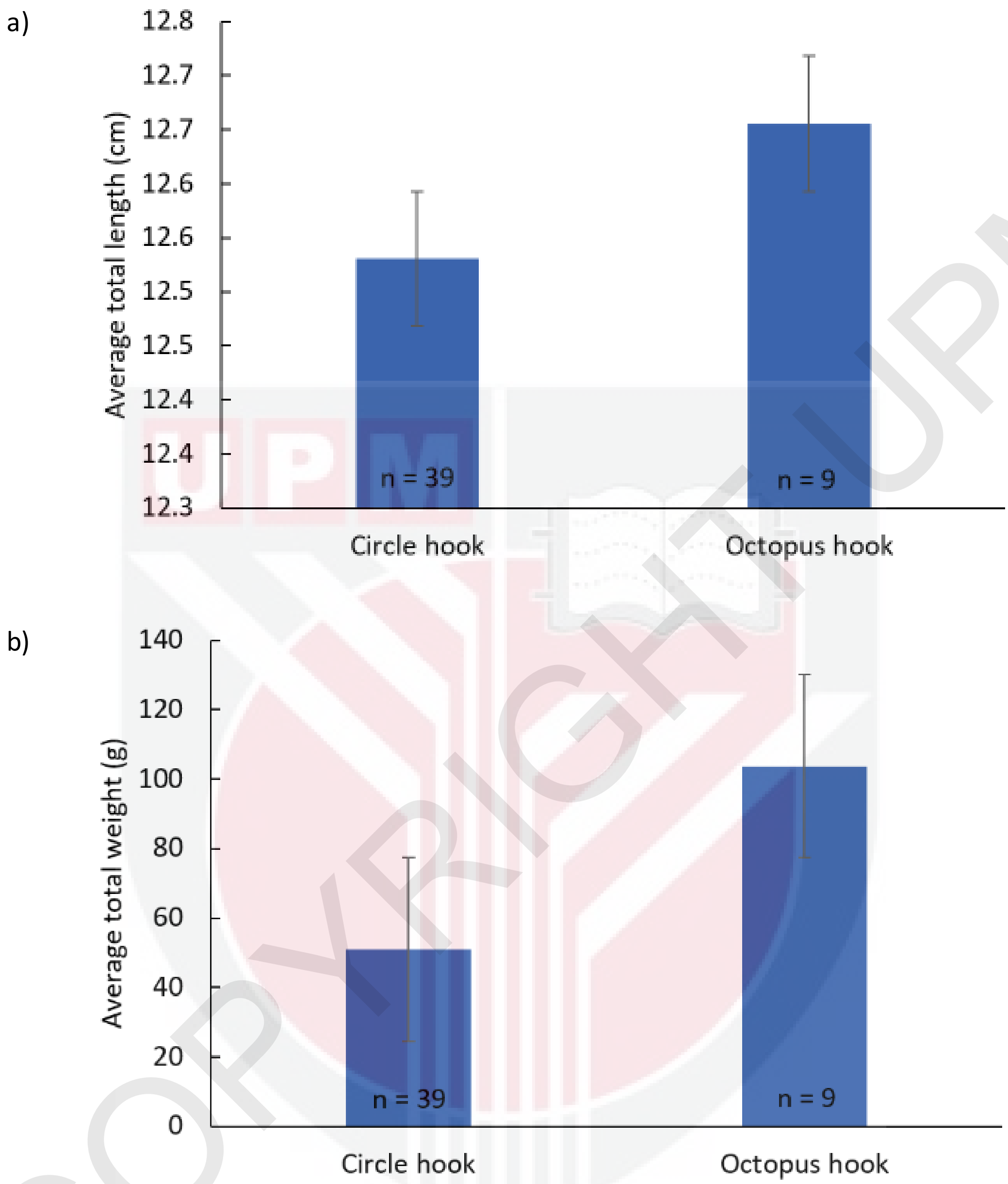

Figure 4.3. (a) Mean length of tilapia (0.008), (b) Mean weight of tilapia (0.015).

There is no significant difference on mean length between fish caught using circle hook and octopus hook. However, the mean weight of tilapia caught using circle hook and octopus hook are significantly different (Figure 4.3).

4.6 Individual length and weight of tilapia

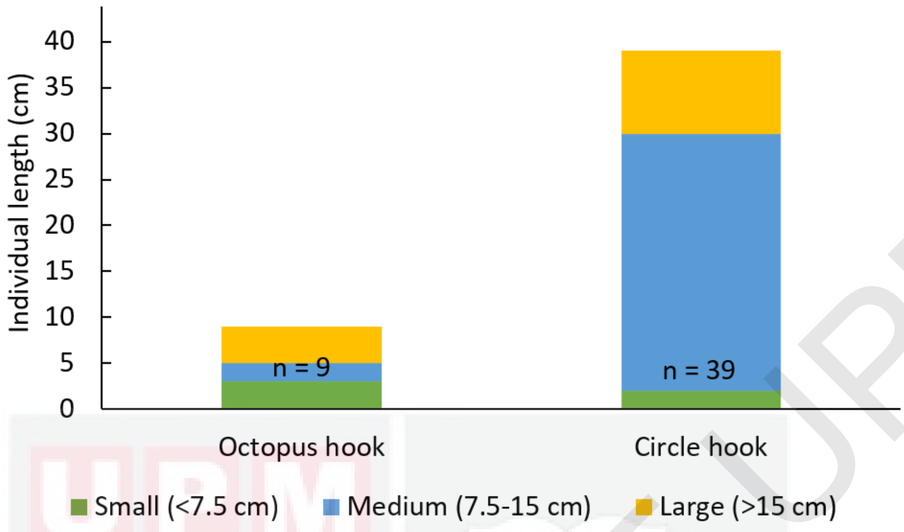

Figure 4.4. The individual length of *Oreochromis* sp. divided by three categories.

In accordance with Figure 4.3., the length of tilapia is divided into three categories, namely small (<7.5 cm), medium (7.5-15 cm), and large (>15 cm). For the tilapia that was caught using octopus hook, there are 33.33 % categorised as small, 22.22 % medium and 44.45 % large size. Meanwhile, for the circle hook, there are 5.13 % categorised as small, 71.79 % medium and 23.08 % large size.

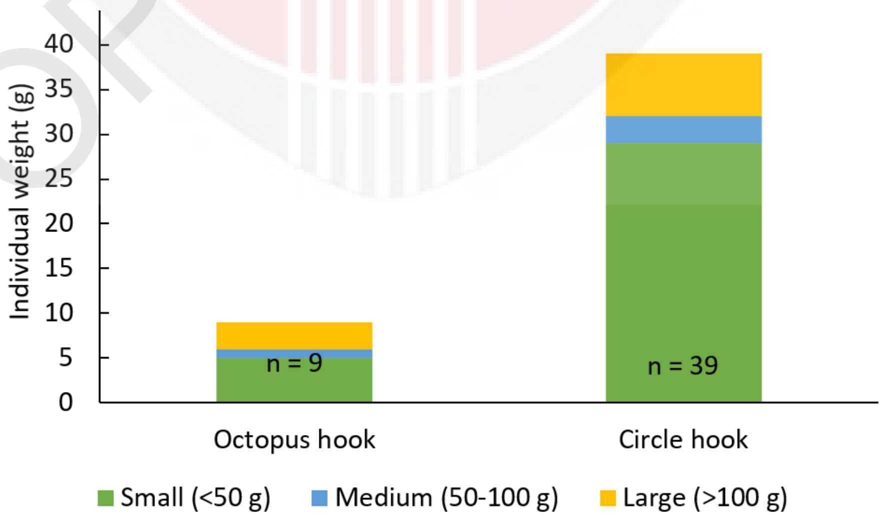

Figure 4.5. The individual weight of *Oreochromis* sp. divided by three categories.

As stated on Figure 4.4., the weight of tilapia is divided into three categories, namely small (<50 g), medium (50-100 g), and large (>100 g). For the tilapia that was caught using octopus hook, there are 55.56 % categorised as small, 11.11 % medium and 33.33 % large size. Meanwhile, for the circle hook, there are 74.36 % categorised as small, 7.69 % medium and 17.95 % large size.

5.0 DISCUSSIONS

Two types of hooks used in this study, which is octopus hook and circle hook demonstrated different results on catch efficiency, injuries, and survival rates of the fish after catch-and-released. The data gathered by Cooke *et al.* (2003) on largemouth bass, *Micropterus salmoides,* captured at central Illinois, by using circle hook and octopus hook resulting on low mortality rates for both hook, 5.1 % and 6.6 %, respectively. In contrast, in this study on tilapia, 15.38 % of fish not survived after circle hook removed from the gills. Cooke *et al.* (2003) also mentioned that the fish captured by using circle hook were hooked less deeply compared to octopus hook. In contrast, in the present study, only circle hook enters more deeply up to the gills area, while octopus hook located less deeply in the fish mouth. This might be due to unbalance number of tilapia captured in this study with octopus hook (n = 9) and circle hook (n = 39), in order to portray the differences of hooking location. According to Ostrand *et al.* (2006), the effectiveness of juvenile muskellunge catch was impacted by hook style, where the J hooks were used to successfully hook and land more fish in their study than circle hooks. Even though circle hooks were less effective than J hooks, they stated that it is more than twice as many strikes using them. Similarly, in this study, circle hook demonstrated two times more strikes in term of fish captured with 41 individuals of fish as compared to octopus hook that only 22 individuals. The fish hooked deeply in vital area such as gills and gullet were identified as potential mortalities due to the difficulty of removing the hook (Cooke *et al.* 2003). This also happened in the present study, whereas the process of removing the hook from the critical area led to the mortality after 24 hours quarantined individually. It seems impossible to leave the fish with less damage at the critical area. Especially during hook removal due to slippery and active fish movement at the moment angler try to disengage the barb from the tissue. This may require vast experience and proper technique to remove the hook by hand to avoid mortality.

Cooke and Suski (2004) has stated that it is more difficult to remove circle hook than J hook and this indicated that hook type influenced the catch effectiveness of tilapia. This is due to the design of circle hook that are more bend inward as compared to octopus hook that more outward which has a high tendency for the fish to self-release. In addition to this, many studies have shown that one of the most influential factors affecting the survival of fish released by anglers relates to where the fish was hooked, specifically, survival has been shown to be greatly reduced for fish that are deeply hooked in the throat or beyond (Cooke and Wilde 2007, Davie and Kopf 2006, Florida Fish and Wildlife Conservation Commission 2022 & Nguyen *et al.* 2013). Hook shape and point-to-shank orientation differences, combined with numerous other aspects of hook size, configuration, and mode of deployment, can change catch rates of target, as well affecting the condition to the fish (i.e., live or dead, damaged or injured) (Alós *et al.* 2009).

Other than that, managing bait type might constitute a simple tool to influence the amount and composition of the fish catch in recreational fishing. We found that other than hook types, natural bait also influenced catch rates, size of fish captured, the fish species composition of the catch as well as hooking location in tilapia recreational fishing (Alós *et al.* 2009). In addition, Arlinghaus *et al.* (2008) also mentioned that the type of bait and size plays an important role in recreational fishing where it is remarkably related to the size of fish captured and hooking location. In their study also showed that natural bait was more deeply ingested than artificial bait, so the time of hook removal and the frequency of bleeding were higher for deeply hooked fish, thus will lead to bleeding and it can increase the possibility of mortality. In agreement with the statement from the study of Arlinghaus *et al.* (2008) where earthworms are one of the small baits, so it makes it easier for the fish to swallow the bait deeper, which causes injury to some tilapia fish that are fished using circle hooks. Earthworm bait was used throughout the present of this study, apart from chicken liver and bread. However, no fish was successfully caught while using these two baits. It may due to the lack of attraction elements of these two baits as compared to earthworm that have an attractive earthy scent with wiggling motion that attract fish even the bait at the bottom. Tilapia feeding behaviour are not just focused on the water surface, but it also bottoms feeder, which will consume and eat almost anything that come across in their habitat (Chaves *et al.* 2015).

The tendency for circle hooks to get caught in the corner of the mouth of tilapia caught by ingesting the hook has a greater effect on anatomical hook location (Gilman *et al.* 2017). Kerstetter and Graves (2006) has stated that although these variations between circle hook and J-hook were not statistically significant, circle hooks more commonly hooked fish in the mouth than J-style hooks, which more frequently hooked fish in the throat or gut. In the present study, 36.4 % circle hook locations on the tilapia are hooked at inner-upper lower jaw followed by the outer lip (45.4 %). For the octopus hook, 62.5 % of hook located at the outer lip tilapia followed by the inner-upper lower jaw (37.5 %). According to Cooke *et al.* (2003), circle hooks rarely penetrated the gullet, the roof of the mouth, or other areas like the eyes and gill arches. Circle hooks tend to cause less injury to the captured fish because they typically lodge in the lower jaw or jaw hinge as opposed to hooking in more damaging areas, such as the oesophagus, respiratory organs, or roof of the mouth (Serafy *et al.* 2012). In many, but not all cases, circle hook use has been associated with improved condition of captured individuals, both of the species targeted and those captured unintentionally (Sales *et* *al.* 2010, Serafy *et al.* 2012). Circle hooks has been shown to increase the survival of angler released fish. With their success already proven for many game fish species, these hooks are now used increasingly for many other common recreational species (Cooke and Suski 2004).

Although 15.38 % fish died due to the location of the circle hook located in the fatal area, the survival rate of fish caught is also high in both types of hooks used. This study is in agreement with Lyle *et al.* (2007), where they stated that the most common causes of death in deep-hooked fish were wounds to the important organs (e.g., gills, heart, liver), and survival was much lower when bleeding was involved. Lyle *et al.* (2007) also stated that the survival rate for fish with shallow hooks was practically 100% compared to 64% for fish with deep hooks in the current investigation, which found that almost all hook-related fatalities were linked to deep hooking. The most crucial element affecting a fish's chance of survival after being hooked has been discovered as the location of the anatomical hook, particularly deep hooking position. This study also in line with Lyle *et al.* (2007) whereas the post-release survival studies indicate that hooking-related mortality happens relatively quickly after capture, usually within 24 hours. Present study shows that fish with critical particularly bleeding wounds were not survive past 24 hours. Snow and Porta (2021) assessed the hooking mortality and mortality-related parameters for Alligator Gar caught using juglines and rod and reel. Majority of jugline mortality caused by deeper hooking depths. They concluded the survival of alligator gar was influenced by temperature, total length, and hooking depth. In this study, parameters such as temperature does not affect the fish mortality, because the fish that has been captured were quarantine in the same pond where it was previously caught.

The usage of circular hooks considered as "fish friendly" tackle due to the low prevalence of deep hooking and circle hooks are marketed with the hope that post-release survival rates will be higher than other hook types (Cooke and Suski 2004). In this study, the survival rate of tilapia approximately 88.89 % after the circle hook was removed from the mouth. Therefore, the hook location influenced the survival rate of tilapia and with the proper technique. Around 15.38 % of tilapia that was died in this study possibly eat the bait slowly without been noticed by the angler. Over time, the bait with circle hook enter deeply to oesophagus before the angler can start reeling the line, which is already late and led the hook at the critical area.

Ostrand *et al.* (2006) has stated that in their study anglers were told to set the hook or start reeling in the line as soon as a strike was detected. As a result, their study found that extremely few fish (<0%) were hooked in potentially dangerous locations. On the other hand, the anglers should give circle hooks plenty of time to be swallowed before exerting pressure (Ostrand *et al.* 2006). Similarly, in this present study, where angler want to ensure that the fish actually eats the bait and catch on the hook. Ostrand *et al.* (2006) also believed that the fish should never be given the opportunity to swallow the hook because doing so just increases the likelihood that they may hook in potentially fatal places.

6.0 CONCLUSION

As a conclusion, the appropriate hook types for C&R should be emphasized and as a result of this study, the octopus hook is the hook that is recommended for anglers to use during C&R practices. Anglers who plan to C&R should use octopus hooks that have a low mortality tendency compared to circle hooks. The satisfaction from C&R will be obtained by angler if they know that the fish survived. This study also revealed that the survival of the fish strongly depends on the anatomical hooking location on the fish caught. This research clearly illustrates the impact of the C&R toward tilapia. Apart from this, the attitude, skills and experience of every angler also play an important role to the survival rate of the fish captured. The results obtained from this study are part of the message that really needs to be delivered to the angler, for the better C&R practices in Malaysia.

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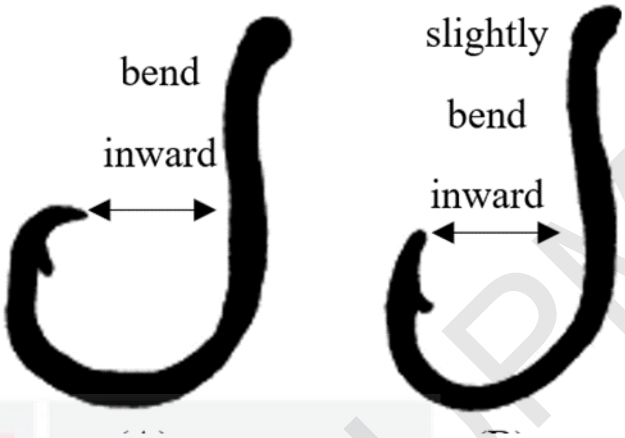
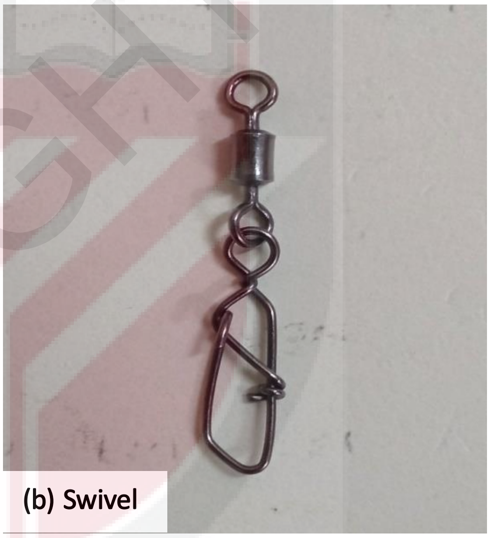
APPENDICES



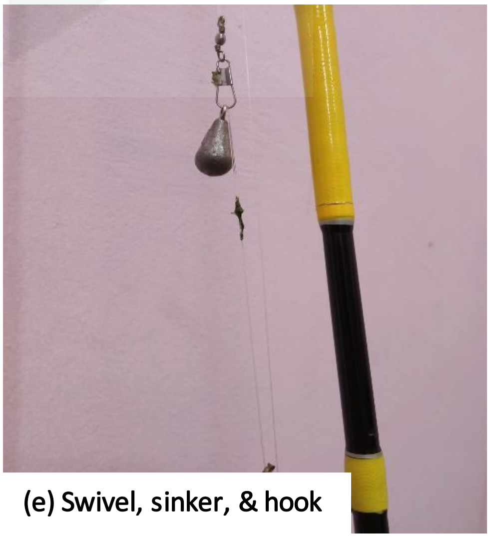
(a) Left-Octopus, Right-Circle



(b) Swivel

(c) Rod

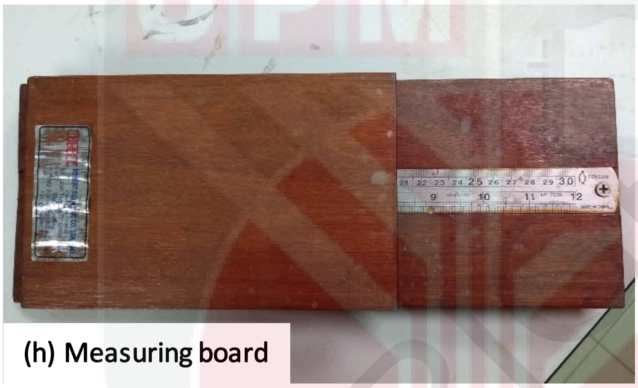
(d) Sinker



(e) Swivel, sinker, & hook

(f) Nylon quarantine net

(g) Stainless steel quarantine cage net



(h) Measuring board

(i) Weighing scale

(j) Handheld GPS Navigator

(k) Tilapia

(l) Tilapia - weight

(m) Tilapia - length

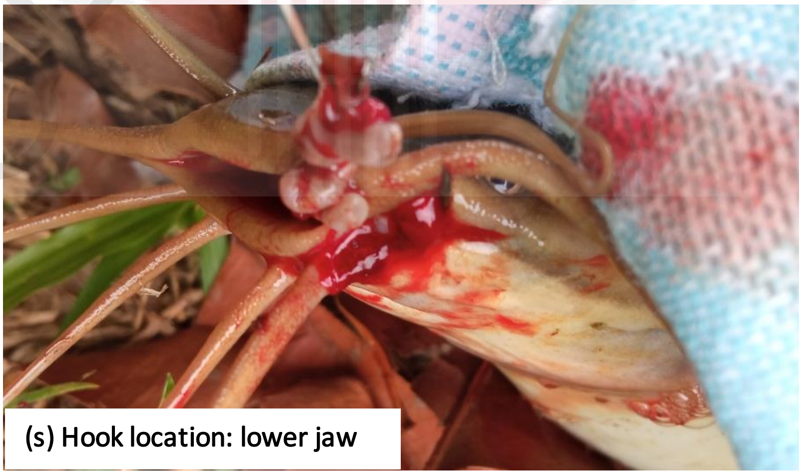
(n) Hook location: gills

(o) Hook location: lower jaw

(p) Hook location: cheek

(q) Hook location: lower jaw

(r) Hook location: eye



(s) Hook location: lower jaw

(t) Hook location: upper jaw

(u) Hook location: mouth

(v) Hook location: mouth roof