UNIVERSITI PUTRA MALAYSIA

EFFECTS OF HOOK SIZE AND BARB TYPES ON INJURY, AND CATCH PER UNIT EFFORT OF FISHES IN THE RECREATIONAL POND AT UPM BINTULU CAMPUS

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EFFECTS OF HOOK SIZE AND BARB TYPES ON INJURY, AND CATCH PER UNIT EFFORT OF FISHES IN THE RECREATIONAL POND AT UPM BINTULU CAMPUS

By

HARITH SYAZWAN BIN MUSLIM

A Project Report Submitted in Partial Fulfilment of the Requirement for the Degree of Bachelor Science Aquaculture in the Faculty of Agricultural and Forestry Sciences, Universiti Putra Malaysia Bintulu Sarawak Campus

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ABSTRACT

Sport fishing is a popular activity among people who want to have fun. Knowledge of the use of fishing tools are also different for each angler such as the selection of appropriate hooks in catch-and-release (C&R) or catch-and-keep (C&K) activities. Hook type can affect physical damage and catch per unit effort (CPUE) while fishing. However, limited information on hook-related damages. The objective of this study is to evaluate the effect of hook size and types on hooking damage, CPUE, survival rate, and species composition of fish in the UPM Bintulu Campus recreational pond. The fishing tools used in this study are rods, lines, reels and two varied sizes of hooks with natural baits on barbed and barbless hook. The species identification, size of the fish, injury level and survival rate of the fish were assessed during the study period. The results indicated the injury level in non-critical areas was 73.2% is higher compared to critical 26.7%. These comprised a considerable number of injuries level at the outer lip (barbed hook 5), upper and lower jaw (barbless hook 5), inner gills (barbless hook 5 and barbed hook 8) and stomach (barbed hook 5). CPUE shows the total catches of *Oreochromis mossambicus* are the highest by using hook size five compared to size eight. The survival rate was significantly higher for both barbless hook sizes 5 and 8 as compared to barbed hook, respectively. Therefore, hook size and hook type selections were important factors to be highlighted in strategizing the implementation of C&R in Malaysia towards the sustainable recreational fisheries industry.

Keywords: Recreational fishing, effectiveness, injury, barbed hook, and barbless hook.

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Abstrak

Sukan memancing adalah aktiviti yang popular di kalangan orang yang ingin berseronok. Pengetahuan tentang penggunaan alat pancing juga berbeza bagi setiap pemancing seperti pemilihan mata kail yang sesuai dalam aktiviti tangkap dan lepas (C&R) atau tangkap dan simpan (C&K). Jenis cangkuk boleh menjejaskan kecederaan fizikal dan tangkapan per unit usaha (CPUE) semasa memancing. Walau bagaimanapun, maklumat terhad mengenai kecederaan berkaitan cangkuk. Objektif kajian ini adalah untuk menilai kesan saiz dan jenis mata kail terhadap kecederaan mata kail, CPUE, kadar kemandirian, dan komposisi spesies ikan di kolam rekreasi UPM Kampus Bintulu. Alat pancing yang digunakan dalam kajian ini ialah joran, tali, kekili dan dua mata kail yang pelbagai saiz dengan umpan asli pada mata kail berduri dan tidak berduri. Pengenalpastian spesies, saiz ikan, tahap kecederaan dan kadar kemandirian ikan telah dinilai semasa tempoh kajian. Keputusan menunjukkan tahap kecederaan di kawasan tidak kritikal adalah 73.2% lebih tinggi berbanding kritikal 26.7%. Ini terdiri daripada bilangan yang agak besar tahap kecederaan pada bibir luar (mata kail berduri 5), rahang atas dan bawah (mata kail tidak berduri 5), insang dalam (mata kail tidak berduri 5 dan mata kail berduri 8) dan perut (mata kail berduri 5). CPUE menunjukkan jumlah tangkapan *Oreochromis mossambicus* adalah yang tertinggi dengan menggunakan mata kail saiz lima berbanding saiz lapan. Kadar kemandirian adalah lebih tinggi dengan ketara untuk kedua-dua mata kail tidak berduri saiz 5 dan 8 berbanding mata kail berduri, masing-masing. Oleh itu, saiz mata kail dan pemilihan jenis mata kail merupakan faktor penting yang perlu diketengahkan dalam menyusun strategi pelaksanaan C&R di Malaysia ke arah industri perikanan rekreasi yang mampan.

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Kata kunci: Memancing rekreasi, keberkesanan, kecederaan, cangkuk berduri dan cangkuk tanpa barbles.

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Approval Sheet

I certify that this research project report entitled "Effects of hook size and barbless hooks on hooking injury, catch per unit effort, and fish size in a mixed-species recreational fishery in the recreational pond of UPM Bintulu Campus" has been examined and approved as partial completion 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

C&R	Catch-and-released
C&K	Catch-and-keep
CPUE	Catch per unit effort
ICES	The International Council for the Exploration of the Sea
GBIF	Global Biodiversity Information Facility
&	and
%	Percentage
cm	Centimetres
n	Number of individuals
g	Gram
*	Multiplication
/	Division
<,>	Less than, more than
P value	Statistically significant
±	Plus-minus significant

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CHAPTER 1

1.0 INTRODUCTION

1.1 Research Background

Recreational fishing represents a popular activity associated with fish stocking, encompassing sport fishing pursued for leisure, fitness, or competitive purposes. Distinguished from commercial fishing, recreational fishing primarily engages in catch-and-release (C&R) practices, enhancing native fish populations by enabling more fish to thrive and reproduce within their natural environment (Cooke and Schramm 2007). While some catches might be taken for personal consumption within harvest limits, the primary focus remains on supporting fish populations through conservation. The adoption of catch-and-release (C&R) techniques holds the potential to reduce direct mortality in fisheries, safeguard fish populations, and uphold the economic and social benefits tied to recreational fishing (Clarke *et al*. 2021). This method is commonly practiced among anglers, either to comply with harvest regulations or as part of fish conservation principles.

Traditionally, both catch-and-keep (C&K) and catch-and-release (C&R) methods have been integral to recreational fishing, a pursuit gaining increasing popularity across various countries (Brownscombe *et al*. 2017). Fishing with technique catch-and-release (C&R) can reduce the risk of getting injuries when fishing through the utilization of the right equipment. A growing number of seasoned and conservation-oriented anglers are showcasing specific equipment and approaches to mitigate the adverse impacts of catch-and-release (C&R) fishing. Consequently, studies related to recreational fisheries have made substantial advancements in comprehending how different factors influence fish catchability (Ward *et al*. 2013).

The application of catch-and-release (C&R) or catch-and-keep (C&K) methods is commonly perceived as enjoyable and typically occurs in recreational lakes or ponds. Ponds, playing a crucial role in water retention, aquatic product supply, and biodiversity conservation, stand as vital habitats (Son *et al*. 2014). Often found in agricultural regions, ponds serve as prevalent forms of artificial wetlands susceptible to human-induced changes, necessitating deeper insights into demographics, conservation, protection, and utilization. Wetlands, where water plays a pivotal role in shaping the environment and fostering diverse life forms, represent critical landscapes (Zedler and Kercher 2005). They contribute significantly to biodiversity and require active management to ensure their ecological integrity amidst evolving human activities.

Many methods exist for capturing fish in diverse environments like seas, ponds, and rivers, ranging from basic approaches like casting to more specific methods such as jigging. The identification of the most productive strategies within the array of fishing techniques and management tactics holds promise for promoting environmentally sustainable fishing practices (Bastardie *et al*. 2022). Given that the acceptability and selection of techniques primarily hinge on the targeted species and its habitat, the effective deployment of fishing methods often relies on this additional knowledge. Fishing techniques entail a spectrum of behaviors shaped by equipment, skill sets employed, and preferences for recreational area environments.

Anglers employ a variety of rods, lines, reels, and hook sizes in combination with natural baits, utilizing both barbed and barbless hooks. The backward-facing orientation of the barbed hook aims to prevent easy dislodgment from the fish's mouth upon entry. Research on barbed hooks, such as that conducted by Meka (2004) has demonstrated

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prolonged handling durations and increased rates of damage. The singular point characteristic of a barbless hook, where no backward-facing barbs exist, represents a pivotal aspect of fishing methodology. This technique, perceived to reduce hooking mortality by minimizing handling time, as suggested by Cooke and Schramm (2007) might not effectively mitigate injuries and mortality. Barbless hooks are a fantastic technique to reduce unhooking time, stress, and hooking injury in freshwater fishing.

The hook position may be influenced by a variety of factors, including the type of lure, gear type, and fishermen expertise. The probability of fish survival can be caused by hooking and unhooking techniques, and the type of gear used. The negative effects of hooking and unhooking will result in physiological abnormalities, physical injury, and behavioral flaws which lead to sudden mortality or reduced fitness. Fishing with technique catch-and-release (C&R) can reduce the risk of getting injuries when fishing through the utilization of the right equipment. Fish caught in vital areas such as the stomach, esophagus, and gills caused substantial bleeding to mortality, as compared to non-critical areas with many fewer injuries which determines fish survival throughout catch-and-release (C&R) activities (Trahan *et al.* 2021).

Catch-and-release (C&R) fishing practices significantly reduced mortality which in return will benefit sustaining fish stock. Fish from catch-and-release (C&R) have a survival percentage ranging from 84 to 98% and deep hooking was the most significant factor that impacted the survival of the catch-and-released (C&R) method (Bartholomew and Bohnsack 2005). The relationship between hook size and the chance of deep-hooking on recreational fisheries does imply the risk of deep-hooking related to hook size. Fish damage can result from using hook sizes that are too big or too small for the species that

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you are targeting, therefore it is crucial to utilize equipment that fits needs (Lennox *et al*. 2015). The most critical element influencing hook size selectivity is most likely based on fish mouth size and body length from previous fishing activity. However, the selection of hook size in reducing fish mortality in recreational fishing remains limited. Especially in the fishponds that inhabit various types of fish species and sizes. Therefore, this research aims to investigate the type of hook and size that might influence the survival rate of each fish species.

1.2 Objectives

There are insufficient details in the literature on the effects of hook size and barbless hooks on hooking injury, catch per unit effort, and fish size in a mixed-species recreational fishery in the recreational pond of UPM Bintulu Campus. Thus, the aims of this research are as follows:

i. to investigate the effect of hook size and type of hooks on hooking injury.
ii. to identify the catch per unit effort (CPUE), survival rate, and fish size of a mixed-species recreational fishery in the recreational pond of the UPM Bintulu Campus.
iii. to identify the species composition of fishes at recreational pond.

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CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Fishing activities

2.1.1 Recreational fishing

Recreational fishing, often termed angling, encompasses fishing activities pursued for pleasure, relaxation, or sport rather than commercial gain. Within the literature review, the concept of recreational fishing delves into diverse aspects and impacts of this leisure pursuit within academic and research contexts. This leisure pursuit of recreational fishing provides an intriguing model highlighting the interconnection between "fishing for fun" and the nutritional advantages associated with it, both contributing to ensuring food security (Cooke *et al*. 2018). Scrutinizing the motivations behind recreational fishing necessitates a comprehensive comprehension of the factors propelling individuals toward engaging in this leisure activity. This inquiry involves exploring and analyzing why individuals opt for fishing as their recreational pursuit. For instance, myriad psychological, health, and nutritional benefits accrue to everyone engaging in recreational fishing, and collectively, participation in this activity yields substantial socio-economic, social, and cultural advantages benefiting the broader community (Tufts *et al*. 2015). Research into recreational fishing holds the potential to contribute to stress alleviation, support mental well-being, and facilitate leisure engagement within natural environments.

In Malaysia, recreational fishing stands as a favored pastime among the public (Kumalah *et al*. 2023). According to Hansen (2020) recreation is a leisure activity that promotes both physical and mental well-being in addition to providing enjoyment. An increasing number of resources are being committed to leisure and recreational activities

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as nations develop and their populations become wealthier (Arlinghaus *et al*. 2021). In 2006, there were an estimated two million anglers in Malaysia, along with more than 150 fishing organizations and associations, 7 monthly fishing periodicals, 12 websites devoted to fishing, and weekly sections about fishing in all major newspapers (Abdul Salam and Gopinath 2006). Recreational fishing activates millions of people around the globe and generates billions of dollars (USD) for a variety of industries (Arlinghaus *et al*. 2019). From a social and economic perspective, recreational fishing significantly contributes to the well-being of individual anglers and the industries reliant on such activities. This includes the facilitation of funding for managing recreational fisheries, fostering active public involvement in natural processes, and advocating for biodiversity conservation (Yusoh *et al*. 2022).

The social dimension in recreational fishing includes the study of social interactions among anglers, social networks built through fishing activities, and their impact on relationships between individuals in the community. This includes social interaction during fishing, and sharing experiences, as well as values and social norms that develop among anglers. According to Morales-Nin *et al*. (2021) approximately 73% of respondents engaged in fishing within seawater regions, while 40% frequented freshwater areas. Furthermore, 13% of respondents indicated fishing in both distinct habitats, namely saltwater and freshwater zones. Consequently, synthetic, or natural ponds, whether freshwater or saltwater, stand out as popular locations for recreational fishing activities. Fishing ponds are commonly situated in rural areas, often on privately owned land, where owners open their ponds for paid access. Recreational anglers are provided with the option to fish in public fishing ponds, which remain accessible to the public. Additionally, the

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construction of saltwater fishing ponds specifically tailored for leisure fishing activities has been observed. These saltwater ponds are typically positioned close to oceanic areas to facilitate a simplified water flow system into the ponds. Studies conducted by Mohd (2015) have focused on researching recreational fishing in freshwater ponds within Malaysia. Moreover, the examination of human aspects, such as anglers' attitudes, norms, and behaviors, has gained traction since the 1970s. This growth stems from managers recognition that they are managing people's behaviors in the context of fishing, not solely focusing on the fish themselves (Parkkila *et al*. 2010).

A crucial element of a sustainable catch-and-release (C&R) fishery lies in its economic viability and stability, offering an alternative to less sustainable practices (Adams 2017). Catch-and-release (C&R) fishing serves as a pivotal tool in preserving fish populations and upholding ecosystem equilibrium. Despite the widespread adoption of catch-and-release (C&R) in recreational fisheries, there remains a dearth of comprehensive data regarding its effectiveness in fisheries management (Arlinghaus *et al*. 2007). Recreational fishing is gaining traction not only in developed nations but also in developing and emerging economies (Brownscombe *et al*. 2017). The rising prevalence of knowledgeable and environmentally conscious anglers underscores the potential for specific tools and techniques to mitigate the adverse impacts of catch-and-release practices. Significant strides have been made in recreational fishing to comprehend the diverse factors influencing fish catchability (Ward *et al*. 2013). Additionally, catch-and-release (C&R) fishing offers valuable opportunities for scientific inquiry and data collection, enabling the recording of crucial information concerning fish species, catch sizes, and locations. Through their contributions, anglers play a pivotal role in fisheries

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management and conservation endeavors. Collaborative efforts between anglers and researchers further deepen insights into aquatic ecosystems and enhance conservation methodologies. The act of releasing fish back into their habitat unharmed actively contributes to the vitality of aquatic ecosystems and ensures the enduring sustainability of fish stocks.

2.1.2 Aquatic Ecosystem

Freshwater and marine ecosystems are intricate environments supporting diverse life forms. Wetland ecosystems, particularly, offer invaluable services such as water retention, flood regulation, biodiversity conservation, and climate change mitigation (McLaughlin and Cohen 2013). These ecosystems are pivotal in maintaining our planet's stability, serving as essential habitats, breeding grounds, and feeding areas. Managing freshwater ecosystems for the future requires balancing the preservation of ecosystem needs with accommodating recreational demands. This ensures the provision of a wide spectrum of Ecosystem Services (ESS), encompassing recreational activities (Röschel *et al*. 2020).

Natural ecosystems like forests and grasslands have multifunctional characteristics, whereas artificial ecosystem services are relatively limited. Ponds, renowned for their remarkable biodiversity, support a wide range of plant and animal species (Fu *et al*. 2018). These aquatic environments serve as critical habitats, fostering biodiversity hotspots. The diverse niches within pond ecosystems facilitate coexistence among multiple species, creating vibrant and dynamic environments. Population abundance and productivity closely align with the quantity and quality of accessible habitat, influenced by species-specific abiotic and biotic factors (MacLeod *et al*. 2022).

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Human activities in both rural and urban settings within farming environments interact with ponds (Olguín *et al*. 2017). Urban ponds often serve as fishing and recreational spots, while rural ponds are utilized for irrigation and fish breeding (Fu *et al*. 2018). The evolving relationship between ponds and human activities is notably influenced by the increasing engagement in fishing as a leisure pursuit, resulting in a closer connection between ponds and human interactions.

2.1.3 Fishing technique

Fishing consists of the application of a wide range of techniques and strategies which depend on the target species and habitat. The type of fish to be caught and the actual fishing location both influence the technique used. Over the years, several fishing methods have remained largely unchanged. Several conventional methods are now combined with modern industrial methods. Fishing has traditionally involved the use of nets, traps, and fishing lines. With the advancement of technology, the gear is now getting better and easier for the fishermen to use. According to the survey conducted by Lloret *et al*. (2008) there is a variety of fishing techniques, with bottom fishing rods being the most popular (74% of all anglers surveyed), followed by flux (12%), trolling (8%), and surface fishing rods (6%).

In addition, commercial fishermen aim for a wide variety of catches to profit from the sale of their catch and typically employ nets more frequently. Modern fishing is distinguished by precision-machined reels, ultra-sensitive graphite composite rods, nearly invisible fishing line, battery-powered lures, underwater cameras, and angling apps that enable anglers to share their fishing experiences with others (Cooke *et al.* 2021). Bottom fishing can be done from a boat or on the side of a river, pond, or beach. The environment

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and target of their prey will influence how anglers or fisherman alter their fishing strategies.

2.1.4 Hooks

The use of a hook and line to capture fish is known as hook fishing, often referred to as angling. It has significance for the sustainability of aquatic systems across the world because hook-related gear is prevalent in both freshwater and marine environments (Anticamara *et al*. 2011). Most fishermen throughout the world use it as one of the most common and traditional methods of fishing.

Understanding the factors that lead to fish capture can help advance many aspects of fish exploitation and management. The terminal hooks are baited with natural or artificial baits designed to elicit aggressiveness or feeding, which may cause a fish to strike but not eat, causing the hook to be retained and, ideally, the fish to be caught (Lennox *et al.* 2017). The fish must decide whether to bite or not irrespective of whether a hook is present, in contrast to other fishing gears that either passively gather fish (such as gill nets) or actively capture fish (such as trawl nets, seine nets) (Løkkeborg *et al*. 2014). The use of hooks to capture fish places a strong priority on fish behaviour. It takes an integrated understanding of fish behaviour, physiology, morphology, and cognition to quantify fish vulnerability to hook-and-line fishing gears, as well as an appreciation of the controlling influence of external variables like the abiotic environment, social contexts, and the fishery (Lennox *et al*. 2017).

Hook size, hook number, hook shape, or bait type might all be restricted depending on the target species to limit the catch of non-target species or the capture of undersized

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or large individuals. Larger fish are preferentially collected in many fishing circumstances, and such size-based exploitation has ramifications for the sustainability of wild stocks (Laugen *et al.* 2014). The ability to ingest and capture by certain hook sizes is restricted by morphological factors such as gape size (Karpouzi and Stergiou 2003). Like any other predator-prey relationship, the size of prey (the bait) that predators can catch and eat is inversely proportional to the length and size of their gape shown in Figure 2.1 (Amarasinghe *et al*. 2011). Therefore, the size of the hook and bait affects the gear selectivity, overall susceptibility, and a crucial result metric called catch per unit effort (CPUE) (Alós *et al*. 2008).

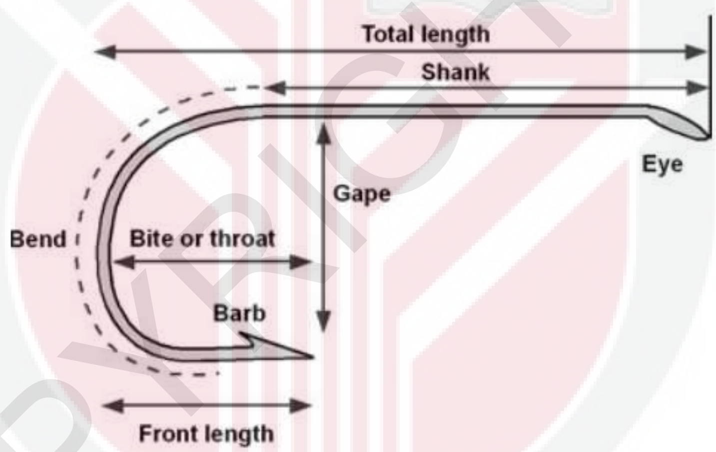

Figure 2.1. Parts of a hook (Amarasinghe *et al*. 2011).

2.1.5 Type of hooks (Barbed and Barbless hooks)

Barbed hooks and barbless hooks are the two primary categories of fishing hooks as shown in (Figure 2.2). The difference is whether there is a little protrusion on the hook shank right behind the tip or not. Anglers must be knowledgeable about hooks to achieve the desired outcomes when fishing. Barbless hooks are one fishing technique believed to lower hooking mortality as compared to barbed hooks by minimizing handling time,

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stress, and trauma (Schaeffer and Hoffman 2002). Angling success depends on choosing the best hooks to use, but choosing one over the other is difficult since it depends on angler's opinions and experience using them both.

Furthermore, barbed hooks have a small, backward-facing projection (the barb) located just below the point of the hook. The purpose of the barb is to make it more difficult for a hooked fish to shake itself free. The barb serves as a barrier, keeping the hook from effortlessly slipping out of the fish mouth or body. According to Alós *et al*. (2008) the barbs on the hook are known to affect the unhooking time. Therefore, it's important to know how much barbed hooks (as opposed to hooks without barbs) affect the unhooking gear performance (Cooke *et al*. 2022). Barbless hooks do not have a small barb present on the shank. In terms of hook design, freshwater fisheries can benefit from using barbless hooks to cut down on unhooking time, stress, and hooking damage (Cooke *et al*. 2001). In catch-and-release situations, these hooks do less harm to the fish since they are easy to remove from a fish's mouth or body without the barb. Moreover, according to Cooke *et al*. (2022) the barbless hooks yielded less tissue damage and less frequent bleeding. Barbless hooks are frequently used because they encourage fish conservation and reduce the possibility of injury to fish populations. They may be just as successful in catching and holding fish as barbed hooks, especially when using the right fishing methods.

It is important to note that fishing regulations regarding the use of barbed or barbless hooks can vary depending on the region, fish species, and specific fishing rules. In a nearshore marine sport fishery in the Gulf of Mexico near St Petersburg, Florida (USA), there are variances in unhooking times, hooking injuries, and catch per unit effort

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(CPUE) caused by various species using barbless and barbed hooks (Schaeffer and Hoffman 2002). Some areas may require the use of barbless hooks for certain types of fishing or in specific waters to protect fish populations and promote sustainable angling practices.

(b) Barbed hook (a) Barbless hook

Figure 2.2. (a) Barbed and (b) barbless hooks.

2.2 Injuries and Survival Rate

2.2.1 Catch effectiveness.

The catch effectiveness in fishing is influenced by various factors, including the reaction of the fish to the bait or lure presented by the angler. Behaviour is a flexible response to environmental changes, and fishing gear often exploits species' tendencies like schooling, foraging, swimming, and habitat use (Jørgensen and Holt 2013). Fish exhibit different behaviors and responses to fishing stimuli, which can impact the success of catching them. To confirm and comprehend how to create superior fishing, it is essential to assess fishing's effectiveness after deciding how effective it is (Herrmann *et al*. 2018). Fish feeding rates are subject to multiple influencing factors including life stage, time of day,

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season, water temperature, dissolved oxygen levels, and other variables about water quality (Craig 2017). These factors can affect the likelihood of fish being more actively engaged in feeding and more prone to striking at bait or lures. Hunger, functioning as an internal physiological demand for food, serves as a potent inducer of eating behavior. It effectively drives fish to seek and consume food (Hoskins and Volkoff 2012). For example, when feed is put in tanks, fish exhibit a feeding response that includes an increase in swimming activity and a quest for food, which declines as the fish grow satisfied (Hoskins and Volkoff 2012). The actual eating behaviour of fish may be characterised as a set of nine movement patterns, the frequency and order of which are adapted to the kind, size, and texture of food (Dabrowski and Portella 2005). Anglers can improve the efficiency of their catches by learning about the target fish species' eating habits and preferences.

Some fish species, especially those that are aggressive or territorial, may respond violently to incursions into their area. As a protective or territorial reaction, this may increase their propensity to strike at bait or lures. Competition for resources may act as a sifting factor in the development of cooperation (Díaz-Muñoz *et al*. 2014). Anglers can target regions and cause a response bite by being aware of the territorial behaviour of fish. Large species are often more susceptible due to ontogenetic food changes and higher physical contact between the hook and the fish that result in size-related gear selectivity (Tsuboi *et al*. 2015).

The complicated behaviour of feeding is influenced by both internal and external influences (Hoskins and Volkoff 2012). Understanding these elements and their effects on fish behaviour can assist anglers in determining the most effective fishing techniques

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and strategies. Fish behaviour may be unpredictable, and there are no assurances that you will catch fish on every fishing trip. Successful fishing typically involves a mix of knowledge, experience, and adaptability to changing situations. Anglers use a variety of strategies, such as modifying bait or lure selection, presentation techniques, and fishing location, to nominal their odds of a good catch depending on fish reactions.

2.2.2 Anatomy of hook location

The anatomy of hook position refers to where the hook becomes stuck in the angles mouth or body. The precise location of the hook might vary based on the fishing technique, the type of fish being pursued, and the angler desired approach. The mouth is the most common area where hooks are set in fish. Anglers aim to hook the fish in the mouth to maximize the chances of a secure hook-up and minimize harm to the fish. Depending on how the fish strikes the bait or lure, the hook may become stuck in the fish lips, jaw, or even deeper in the mouth.

Hooking the fish in the corner of the mouth is often considered ideal for catch-and-release fishing. When the hook is set in the corner, it is less likely to cause significant damage to the fish vital structures, such as the gills or internal organs (Figure 2.3) (James 2006). This location also provides a secure hook hold, and reduces the chance of the fish shaking the hook loose. According to Aabers *et al*. (2004) the hook position that enters the fish mouth can be classified into eight positions for scoring purposes (Figure 2.4). Throat or gut hooking is generally less desirable, as it can cause harm to the fish and decrease its chances of survival if it is released. By employing correct fishing methods and keeping an eye on the fish's behaviour, anglers can reduce the likelihood of throat or gut hooking. Furthermore, it is critical to follow local fishing regulations, which may

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include limits on hook kinds, sizes, and mandatory practices to protect the fish population and encourage sustainable fishing practices. When bleeding was predominantly influenced by hook location, the bleeding intensity did not substantially differ between gears (Lennox *et al.* 2017). Anglers should try to avoid catching fish in sensitive regions, use correct hook removal procedures, and handle fish with caution to avoid stress and harm.

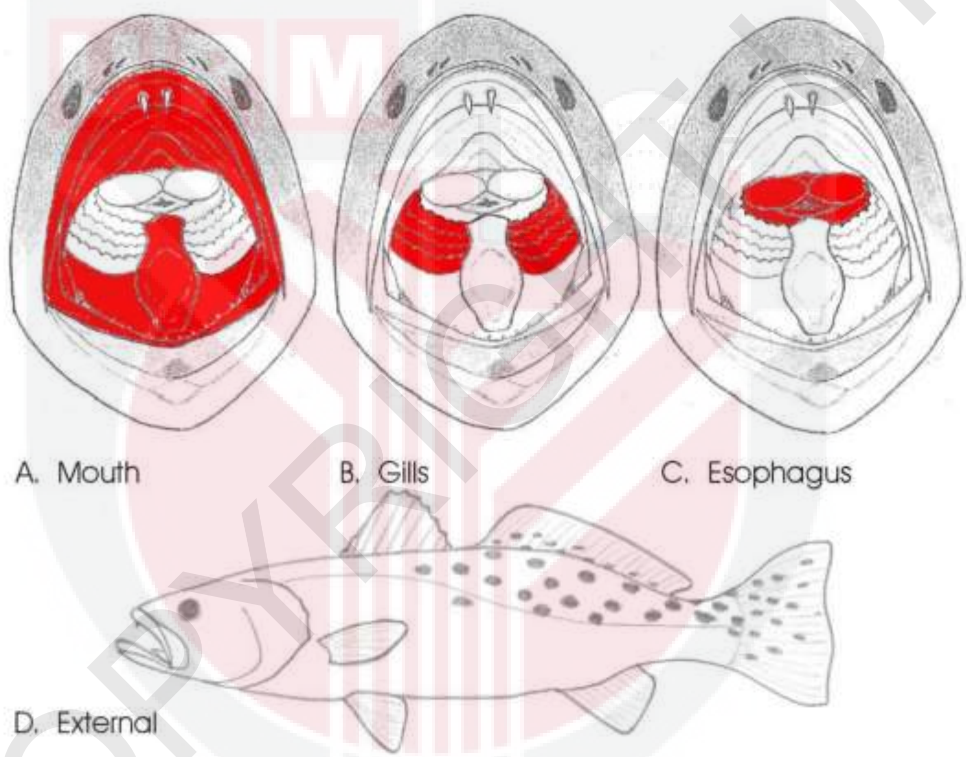

Figure 2.3. Four designated anatomical hooking locations (shaded areas) in spotted seatrout caught on hook and line along the Texas coast: (A) mouth, (B) gills, (C) esophagus, and (D) external (outside the oral cavity) (James 2006).

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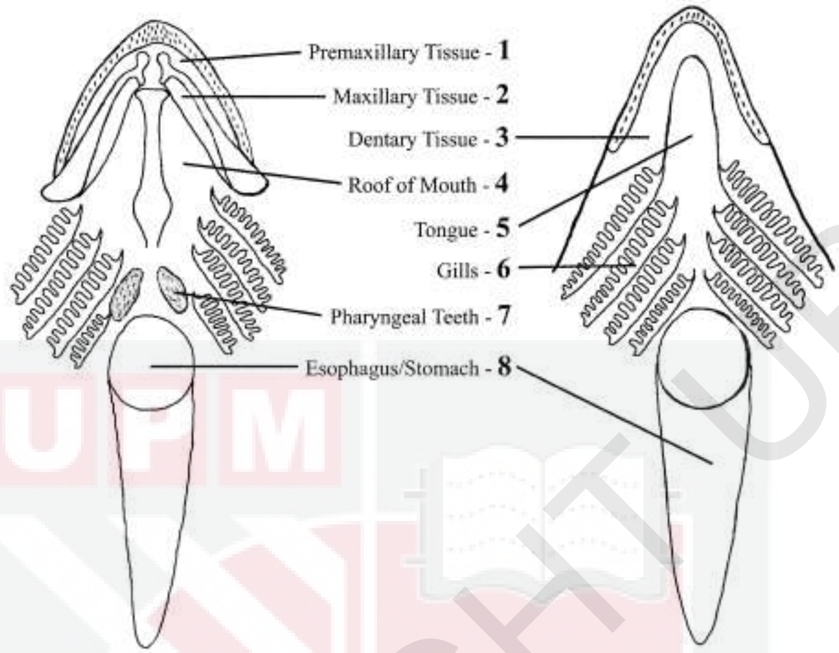

Figure 2.4. The eight locations used to score the anatomical hook position are shown on the left (dorsal) and right (ventral) sides of the body (Aalbers *et al.* 2004).

2.2.3 Injuries

An injury is physiological damage to living tissue caused by direct physical stress, either intentionally or inadvertently caused by a hook. During a catch, fish may experience significant stress and mortality, influenced by environmental variables, innate biotic factors, and angler behavior (Cooke and Suski 2005). The process of capturing and handling fish can lead to diminished fitness or mortality (Arlinghaus *et al*. 2007). This outcome typically arises from physiological stress, injuries, and associated mortalities (Bohaboy *et al*. 2020). Hooks are another factor, as improper hook exit can cause physiological damage and reduce the fish survival chances post-release. The hook position did not change across gears, and most fish were caught in the jaws. While bleeding was

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primarily impacted by hook location, the bleeding did not differ across gears, although barbless hooks minimized unhooking injuries (Schaeffer and Hoffman 2002).

When fish are caught and kept out of the water for an extended period, their ability to breathe and recover is compromised. Fish need water to obtain oxygen, and prolonged air exposure can cause stress, asphyxiation, or even death. Minimizing the time fish spend out of the water and handling them gently can help reduce the risk. A fish's ability to locate or digest food may be impaired by stress or damage sustained during capture or handling, which may lead to death later. Long fights, exposure to the air, and hooking injuries can cause blood acidity, hypercapnia, and injuries, respectively (Meka 2004). Sometimes fish can swallow bait, lures, or hooks deeply, making it difficult to remove them without causing significant harm. Ingestion of foreign objects can injure fish digestive system, impair feeding, and increase mortality risk. Instant mortality is defined as death caused by acute injuries or predation because of hooking the fish (Pollock and Pine 2007). The consequences of hooking and unhooking methods can affect the survival probability of fish, and the choice of gear can affect injury to fish (Stalhammar *et al*. 2014).

2.2.4 Survival rate

In recreational fishing, the terms "survival rate" and "mortality rate" describe the possibility that fish will live or die after being caught and released. The effects of fishing on fish populations and conservation efforts are measured using these phrases. The technique of catch-and-release fishing has grown in popularity to lessen the detrimental effects on overexploited populations (ICES 2020). For instance, the quantity of salmon captured and released in Canada grew by 109% between 1991 and 2019 (ICES 2020). The

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ability of released fish to reproduce is crucial to the effectiveness of catch-and-release as a management strategy (Brownscombe *et al*. 2017).

The survival rate of fish catch-and-release (C&R) released by recreational anglers refers to the percentage or proportion of fish that remain alive after the release. The risk of post-release mortality in recreational fishing varies based on various factors including fish species, fishing techniques, environmental conditions, angler handling practices, and the duration of the catch often proving to be a reliable predictor of this risk (Gale *et al*. 2013). Hooking injuries and subsequent bleeding have been recognized as primary contributors to the elevated post-release mortality observed in numerous fish species (Hühn and Arlinghaus 2011). These injuries inflicted during the hooking process can significantly impact a fish's ability to survive after being released back into the water.

Unaccounted fishing mortality poses a significant threat to the sustainability of key market species and vulnerable species. This unaccounted mortality can result in surpassing critical threshold reference points for multiple species within an ecosystem, ultimately impacting ecosystem structure and vital processes (ICES 2020). Such consequences can have far-reaching effects, jeopardizing the overall health and balance of the ecosystem.

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CHAPTER 3

3.0 MATERIAL AND METHODS

3.1 Study area

The sampling was conducted at the recreational pond (Figure 3.1) situated at Universiti Putra Malaysia Bintulu Campus Sarawak (3˚12’37.4” N 113˚0508.6” E) for 6 months, from April until November 2023.

Figure 3.1. Sampling site.

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3.2 Sampling procedure

The sampling was conducted during a daytime period. Four sets of fishing rods equipped with barbed hooks and barbless hooks were used throughout the study. Two sizes of hooks were used in this study, which are size 5 and size 8 for both types of barbed and barbless hooks respectively. The dimensions of hook numbers 5 and 8 are shown in Figure 3.2 (EXPERT GRAPHITE model 3131 and MUSTAD CHINU model). The gear was hooked to a 10-pound main nylon leader reel. All hooks were hooked with earthworm bait that covered the whole hook surface.

In this study, the bottom-line technique was applied for all four sets of fishing rods namely Barbed 5, Barbed 8, Barbless 5, and Barbless 8. The specimens that were caught were placed in a tray for hook removal, injury assessment and species identification. Every specimen caught was photographed and identified. Hooking sites were classified as non-critical (where the fish sustained an injury to the lips or jaws) or critical (when the injury was to the inner gills, esophagus, or stomach). The fish then were quarantined in a stainless cage net that was kept in the water for 24 hours for monitoring purposes before it can be released back to the pond.

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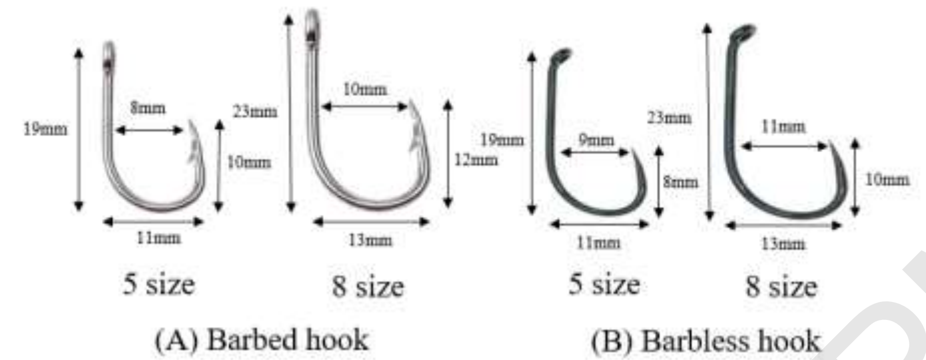

Figure 3.2. The dimensions of barbed hook (A) and barbless hook (B) sizes 5 and 8 were used for the experimental angling sessions. Barbed and barbless hooks had the same dimensions (Alós *et al*. 2008).

3.3 Catch per unit effort (CPUE)

CPUE can be described as the quantity of each of the four types of hook treatments (barbed and barbless) or as the quantity of fish caught at a certain time. It is calculated by dividing the overall catch by the equivalent fishing effort, which is frequently specified in terms of time, equipment, or area (Tian *et al*. 2009).

The steps for calculating CPUE:

i. Establish the total catch:

The total weight or quantity of fish recorded during the fishing activity should be added up. This might be discovered by weighing the catch or by counting each fish in isolation.

ii. Determine the fishing effort:

Define the unit of effort used in the calculation, which could be the time spent fishing (hours), the area covered (square kilometers), or the amount of fishing gear deployed (number of rods).

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Formula CPUE:

Divide the total catch by the fishing effort. The resulting value represents the average catch per unit effort. This formula was adapted from Tian *et al*. (2009).

$$CPUE = Total\ catch\ /\ Fishing\ effort$$

$$CPUE = \_\_\_\_\ kg/hour$$

3.4 Hook removal

The hook was removed carefully by determining the position of the hook on the fish before documented the position. There are two types of hook sites: critical (when the fish sustains damage to the gills, esophagus, or stomach) and non-critical (when the fish sustains an injury to the lips or jaw).

3.5 Survival rate

The percentage of fish that live or die during a specific time is known as the survival rate (Ljubojević *et al*. 2013). It estimates the rate of mortality or survival within a population and is frequently used to evaluate the effects of different causes or treatments.

The steps to calculate the survival rate or death rate:

i. Ascertain the total population of fish at the start of the period under study.

ii. Count the number of fish that have lived or perished after the time or under circumstances.

Formula Survival rate:

$$Survival\ Rate = (Number\ of\ Survivors\ /\ Total\ Number\ at\ Start) * 100$$

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Survival Rate = ____%

Formula mortality rate:

Mortality Rate = (Number of Deaths / Total Number at Start) * 100

Mortality Rate = ____%

3.6 Data analysis

Data was collected and calculations were performed in Microsoft Excel and Statistical Analysis System (SAS). The simple proportions were applied to portray the percentage of catch effectiveness of hook size and type (barbed and barbless) on hooking injury, catch per unit effort (CPUE), survival rate, and fish size. Analysis of variance (ANOVA) for treatment effect. Turkey's test at *p* values less than 0.05 for mean comparison.

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CHAPTER 4

4.0 RESULTS

In total of 617 fishes were captured, representing nine species of fish inhabiting the recreation pond at UPM Bintulu Sarawak Campus. Five families of fish that have been namely identified Anabantidae, Cyprinidae, Channidae, Clariidae, and Cichlidae, it was represented by one species each namely *Anabas testudineus*, *Anabas spinosus*, *Barbonymus collingwoodii*, *Channa lucius*, *Channa striata*, *Clarias batrachus*, *Clarias macrocephalus*, *Oreochromis mossambicus*, and *Oreochromis niloticus* respectively (Table 4.1).

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Table 4.1. Species, total catches, injuries (%), weight (g), length (cm) survival rate and self-released in the experiment.

Type of hooks	Species	Total catches, n (%)	Non-critical hooking location, n (%)		Critical hooking location, n (%)		Weight (g)	Length (cm)	Survival rate	
			Outer lip	Upper and lower jaw	Inner gills	Inner stomach			Yes	No
Barbed 5	*Anabas testudineus* (Bloch, 1792)	14 (7.9)	7 (50)	4 (28.6)	3 (21.4)	-	42.5 ± 28.0	16.1 ± 5.3	13	1
	Anabas spinosus Gray, 1834	1 (0.6)	-	-	1 (100)	-	13.0 ± 0.0	10.0 ± 0.0	1	0
	Barbonymus collingwoodii (Günther, 1868)	32 (18.1)	12 (37.5)	13 (40.6)	5 (15.6)	2 (6.3)	28.7 ± 16.9	11.9 ± 2.4	28	4
	Channa striata (Bloch, 1793)	5 (2.8)	4 (80)	-	-	1 (20)	317.4 ± 130.8	28.6 ± 4.1	5	0
	Clarias batrachus (Linnaeus, 1758)	1 (0.6)	-	-	-	1 (100)	320.0 ± 0.0	28.0 ± 0.0	0	1
	Oreochromis mossambicus (Peters, 1852)	119 (67.2)	30 (25.2)	61 (51.3)	21 (17.6)	7 (5.9)	32.3 ± 34.8	11.0 ± 2.8	100	19
	Oreochromis niloticus (Linnaeus, 1758)	5 (2.8)	1 (20)	1 (20)	3 (60)	-	29.0 ± 5.4	11.0 ± 0.7	4	1
	TOTAL	177	133		44				151	26
Barbless 5	*Anabas testudineus* (Bloch, 1792)	8 (4.8)	1 (12.5)	6 (75)	1 (12.5)	-	21.6 ± 10.2	11.9 ± 2.9	8	0
	Anabas spinosus Gray, 1834	9 (5.4)	1 (11.1)	2 (22.2)	6 (66.7)	-	54.0 ± 21.1	19.3 ± 4.1	9	0
	Barbonymus collingwoodii (Günther, 1868)	37 (22.2)	5 (13.5)	23 (62.2)	8 (21.6)	1 (2.7)	29.6 ± 15.7	11.9 ± 2.2	33	4
	Channa striata (Bloch, 1793)	11 (6.6)	1 (9.1)	8 (72.7)	2 (18.2)	-	194.7 ± 124.1	27.4 ± 8.0	11	0
	Clarias macrocephalus Günther, 1864	2 (1.2)	-	1 (50)	1 (50)	-	186.0 ± 35.4	26.0 ± 4.2	2	0
	Oreochromis mossambicus (Peters, 1852)	98 (58.6)	22 (22.4)	53 (54.1)	20 (20.4)	3 (3.1)	37.0 ± 36.3	11.4 ± 2.1	95	3
	Oreochromis niloticus (Linnaeus, 1758)	2 (1.2)	2 (100)	-	-	-	31.0 ± 17.9	10.5 ± 2.1	2	0
	TOTAL	167	125		42				160	7

Continued.

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Table 2. Species, total catches, injuries (%), weight (g), length (cm) survival rate and self-released in the experiment.

Type of hooks	Species	Total catches, n (%)	Non-critical hooking location, n (%)		Critical hooking location, n (%)		Weight (g)	Length (cm)	Survival rate	
			Outer lip	Upper and lower jaw	Inner gills	Inner stomach			Yes	No
Barbed 8	*Anabas testudineus* (Bloch, 1792)	6 (4.1)	1 (16.7)	3 (50)	2 (33.3)	0 (0)	39.5 ± 27.9	16.5 ± 5.1	6	0
	Anabas spinosus Gray, 1834	4 (2.8)	0 (0)	1 (25)	3 (75)	0 (0)	39.3 ± 23.2	15.5 ± 6.6	4	0
	Barbonymus collingwoodii (Günther, 1868)	19 (13.1)	6 (31.6)	9 (47.4)	3 (15.7)	1 (5.3)	33.5 ± 37.9	12.9 ± 6.2	17	2
	Channa striata (Bloch, 1793)	38 (26.2)	4 (10.5)	19 (50)	10 (26.3)	5 (13.2)	287.5 ± 196.9	28.7 ± 8.7	38	0
	Clarias macrocephalus Günther, 1864	1 (0.7)	0 (0)	1 (100)	0 (0)	0 (0)	152.0 ± 0.0	24.0 ± 0.0	1	0
	Oreochromis mossambicus (Peters, 1852)	71 (49.0)	18 (25.4)	34 (47.8)	18 (25.4)	1 (1.4)	40.2 ± 41.2	11.5 ± 3.1	67	4
	Oreochromis niloticus (Linnaeus, 1758)	6 (4.1)	1 (16.7)	4 (66.6)	1 (16.7)	0 (0)	89.0 ± 79.4	14.0 ± 5.9	6	0
	TOTAL	145	101		44		680.9	123.2	139	6
Barbless 8	*Anabas testudineus* (Bloch, 1792)	6 (4.7)	2 (33.3)	2 (33.3)	1 (16.7)	1 (16.7)	30.7 ± 23.5	13.8 ± 2.7	6	0
	Anabas spinosus Gray, 1834	3 (2.3)	0 (0)	2 (66.7)	1 (33.3)	0 (0)	17.3 ± 5.5	12.7 ± 1.2	3	0
	Barbonymus collingwoodii (Günther, 1868)	20(15.6)	4 (20)	11 (55)	5 (25)	0 (0)	31.1 ± 18.9	14.4 ± 10.1	19	1
	Channa Lucius (Cuvier, 1831)	1 (0.8)	0 (0)	1 (100)	0 (0)	0 (0)	217.0 ± 0.0	35.0 ± 0.0	1	0
	Channa striata (Bloch, 1793)	29 (22.7)	5 (17.2)	14 (48.3)	6 (20.7)	4 (13.8)	329.3 ± 290.0	30.2 ± 10.1	28	1
	Oreochromis mossambicus (Peters, 1852)	64 (50.0)	13 (20.3)	36 (56.3)	13 (20.3)	2 (3.1)	31.0 ± 38.4	10.3 ± 3.5	60	4
	Oreochromis niloticus (Linnaeus, 1758)	5 (3.9)	0 (0)	3 (60)	2 (40)	0 (0)	26.0 ± 29.7	10.0 ± 2.8	5	0
	TOTAL	128	93		35		682.3	126.5	122	6

The level of injury is expressed in number and percentage (%)

Weight (g)and TL (cm) are expressed as means (± standard deviation).

, No fish caught

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4.1 The hooking location and injury level

The total number of individuals caught using different types of hooks like barbed 5, barbless 5, barbed 8 and barbless 8 were 177, 167, 145 and 128 individuals, respectively. This result indicates the proportion of catch was higher on barbed hook 5 (28.7%), followed by barbless hook 5 (27.1%) barbed hook 8 (23.5%) and barbless hook 8 (20.7%). In terms of hooking location approximately 452 (73.2%) and 165 (26.7%) of fish were hooked on non-critical and critical areas, respectively.

The highest number of fish that were hooked at the outer lip (Figure 4.1A) are from barbed hook 5 (n=54), followed by barbless hook 5 (n=32), barbed hook 8 (n=30) and barbless hook 8 (n=24). Meanwhile, the highest number of fish that were hooked on the upper and lower jaw (Figure 4.1B) are from barbless hook 5 (n=93), followed by barbed hook 5 (n=79), barbed hook 8 (n=71) and barbless hook 8 (n=69). In addition, the highest number of fish that were hooked at inner gills (Figure 4.1C) are from barbless hook 5 (n=38), followed by barbed hook 5 (n=33), barbed hook 8 (n=37) and barbless hook 8 (n=69). Thus, the highest number of fish that was hooked at the inner stomach (Figure 4.1D) are from barbed hook 5 (n=11), followed by barbless hook 5 (n=4), barbed hook 8 (n=7) and barbless hook 8 (n=7).

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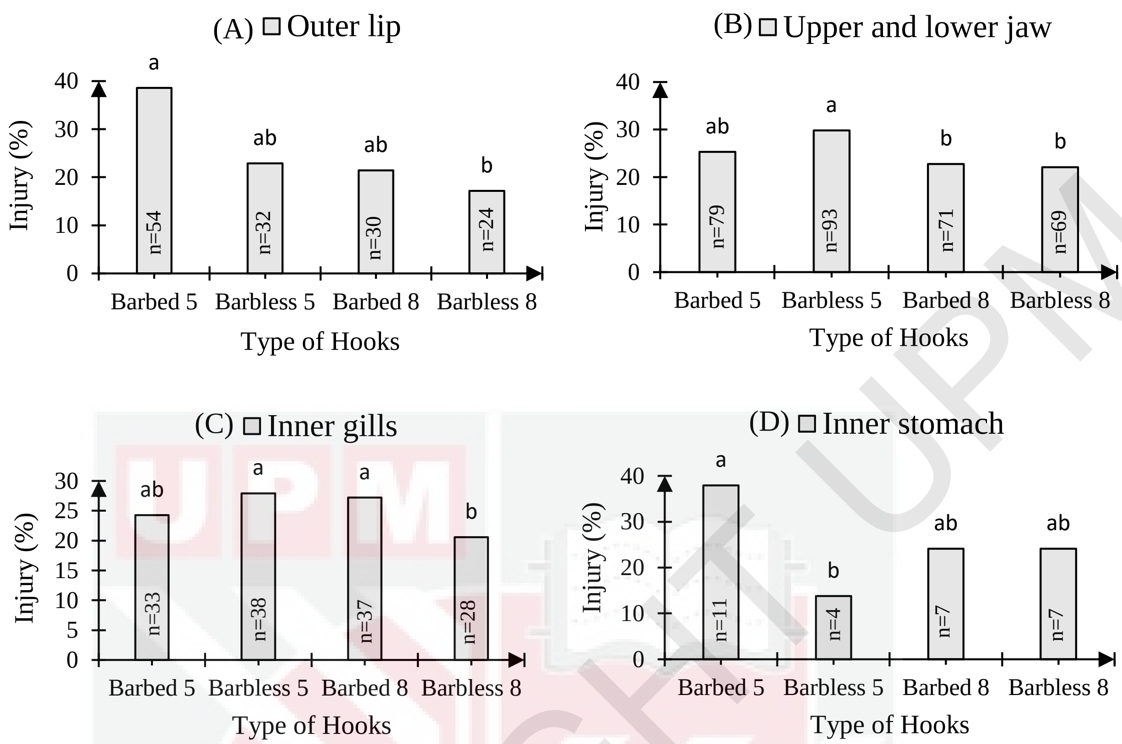

Figure 4.1. The type of injuries on hooking location in the experiment. Means between columns with a different letter(s) indicate significant differences between treatments by Tukey's test at $p < 0.05$. Bars represent the mean values ± SE.

4.2 Species composition with different hook types

The recreation pond area of the Universiti Putra Malaysia Bintulu Campus accommodated a diverse range of species (Table 4.2), namely *testudineus*, *spinosus*, *collingwoodii*, *Lucius*, *striata*, *batrachus*, *macrocephalus*, *mossambicus*, and *niloticus*. The percentage of each species caught by using different types of hooks were portrayed in Figure 4.2. Specifically, barbed hook 5 exhibited a notably higher percentage occurrence of *mossambicus* (67.2%) compared to *spinosus* (0.6%) and *batrachus* (0.6%), which are both equally low occurrences. Next, barbless hook 5 displayed a higher percentage of

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mossambicus (58.6%), followed by *collingwoodii* (22.2%), meanwhile other species less than 20% were caught. For the barbed hook 8, a high percentage of *mossambicus* (49.0%), followed by *striata* (26.2%), *collingwoodii* (13.1%), and other species less than 10% were caught. Lastly, the barbless hook 8 hook type displayed a high number of occurrences of *mossambicus* (50.0%), followed by *striata* (22.7%), *collingwoodii* (15.6%), while other species of less than 10% were caught.

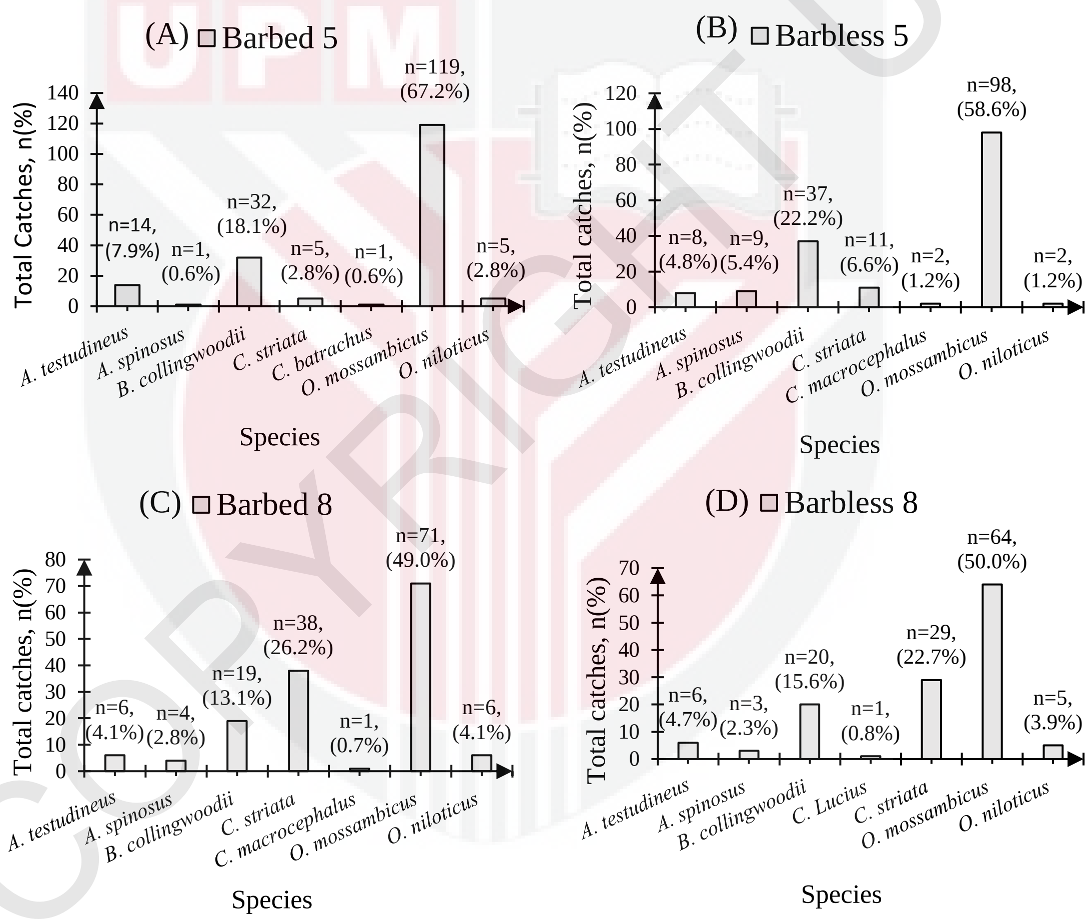

Figure 4.2. The number of species in the experiment.

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4.3 Analysis of Catch Per Unit Effort (CPUE)

The Catch per Unit Effort (CPUE) was determined across various species captured over 60 minutes using four distinct hook types (Table 4.2), assessing fishing efficiency (Figure 4.3). CPUE almost balances both types of hooks barbed and barbless. The result of CPUE for 3 main species caught are *mossambicus*, with 352 captures, displayed the highest CPUE with barbed hook 5 (1.75 ± 1.31), followed by barbless hook 5 (1.44 ± 1.16), barbed hook 8 (1.04 ± 1.01), and barbless hook 8 (0.94 ± 0.94). Next, *collingwoodii*, captured 108 individuals, showcased higher CPUE values with barbless hook 5 (0.54 ± 0.76), followed by barbed hook 5 (0.47 ± 0.68), barbed hook 8 (0.28 ± 0.62) and barbless hook 8 (0.29 ± 0.52). Thus, *striata*, totaling 83 individuals, showcased higher CPUE values with barbed hook 8 (0.56 ± 0.53), followed by barbless hook 8 (0.43 ± 0.49), barbless hook 5 (0.16 ± 0.37) and barbed hook 5 (0.07 ± 0.26).

Table 4.2. Species and total catches in the experiment by different hook treatments.

Species	Total catch	Barbed 5	Barbless 5	Barbed 8	Barbless 8
Anabas testudineus	34	0.20 ± 0.76[a]	0.12 ± 0.44[b]	0.08 ± 0.45[c]	0.08 ± 0.33[c]
Anabas spinosus	17	0.01 ± 0.12[c]	0.13 ± 0.49[a]	0.05 ± 0.29[b]	0.04 ± 0.21[b]
Barbonymus collingwoodii	108	0.47 ± 0.68[a]	0.54 ± 0.76[a]	0.28 ± 0.62[b]	0.29 ± 0.52[b]
Channa Lucius	1	-	-	-	0.01 ± 0.12[a]
Channa striata	83	0.07 ± 0.26[c]	0.16 ± 0.37[b]	0.56 ± 0.53[a]	0.43 ± 0.49[a]
Clarias batrachus	1	0.01 ± 0.12[a]	-	-	-
Clarias macrocephalus	3	-	0.02 ± 0.17[a]	0.01 ± 0.12[a]	-
Oreochromis mossambicus	352	1.75 ± 1.31[a]	1.44 ± 1.16[b]	1.04 ± 1.01[c]	0.94 ± 0.94[c]
Oreochromis niloticus	18	0.07 ± 0.31[b]	0.02 ± 0.17[c]	0.09 ± 0.51[a]	0.07 ± 0.39[b]

Catch per unit effort (CPUE) are expressed as means (± standard deviation)
*Fish caught per angler per 60 min.
-, No fish caught

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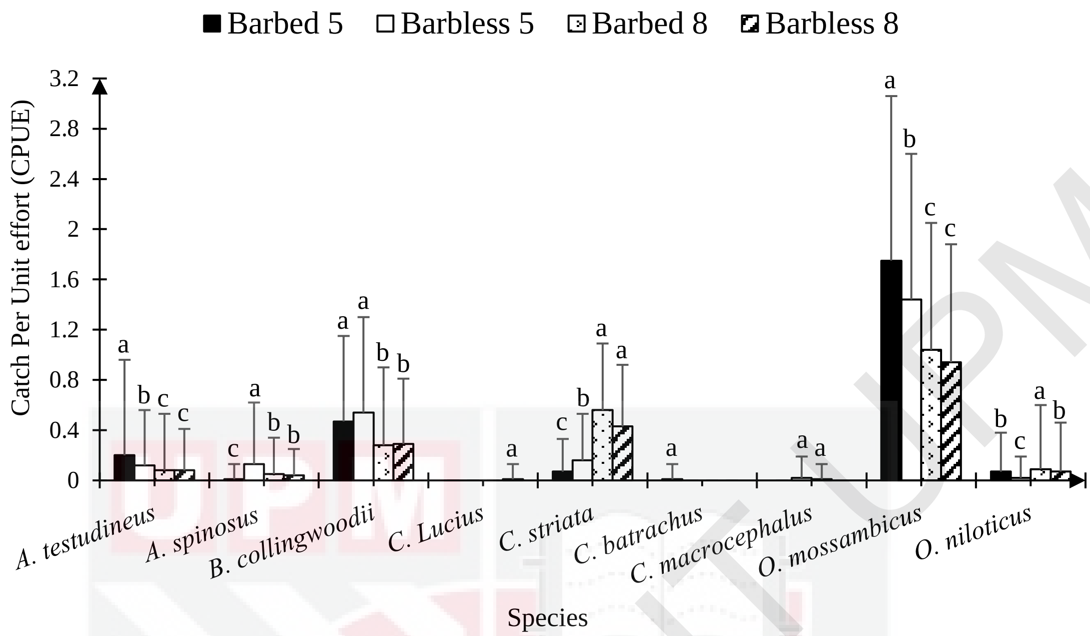

Figure 4.3. CPUE in the experiment. Means between columns with a different letter(s) indicate significant differences between treatments by Tukey's test at $p < 0.05$. Bars represent the mean values ± SE.

4.4 Weight and length of fish caught

This study examines size variation, measured in weight (g) (Figure 4.4) and total length (cm) (Figure 4.5) across various species, presented as mean ± standard deviation in Table 4.1. The catch from barbed hook 5, *Clarias batrachus* showed the largest weight size (320.0 ± 0.0) and total length (28.0 ± 0.0), followed by *Anabas spinosus* showing the lowest weight size (13.0 ± 0.0) and total length (10.0 ± 0.0) compared to the catch of the species other fish in this study. In addition, the catch from barbless hook 5, *Channa striata* showed the highest weight size (194.7 ± 124.1) and total length (27.4 ± 8.0), followed by *Anabas testudineus* showed the lowest weight size (21.6 ± 10.2) and total length (11.9 ± 2.9).

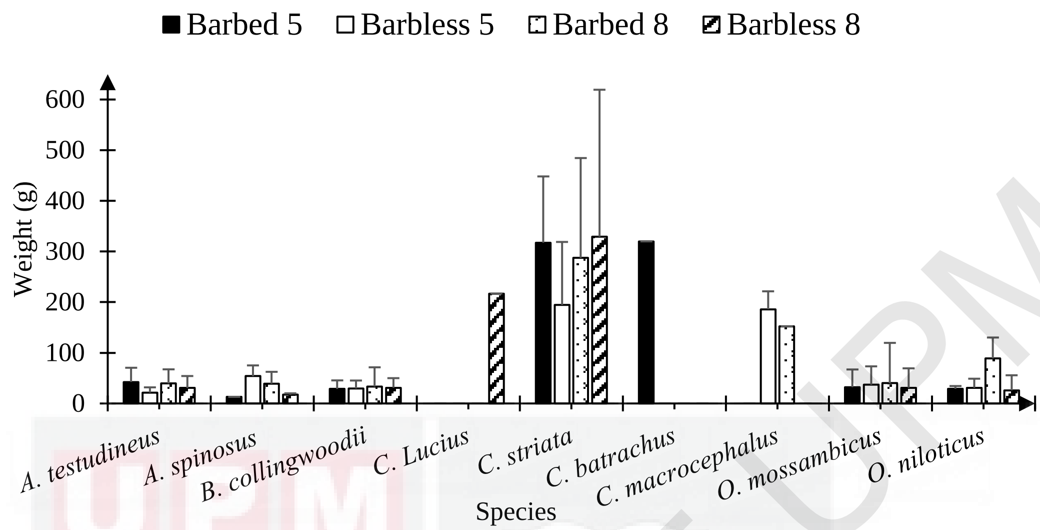

Figure 4.4. The weight (g) of fishes in the experiment.

In addition, the catch from barbed hook 8, *Channa striata* showed the highest weight size (287.5 ± 196.9) and total length (28.7 ± 8.7), followed by *Barbonymus collingwoodii* showing a low weight size (33.5 ± 37.9) and total length (12.9 ± 6.2). Therefore, catch on barbless hook 8 *Channa striata* showed the largest weight size (329.3 ± 290.0) and total length (30.2 ± 10.1), followed by *Anabas spinosus* showing the lowest weight size (17.3 ± 5.5) and total length (12.7 ± 1.2) compared to the catch of other fish species in this research.

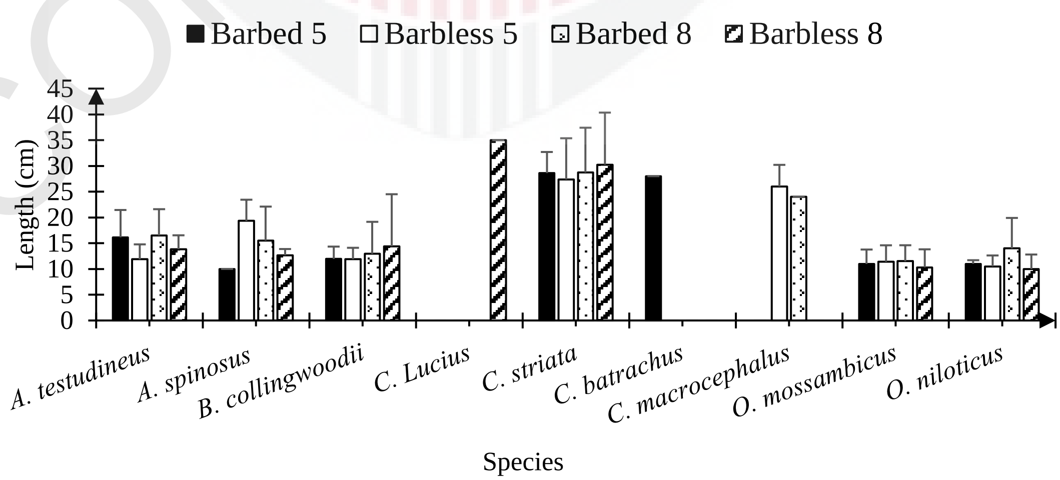

Figure 4.5. The length (cm) of fishes in the experiment.

4.5 Survival rate of fish caught

The survival rates of the fish that were caught using barbless hook 5 (95.81%) and barbless hook 8 (95.31%) were significantly higher as compared to barbed hook 5 (85.31%), and barbed hook 8 (88.28%) (Figure 4.6). Conversely, the mortality rate was notably higher in barbed hook 5 (14.69%) compared to the markedly lower rates observed in barbless hook 5 (4.19%) and barbless hook 8 (4.49%), with almost equivalent values, while barbed hook 8 displayed an intermediate mortality rate (11.72%).

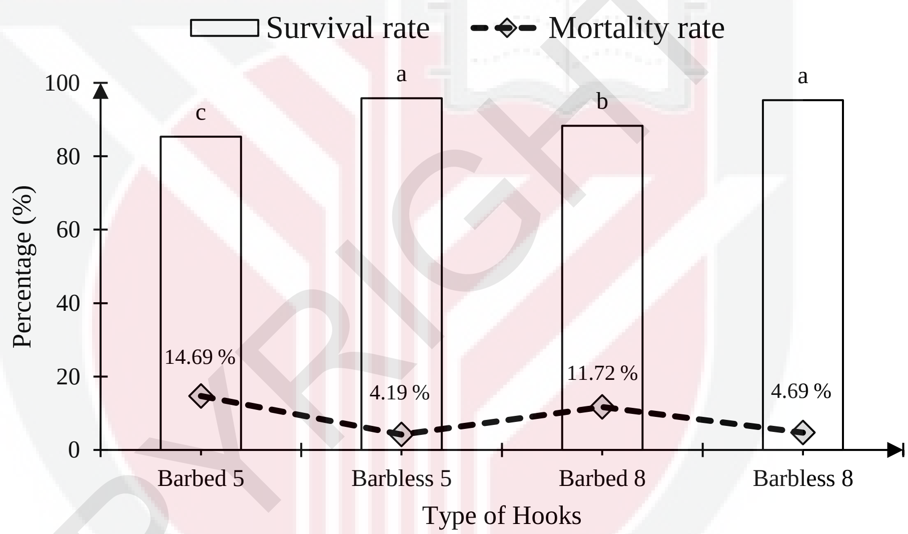

Figure 4.6. The percentage (%) of survival rate and mortality rate of fish in the experiment. Means between columns with different letter(s) indicate significant differences between treatments by Tukey's test at $p < 0.05$. Bars represent the mean values ± SE.

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CHAPTER 5

5.0 DISCUSSION

5.1 Diversity and abundance of fish species

Reservoirs and lakes serve multifaceted roles in societal functions like supporting fishing endeavors and enabling recreational activities (Sharip and Zakaria 2007). Lake boasts a rich variety of terrestrial and aquatic habitats, fostering diverse species of flora and fauna (Azmi and Geok 2016). Additionally, it serves as a habitat for numerous species of freshwater fish and exotic wildlife (Rosle *et al*. 2018). In a recent study by Kamaruddin *et al*. (2010) the fish diversity within the Pengkalan Gawi-Pulau Dula section of Kenyir Lake was investigated, revealing *Barbodes gonionutus* as the predominant fish species, followed by *Notopterus sp.* and *Hampala macrolepidota*. According to Rosle et al. (2018) like a prior study conducted at Lake Kenyir, found *Hampala macrolepidota* as the most dominant species at Lake Kenyir, with 879 individuals, followed by *Cyclocheilichthys apogon* with 376, and *Mastacembelus armatus* with once.

Cyprinidae is the dominant fish family in Pergau Lake, accounting for exactly 50% of the capture (Alias *et al*. 2019). Several similarities remain between this study with most of the research carried out in Malaysian freshwater areas, showing that the family Cyprinidae recorded the highest percentage of catch in freshwater environments (Mohd Fadzil *et al*. 2016; Farinordin *et al*. 2016). The Cyprinidae is the biggest family of freshwater fishes, (Ambak *et al*. 2012). In terms of the number of genera and species, as well as the quantity of fish in rivers and lakes, it is known as the biggest family of freshwater fish in Malaysia (Alias *et al*. 2019).

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Notably, *Oreochromis mossambicus* manifests a pronouncedly higher catch percentage across various hook variations compared to its counterparts within the recreational pond area of UPMKB. Similarly, in the study conducted by Morni *et al*. (2023) at the UPMKB recreational pond, a high number of *Oreochromis sp.* was captured by using an octopus hook and circle hook. This heightened prevalence could be attributed to the species' rapid reproductive rate, contributing to its increased presence. Corroborating these findings, Alós *et al*. (2008) supported the notion that the site of capture stands as the most influential factor contributing to the variability in both species' abundance and composition, aligning closely with the outcomes derived in this study.

5.2 Catch per Unit Effort (CPUE)

Catch per unit of effort is a fundamental fisheries science measure used to assess trends in relative abundance and understand the efficiency of fishing gear (Belhabib *et al*. 2018). According to Soykan *et al*. (2021) the CPUE value of the catch based on the hook type, with 43.3% using a C-hook and 56.7% using a J-hook, but a significant effect was detected for two discard species, *D. annularis* and *S. cabrilla*. According to Kapusta and Czarkowski (2022) CPUE showed no significant difference for each hook type, with barbed J-hooks having a mean CPUE of 17.2, barbless J-hooks having a mean CPUE of 15.6, and circle hooks having a mean CPUE of 14.4. According to Czarkowski and Kapusta's (2019) research similar cyprinid capture rates were seen while using barbed and barbless J-hooks for float fishing. Schaeffer and Hoffman (2002) compared the CPUE of barbed and barbless hooks in nearshore marine fisheries in the Gulf of Mexico, and Alós *et al*. (2009) came to similar conclusions when analyzing catch rates for mixed-species recreational boat fisheries in the Balearic Islands using circle hooks and J-hooks.

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In marine recreational fisheries, Schaeffer, and Hoffman (2002) reported a 20% increase in fish landed with barbed hooks. Schaeffer and Hoffman (2002) stated that disparities in catch rates between hook types could also stem from species-specific differences in hooking efficiency, with barbless hooks being particularly inefficient. Despite reports of barbless hooks reducing handling time, there are instances where catch efficiency is compromised (Meka 2004). Conversely, in this study, CPUE for barbed hook and barbless hook does not illustrate differences in catch rates per hour.

According to Czarkowski and Kapusta (2019) the landing efficiency varied, ranging from 71.2% for novice anglers employing barbless hooks to 85.8% for experienced anglers using barbed hooks. According to Meka (2004) and Alós *et al*. (2008) the same data similarity in the utilization of barbed hooks resulted in a higher landing efficiency compared to barbless hooks. This study also implies that due to differences in fish size and mouth morphology, landing success will probably fluctuate all through species. A barbless hook would probably unintentionally be released from a fish before it is landed if the fish engaged in fighting actions that release tension on the hook, such as swimming towards the angler or jumping.

Interim of species in this study, species like *mossambicus* and *collingwoodii*, the barbed hooks (5 and 8) had higher CPUE compared to the barbless hook in this study. However, *striata* demonstrate a preference for larger hooks, and barbed hooks which influence their catch frequency. In our opinion, total catch efficiency, consisting of biting, hooking, and landing components, is crucial for determining the correctness of fishing methods, procedures, and conditions. The species-specific preference for specific hook

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types and sizes significantly influences catch outcomes, as different fish species may respond differently to hook types based on size, mouth structure, and behavior.

5.3 Injury

Hooking location can affect the level of injury. A hook in a non-critical location, such as the outer lip or upper and lower jaw, can cause less injury than a hook in a critical location, such as the inner stomach or gills. Differences in hooking location between barbed and barbless hooks were observed, consistent with findings from other studies (DuBois and Dubielzig 2004). The distribution of the total number of individuals caught between the various hook types shows an overall view of how effective each type of hook is at catching fish. In comparison to hook size 8, the proportions indicate that hook size 5 had higher catch rates.

The findings of this study show that using barbless hooks reduces stress and increases survival rates, as hooks on the upper and lower jaws do not have a critical effect. According to Cooke *et al.* (2001) support that barbless hooks contribute to reduced hook release time, thereby minimizing stress on the fish, marking it as a significant factor. However, barbless hooks decrease the effectiveness of the capture, while other studies have not shown any appreciable variations in mortality and hooking damage between barbed and barbless hooks (DuBois and Dubielzig 2004). According to our study, using a barbed hook increases stress as well, and the survival rate is lower (85.31%) because of substantial bleeding on the inner gills and stomach. Additionally, our study aligns with the endorsement of barbless hooks for catch-and-release fishing due to their potential for reducing release time, which might vary according to the behavior of anglers and fish competing.

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Barbed and barbless hooks caught fish in the same anatomical sites, and several studies have established that hook position is the key factor determining post-release mortality across a wide range of species and environments (Taylor *et al*. 2001). The results of this study imply that using barbless hooks could potentially contribute to higher survival rates (95.81%) and lower mortality rates (4.19%) among caught fish compared to barbed hooks. According to Arlinghaus *et al*. (2007), where the fish is caught, hooking mortality rates in fact should range from 1% to 90%, with the latter likely including a hook to the fish's critical organs. If the fish is released, it may suffer from wounds or internal injuries that can impact its survival. Although the position of the hooking also had an impact on the harm, barbless hooks considerably decreased the percentage of injured fish discharged (Lennox *et al*. 2017). Most of the fish 80% were caught in the jaws, with the remaining 20% hooked in sensitive places (Lennox *et al*. 2017). The mortality rate of common snook (*Centropomus undecimalis*) rose from 1.2% for fish caught in the mouth to 16.7% for fish hooked in the stomach (Taylor *et al*. 2001). Lower survival rates for striped bass hooked to the gills either anteriorly or posteriorly (Millard *et al*. 2005). Fish hooked posterior to the gills died at a rate of 69%, compared to 27% for fish hooked anterior to the gills (James 2006). White seabass (*Atractoscion nobilis*) hooked anteriorly to the esophagus had a 0% death rate whereas fish hooked in the esophagus had a 67% mortality rate (Aalbers *et al*. 2004). Consistent with prior research, it is evident that barbless hooks facilitate quicker release compared to barbed hooks, potentially mitigating the disruption of stress-related reflexes (Cooke *et al*. 2021; Trahan *et al*. 2021).

Our study revealed the importance of understanding certain hooking locations and their effects by identifying notable variations in fish injuries caused by hook type and size.

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Furthermore, it offers valuable insights into the efficiency of diverse hooks in targeting regions within the fish oral cavity or body. Cooke and Suski (2004) show that the effectiveness of a new piece of tool catch strongly impacts its introduction as a safer option for fish. Size selection might only become discernible with a substantial increase in hook size (Alós *et al*. 2008). To reduce harm to the captured species, it is important to consider this when conducting fishing operations.

5.4 Weight and length of fish caught

This study attempts to examine how the weight and overall length of various fish species affect size variation. Analyzing data can be crucial for understanding the dynamics of fish populations, their growth patterns, and potentially even environmental factors influencing their sizes. However, our study at the recreational pond UPM Bintulu Campus showed that *Channa striata* had the largest weight and total length, while *Anabas spinosus* had the smallest among other species. According to Muchlisin *et al*. (2010) stated that the large-sized individual is *T. thynnoides* (weight, 59.7 g to 296.7 g and length, 14.2 cm to 23.5 cm), while the small-sized individual is *O. vittatus* (weight, 20.5 g to 127.6 g and length, 9.0 cm to 16.8 cm) that were caught in Raban Lake, Perak. According to Burhanuddin *et al*. (2023) revealed large-sized individual is *P. hypophthalmus* (weight, 3,297.00 g and total length, 58.00 cm), while a small-sized individual is *B. schwanenfeldii* (weight, 3.46 g and total length, 4.93 cm) that were caught in Lake Putrajaya.

In this study, individual fish measurements concerning weight and total length displayed significant variations attributable to different treatments (hook type and size) specific to the captured fish species. Predominantly, the fishing activities in this study yielded a prevalence of small-sized fish (weight 13 g to 100 g and total length 10 cm to

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25 cm), although larger specimens (weight 100 g to 350 g and total length 25 cm to 40 cm) were also captured. Richter (2007) and Blackwell *et al*. (2000) emphasize that analyzing fish weight and length variations on an individual or group basis serves to provide insights into aspects such as obesity, health, productivity, physiology, and gonadal development, aiding in comprehensive assessments of fish condition and well-being.

5.5 Survival rates and mortality rates

The assessment of survival and mortality rates post-capture (24 hours of quarantine) offers insights into the impact of treatments on fish safety. Hook location is identified as a crucial factor governing post-release mortality across various species and conditions (Taylor *et al*. 2001). While barbless hooks expedite release, quick releases with barbed hooks are common, particularly for fish hooked in sensitive areas, potentially leading to prolonged release times. The mortality rate caused by barbed hooks is high (14.69%) and the survival percentage using a barbed hook is 85.31%. The use of barbed hooks in bait fishing resulted in much higher post-release death of trout than the use of barbless hooks (33.5% versus 8.4% mortality, respectively) (DuBois and Pleski 2007). During the process of extraction, it can further harm the fish's mouth or neck. Barbed hooks might potentially do greater harm to the fish when used in catch-and-release fishing and lower the likelihood of the fish surviving after release. Barbed hooks exhibited a slightly more substantial mortality rate than barbless hooks (DuBois and Dubielzig 2004). Fish caught in such conditions, especially those with deep hooks, may face increased mortality irrespective of the hook type (Schaeffer and Hoffman 2002). Most sizes may be larger than the recreational pond at UPM because no food is provided.

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The findings align with Lyle *et al*. (2007) emphasizing that injury to vital organs, such as the gills and stomach, was the leading cause of death in deep-hooked fish. Similarly, in a current study, 14.6% of mortality happened due to hooking location at the critical location. Survival rates were notably lower when bleeding was involved, with nearly all hook-related deaths linked to deep-hook incidents. Contrarily, shallow hooks displayed nearly 100% survival rates compared to 64% for deep-hooked fish in this study, affirming that most hook-related fatalities were associated with deep hooks (Lyle *et al*. 2007). However, there is no conclusive agreement on whether shortened release times decrease hooking mortality, considering that fish removal from water induces stress (Cooke *et al*. 2001). Alós *et al*. (2008) advocate for larger hooks, which reduce deep hooking incidents across various species, consequently minimizing bleeding and potential hooker mortality.

The analysis underscores that using barbless hooks positively impacts fish survival rates, while smaller-sized barbed hooks tend to increase mortality rates. The mortality related to catch-and-release (C&R) may be broken down into two parts: the death brought on by a hooking or handling injury, and the extra mortality brought on by indirect consequences, such as increased predation risk after release (Pollock and Pine 2007). It is important to evaluate survival rates and mortality in recreational fishing to manage and protect sustainable fisheries. Consequently, selecting the appropriate hook type plays a pivotal role in ensuring fish safety post-capture, a crucial element in fostering sustainable and responsible fishing practices.

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CHAPTER 6

CONCLUSION

In summary, this study was designed with several objectives aimed at investigating the impact of hook size and type on injury rates. The results obtained contribute to understanding the correlation between hook characteristics and injury severity. Additionally, the study encompassed the assessment of catch per unit effort (CPUE), survival rates, and the size of fish species at the UPM Bintulu Campus Recreation Pond. These findings offer valuable insights into the relationship between hook variations, catch efficiency, survival percentages, mortality rates, and the size range of captured fish. Moreover, the research identified nine species of fish that inhabit recreational ponds and highlighted differences in the effectiveness of barbed hook and barbless hook. Therefore, the type and size of the hook influences the catch efficiency, injury patterns, CPUE, survival rates, and fish size in recreational fishing settings. Hook size and hook type selections were important things to be highlighted in strategizing the implementation of C&R in Malaysia toward the sustainable recreational fisheries industry. For future research directions, expanding the investigation beyond hook types to explore other facets of recreational fishing in diverse locations would improve our understanding of barbed hooks and barbless hook dynamics.

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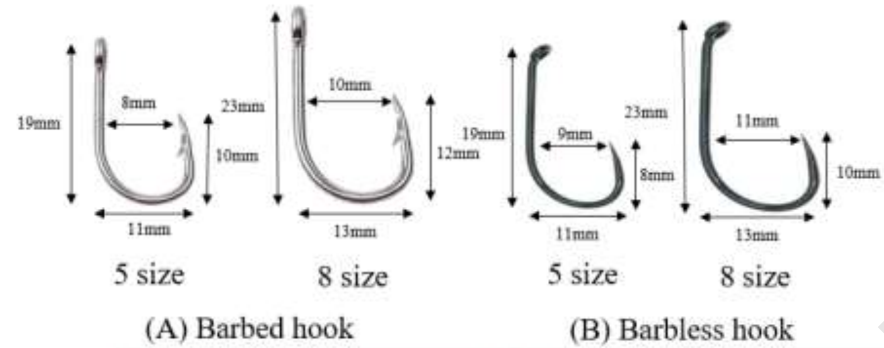
APPENDICES



(A) Barbed hook and barbless hook

(B) Swivel

(C) Float

(D) Rod

(E) Nylon quarantine

Appendix 3.1. Fishing equipment.

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(F) *Channa striata* - weight

(G) *Oreochromis mossambicus* - length

Appendix 3.2. Measuring weight (g) and length (cm).

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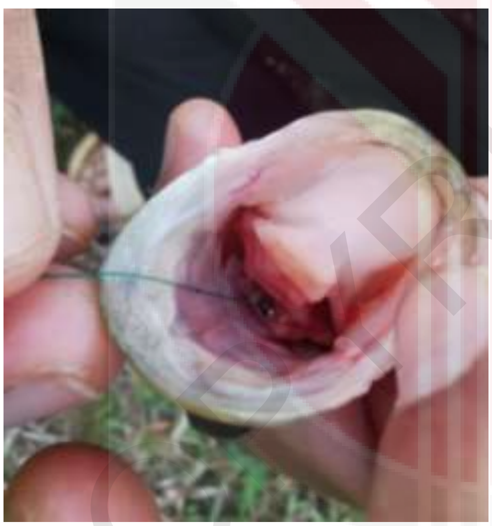
(H) Hook location – Outer lip (I) Hook location – Upper and lower jaw



(J) Hook location – Inner gills (K) Hook location – Inner stomach

Appendix 3.3. Hooking location and level injury.

Appendix 3.4. Sampling site at the recreational UPM Bintulu Sarawak Campus

(L) *Oreochromis mossambicus*

(M) *Oreochromis niloticus*

(N) *Channa striata*

()) *Channa Lucius*

Appendix 3.5. Distribution of fish species at the recreational pond at UPM Bintulu Campus.

(P) *Barbonymus collingwoodii*

(Q) *Anabas testudineus*

(R) *Anabas spinosus*

Appendix 3.5. Distribution of fish species at the recreational pond at UPM Bintulu Campus.

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