8.1. Introduction

The fishing efficiency of the hook is an important factor deciding the performance of any hook and line fishing gear. Hook efficiency can be expressed as the number of successful hooking divided by the number of attempts or number of fish caught divided by number of fish taking the bait (Number of bites). Hooking rate is generally expressed as the number of fish caught per hundred hooks (Gibson, 1979). The physical and mechanical properties of the hook and the biological aspects of the target fish affect catching efficiency of a hook (Lokkeborg and Bjordal, 1992). The size, shape and design of the hook are the important factors affecting the performance of a hook set against a targeted species. According to Baranov (1976) the success of the catch from a hook depends on the angle, the spear of the hook makes with the direction of the pull.

The hooking efficiency is also influenced by the size and species of the target fish (Johannessen, 1983). The responses of cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) to baited hooks were analysed by Huse and Fernö (1990) to determine their behaviour patterns, which could form the basis for improved longline hook design. The most important behaviour pattern observed for successful hooking of fish was when the fish swam away rapidly with the baited hook in its mouth, termed as the "rush" behaviour (Huse and Fernö, 1990). A
hypothesis for hook design was formed, which proposes that a longline hook with its point towards the line of pull would catch more fish than a typical Atlantic longline hook with its point parallel to the line of pull. Two experimental hooks conforming to this hypothesis were compared with a standard hook in fishing experiments. Butcher et al. (2007) have studied performance of different designs and sizes of commonly used fishing hooks both in field and in fish cages. The study involved hooking yellowfin bream using 50 designs and sizes of commonly-configured circle and J-hooks, and a modification to a small J-hook termed the ‘stop swallow’.

Few studies have been conducted on hooking rate of fishing hooks in the Indian context (Despande et al., 1970; Kartha et al., 1973; Manohardoss, 2002; Manohardoss et al., 1981; Sulochanan et al., 1989; George et al., 1991 and Durai 2003). Despande et al. (1970) studied fishing efficiency of imported 4/0 Mustad hook whereas, Kartha et al. (1973) studied the effectiveness of different sizes of Mustad round bent hooks with different types of baits. Sulochanan et al. (1989) have analysed the hooking rate of tuna in the Arabian Sea with particular reference to yellow-fin tuna, Thunnus albacares. Manohardoss et al., (1981) and George (2002) studied the comparative fishing efficiency of Kirby bent hooks to that of round bent hooks in inland waters. George et al. (1991) studied relative fishing efficiencies of large sized 4/0 round bent indigenous hooks against that of imported Mustad hooks of comparable size. They studied the hooking rates of both the types and the hook’s efficiency in terms of weight of fish landed, operated from a marine fishing vessel off South-West Bombay, targeting sharks. Varghese et al. (1997) evaluated fishing performance of indigenous unbranded hooks against that of standard control branded hooks (Mustad hooks). This was conducted through fishing experiments targeting sharks and smaller varieties of fishes.
Recently, circle hooks gained much relevance and attention of researchers owing to their ability to reduce bycatch and deep hooking – especially marine turtles - as evidenced by many research findings (Muoneke and Childress 1994; Hoey, 1996; Grover et al., 2002; Falterman and Graves, 2002; Prince et al., 2002; Skomal et al., 2002; Zimmerman and Bochenek, 2002; Anon, 2004a; Beckwith and Rand, 2005; Kerstetter and Graves, 2006 and Minami, et al. 2006). The main differences between a circle hook and a standard J-hook are their shape and the orientation of the point of the hook. Circle hooks are generally circular in shape and the point is turned inwards, pointing towards the shank of the hook (Fig. 8.1.). The point of a J-hook is generally parallel to the shank of the hook (Fig. 8.1.) (Anon, 2004a).

![J-hook (Round bent hook) vs Circle hook](image)

Fig. 8.1. Comparison of J-hook and Circle hook

The design of a circle hook reduces the likelihood of a hook being caught in the gut cavity or throat if swallowed (deep hooking). If the hook is swallowed, the shape of the hook allows it to slide toward the fish’s jaw as the angler starts reeling, typically hooking itself in the corner of a fish’s mouth. However, some studies have found that the effectiveness of a circle hook for reducing foul-hooking is compromised when the hook point is offset i.e. the point of the hook is not in the same plane as the shank of the hook (Anon, 2004a).
Circle hooks have been used for years by commercial fishers in the U.S. (IPHC, 1998) and are now increasingly being used in a number of marine catch and release fisheries. Some commercial tuna fishing vessels have switched voluntarily to circle hooks (Hoey, 1996; Falterman and Graves, 2002) indicating that circle hooks may increase tuna catch rates. The International Commission for the Conservation of Atlantic Tunas (ICCAT) has been encouraging the use of circle hooks in the Atlantic pelagic longline fisheries (Kerstetter and Graves, 2006). Use of circle hook is mandatory in the U.S. longline fishery (Federal Register 69: 40733, 2004). Primarily it is a regulatory measure taken for the reduction of sea turtle catch rate than the bycatch of pelagic fishes.

Many studies have been conducted to analyse the relationship between release mortality rates and incidence of foul-hooking associated with different hook types (A hook lodged outside of the mouth or anywhere on the exterior of a fish’s body is defined as foul-hooking (Prince et al., 2002). Some of these studies have been focused on a single type of hook or style of fishing only, while others have compared foul-hooking rates among different types of hooks (Muoneke and Childress 1994; Malchoff et al., 2002; Prince et al., 2002; Skomal et al., 2002; Cooke, et al., 2003; Kerstetter and Graves, 2006). Many recent studies have directly compared circle hooks to similar sized J-hooks/round bent hooks (Muoneke and Childress 1994; Grover et al., 2002; Anon, 2004a). These studies have examined a variety of species ranging from billfishes and pelagics to gamefishes, such as red drum and striped bass etc. However no such studies have been conducted in the Indian context involving circle hook and locally available fish species.

Recent international research on the effect of hook type and survival was confined to the recreational fishery where 'catch and release' fishing practice is common (Malchoff et al., 2002; Prince et al., 2002; Skomal et
al., 2002). Beckwith and Rand (2005) investigated the incidence of deep hooking by applying different treatments of terminal tackle during fishing trials. They have studied the probability of deep hooking using three different sizes of circle hooks against a standard 7/0 J-style hook treatment along with different leader and weight configurations.

Prince et al. (2002) compared the performance of circle hook and "J" hook in recreational catch-and-release fisheries for billfish. This study was carried out in response to requests for more information on the use of circle hooks for catching billfish, to promote the live release of these important resources (USDOC, 1999). In this study the hooking and catch percentages between terminal tackles (circle and “J” hooks) used in the trolling/pitch bait recreational fisheries for billfishes and sailfishes were compared. They found that circle hooks used for sailfish had a hooking percentage 1.83 times higher than "J" hooks. More sailfish were hooked in the corner of the mouth using circle hooks (85%), as compared with “J” hooks (27%). On the other hand, 46% sailfish were deep hooked in the throat and stomach with “J” hooks, as compared with circle hooks (2%). Only 1% was foul hooked using circle hooks, while 9% sailfish caught on “J” hooks were foul hooked. In this study it was found that the sailfish caught on “J” hooks are 21 times more likely to suffer hook-related bleeding than those caught on circle hooks. Minami, et al. (2006) studied the effect of circle hooks and feasibility of de-hooking devices to reduce incidental mortality of sea turtles in the Japanese longline fishery.

Many imported branded hooks are popularly used all over India along with the Indian hooks. Popularity of recreational angling using hooks is also on the rise in India. Regardless of all these, there is scarcity of sufficient and dependable data as detailed studies on the fishing performance of different types of fishing hooks in the Indian context are
very limited. Hence, this study has been taken up with the following objectives:

1. To compare the fishing performance of imported and Indian hooks.
2. To compare the fishing performance of circle and 'J' hooks.
3. To compare the difference in hooking locations and severity of wound/injuries between circle hooks and standard J-style round bent hooks.

8.2. Materials and Methods

8.2.1. Study area and period

The experiments were carried out from January 2007 to April 2008 in different water bodies viz., freshwater, brackish water and marine, in Kerala state. Diverse water bodies were selected as different water bodies have different types of fishes which may exhibit varied behaviour towards hook types selected for the study. Experimental fishing was conducted at eight different fishing locations namely, Thevara, Thoppumpady, Fort Cochin, Vypeen, Njarackal, Muvattupuzha in Ernakulam district, Thodupuzha in Idukki district and Padanilam in Kollam district (Fig. 8.2.) with the help of local fishermen in these areas.
8.2.2. Gear configuration

The experimental fishing was carried out with handline fishing gear configuration using the selected hooks as the terminal gear. The gear configuration used was identical with the handline configuration used by the artisanal fishermen in the areas where this study has been carried out (Fig. 8.3.). Polyamide monofilament yarn of 0.8 mm diameter was used as the line. The hook was rigged at one end of a leader line of about 50
cm length as per Beckwith and Rand (2005), which in turn was connected to a leaded swivel to avoid entangling of the line. One end of the swivel was connected to the main line. Only single hook was rigged to the gear.

![Diagram of handline gear configuration](image)

**Fig. 8.3.** Schematic diagram of the handline gear configuration used

Different types of natural dead baits such as oil sardine, chicken waste and dough bait, the popular baits used in the study area were used to bait the hooks. Care has been taken to operate the two types of hooks in identical conditions, using the same type and size of bait to avoid interferences due to difference in bait types, sizes and location. Depth of operation varied from place to place. It was adjusted according to the
water body where the gears were operated and also the targeted fish species. However, both the type of hooks were operated at same area and depth for a given trial.

The baited handlines were cast concurrently in the same location. Each casting was recorded as one attempt. The number of bites, number of successful hooking, location of hooking injury on fish’s body, severity of wound and the type of fish caught were recorded. A fish bite was considered to be a strike that resulted in the line being pulled out of the water, or when a bite is witnessed visually. Injuries due to hooking were assessed by evaluating hooking location, as well as incidence and amount of bleeding observed. Hooked fish was pulled out of the water, the mouth opened, and the hook location and amount and source of bleeding were noted. Locations of hooking were categorized as ‘lip hooked’, ‘deep hooked’ and ‘foul hooked’. The term ‘lip hooked’ is used when the hook is lodged at any part of the lip/jaw portion of the fish. The term ‘deep hooked’ is used to indicate hooks lodged deep inside the mouth, throat or deeper in the alimentary tract. The term ‘foul hooked’ was used to indicate a hook lodged outside of the mouth or anywhere on the exterior of a fish’s body (Anon, 2004a). The severity of wounds was classified based on the bleeding observed in the captured fish after removal of the hook on a four point grade scale from 0 to 3 as per Rapp et al. (2008) (Table 8.1.).

Table 8.1. Classification of bleeding

<table>
<thead>
<tr>
<th>Occurrence of bleeding</th>
<th>Scale/ Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>No bleeding</td>
<td>0</td>
</tr>
<tr>
<td>Light bleeding</td>
<td>1</td>
</tr>
<tr>
<td>Medium bleeding</td>
<td>2</td>
</tr>
<tr>
<td>Severe bleeding</td>
<td>3</td>
</tr>
</tbody>
</table>
Based on this score injury of a fish is categorized into ‘minor’, moderate’ and ‘severe’. A wound was classified as of ‘minor’ severity if there was a score of 0 (no bleeding) or 1 (light bleeding). Likewise, wounds with score 2 (medium bleeding) were categorized as ‘moderate’ and those with score 3 (severe bleeding) were categorized as ‘severe’ (Malchoff et al., 2002).

8.2.3. Comparative fishing performance: Indian Vs imported fishing hooks

Preliminary surveys were conducted at various fishing centers of different water bodies of Kerala to identify the common types of fishing hooks used and their operations. It was found that straight shank J-style hooks (round bent) are the most common type of fishing hook used in Kerala. Hence, two most popular commercial brands of the J-style hooks used by the local fishermen were selected for this study. The selected brand of imported fishing hook was named as ‘Imported’ and the Indian hook was named as ‘Indian’ for this study. The number 9 hooks were selected as they are commonly used by the fishermen in the study area. The physical and mechanical properties of the hook used are given in the Table 8.2.

<table>
<thead>
<tr>
<th></th>
<th>Indian Hook</th>
<th>Imported Hook</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hook number/Size</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Wire Diameter (mm)</td>
<td>1.49</td>
<td>1.45</td>
</tr>
<tr>
<td>Gape (mm)</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>Bite (mm)</td>
<td>13.4</td>
<td>14.2</td>
</tr>
<tr>
<td>Total Length (mm)</td>
<td>33.1</td>
<td>31.8</td>
</tr>
<tr>
<td>Weight (g)</td>
<td>0.791</td>
<td>0.710</td>
</tr>
<tr>
<td>Unbending Load (N)</td>
<td>292.317</td>
<td>213.286</td>
</tr>
</tbody>
</table>
A total of 287 operations were carried out with both the hook types. The results of each operations and corresponding observations were recorded and analyzed. From the data, hooking rate per hundred hooks was calculated which is used to compare the efficiency among the two types of hooks experimented.

8.2.3.1. Calculation of hooking efficiency

In order to allow a preliminary comparison of the hooking efficiencies of the different hooks studied, catch per unit effort (CPUE) and hooking rates were calculated. CPUE was calculated as number of fish caught per 100 hooks (Gibson, 1979; Falterman and Graves, 2002; Zagaglia et al., 2004) as per the following formula:

\[
\text{Catch per unit effort (CPUE)} = \frac{\text{number of fish caught}}{\text{number of hooks deployed}} \times 100
\]

Similarly, the hooking rate was expressed as the ratio of number of successful hooking divided by the number of fish bites (Prince et al., 2002).

\[
\text{Hooking rate} = \frac{\text{number of fish caught}}{\text{number of bites}} \times 100
\]

A strike that resulted in the line being pulled out is considered as a fish bite.

8.2.4. Comparative fishing performance: Circle hooks Vs ‘J’ style hooks

The fishing gear configuration used in this study was as per Fig. 8.3. except for the line diameter and terminal gear (hook) used. PA
monofilament line of 1.0 mm diameter was used as the size of hook used was larger. Circle hooks and J-hooks of comparable size were used as the terminal gear and their fishing performance were evaluated. Circle hook styles and sizes are not consistent between models, and they do not correspond to hook size numbering of traditional “J” hooks. Non-offset circle hook of 9/0 size and straight shank “J” hook of number 6 size were selected. The physical and mechanical properties of the hook used are given in the Table 8.3. Though the commercially-listed sizes of the two hooks used in this study were different, the actual sizes of the hook types were almost identical.

Table 8.3. Properties of hooks used for the fishing performance evaluation of Circle hooks and ‘J’ style hooks

<table>
<thead>
<tr>
<th></th>
<th>Circle hook</th>
<th>‘J’ style hook</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hook number/Size</td>
<td>9/0</td>
<td>6</td>
</tr>
<tr>
<td>Wire Diameter (mm)</td>
<td>2.35</td>
<td>2.06</td>
</tr>
<tr>
<td>Gape (mm)</td>
<td>18.60</td>
<td>17.40</td>
</tr>
<tr>
<td>Bite (mm)</td>
<td>18.10</td>
<td>19.50</td>
</tr>
<tr>
<td>Total Length (mm)</td>
<td>28.30</td>
<td>42.90</td>
</tr>
<tr>
<td>Weight (g)</td>
<td>2.387</td>
<td>1.983</td>
</tr>
<tr>
<td>Unbending Load (N)</td>
<td>814.294</td>
<td>551.863</td>
</tr>
</tbody>
</table>

These hooks were rigged, baited and operated in the traditional way except for the hook setting technique. The traditional hook setting technique of jerking the fishing line was used for “J” hooks while, the circle hooks were operated in a more passive approach, by simply reeling the line tight as the fish swims away with the bait. This modification was done according to the design peculiarity of the circle hooks and their mode of hooking.
8.2.5. Statistical analysis
Statistical analyses were performed using Statistical Package for the Social Sciences (SPSS, version 10) and test results were considered significant at the 5% confidence level (i.e., $P < 0.05$). One-way Analysis of Variance (ANOVA) test was used to assess the relationship between the different types of hook combinations experimented.

8.3. Results and Discussion

8.3.1. Comparative fishing performance: Indian Vs imported fishing hooks

8.3.1.1. Hooking efficiency
Out of the 287 operations conducted, the imported brand was able to land 37 fishes out of 261 bites, while the Indian brand managed to land 33 fishes out of 266 bites. Different species of fishes caught in the experimental fishing operations are listed in Table 8.4.
Table 8.4. Fishes caught during experimental hook and line operations

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Local Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cat fish</td>
<td>Arius Spp.</td>
<td>Aetta</td>
</tr>
<tr>
<td>2</td>
<td>Indian mottled eel</td>
<td>Anguilla bengalensis</td>
<td>Malanjil/Mananjil/Malan/Aarell</td>
</tr>
<tr>
<td>3</td>
<td>Snapper</td>
<td>Lutjanus Spp.</td>
<td>Chembally</td>
</tr>
<tr>
<td>4</td>
<td>Tilapia</td>
<td>Oreochromis mossambicus</td>
<td>Tilapia/Tilopia/Thilopia/Silopia</td>
</tr>
<tr>
<td>5</td>
<td>Pearl spot</td>
<td>Etroplus suratensis</td>
<td>Karimeen</td>
</tr>
<tr>
<td>6</td>
<td>Freshwater garfish</td>
<td>Xenentodon cancila</td>
<td>Kolan</td>
</tr>
<tr>
<td>7</td>
<td>Banded Snakehead</td>
<td>Channa striatus</td>
<td>Bral/Varal/Varaal</td>
</tr>
<tr>
<td>8</td>
<td>Fresh water cat fish</td>
<td>Wallago attu</td>
<td>Attu valah/Valah</td>
</tr>
<tr>
<td>9</td>
<td>Walking Catfish</td>
<td>Clarias batrachus</td>
<td>Mushi/Muzhi</td>
</tr>
</tbody>
</table>

The imported hook had a CPUE of 13.31 (No. fishes caught/100 hooks) while the Indian hook had a CPUE of 11.87. The hooking rates were 14.18% and 12.41% for the imported and Indian hooks respectively (Fig. 8.4.). There was no significant difference in hooking rate of the two types of hooks (P > 0.05) indicating that Indian hooks are at par with imported hooks in terms of fishing performance.

This result is in agreement with a similar study conducted by George et al. (1991) in which both Indian and imported hooks were found comparable in fishing efficiencies. Their study showed that the imported hooks had a hooking rate of 6.63% while the indigenous hooks had a slightly higher hooking rate of 6.83%. Though both the type of hooks were comparable in terms of hooking efficiency, the Indian hooks were more fragile and liable to deformation under load when compared to the imported hooks.
In a fishery resource survey of the Indian Exclusive Economic Zone (EEZ) around Andaman and Nicobar Islands during August 1989 to December 2002, the overall hooking rate recorded for tuna hook was 1.85% (John et al., 2005). Sulochanan et al. (1989) reported that the catch index for all tuna and that separately for yellow-fin tuna was 1.54% and 1.43% respectively. Anderson and Waheed (1990) have reported that the hooking rate for the shark longline was about five per 100 hooks (5%) and that for tuna longline was only one per 100 hooks (1%). In this study, they used standard round bent hooks and tuna hooks respectively for the shark longline and tuna longline. George et al. (1991) have compared the hooking rate of sharks for the 4/0 round bent indigenous hooks along with imported Mustad hooks and found that both the hooks are comparable in hooking rate. These experiments were conducted with shark longline operated from M. V. Saraswathy of CIFE, Bombay in and around Angrea Bank and off southwest Bombay. The hooking rate of the present study is almost double that of the hooking rates reported in some other studies.
Varghese et al. (1997) have reported a hooking rate of 6.83% for indigenous unbranded hooks and 6.63% for imported Mustad hook used as control in their fishing experiment targeting sharks and smaller varieties of fishes.

8.3.1. 2. Hooking location

The hooking location remained generally the same for the two types of hooks used. Out of the 37 fishes caught with the imported hook, 18 fishes (48.65%) had the hook lodged in the lip (Fig. 8.5.). Similarly, about 37.84% fishes were deep hooked (Fig. 8.6.) and about 13.51% were foul hooked. In most of the deep hooked fishes, the hook had injured the esophagus and the de-hooking process was difficult due to the deep location of the hook. A graphic representation of percentage occurrence of different hooking locations is given in Fig. 8.7.

Fig. 8.5. Lip hooked fish (Hook lodged on the lower jaw)
In the case of Indian hook, the percentage occurrence of lip hooked, deep hooked and foul hooked fish were respectively 42.42%, 39.39% and 18.18% (Fig. 8.7.). There was no significant difference between the two types of hooks experimented in terms of hooking location. In the study by Skomal et al. (2002) fifty-two percent of the bluefin tuna caught on
straight ("J") hook were hooked in the jaw, and thirty four percent were hooked in the pharynx or esophagus.

The hooking location is an important factor determining the survival of the fish during and after release, in the case of catch-and-release fishery. Deeply hooked fish of any species generally suffer higher mortality than shallow-hooked fish (Muoneke and Childress 1994). Zimmerman and Bochenek (2002) have found that hooking of fish in the esophagus/gill area contributed to high mortality after release. Many studies indicated that fish caught by hooks are generally hooked either in the mouth, particularly in the jaw or in the alimentary tract if the hooks are swallowed (Lokkeborg et al., 1989; Huse and Fernö, 1990; Lokkeborg and Bjordal, 1992). Many factors such as the size and type of the hook, type of fish caught, fishing method/setup used etc. can influence the location of hooking. An overall low incidence of deep hooking has been reported by Beckwith and Rand (2005) in instances where the hook and line is operated from shore in tidal inlets and marine systems with more active currents. Fishes caught in the mouth or jaw would suffer less physical damage and presumably have higher rates of survival after release (Kerstetter and Graves, 2006).

A unique experiment by Willis and Millar, (2001) by adding a wire to a hook on the side opposite to the tip (bite), with an angle of around 45 degrees from the shank, made the hook wider without affecting the biting end. This has reduced gut hooking in fishes, and it may also help to reduce deep hooking in sea turtles (Bayliff, 2007). According to Beckwith and Rand (2005), the probability of deep hooking of 7/0 J-style hooks with a shortened length of leader with a fixed weight was reduced by a factor of two regardless of the style of the hook.
8.3.1. 3. Severity of wound

The severity of the wound caused by the hooking has a decisive role in determining the hooking mortality rates of fishes. In this study, about 10.81% of the total fish caught with the imported fishing hook suffered only minor injuries, while 45.95% suffered moderate injuries and 43.24% had severe injuries due to hooking (Fig. 8.8.). On the other hand, about 9.09% fishes caught on the Indian fishing hooks had minor injuries, 42.42% had moderate injuries and 48.48% suffered severe injuries (Fig. 8.8.). The Indian hook exhibited slightly higher rate of severe injuries and remarkably they had slightly high incidence of deep hooking also. However, the differences were found to be statistically insignificant.

Fig. 8.8. Percentage of severity of wounds – imported and Indian hook

Grover et al. (2002) confirmed that the post release mortality rates depended strongly on hook wound location. Injuries to internal organs as
a result of deep hooking or hooking in locations other than the mouth substantially increase release mortality (Anon, 2004a). Lukacovic and Uphoff (2002) reported that catch-and-release mortality is influenced by hook location, bait and hook type, angler experience, and season, based on their studies on striped bass (*Morone saxatilis*). Lukacovic (1999) reported a mortality rate of 9.1% for fish caught on conventional hooks while it was only 0.8% for the fish caught on circles hooks. Grover *et al.* (2002) observed that among different fishes caught on hooks kept under observation, only gut-hooked fish died within 24 hours of holding, while in lower-jaw hooked fish mortality was observed only after 24 hours of holding.

On the other hand, in a catch-and-release fishing mortality study, comparing circle hooks to similar sized J-hooks conducted by Florida Fish and Wildlife Conservation Commission on Tarpon fish, regardless of the hook type, post-release mortality was equal among different fishing methods and appeared to be unrelated to hook type (Anon, 2004a). Similar observations were also made by Malchoff *et al.* (2002) that hook type was not a significant factor in the prediction of mortality.

### 8.3.2. Comparative fishing performance: Circle hooks Vs ‘J’ style hooks

#### 8.3.2.1. Hooking efficiency

A total of 178 fishing operations were carried out with both circle and conventional J-hooks. The J-hooks caught 14 fishes out of a total of 90 fish bites experienced during the experimental fishing. The hooking rate was very low in the case of circle hooks with only 9 fishes caught out of 104 bites experienced.
The catch per 100 hooks (CPUE) of the circle hooks was 5.06 whereas the J-hook registered a CPUE of 7.87. Similarly, the circle hooks showed a hooking rate of 8.65% while the J-hook had a higher hooking rate of 15.56% (Fig. 8.9.). The circle hooks showed significantly lower ($P < 0.05$) hooking rate compared to the “J” hooks.

The results are found to be in disagreement with many other studies conducted elsewhere. In the comparative study of circle hooks against “J” hooks by Falterman and Graves (2002) the circle hooks had a higher CPUE of 5.05 in contrast to 2.28 observed in the case of "J" hooks. The CPUE was approximately 2.5 times higher with circle hooks as compared with J-hooks when only the targeted tuna was taken into consideration (3.33 tuna/100 hooks). Prince et al. (2002) reported that circle hooks used on sailfish had hooking percentages that were 1.83 times higher compared with "J" hooks. However it may be noted that all these studies were conducted on larges sized tuna/tuna like fishes while the present
study was conducted using handline operated from shore and the targeted fishes were largely small sized in comparison to the large sized pelagic fishes. Moreover, larger hooks require a stronger force to allow the hook to fully penetrate the inside of the mouth cavity (Johannessen, 1983) and the size of the fish striking the fishing hook has an important role in deciding a successful catch.

8.3.2. 2. Hooking location

Unlike in the case of previous experiment, the hooking locations varied widely between the two hook types (Fig. 8.10.). In the case of circle hooks, 77.78% of the fish caught were hooked at the lip and only 22.22% fishes were deep hooked. There was no foul hooked fish with circle hook during the experimental fishing. In a study reported in 2004 on striped bass, foul hooking was significantly less in circle hook than in J-hooks viz., 1.5% vs. 15% (Anon, 2004a).

Fig. 8.10. Percentage occurrence of hooking locations – Circle hook and J-style hook
In contrast, only 50% of fishes caught with the J-hook were lip hooked, 42.86% deep hooked and 7.14% were foul hooked. On statistical analysis it was found that there is significant difference between the two types of hooks in terms of hooking location ($P<0.05$). The percentage occurrence of hooking locations and severity of wounds observed in this study are given in Table 8.5. It was observed that, in most of the fishes caught with the circle hook, the hook found to be lodged at one corner of the mouth opening.

Similar results were reported by Prince et al. (2002). In their study, significantly higher number of sailfish were hooked in the corner of the mouth using circle hooks (85%) compared with “J” hooks (27%). In contrast, significantly more sailfishes were deep hooked in the throat and stomach with “J” hooks (46%) compared to circle hooks (2%). Only one sailfish (1%) was foul hooked using circle hooks, while 11 (9%) sailfish caught on “J” hooks were foul hooked. Sailfish caught on “J” hooks were 21 times more likely to suffer hook-related bleeding than those caught on circle hooks.

The frequency of deep hooking increased when J-hooks were used (Anon, 2004a). Beckwith and Rand (2005) observed that the use of intermediate size (14/0) circle hooks with a short leader and a fixed weight reduced deep hooking incidence by a factor of five. The lowest incidence of deep hooking of 4% was achieved using large or intermediate size circle hooks on short leaders with fixed weights. Deep hooking can be lethal to the fish caught as it causes severe internal injuries and excessive bleeding which can cause physiological stress and reduced growth (Muoneke and Childress, 1994; Cooke et al., 2003; Beckwith and Rand, 2005). This aspect is very important in catch-and-release fisheries.
Faltermann and Graves (2002) observed that circle hooks consistently had a higher frequency of jaw hooking and a lower frequency of gut hooking than J-hooks. In their study, 95% of the fish caught with circle hooks were hooked in the jaw. Skomal et al. (2002) reported that there was a significant association between hook type and hook location. They observed that 94% of the bluefin tuna caught on circle hooks were hooked in the jaw, and 4% were hooked in the pharynx or esophagus. Lukacovic and Uphoff (2002) observed only 10.6% fish deeply hooked on circle hooks in comparison to 45.6% on standard ‘J’ hooks. According to Zimmerman and Bochenek (2002) there was no statistical difference between circle hook and standard hook sets for both hook set location and release condition (P=0.05). However, the instances of gut hooked summer flounder were lower (4.7%) in fish caught with circle hooks than in fish caught with standard J-hooks (15.6%) (Zimmerman and Bochenek, 2002).

8.3.2. 3. Severity of wound

Higher incidence of minor injuries was observed in the case of fish caught with circle hooks (66.67%). About 22.22% of fishes suffered moderate injuries and only 11.11% suffered severe injuries with circle hooks (Fig. 8.11.). In contrast, 21.43% of fish caught using the conventional J-hook had minor injuries, 35.71% had moderate injuries and 42.86% had severe wounds (Fig. 8.11.).
The differences in the severity of wounds observed in the two types of fishing hooks were found to be statistically significant at 95% confidence level ($P < 0.05$).

In the experiments carried out by Zimmerman and Bochenek (2002) more than 80% of the hook sets on circle hooks occurred in the upper and lower jaws (minor injuries). Only 1.6% experienced gill damage, 4.7% experienced gut damage, and 12.5% experienced bleeding. In the case of fish caught with the standard J-style hooks, 77.1% were easily unhooked with no damage, 2.1% had gill damage, 11.5% gut damage, and 9.4% exhibited bleeding.

Owing to the low incidence of severe injuries, circle hooks seem to be a promising type of hook to reduce release mortality (Anon, 2004a) as the...
hooked fish remains alive for long, till they are taken out. These hooks are designed to move to the corner of the fish's mouth and set themselves as the fish swims away. The more a fish swims away from the pull point, the more likely the hook will move to the rear corner of its mouth. (Anon, 2005a). In a study conducted in 1999 Lukacovic reported a release mortality rate of 9.1% for fish caught on conventional hooks whereas it was only 0.8% for the fish caught on circles hooks.

Similarly, significantly lower release mortality in striped bass when using non-offset circle hooks, as opposed to conventional “J” hooks is reported (Lukacovic, 1999, 2001; Lukacovic and Uphoff, 2002). Studies by Prince, et al. (2002) on billfish, Skomal, et al. (2002) on bluefin tuna, Falterman and Graves (2002) on yellowfin tuna, and Trumble, et al. (2002) on Pacific halibut also showed significant decrease in release mortality while using circle hooks. Cooke, et al. (2003) reported that circle hooks can be used for reducing release mortality in rock bass. While on bluegill and pumpkinseed there was no significant benefit by using them.

The practice of catch-and-release is becoming increasingly common in recreational fishery in recent days (Beckwith and Rand, 2005). Researchers are working on different methods to reduce the negative impacts of recreational fishing. Efforts have been underway to design terminal tackle that reduce severity of injury of hooked fish. Though there are many studies on the injury points and mortality rates of fishes by the use of circle hooks and other hooks in other parts of the world, such studies are lacking in the Indian context. In view of the angling related tourism development promoted in many states of India (Thomas et al., 2007) similar studies are very essential. At many parts of the world circle hooks have been promoted as a promising gear to meet the responsible fishing requirement. Unfortunately, there have been few studies that have investigated the efficacy of circle hooks in the Indian conditions. Hence
this study is thought to act as a triggering point for further detailed studies on circle hooks in the Indian context.

8.4. Conclusions

Based on the studies carried out, it can be concluded that the Indian hooks are comparable in terms of fishing efficiency, hooking location and severity of wound to imported hooks. There is no significant difference in hooking pattern of the two types of hooks ($P>0.05$). In the fishing performance study involving circle hook and ‘J’ hooks, the circle hooks showed significantly lower ($P<0.05$) hooking rate compared to the ‘J’ hooks. Also, there is a significant difference between circle hooks and ‘J’ hooks in terms of hooking location ($P<0.05$). More fishes were lip hooked with minor injuries in circle hooks against that of ‘J’ hooks. This finding is in agreement with the related studies carried out on circle hooks in other parts of the world. This feature of the circle hook makes it an ideal hook type that can be used for ‘catch-and-release’ (recreational) fisheries.