Development of pelagic longline gear for the exploitation of Needle fishes along the coast of Ramanathapuram district, Tamil Nadu

Thesis submitted in part fulfillment of the requirements for the Degree of **Master of Fisheries Science in Fisheries Engineering and Technology** *to the Tamil Nadu Fisheries University, Nagapattinam*

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CERTIFICATE

This is to certify that the thesis entitled, **"Development of pelagic longline gear for the exploitation of Needlefishes along the coast of Ramanathapuram district, Tamil Nadu"** submitted in part fulfillment of the requirements for the degree of **Master of Fisheries Science** in Fisheries Engineering and Technology to the Tamil Nadu Fisheries University, Nagapattinam is a record of bonafide research work carried out by **Mr. M. ILAIYARAJA, MFT 14040** under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or similar titles or prizes and that part of thesis has been published in peer reviewed journal(s) and copy / copies appended.

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Dedicated to My lovable

Mother ,brothers ,

My guide and fisherfolk

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(M. ILAIYARAJA)

Abstract

ABSTRACT

Title	**:**	Development of pelagic longline gear for the exploitation of Needlefishes along the coast of Ramanathapuram district, Tamil Nadu
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The present study dealt with evolving a selective long line gear alternate to pelagic drift gillnets to capture Needlefishes. A survey undertaken in Ramanathapuram district on the drift gillnet fishery revealed many common features in the net designs. Six species of Needle fishes such as *Ablennes hians, Tylosurus crocodiles, T. choram, T. agus, Strongylura strongylura* and *S. leiura* were found to constitute fishery in the gillnets with the domination either by *A. hians* or by *T. crocodiles.* The point of the 'J' hook bearing hook No.10 was bent manually to right by 5° to make 'Reversed hook' and the same was bent to left by 5° to make 'Kirbed' hook. Four units of experimental longlines each with 350 hooks of different design such as (i) 'J' hook (ii) Reversed hook (iii) Kribed hook and (iv) Bait holder hook were designed and fabricated. Fishing trials were conducted from March 2016 to June 2016 in the coastal waters of Mundal fishing village of Ramanathapuram district.

Four species of Needle fishes viz. *A. hians, T. crocodiles, T. choram* and *S. strongylura* were found *to* form fishery in the experimental longlines.

Domination of *T. crocodilus* followed by *A. hians* invariably in the catches of all the four experimental long lines revealed the fact that *T. crocodilus* is more vulnerable than to *A. hians* longlines. Significant difference could be observed between the catch rates of different species (P<0.0) besides catch rates of different hooks studied (P<0.05). Among the gears tested, the long line unit with 'Reverse hooks' showed highest overall hooking rate of 7.4 % indicating more vulnerability of Needle fishes to hooks with its point bent towards right (i.e. Reversed hook). Though sporadic occurrences of sucker fish (*Echenis naucrates*) and the cat fish (Arius *thalassinus*) could be observed during experimental fishing trials, the bycatch was insignificant compared to that of gill nets.

Among the fishes caught *T. crocodiles* showed 4 % increase in fish catch when the catch was expressed in terms weight particularly in gears with 'J' and 'Reversed' hook due its higher weight in relation to length compared to other species. Despite its low hooking rate, Kribed hook ranked first in terms of hooking ability at correct position (i.e at Jaw) (51%). The 'J' hook was found to have highest percentage of hooking at throat (33%) and gut (21%) which are not proper hooking locations as for as longlining is concerned. The 'Bait holder' hook followed by 'Reversed hook' was found to be more efficient in bait holding efficiency.

S*ardinella fimbriata* could serve as in ideal bait for capture of Needle fishes by long lines owing to its low cost and easy availability. The study revealed that operation of newly evolved longline gear with 2,800 'Reverse hooks' would to be a better alternative to pelagic drift gillnets of Ramanathapuram district for the capture of Needle fishes owing to higher selectivity for Needle fishes and lesser cost of construction and operation.

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Introduction

INTRODUCTION

Longlining has been practiced throughout the world since ancient times. This method has been evolved over time from small artisanal fishing craft to modern mechanised longlining all over the world. Mathai (2002) reported that about 12% of the global fish catch is contributed by catches from longlines. The International Code of Conduct for Responsible Fisheries (CCRF) developed by the Food and Agriculture Organization (FAO) in consultation with member countries of the United Nations (UN) points out the need for concentrating more on the artisanal and small-scale fishing methods, which use selective and energy efficient fishing gears with hook and lines for the sustainable exploitation of aquatic resources, protection of aquatic environment besides energy conservation (FAO, 1995).

The term “longline” denotes the fishing line which is usually very long and runs to even few kilo meters. In broad terms, a longline consists of a main line where in many branch lines with hook are attached. Hooks are baited to attract different targeted fish species. Longlining has been proved to be an appropriate fishing method for catching large, high quality and high value carnivorous fishes. It has evolved as popular method throughout the world since 1980s. Being a low energy - demanding fishing method in terms of fuel, a transition from trawl to longline is on progress as long lining is not vulnerable to the increase in fuel price (Bjordal, 1983).

Line fishing is considered as eco-friendly and fuel efficient fishing method to catch scattered and sparsely distributed fishes. This fishing technique makes it possible to fish in the rocky and uneven bottom, where other fishing methods are inefficient. The catches obtained by the line fishing are found to be of superior quality. Longline operation is based on fish attraction by means of bait, which serves as the source of smell and taste stimuli to lure the fish to the gear and stimulate it to ingest the baited hook (Bjordal and Lokkeborg, 1996).

Longline is classified under passive fishing gear as the gear as there is stationary and the fishes encounter the gear as the result of their movements towards its owing to the attraction by bait. Longline fishing is a highly selective, economically viable and a low energy fishing method well suited for the exploitation of sparingly distributed fishes (Lokkeborg and Bjordal, 1992). Longlining consumes only 0.15 to 0.25 kg of fuel to catch one kilogram of fish in contrast to 0.8 kg required for trawling (Gulbrandsen, 1998).

Longline gear consists of several basic components such as main line, branch line, hook and bait etc. However the hook and bait are the two factors which directly decide the catch efficiency and selectivity. Invariably all the parts of longline are adaptable to specific species by bringing out changes in material of construction and dimensions of different parts.

Longline fishing in India has a long history in the marine fisheries of the country. In the early eighties tunas and large pelagic fishes were targeted by traditional fishermen using hand lines from traditional crafts along the coast of Tamil Nadu. Further in the mid-eighties, chartered commercial longline LOP (Letter of Permit) vessel were introduced for catching oceanic tunas which witnessed phenomenal growth in terms of catch over the years (Kurien, 1995). Longline is one of the most effective low energy fishing gears operated in the Indian coastal waters to capture seer fishes, tunas, perches, carangids, marine cat fishes and elasmobranches especially from rocky, coral or uneven fishing grounds where trawling is not possible.

Longline fishing is one of the most important commercial fishing methods in the mechanized fishing sector of Kerala, Tamil Nadu and Andhra Pradesh (Vipin et al., 2014). West Bengal ranks first in longline fishing (55%) followed by Tamil Nadu (33%), Odisha (10%) and Kerala (2%) (Anon, 2010). In Tamil Nadu, 10.6% of seer fish, 1.2% of tuna and 4.2% of elasmobranches have been reported to be contributed by through hook and line fishing (Anon, 2011). Beside these major fish groups Needlefishes are also found to be vulnerable to hook and lines and are reported in catches of trolling lines with surface or near-surface lures and in longlines. Their contribution to the catches of drift gill nets have also been reported in Indian waters (Anon, 2011). However, reports on their catch contribution in longlines are scantly.

Needlefish with the vernacular name 'Mural*'* has wide distribution in the tropical and sub tropical regions of the world. The family Belonidae is represented by 10 genera and about 32 species. However only 8 species represented by 4 genera occur in the western Indian Ocean. In Indian water four genera such as (Ablennes, Platybelone, Strongylura and Tylosurus) are represented by 9 species such as *Ablennes hians, Platybelone argalus platyura, Platybelone argalus platura, Strongylura incise, Strongylura leiura, Strongylura strongylura, Tylosurus acus melanotus, Tylosurus crocodiles crocodiles* and *Tylosurus choram* (FAO,1983).

Ramanathapuram is a notable maritime district of Tamilnadu and occupy third position in marine fish production. It has a coast line of 237 km and has about 22% of the state fisher population contributing more than 20% of the fish landing of the state. The Marine fisheries profile of the Ramanathapuram district is given in Table 1.

Vallams and FRB Boat are generally used to capture Needle fish along Tamil Nadu coast. In big meshed drift gillnets Needle fishes from by catch. The fishery is contributed by species such as *Ablennes hians, Strongylura leiura, S.strongylura, Platybelone argalus platyura, Tylosurus acus, T.crocodiles, T. choram*. As on date there is no exclusive fishing gear to fish this fish group. The present study aims at evolving a new type of pelagic longline specific to capture Needle fishes. Evolving selective Needle fish longline is attempted by changing the hook design besides making the gear pelagic adjusting buoyant force. The study was under taken with the following objectives,

- To analyses the present status of fishing gears used for the capture of Needle fishes along the coast of Ramanathapuram district
- To design and fabricate an effective pelagic longline fishing gear with different hook combinations for the exploitation of Needle fishes
- To standardize the design features of longline fishing gear for the exploitation Needle fishes through experimental fishing.

Table 1. Marine fisheries profile of the Ramanathapuram district (Johnson et al., 2013).

Sl. No	**Particulars**	**Values**
1.	Total coastline length	237 km
2.	No of fishing villages	178
3.	Total fisher population	1,93,413
4.	No. of fishermen families	41,048
5.	No. of Mechanized boats	4,920
6.	No. of Motorized boats	372
7.	No. of Non-Motorized boats	1926

Review of literature

2. REVIEW OF LITERATURE

Various attempts have been made both in India and rest of the world to use longline as a commercial important fishing gear.

2.1. Research on longline fishing in the World

The most widespread form of pelagic longline gear appears to have been originally developed by the Japanese. Nakamura et al (1999) studied the optical characteristic of nylon monofilament and flurocarbon monofilament in the hook line Tuna Fishing. Hazin et al. (2000) made preliminary analysis on the feasibility of transferring new longline technology to small artisanal vessels off north eastern Brazil.

Woll et al. (2001) studied the catch rate and bait selectivity of longline fishery of Greenland halibut at East Greenland. Furthermore, they reported that the traditionally used hook namely EZ 12/0, was found to show lower catch rate in the circle hooks. Willis and Millar (2001) reported that modified hooks could reduce both the catch rate and gut-hooking rate of undersized snapper in the commercial longline fishery of New Zealand. American type of longlining has been popular among the fishermen mainly due to its ability to be set in deeper waters and its easier handling, compared to the traditional longline (Tserpes and Peristeraki, 2004). Hazin et al. (2005) studied that effect of light-sticks and electralume attractors on surface-longline catches of sward fish in the southwest equatorial Atlantic. Technological developments such as polyamide monofilament line and modern fishing vessel construction have resulted the evolution and expansion of this gear types as the primary worldwide method of commercially harvesting large pelagic fishes (Watson and Kerstetter, 2006).

Further (Watson and Kerstetter, 2006) they reported that modified the pelagic longline fishing gear to avoid or to reduce the mortality of bycatch species. Among various factors, design, material, types of hooks and baits were reported to be the crucial factors that decide the success of the longline fishing besides factors such as population density of species, behaviour and soaking time.

Swimmer et al. (2011) found that longline with modified circular hook could improve the selectivity of hook and reduce incidental capture of non-target species. Coelho et al (2012) observed the effects of hooks and baits on targeted and non-targeted bycatch fishes in pelagic longline fishery of equatorial Atlantic Ocean. Campbell and Young (2012) studied the behaviour of tuna and billfishes longline gears operated at different depths and time in the eastern Australian fishery.

2.1.1. Design of longline

Longline gear consists of several basic components such as main line, branch line, swivel, sekeyama, snood wire and hook. The parts of longline are adaptable to target specific species through bringing out changes in materials, lengths, and other development strategies (Gil and Palmason, 2005). Ward (2008) reported that the catchability of commercially valuable bigeye tuna increased substantially because of the stronger and less visible line materials, longer duration and extension of the depth of operation. Cambie et al. (2013) suggested that increasing of the depth (from surface (10-100 m) to mid- water

(100-500 m)) and soaking time (from 11 h to 25-30 h) of operation resulted in increased catch rates of sword fish.

2.1.1.1. Main line

Nakamura (1951) has reported the usage of hemp as main line in the Japanese longline gear and Subsequent main line made of hemp with subsequent improvements resulted in the usage of materials including cotton and braided nylon. One of the important technological improvements in the main line part of the gear was developed that of heavy-gauge single strand polyamide monofilament in the late 1970s. Bjordal and Løkkeborg (1996) reported the usage of natural fibres in earlier days and however, synthetic materials are widely used because of their higher breaking strength and higher resistance to deterioration. During the last 30 years, monofilament main lines have been used in almost all longline fishing gear since the catching performance of monofilament lines has been shown to be superior to that of multifilament lines.

2.1.1.2. Branch lines

Branch lines are connected to the main line at appropriate intervals. Branch lines affect the catch rate with regards to their material, length, thickness and the attachment. Bjordal and Lokkeborg (1996) reported that the lower visibility of the monofilament branch lines results in higher catch rates. Monofilament branch line gives 10-29% higher catch rates for cod and haddock as compared to multifilament branch line. Further, thinner branch line was found to give better catch rates than thick ones. Attachment of swivel could improve the catch rate by about 15%, depending on the type of fishery, the target fish and the weather conditions. Further, Bjordal and Lokkeborg (1996) reported that when the length of branch line is increased, the catch rate usually increases, because longer branch lines tend to tangle easily, when their length is limited to less than half the hook spacing.

2.1.1.3. Hook design

Hook can be considered as the heart of a longline system. It consists of parts such as eye, shank, bend, point, gap and throat. Selection of the right type and size of hook is very critical for successful hook and line fishing operations. A good understanding of different hook pattern, their usage and the numbering system is important t for selection of hook for a particular fish. Choice of hook depends on several factors such as the quality of the hook, the size of the targeted fish, its preferred bait, feeding habit, the fishing area and the size of the line used. The pelagic longlines are currently used to commercially harvest the tuna and tuna like fishes worldwide. Longline is considered as a size selective gear (Bjordal, 1981).

Ralston (1982) obtained in significance effect on selectivity while modifying the hook size. However, Bjordal (1983) reported mean increase by 17% in the cod catch when wide gap hooks were used instead of 'J' hook. However, superiority of this hook design decreased with increase in fish density. The Double hook gave a total increase of 58% in a mixed species fishery (tusk, ling, haddock), and showed a size selective effect compared to the normal single hook. Peeling and Rodgers (1985) reported that the traditional J-shaped hook performed better the circle hook for catching halibut (*Hippoglossus hippoglossus)*. However, for cod and tusk, there was no significant difference in the number of fish caught by the two types of hooks. Skeide et al. (1986) tested a new hook design through comparative long line fishing trials.

Huse and Ferno (1990) observed the size of the hook as an important factor that affect the hook selectivity. Hooks are the most important part in the gear and it varies in shape and size. Most commonly used hooks are ‘J’ hook, Japanese tuna hook and circle hook. ‘J’ hooks are not advisable because of the injury caused by deep hooking during the capture which reduces the post-release survival rate of the non targeted animals like dolphins and turtles (Huse and Ferno, 1990). Polacheck (1991) suggested that the number of hooks in a longline can be used as the best measure of effort for stock assessment. Lokkeborg and Bjordal (1992) made extensive review on species and size selectivity in long line fishing. The review included species and size selectivity by hook. The mechanical properties of the hook and the biological aspects of the target fish affect catching process (Lokkeberg and Bjordal, 1992).

Japanese tuna hook has an intermediate style between ‘J’ hook and circle hook (Whitelaw and Baron, 1995). Engas et al. (1996) studied comparative fishing of for cod and haddock with commercial trawl and longline at two different stock levels. On analysing haddock cod ratio the fishing trials showed higher ratio in longline than in trawl. Erzini et al. (1998) observed no evidence of differences in the selectivity of different sizes of hooks for white seabreams and red sea breams. However, general decrease in catch rate with the increase in hook size was also observed. Wall et al. (2001) reported that the CPUE for the circular hook was 36% higher making an overall significant difference in CPUE between EZ hook and circle hooks.

2.1.1.3.1 Hook selectivity

Stergiou and Erzini (2002) compared the selectivity of longlines and monofilament gillnets for five different species. While the length frequencies from gillnet catch showed a clear size selection, there was high overlapping of length frequency of catch obtained from longline. Yokota et al. (2006) reported that circle hooks had little impact on catch of the rates blue shark and its size compositions. The overall hooking rate is reported to be very high in ‘J’ hooks (Kerstetter and Graves, 2006). Yokota et al. (2006) studied that comparison of circle and tuna hooks shark catch in pelagic longline fishery their result indicated that compared to J- hooks catch rates significantly increased by 8-9% when circle hooks were used with squid bait. Tuna longlining has been undergoing many changes in the shape and structure for improving the fishing efficiency and to reduce bycatch (Ward and Hindmarsh, 2007).

Prince et al. (2007) studied that performance of two types of non-offset circle hooks (traditional and non-traditional) and a similar size “J” hook commonly used in the south Florida. Ward et al. (2009) documented that small circle hook have several beneficial effects on commercial longline fishery. Czervinski et al. (2009) studied that hooks selectivity for blackspot seabream (*Pagellus bogaraveo)* in the strait of Gibraltar. Amarasinghe et al. (2011) studied that quantify hook selectivity of two carangid species in sufficient numbers of *Caranx ignobilis* per 100 hooks were caught by hook sizes 8-11 mm. *C. gymnostethus* caught by hook sizes 10-13 mm used in hook and line fishery of Sri Lanka.

2.1.1.3.2 Shape of hook

Shimizu and Miura (2000) studied that size selectivity of cod hooks used on the longline for Walleye Pollock *Theragra chalcogramma* in Hokkaido. Prince et al. (2002) conducted comparative study on the performance of circle hook and “J” hook in the recreational catch-and-release fisheries for billfishes. The hooking percentages of circle hook used on billfish was 1.83% which was higher than that of “J” hook. The amount of “offset” may be important for the evaluation of hooking location. Promjinda et al. (2007) studied the efficiency of the Circle Hook in Comparison with J-Hook in longline Fishery. They observed, the catch rates in overall CPUE (individual/1000 hooks) of circle hook was lower than that of J-hook (4.77 versus 7.48). Cambie et al. (2012) suggested introduction of circle hooks in the swordfish longline fishery in order to reduce the by-catch of loggerhead turtles.

2.1.1.3.3 Numbering and size

There is no uniform, universally accepted system of hook numbering for designating different hooks. Hook sizes are mostly arrived at by different proprietary standards. The gape, shank length etc. of standard hook sizes of different companies often differ. Visual familiarity with various hook patterns is the only workable gauge for the fisherman. Hooks are usually designated by numbers, the value either decreasing with increase in the size of hooks or vice versa. Andreev (1963) described three types of numbering systems used to denote the size of fishing hooks. These are Marine numbering, River numbering and the third based on the Gap size of hooks. These systems are interrelated and also related with the weight of the hooks. According to him, the physical parameters of the hook were independent of the shape and nature of the hook. Baranov (1976) states that most of the hooks come under the two categories of numbering namely sea and river numbering system and the size is characterised by the weight of 1000 hooks. Baranov (1976) explained about two numbering systems in practice for hooks viz., Sea numbering system and River numbering system. He also describes a system in which the size of a hook is expressed in terms of weight (kg) of 1000 hooks. Hooks come in short, regular or long shank versions. Beverly (2006) reported that most common sizes of J hooks used for swordfish are 8/0 and 9/0. A 9/0 J hook measures 15 cm from the eye to the point so it is not easy to compare numbers for J hooks with other hook designs. A9/0 J hook, in fact, is similar in size to a 16/0 circle hook.

2.1.1.3.4. Hooking Efficiency

The hooking efficiency is influenced by the size and species of the target fish. 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). Kartha et al. (1973) studied the effectiveness of round bend hooks (Mustad) of different denominations using different baits. Hooking rate is generally expressed as the number of fish caught per hundred hooks (Gibson, 1979). George et al. (1991) experimented 4/0 round bend indigenous hooks along with imported Mustad hooks. They have compared the hooking rate of sharks for the two types of hooks and found that both are comparable. Prince et al. (2002) has compared the performance of circle hook and "J" hooks in recreational catch-and-release fisheries for billfish. They have reported that circle hooks used on sailfish had hooking percentages that were 1.83 times higher compared with "J" hooks.

2.1.1.3.5. Hooking location

Fish caught by longlines are generally hooked in the mouth, particularly in the jaw or in the alimentary tract if the hook is swallowed (Huse and Ferno, 1990). Skomal et al. (2002) studied that compared the performance of circle hooks to strait hooks, relative to hooking location, damage, and catching success in natural bait fisheries in bluefin tuna in Atlantic coast. The major hooking locations were identified as lip, jaw, throat and gut in addition to foul hooking. Hooking anywhere outside the body is referred as foul hooking. In order to compare hooking locations by different hook types the hooking locations they were categorised as ‘Preferred and Non-preferred hooking locations’. Lip and jaw were considered as the preferred hooking locations, while throat, gut and foul hooking were considered as ‘Non-preferred hooking locations’. Fish hooked in sensitive areas such as stomach, esophagus, and gills suffered greater mortality than those hooked in non-critical areas. Many swordfish and *mahi mahi* were hooked in the throat, but these were fewer then the number hooked through the lip or jaw Ward et al. (2009). Kumar et al. (2013) reported that twenty seven percent of the fish caught in Japanese hooks were hooked in the jaw and no lip-hooking was observed.

2.1.1.4. Baits and it their Importance

The principle of line fishing is to lure fish to bite the bait that has been secured on a hook. Therefore, use of appropriate bait is one of the most important factors that determine the efficiency of line fishing. Johnstone and Hawkins (1981) reported mussel and squid meat as the effective baits for the capture of cod. Bjordal and Lokkeborg (1996) reported as the bait fundamentally important factor during the capture process. Though hook was probability found to be species specific, larger baits were found to catch larger fish.

Godo et al. (1997) studied the bait defence behaviour of wolf fish and its impact on longline catch rates. Bach et al. (2000) reported that catch rate depends to a large extent on bait type, quality and size. Broadhurst and Hazin (2001) tested various artificial baits and found that artificial baits tend to have lower catch rates than natural bait.

Wall et al. (2001) analysed the catch rate and hook selectivity of Greenland halibut in the longline fishery of East Greenland using squid and fish (grenadier) as baits. The results showed that the CUPE of Greenland halibut was 25% higher for grenadier bait than the squid bait. Gil and Palmason (2005) studied the longline fisheries with special emphasis on bait size (small, medium and big) in Korea waters. The results indicated that the use of medium sized baits resulted in higher catch rate of (haddock, little cod, cat fish and whiting) in terms of number and weight than with small and big sized baits.

2.1.1.4.1. Bait size

Johannessen (1983) reported the bait size is regarded as the most important factor affecting the size of fish caught by longlines and using baits of increased size could therefore be a solution to avoid the capture of under sized fishes. However, increasing the bait size increases the amount of bait required and raises the bait cost for the fishermen (Lokkeborg and Bjordal, 1992). Therefore effort to reduce the proportion of smaller fishes in longline catches by increasing bait size lead to increase in total bait consumption. An alternative solution to this problem has been sought by using an inedible body on the longline hooks (Lokkeborg and Bjordal, 1995).

Bjordal and Lokkeborg (1996) studied size-selective effects due to the size of the bait by increasing the bait size with the help of an inedible body on longline hooks. The study that baited hooks with a plastic body attached to the shank caught lower proportion of under-sized haddock (less than 44 cm) than hook with bait only. Fish feeding in a habitat with a mixture of natural prey of different sizes will often show a preference for a certain prey size (Bjordal and Lokkeborg, 1996). Many investigations into the effects of hook and bait type have been carried out, but in regard to bait size, little is known (Bach et al. 2000).

Bait size has been found to be an important factor that affected the size of the fish to be caught and its catch rate as smaller fishes prefers smaller prey because of their smaller mouth size and less ability to bite and handle the prey (Gil and Palmason, 2005). Therefore, the potential for improved size selection in longlining is probably greatest for species caught in shallow water or using pelagic longlines.

2.1.1.4.2. Shape, texture and physical strength of Bait

Once the fish has encountered the baited hook, the shape of the bait may also affect the likelihood of attack and ingestion of the bait. Some species use texture to elicit ingestion, thereby sorting prey items from less palatable or inedible objects (Atema 1980). Lokkeborg (1990) studied that behaviour of cod (*Gadus morhua*) towards the two bait shapes and reported bait shape is not an important characteristic feature for the development of artificial bait. However, the reported that bait shape may be an important factor for bait selection when fish live in less diverse communities. In one of the field observations study, Lokkeborg and Bjordal (1992) observed that cut pieces of mackerel as baits could attract 5% of the cod captured and concluded cut pieces of mackerel as a novel prey. In addition to its chemical and visual properties, the efficiency of longline bait is determined by its physical strength and ability to remain on the hook throughout the soak period (Bjordal and Lokkeborg, 1996).

2.1.1.5. Soak time

The duration which the longline is in the water between setting and hauling is known as the ‘Soak time’. There are a number of risks associated with extended soak times which lead to loss of bait damage through predation by sea lice and sharks, increased chance of gear loss through shark interactions, and decreased survival of fish caught in the longline. As a general rule, fishers should aim to reduce the soak time to the shortest term practical. The effect of soak time varies considerably between species. The relationship between soak time and catching efficiency of longlines is influenced by attractant of bait release rate (Lokkeborg, 1994).

Studies on the effects of setting time, setting direction and soak time on catch rates can generate further information on the longline catching process (Lokkeborg and Pina,1997). Soaking during dusk periods have strong positive effects on the catch rates of many species. In particular, the catch rates of most of the sharks and bill fish species increase with soak time (Ward et al., 2004). Carruthers et al. (2011) reported that minimum soaking time need to be decreased based on the mortality rates in sword fish longline fishery.

2.1.1.6. Bait Loss

The bait starts losing its catching ability from the time of dropping into the water. Three major reasons involved: Through under water observation from a responsible for bait loss may be (1) how the bait is hooked (2) how the longline is put into the sea and (3) slow eating by crabs, starfishes and other creatures. Skud (1978) reported upon experiments conducted by the International Pacific Halibut Commission (IPHC) and related soak time with bait loss. They attributed the bait loss to feeding both by target species and non-targeted predators. High (1980) studied the bait loss from halibut longline gear submersible.

2. 2. Research on longline fishing in Indian waters

Only few attempts have been made to carry out research related to line fishing in Indian waters. Balasubramanyan (1964) made analysis on the different types of natural baits used in longline fishing in Indian seas. Despande et al. (1970) studied the hooking rate and efficiency of 'Mustad' hook 4/0 in the longlining. Kartha et al. (1973) studied selective action of three types of baits and four hook sizes in capturing elasmobranchs of Veraval coast using bottom-drift longlines. Hameed (1982) studied vertical long lines for sharks with different hooks and baits at different depths in Cochin waters.

Rajan (1982) studied shark long lines by mechanised boats in Thoothoor village of Kanyakumari coast of Tamilnadu. The line fishery at Thoothukudi has been reported to exist throughout the year and mostly carried out by traditional non-mechanised and mechanised crafts Menon et al. (1989). Further, they reported that each fishing unit was found to have 1000 to 1300 'Mustad' No.7 hooks. Lesser sardines and chank meat were found to be used as baits. Sukumaran et al. (1989) reported successful deep sea sharks at Malpe and Kolam. Further, he was reported that the season started in September and extended up to May with peak the peak during November and December.

Menon et al. (1989) reported that longline fishermen from Thoothukudi migrated towards Pamban and Mandapam region during the months from December to March to operate longlines from in board engine fitted country craft in the reef area of Dhanushkodi in fishing grounds with the depth ranging from 18 to 25m. About 1000 to 3000 hooks of Musted No.7 hook were used per unit and *sardinella* spp were used as bait. Mathew and Venugopal (1990) studied the hook and line fishery for Kalava at Cochin, and reported that hook nos. 7 and 8 were most popularly used for capturing Kalava in Cochin waters. Joel and

Ebenezer (1993) studied sharks long-lining practiced at Thoothoor village of Kanyakumari coast.

Kasim et al. (1996) reported full beaks, *Ablennes hians* as one of the dominant species in the gillnets operated along the Thoothukudi in the Gulf of Mannar. Varghese et al. (1997) studied physical and chemical properties of indigenous as well as imported hooks and analysed the comparative fishing performance. Kasim et al. (1997) reported three species belonids such as *Tylosurus crocodilus crocodiles, Strongylura leiura, and Ablennes hain* from Gulf of Mannar.

Thomas et al. (2007) reviewed the terminology of hooks, their properties, classification, numbering, testing procedure and hooking efficiency. Durai et al. (2011) reported high fishing pressure on juveniles of *Lethrinids elongates* in the commercial longline fishery along Thoothukudi coast and hooks no. 10, 11 and 8 were found to be ideal for the commercial exploitation of *L. elongates*. Immanuel and Rao (2012) studied social status of hook and line fishermen of Pedajalaripeta village in Visakhapatnam district of Andhra Pradesh.

Sundaramoorthy et al. (2013) studied the longline selectivity of *Epinephelus malabaricus* along Thoothukudi coast and concluded that hook nos. 5 and 6 were found ideal for the commercial exploitation of main species. Kumar et al. (2013) studied the effect of hook design on the longline fish catch in Lakshadweep Sea and reported the beneficial effect of circular hooks in reducing by-catch. The hook no. 2-8 was found commonly used for shark and tuna longlining. Sardine, mackerel and flying fishes were found to be the most commonly used baits in the longline gear of in Lakshadweep waters. Vipin et al.

(2014) studied longline fishing for high value species off Southern India with special reference to structural and operational changes.

Needle fishes belong to the family Belonidae and form commercial fishery in the longlines among to their predatory habit 9 number of species have been reported in Indian waters (FAO,1983) and among the 3 numbers have been reported to have distribution in Gulf of Mannar (Kasim et al. 1997). Though this species can be caught using pelagic longline gear among to their predatory habit, attempts have been not yet made to capture this important fishery resources using longline. At present needle fishes are captured using set gill nets and drift gill nets. Under these circumstances, the study was carried out with the following objectives.

Materials and methods

3. MATERIALS AND METHODS

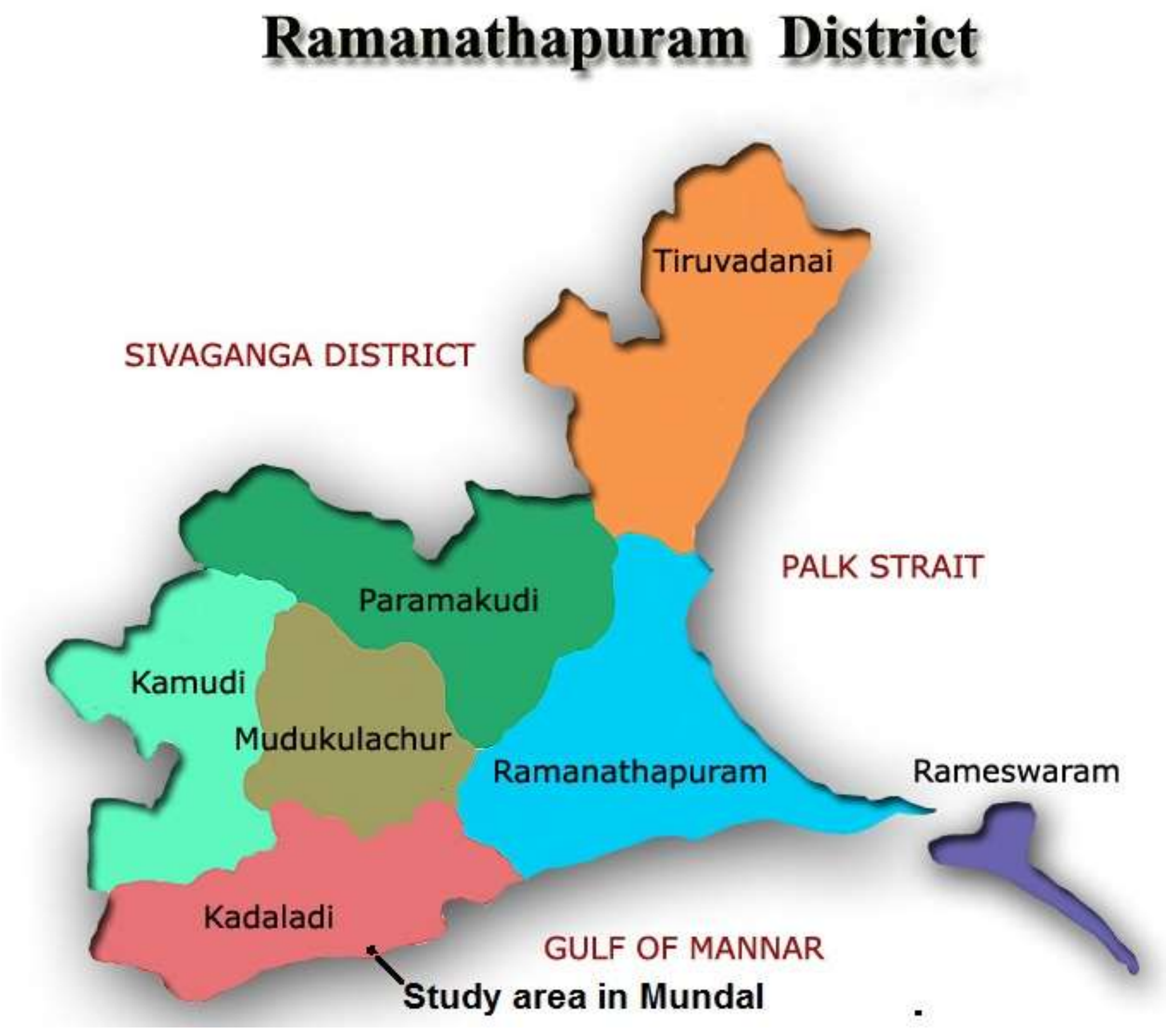
3.1. Description of the study area

The present study was carried out for four months from March 2016 to June 2016 in coastal waters of Mundal fishing village (Lat.09°06’7”N; Long.78°35’6”E) of Ramanathapuram district, which is located near Nallathanni island. The location of Mundal village and the actual fishing ground are illustrated Fig.1. Fishing is one of the major occupations for the people of the Mundal village. There are about 480 active fishermen inhabiting this village having fishing as their primary occupation. A survey was undertaken covering four fishing villages of Ramanathapuram coast such as Mundal, Velayuthapuram, Pamban and Mandapam. Technical and operational details of pelagic drift gill nets operated in the above village were collected. The survey included collection of specifications of crafts such Overall Length (OAL), beam, and depth. Under gear, survey fifteen parameters pertaining to gill net such as type of material, twine thickness, color, length, hung depth, mesh size, meshes in length, meshes in depth, hanging coefficient, number of units operated, material of head rope, head rope thickness, float material, float weight, and float interval in the gear. The design of gillnets were drawn as per the FAO guidelines given by Nedelec (1975). Operational details of the gill nets were studied involving parameters such as number of fishing trips per month, depth of operation, nature of operation, distance to fishing ground, fishing season, CPUE, dominant species and bycatch.

3.2. Design details of experimental longlines

Four experimental longlines namely (i) ‘J’ hook longline, (ii) Reversed hook longline, (iii) Kribed hook longline and (iv) Bait holder hook were designed and fabricated. The experimental gears differed with respect hook design and

Figure 1. Description of the study area



resembled with each other in other design parameters. Each gear unit consisted of 350 hooks. The design features of the experimental longline gears are shown in Table 2 to 5 and Figure 2 to 5.

3.2.1. Main line

The main lines of the all four experimental longline gears were made with Polyamide monofilament twine with the diameter of 1.0mm. Dropper loops were formed on the main line to facilitate the attachment branch lines. The loops were made with the help of knots using nylon thread in such a way that the branch lines do not slip over the main line. (Plate 1a)

3.2.2. Branch line

All the branch lines had identical length of 1 m and were connected to the dropper loops of main line with the help of clips (Plate 1b). Each of the experimental long line unit consisted of 350 branch lines.

3.2.3. Swivel

Each branch line had a swivel attached at a distance of 10m from the main line so as to avoid twisting of branch lines. Swivel each weighing 5 g with the commercial trade number 8 and were used in the experimental long line (Plate 1c).

3.2.4. Snap clip

Snap clip served as an important component of branch line. It facilitated the connection of branch line with the main line through Dropper loop. Snap clips were also used to attach the floats in the float line. (Plate 1c)

3.2.5. Experimental hooks

The hook consisted of an eye, shank, bent, point, gap and throat. One of the most important measurements of a hook is gap, which is the distance between the point and shank. Invariably all the experimental hooks had a

Figure 2. Experimental longline with 'J' hook

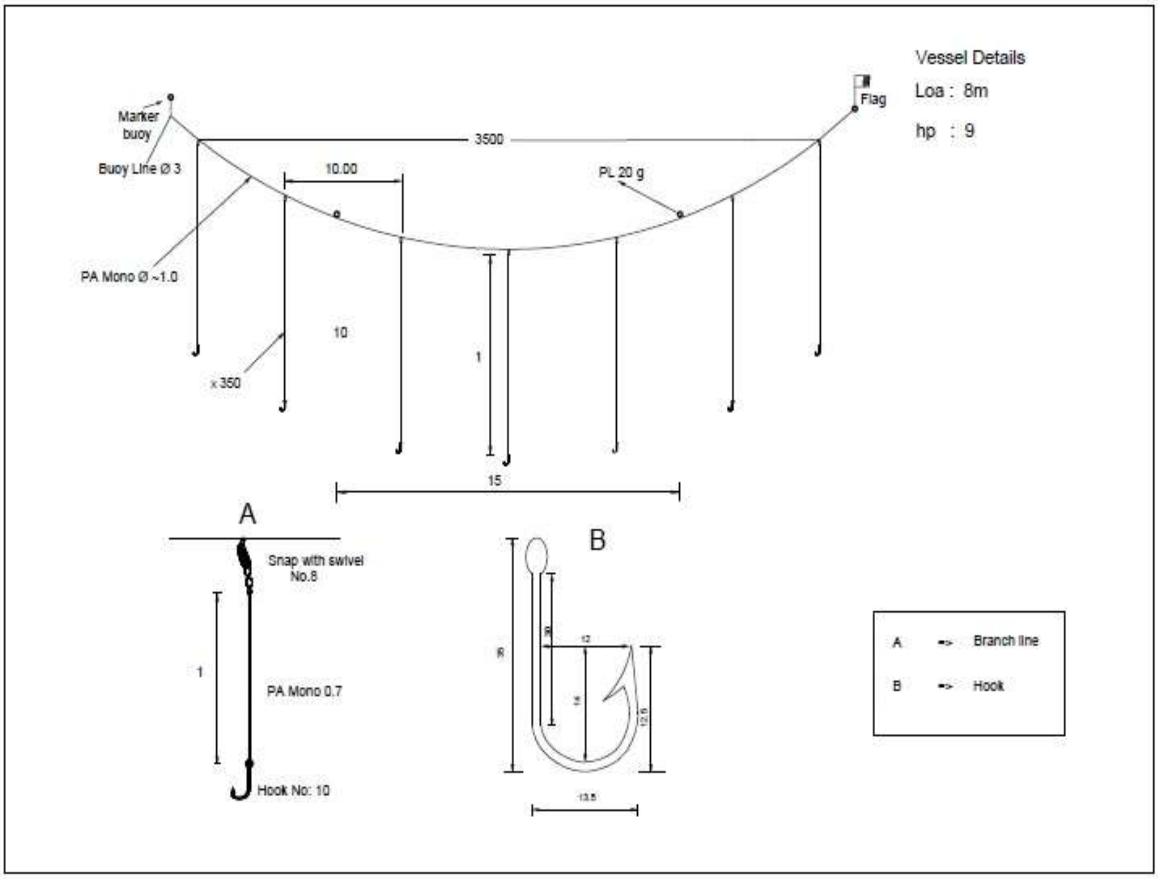


Figure 3. Experimental longline with 'Reversed' hook

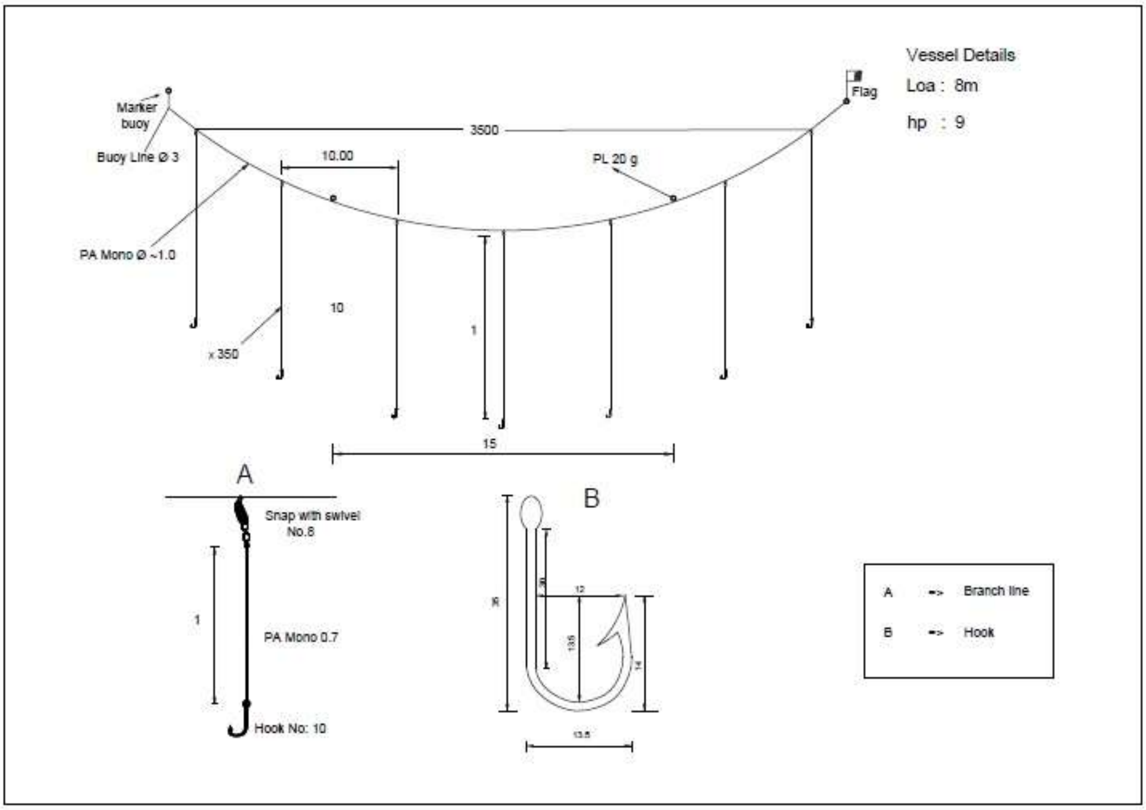


Figure 4. Experimental longline with 'Kribed' hook

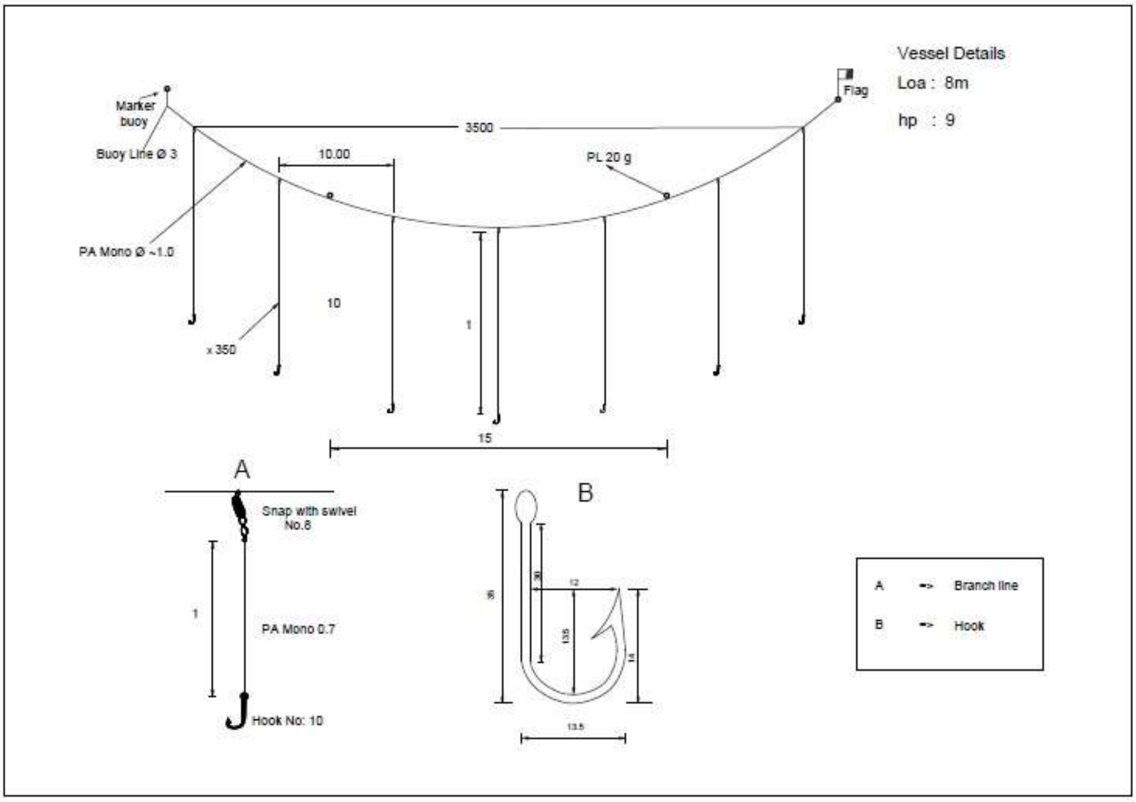
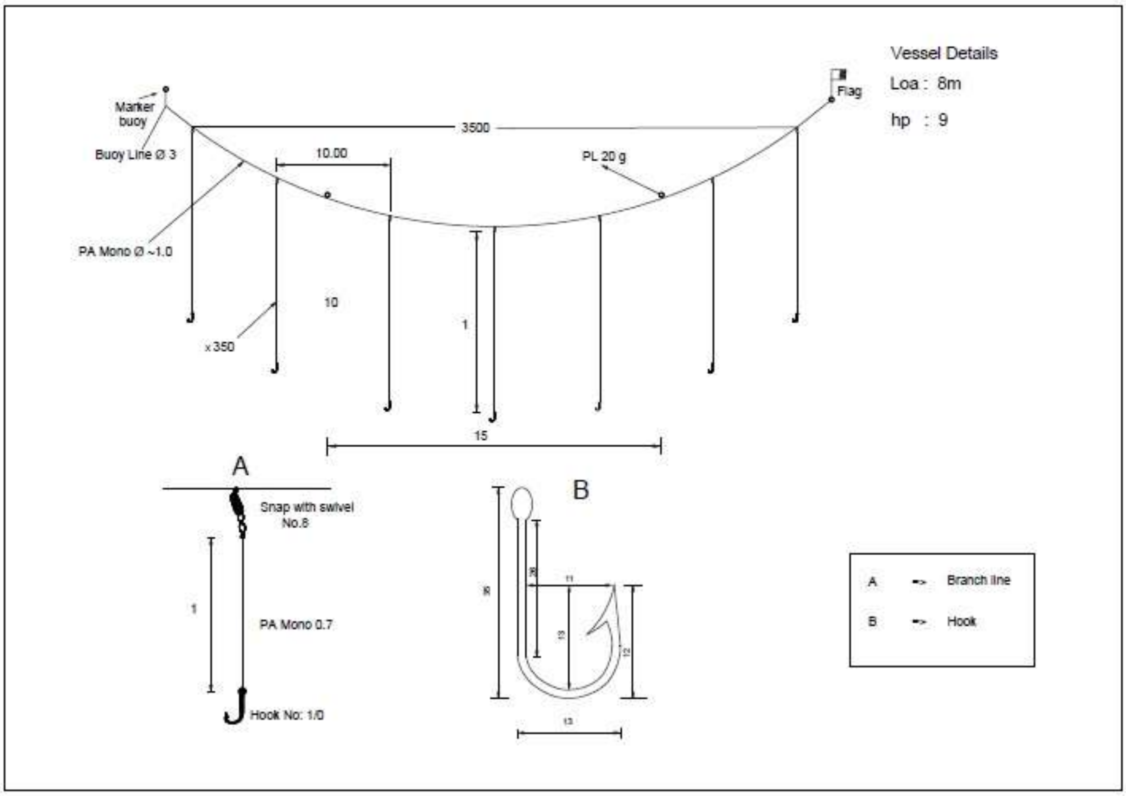


Figure 5. Experimental longline with 'Bait holder' hook



common gap distance of 12 mm to enable comparison. In the present study four difference types of hooks viz (i) 'J' hook (ii) Reversed hook (iii) Kribed hook and (iv) Bait holder hook were used (Fig.6)

3.2.5.1. 'J' Hooks

The 'J' type hooks used in the present study belongs to hook No. 10 manufactured by Viaadi pvt. Ltd., New Delhi, India. This type of hook had a total length of 35 mm and each weighed 5 g. It is made up of high carbon steel. The design parameters of 'J' hook such as gape, shank length, hook thickness, etc., are given in Table 6 and Fig. 7.

3.2.5.2. Reversed hooks

The point of the 'J' type hook bearing hook No.10 was bent offset to the right, manually by bending the front portion of the point away from the plane of the shank right at 5° angle and was named as 'Reversed hook'. The Reversed hook weighed 5 g each and had a total length of 35 mm. The details of design parameters of Reversed hook are given in Table 6 and Fig. 8.

3.2.5.3. Kribed hook

The term "Kribed" is a latin ward meaning bent towards left. The point of the 'J' type hook bearing hook No.10 was turned offset to the left manually by bending the front portion of the point away from the plane of the shank at 5° angle and was named as 'Kribed hook'. "Kribed hooks" weighed 5g each and had a total length of 35 mm. The details of design parameters of 'Kribed hook' are given in Table 6 Fig. 9.

3.2.5.4. Bait holder hook

"Bait holder hooks" manufactured by a Korean company, "Youvella", were used as third set of experimental hook. Bait holder hook has the point bent away from the plane of the shank in right side as in ‘Reversed’ hook. However, apart from right side bent, this hook has two beaks over the shank to improve the bait holding capacity against water currents as well as untargeted animals. This hook weighed 5 g each and had a total length of 33 mm. The details of design parameters of ‘Bait holder’ hook are given in Table 6 and Fig. 10.

3.2.6. Gear holding tub

An inter spacing of 10 m was maintained between branch lines in all of the four experimental longlines. Each experimental gear consisted of 350 branch lines and two HDPE floats with the dia meter of 200 mm master floats. The master floats were attached one at each end of the long line unit which served as marker floats. Each of the experimental gears was stored in a plastic tub with in the dimension of 55, 35 and 30 cm. The hooks were kept arranged serially along the margin of the tub as shown in the Plate 1e.

3.2.7. Floats

A total of 230 floats were used on the main line of experimental gear each at an interval of 15 m. Polyethylene twines of 20 cm long with 1 mm dia were used as float lines.

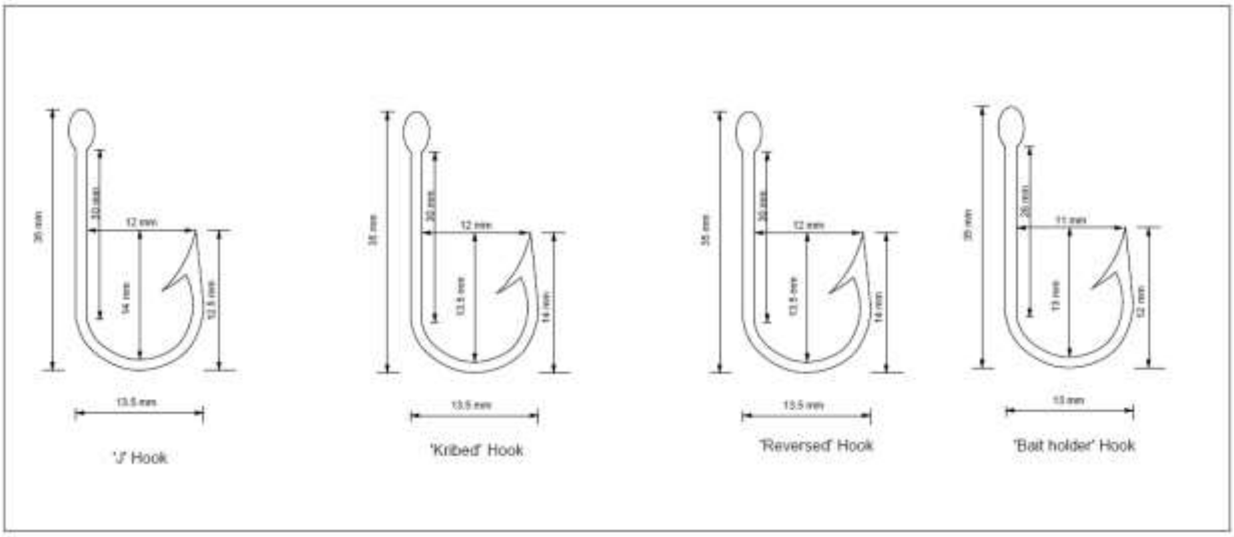
3.2.8. Flag poles

Flag poles were attached with the Master floats (which also served as marker floats) to facilitate easy identification.

3.2.9. Sea anchor

A parachute type sea anchor was fabricated using a white nylon cloth, Polypropylene bridles, iron sinkers and two HDPE floats. Four HDPE rope bridles each with the length 7.0 m long and 3 mm dia. were fastened at four corners of the sea anchor. The inter distance between the four bridles was kept as 1 m so

Figure 6. Measurement of experimental longline hooks used in the study



as to have square shaped mouth. The total length of the anchor was 1.4 m. Two iron sinkers each weighting 200 g were attached to the lower side of the mouth. The rear end of the sea anchor had a square shaped mouth each side having the length of 40 cm. To facilitate floating of the sea anchor, two HDPE floats of 70 mm dia. were attached on the upper side of the mouth. The sea anchor was connected with the longline gear through an extended bridle line of 7 m long. The sea anchor was attached in with the longline gear such a way that it facilitated drifting of line unidirectionaly along the direction of its attachment with the longline and avoided the encircling of main line due to wind (Plate 1f)

3.2.10. Bait

The ‘Fringescale sardine’ (*Sardinella fimbriata*) with the vernacular name “Choodai” was used as bait in the experimental longlines. The bait was procured from fish landing centre at a price of Rs.100/kg. A total 4 kg of bait was used per experimental gear. Fishing operations were carried out at a rate of four per month. (Plate 2a)

3.2.11. Operational procedure for experimental long lines

Fishing operations were mostly carried out during the early morning with the soaking duration of 2 hrs for all the experimental longline units. Shooting and hauling of the lines took approximately 1to 1.30 hrs respectively. Soon after hauling the total numbers of fish caught in each of the longline units were segregated species wise and counted. Their total length was taken nearest to millimeter and weight was taken using a top pan balance on board the fishing boat. The experimental longline were operated in a coastal fishing ground of Mundal (Lat: 08˚59’6 N’’; Long: 078˚ 08’ 992”E, Lat: 08˚50’8N’’; Long: 078˚ 43’ 187E”, Lat: 09˚5.5’5N’’; Long: 078˚ 39’ 1”E, Lat: 08˚45’9’’N; Long: 078˚ 38’ 5”E,

Plate 1. Experimental longline materials and accessories

	
1 a. Main line	**1 b.** Branch line
	
1 c. Swivel with snap slip	**1 d.** Extreme left - ‘J’; 2^{nd} - ‘Reversed’; 3^{rd} - ‘Kribed’; Extreme right - ‘Bait holder’
	
1 e. Hook holding dub	**1 f.** Sea Anchor

Plate 2. Bait used in experimental longline

2 a. Cutting of *Sardinella fibriata* to use as bait and Lat: 09˚00’3’’N; Long: 078˚ 34’ 3”E, with pelagic substratum having the depth of 18 to 35 m.

3.3. Analyses of hooking rate of the experimental longlines with different hooks

The catching efficiencies of the different experimental longlines were expressed as hooking rate. The overall hooking rate was estimated for each species in different experimental gear using the following formula.

$$\text{Over all Hooking rate (\%)} = \frac{\text{Number of fishes caught in the particular type of hook}}{\text{Total nuber of particular type of hook operated during}}\ x\ 100$$

Catch composition was expressed both in terms of number as well in terms of weight for different experimental gears.

3.4. Analysis of hooking pattern

The major hooking location were observed for all the species caught gear wise immediately after hauling of the long line while removing the fish from hooks for different experimental long line units. Fishes were noted for the hooking locations whether they were caught in jaw, throat and gut. The fishes caught through anywhere outside the body was referred as ‘foul hooking’.

3.5. Analyses of bait holding efficiency

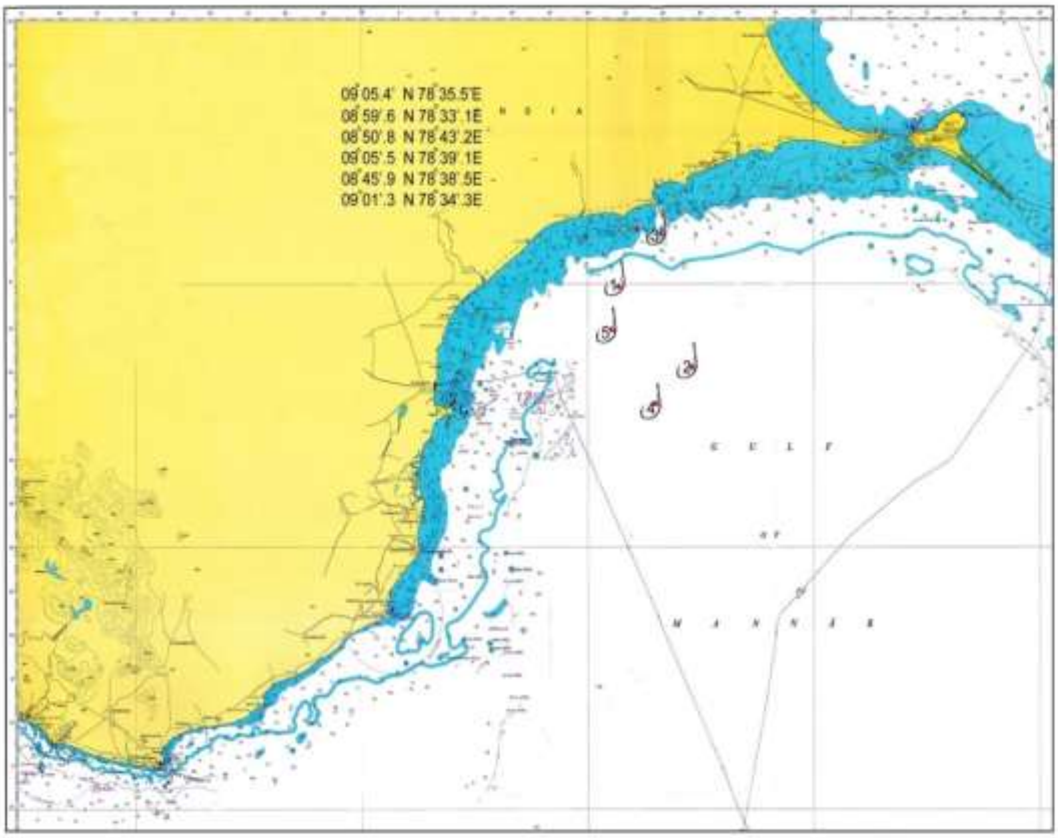
Bait holding efficiencies of different types of hooks was worked the using the following formulas

$$\text{Bait holding efficiencies} = \frac{\text{Number of hook with bait after soaking}}{\text{Total nuber hook} - \text{Number of hook that catch fishes}}\ x\ 100$$

3.6. Analyses of variance

The impact of design and the season on the hooking rates of different types of longline units were worked out using two way Analyses of variance.

Figure 7. Fishing grounds of experimental longlines and pelagic drift gillnets of Mundal for Needle fishes



Experimental longline fishing stations   Commercial pelagic drift gillnet fishing grounds

3.7. Calculation of hooking efficiency

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. Catch per unit effort (CPUE) = (number of fish caught/number of hooks deployed) x 100. Similarly, the hooking rate was expressed as the ratio of number of successful hooking divided by the number of fish bites. Hooking rate = (number of fish caught/number of bites) x 100

Table 2. Description of the experimental long line gear with ‘J’ hooks

Sl. No	Particulars	Type/Number /Length
1.	Material used for main line	PA (monofilament)
2.	Diameter of main line	1.0 mm
3.	Length of main line	3,500 m
4.	Material used for branch line	PA (monofilament)
5.	Diameter of branch line	0.7 mm
6.	No. of branch lines	350
7.	Length of branch line	1m
8.	Inter difference between branch lines	10m
9.	Hook number	10
10.	Hook type	“J”
11.	Swivel with snap number	No: 8
12.	Type of line float	Thermocoal
13.	Material of marker float	HDPE
14.	Number of line floats	230 Nos.
15.	Height of float line	20 cm
16.	Inter distance between floats	15 m
17.	Number of baskets per gear	1
18.	Number of hooks per basket	350
19.	Depth of operation	1-1.5 m
20.	Bait used	*Sardinella fimbriata* (Sardine)

Table 3. Description of the experimental long line gear with 'Reversed' hooks

Sl. No.	Particulars	Type/Number /Length
1.	Material used for main line	PA (monofilament)
2.	Diameter of main line	1.0 mm
3.	Length of main line	3,500 m
4.	Material used for branch line	PA (monofilament)
5.	Diameter of branch line	0.7 mm
6.	No. of branch lines	350
7.	Length of branch line	1m
8.	Inter difference between branch lines	10m
9.	Hook number	10
10.	Hook type	"Reversed"
11.	Swivel with snap number	No: 8
12.	Type of line float	Thermocoal
13.	Material of marker float	HDPE
14.	Number of line floats	230 Nos.
15.	Height of float line	20cm
16.	Inter distance between floats	15m
17.	Number of baskets per gear	1
18.	Number of hooks per basket	350
19.	Depth of operation	Pelagic region
20.	Bait used	*Sardinella fimbriata* (Sardine)

Table 4. Description of experimental long line gear with 'Kribed' hooks

Sl.No	Particulars	Type/Number /Length
1.	Material used for main line	PA (monofilament)
2.	Diameter of main line	1.0 mm
3.	Length of main line	3,500 m
4.	Material used for branch line	PA (monofilament)
5.	Diameter of branch line	0.7 mm
6.	No. of branch lines	350
7.	Length of branch line	1m
8.	Inter difference between branch lines	10m
9.	Hook number	10
10.	Hook type	"Kribed"
11.	Swivel with snap number	No: 8
12.	Type of line float	Thermocoal
13.	Material of marker float	HDPE
14.	Number of line floats	230 Nos.
15.	Height of float line	20cm
16.	Inter distance between floats	15m
17.	Number of baskets per gear	1
18.	Number of hooks per basket	350
19.	Depth of operation	Pelagic region
20.	Bait used	*Sardinella fimbriata* (Sardine)

Table 5. Description of experimental long line gear with ‘Bait holder hooks

Sl.No	Particulars	Type/Number /Length
1.	Material used for main line	PA (monofilament)
2.	Diameter of main line	1.0 mm
3.	Length of main line	3,500 m
4.	Material used for branch line	PA (monofilament)
5.	Diameter of branch line	0.7 mm
6.	No. of branch lines	350
7.	Length of branch line	1m
8.	Inter difference between branch lines	10m
9.	Hook number	10
10.	Hook type	“Bait holder”
11.	Swivel with snap number	No: 8
12.	Type of line float	Thermocoal
13.	Material of marker float	HDPE
14.	Number of line floats	230 Nos.
15.	Height of float line	20cm
16.	Inter distance between floats	15m
17.	Number of baskets per gear	1
18.	Number of hooks per basket	350
19.	Depth of operation	Pelagic region
20.	Bait used	*Sardinella fimbriata* (Sardine)

Table 6. Anatomy of experimental long line hooks

Sl.no	Hook dimensions	Hook type			
		'J' type	**Kribed**	**Reversed**	**Bait holder Hook**
1	Length (mm)	35mm	35mm	35mm	33mm
2	Breath (mm)	13.5mm	13.5mm	13.5mm	13mm
3	Weight of hook (g)	500mg	500mg	500mg	500mg
4	Gape (mm)	12mm	12mm	12mm	11mm
5	Bite (mm)	14mm	13.5mm	13.5mm	13mm
6	Shank length (mm)	30mm	30mm	30mm	26mm
7	Front length	12.5mm	14mm	14mm	12mm
8	Hooks number	10	10	10	1/0
9	Hook thickness	1.2mm	1.2mm	1.2mm	1.2mm
10	Bending angle (degree)	_	5-7	5-7	5
11	Material ©	HCS	HCS	HCS	HCS
12	Brand name	Viaadi	Viaadi	Viaadi	Youvella

© HCS – High Carbon Steel

Results

4. RESULTS

The results of the present investigation are presented under two headings such as (i) ‘Pelagic drift gillnets survey of Ramanathapuram district’ where in Needle fishes are caught and (ii) ‘Performance of experimental pelagic longlines gears’ tested for capturing Needle fishes.

4.1. Pelagic drift gillnets fishery of Ramanathapuram district

Pelagic drift gillnets were found operated to capture Needle fishes along with other commercially important fishes. The details on the types of fishing crafts used for the operation of pelagic gill nets and design feature of gillnets operated in four selected fishing villages such as Mundal, Velayuthapuram Mandapam and Pamban are discussed.

4.1.1. Details on the fishing crafts engaged in gillnets

Both FRP boats and Vallam were found used for operating surface drift gill nets. Relatively smaller fishing crafts with a OAL ranging from 4 to 8 meters were found engaged for surface gill netting (Table 7). Among the four fishing villages, Vallam were alone found to be used in Pamban.

4.1.2. Design features of pelagic drift gill nets used for the capture of Needle fishes

Design details of different types of pelagic gill nets operated form four different fishing villages of Ramanathapuram coast are given in Table 8. The design parameters of gill nets showed notable difference with respect to different villages studied. Regarding material of construction, webbing made up of both multi-filament nylon twine with the specification of 23 tex x2x3 and mono-filament nylon twine with the thickness of 1.0mm were found to be used in the gillnets of Velayuthapuram. However in all other three villages, only webbings fabricated with multi-filament nylon twine with the specification of 23tex x 2x3 were found to be used. The gillnets were coloured either green or yellow and out of the two colours, green was found to be mostly preferred colour. Head Rope length (HRL) of gill nets ranged from 40.5 to 104.0 m. While hung depth of gill nets used in Velayuthapuram was 1.1 m, it was 2.7 m in other villages.

The mesh size of the gillnets ranged from 30 -52 mm. In the gill nets used in Mundal, the numbers of meshes in length were 4,000. However, the number of meshes along length of gillnets used in Pamban and Mandapam were 3,750. Regarding Velayuthapuram, the gillnets were relatively shorter with only 2,700 meshes along the length. Further, the number of meshes in depth were 55 for the gillnets used in Mandapam and Pamban. This was 60 for gillnets of Mundal and 52 for that of Velayuthapuram. Fishermen were found to use 8 to 14 gillnets per trip. While the fishermen of Velayuthapuram used Polypropylene rope with thickness of 2.5 mm as head rope, fishermen of other fishing villages used Nylon rope with the thickness of 2 mm thickness as head rope. During the study period, floats made up of plastic and cork were found used in Velayuthapuram, where as plastic floats were alone used in other three fishing villages. The weight of the individual plastic was float about 20 g with the extra buoyancy of 30 g in sea water. The inter distance between two floats was 0.45 m in the gillnets of Velayuthapuram and it was 1.3 m for the gillnets of other three fishing villages (Table 8 and Fig. 7-10)

4.1.3. Fishing operations

Fishermen belonging to the four fishing villages surveyed under the present study were found to operate the gill nets with the number of fishing days ranging from 16 to 25 per month (Table 9). Further, fishermen of the Mandapam were found to restrict their number of fishing days not exceeding 20 per month

Figure 8. Drift pelagic gillnet of Mundal

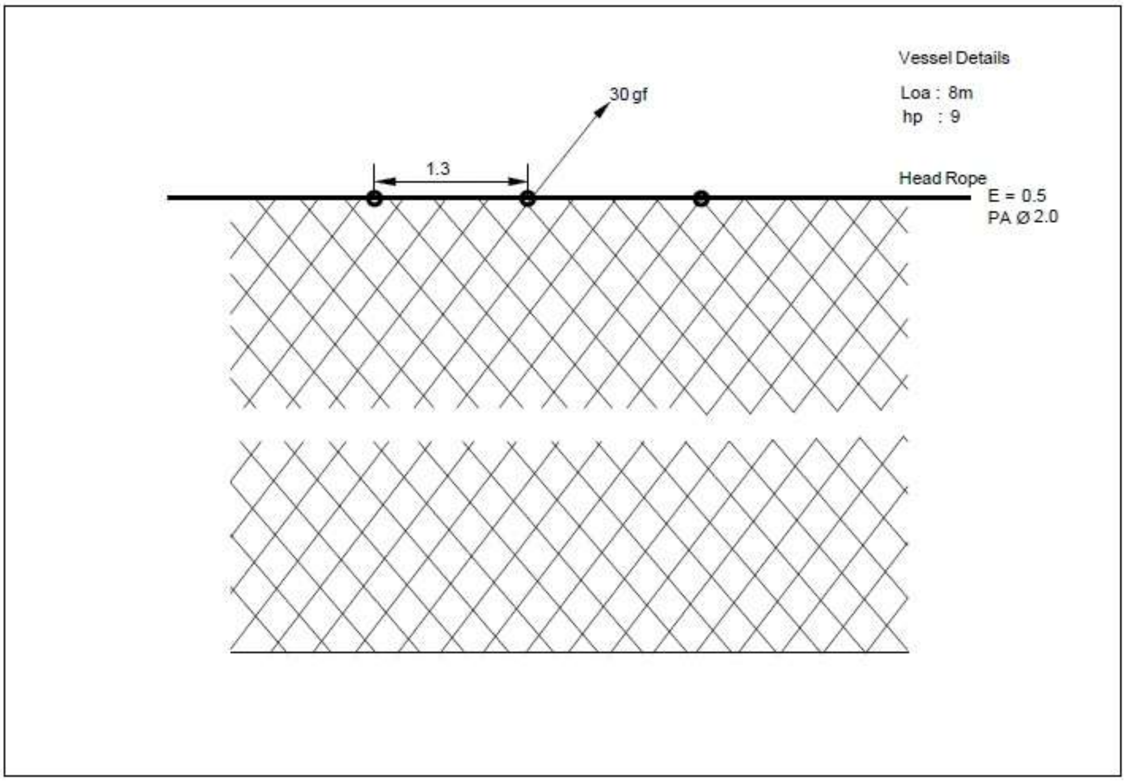


Figure 9. Drift pelagic gillnet of Velayuthapuram

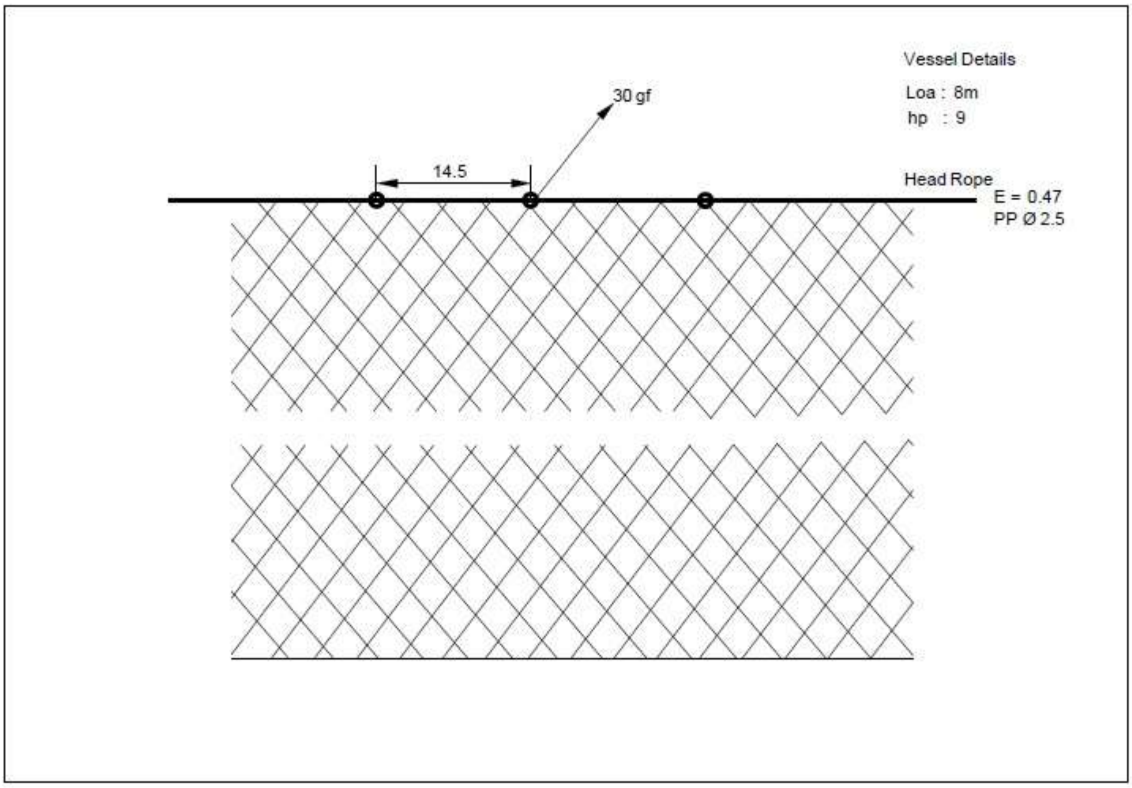


Figure 10. Drift pelagic gillnet of Mandapam

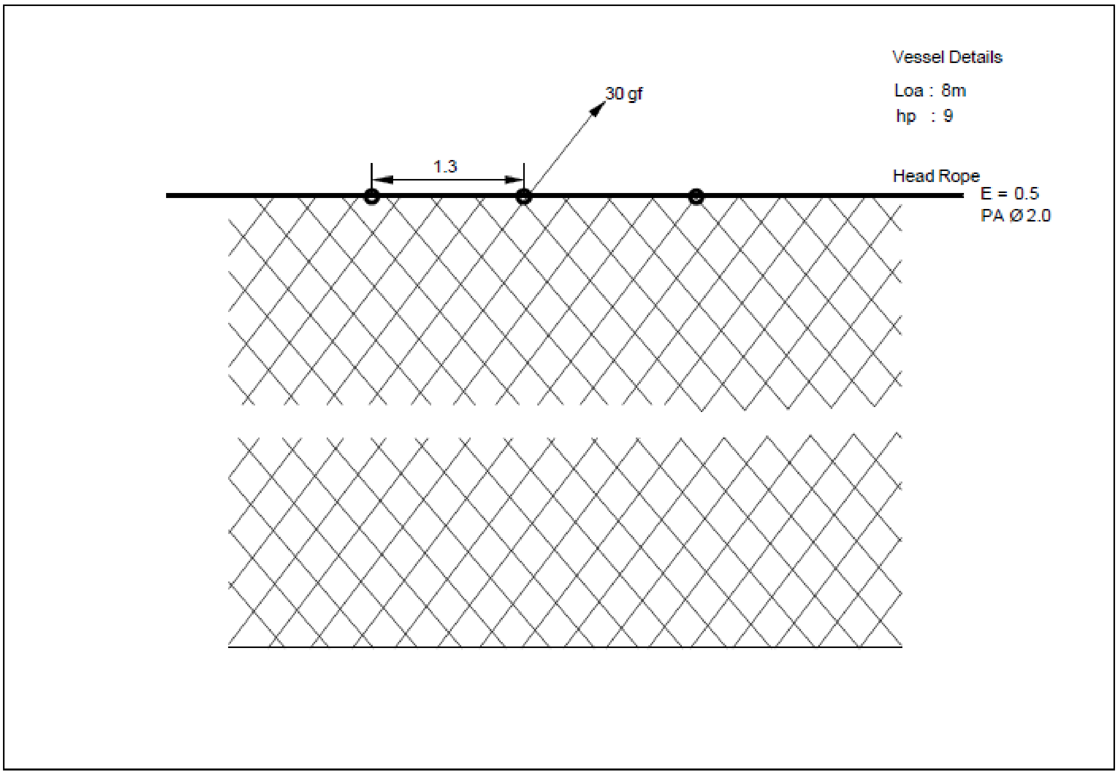
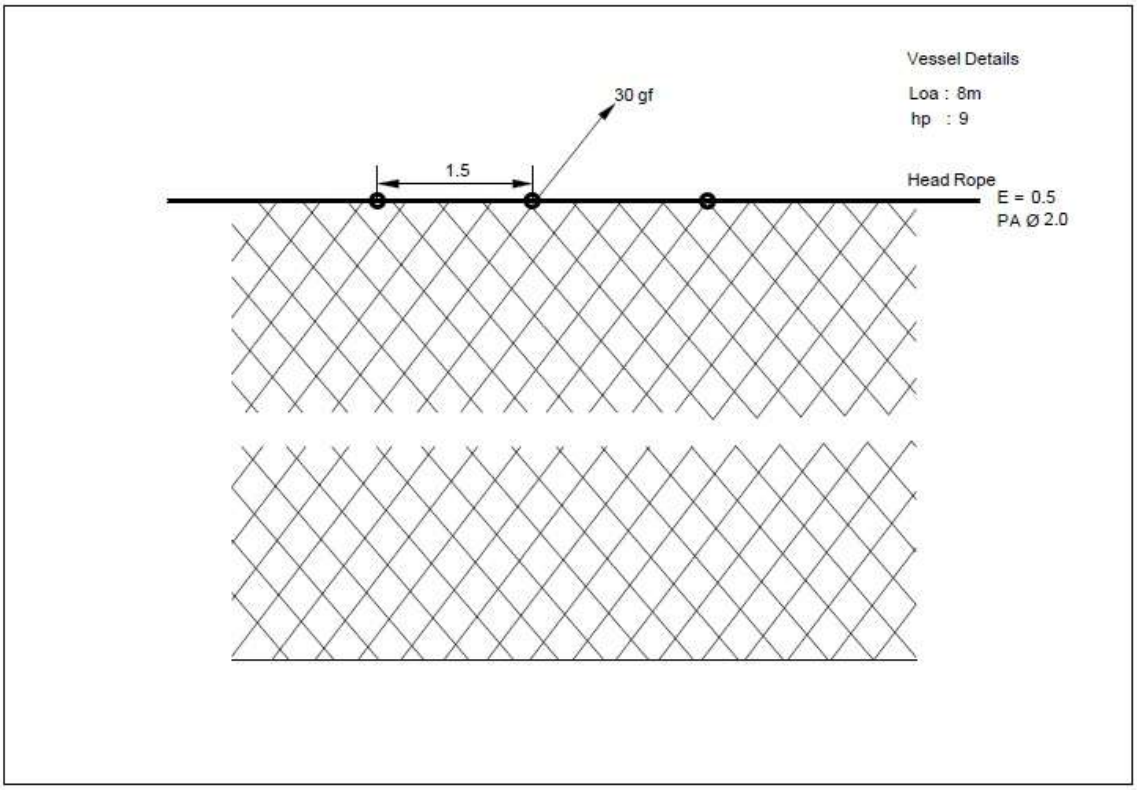


Figure 11. Drift pelagic gillnet of Pamban



with the range from 16-20 days per month. The operation of pelagic gillnets with 6-12 m operational depth had the advantage of operating in wide range of coastal regions with the operational range varying from 12-25 Nm from the coast. Though the fishing operations were carried out throughout the year, the peak fishing season in Mundal and Velayuthapuram was from October to January. In the case of Mandapam and Pamban, the peak fishing season was from found to be from April to July. The total catch ranged from a 30-90 kg fish per fishing trip depending upon the fishing season (Table 9).

4.1.4. Catch composition of pelagic drift gill nets

Among the mean total catch Needle fishes contributed only 60% and the remaining 40 % was contributed by seer fishes, barracudas mackerels and sail fishes. During the study period, six species of Needle fishes such as *A*. *hians, T*. *crocodiles, T.choram, T.agus, S. strongylura,* and *S. leiura* were found to constitute the catches of gill nets. The catch composition of other commercially caught in the pelagic drift gillnets in the selected fishing villages of Ramanathapuram district are given in Table 10. During the study period, *A. hians* was found to be the most dominant among the Needle fishes caught in the gill nets operated from Mundal and Velayuthapuram with the percentage contribution of 49% and 50% respectively. Occurrence of *T. crocodilus* was the dominant species among the Needle fishes caught in the gill nets Table 10.

4.1.5. Catch and effort details of pelagic drift gill nets during the study period

Regarding the effort made and catch obtained, a total of 96 fishing days was recorded as the total effort for the period from March to June. The highest number of 27,908 Needle fishes were was recorded during the month of June (Table 11).The second highest catch rate was observed during the month of April with the total catch of 26,649, Further third highest total fish catch of 24,552 Nos. of Needle fishes were recorded during the month May. The lowest Needle fish catch of 21,762 Nos. were recorded during the month of March.

Table 7. Specifications of crafts involved in gill netting in the selected fishing villages of Ramanathapuram district

Sl.No	Parameter	Name of the fishing village						
		Mundal		Velayuthapuram		Mandapam		Pamban
1	Type of craft	Vallam	FRP Boat	Vallam	FRP Boat	Vallam	FRP Boat	Vallam
2	Length (m)	7.0 – 8.0	4.0	7.0-8.0	4.0-5.0	6.0-7.0	4.0	7.0-8.0
3	Beam (m)	2.0	1.5	2.0	1.5	2.0	1.5-2.0	1.5
4	Depth (m)	1.8 – 2.0	1.0–1.5	2.0	1.5	1.5-2.0	1.5	2.0-2.5
5	No. of crafts	35	20	20	10	15	9	17
6	No. of fishermen involved in fishing	180-200		100- 120		100-110		70-80

Table 8. Specifications of the gill nets operated in the selected fishing villages of Ramanathapuram district

Sl.No	Parameters	Name of the fishing village			
		Mundal	**Velayuthapuram**	**Mandapam**	**Pamban**
1	Webbing material	Multi- filament (Nylon) twine	Multi- filament (Nylon) twine	Multi filament (Nylon) twine	Multi- filament (Nylon) twine
2	Twine specification(tax)	23 tex x 2 x 3	23 tex x 2 x 3	23 tex x 2 x 3	23 tex x 2 x 3
3	Colour	Green	Green & Yellow	Green	Green
4	Length (m)	104.0	40.5	97.5	97.5
5	Hung depth (m)	2.7	1.1	2.7	2.7
6	Mesh size (mm)	50,51,52	30,32	51,52	50,51
7	No. of meshes in length	4,000	2,700	3,750	3,750
8	No. of meshes in depth	66	52	55	55
9	Hanging coefficient	43	40	52	52
10	No of units operated	8-14	8-12	10-14	10-12
11	Material of head rope	Nylon	Polypropylene	Nylon	Nylon
12	Head rope thickness(mm)	2.0	2.5	2.0	2.0
13	Material of float	Plastic	Plastic & cork	Plastic	Plastic
14	Float weight (g)	20	20	20	20
15	Buoyancy of the float(g)	30	30	30	30
16	Float Interval (m)	1.3	0.45	1.3	1.3

Table 9. Operational details of surface gill nets in selected fishing villages of Ramanathapuram district

Sl. No	Parameters	Name of the fishing village			
		Mundal	**Velayuthapuram**	**Mandapam**	**Pampban**
1	No of fishing trips per month	25	25	16-20	20-25
2	Depth of operation (m)	8 – 9	12 – 13	8 - 9	6 – 7
3	Nature of operation	Pelagic; drift	Pelagic; drift	Pelagic; drift	Pelagic; drift
4	Distance to fishing ground (Nm)	25	14	12	25
5	Fishing season	Throughout the year	Throughout the year	Throughout the year	Throughout the year
6	Peak fishing season	Oct-Jan	Oct-Jan	April-July	April-July
7	Range of CPUE (Kg/trip/boat)	30-90	40-80	30-60	20-80
8	Mean CPUE (Kg/ trip/boat)	60	60	45	50

Table. 10 Catch composition pelagic drift gillnets selected fishing villages of Ramanathapuram district

Sl. No	Name of the fishing village			
	Mundal	**Velayuthapuram**	**Mandapam**	**Pamban**
1	*Ablennes hians (45%)*	*Ablennes hians (50%)*	*Tylosurus crocodilus (60%)*	*Tylosurus crocodilus (70%)*
2	*Tylosurus crocodilus (27%)*	*Tylosurus crocodilus (22%)*	*Tylosurus acus melanot(20%)*	*Tylosurus acus (15%)*
3	*Tylosurus acus (14%)*	*Tylosurus acus (17%)*	*Ablennes hians (12%)*	*Ablennesh ians (8%)*
4	*Strongylura leiura (7%)*	*Strongylura leiura (5%)*	*Strongylura strongylura(3%)*	*Strongylura strongylura((4%)*
5	*Strongylura strongylura(5%)*	*Strongylura strongylura (4%)*	*Strongylura leiura(3%)*	*Strongylura leiura(2%)*
6	*Platybelone argalus (2%)*	*Platybelone argalus (3%)*	*Platybelone argalus (2%)*	*Platybelone argalu(1%)*
7	Seerfishes, Barracudas, Mackerals & Sailfish	Flyingfish, Barracudas, Mackerals and half beaks	Seerfish, Barracudas, Mackerals and Queenfishes	Seerfish, Barracudas, Mullets, and Mackerals.

Table: 11 Catch per unit effort of pelagic drift gill nets operated at Mundal village from March 2015 to June 2015

Sl. No	Month	Average number of boats operated per day (a)	Number of Fishing days (b)	Monthly fishing effort (boat days) (c)	Mean number of Fishes landed / boat / day (d)		Catch / boat / month (b) x (d)		Month wise total catch of the village (c) x (d)	
					Needle fishes	Other fishes	Needle fishes	Other fishes	Needle Fishes	Other Fishes
1	March	46.50	24	1,116	19.5	13.00	468	312	21,762	14,508
2	April	47.25	24	1,134	23.5	14.75	564	354	26,649	16,727
3	May	46.50	24	1,116	22.0	15.50	528	372	24,552	17,298
4	June	44.50	24	1,068	26.1	17.50	624	420	27,907	18,690
Group wise total catch (Nos) /effort in boat days during the study period				4,434	91.1	60.75	2184	1458	1,00,870	67,223
Total catch (Nos) / effort in boat days During the study period				4,434	152		3,642		1,68,093	

Table 12. Catch – effort particulars of Needle fishes caught in experimental gears

Sl No	Name of fish			Length Range (cm)	Weight range (kg)	Types of Hook / Month															
	Ver nacular name	Common name	Scientific Name			'J' Hook				Reversed Hook				Kirbed Hook				Bait holder Hook			
						Mar	Apr	May	June	Mar	Apr	May	June	Mar	Apr	May	June	Mar	Apr	May	June
1	Valai mural	Banded Needle fish	*Ablennes hain*	65-75	.650-.750	16	19	16	36	28	27	25	60	14	13	12	29	32	35	23	42
2	Kalinkan mural	Hound Needle fish	*Tylosurus crocodiles*	56-80	.750-1	30	28	25	50	35	40	33	50	24	13	18	31	42	38	14	51
3	Pallu mural	Spoited Needle fish	*Strongylura strongylura*	60-70	.450-.600	11	10	9	30	9	15	15	28	19	6	10	36	12	14	8	19
4	Karuppu mural	Ruppell Needle fish	*Tylosurus choram*	60-75	.500-.800	8	7	15	17	9	8	16	16	7	3	11	17	10	9	15	11
Monthly total catch for the effort by 1,400 hooks						65	64	65	133	81	90	90	89	54	35	51	113	96	96	86	123
Total catch for the study period of 4 months for with total effort by 5,600 hooks						327				415				253				401			
Total catch projected for 24 days / month						1,962				2,490				1,518				2406			

4.2. Performance of experimental pelagic longline gears

The catch particulars of fishes caught in experimental gears with four different design of hooks such as (i) ‘J’ hook (ii) Reversed hook (iii) Kribed hook and (iv) Bait holder hook are given in Table 12. A total of 4 species such as *A. hians, T. crocodiles, T. choram* and *S. strongylura* contributed the fishery during the experimental fishing operations. Among the four types of hooks tested, the monthly catch rate was high irrespective of the hook design during month of June except for the ‘Reversed’ hook which recorded almost a uniform catch rate of (90 Nos per month) during April, May and June. With regard to the total catch during the study period with the effect of 5,600 hooks, ‘Reversed’ hook ranked first with the total catch of 415 fishes followed by Bait holder hook (401 fishes), ‘J’ hook (327 fishes) and Kribed hook (253 fishes) the details of onboard fishing operation, Needle fishes and by catches in the experimental long lines are given in the plates 3, 4 and 5.

4.2.1. Catching efficiency of experimental longline with ‘J’ hooks

In case of longline unit with ‘J’ hook the overall hooking rate was higher for *T. crocodiles* during the study period of four months (133Nos for 5600 hooks) followed by *A. hians* (87 Nos for 5600 hooks), *S. strongylura* (60 Nos for 5600 hooks) and *T. choram* (47Nos for 5600 hooks). A total of 327 Needle fishes with the total weight of 232 kg were found caught during experimental fishing (Table 13 and Fig. 12).

Plate 3. Onboard fishing operation with experimental longlines

	
3 a. Baiting of hooks	**3 b.** Shooting of longline
	
3 c. Hauling of long line	**3 d.** Needle fish in hooked condition
	
3 e. Hauling of fish caught in the hook	**3 f.** Release of fish from the hook

Plate 4. Needle fishes caught in experimental longlines

4 a. *Tylosurus crocodilus*

4 b. *Abblens heines*

4 c. *Strongylura strongylura*

4 d. *Tylosurus choram*

Plate 5. By catches from experimental longlines

5 a. *Echenis naucrates*

5 b. *Arius thalassinus*

Table 13. Hooking rate of experimental long line with ‘J’ hooks

S.No	Species	Month of operation/ Catch in number				Total no of fishes	Over all hooking rate (%)
		March	April	May	June		
1	*Ablennes hians*	16	19	16	36	87	1.6
2	*Tylosurus crocodiles*	30	28	25	50	133	2.4
3	*Strongylura strongylura*	11	10	9	30	60	1.0
4	*Tylosurus choram*	8	7	15	17	47	0.8
Total catch (Nos)		65	64	65	133	327	5.8

4.2.2. Catching efficiency of experimental longline with ‘Reversed’ hooks

A total of 414 Needle fishes with the total weight of 303.5 kg were found captured by ‘Revered’ hook during the entire study period. This hook captured 158,140, 67, and 50 numbers of *T. crocodiles, A.hians, S. strongylura* and *T. choram* respectively (Table 14 and Fig. 13).

Table 14. Hooking rate of experimental long line with ‘Reversed’ hooks

S.No	Species	Month of operation/ Catch in number				Total no of fishes	Over all hooking rate (%)
		March	April	May	June		
1	*Ablennes hians*	28	27	25	60	140	2.5
2	*Tylosurus crocodilus*	35	40	33	50	158	2.8
3	*Strongylura strongylura*	9	15	15	28	67	1.2
4	*Tylosurus choram*	9	8	17	16	50	0.9
Total catch (Nos)		81	90	90	154	415	7.4

Figure 12. Hooking rate of experimental long line with 'J' hooks

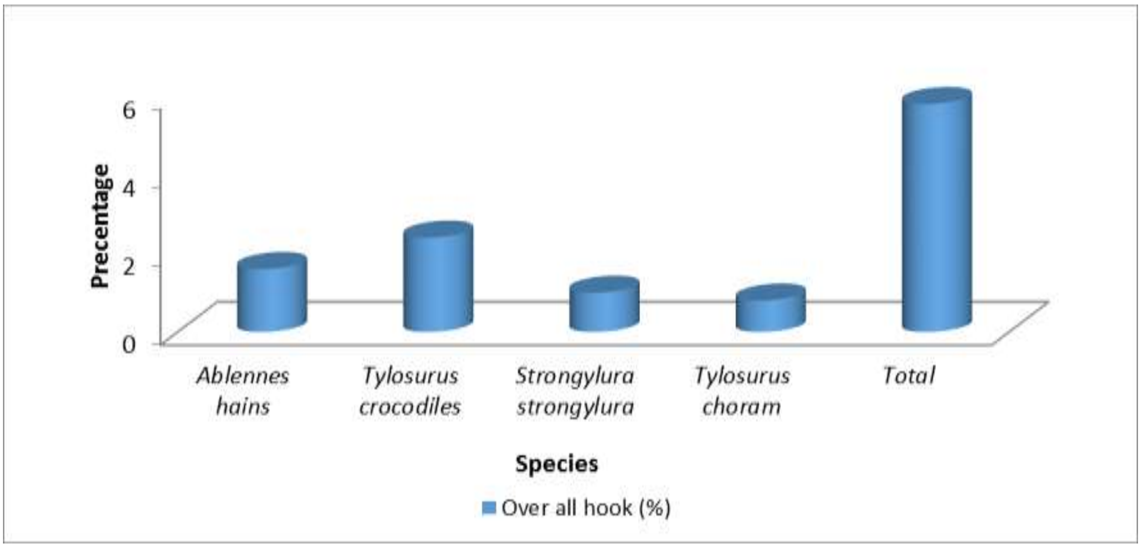
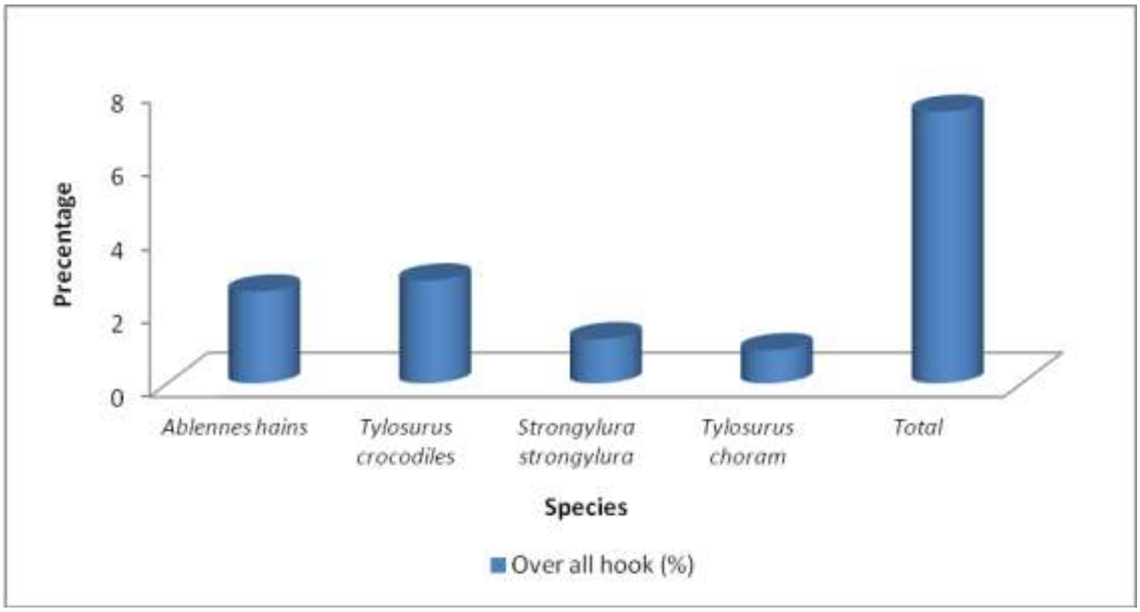


Figure 13. Hooking rate of experimental long line with 'Reversed' hooks



4.2.3. Catching efficiency of experimental longline with 'Kribed' hooks

In case of longline unit with 'Kribed' hook, a total of 253 Needle fishes with the total weight of 169.5 kg were captured during the fishing operations (Table 15 and Fig. 14). The overall hooking rate *T. crocodiles* for the entire study period was (86 Nos for 5600 hooks) followed by *A. hians* (61Nos for 5600 hooks), *S. strongylura* (72Nos for 5600 hooks) and *T. choram* (38 Nos for 5600 hooks).

Table 15. Hooking rate of experimental long line with 'Kribed' hooks

S.No	Species	Month of operation/ Catch in number				Total no of fishes	Over all hooking rate (%)
		March	April	May	June		
1	*Ablennes hians*	14	13	12	29	68	1.2
2	*Tylosurus crocodiles*	24	13	18	31	86	1.5
3	*Strongylura strongylura*	9	6	10	36	61	1.0
4	*Tylosurus choram*	7	3	11	17	38	0.7
Total catch (Nos)		54	35	51	113	253	4.4

4.2.4. Catching efficiency of experimental longline with 'Bait holder' Hooks

In case of longline unit with 'Bait holder' hook, the overall hooking rate was higher for *T. crocodiles* during the study period of four months (171Nos for 5600 hooks) followed by *A. hians* (132 Nos for 5600 hooks), *S.strongylura* (53 Nos for 5600 hooks) and *T.choram* (45 Nos for 5600 hooks). A total of 401 Needle fishes with the total weight of 285.5 kg were found caught during experimental fishing (Table 16 and Fig.15).

Table 16. Hooking rate of experimental long line with 'Bait holder' hooks

S.No	Species	Month of operation/ Catch in number				Total no of fishes	Over all hooking rate (%)
		March	April	May	June		
1	*Ablennes hians*	32	35	23	42	132	2.6
2	*Tylosurus crocodilus*	42	38	40	51	171	3.0
3	*Strongylura strongylura*	12	14	8	19	53	0.9
4	*Tylosurus choram*	10	9	15	11	45	0.8
Total catch(Nos)		96	96	86	86	401	7.3

4.2.5. Analysis of variances of impact of hook designs on the hooking efficiency of different species of Needle fishes

The analysis of variances of impact of four different hook designs such as (i) 'J' hook longline, (ii) Reversed hook longline, (iii) Kribed hook longline and (iv) Bait holder hook on the hooking efficiency of different species of Needle fishes revealed that there existed significant difference in hooking rate between various species caught such as *A. hians, T. crocodiles*, *S. strongylura, T. choram* (P > 0.01). Further, Significant difference could be observed with respect to hooking rate of four different hooks (P > 0.05).

Table 17. Analysis of Variances of impact of hook designs on the hooking efficiency of different species of Needle fishes

Source of variation	Degrees of freedom	Sum of square	Mean sum of square	F ratio	F table		P value
					1 %	5%	
Species	3	22288	7429.33	17.43	6.99	3.86	P < 0.01
Hooks	3	5000	1666.66	3.91	6.99	3.86	P < 0.05
Error I	9	3835	426.11				

Figure 14. Hooking rate of experimental long line with 'Kribed' hooks

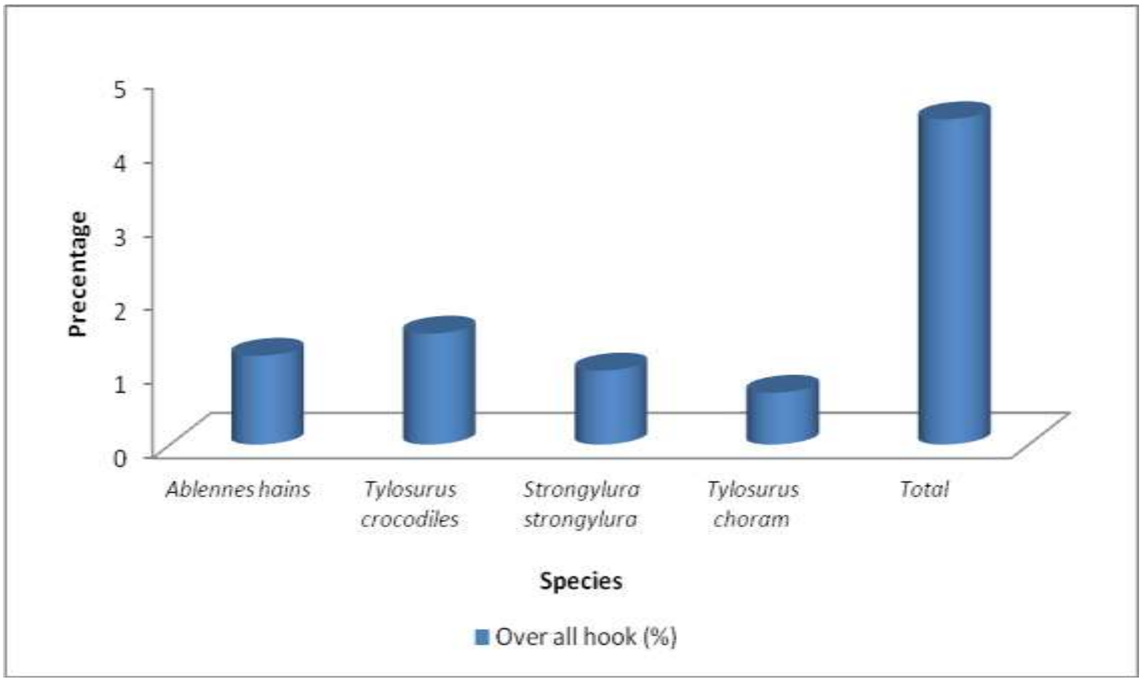
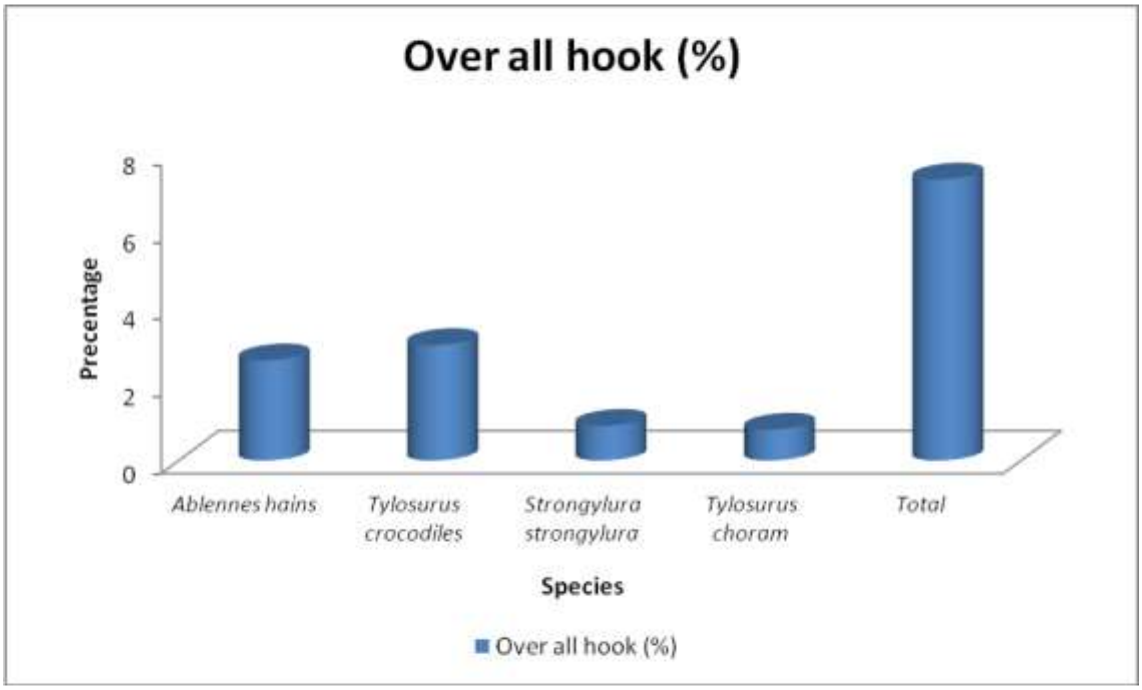


Figure 15.Hooking rate of experimental long line with 'Bait holder' hooks



4.2.6. Percentage composition of fish catch from experimental longlines based on the number and weight

The catch details in number of fishes caught per unit, length range of fish and the mean length of fish caught with respect to different experimental longlines are given in Table 12. Apart from them, hook wise percentage composition of fishes caught from different experimental gear in terms of number as well as weight basis are discussed below.

4.2.6.1 Percentage composition of fish caught from experimental longline with 'J' hooks based on number

Percentage composition of fishes caught from experimental longline with 'J' hooks is shown in Fig. 16. Regarding the overall catch, *T. crocodilus,* could be observed as much as 40.6% in this gear. Further, *A. hians* contributed 26.6%, followed by *S.strongylura* which contributed 18.4%. The least dominant species which contributed only 14.4% of the fish catch of the longline with 'J' hooks during the experimental period was *T. choram*. Notable difference in the catch rate between the four species could be observed throughout the study period (Table 18). June was found to be the peak fishing month during which as much as 40.68% of the overall fish catch was recorded in this type of longline gear.

Table18. Hooking percentage of caught from experimental longline with 'J' hooks (based on number)

S.No	Species	Month of operation/ Catch in number				Total no of fishes	Percentage contribution
		March	April	May	June		
1	*Ablennes hians*	16	19	16	36	87	26.6
2	*Tylosurus crocodilus*	30	28	25	50	133	40.68
3	*Strongylura strongylura*	11	10	9	30	60	18.4
4	*Tylosurus choram*	8	7	15	17	47	14.4
Total catch (Nos)		65	64	65	133	327	100

4.2.6.2. Percentage composition of fishes caught from 'experimental longline with 'J' hooks based on the weight

The percentage catch composition based on the weight of catch with respect to 'J' hook experimental longline is shown in Table 19. A total of 16 operation days was recorded as the total study period. Regarding the overall catch in term of weight *T. crocodilus,* this species could be observed as much as 44.4% in J type experimental longline. During the experimental period, the species such as *A. hians, S. strongylura* and *T. choram,* 25.6, 14.5 and 15.4 % respectively in the fish catch of longline with 'J' hook. Notable difference in the total weight between the four species could be observed throughout the study period. (Table18). June was found to be the peak fishing month during the experimental longline compared to other month during which as much as 44.4% of the overall fish weight was recorded in longline with 'J' type hooks (Fig. 17). In general notable difference could not be observed in the catch in terms of number and catch in terms of weight. However an increased contribution of 3 % and 4% in addition could be observed for *Strongylura strongylura* and *T. crocodilus* respectively due to their higher weight contribution.

Table 19. Hooking percentage of fishes caught from experimental longline with 'J' hooks (based on weight)

S.No	Species	Month of operation/ Catch in number				Total weight of fishes (kg)	Percentage contribution
		March	April	May	June		
1	*Ablennes hians*	13	12.5	10.5	24	60	25.6
2	*Tylosurus crocodilus*	26	21	17	40	104	44.4
3	*Strongylura strongylura*	6	6.5	5.5	16	34	14.5
4	*Tylosurus choram*	6	4	7	9	36	15.4
Total catch		51	44	40	89	234	100

4.2.6.3. Percentage composition of fishes caught from experimental longline with 'Reversed' hook based on number

Percentage composition of catch from experimental longline with 'Reversed' hook is shown in Figure 18. Regarding the overall catch *T. crocodilus,* this species could be observed as much as 38% in this gear. Further, *A.hians* contributed 33.9%, followed by *S. strongylura* which contributed 16.1%. The least dominant species which contributed only 12 % of the fish catch longline during the experimental period was regarding *T. choram,* notable difference in the catch rate between the four species could be observed throughout the study period. (Table 20). June was found to be the peak fishing month during which as much as 38% of the overall fish catch was recorded in this type of longline gear.

Figure 16. Hooking percentage of fishes caught from experimental longline with 'J' hooks (based on number)

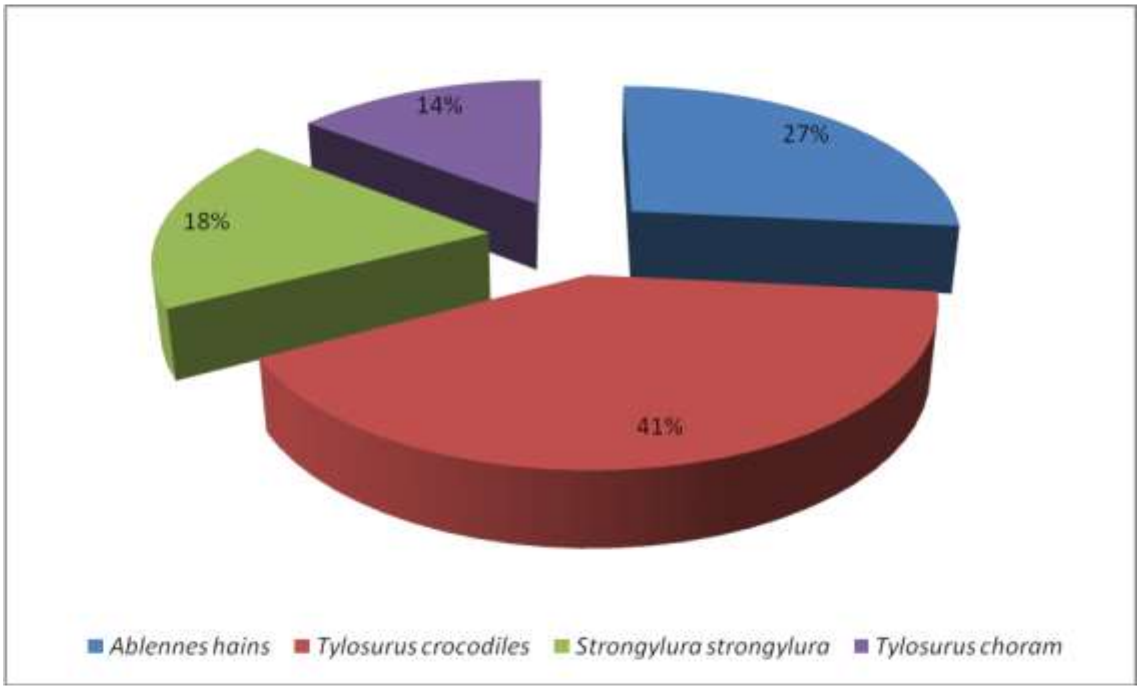


Fig 17. Hooking percentage of fishes caught from experimental longline with 'J' hooks (based on weight)

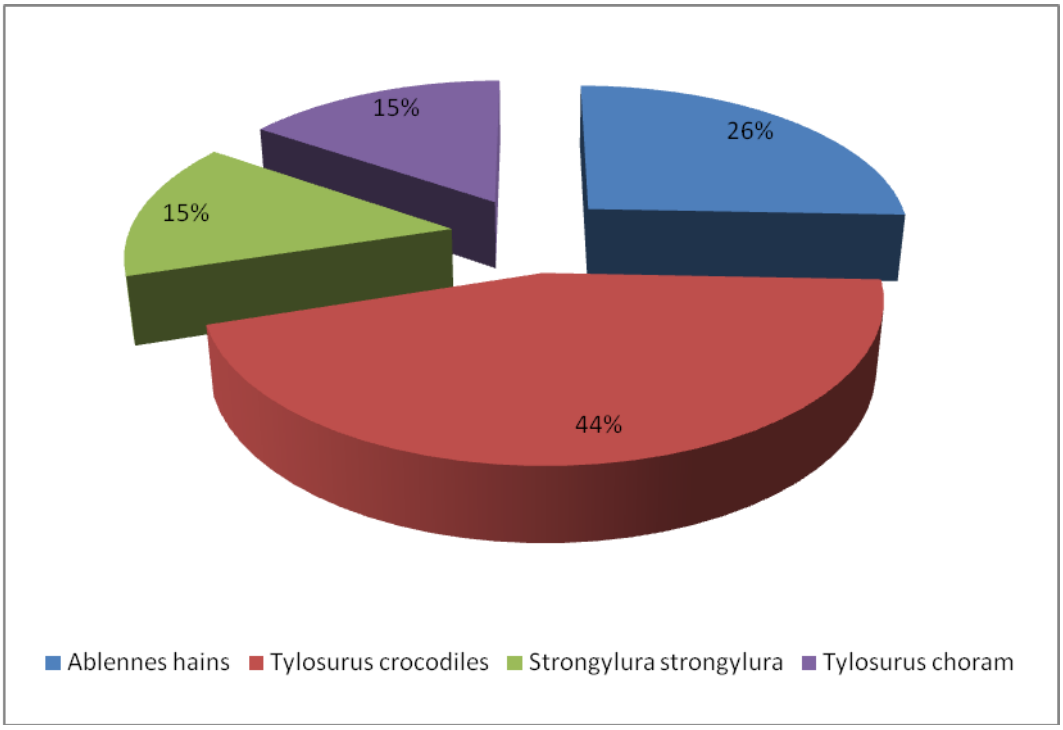


Table 20. Hooking percentage of fishes caught from experimental longline with 'Reversed' hook (based on number)

S.No	Species	Month of operation				Total no of fishes	Percentage contribution
		March	April	May	June		
1	*Ablennes hians*	28	27	25	60	140	33.9
2	*Tylosurus crocodilus*	35	40	33	50	158	38
3	*Strongylura strongylura*	9	15	15	28	67	16.1
4	*Tylosurus choram*	9	8	17	16	50	12
Total catch		81	90	90	89	415	100

4.2.6.4. Percentage composition of fishes caught from 'experimental longline with 'Reversed' hooks based on the weight

The species composition was estimated as occurrence percentage (in terms of weight) for each species caught per 1,400 hooks. The percentage composition based on the weight of catch with respect to Reversed hook experimental longline is shown in Table 21. Regarding the overall catch in terms of weight, *T. crocodilus,* and this species could be observed as much as 42.2% in 'J' type experimental longline. In the total catch in terms of weight during the experimental period, *A. hians, S. strongylura and T. choram* contributed 32, 15.8 and 10 % respectively . Notable difference in the total weight between the four species could be observed throughout the study period (Table 21). June was found to be the peak fishing month during the experimental longline constituted 42.2% of the fish catch (Fig. 19). In general notable difference could not be observed between the catch in terms of number and catch in terms of weight. However, an increased contribution of 2% and 4% in addition could be observed for *A. hians and T.crocodilus* respectively due to their higher weight contribution.

Figure 18. Hooking percentage of fishes caught from experimental longline with 'Reversed' hook (based on number)

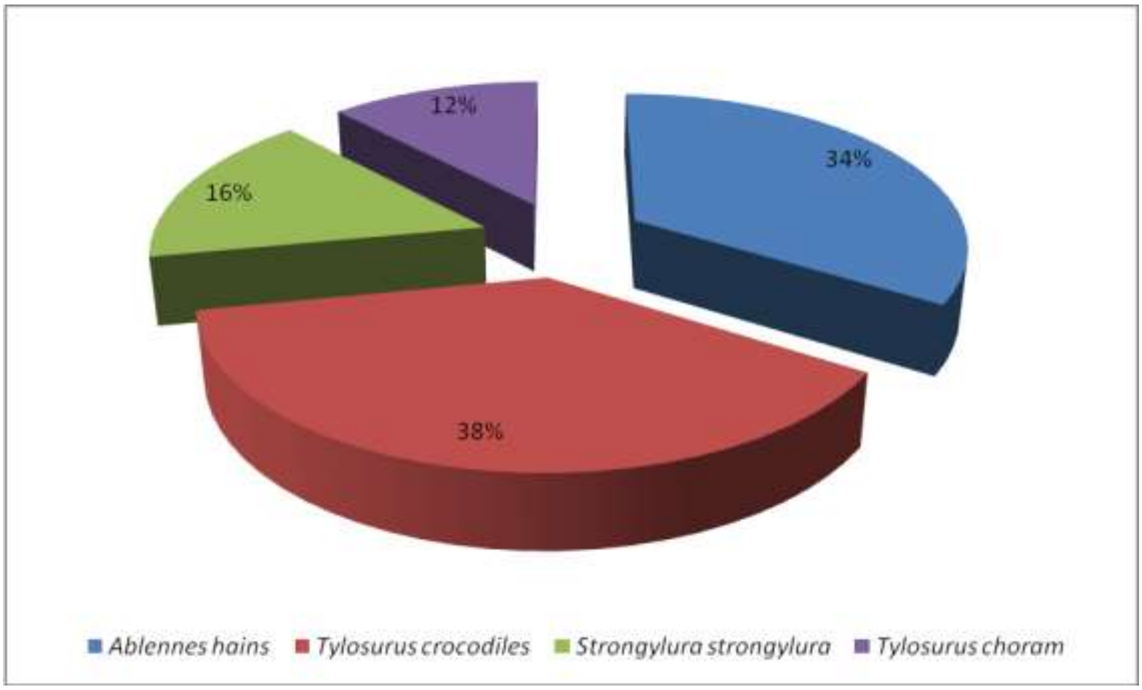


Figure 19. Hooking percentage of fishes caught from experimental longline with Reversed' hook (weight basis)
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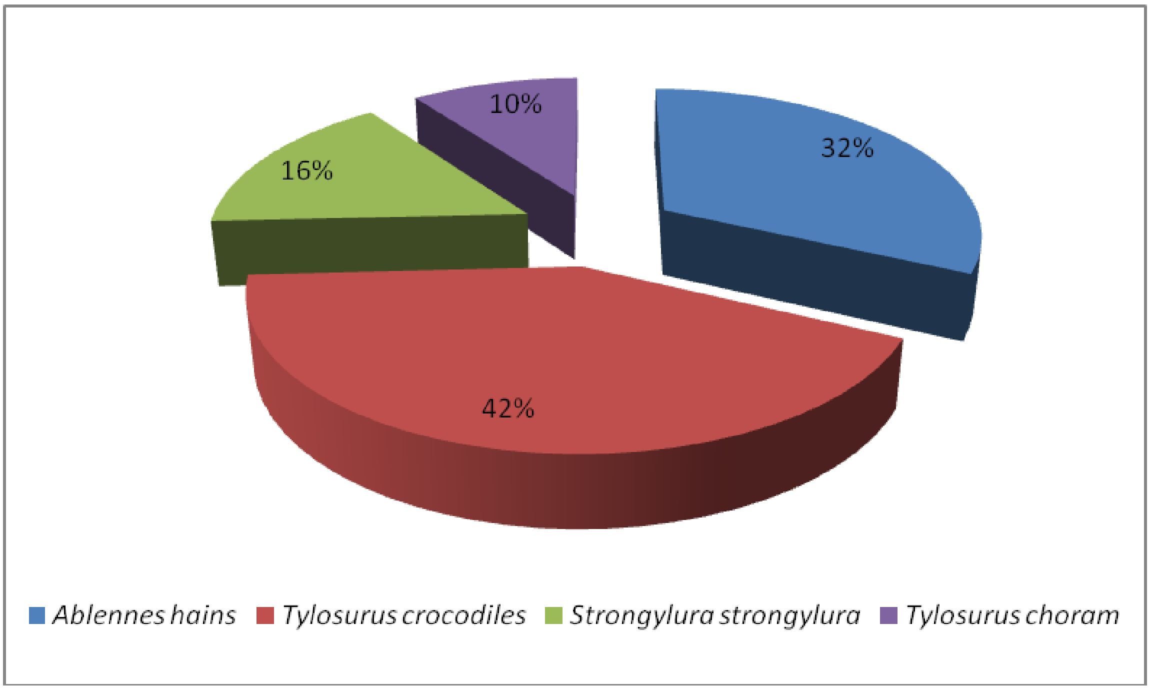


Table 21. Hooking percentage of fishes caught from experimental longline with 'Reversed' hooks (weight basis)

S.No	Species	Month of operation/ Catch in number				Total weight of fishes (kg)	Total weight of fishes (%)
		March	April	May	June		
1	*Ablennes hians*	24	18	17	38	97	32
2	*Tylosurus crocodilus*	31	29	28	40	128	42.2
3	*Strongylura strongylura*	5.5	11.5	11	20	48	15.8
4	*Tylosurus choram*	6	5	10	9.5	30.5	10
Total catch		66.5	68.5	66	107.5	303.5	100

4.2.6.5. Percentage composition of fishes caught from experimental longline with 'Kribed' hooks based on number

Percentage composition of catch from experimental longline with 'Kribed' hook is shown in Fig. 20. Regarding the overall catch *T. crocodilus,* this species could be observed as much as 34% in this gear. Further, *A. hians* contributed 27%, followed by *S. strongylura* which contributed 24. The least dominant species which contributed only 15 % of the fish catch longline during the experimental period *T. choram*. Notable difference in the catch rate between the four species could be observed throughout the study period (Table 22). June was found to be the peak fishing month during which as much as 40.68% of the overall fish catch was recorded in this type of longline gear (Fig. 24). As in the case of 'J' hook, notable difference could not be observed between the catch in terms of number and in terms of weight.

Table 22. Hooking percentage of fishes caught from experimental longline with 'Kribed' hook (based on number)

S.No	Species	Month of operation				Total no of fishes	Percentage contribution
		March	April	May	June		
1	*Ablennes hians*	14	13	12	29	68	27
2	*Tylosurus crocodilus*	24	13	18	31	86	34
3	*Strongylura strongylura*	9	6	10	36	61	24
4	*Tylosurus choram*	7	3	11	17	38	15
Total catch		54	35	51	113	253	100

4.2.6.6. Percentage composition of fishes caught from experimental longline with 'Kribed' hooks based on the weight

The percentage composition based on the weight of catch with respect to Kribed hook experimental longline is shown in Table 23. The highest weight of 74 kg was observed during the month of June. Regarding the overall catch in terms of weight *T. crocodilus,* this species could be observed as much as 3 5.5% in 'J' type experimental longline. *A. hians* contributed 26.4%, *S. strongylura* contributed 23.5% and *T.choram* was the least dominant species which contributed only 14.6% of the fish weight longline during the experimental period. Notable difference in the total weight between the four species could be observed throughout the study period. (Table 21 and Fig. 21). No notable difference could be observed between the catch in terms of number and in terms of weight.

Figure 20. Hooking percentage of fishes caught from experimental longline with 'Kribed' hooks (based on number)

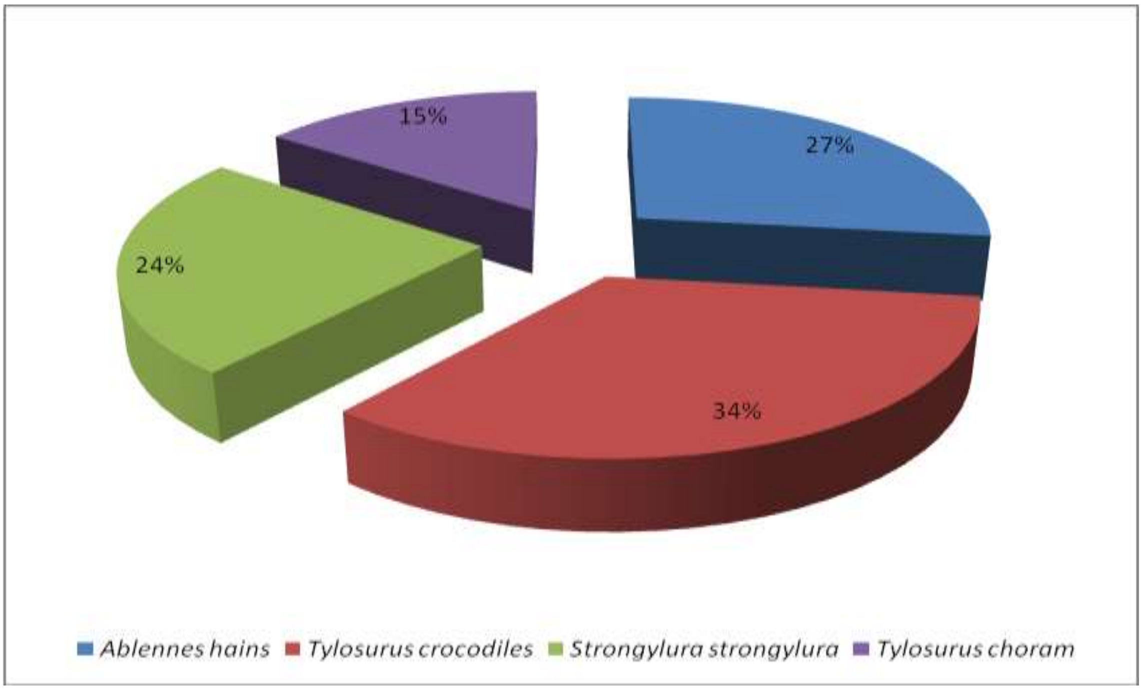


Fig 21. Hooking percentage of fishes caught from experimental longline with 'Kribed' hook (based on weight)

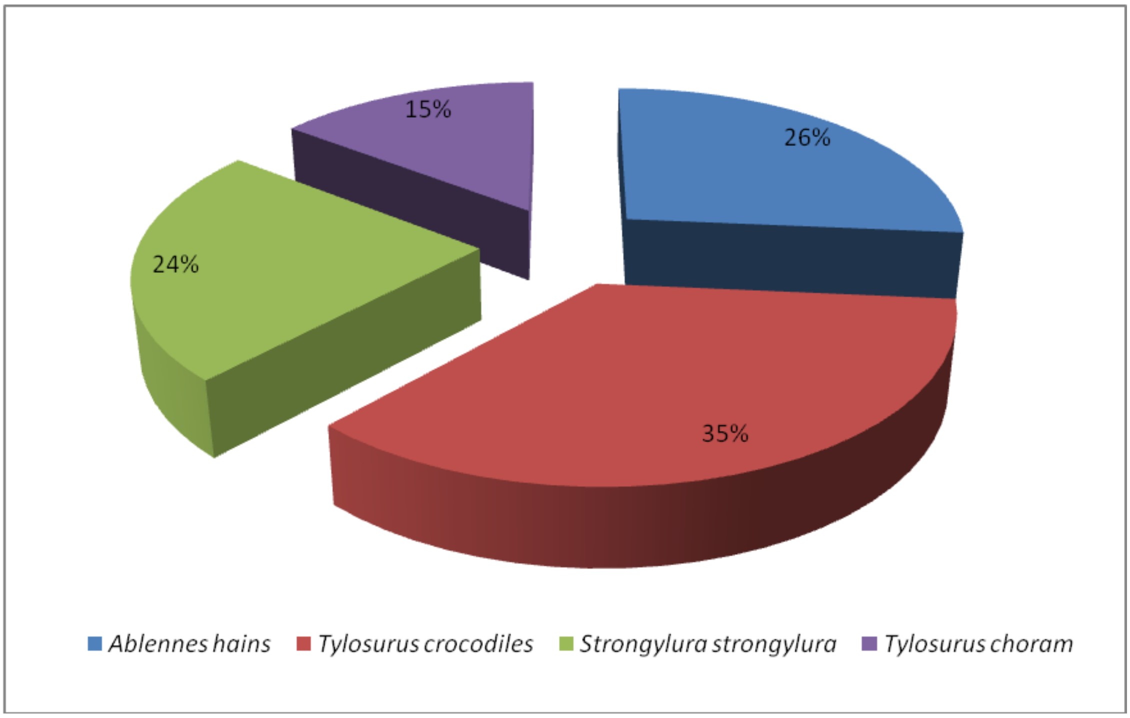


Table 23. Hooking percentage of fishes caught from experimental longline with 'Kribed' hook (based on weight)

S.No	Species	Month of operation/ Catch in number				Total weight of fishes (kg)	Percentage contribution
		March	April	May	June		
1	*Ablennes hians*	9	10	8	18	45	26.4
2	*Tylosurus crocodilus*	18	10	13.5	19	60.5	35.5
3	*Strongylura strongylura*	5	4	6	25	40	23.5
4	*Tylosurus choram*	4	2	7	12	25	14.6
Total catch		36	26	34.5	74	170.5	100

4.2.6.7. Percentage composition of fishes caught from experimental longline with 'Bait holder' hooks (based on number)

Percentage composition of catch from experimental longline with 'Bait holder' hook is shown in Fig. 22. Regarding the overall catch, *T. crocodilus,* could be observed as much as 42.6% in catch of this gear. Further, *A. hians* contributed 33%, followed by *S. strongylura* which contributed 13.2. The least dominant species which contributed only 11.2 % of the fish catch of this longline during the experimental period was *T. choram* . Notable difference in the catch rate between the four species could be observed throughout the study period. (Table 24). June was found to be the peak fishing month during which as much as 40.68% of the overall fish catch was recorded in this type of longline gear.

Table 24. Hooking percentage of fishes caught from experimental longline with 'Bait holder' hooks (based on number)

S.No	Species	Month of operation				Total no of fishes	Percentage contribution
		March	April	May	June		
1	*Ablennes hians*	32	35	23	42	132	33
2	*Tylosurus crocodilus*	42	38	40	51	171	42.6
3	*Strongylura strongylura*	12	14	8	19	53	13.2
4	*Tylosurus choram*	10	9	15	11	45	11.2
Total catch		96	96	86	86	401	100

4.2.6.8. Percentage composition of fishes caught from experimental longline with 'Bait holder' hooks (based on the weight)

The percentage composition based on the weight of catch with respect to experimental longline with Bait holder hooks is shown in Table 25. The highest weight of 127.5 kg was observed during the month of June. Regarding the overall catch in terms of weight *T. crocodilus,* this species could be observed as much as 44.7% in experimental longlines with 'Bait holder' hooks. During the experimental period, *A. hians S. strongylura* and *T. choram* contributed 34.3%, 11.7% and 9.3 % respectively. Among the four species, *T. choram* was the least dominant species (Fig. 23). No notable difference could be observed between the catch in terms of number and that of in terms of weight.

Figure 22. Hooking percentage of fish caught from experimental longline with 'Bait holder' hooks (based on number)

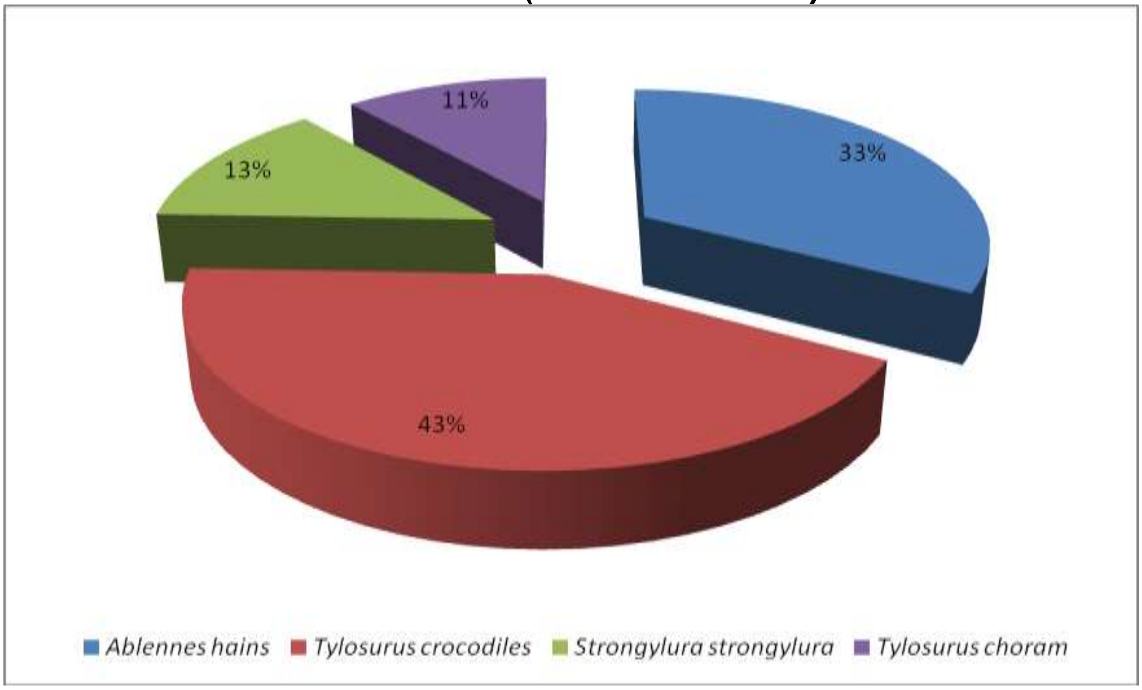


Figure 23. Hooking percentage of fishes caught from experimental longline with 'Bait holder' hook (based on weight)

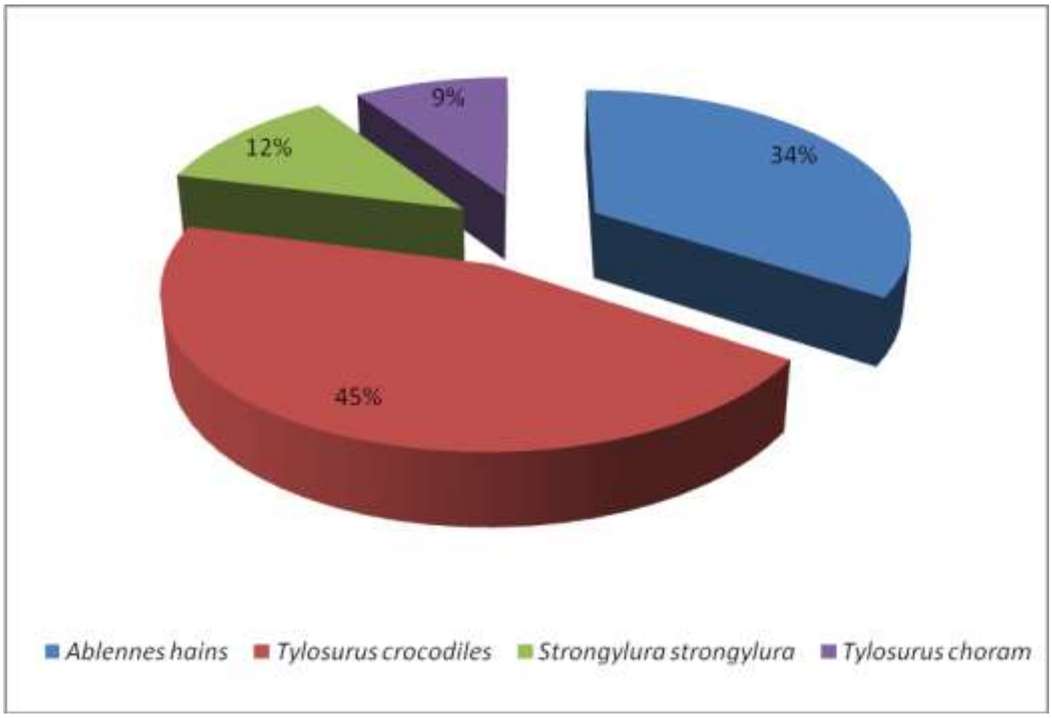


Table 25. Hooking percentage of fishes caught from experimental longline with 'Bait holder' hooks (based on weight)

S.No	Species	Month of operation/ Catch in number				Total weight of fishes (kg)	Total weight of fishes in (%)
		March	April	May	June		
1	*Ablennes hians*	27	28	14	29	98	34.3
2	*Tylosurus crocodilus*	36	31	26.5	34	127.5	44.7
3	*Strongylura strongylura*	8	9	5.5	11	33.5	11.7
4	*Tylosurus choram*	6	5	8.5	7	26.5	9.3
Total catch		77	73	54.5	81	285.5	100

4.2.7. Hooking pattern with respect to different types of hooks

In the present study the major hooking locations of Needle fishes by different types of hooks were identified as jaw, throat and gut besides foul hooking.

4.2.7.1. Hooking pattern of experimental longline with 'J' hooks

During the fishing trials in experimental longline with 'J' hook , different hooking pattern were observed. During study period, a total of 327 fishes were caught by "J" hook with the total effort of 5,600 hooks. The 'J' hook was found to hook the fish at sensitive locations like throat, jaw and gut or stomach. The hooking patterns in terms of percentage were as follows:

Jaw (28.7%) throat (33.3%), gut (21.1%) and foul hooking (16.8%). From the (Fig 24) it is evident that 'J' hooks catch Needle fishes mainly at throat region Table 26.

Table 26. **Hooking pattern of experimental longline with 'J' hooks**

S.No	Hooking position	Month of operation				Total number of fishes	Over all hooking pattern (%)
		March	April	May	June		
1	Jaw	16	23	17	38	94	28.7
2	Throat	23	19	21	46	109	33.3
3	Gut	17	14	22	69	69	21.1
4	Foul	9	11	9	26	55	16.8

4.2.7.2. Hooking pattern of experimental longline with 'Reversed' hooks

In the catch of experimental longline with 'Reversed' hooks the hooking locations were observed as follows, majority of the fishes hooked were found hooked at jaw (46%) followed by throat (27.4%), gut (6.6%) and foul (20%). As much as 20% were caught by foul hooking Table 27 and (Fig 25).

Table 27. Hooking pattern of experimental longline with 'Reversed' hooks

S.No	Hooking position	Month of operation				Total number of fishes	Over all hooking pattern (%)
		March	April	May	June		
1	Jaw	42	44	39	36	161	46
2	Throat	19	21	26	30	96	27.4
3	Gut	3	6	9	5	23	6.6
4	Foul	17	19	16	18	70	20

Figure 24. Overall hooking pattern of Needle fishes by ‘J’ hooks

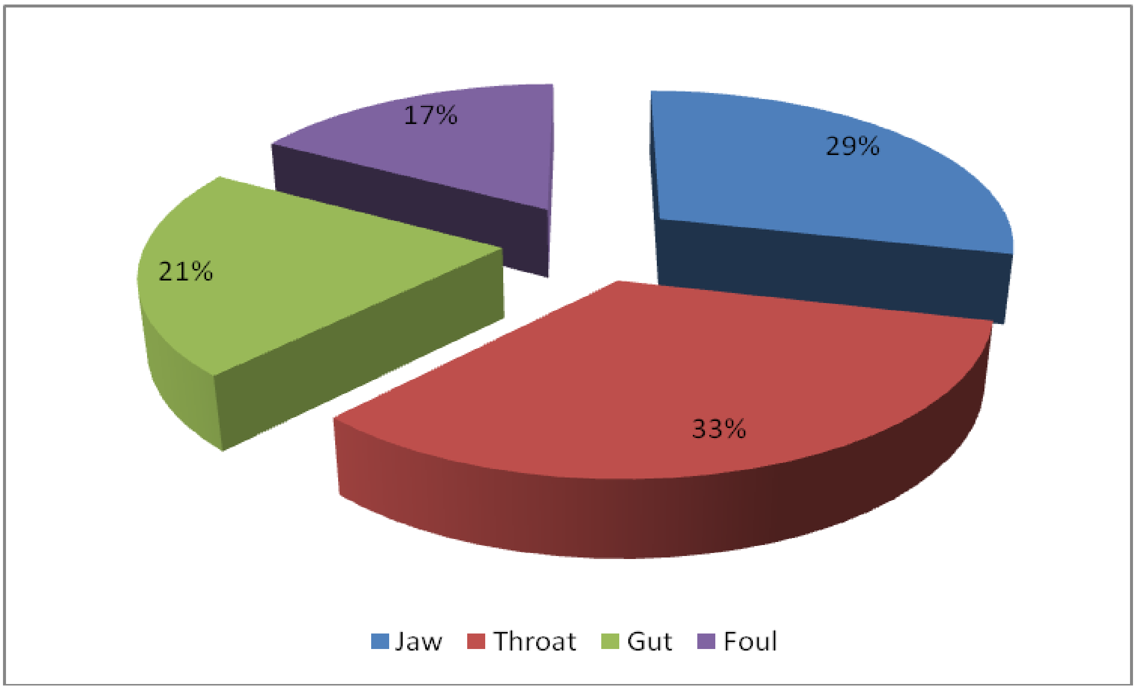
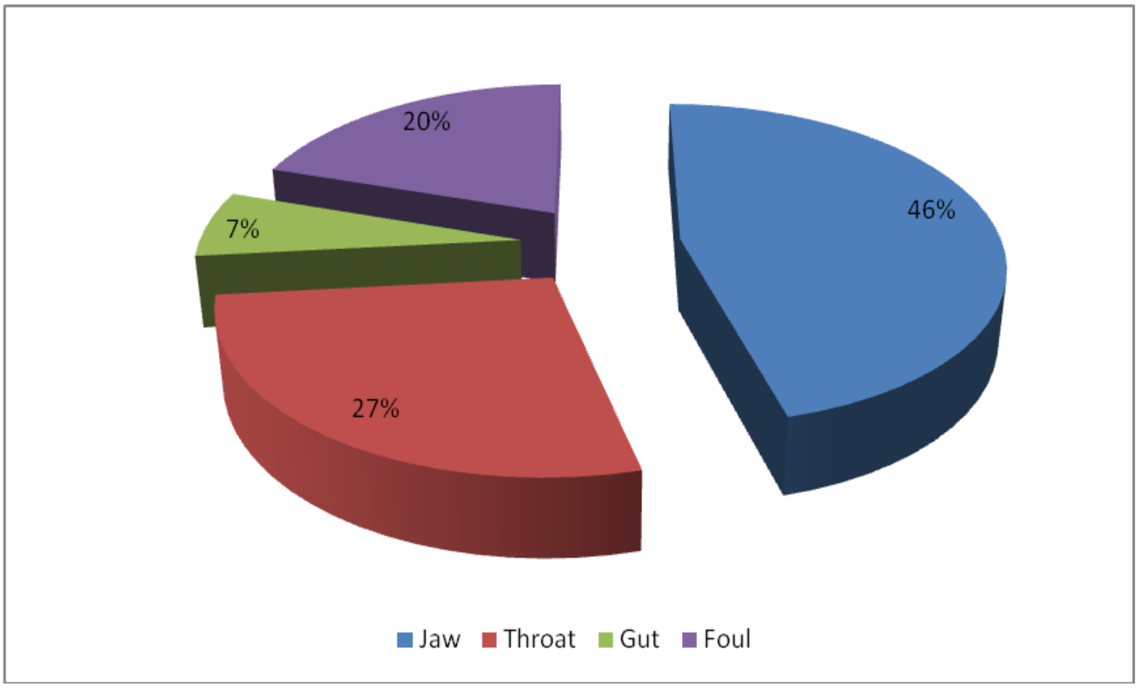


Figure 25. Over all hooking pattern of Needle fishes by ‘Reversed’ hooks



4.2.7.3. Hooking pattern of experimental longline with 'Kribed' hooks

As for as experimental longline with 'Kribed' hook was concerted, the hooking percentage was higher in the jaw (50.6%) followed by throat (30.9%), gut (5.6%) and foul hooking (12.9%). Though "Kribed' hooks were found to capture more than 50% of the fish caught at jaw, their overall hooking rate was less compared to 'Reversed' hook as per Table 28 and Fig. 26. Foul hooking relatively less (12.9 %) by this hook.

Table 28 Hooking pattern of experimental longline with 'Kribed' hooks

S.No	Hooking position	Month of operation				Total number of fishes	Over all hooking pattern (%)
		March	April	May	June		
1	Jaw	25	14	23	64	126	50.6
2	Throat	17	12	15	33	77	30.9
3	Gut	3	1	4	6	14	5.6
4	Foul	9	5	8	10	32	12.9

4.2.7.4. Hooking pattern of experimental longline with 'Bait holder' hooks

In case of experimental longline with 'Bait holder' hooks, they hooked the Needle fishes mainly at jaw (49.6%) followed by throat (25.9%), gut (5.7%) and foul (18.7%). In 'Bait holder' hooks 18.7 % of the fishes were caught by foul hooking. Very low percentage of 7.5% fishes was hooked in gut (Table 29 and Fig. 27).

Figure 26. Over all hooking pattern of Needle fishes by 'Kribed' hook

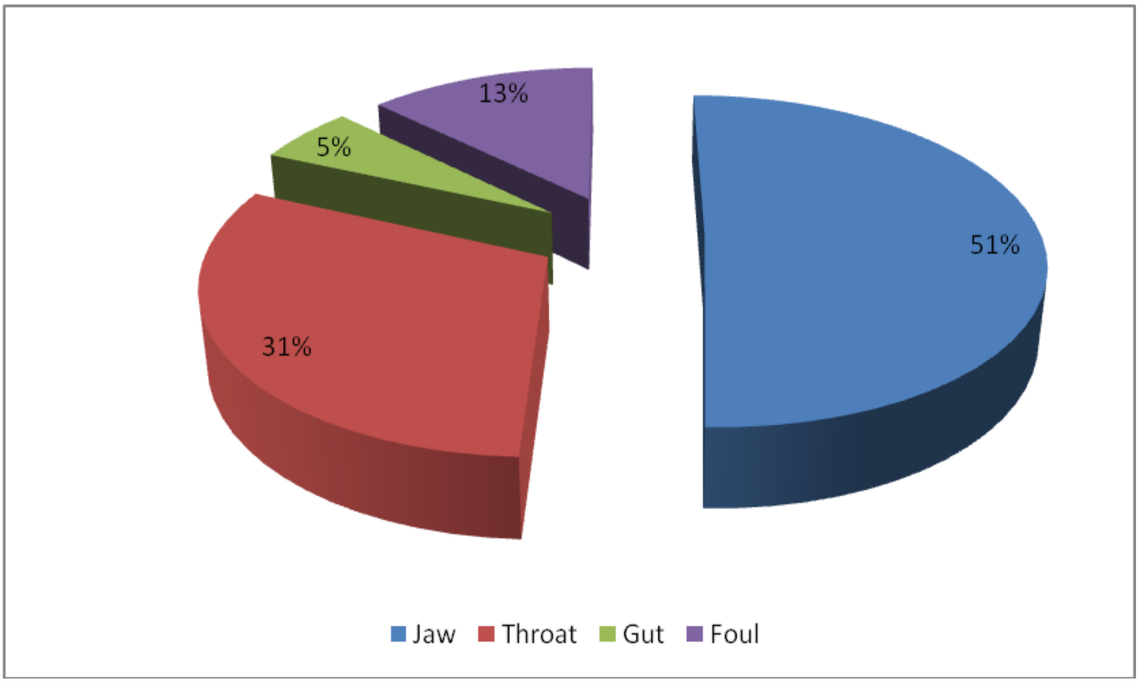


Figure 27. Overall hooking pattern of Needle fishes by 'Bait holder' hooks

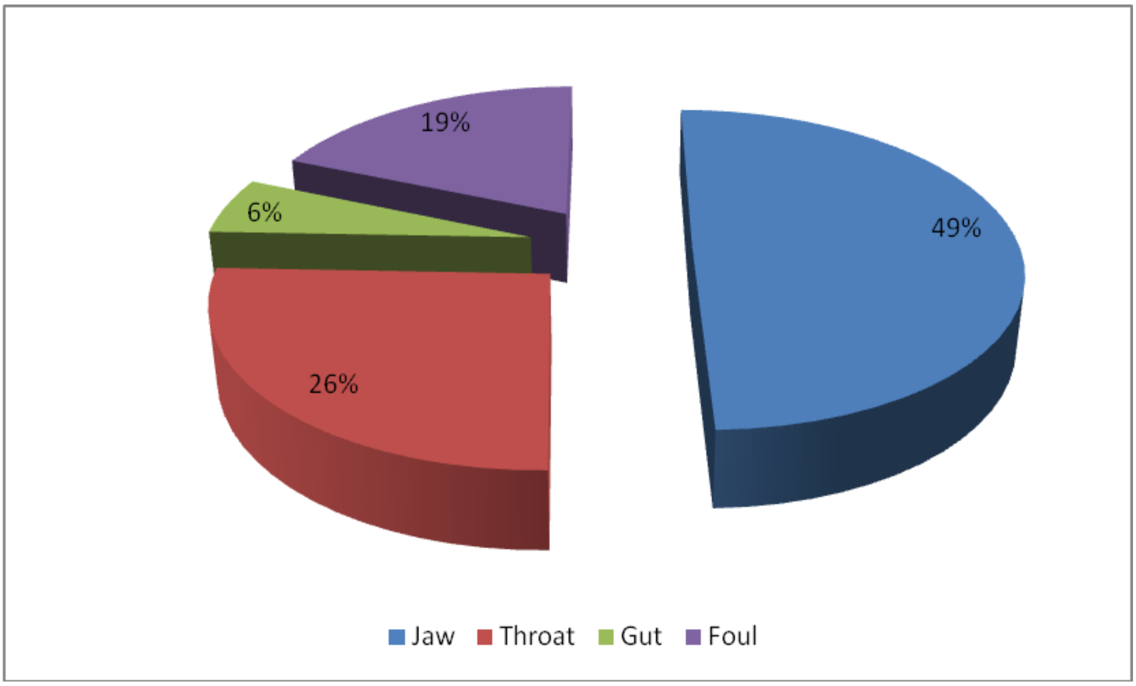


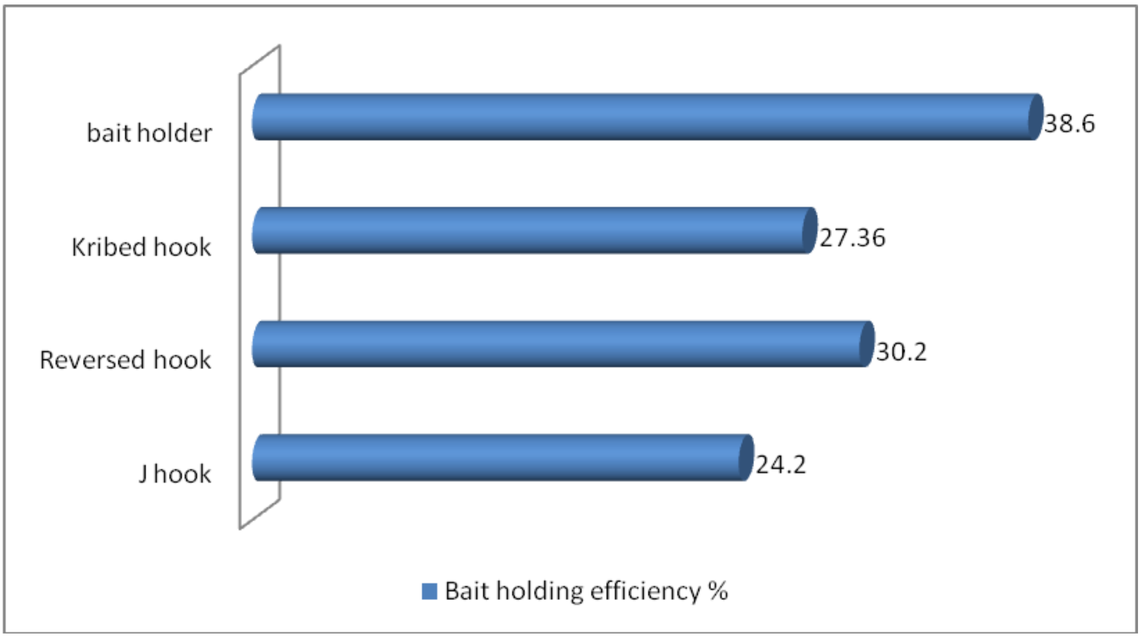
Table 29.Hooking pattern of experimental longline with 'Bait holder' hooks

S.No	Hooking position	Month of operation				Total number of fishes	Over all hooking pattern (%)
		March	April	May	June		
1	Jaw	46	42	38	73	199	49.6
2	Throat	27	34	25	18	104	25.9
3	Gut	3	5	4	11	23	5.7
4	Foul	20	15	19	21	75	18.7

4.2.8. Bait holding efficiency of the experimental hooks

The bait holding efficiency of different types of experimental hooks expressed as a percentage of hooks which retained the bait after the given soaking time of 2hrs were recorded in the present study. It is clear from Fig. 28, that 'Bait holder' hook was the most efficient hook in holding the bait (38.6%) followed by 'Reversed hook' (30.2%) 'Kribed hook' (27.36%) and 'J' hook (24.2%).

Figure 28. Bait holding efficiency of experimental hooks



Discussion

5. DISCUSSION

The results of investigation made on the existing status of fishing for the exploitation of Needle fishes along the coast of Ramanathapuram District are compared with results obtained from newly designed longline gears with four different types of hooks and are presented below:

The survey undertaken four important fishing villages of Ramanathapuram Districts such as Mundal, Velayuthapuram, Mandapam and Pamban on the fishing gears used for the commercial exploitation of Needle fishes revealed that these is no exclusive fishing gears for the exploitation of Needle fishes.

Among the four fishing villages, the effort for capturing Needle fishes by gill nets got restricted owing to operation of trawlers. Insignificant difference in the pelagic drift gill nets operated in four different fishing villages reviewed the existence of better communication between the fishermen and good knowledge sharing among them.

5.1. Catch composition of pelagic drift gill nets

The catch composition of pelagic drift gilled nets revealed that they are not selective for Needle fishes alone as other commercial important fish group such as seer fishes, barracudas mackerels and sail fishes also contributed notably to the catches of pelagic drift gill nets of Ramanathapuram district. The total catch was contributed as much as 40% by the Needle fishes and the remaining by other commercial important fish groups.

The exclusive use of ‘Vallam’ by the fishermen of Pamban in contrast to the other fishing villages may be attributed to rough sea condition which prevented the operation of FRP boat. Regarding catch obtained and effort made, the particulars for pelagic drift gill nets and the experimental longline gears could be collected for four months owing to the other research activities involved in the study such as (i) survey of existing gill net fishery of Ramanathapuram district in four different villages and (ii) designing of experimental longline with four different hooks. The study further recommends for the year round survey on the catch - effort particulars of four selected fishing villages of Ramanathapuram district selected for the study besides year round performance study on the newly evolved longline with Reversed hook.

5.2. Catch Per Unit Effort of drift gill nets in comparison with experimental Longline

The CPUE of pelagic drift gill nets operated at Mundal village from March 2015 to June 2015 revealed that Mundal is a notable fishing village of Ramanathapuram district with respect to pelagic drift gill nets fishing as evidenced through a total catch of 1, 00,870 numbers of Needle fishes and 67,223 other commercially important fishes for a total fishing effort of 4,434 fishing days (Table 11). It could be observed from the Table 12 that as much as 2, 490 Needle fishes could be captured as mean catch per month by operating the successfully developed longline with reversed hook in the present investigation against a total number of catch of 3,642 including 2,184 Needle fishes and 1,458 other commercially important fishes. The higher catch of Needle fishes in the experimental longlines with Reversed reflects high selectivity of longlines for Needle fishes. It is worth mentioning that no other carnivore’s fishes except Needle fishes were caught in any of the longline units during the study period. It is evident that at the present fishing effort of experimental longline with 1,400 hooks per vessel per day is seemed to be less efficient and yielded low catch in relation to gillnets. However, since there is a possibility of doubling the number of hooks presently operated in the experimental long line gear (2800 hooks / day / boat) with reverse hook would be a better alternative for drift pelagic gillnet being used in different fishing villages of Ramanathapuram district.

5.3. Comparison of composition of Fish catch from Drift pelagic gillnets and Experimental longlines with different hooks

Six species of Needle fishes were found to form fishery in the gillnets of Ramanathapuram district (Table 10) while only four species constituted fishery in the longlines (Table 12). In the present study *A. hians* was the most dominant species followed by *T. crocodilus* in Mundal and Velayuthapuram. Similar observations have been made by Kasim et al. (1997) who reported *A hians as* the most dominant species followed by *T. crocodilus* of Needle fishes in the drift gill net catches of Thoothukudi coast.

Catching efficiency of longline with different experimental hooks

Among the six species that showed fishery to lesser extent in the gillnets of surveyed fishing village were *S. strongylura* and *P. argalus.* These two species were completely absent invariably all the experimental longlines with four different of hooks. The reason may be attributed to the association of this two species very closer to the Islands were commercial gillnets are rarely operated and experimental longline were not operated. From the Fig. 1, which explains position of both commercial gillnetting ground and experimental longline ground, it is evident the absence of *S. strongylura* and *P. argalus* in the experimental longline catches cannot be attributed to the hook selectivity as the gear of not operated closer to Islands.

In gillnets both *T. crocodilus* as well as *A. heines* inter changeably dominated the gillnets catch. While *A. heines* dominated in two fishing ground such as Mundal and Velayuthapuram, T. *crocodiles* dominated gillnets fish catch in Mandapan in Pamban waters (Table 10). Unlike gillnets, *T. crocodilus* contributed 34 to 45 % of the longline catch (Fig. 20 to 24) irrespective of types of hook tested followed by *A. heines.* The almost uniform fishing pattern observed with the first domination by *T . crocodilus* followed by *A. heines* may be attributed to the selective characteristics of longline towards *T. Crocodiles*. It is understood *T. crocodilus* is easily get attracted to baits than *A. heines* in longline.

5.4. Catching efficiency of longline with different experimental hooks

Among the four hooks tested such as 'J' hook, 'Reversed' hook, 'Kribed' hook and' Bait holder' hook, the highest overall percentage of 7.4 % was observed for longline with Reversed hook. This shows that Needle fishes are more prone capture by hooks with its point bent towards right (Table 14 and Fig. 17). Kerstetter and Graves, (2006) reported high overall hooking rate for 'J' hooks compared to circle hook for Tuna and sward fishes which reveal the behavioural difference between Tuna and Needle fishes. Bait holder hook ranked second in term of its hooking rate with 7.3 % (Table 16 and Fig 19). This may be attributed to better hooking efficiency besides higher bait holding efficiency (Fig. 32). The poor performance by 'Kribed' hook with overall hooking percentage 4.4% stress the fact that Needle fishes are less prone to capture by hooks with its point bent towards left (Table 15 and Fig. 18).

As for as the traditional 'J' hooks concerned, its showed intermediate over all hooking rate of 5.8% (Table 13 and Fig. 16) which may be attributed its moderate ability to catch pelagic carnivorous fishes like Needle fishes. It's poor bait holding capacity (24.2%), (Fig. 32) may also be quoted for its moderate performance.

5.5 Hooking percentage of number and weight

Bjordal (1983) observed increase in average of catch of cod by 'J' hook about 17% by widening the gap of the hook .However in the present study increased catch rate was while the point of the 'J' hook was turned right by 5^0 right.

Wall et al (2001) revealed that the CPUE for circler hook was 36% higher than the EZ and hooks. However, Woll et al (2001) observed lower catch rate of Circle hooks than EZ hook with respect to Greenland halibut. The study suggests further research on the performance of Circle hooks and EZ hook in catching Needle fishes.

As revealed through hooking rate, the highest percentage of contribution in terms of number was observed for *T. crocodiles* (34 to 44%) followed by *A.heines* (26 to 34 %) (Table 18, 20, 22 and 24 and Fig. 20, 22, 24 and 26). An increased percentage contribution when the catch composition was expressed as basis of weight instead number for *T. crocodiles* in 'J' hook (Fig. 20-21) and Reversed hook (Fig. 22-23) by about 4% may be attributed to its higher weight in relation to length compared to other species.

5.6. Hooking pattern by different experimental hooks

Among them four types of hooking position such as hooking at jaw, throat, gut and foul hooking, foul hooking was found be highly prevailed in 'Reversed' hook (20%) followed by Bait holder hook(19%), J hook (17%) and Kribed hook (13%) (Fig. 28 to 32 and Table 26 to 29). There existed positive relation between general hooking efficiency and foul hooking. It indicates as the efficiency of the hook increases foul hooking also increase. As for as right type of hooking pattern concerned, hooking at jaw was found to be ideal as good not damage the fish leading to early death after getting hooked.

Among the four hooks tested ‘Kribed ‘hook rank first in terms of hooking at correct position (51%) (Fig. 30). However, it showed overall poor hooking rate of (4.4%) (Table.15). Among the other hooks, hooking percentage at jaw was found to be better for ‘Bait holder’ hook (49%) followed by ‘Reversed’ (46%) and ‘J’ hook (29%). Kumar et al. (2013) carried out experimental fishing with ‘3.5 sun Japanese tuna hooks’ for the capture of large predatory fishes in water north of Agatti Island of Lakshadweep sea. The‘3.5sun Japanese tuna hooks were mostly found to capture (as much as 27%) of the fishes by hooking at jaw. It was may be attributed to the curvature present ‘3.5 sun Japanese tuna hooks. Such ‘bending’ can also be attempted either manually or mechanically to and ‘J’ hook and efficiency of such hook in capturing Needle fishes can also be attempted. . Among the four type hook tested ‘J’ hook was found to have highest percentage of hooking at throat (33%) and gut (21%) (Table 26 and Fig. 28) which are not proper hooking locations in longline fishing, as hooking at both throat and gut may lead to high struggle and quick death of hooked fishes that my result in fast degradation in quality (Table 26 and Fig. 28). In the New Zealand commercial long line fishery, Willis and Millar (2001) reduced the hooking rate of undersized snapper at gut by attaching a 40 mm wire appendage. Similar studies can also be attempted for Needle fishes as ’J’ hook in the present study captured as much as 21%of Needle fishes by hooking at gut.

Ward et al. (2009) observed that regardless of types of hooks tested, Sword fishes were found captured mainly at throat and to a lesser extend at lip or Jaw indicating its bait swallowing behaviour. However, in the present study even in ‘J’ hook, considerable proportion of Needle fishes were caught at jaw indicating lesser bait swallowing behaviour of Needle fishes in relating to Sword fishes.

5.7. Bait holding efficiency of experimental hooks

Among the four types of hook tested the Bait holder hook was found to be most efficiencies in terms of holding the bait in the hook for about two hours after soaking. This may be attributed to the presence of two beaks like protrusions which prevented loosing of bait from the hook owing to fish baiting or due to waves or currents. It was observed bending point of the normal ‘J’ hook either to the left or right could improve the bait holding capacity from 24.2% to 27.4 % (Kribed hook) or 30.2 % (Reversed hook) (Fig .32).

Kumar et al. (2013) found circle hooks to have relatively higher bait holding efficiency (78%) than the ‘3.5 sun Japanese hook (73%) using *Amblygaster clupeoides* as bait. However in the present study using *Sardinella fimbriata* as bait, highest level of bait holding efficiency of 38.6% could be observed for ‘Bait holder’ hook and this value was 30.2% for ‘Reversed’ hook. As bait holding efficiency of a fish hook depends on many factors, further detailed investigations are required in this regard involving ‘Circular’ and Japanese hooks of optimum size for studying the bait holding efficiency while capturing Needle fishes. The hypothesis derived is as follows “Baits may easily get detached from the hooks of the pelagic long lines due to waves winds and surface currents, while keeping the branch lines with baited hooks nearer to the surface for attracting the surface dwelling Needle fishes. Regarding the bait, the lesser sardine popularly called as ‘Choodai’ (*sardinella fimbriata*) could serve as ideal bait for the capture of Needle fishes by long lines owing to its low cost and easy availability.

To conclude, among the four types of hooks tested, the overall performance of ‘Reversed’ hook was found to be better than other hooks in terms of higher hooking rate (7.4) (Table 14 and Fig. 17) and relatively higher rate of hooking at jaw which is considered to be preferable hooking location in long lines (46%) (Fig. 29).

Summary

6. SUMMARY

1. Similarity in the designs of pelagic drift gill nets operated in four different fishing villages of Ramanathapuram districts such as Mundal, Velayuthapuram, Mandapam and Pamban engaged for the capture of Needle fishes revealed good knowledge sharing among fishermen of these villages.
2. The catch compositions of pelagic drift gilled nets revealed that they are not selective for Needle fishes alone as other commercialy important fish groups such as seer fishes, barracudas, mackerels and sail fishes also contributed notably to the catches.
3. During the study period, six species of Needle fishes such as *Ablennes hians, Tylosurus crocodiles, T. choram, T. agus, Strongylura strongylura,* and *S. leiura* were found to constitute the catches of gill nets with the domination either by *A hians or* by *T. crocodiles* .
4. Sporadic occurrences of sucker fish (*Echenis naucrates*) and the cat fish (*Arius thalassinus*) could be observed during experimental fishing trials with longlines However the numbers were insignificant to report as bycatch.
5. The exclusive use of ‘Vallam’ by the fishermen of Pamban for gill net fishing in contrast to the other fishing villages may be attributed to rough sea conditions prevailing in Pamban which prevented the operation of FRP boats.
6. Operation of newly evolved longline in the present investigation with reverse hook with the effort of 2800 hooks / day / craft was found to be a better alternative to drift pelagic gillnets presently being used in different fishing villages of Ramanathapuram district.
7. During the experimental fishing, four species of Needle fishes viz. *A. hians, T. crocodiles, T.choram, S. strongylura,* were alone caught in different types of

longlines, while species such as *S. strongylura* and *P. argalus* also formed fishery to a lesser extent in the pelagic drift gill nets .

8. Absence of *S. strongylura* and *P. argalus* in the experimental longline catches could not be attributed to the hook selectivity. As these two species were found to have distribution closer to Islands which are for away from the experimental stations selected for the study.
9. Almost uniform fishing pattern observed with the domination of *T. crocodilus* followed by *A. heines* in all the four experimental long lines revealed the fact that *T.crocodilus* gets easily attracted to baits than *A.heines* in longlines.
10. Among the four hooks tested such as 'J' hook, 'Reversed' hook, 'Kribed' hook and 'Bait holder' hook, the highest overall percentage of 7.4 % was observed for longline with 'Reversed' hook indicating the fact that Needle fishes are more prone to capture by hooks with its point bent towards right (i.e. Reversed hook)
11. Significant difference could be observed between the catch rates of different species caught in different types of experimental longlines ($P<0.01$).
12. Design of pelagic longline showed significant difference between the catch rate of experimental longline different types of hooks ($P<0.05$).
13. An increased percentage contribution by *T. crocodiles* when the catch composition was expressed as basis of weight instead number particularly in longlines with 'J' hooks and 'Reversed' hook by about 4 % may be attributed to its higher weight in relation to length compared to other species**.**
14. The experiment long line fishing trials conducted for capturing Needle fishes with four different types of hooks revealed that they are hooked in different hooking locations such as 'Jaw', 'throat' and 'gut' besides 'foul hooking'.

15. Hooking at jaw was found to be ideal method of hooking as it cause leastdamage to fish avoiding early death after getting hooked. Among the four hooks tested, Kribed hook rank first in terms of hooking at correct position (51%). However, it showed overall poor hooking rate of (4.4%).
16. Foul hooking was found to be highly prevaiing in ‘Reversed’ hook (20%) followed by Bait holder hook(19%), J hook (17%) and Kribed hook (13%) . Positive relation between general hooking efficiency and foul hooking could be observed indicating the fact that foul hooking increased with increases in hooking efficiency.
17. Among the four hook types tested ‘J’ hook was found to have highest percentage of hooking at throat (33%) and gut (21%) which are not proper hooking locations for longline fishing, as hooking at both throat and gut may lead to high struggle and quick death of hooked fishes that my result in fast degradation in quality.
18. Among the four types of hook tested, the ‘Bait holder’ hook was found to be most efficient in terms of holding the bait in the hook for about two hours after soaking. This may be attributed to the presence of two ‘beaks’ like protrusions which prevented loosing of bait from the hook owing to fish baiting or due to waves or currents.
19. It is worth mentioning that simply bending point of the normal ‘J’ hook by 5^0 to the left (Kribed hook) or right(Reversed hook) could improve the bait holding efficiency from 24.2% to 27.4% and 30.2% respectively.
20. Among the four hooks tested overall performance of ‘Reversed’ hook was found to be better than other hooks in terms of higher hooking rate (7.4) and

relatively higher hooking at ‘jaw’ which is considered to be safe hooking position in long linking.

21. The lesser sardine popularly called as ‘Choodai’ (*sardinella fimbriata*) could serve as ideal bait for the capture of Needle fishes by long lines owing to its low cost and easy availability.

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