Longlines are passive fishing gears which are meant to catch sparsely
distributed large pelagic fishes like tunas, billfishes and sharks. The main
principle behind this fishing method is foraging behaviour of the targeted
fish. This fishing method is considered as highly energy efficient, eco-
friendly and species and size selective compared to other fishing methods
such as trawling and purse seining. Longline vessels accounts for
approximately 14% of the world tuna production. Majority of the catch in
terms of weight is taken by purse seines. Skipjack tuna are the major group
of tuna species landed from the world oceans in terms of quantity and
major portion utilized for canning. Skipjack tuna and yellowfin tuna
contributed nearly 80% of the tuna landed from the Indian Ocean waters.
Skipjack and yellowfin are the major tuna species landed, in the Indian
EEZ.

Hooks are considered as the heart of the longline fishing gear. Most
commonly used hook designs in longline fishing operations are ‘J’ hooks,
Japanese tuna hooks and circle hooks. Previous studies reported that a
change in hook design can be used as an effective management and
conservation tool to reduce the bycatch rate without compromising the
targeted catch. Types of bait have profound influence on the selectivity and
efficiency in the longline fishing operations. Natural baits are found to be
more superior in the catching efficiency, compared with artificial baits.
Tuna longlines has been reported to catch many other species such as marine turtles, seabirds, sharks and cetaceans apart from targeted species. Discarded catch pose serious threat to the global efforts for the conservation of already depleted marine biodiversity. Shark catch has been reported to be one of the major concerns in the longline fishing operations. Most of these bycatch issues have been effectively mitigated by certain adjustments and modifications in the fishing gear and fishing operations. Alarming decrease in the tuna stock, poor management and conservation measures, IUU fishing and bycatch of marine turtles, seabirds, sharks and cetaceans are the major bottlenecks for the further expansion of the fishing operations. The content of the thesis is organized into 7 chapters.

**Chapter - 1**

The first Chapter deals with the introduction to the topic of the study. The chapter mainly discussed (i) marine fisheries of India, (ii) fisheries in Lakshadweep, (iii) fishing boats and gears of Lakshadweep, (iv) line fishing, (v) horizontal longline fishing - world scenario, (vi) horizontal longline fishing - Indian scenario and (vii) rationale and objectives of the study. India is blessed with a coastline of 8128 km, 2.02 million square km of EEZ and continental shelf area of 0.5 million sq. km. Substantial development has been witnessed during the last decade due to the innovative and efficient fishing practices, government policies, development in the harvest and post-harvest technologies and increased demand for fish and fish products in the international and domestic markets. Lakshadweep group of Islands has one of the largest oceanic territories, contributing immensely to the fisheries sector of our country. Pole and line fishing operation for catching skipjack tuna is the mainstay of the Island economy. Apart from the pole and line fishing, other major livelihood activity is the
coconut cultivation. The most popular fishing methods in the Lakshadweep Islands includes pole and line, gillnets, hook and line, troll lines, shore seines and traps. Lakshadweep Sea has very rich resources of tunas, sharks and billfishes. Recent studies showed that there is a scope for the further expansion of capture fisheries of the high value oceanic fishery resources. Detailed description of the fishing crafts and gears are given in this Chapter. Wood is the most popular boat building materials in the Islands. Mechanisation of boats in the early sixties and extension of pole and line fishing from the Minicoy Islands to other Islands made significant developments in the fisheries sector of Lakshadweep Islands.

A detailed description on the various line fishing methods such as handlines, pole and lines, troll lines, jigging, longlines are given in this Chapter. Present scenario of the longline fishing operations carried out worldwide and India have been discussed in detail. The objectives of the present study have been:

- studies on the operational performance of tuna longline in Lakshadweep Sea
- studies on the efficiency of hooks in the longline operation
- studies of the efficiency of baits in the longline operation
- studies on bycatch in longline operation
- studies on depredation of the longline catch and hook loss encountered during the fishing operation
Chapter - 2

Chapter 2 is dedicated to the literature review in connection with the study. The available literature under (i) historical evolution of tuna longlining, (ii) longline fishing, (iii) classification of longline gears, (iv) tuna longline performance, (v) hooks and hook loss in tuna longlining, (vi) baits and bait loss in tuna longlining and (vii) bycatch issues and mitigation measures in tuna longlining have been reviewed. From the literature, it was evident that the first form of longline was originally developed in Japan. This fishing operation spread outside Japan after the Second World War. The longline operations in the Indian Ocean waters were started by the Republic of Korea and Taiwan. Today, Sri Lanka and Maldives are the two main coastal countries that have well developed tuna longline fleets in the Indian Ocean, neighbouring India. Longline is a passive fishing gear which can be operated as horizontal and vertical longlines. Horizontal longlines are also known as drift longlines used to catch sparsely distributed large pelagic fishes. The use of monofilament longlines and light sticks are some of the recent developments in the longline fishing operations. Bottom set longlines are used to catch predatory demersal fishes such as sharks, seabreams and groupers. Vertical longline are effective when the bottom conditions are rough. FAD assisted vertical longline operation has been found to be very effective in catching large tunas by exploiting the vertical range of distribution of the target species. Another modified longline is bottom vertical longline which has been designed to catch demersal fishes in rough fishing grounds.

Catch per day and catch per 1000 hooks are considered as the better indicators of apparent abundance than catch per trip. The fishing efficiency of the longlines are usually expressed as number or average weight of the
fish per 1000 hooks. The hooking rate reported for tuna in various longline fleets from the world oceans is discussed in the Chapter.

Hooks are considered as the heart of the longline fishing gear. Earlier studies confirm the effect of hook design on the catching efficiency and species selectivity in the longline fishing operations. Studies on the effect of different designs of hooks on the catching ability, species selectivity and bycatch rate are reviewed in the Chapter. Available information indicated that a shift from the ‘J’ hooks or Japanese tuna hooks to circle hooks can help to reduce the bycatch rate considerably.

Catch rates and species selectivity depend to a large extend to the type, quality and size of the bait used. The selection of the bait mainly depend upon the preference of the targeted fish, local availability and firmness to hold to the hook. The natural bait is superior to artificial baits on the catching efficiency. Squid is considered as an effective bait for longline fishing. A detailed review of previous studies carried out on catching efficiency and selectivity of various bait types is given in this chapter. Bait loss is a serious issue which hinders successful fishing operations. The bait loss vary among bait species and has been reported to increase with depth. Various factors affecting the bait loss have been discussed.

Tuna longline not only catch targeted species but also many other species which are accidently caught during the fishing operations. The non-targeted species is known as bycatch. Turtles, cetaceans, sharks and seabirds are the main species which are discarded as bycatch and pose serious threat to the biodiversity conservation programmes. A detailed review on the bycatch issues facing by the longline fishing operations is
made in this Chapter. A change in hook design, bait type, time of operation, depth of operation are considered as potential mitigation measures to reduce the bycatch rate. The bycatch issues facing the longline fishing operations and the effective mitigation measures for reducing the bycatch rate is discussed in detail.

Chapter - 3

Chapter 3 deals with the methodology adopted for the studies. Fishing area, fishing systems, fishing operations and aspects of field trials, data collection and analysis have been presented. The experimental longlining operations were carried out in the Lakshadweep Sea around Agatti Island. The fishing operations were carried out from 3 modified Pablo boats selected from the Agatti Island. All these boats were mechanised and were previously used for pole and line fishing for catching skipjack tuna. These Pablo boats were suitably modified with minor alteration in the deck layout. The alterations and modification of the Pablo boats are also discussed in detail. A detailed description and specifications of the longline gear and the method of fishing operations carried out are also discussed in this Chapter. Two different designs of hooks viz., Japanese tuna hooks and circle hooks were used for the selectivity studies. *Rastrelliger kanagurta, Amblygaster clupeoides* and *Sardinella longiceps* were the three different bait species used for studying the effect of bait type on longline catch rates and species selectivity. A general description on the methodology used for data collection and analysis has been furnished in the Chapter. Detailed description of the methodology adopted for the data collection, data analysis and statistical analysis used for the analysis are discussed in the respective Chapters. Data collected were compiled and
analysed using $\chi^2$ for the goodness of fit and ANOVA using SPSS (IBM SPSS Statistics, Version 20).

Chapter - 4

The fourth Chapter deals with operational performance of experimental tuna longlines. The main objectives of the study have been (i) to study the catch composition, size frequency and CPUE in the longline operation, (ii) to study the depth of operation and catch rates, (iii) to evaluate the effect of time fishing operation on the catch rates, (iv) to understand the monthly and seasonal variations in the longline catch rates, and (v) to study the effect of soaking time on catch rates. CPUE and various factors affecting the catching performance of experimental longline fishing operations in the Lakshadweep Sea are discussed in detail. The catch comprised of two species of tuna, six species of sharks, one species of sailfish and four species of lagoon fishes. Sharks were the dominant species contributing to the catch, followed by tunas, miscellaneous fishes and sailfishes. The size frequency of the main species caught, are discussed in the Chapter. Studies carried out to understand the effect of time of fishing on the hooking rate revealed that time of operation has significant effect on the overall catching performance with no significant change in the species composition. The fishing operations could not be carried out during monsoon season due to the bad weather conditions. The overall hooking rate was found to be high during the month of October. There was significant difference in the species composition with respect to the month of fishing operations. Shark catch ranks first when compared to other group of fishes every month. High shark catch was reported during the month of October. The results indicated that there was no significant difference in the hooking rate during pre-monsoon and post monsoon seasons. Studies were carried out to understand the
effect of hook depth on the hooking rate and species selectivity in the longline fishing operations. There was significant association between the depth of operation (35-100 m) on overall catching ability and species selectivity. Further studies at deeper depths (>100 m) are needed for establishing the effect of hook depth on the catch rates and species selectivity. Comparative studies showed that soaking time did not have any significant effect on the hooking rate of different species.

Chapter - 5

The fifth Chapter deals with studies on bait efficiency in longline operations in the Lakshadweep Sea. The main objectives of the study were (i) to understand the effect of bait type on the hooking rate, (ii) to study the effect of bait type on the species selectivity, (iii) to understand the effect of baiting pattern on the hooking rate, and (iv) to find the hook holding ability of different types of baits. Three different types of baits viz., *Sardinella longiceps*, *Rastrelliger kanagurta* and *Amblygaster clupeoides* were used for the experiments. The results indicated that there was no statistically significant difference in the overall hooking rate with three different baits. The results confirm that bait species have no significant effect on the species selectivity. The studies carried out to understand the effect of baiting pattern on the hooking rate indicated that there was no significant difference in the hooking rate between horizontal or vertical baiting pattern. Results of experiments conducted to understand the rate of bait loss in the fishing operations indicated that there was no significant difference among three different baits. Experiments carried out to understand the effect of soaking time on the bait loss rate revealed that bait loss tended to increase with soaking time. Further studies are required to be carried out with squids and artificial baits to evaluate their efficiency in the longline fishing
operations. Studies carried out to understand the effect of depth of operation on the bait loss indicated that depth of operation has no significant effect on the bait loss. Very high rate of bait loss due to scavenging, predation or partial removal by small fishes was observed during the fishing operations which may hinder the successful fishing operations.

Chapter - 6

The sixth Chapter deals with studies on hook efficiency during longline operation in Lakshadweep Sea. The main objectives of the study were to find out (i) the influence of hook design on the hooking rate, (ii) the influence of hook design on species selectivity, (iii) the effect of hook design on the retaining ability of the baits and (iv) the relationship between hook design and hooking location of the hook. Two hook designs were tested during the fishing trials viz., Japanese tuna hooks (3.5 sun) and circle hooks (14/0 non-offset). A detailed description on the experimental set up and methodology for data collection adopted for the selectivity studies have been furnished in the Chapter. The bait holding ability of two hook designs and baiting pattern were also studied. The results indicated that a change in hook design has significant effect on the species selectivity. The studies have also indicated that hook design has no effect on the bait holding ability. Experiments were carried out to understand the effect of hook design on the hooking pattern in the fishes caught. The hooking locations were categorised into two groups viz., preferred hooking and non-preferred hooking. Jaw and lip hooking were considered as preferred hooking locations and throat and deep hooking were considered as non-preferred hooking. The preferred hooking locations are considered as a mitigation measure to reduce the post-release mortality due to accidental hooking of
the untargeted species. Significant difference was noticed with regard to preferred and non-preferred hooking between the two different hook designs.

Chapter - 7

The seventh Chapter deals with studies on bycatch and depredation during longline fishing operations carried out in the Lakshadweep Sea. The main objectives of the study included (i) hooking rate and composition of bycatch, (ii) monthly variation in the bycatch rates, (iii) effect of depth on the bycatch rates, (iv) variation in the bycatch rates with respect to time of operation, (v) effect of soaking time on the bycatch rates and (vi) depredation in longline fishing in Lakshadweep Sea. Bycatch rate is the proportion of non-targeted species in the total catch that is caught in fishing operations. The studies indicated that the fishing is free from bycatch species usually encountered during the fishing operations in other fishing areas, such as marine turtles, seabirds and cetaceans. The major group of species constituting the bycatch, which need special measures for their conservation, are sharks. A total of six species of sharks, one species of sailfish and four species of lagoon fishes were caught as bycatch. The species which contributed to the bycatch were grouped into three categories viz., sharks, sailfishes and miscellaneous fishes. The comparative studies indicated that there was a significant difference in the hooking rate of different species and the shark catch was found to be significantly higher. The studies carried out to assess the effect of time of fishing operation indicated that there was no significant difference in the species-wise hooking rate between morning and evening hours. The season and month of operation had no significant effect on the species selectivity except for sailfish. High sailfish hooking rate was observed during post-monsoon and
among months, January registered higher hooking rate compared to other months. The results indicate that shark catches declined with increase in soaking time which need to be substantiated by further experiments. Observations were made to understand the rate of depredation and resultant hook loss. A few incidents of depredation, presumably by sharks, were noticed and it was not possible to identify the exact species responsible for the depredation.

**Recommendations**

i). The present study highlights the scope for developing longline fishing operations for catching under-utilised large pelagic fishes from the Lakshadweep Sea and indicates the possibility for diversification of fishing activities from the conventional pole and line fishing which targets skipjack tuna to longlines targeting large high value yellowfin tuna, with a precautionary approach.

ii). The existing fishing vessels used for pole and line fishing can be effectively modified for the operation of longlines. It is recommended that a few vessels from each Island may be modified for longline operations targeting large pelagic fishes.

iii). The locally available bait species can be used effectively for the longline operations in the Lakshadweep Sea. However, attention needs to be given for the development of alternate baits including artificial baits, for longlining.

iv). The use of circle hook can be promoted to minimise injuries and hence reduce the post-release mortality of unwanted species and also to reduce the bycatch.
v). Insufficient infrastructural facilities such as cold storage and ice plants and transportation facilities are major constraints for a successful value chain based on longline landings, which need to be addressed in Island fisheries development schemes.

vi). Mother vessel-catcher vessels concept will be helpful to overcome the logistical issues which will ensure the proper storage, processing and transportation of the fishes caught.