SUMMARY AND RECOMMENDATIONS

Fishing hooks were in use from time immemorial. Fishing hooks used in the ancient days were made of wood, bones and sea shells. They were later succeeded by copper (Cu) and bronze hooks. The present day fishing hooks are made from high carbon steel wire. Fishing hook is considered as a simple, easy to operate, economically viable and efficient fishing tool. And they form the indispensable part of any hook and line fishing system. Hook and line fishing is considered as a highly selective low energy fishing method and is well suited for the exploitation of sparingly distributed fishes in a sustainable way. Moreover, the fishes captured by hooks and line fishing are of relatively large in size and of better quality. Hook and line fishing is becoming increasingly important in the Indian fisheries also, especially in the harvesting of under exploited tuna resources in the Indian Exclusive Economic Zone (EEZ). Despite their importance in fishing, very few studies have been conducted on fishing hooks. Baranov (1976) and Kenchington and Halliday (1994) have reported that there is a scarcity of research work on the different properties and quality of fishing hooks. Hence this study has been undertaken with the objectives of (i) evaluation of current status of availability and cost of fishing hooks in India, (ii) evaluation of physical and mechanical properties of different types and sizes of hooks, (iii) standardization of the hook numbering system, (iv) correlation of mechanical strength of fishing hooks with the chemical composition, (v) evaluation of corrosion resistance of hooks and probable corrosion protection/prevention measures and (vi) comparative evaluation of fishing performance of hooks.
The content of the thesis is organized into various Chapters and a summary of each chapter is given below:

The first chapter gives a general introduction to fishing hooks, and their importance as fishing tool and related problems. The background of the topic and the significance of the study are highlighted. The importance of hook and line fishing as a low energy fishing method and as a selective fishing gear is brought in this introductory chapter. This chapter also covers the present status of hook and line fishing from the world and Indian perspective. The importance of hook-based fishing methods such as tuna fishing, sport fishing/recreational angling are also discussed. The history of fishing hooks, hook terminology, hook manufacturing process, hook types, their classification and hook numbering systems are explained. The evolution of fishing hooks from the pre-historic ones to the present day metallic hooks is also discussed. Different parts of fishing hooks, their terminology and morphological characteristics are also dealt in detail. The manufacturing process of modern metallic hooks, their classifications based on shape, number of bends, point and barb are also discussed. Different hook numbering systems and their comparison is given. The aim, scope and the objectives of the research work on fishing hooks is also detailed.

The second chapter deals with a detailed review of work carried out by different researchers on the physical, mechanical and chemical properties, corrosion resistance and fishing performance of fishing hooks. Various aspects relating to fishing hooks collected through detailed literature survey are discussed in detail. This review brings out the gaps in the research work on fishing hooks.
The materials and methods followed in this study are detailed in the third chapter. Area of the study, sample collection methods, procedures followed for the measurement of different properties of fishing hooks and sample preparation procedures for different analysis are described. Experimental procedures for the evaluation of mechanical strength, chemical composition, corrosion resistance and fishing performance of the fishing hooks studied are also outlined. Statistical methods followed for the analysis of the data are also given. There were four distinct systematically planned phases in this study. In the first phase, a detailed review of the literature on studies done on fishing hooks was undertaken. In the second phase a preliminary survey was conducted to assess the availability and present status of fishing hooks and their use in India. In third phase, different types and sizes of fishing hooks were collected form different parts of the country, covering all major fishing centres. The fourth and final phase involved analysis of different parameters of the collected hooks in laboratory and evaluation of their performance in actual field.

The current status of availability of different types fishing hooks and their prices in India are detailed in fourth chapter. Selection of sample and data collection centres and methods followed in sample and data collection are dealt in detail. It was found that a large variety of fishing hooks, of varying quality and price, manufactured under different brands, both imported and Indian, and unbranded locally made are available in India. Round bent, Kirby, Limerick, Circle hooks, Tuna hooks and Treble hooks are the major commercial types of fishing hooks available in India. A total of 282 types of hooks of different size/number, coming under 7 imported brands, 7 Indian brands and 4 unbranded Indian hooks were collected as part of this study. The availability of important Indian and imported brands and unbranded indigenous hooks and their prices are discussed. The prices of imported brands of hooks were found to be double that of Indian brands and three fold that of unbranded locally made hooks. A data base
developed on the availability and cost of fishing hooks in India as part of this study is presented.

The fifth chapter deals with the results and discussion on the physical and mechanical properties of fishing hooks. Physical and mechanical properties of all the 282 denominations of fishing hooks collected were studied, analysed and catalogued. A data base on the physical and mechanical properties was made as part of this study. No significant variation was observed among different types of hooks tested with respect to dimensional characteristics such as total length, hook wire diameter, gape and bite. However, considerable variability was noticed in their resistance towards unbending viz., deformation equal to bite length. The physical properties and the mechanical strength of fishing hooks show that indigenous fishing hooks are comparable to imported fishing hooks in terms of physical and mechanical properties. Since unbending test results were in conformance with the mechanical strength performance observed in the field, it is concluded that unbending test could be used for the selection of most suitable fishing hook from different types of hooks as per the strength requirements. It was found that there is a highly positive correlation between the hook number and the gape width of hooks (P=0.01). Similarly, there is a positive correlation between the weight and wire diameter of hook with their unbending force. A new standard specification for fishing hooks and a new hook numbering system based on gape width was developed as an outcome of this study.

The studies on chemical composition of fishing hooks are presented in the sixth chapter. Comparison of chemical compositions of indigenous unbranded hooks with that of indigenous and imported branded hooks was carried out. The composition of the hooks of different brands was approximately same with same elemental makeup. The samples contained 0.75 to 0.76 wt. % of carbon (C). The correlation between
different elements with the mechanical strength of fishing hook is also analysed and the results are presented. Significantly high positive correlation was found between the carbon content and the unbending resistance of the hooks studied (r=0.99, P<0.05). Though the chemical constituents of the hooks studied were approximately same, significantly large amounts of lead (Pb) was present in unbranded indigenous samples.

The outcome of the corrosion resistance studies of fishing hooks is discussed in seventh chapter. Corrosion is the most important factor, which affects the service life of fishing hooks. Corrosion of metallic fishing hooks is a perpetual problem as they are operated in highly corrosive environment like the seawater. Results showed that tinned and nickeled hooks (coated with nickel) are superior in corrosion resistance to that of polymer coated hooks. On accelerated corrosion analysis, tinned hooks recorded a mean weight loss of 5%, whereas the blue finished hook (coated with blue coloured polymer) showed significantly high weight loss of 20% by weight (P<0.05). Among large sized shark hooks (hook number 1, ‘J’ style fishing hooks), Indigenous unbranded hooks found to be better in resisting accelerated corrosion tests than imported and Indian branded hooks. It was found that rigging snood wires to the fishing hooks significantly increases the corrosion rate. The corrosion rate of hooks with snood wire was 109.316 mpy and that of hooks without snood wire was 60.21mpy. Treating fishing hooks with Cerium (Ce) was found to resist corrosion at the initial phase of accelerated corrosion tests i.e., the first 100 h of exposure, which is equivalent to about 1 year exposure in seawater. However, its effect is found to be insignificant in resisting corrosion when exposed to 300 h of salt spray. Application of lubricant oil and fish oil was found to be very effective in preventing corrosion in fishing hooks exposed to salt spray.
The fishing performance of different types of hooks is discussed in the eighth chapter. In the first part, hooking rate of imported branded hooks was compared with that of Indian branded hooks. The hooking rates were 14.18% and 12.41% for the imported and Indian hooks respectively. However statistically there was no significant difference in hooking rate of the two types of hooks ($P > 0.05$). The location of hooking and the severity of wound were also studied. World over, circle hooks are being promoted as a responsible fishing gear. But very little information is available on the fishing performance of circle hooks in the Indian context. Considering this, fishing performance evaluation of circle hooks with that of ‘J’ style hooks was also carried out. Difference in hooking rate, hooking location and severity of wound in circle hook and ‘J’ hook are discussed. The circle hooks showed significantly lower ($P < 0.05$) hooking rate compared to the “J” hooks. The circle hooks showed a hooking rate of 8.65% while the J-hook had a higher hooking rate of 15.56%. There was a significant difference between circle hooks and ‘J’ hooks in terms of hooking location ($P < 0.05$). More fishes were lip hooked with minor injuries in circle hooks. This feature of the circle hook makes it an ideal hook type that can be used for catch-and-release (recreational) fisheries.

The salient findings of the study are summarized below:

1. Prepared data base on availability, cost and properties of fishing hooks, of different size specifications available in India.
2. A data base on the physical and mechanical properties of different types of hooks was made which can be used in further studies on fishing hooks.
3. Standard specifications for the different sizes of hooks viz., hook number, gape, hook wire diameter, length of the hook, bite length, weight and unbending load worked out for hooks of different sizes based on the physical and mechanical properties of 282 types of
hooks of different brands, size/number and material that were collected as part of this study.

4. A new system of hook numbering based on gape width was developed incorporating merits of conventional marine numbering system and the Indian Standard specification for fishing hooks.

5. Indian hooks were comparable in their physical and mechanical properties with that of imported costly brands.

6. The unbending test method employed to analyse the mechanical strength of fishing hook in this study was in agreement with the actual performance by the fishing hooks in the field and this test could be effectively used to evaluate mechanical strength of fishing hooks.

7. There was significant positive correlation between the carbon (C) content and the unbending resistance of the hook samples studied.

8. Indigenous hooks were found to be better in resisting corrosion than imported hooks.

9. Tin (Sn) coated hooks were better in resisting corrosion in contrast to blue polymer coated hooks and were more suited for marine applications.

10. Attaching snood wires to the fishing hooks significantly increased the corrosion rate of hooks. The enhancement of corrosion rate of hooks rigged with snood wire was found to be due to the combined effect of bimetallic corrosion and retention of corrosive medium in crevices at the point of attachment.

11. Treating fishing hooks with cerium (Ce), fish oil and lubricant oil were found to be very effective in controlling corrosion.

12. There was no significant difference between Indian hooks and imported hooks in fishing efficiencies, hooking locations and severity of wounds. In experimental fishing study, significantly more number of fishes were lip hooked with minor injuries in circle hooks than in ‘J’ hooks.
In short, it was found that indigenous fishing hooks are comparable with imported hooks in terms of mechanical strength, corrosion resistance and material composition. They fared very well in fishing performance studies also. Results from the present study have implication in the design, fabrication and operation of different types of hook and line gears. This would help in the selection of appropriate hook with required properties. Besides, the results of this study also have other implications like substitution of imported hooks with indigenous hooks, which can save about Rs. 5.83 crores annually in foreign exchange. Results from the present study also have significance in the development of newer hook designs and patterns.

9.1. Scope for further studies

It is evident from the present study that there is a vast scope for further research work on fishing hooks, especially giving emphasis on their physical and mechanical properties, introduction of newer materials, coatings, corrosion resistance in actual field environment, design improvements and fishing performance etc. These studies should take into account the changes in the modern manufacturing methods, materials and products with an objective to facilitate easy selection of the right hook for fishing purposes.

The important suggestions for further studies are listed below:

1. Application of new composite materials and alloys in manufacture of hooks with improved mechanical properties and corrosion resistance can be studied.
2. The effect of corrosion on the tensile strength properties of the hooks can be taken up.
3. A detailed evaluation of the corrosion resistance of hooks in actual field environment can also be further studied with emphasis on suitable corrosion control methods.

4. Studies can be undertaken to prevent/reduce the higher corrosion observed in fishing hooks tied with snood wire. This could be prevented by using non-corrosive rings or non-metallic alternative materials which will avoid/minimize the crevices at the point of attachment and would also avoid the bimetallic corrosion.

5. There is scope for further exploring the effect of lubricant oil and fish oil treatment on corrosion prevention and fish behaviour in the filed condition. It is assumed that there would be certain favorable effect in attracting fish towards the hook when fish oil is used.

6. Large scale fishing performance studies with different sizes and types of fishing hooks in the Indian context can be taken up. Studies to find out optimum hook sizes/gape width for different fish species can also be taken up.

7. Detailed studies on the performance of circle hooks in Indian waters needs to be taken up focusing on their ability to reduce gut hooking and by-catch. Their use in catch-and-release (recreational) fisheries needs to be further explored. Such studies would aid the decision makers in implementation of regulations related to fish welfare and sustainability.

9.2. Recommendations

Based on the present study the following recommendations are put forwarded:

- Indigenous branded and un branded hooks may be promoted against the costly imported hooks without compromising on performance.
The standard specifications worked out for fishing hooks may be implemented for uniformity in quality of hooks produced by different manufacturers. Competent authority may be authorized to monitor the quality standards of fishing hooks sold in the market.

The new hook numbering system may be adopted which gives more sensible idea about the size and properties of a hook.

Tinned hooks may be preferably used in marine conditions owing to their better salt tolerance than the blued hooks.

More emphasis should be given to corrosion control measures when metallic snood wires are tied to fishing hooks.

Simple measures like treatment with cerium (Ce), application of fish oil and lubricant oil may be used for effective control of corrosion in hooks.

In recreational angling or catch-and-release fishing (sport fishing) fast corroding fishing hooks may be promoted over corrosion resistant fishing hooks. A fast corroding hook will improve the survival rate of released fish in those cases (When a fish is ‘deep hooked’ where it is very difficult to remove the hook without seriously injuring the fish) wherein the fish has to be released with the hook inside the body.

Use of circle hooks may be promoted in Indian waters to reduce severe injury to the fishes caught, especially in ‘catch-and-release’ recreational fisheries.

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