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Climatic Variability and Diversification in Fishery Livelihood- a Case Study of Puffer Fish Fishery along South Eastern Arabian Sea

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ABSTRACT

Impacts of climate variability and resulting changes in aquatic ecosystems have caused a rapid shift in the spatial distribution of species. This shift forces diversification in livelihood options among the fishers. Many resources are emerging as new fishery which could be the indicator of changes in the food web and ecosystems as a whole due to climatic variability coupled with changes in exploitation patterns. One of the emerging non-conventional fishery resources is the pufferfish which is exploited along the Karnataka coast, south-eastern Arabian Sea. A decrease in mean trophic level due to the increased fishing effort or climatic variability resulted in the removal of top-level predators leading to the rise of mid-level carnivores like *Lagocephalus inermis* in the Arabian Sea. A substantial increase has been noticed in the landing of pufferfish in trawl along with Karnataka since 2007 and has resulted in diversification of the employment in the fisheries sector. The pufferfish brought to the shore by trawlers are degutted, de-skinned, and cut into small pieces, and packed for transportation to other parts of the country. This sector has provided employment to about fifty women in each landing center, and each of them earns INR 200-300/day. The matured eggs collected from the fish are sold at a price of INR 10/kg. In addition, the trade of salted and dried fishes generated employment to an additional 50 women in the sector. This diversification has given more employment opportunities, especially to women. The study conducted revealed an increase of 1.5 fold from landing to the final product. Diversification of the livelihood to cope up with the changes in the fishery is an adaptation measure to combat species shift associated with climate change and climatic variability.

INTRODUCTION

Climate change has become one of the most important driving factors for changes in the marine processes and ecosystem. Considerable changes have been reported in the phenology, abundance and distribution of marine species (**Alabia *et al.*, 2015; Poloczanska *et al.*, 2016**). Significant changes can be seen in the physical and the chemical properties of the world oceans due to anthropogenic activities which have adverse effects on marine species (**Halpern *et al.*, 2008; Pörtner *et al.*, 2014**). Multiple drivers can influence the response of the species abundance, distribution, physiological tolerance, and preference of both food and habitats. Many marine organisms comprise complex life cycles, having distinctive stages dwelling in entirely different habitats wherein they are exposed to variable environmental conditions and sensitivities to climate change (**Rijnsdorp *et al*., 2009**). Evidences have proved that there are threshold limits of different species and ecosystems to tolerate changes in climatic conditions resulting in altered function and structure of the ecosystem (**Smith, 2011**).

The effect of climate change coupled with human activities such as overfishing, pollution and eutrophication influence ocean conditions. Studies have shown that fishing pressure and climate change play a key role generating a top down trophic cascades in the marine ecosystem (**Heithaus *et al*., 2008**). Trophic cascade as defined by Encyclopedia Britannica is an ecological phenomena which is triggered by the increase or decrease of the population of top predators resulting in consequent alterations in the food chain causing drastic changes in the structure of the ecosystem (**Mohamed *et al*., 2013**). Significant decrease in the population of top predators has resulted in the increase in meso-predator and invertebrate predation population in the ocean (**Baum *et al*., 2009**). **Mohamed *et al.* (2013)** detected signs of the onset of trophic cascading in the Arabian Sea resulting in the sudden increase in the biomass of puffer fishes since 2007. Collapse in cod fishery and other benthic fish community of Nova Scotia Coast, and Canada is also attributed to trophic cascading (**Frank *et al*., 2005**). Increase in meso-predator and invertebrate population can have serious implications on the socio-economics, livelihood, conservation and management strategies. The effect of climate change is most pronounced on the coastal populations than their inland counterparts because fishing is the primary source of livelihood among the fishermen community of the coast. Geographically, coastal habitats are only 8% of the total surface area of the earth, accommodating 70% of the human population and contributing 90% to the total fish catch (**Salim, 2019**). In addition to climate change, both the global demand for marine protein and the increasing population pressure are constantly reshaping the coastal habitats and increasing the vulnerability of the global coastal populations. Thus, climatic variability and trophic cascading force the fishers to adapt and diversify their livelihood options. This paper focused on the diversification in fishery livelihood along the Karnataka coast in South-east Arabian Sea where puffer fish has emerged as a fishery resource in recent times which is mainly attributed to trophic cascading and climatic variabilities. The study undertaken would help in understanding the fishery processing and trade of this emerging resource along the Indian coast.

MATERIALS AND METHODS

The study was conducted in Mangalore fishing harbour (N 12° 51' 33.10" E 74° 50' 02.34") in Karnataka, a major fish landing centre where the majority of the trawl catches along the coast are landed. The puffer fish, *Lagocephalus inermis*, are caught by trawlers only that landed in this fishing harbour. This is the only harbour in India where landing and processing of puffer fish is taking place. As it is an emerging fishery along Karnataka coast, an average of approximately 3000-5000 tonnes are landed every year.

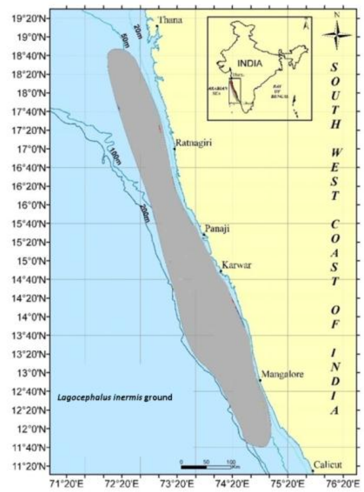

Fig. 1. A map for the study area

1. Case study

To understand the dynamics of the fishery and utilization, a case study was utilized for the collection of data (**Eisenhardt, 1989**). This approach provided an opportunity to study in detail the social processes and relationships and also helped to gather ground truth data using questionnaires and interviews (**Yin, 1984; Eisenhardt, 1989**).

2. Data collection

A combination of quantitative and qualitative methods were used to gather data for the study. Qualitative methods (e.g., structured questionnaires) gave information of the context and qualitative methods [e.g., focused group discussions (FGDs), key informant interviews] gave a detailed and ground truth data (**Nightingale, 2003**). This study was carried out for a period of two years from 2017-19. The fishers involved with puffer fish fishery alone have been interviewed for data collection. A total of approximately 250 people are involved in this industry for the processing and the trade of this fish. A total of 212 respondents were selected through a random sampling method. Out of that, 55 boat crew members were interviewed through structured questionnaires. To gather information regarding the processing, women FGDs were done separately as only women were involved in post-harvest and processing sector. A total of 10 FGDs, each consisting of 15 members were conducted for the women involved in cutting, salting and drying. Lastly, the key informants were the traders involved in the trade of puffer fish. A total of 7 traders were interviewed for the study. The questions asked included both open and close ended questions.

RESULTS

1. Fishery

A total of 1500 trawlers are operating at Mangalore fishing harbour. An average of 100-150 boats are landed every day in which 50% are involved in this puffer fish fishery. Puffer fishes were abundant in a depth range of 20-100m. Multiday trawlers with 4 fishing days brought this resource with an average of 5 trips per month. The fishes were caught mostly during the night. Maximum puffer fishes landed during November to January with an average catch of 15 tons per trip. The boat owners sold the catch at a price of INR 1600-1800/crate with each crate weighing approximately 50-65 kgs. In each trip, about 200-240 crates are landed during the peak season (November to January) of the fishery.

2. Market Structure and distribution of fish

The fishes were landed by trawlers mostly in the early morning hours and then they were auctioned in the landing centre by the trawl boat owners. The mode of payment was mainly cash and then they were taken by the merchants for further processing. The fishes were bought by the fish merchants and fish drying centres. The fish merchants degutted and de-skinned the fish, and then the viscera (excluding ovary) was sold separately to the fish meal factories ,while the ovaries were collected and traded separately. There is no institutional training given to the fisher folks for the processing of puffer fishes, but traditional knowledge are put into practice. This is an opportunistic fishery where the fishermen start exploiting an emerging resource on a commercial scale. However, no fatalities have been recorded from the Indian coast due to the consumption of this species, and hence, it is assumed that *L. inermis* after the removal of skin, head and viscera would become non-toxic. However, efforts are being made by various institutes for studying the toxicity of this species. During the study, it was found that puffer fishes have no local demand as other species which are traditionally consumed. Therefore, puffer fishes are abundantly available and transported to the remote areas of the neighbouring states of Tamil Nadu and Kerala. The structure of the market is given below in Fig. (2).

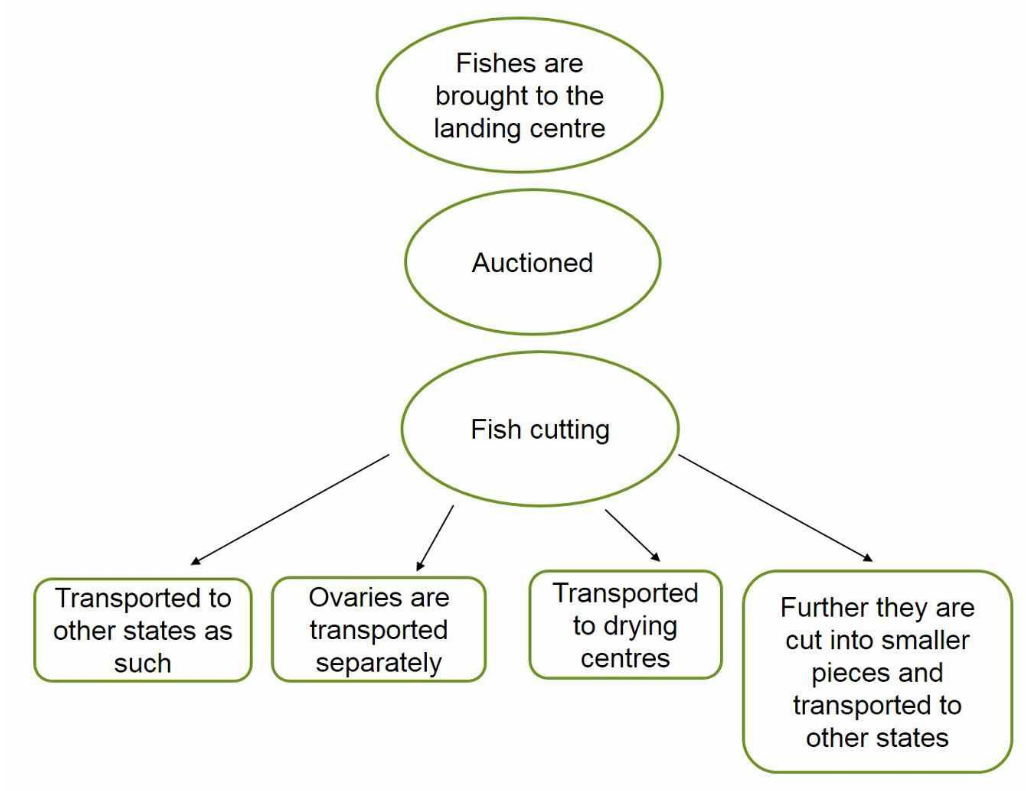

Fig. 2. Flow chart depicting the market structure of Lagocephalus inermis fishery

3. Processing

The processing of puffer fish is mostly done in the harbour by women from the neighbouring state of Tamil Nadu earning about INR 500/day during the peak season (Fig. 3). Each fisherwomen deguts approximately 5-10 crates in a day depending on the landings and each crate contains approximately 50 kgs of fishes. These fisherwomen are generally involved in cutting other commercial fishes which are bought by the customers from the landing centre. The degutting and processing of the puffer fish provide an additional source of income to them. This puffer fishery has helped in diversifying their livelihood opportunities and they are benefitted by the enhanced daily income. In the harbour, there are few selective merchants who deal with the trade of puffer fishes. After the fishes are bought by the merchants, the crates are taken to designated areas in the landing centre for processing. The head and gut are then cut using a special sickle and the skin is peeled. A special skill and technique is required to use the sickle for degutting the fish. The ladies are also provided with hand gloves made of canvas material to ease fish handling. The skin, head and viscera are sold off to the nearby fish meal factories. A part of the processed fish is bought by the fish drying centres where they are salted and sun dried and then transported. To salt 1 kg of puffer fish, 1 kg of salt is used. In drying centres, the fishes are bought at a price of INR 25-40/kg, and then salt cure and dry fishes and are sold at a price of INR 70-100/kg (Fig. 4). The eggs are separated from the viscera during processing and are sold separately at a price of INR 10/kg, and about 300-1000 kgs of eggs are procured per day depending on the season of the fishery. The eggs are salted after buying, and (from the information gathered) they are transported to Gujarat.

The processed fishes are mostly transported to different parts of Tamil Nadu like Tiruppur, Salem, Madras, Erode, Katpadi, and Coimbatore since there is no value or acceptance with respect to this fish in the local market. In Tamil Nadu, they are mostly bought and served in restaurants and bars as Indian fish delicacies such as *tandoori, tikka, kebabs, pakodas* etc.

Fig. 3. Women engaged in processing of *Lagocephalus inermis* in Mangalore fishing harbour, Karnataka, India

Fig. 4. Salted and sun-dried Lagocephalus inermis

4. Trade

When assessing the value of the puffer fish, it was found that there is many fold increase in the price of processed fish compared to the price of the fish landed. In the landing centre prior to processing, the cost of the fish is approximately INR 30 /kg. After beheading and degutting, the price increases by 1.5 fold when considering the dressing loss of 30-40%. The viscera and head are traded separately at price of INR 15-20/kg and it is bought by the local fish meal plants which are used for making poultry feeds. It was found from the interviews that the ovaries of the fish are separated, salted and sold at a price of INR 10/kg to the pharmaceutical industries, however no information is available on its utilization.There are three ways of trading the flesh of this fish. In the first instance it is sold at a price of INR 60/kg and in the second one, it is further washed, cleaned, cut into smaller pieces, packed and then sold at a rate of INR 80-100/kg (Fig. 5). While, in the third way, the flesh is salted at a ratio of 1:1 and stored till the dry fish is demanded. When the demand exists, the fishes are taken out and sun dried for 3 days, packed in gunny packs and sold at a price of INR 70-100/kg. All the products are transported to the neighbouring states since there is no local demand for this fish except for few fisher folks from Tamil Nadu who locally consume it.

Fig. 5. Processed and packaged flesh of *Lagocephalus inermis*

DISCUSSION

Fisheries play a pivotal role in the lives of the coastal community through food security, generation of employment and upliftment of the rural populations. Studies have shown that diversification in livelihood options reduces fishing pressure on commercial stocks (**Brugère *et al*., 2008**) and also helps fishermen in coping up with the changing fishing conditions (**Jul-Larsen *et al*., 2003**). Along the Karnataka coast, similar diversification is observed and one of the best examples is the emergence of *L. inermis* as a targeted fishery. Previously, *L. inermis* was treated as a menace and discarded in the sea after being caught. It has been reported that from 2007, the fishery of *L. inermis* has commenced along Karnataka coast (**Thomas *et al*., 2007**). The catch revealed some fluctuations over the years and due to the increasing demand for *L. inermis*, it has become a targeted fishery. There is a steep rise in the economic value of the resource since its commencement (**Saha *et al*., 2019**); a five-fold increase has been observed in the price compared to its emergence in 2007. Although there is a possibility that this fishery is happening elsewhere in the world, Karnataka is the only region along the Indian coast where *L. inermis* fishery has been documented (**Saha *et al*., 2019**).

Evidently, fish marketing in India is witnessing several intermediaries from the landing centre to the consumers. The major intermediaries are auctioneer, wholesaler, retailer and vendor. At each stage, while the fish is passing through these intermediaries, the value is added (**Bishnoi, 2005**). In the present study, similar marketing structure was observed. Except for puffer fish, all other commercial species are transported to markets or processing centres for further processing and value addition. However, the processing of the puffer fish starts right in the landing centre itself where it is degutted and de-skinned before being transported to other parts. It was observed that, *L. inermis* is the only species where partial processing is done in the landing centre.

The consumption of puffer fishes, which are known for its presence of tetrodotoxin are limited to south-eastern Asian countries. Review of literature revealed that no information on the processing of puffer fish, *L. inermis* is available. Puffer fish processing is more common in Japan, where it is a well-established commodity in seafood industry. There are different types of puffer fishes and not all species of puffer fishes are toxic. In Japan, the processing of puffer fishes is done very quickly so that the toxin would not penetrate into the flesh. This is done only by licensed chefs who obtain it after undergoing special training and official examination (**Nader *et al*., 2012**). In the current study it was found that, no such strategy is being followed and they are cut open directly by the fisherwomen in the landing centres.

Reports on the toxicity of *L. inermis* are available from elsewhere. This species is known to be highly toxic in Japan (**Nagashima *et al.*, 2012**). From the east coast of India the *L. inermis* has been reported to be mildly toxic (**Ghosh *et al*., 2004**). Even though *L. inermis* found along the west coast of India is being commercially exploited and exploited, no fatality has been reported till now with respect to this species. However, since the toxicity of puffer fish depends on various factors, such as species, geographical location, season etc. (**Homaira *et al*., 2010**), it is important to formulate monitoring strategies for the consumption of this species to ensure safety of the consumers. It was reported that, puffer fishes don't produce the toxin, it is rather being accumulated from the food chain (**Arakawa *et al*., 2010**). The main producers of tetrodotoxin are bacteria belonging to different genus (**Yan *et al*., 2005**). The non-toxic nature of the *L. inermis* along the west coast of India (from 0 fatality report) could be assumed that the TTX producing bacteria along this coast are not found in sufficient quantity to induce toxicity in *L. inermis*. Continuous monitoring of *L. inermis* for toxicity is required, because with the availability of the bacteria in the ecosystem, this species has the potential to become toxic in future. It is very important for the Indian food sanitation authorities to monitor and assess the toxicity of the puffer fishes which are consumed by the coastal population, mostly the fishermen, from the standpoint of food safety.

Processing of fishes is done in order to increase the market value and gain more profit from the catch. In general, processing of fishes is done in companies, fish meal plants or drying centres, except for this species. Another important observation was that all parts of the fish are being traded separately. Apart from flesh, the head, skin and viscera are bought by the fish meal plants, and ovaries are salted and sold separately. Thus, this species is fully utilized and none of the parts goes as wasteage. Consequently, value is added at each stage and increases by many folds at the end stage. This fish is particularly common in the southern coast of India, and exploited commercially along the Karnataka coast only. Due to the absence of local demand, all the catches are transported to the neighbouring states.

The changes in the environment is drastically affecting the species composition and the people who depend on these natural resources (**Reilly *et al*., 2003**). The research mainly focused on climate change and the resources (**Parmesan, 2006**) and less attention was directed to how the users of these natural resources respond to these changes (**Barnes & Dove, 2015**). The present case study on the emergence of the puffer fish resources and its utilization by the fishers is an example of the diversification done by fishers to cope up with the changes to utilize them as alternate source to enhance their livelihood. The distribution and changes in species composition in the fishery can be attributed to the fishing pressure, and climatic variability. However previous studies have inferred that the emergence of this species could be attributed to the trophic cascading happening in the Arabian Sea (**Mohamed *et al*., 2013**). Due to the change of fishing composition, stocks of the previously available commercial species are being replaced by non-conventional resources. The non-conventional resources are increasing in numbers due to the abundance of space and food, and the lesser threat to mortality due to the absence of their predators and most importantly due to being resilient to the changing environmental conditions. The exploitation of this resource and its utilisation by the fishers is an adaptation to the changing fishery scenario which helps to reduce the impact on trophic structure and further improve the economy of local fishers.

CONCLUSION

Fisheries and allied sector provide livelihood for coastal people and the climate change affects both the fishery resources and the people who depend on it. Global studies are conducted on the climatic changes and the adaptation and mitigation measures done to combat the issue. For a sustainable fishery, it is imperative to understand the mechanism of interactions between global change and localized disturbances for which regional responses including the socio economic changes has to be studied. The present case study spotted light on the diversification of the fishers to the changing fishing scenario. The value addition done for the resource also shows the adaptive capacity of the fisher communities. For better understanding and management of resources in the ecosystem, inclusively with respect to the changes in species composition or species shift due to climate change, long term monitoring programs need to be formulated.

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