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Policy framework and development strategy for freshwater aquaculture sector in the light of COVID-19 impact in Andaman and Nicobar archipelago, India

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ABSTRACT

The present study was aimed at understanding the impact of COVID-19 pandemic related restrictions on the freshwater aquaculture sector of Andaman and Nicobar archipelago (ANI). We interviewed the freshwater fish farmers (N = 211) covering all the three districts (North and Middle, South Andaman, Nicobar district) of the archipelago. The results revealed the critical issues faced by the stakeholders such as fish seed unavailability, limitations in feeding, insufficient logistical support, movement related restrictions, lack of inputs, manpower shortages, etc. as the important constraints during lockdown. Our surveys also revealed that there was a significant reduction in the income of the farmers post COVID-19 outbreak (p < 0.001). Possible reform strategies that could promote the sector development and resilience were outlined to recover from the COVID-19 impacts. The study also highlights the significance of effective networking among the stakeholders and necessary preparedness measures to be undertaken by the fish farmers to deal with the exigencies. The study also recommends a policy framework to strengthen the planning and management of freshwater aquaculture sector towards the path of sustainability.

1. Introduction

The COVID-19 pandemic has caused serious worldwide health issues (Stephens et al., 2020; Reid et al., 2021) enforcing lockdown and movement restrictions (Waiho et al., 2020; Fakir and Bharati, 2021) which resulted in extensive socio-economic impacts (Bennett et al., 2020; Russo et al., 2021) and politico-economic crisis (Ploeg, 2020; The Economic Times, 2020) as the side effects. The COVID-19 pandemic has seriously affected the livelihood of farmers and fishers involved in aquaculture and fishing activities across the globe (FAO, 2020, 2021; Jamwal and Phulia, 2020; Kumaran et al., 2021; Rafiquzzaman, 2020; Senten et al., 2020; Waiho et al., 2020; Islam et al., 2021; Love et al., 2021). Fisheries related activities were severely affected due to the COVID-19 related lockdown in India (Gopal et al., 2020; Avtar et al., 2021; Sara et al., 2021).

Andaman and Nicobar is a tropical archipelago of India located in the Bay of Bengal which comprises of 572 Islands and well known for their biodiverse nature and proximity to South-East Asian countries such as Myanmar, Thailand and Indonesia (ANDFISH, 2005; Kiruba-Sankar et al., 2019). Freshwater fish farming remains the most active fish farming sector in the Islands than the abundantly available marine fishes due to the availability of candidate freshwater fish species and freshwater fish preferring local populace with good market demand (Kiruba-Sankar et al., 2018, 2021). Indian Major Carps (Catla catla, Labeo rohita, Cirrhinus mrigala), Red bellied pacu (Piaractus brachypomus), Sutchi catfish (Pangasianodon hypophthalmus) are some of the most common freshwater fishes cultured by the farmers in the Islands (Kiruba-Sankar et al., 2021). The Islands also rely upon the mainland Indian port cities such as Chennai and Kolkata for procurement of essential goods and need-based aquaculture inputs. The declaration of COVID-19 related lockdown in India since March 2020, has severely hampered the freshwater aquaculture sector of the archipelago. The period of lockdown and related restrictions also coincided with the breeding season of Indian Major Carps (C. catla, L. rohita and C. mrigala) during June to August being the period of Southwest monsoon. The disruption in the entire chain of breeding and culture activities has seriously affected the dependent fish farmers. With this background, this article outlines the
constraints and economic impacts faced by the fish farmers due to COVID-19 restrictions and also attempts to provide solutions to promote resilience with a decision-support framework for augmenting the growth of freshwater aquaculture sector in the archipelago.

2. Materials and methods

2.1. Identification of respondents

A checklist of the baseline data of freshwater fish farms was generated under the National Surveillance Programme for Aquatic Animal Diseases (NSPAAD) project. The baseline information was used to identify the respondents for interview along with their pond details such as size of the pond, geographical location, etc. Fish farmers (N = 211) were interviewed through a structured questionnaire (supplementary data) through telephonic mode considering the restrictions and precautionary measures imposed from time to time by the local administration. The interviews were conducted from October to November 2020. Respondents were primarily briefed on the purpose of the interview and then questioned in their convenient languages (Bangla and Hindi). Only the relevant and complete answers received from the respondents were used for further analysis.

2.2. Garrett ranking analysis

Garrett ranking was carried out to order the constraints faced by the fish farmers of the Islands by following Garrett and Woodworth (1969) and Kumaran et al. (2021) as follows.

Percentage score = \(\frac{-100(Rij - 0.5)}{Nj}\)

Wherein,

\(Rij = \) Rank given for the \(i^{th}\) item by \(j^{th}\) individual.

\(Nj = \) Number of items ranked by the \(j^{th}\) individual.

2.3. Rank based quotient analysis

Rank based quotient analysis (RBQ) was used to order the severity of issues (Kumaran et al., 2021) by using the formula proposed by Sabarathnam and Vennila (1996) adopted in the study of Kumaran et al. (2021) as follows.

\[ RBQ = \frac{\sum (Fi)(n+1-i)}{Nn} \times 100 \]

Wherein,

\(Fi = \) Number of responses indicating a particular problem under \(i^{th}\) rank.

\(N = \) Number of the respondents.

\(i = \) Number of ranks.

\(n = \) Number of constraints identified.

2.4. Statistical analysis

Data collected were entered systematically in Microsoft excel spreadsheet and the statistical analysis such as frequency analysis and Wilcoxon signed rank test were performed using SPSS software (Release16 SPSS, Chicago, IL, USA). The study area map was prepared by using QGIS, an open source GIS software.

2.4.1. Wilcoxon signed rank test

Wilcoxon signed rank test was performed to analyze the impact of COVID-19 outbreak and related lockdown on the income generation. Income was calculated as the average semi-annual income generated per acre of pond. The test static is,

\[ Z = \frac{T - \mu_w}{\sigma_w} \]

Where,

\(T = \) \(\min(T^+, T^-)\) in which \(T^+\) is sum of positive ranks and \(T^-\) is sum of negative ranks.

\(\mu_w = \frac{n(n + 1)}{4}\)

\(\sigma_w = \sqrt{\frac{n(n+1)(2n+1)}{24}}\)

\(n = \) number of pairs of observation.

3. Results

3.1. Demographic profile of the respondents

The location of the respondents participated in the interviews are shown in Fig. 1. The respondents predominantly belonged to the Andaman group of Islands (97.7%) whereas, the rest (2.3%) were from the Nicobar group of Islands. Around 91% of the respondents were male whereas, the rest (9%) were female respondents. The age group of the respondents was in the range of 30–60 years. The majority of the respondents (92.9%) were educated (from primary to post-graduation) whereas, the rest (7.1%) were illiterate. The respondents mainly belong to the Bengali, Tamil, Telugu, Malayali, Ranchi and Hindi ethnic groups. Among the respondents interviewed, the Bengali population was dominant (83.3%) followed by Tamil (7.0%) and the rest comprised of Malayali, Telugu, Hindi and Ranchi populations. Freshwater aquaculture practices were most popular among the Bengali settler community in the Islands and hence they formed the predominant group among the respondents. Fish farmers interviewed were having experience in the range of 1 to 10 years (44.1%), 11 to 20 years (42.6%), 21 to 30 years (12.8%) and 31 to 40 years (0.5%). The farm area (Acre) of the respondents was in the range of less than 1.00 (93.3%) followed by 1.01 to 2.00 and 2.01 to 3.00 (2.4% each) and 3.01 to 4.00 (1.9%).

3.2. Constraints faced in freshwater aquaculture sector

Due to the lack of systematic fish culture practices in the Islands, only few farmers could be able to breed and produce the fish seeds for their own purposes as well as for sales. Most of the respondents only carry out culture activities through the procurement of fish seeds from farmers as well as from the local fisheries department and research organizations. Despite the stocking of fish seeds, farmers seldom carry out management practices as majority of the fish ponds in the Islands remains extensively managed. Of the 211 respondents, only 11 (5.2%) carry out both freshwater fish breeding and seed production as well as grow-out production activities. Indian Major Carps (Catla, Rohu, Mrigal) were the most widely used species for breeding purposes (81.8%) followed by Chinese carps (Silver carp, Common carp and Grass carp) (36.4%).
impact of the lockdown on fish breeding and seed production is given in the form of Garrett mean score (Table 2). Restrictions in transportation (64.5) ranked higher followed by breeding hormone unavailability (60.2), lack of labour (48.3), farm input unavailability (44.5), lack of feed (33.5) and lack of fish seed packing materials (7.0).

3.4. Harvesting and marketing

Among the 211 respondents, 88 farmers (41.7%) responded that they faced problems while harvesting and marketing whereas the remaining 123 respondents (58.3%) did not face difficulties in harvesting and marketing. The order of severity of the issues are given in the form of

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**Table 1**

Major constraints faced by the freshwater fish farmers during COVID-19 pandemic \( (N = 211) \).

| Constraints                  | Garrett mean score | Rank |
|------------------------------|--------------------|------|
| Seed unavailability         | 59.6               | 1    |
| Restrictions in transportation| 44.2               | 2    |
| Feed unavailability         | 42.1               | 3    |
| Lack of manpower            | 12.0               | 4    |

**Table 2**

Constraints faced in fish breeding and seed production during COVID-19 pandemic \( (N = 11) \).

| Constraints                  | Garrett mean score | Rank |
|------------------------------|--------------------|------|
| Hormone unavailability       | 60.2               | 2    |
| Lack of labour               | 48.3               | 3    |
| Farm input unavailability    | 44.5               | 4    |
| Lack of feed                 | 33.5               | 5    |
| Restrictions in transportation| 64.5               | 1    |
| Lack of fish seed packing materials | 7.0               | 6    |
Fish ponds which are located very close to the residence of farmers were for food security and market (Rajan et al., 2018; Kiruba-Sankar et al., 2020) due to the settler population preferring the culture of freshwater fishes. Fish ponds and 91% of the respondents did not face any such poaching. About 97% of the respondents were aware of the COVID-19 related lockdown. Further, about 96.6% of the farmers (204 numbers) were supported by the fish production of their own ponds to secure their food security. Fish farmers of the Islands were not exclusively doing fish farming only whereas they are also involved in mixed farming wherein agriculture and animal husbandry are also carried out in tandem with the fishery components. Hence, 65.8% (139 numbers) of the respondents had an alternative livelihood option other than fish farming such as agriculture, animal husbandry and other business activities. About 97% of the respondents were aware of the COVID-19 related advisories issued by research and development departments of which, 99.5% of the respondents felt that the advisories were useful for their fish farming activities. Freshwater fish is a lucrative commodity that is prone to theft as in several incidents reported across the Islands by the farmers. During the COVID-19 related lockdown period, only 9% of the respondents felt that there was an issue of poaching of the fishes from fish ponds and 91% of the respondents did not face any such poaching. Fish ponds which are located very close to the residence of farmers were less prone to poaching whereas the ponds located far away from monitoring were generally prone to the poaching activities.

### 3.5. Awareness and alternative livelihoods of the fish farmers

About 89.5% of the respondents were unaware of the information that aquaculture related activities were exempted from COVID-19 related lockdown. Further, about 96.6% of the farmers (204 numbers) were supported by the fish production of their own ponds to secure their food security. Fish farmers of the Islands were not exclusively doing fish farming only whereas they are also involved in mixed farming wherein agriculture and animal husbandry are also carried out in tandem with the fishery components. Hence, 65.8% (139 numbers) of the respondents had an alternative livelihood option other than fish farming such as agriculture, animal husbandry and other business activities. About 97% of the respondents were aware of the COVID-19 related advisories issued by research and development departments of which, 99.5% of the respondents felt that the advisories were useful for their fish farming activities. Freshwater fish is a lucrative commodity that is prone to theft as in several incidents reported across the Islands by the farmers. During the COVID-19 related lockdown period, only 9% of the respondents felt that there was an issue of poaching of the fishes from fish ponds and 91% of the respondents did not face any such poaching. Fish ponds which are located very close to the residence of farmers were less prone to poaching whereas the ponds located far away from monitoring were generally prone to the poaching activities.

### 4. Discussion

The Andaman group of Islands are divided from the Nicobar group of Islands by a ten-degree channel hence, there is a contrast between these Islands in terms of fishing activities and fish culture practices (ANDFISH, 2005). Freshwater fish farming is the most active food producing sector in the Andaman group of Islands (North, Middle and South Andaman) due to the settler population preferring the culture of freshwater fishes for food security and market (Rajan et al., 2018; Kiruba-Sankar et al., 2018). In the Nicobar group of Islands, freshwater fish culture is limited to Great Nicobar (Campbell Bay) wherein settler population is prevalent, whereas the rest of the Nicobar group of Islands has restricted access to outsiders and are primarily inhabited by the traditional communities engaged in marine fishing activities for their subsistence (Ravikumar et al., 2016; Kiruba-Sankar et al., 2020). Hence in our interviews, the respondents were mostly from the Andaman group of Islands whereas there was a smaller representation from the Nicobar group of Islands.

Our stakeholder surveys provided valuable insights into the constraints faced and the economic losses incurred in the wake of pandemic related restrictions across the Andaman and Nicobar archipelago. The global aquaculture sector faced a plethora of issues such as labour unavailability, limitations in farm inputs, limited logistical support, issues in marketing and supply chain which caused economic losses to the dependent stakeholders (FAO, 2020; Jamwal and Phulia, 2020; Rafiqzaman, 2020; Rosen, 2020; Sen et al., 2020; Seshagiri et al., 2020; Kumaran et al., 2021). We found a substantial homogeneity in the issues faced by the Island farmers as reported from other studies indicating the most common constraints such as movement restrictions, unavailability of farm inputs, labour shortages, lack of market demand, and logistical issues. Garrett ranking and Rank based quotient values ranked the seed unavailability, restrictions in transportation and movement as the major issues faced during the pandemic. Lack of public transportation and movement restrictions has halted the planned activities during pandemic (Jamwal and Phulia, 2020; Love et al., 2021). Manlosa et al. (2021) in their studies on COVID impact in Philippines outlined the negative impact on aquaculture production through disrupted availability of fry, fingerlings, increased cost of fingerlings, mobility restrictions and issues with the access to necessary aquaculture related inputs. Lack of labour, limitations in inputs such as harvest net, feed unavailability and seed packing units also further contributed to the issue in the Islands. Movement restrictions also severely hampered the harvesting and marketing activities. Labour shortages were another hindrance which impacted the planned farm-related activities. At the beginning phases of lockdown, there was a fear among the general public to consume animal meat products including fishes due to the fear of COVID-19 leading to less market demand. The decline in the price of fishes due to low market demand was also reported in other studies of Campbell et al. (2021) and Islam et al. (2021).

Income loss has been reported invariable across the aquaculture sector (Waiho et al., 2020; FAO, 2021; Kumaran et al., 2021). The South-West monsoon (May to August), being the breeding season of Indian major carps remains the most productive period for freshwater aquaculture in the Islands. The preceding pre-monsoon months are generally used for sorting of adult fishes that are to be used for induced breeding. As the lockdown began during March, the major preparations and inputs procurement activities were halted leading to unpreparedness in the farm-related activities. Although exemptions were made on the culture sector at later stages, the restrictions in movement, logistical issues, manpower unavailability and the fear of COVID-19 has dented the further management activities. In this present study, the details of income expressed by the farmers are in approximate values only as many farmers did not have proper records of income obtained from fish production over a period of time. They were also uncertain on the quantum of aquaculture based income as some of them were also involved in mixed farming practices which includes agriculture and animal husbandry components. We also observed that the farmers were found free in expressing their opinions and issues however, quite reluctant to share the income details due to some uncertain reasons.

Unavailability of sufficient quantities of quality fish seeds remains an issue to be addressed in the Islands as pond based farming systems remains one of the most popular culture practices in the Islands. The demand for fish seeds keep rising however, the limitations in availability of brood fishes, management issues, infrastructure and skilled manpower remains a concern. Even though the seed production activities were taken up by the selected fish farmers, the geographically scattered nature of the Islands demand travelling across the Islands to procure the fish seeds. The limitations on the transportation facilities and movement restrictions have dented the prospects to procure fish seeds that were available with the other farmers.

### Table 3

Problems faced while harvesting and marketing of fishes during COVID-19 pandemic (N = 88).

| Constraints                      | RBQ value | Rank |
|----------------------------------|-----------|------|
| Lack of labour                   | 68.5      | 2    |
| Fear to intake fish produces by the consumers | 9.9       | 4    |
| Restriction in movement          | 85.5      | 1    |
| Lack of marketing facility       | 60.8      | 3    |

### Table 4

Impact of COVID-19 related lockdown on the average semi-annual income of fish farmers. Values are represented as mean ± standard error.

| Scenario   | Average semi-annual income (Rs.) | Wilcoxon signed rank test |
|------------|----------------------------------|---------------------------|
| Pre COVID-19 | 57,100 ± 6241                     | Z = -12.452, p < 0.001    |
| Post COVID-19 | 28,574 ± 4476                     |                           |

Rank based quotient values (RBQ) in Table 3. RBQ analysis showed that restriction in movement (85.5) as the top issue, followed by lack of labour (68.5), lack of marketing facility (60.8) and the fear to intake fish produces by the consumers (9.9). Our analysis also revealed that there was a significant reduction in the average semi-annual income during post COVID-19 outbreak (p < 0.001). The average semi-annual income before the outbreak was found to be Rs. 57,100 ± 6241 whereas post outbreak, the average semi-annual income was found to be Rs. 28,574 ± 4476 (Table 4).
4.1. Reform strategies suggested for the sector development

Considering the constraints and the negative impacts caused due to COVID-19 pandemic, fish farmers, administrators and research organizations should reinvent the fish culture practices in an efficient and organized manner. A paradigm shift in fish farming activities is the need of the hour and we hereby outline some of the recovery plans to upscale the fish farming and marketing activities in the archipelago.

4.1.1. The shift towards Better Management Practices (BMP) in aquaculture

Incidences of diseases and health management remain an issue to be addressed in the aquaculture sector (Meena et al., 2013; Saravanan et al., 2015, 2017, 2021). Advisories on better management (health management, water quality, etc.) can be provided through mobile phone based apps on regular basis and mass sensitization through radio or television programmes. A toll-free number for scientific and technical assistance can be provided to assist the farmers in better management practices. An inventory of the Island fish farmers and their farm structure needs to be developed to disseminate the advisories on BMP. Farmers also should proactively reorient their culture activities in a more systematic manner. Flagship programmes like Pradhan Mantri Matsya Sampada Yojana (PMMSY, 2020) launched in 2020 should be popularized and encouraged to be taken up by the fish farmers for construction of new ponds, fish nurseries, etc. Research and development departments should provide technical backstopping in order to sensitize the better management practices for increased fish production.

4.1.2. Feed-based aquaculture practices

Sustainable production in aquaculture can be achieved by developing and promoting low cost nutritional feeds which should also be easily digested (Prabu et al., 2017; Boyd et al., 2020). The extensive method of fish farming and lack of knowledge on supplementary feeding is the main reason behind the lower freshwater fish production in the Islands (Sivaramakrishnan et al., 2017). Farmers should be encouraged to adopt feed-based aquaculture practices so as to augment the unit production of fish in their existing culture system. Small-scale fish feed mills can be installed by a group of fish farmers at village or taluk level with technical backstopping from the research and development institutions by availing the subsidies through flagship programmes of the Government to motivate such initiatives so that the importance of feeding will be disseminated on large-scale.

4.1.3. Availability of quality seeds

Availability of quality fish seeds remains a constraint to be addressed in India (Vignesh et al., 2017; Jayasankar, 2018). At Island level, the issue is still severe as these Islands are cut off from mainland India and are heavily dependent on the aquaculture related inputs from the mainland. On the path towards sustainable aquaculture production, it is necessary to estimate the annual requirement of fish seeds such as fry or fingerlings required for stocking in Island ponds. Accordingly, the resources available locally as well as the inputs that are to be mobilized from mainland India are to be streamlined. New infrastructure such as fish hatcheries should be promoted for taking up by the fish farmers. One major issue is that the poor and marginal farmers are not ready to afford the cost-intensive structures with high capital investment. Under such circumstances, suitable subsidy packages should be worked out depending on the income and economic state of the farmers. Research organizations and the fisheries department should ensure and facilitate the year-round availability of quality fish seeds for stocking. Novel initiatives such as satellite fish nurseries which were proven to provide considerable success in the Islands can be encouraged further to be taken up on a large-scale by the Island farmers (ICAR Newsletter, 2012). Besides, the progressive fish farms in a particular locality should be identified and promoted as seed multiplication centers to cater quality fish seeds.

4.1.4. Explore alternative marketing strategies

Identification and promotion of alternative domestic marketing systems were suggested as a promising strategy under uncertain circumstances (Lebel et al., 2021). The fish marketing system in India is changing much rapidly due to the increased use of digital technologies and consumer preferences (Salim et al., 2018). Further, the buying behaviour pattern has also changed drastically in the times of COVID-19 lockdown with greater demand for online transactions and home delivery options (Varshney et al., 2020). The importance of marketing aquaculture products online (Waiho et al., 2020) during the time of pandemic and resorting to digital marketing platforms was also recommended in the study of Azra et al. (2021) to mitigate the negative impacts of such unprecedented lockdown. FAO (2021) also reports the increased use of online orders and home delivery services with the customers preferring e-commerce alternatives during the times of lockdown and restrictions. The scope of direct marketing of fish to private households was also discussed in Love et al. (2021). Digitalization of aquaculture can also facilitate easier mode of advertising, marketing and payment options (Belton et al., 2021). In case of Andaman and Nicobar Islands, better marketing practices remains a thrust area to be addressed for the sector development. In the Islands, networking and internet connectivity has greatly improved since the year 2020 and there is a huge scope for developing digital marketing platforms for aquatic food products. Seafood retailers in Port Blair, the capital city of the Islands managed the COVID-19 crisis period through digital marketing and home delivery services whereas, market-based sales were highly affected due to the reduced movement of consumers into the market. The scope of such digital marketing has been realized recently in the case of seafood products as there are many new seafood outlets emerged in Port Blair city to tap the scope of digital marketing. The scope for seafood marketing through alternative marketing practices were gaining popularity whereas, the freshwater fishes were still sold in conventional market-based sales. As freshwater fishes form an important part of the diet for Island communities, the scope of digital marketing can offer resilience to the sector even in case of unprecedented lockdown as the farmers can market the fishes with ease in difficult times and continue to earn revenue.

4.1.5. Relief packages in light of COVID-19

Relief packages and subsidies could be an effective coping strategy for structuring the livelihood of stakeholders (Bennett et al., 2020; Kumaran et al., 2021; Manlosa et al., 2021; Islam et al., 2021). Special relief packages could be provided to the fish farmers considering the losses incurred during COVID-19 lockdown and free supply of essential inputs can also be provided for the next breeding season to motivate and encourage the farmers to continue their farming practices.

4.1.6. Insurance and institutional finance schemes

The stakeholders and the resources should be covered under insurance to cope with uncertain circumstances (Islam et al., 2021). Kumaran et al. (2021) in their studies on COVID-19 impact on shrimp aquaculture sector recommends the mitigation measures such as minimum wages, health cover, and life insurance as some of the strategies to overcome the impacts. Fish farmers could be protected against the unanticipated loss of fish harvests through insurance schemes which ultimately benefits the farmers (NIFAP, 2019).

4.1.7. Enforcing monitoring and regulations

A taskforce is required at Island level to monitor the freshwater aquaculture sector since the sector is active with more dependent stakeholders in comparison to mariculture and brackishwater aquaculture sectors. Due to high demand and local market, lot of non-native freshwater fishes were also transported into the Islands. Such kind of
practices which were followed earlier has led to the entry of several non-native fishes in the Islands. Such non-native species which are desirable for culture as the candidate species should be cleared at a task force level for further action. The information on the candidate local species which are suitable for aquaculture and the non-native invasive species which should be avoided for aquaculture should be sensitized to the stakeholders. Stringent rules and enforcements are required for environmental protection and regulation which can be developed and effectively monitored by the Island level task force.

4.1.8. Developing resource inventory

There is a lack of proper information on the inland fish production in Andaman and Nicobar Islands (Handbook of Fisheries Statistics, 2020). Developing an inventory on the current state of inland capture and culture based production could be crucial information for the sector development. Although there are reports of around 2605 freshwater ponds, these ponds were constructed for minor irrigation purposes (ANI Fisheries Policy, 2018) whereas limited information is available on the classification between fish ponds and irrigation ponds. Research organizations and the local fisheries department should work closely towards obtaining a reliable inland fish production data from the fish farmers of Andaman and Nicobar Islands. Digitalization of farm characteristics and activities such as pond size, water spread area, water quality, species cultured, production, productivity, management practices including nutrition and health management, etc. could be a valuable inventory for further planning and management of the sector to augment the fish production in near future.

4.1.9. Species diversification practices

The ponds in majority are minor irrigation ponds constructed mainly for the water storage purposes in order to support the agriculture and allied activities in the Islands. Farmers mostly have a mixed farming model with agri-horticulture and livestock component in which pond remains an integrated unit. The ponds in general remain extensively managed with limited inputs whereas the farmers also prefer stocking of the fishes like Catla, Rohu and Mrigal (Indian Major Carps). Due to the poor management, the productivity of the ponds are generally considered low. Under such scenario, selection of candidate fishes for aquaculture plays an important role in successful pond management practices with increased economic benefits. Diversifying the culture with hardy species like Tilapia, air breathing fishes, etc. could be a better strategy since carp culture demands proper pre-stocking and post-stocking management practices with adequate care whereas hardy fishes like air breathing fishes can be better managed with limited inputs. Carp cultured in ponds also affected due to limited water availability in the dry months of February to April every year whereas, hardy fishes can withstand such adverse conditions and are also suited for polyculture along with other candidate fishes (Uddin et al., 2006; Wang and Lu, 2015). Tilapia culture is preferred widely due to the ease in their aquaculture with good market scope and stable prices (Wang and Lu, 2015). Tilapia could also be a candidate species for aquaculture in view of climate change adaptation (Rahman et al., 2021) which would be very much relevant in case of Andaman and Nicobar archipelago which are prone to climate change events. Aquaculture diversification with hardy fishes like Tilapia is recommended in the Islands however, the case of biosecurity and culture of all male tilapia and GIFT tilapia should be very well considered for sustainable management and production from extensively managed ponds.

4.2. Farmer preparedness to tackle uncertain events

The aquaculture sector remains vulnerable to the natural and anthropogenic impacts with a wide range of challenges that need to be addressed (Brown et al., 2010). The COVID-19 pandemic and the related lockdown period is one of the most unique situations ever faced by the fish farmers in the Islands. Such unprecedented closure leading to the halt of regular activities also showcase the significance of preparedness to tackle such events. Formulation of coping strategies is essential to confront any such unforeseen events in future. In Mekong region, coping responses like adjustment in stocking practices, reduced labour inputs, alternative new markets, savings and credit support were reported (Lebel et al., 2021). Coping strategies like moving towards digital marketing is a good option to reach out the customers at the times of uncertainty. The impact and the associated issues due to COVID-19 seem to remain further and the mitigatory measures and preparedness should be addressed collectively to recover from the impacts. The critical issues faced by the fish farmers which hindered the planning and management of farming activities is the starting point to begin the preparedness check. Such pandemic situations might also threaten the sustainability of the aquaculture sector in future. Therefore, adequate preparations are necessary to mitigate the impacts of any pandemic in future. Some of the preparedness checks recommended for the fish farmers are listed in Table 5.

4.3. Policy framework for sustainable aquaculture

Considering the stakeholder surveys, identified constraints, management issues and farmer practices, we hereby recommend a framework towards the sustainable management of the sector (Fig. 2). The framework emphasizes a lot on developing a resource inventory as there is an acute lack of information on the production and other farm-related activities in the Islands. Such resource inventory could also assist in understanding the current scenario so that the sector can move ahead in setting and achieving the targets and improvising the infrastructure to tackle the emerging challenges.

5. Conclusion

The telephone based interviews revealed the constraints and negative impacts faced by the farmers amid the pandemic. Even in pre COVID-19 times, the sector has been facing various issues such as poor pond management, lack of infrastructure, limited input availability and shortage of quality seeds, manpower, etc. The COVID-19 pandemic and lockdown restrictions have further aggravated the negative impacts which demands immediate attention in terms of research, extension and governance. Our telephone-based interviews have faced certain limitations such as time unavailability of the respondents, uninterested respondents, respondents who were in a rush to complete the surveys, respondents who hesitated to share complete information and the

| No. | Farmer’s preparedness follow up |
|-----|--------------------------------|
| 1   | Review the entire COVID-19 pandemic situation |
| 2   | Recollect the critical gaps encountered in the farming activities |
| 3   | The gaps identified are the beginning point to the preparedness. Address it through collective efforts |
| 4   | Organize group meetings at your village level and discuss the potential gaps that needs to be addressed |
| 5   | Sensitize the need to revamp the fish farming activities to new normal and then frame the reform strategies |
| 6   | Take collective decisions and convey the decisions to local administration |
| 7   | Strengthen the linkages with research organizations and development departments |
| 8   | Engage in participatory farming activities |
| 9   | Laser focus on E-marketing options, mobile applications based marketing, focus on home delivery options |
| 10  | Farming inputs are the key drivers. Sensitize the support required from the local administrators |
| 11  | Focus on better management practices in aquaculture |
| 12  | Investment driven culture practice could give productive results |
| 13  | More focus on aquaculture insurance schemes |
| 14  | Learn and adjust with the situation |
mobile network coverage issues at certain remote parts of the archipelago. Despite these indicated limitations, our study could provide essential insights on the negative impacts of COVID-19 which could be useful in framing policy decisions towards revamping the freshwater aquaculture sector. Hence, considering these preliminary findings, we recommend for further detailed studies in order to understand the extended impacts of COVID-19 in the freshwater aquaculture sector. The present study only highlights the immediate impacts faced by the fish farmers due to pandemic related restrictions during the year 2020 which basically represents the first wave of COVID-19 in India. However, it is anticipated that there would be a further wave of COVID-19 in future which might cause further restrictions with the possible impact on the farming related activities. The need of the hour is to build stronger linkages and networking among the fish farming community, research organizations, Government departments and extension functionaries to deal with the situation by providing innovative solutions and alternative marketing guidance. Farmers should look out for innovative solutions like digital marketing, group insurance schemes and better management practices to deal with such unprecedented situation in future. As a short term initiative, fish farmers should reorient their approach towards better management practices and digital marketing platforms. On a long-term basis, administrative efforts in collaboration with research organizations should focus on restructuring the existing culture practices to efficiently utilize the aquaculture resources for augmenting the income and to provide employment opportunities for sustainable aquaculture growth in the Andaman and Nicobar archipelago.

Ethical standards

The ethical standards in the present study was taken up by following Patankar (2019). Due to the telephonic mode of interviews carried out in consideration with the prevailing restrictions of COVID-19, no written consent was obtained from the respondents whereas verbal consent to participate in the interview was obtained prior to get the responses.

CRediT authorship contribution statement

**R. Kiruba Sankar:** Conceptualization, Methodology, Formal analysis, Writing - original draft, Writing - review & editing. **K. Saravanan:** Conceptualization, Formal analysis, Writing - original draft. **Haridas:** Data curation, Analysis, Writing - review & editing. **J. Praveenraj:** Methodology, Writing - review & editing. **Utpal Biswas:** Methodology, Data curation. **Ritika Sarkar:** Methodology, Data curation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.aquaculture.2021.737596.

References

ANDFISH, 2005. Draft Roadmap for the Development of Fisheries in Andaman and Nicobar Islands. ICAR-CIARI, Port Blair, p. 87.

ANI Fisheries Policy, 2018. Draft Andaman and Nicobar Islands Fisheries Policy. Department of Fisheries, Andaman and Nicobar Administration, p. 17.

Avtar, R., Singh, D., Umarhadi, D.A., Yunus, A.P., Misra, P., Desai, P.N., Phanindra, K.B. V.N., 2021. Impact of COVID-19 lockdown on the fisheries sector: a case study from three harbors in Western India. Remote Sens. 13, 183. https://doi.org/10.3390/rs13020183.
Indian major carps (IMC) seed rearing farmers in Thanjavur district, Tamil Nadu. Int. J. Fish. Aqua. Stud. 5 (4), 308–310.
Waiho, K., Fadhlan, H., Ishak, S.D., Kasan, N.A., Liew, H.J., Noraini, M.H., Ikhwanuddin, M., 2020. Potential impacts of COVID-19 on the aquaculture sector of Malaysia and its coping strategies. Aquac. Rep. 18, 100450. https://doi.org/10.1016/j.aqrep.2020.100450.
Wang, M., Le, M., 2015. Tilapia polyculture: a global review. Aquac. Res. https://doi.org/10.1111/are.12708.