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Living with Salinity in the Southern Indus Basin through Aquaculture

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Disclaimer

Executive Summary

IUCN under the Adapting to Salinity in Southern Indus Basin (ASSIB) project funded by Australian Centre for International Agricultural Research (ACIAR) collaborated with salinity-affected communities in the Indus Delta to enhance their capacity to develop strategies for enhanced resilience and livelihood sustainability through aquaculture.

Under the project, two interventions were identified through a co-design and co-inquiry process in selected villages that are part of the Tippun Dublo ‘bright spot’ near Keti Bandar in Thatta district. These included (1) Shrimp Aquaculture in an estuarine pond with the Ayub Dablo village community, and (2) Cage Aquaculture in a tidal river with shifting salinities with the Haji Musa Katiyar village community. Both experiments were carried out through three cycles over the years 2022 and 2023.

The two aquaculture experiments proved to have an eye-opening effect for the coastal communities involved, and they have high confidence that that their small-scale shrimp and cage fish enterprises will be replicated as a thriving source of livelihood across the coastal communities of Pakistan. Community enthusiasm for and ownership of these community-based enterprises builds on their past experience with similar scale crab fattening enterprises, which had also not been commonly practised in Pakistan until it was introduced as a small-scale initiative a decade ago.

Each experiment had limitations mainly revolving around availability of shrimp or fish seed due to nonexistence of relevant hatcheries selling commercial shrimp feed and quality fish feed in the country. Hence both experiments mainly relied on wild seed caught from the sea and sourced through traditional channels, or raw feed that included rice bran, oil seed cake and wild caught fish / shrimp bycatch from the local fishing boats that employ men from the community. Other constraints included non-availability of electricity and limited experience of specific aquacultural practices intended under the experiment among the communities.

The shrimp pond aquaculture faced issues of flooding from exceptional high tides during 2022, and risk of entry of wild predatory fishes into the pond due to crevices and cracks that developed in the pond banks. The fish cage was established in an abandoned river which gets water from irrigation channels, agriculture run off, rainfall and the sea. Its salinity keeps changing from near zero to around 15 parts per thousand (ppt). Therefore, both experiments faced challenges requiring exploration of most suitable solutions.

The shrimp pond provided an excellent first cycle growth as compared to the second, which was marred due to off-season colder weather. The first cycle gave great encouragement to the community but was then impacted by a sudden total mortality event that lowered the morale of the community. This unfortunate event was then followed by the poorer performing second cycle. However, the experiment established a “could be” game changer model that has provided a base for replication and the model is being followed by others in the coastal communities.

The cage culture experiment was the result of brilliant brainstorming for an additional livelihood opportunity among landless fishing communities along the coast. However, the economic viability of the cage culture in the tidal river with fluctuating salinity is still questionable due to low market price and high input cost especially fish seed and feed. The economic viability would be more likely if a hatchery was available producing marine fish seed such as seabass. As a second option, improved and well acclimatised tilapia seed could be another possibility.

Contents

Introduction

The southern Indus Basin has historically been a fertile agricultural land, but in recent years, salinity has emerged as a growing concern for communities living there. Extreme weather events and desertification have deteriorated the situation leading to declines in average crop yields, income loss and food insecurity. Shortage of freshwater for crops combined with seawater intrusion has degraded soils rendering them unsuitable for traditional agriculture crops. This situation has in turn induced a shift from agriculture to fishing as a source of livelihoods in coastal areas. An integrated development strategy that can draw populations out of poverty traps and risks associated with climate change requires innovation and diversification. Community-based aquaculture is one such innovative option to secure livelihoods and ensure sufficient food production.

Under such circumstances, and to overcome this challenge, the Adapting to Salinity in Southern Indus Basin (ASSIB) project funded by Australian Centre for International Agricultural Research (ACIAR) collaborated with salinity-affected communities in the Indus Delta to enhance their capacity to develop strategies for enhanced resilience and livelihood sustainability. The project used community-based research co-inquiry as its strategy, which takes a bottom-up approach for building community resilience. This report presents the outcomes of this strategy as drawing on the experiences and knowledge gained by the coastal village communities of Ayub Dablo, and Haji Moosa Katiyar of Keti Bandar, in Sindh, Pakistan. Collaborating with the ASSIB project, the communities of these villages investigated aquaculture as a means of income and resilience through which they could adapt to changing climatic conditions. The co-inquiry investigation was conducted over two years involving collaboration between the community and IUCN as an ASSIB project partner. Both parties were equal stakeholders in the research which enabled the community to learn through practical adaptation to the changing circumstances. Other ASSIB partners, notably the Society of Facilitators and Trainers (SOFT), offered support for these collaborative co-design and co-inquiry efforts.

Such a different community-based path has emerged through the application of co-inquiry principles, as exemplified by shrimp and fish cage experiments. This approach of co-inquiry combines scientific and indigenous knowledge, demonstrating its potential to benefit both the ecosystem and livelihood of the communities living along the sea. The shift from fishing to a community-driven income generation model based on co-inquiry is important because it addresses the productivity issues and offers promising alternatives for sustainable livelihoods with community participation in the face of climatic challenges. These alternatives served as sustainable income generation models worthy of replication with a potential to contribute to enhanced opportunity for resilience and livelihood sustainability in coastal areas of Pakistan.

Methods

Site selection and background

The fish farmers involved belonged to two fishing villages along the coast of Sindh province. Each farmer was supported by their families who complemented their efforts during the time they were out for fishing etc. The community leader responsible for the shrimp experiment had no formal schooling while his sons had received lower primary-level school education. The community leader responsible for the fish cage had a few years of primary education himself but his sons had never been to school. The shrimp farmer was mostly unreachable through mobile phone which created a communication hurdle as well; the only communication option was through personal visits and meetings. Hence the technical team had to struggle to keep balance between the traditional wisdom and the scientific knowledge to keep the experiments going through co-inquiry process. Overall, the community of Haji Musa Katiar village had a better understanding of the process of learning and understanding the technical aspects required to successfully handle the experimental requirements.

The selection criteria involved such communities living in salinity-affected landscapes that are capable of not only sustaining but potentially enhancing their livelihoods through proactive, community-driven adaptation measures (for more details see Appendix in Allan et al., 2024). The Tippun Dublo community, situated along the frontage of the sea in the Indus Delta, were a key part of IUCN Pakistan in a previous project that involved establishing mangrove plantations as the first line of defence against natural disasters, enabling the community to earn a living through mangrove planting as the agricultural land became unproductive due to seawater intrusion and high salinity levels. In the past the target area used to be paddy fields as sweet water was available all year round but today these areas are barren, salinised drylands and mudflats. The community has adapted to the situation by finding alternate means of making livelihoods.

Despite the loss of arable land and with limited access to clean drinking water, the communities have not only survived but thrived. Their resilience in the face of climate change and related disasters is a defining trait, qualifying them to be selected as one of the bright spots. Further, the selected communities have demonstrated great resilience against the climate change induced disasters. Therefore, the community qualified as an ASSIB project bright spot community.

Process of co-designing the intervention

This study investigated the implementation of community-based interventions as an adaptive strategy for community growth and resilience. Establishing co-inquiry as the cornerstone principle entails collaboratively integrating scientific expertise with indigenous knowledge, thereby nurturing a grassroots approach to research. The selection of the study area followed a systematic process aimed at identifying and engaging communities interested in addressing salinity challenges. The active engagement of the local community, in decision-making processes was facilitated by the Stakeholder Engagement and Research Learning (SERL) model. The SERL model, guided by the principles outlined by Heaney-Mustafa et al. (2023), facilitated the co-inquiry method for involving local communities in decision-making processes. This methodology is rooted in asset-based community development (ABCD) and comprises three key phases: a pre-plan phase, involving stakeholder engagement to lay the groundwork for collaboration; a workshop phase, where community members participate to identify available resources, evaluate areas for improvement, and devise an action plan through a thorough strengths, weaknesses, opportunities, and threats (SWOT) analysis; and an implementation phase, where the action plans collaboratively developed during the preceding phases are put into effect to address identified needs and capitalise on community strengths.

The communities of the target villages have been actively involved in artisanal fisheries for generations, having deep-rooted connection to the fishing sector. Drawing on their foundational understanding of livelihood-enhancing practices, particularly in crab fattening, the communities exhibited a favourable response when introduced to the concept of shrimp and cage culture as one of the viable solutions for alternate means of income at their doorstep. Leveraging their extensive experience in the fisheries sector, community members contributed valuable insights into management options and construction associated with pond and cage culture.

Implementation through co-inquiry

The collaborative engagement developed the community's capacity in shaping a sustainable aquaculture option having potential for replication. Further details of the implementation of the experiments through the process of co-inquiry is explained separately for both the projects.

1. Shrimp Aquaculture Experiment

This experiment investigated the feasibility of the aquaculture of wild shrimp seeds in a small earthen pond which was watered by the tidal flow in the estuarine environment. A small pond of around 2,000 square feet was constructed for the community-based co-inquiry into shrimp farming as an alternate means of sustaining livelihoods. The pond was stocked with shrimp seeds from the wild. The observation of shrimp farming practices was conducted with collection of data to gain a detailed understanding of opportunities and challenges faced in the experiment.

This co-inquiry experiment, the first of its kind, led the community to go into the open sea and collect seed from the wild, as there is currently no private or governmental hatchery providing seeds for shrimp culture. This endeavour has also provided them with valuable skills in collecting wild seeds, potentially leading to a small value chain for future opportunities as juvenile shrimp seed suppliers. Although the community initially aimed to collect Tiger Shrimp (*Penaeus monodon*) for its higher market value, which was hardly caught, the co-inquiry team decided to stock whatever wild species were available, therefore Banana Shrimp (*Penaeus merguiensis*), Indian White Shrimp (*Penaeus indicus*), and *Metapenaeus* species were collected. A total of 10,000 seeds were stocked in the pond during the first experimental cycle.

The community fed the shrimp with rice bran which showed good growth. The aquaculture operations were jointly undertaken by the male and female members of the community, wherein the women of the community played an active role in feeding and monitoring the shrimp farm while the men were away for fishing. Since maintaining the water quality of the pond was crucial, it was initially planned to install an aerator in the pond. However, due to non-availability of electricity infrastructure in the area, it could not be installed and the solar or wind energy solutions were also not available particularly for the purpose. So, water quality was maintained through water exchange. The pond was in an estuary, enabling frequent water exchange through tidal action which helped maintain water quality. For this purpose, the pond was provided with a two-way pipe which was used to fill the pond with water, as well as flush the pond when needed to maintain water quality.

During the culture period, the family fed the shrimp twice a day with rice bran, resulting in excellent growth over a period of approximately 40 days. To enhance the growth of shrimp, the farmer and IUCN team jointly agreed to use a commercial fish feed, ground up into a powdered form. However, after a few days of feeding, the shrimp experienced total mortality. The change in pond water colour from green to brown, observed by the farmer, indicated a crash in the phytoplankton population, leading to oxygen depletion and total mortality of the shrimp over a period of two-four days. The theory is further supported by the cloudy weather during that period. However, the farmer reported that the mortality was because of the commercial fish feed, which deteriorated the water quality. Technically, the weather factor seems more likely to have been responsible for the shrimp mortality. Installation of an aerator might have averted the mortality. However, the non-availability of electricity was a major hurdle in this regard. Further, due to bad weather and heavy rains the mobile phone signals were too bad for the farmer to timely report the changing situation to IUCN to make timely examination of the situation for remedy or assessing the real reasons behind the total mortality.

Following the lessons learned from the mortality during the initial shrimp farming cycle, the community made a concerted effort to undertake a second cycle of shrimp cultivation. Before restocking the pond, the community was advised to use lime to neutralise and sanitise the water before releasing it to the sea. Once completed, the pond was emptied, and dead shrimp were removed and disposed of properly to prepare for the next cycle after due fertilisation. In the subsequent cycle, the farmer collected around 4,873 seeds from the wild and this time monitored the pond very closely. The traditional feed comprising rice bran was exclusively used twice a day, leading to good growth and a successful harvest of 70.2 kg of shrimp over a duration of almost two and half months (Appendix 1).

2. Fish Cage Experiment

This experiment investigated the feasibility of aquaculture through culturing fish in a cage placed in a water body that was inconsistent in its salinity. Haji Moosa Katiyar village is situated on the bank of an abandoned river known as Ochito River, a former course of the Indus River now resembling a lake, that transitions back and forth from near freshwater to saline conditions, as determined by the source of water which may include agricultural runoff, canal escape, seawater and rainfall. The community showed keen interest when introduced to the concept of the fish cage (fish farming in a netted environment) in the abandoned river as one of the solutions for additional source of income. The fish cage construction was co-designed and co-executed with the farmer Mr. Essa Katiar, who is a retired Naakho (skipper of a large fishing boat).

With this background in mind, a floating fish cage was installed at the Haji Moosa Katiyar on 5 August 2022. A skilled labourer was hired to construct the cage, and he also trained the target community in constructing new cages and repairing them. This fish cage was 4.5 square metres with a depth of 2.4 metres. Although the cage can be built by using imported expensive materials, this cage was built using locally available low-cost materials, which included bamboos, recycled plastic drums, fishing nets of required strength and mesh size, ropes and some other materials required in cage construction.

The community's traditional knowledge proved instrumental in identifying the profitable culturable species and the source of seed, which in this particular case was barramundi (*Lates calcarifer*) Asian seabass, followed by freshwater fishes of African Catfish and Tilapia through successive phases of success-failure-success and meaningful learning. The seabass was selected keeping in view the changing salinity situation, which proved a viable option biologically. However, some drawbacks were observed including: (1) non-availability of its seed from hatchery; and (2) high price of the seeds affecting its economic viability under the given conditions.

The fish seed was stocked in the cage in two batches based on availability. The first batch containing 135 juvenile seeds was stocked on 17 August 2022. The seeds were purchased from a tidal shore known as Zero-Point in Runn of Katch in Badin district, some 200 km from the cage site. The juveniles varied in size from 1 to 7 inches (2.5 to 18 cm) because they were collected from the wild. This seed was stocked into the cage on the same day late at night when received. The second batch of 125 fish seed was stocked with a time gap of 15 days on 31 August 2022 with the size varying from 4 to 8 inches (10 to 20 cm). A total of 260 seeds were stocked in the cage.

The farmer used to feed the caged fish with minced fish waste and shrimp bycatch from their fishing boats, which they got free or at meagre cost. Better management practices were adopted while feeding the caged fish to satiation on a daily basis. They used to feed the fish in a floating tray in the cage and stopped further feeding when fish showed they were refusing further consumption.

Some mortality of fish occurred during transportation and in the cage after a few days. Sixteen (16) fish died during transportation in both batches which can be considered normal. Thirteen (13) fish were reported dead by the farmer during the whole farming period, which shows a high survival rate and an encouraging sign of good management of the cage farming by the community.

Incidence of net damage in the cage were reported during the farming period that caused a loss of 44 fish escaping from the cage. This loss was only revealed on the harvest day. The incidence of net damage highlights the need for reconsideration on the selection of net quality / strength. It further suggests the need for installing an additional protective net layer of higher strength around the cage. Total loss of fish from mortality and net damage were 73 fish out of the 260 originally stocked, leaving 187 to be harvested (72%). The harvest of fish from the floating cage started after 100 days on 26 November 2022 and continued until 4 December 2022 so the last catch was reared for 108 days. The farmer harvested the fish in stages to sell them at the local market of Keti Bandar town to secure a better price (Appendix 2).

Data Collection

The initial water quality data were provided by the government agriculture lab at the district headquarters based on water samples collected by the IUCN team. Other data related to the experiment were also gathered by the whole team (the farmers and the technical team) with day-to-day records maintained by farmers, including shrimp and fish stocking, feeding, checks on fish and shrimp behaviour and health, maintenance of the pond and the cage; while scientific data such as salinity, dissolved oxygen, pH etc. were collected periodically by the IUCN team through personal visits. For salinity, a refractometer (The Brix refractometer 0-90) was used, while for other parameters, a titration kit (HANNA HI3810 Dissolved Oxygen Test Kit) was used.

Results

1. Shrimp Aquaculture Experiment

The second experiment involved co-inquiry into shrimp farming feasibility in coastal areas under circumstances of non-availability of hatchery-produced shrimp seeds in addition to no information on availability or successful culture of wild seeds in the past two to three decades. Therefore, the project experimented on: (1) feasibility on the catchability and value chain of the wild shrimp seeds; and (2) feasibility of successful rearing of the wild shrimp seeds.

The co-inquiry experiment successfully proved the feasibility of both the above questions. The seed of the shrimp from the wild was not only catchable, but it opened up a value chain for the supply of wild shrimp seeds for culturing in ponds in the estuarine or near coastal areas that can receive seawater, and possibly for ponds that can be watered through pumping saline groundwater of a salinity similar to the sea. Further, the wild shrimp seeds responded well on accounts of growth and survival in a small earthen pond, though they faced total mortality in the first instance, which is attributed to water quality deterioration from the cloudy weather and rains for many days. However, under the subject co-experiment it is well established that the wild seeds can be a good candidate for aquaculture until a hatchery producing shrimp seeds is made available for shrimp farming in Pakistan.

2. Fish Cage Experiment

The fish cage initiated under the ASSIB project in a water body with constantly changing salinities was a big challenge and the co-inquiry experiment responded well to the research questions to: (1) identify a suitable fish that can be reared in such a water body; and (2) compare the economic viability and profitability among various options. Under the co-inquiry experiment various fishes were stocked in cages which included Asian Seabass (*Lates calcarifer*), African Catfish (*Clarias gariepinus*) and Tilapia (*Oreochromis nilotica*). The Asian Seabass gave the most economic and survival viability, followed by Tilapia, and lastly catfish, which showed low survival and low economic viability. However, the seabass cage culture may not be feasible for the said water body due to the long distance from the seed source and the high price of the wild seed, whereas the seabass culture seems very suitable for areas near to the seed source. The target water body was thus seen as a potential candidate for seabass cage aquaculture once a hatchery producing seeds is available.

Discussion

1. Shrimp Aquaculture Experiment

Community-based participatory innovations, rooted in the sustainable livelihoods framework, aim to strategically employ aquatic resources to alleviate rural populations from poverty and address climate change-related risks. Shrimp farming presents itself a promising avenue to secure livelihoods and ensure sufficient food production, given its rapid growth within the global aquaculture industry. Despite Pakistan's potential to become a significant player in shrimp farming, the sector remains in its nascent stages due to challenges such as irregular seed production, limited technical expertise, and insufficient research and brood stock management or hatchery produced seed supply. The aquaculture sector holds the potential to generate employment opportunities and stimulate positive economic impacts at local, regional, and national levels through the provision of inputs like locally produced feed and seed (Hernandez et al., 2018). Furthermore, small-scale aquaculture potentially contributes much more to the society in terms of livelihood when compared with large industrial fisheries (Chuenpagdee et al., 2006). The ASSIB project, using an integrated co-inquiry approach, underscores the importance of indigenous knowledge and community experience in fostering sustainable livelihoods.

Elaborating on economic prospects, the case study unveils key instrumental findings. One notable discovery involves the strengthened seed collection capabilities of communities, positioning them as potential seed suppliers gaining space in the aquaculture value chain. The convenience of pond management with entire families engaged, low operational costs, and enhanced sustainability through the use of raw feeds and natural productivity contribute to the success of the venture. Additionally, the cultivation of an environmental ethos is evident through the growing mangrove plantation adjacent to the pond embankment. Further, it has been demonstrated that individuals engaged in small-scale fishing often play a significant role in stewardship initiatives and conservation endeavours aimed at preserving their local environments (Chuenpagdee and Juntarashote, 2011).

Another significant revelation centres on the emergence of women leaders actively participating in and shaping the experiment. This increased involvement of women in decision-making processes within fisheries has been correlated with the acquisition of new skills and leadership capacities, drawing inspiration from existing female role models, as evidenced in a similar case study conducted in Mexico (Torre et al., 2019). In short, the case study presented for the ASSIB community has not only demonstrated empowerment but also underscores their essential role in steering the trajectory of sustainable aquaculture practices for the betterment of communities.

2. Fish Cage Experiment

The results of this experiment have provided valuable insights for the ongoing conversation regarding sustainable aquaculture development in the country. One notable outcome underscores the significance of involving local communities in aquaculture initiatives to ensure the sustainability of such enterprises. Local communities, drawing on their extensive history of interaction with natural resources, inherit a rich repository of intergenerational knowledge and expertise (Silvano and Hallwass, 2020). These local communities possess valuable knowledge about ecosystem dynamics, species behaviour, and sustainable resource management, thereby having potential for promoting a comprehensive approach to aquaculture. By employing participatory methods, communities can use scientific knowledge and gain the capacity to independently manage aquaculture projects, thereby fostering self-sufficiency. Empowering communities through upliftment and direct involvement could be crucial for ensuring the sustainability and profitability of aquaculture ventures, especially given the limited support for marine aquaculture in terms of increasing fish production. The successful implementation of community-led initiatives in Bangladesh and other countries, based on the adaptive co-management principle, serves as a potential model for Pakistan, contributing to enhanced resource sustainability and increased community resilience by employing new livelihood sources (Hernandez et al., 2018; Rashid et al., 2015).

The experiment's achievement in addressing productivity challenges and providing sustainable alternatives reinforces the call for community-driven models to bolster resilience and secure livelihoods amidst climatic adversities. Unexpected positive outcomes, such as the community's development of acclimatisation skills, are in line with broader endeavours to enhance technical proficiencies. Furthermore, the experiment demonstrated women's active involvement in monitoring activities, particularly when they assume responsibility for managing the cage while the male members of the family are out earning a livelihood through fishing. This highlights the potential for women's empowerment through aquaculture initiatives. Empowering women with skills that can serve as a means of livelihood and entrepreneurship contributes to gender equality and economic empowerment. The multifaceted results observed prompt consideration of the broader implications for sustainable livelihoods, while also fostering self-employment and entrepreneurship approach enhancing food security for coastal communities grappling with challenges such as climate change, salinity, and declining fishery resources.

The enabling environment under the co-inquiry approach encouraged the community to engage in an innovation in cage culture by installing a new cage and stock shrimp from within the same waterbody as a viability option and an experiment that is initiated and owned by the community itself.

Conclusion

1. Shrimp Aquaculture Experiment

In conclusion, the shrimp farming venture undertaken by the coastal community of Pakistan under the ASSIB project encountered several formidable challenges that cast a shadow on its sustainability. However, the resilience of the community and the invaluable lessons derived from these challenges have not only strengthened their capacity but have also propelled them into the realm of entrepreneurs. This shrimp farming experiment underscores the significance of integrating traditional knowledge, specifically in identifying locations with consistent seed availability, with technical and extension support. The adoption of the ASSIB approach through collaborative inquiry and joint decision-making emerges as a cornerstone in sustaining shrimp farming enterprises. This transformative journey not only uplifts the community but also breathes new life into their entrepreneurial spirit, providing them with a sustainable option for livelihood generation and food security. In essence, the uplift of this sector hinges on the synergy fostered through collaborative efforts among stakeholders, government bodies, and industry players, creating a vibrant tapestry for the long-term success and robust growth of the shrimp farming industry in Pakistan.

2. Fish Cage Experiment

Whether intended for livelihood diversification or salinity adaptation, participatory community-based approaches to aquaculture showcase a transformative vision for sustainable coastal development. As exemplified by the ASSIB project in coastal Pakistan, the integration of scientific expertise and indigenous knowledge has led to a community-led fish cage experiment, representing a departure from the prevailing top-down paradigm in community development and extension. Embracing the heterogeneity of the local environment, recognising fluctuations in water quality and salinity levels. This adaptive approach reflects the innovative and unconventional nature of this project. This community-centric, grassroots foundation not only aims to generate sustainable income on a smaller scale but also serves as an alternate source of income, reducing strain on overburdened natural fishery resources. Importantly, this model sets a pioneering precedent for Sindh and the broader Pakistani context. In broader terms, the research and evaluation of participatory community-based approaches to aquaculture are crucial for refining methodologies and expanding their impact on a local scale. As the world grapples with the need for sustainable development, the lessons learned from initiatives like co-inquiry by ASSIB provide valuable insights for creating an enabling environment that promotes the long-term sustainability of marine resource-dependent coastal communities.

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Appendix 1. Summary of Annual Costs and Returns of Shrimp Aquaculture Experiment

Here we provide our economic analysis of the experiment. However, due to the mortality during the first cycle, and the short and out of season second cycle which stretched for 71 days due to unfavourable low temperature weather, hindered to materialise the potential economic returns which is given under the economic analysis. Hence the experiment may not provide for a potentially replicable model.

However, assuming that under a realistic situation a farmer, while doing such farming, will utilise the optimum weather conditions or temperature, and will culture shrimp for a right length of time required for shrimp growth and maintain recommended farming conditions, the economic returns will be better. So, a second scenario economic analysis was developed to see whether a farmer while keeping all other conditions constant as under the current scenario. while compensating the feed inputs for additional growth, will be able to make better returns. The same has been presented under the second scenario which gives a better outlook with a good potential for replication.

Table 1. Economic Analysis: Actual Scenario

Item	Quantity	Rate	PKR
Estimated Return (Income)			
Shrimp (kg)	70.2	690.0	48,438.0
Total			**48,438.0**
Capital Cost			
Pond construction	1	365,000.0	365,000.0
Total			**365,000.0**
Operating Cost			
Shrimp Seeds	4,873	2.0	9,746.0
Feed (kg)	82.0	100.0	8,200.0
Misc cost			5,000.0
Total			**22,946.0**
Total Investment Cost			
Year 1 investment			**387,946.0**
Annual Operating cost (year 2 & ahead)			**22,946.0**
Economic Analysis			
Per unit production cost / break-even cost per kg			586.8
Profit per unit			103.16
Payback Period (Years)			14.32

Table 2. Financial Analysis, Actual Scenario

Year	0	1	2	3	4	5	6	7	8	9	10
Cash Inflow - Sales	0	48,438	48,438	48,438	48,438	48,438	48,438	48,438	48,438	48,438	48,438
Cash Outflow - Capital Investment	365,000	0	0	0	0	0	0	0	0	0	0
- Operating Cost	0	22,946	22,946	22,946	22,946	22,946	22,946	22,946	22,946	22,946	22,946
Total Cash Outflow	365,000	22,946	22,946	22,946	22,946	22,946	22,946	22,946	22,946	22,946	22,946
Net Cash Flow	minus 365,000	25,492	25,492	25,492	25,492	25,492	25,492	25,492	25,492	25,492	25,492

Year	11	12	13	14	15	16	17	18	19	20	Total
A. Cash Inflow - Sales	48,438	48,438	48,438	48,438	48,438	48,438	48,438	48,438	48,438	48,438	968,760
Cash Outflow - Capital Investment	0	182,500	0	0	0	0	0	0	0	0	547,500
- Operating Cost	22,946	22,946	22,946	22,946	22,946	22,946	22,946	22,946	22,946	22,946	458,920
Total Cash Outflow	22,946	205,446	22,946	22,946	22,946	22,946	22,946	22,946	22,946	22,946	1,006,420
Net Cash Flow	25,492	25,492	25,492	25,492	25,492	25,492	25,492	25,492	25,492	25,492	minus 37,660

Payback Period (Years)	14.32
Net Present Value (NPV) @ 10%	minus 206,122
Internal Rate of Return (IRR) (%)	minus 1%
Benefit Cost (B/C) Ratio @ 10%	$0

Table 3. Economic Analysis: Projected Scenario 2

Item	Quantity	Rate	PKR
Estimated Return (Income)			
Shrimp (kg)	170.555	690.0	117,683.0
Total			**117,683.0**
Capital Cost			
Pond construction	1	365,000.0	365,000.0
Total			**365,000.0**
Operating Cost			
Shrimp Seeds	4,873	2.0	9,746.0
Feed (kg)	200.0	100.0	20,000.0
Misc cost			5,000.0
Total			**34,746.0**
Total Investment Cost			
Year 1 investment			**399,746.0**
Annual Operating cost (year 2 & ahead)			**34,746.0**
Economic Analysis			
Per unit production cost / break-even cost per kg			310.7
Profit per unit			379.27
Payback Period (Years)			4.40

Table 4. Financial Analysis, Projected Scenario 2

Year	0	1	2	3	4	5	6	7	8	9	10
Cash Inflow - Sales	0	117,683	117,683	117,683	117,683	117,683	117,683	117,683	117,683	117,683	117,683
Cash Outflow - Capital Investment	365,000	0	0	0	0	0	0	0	0	0	0
- Operating Cost	0	34,746	34,746	34,746	34,746	34,746	34,746	34,746	34,746	34,746	34,746
Total Cash Outflow	365,000	34,746	34,746	34,746	34,746	34,746	34,746	34,746	34,746	34,746	34,746
Net Cash Flow	minus 365,000	82,937	82,937	82,937	82,937	82,937	82,937	82,937	82,937	82,937	82,937

Year	11	12	13	14	15	16	17	18	19	20	Total
A. Cash Inflow - Sales	117,683	117,683	117,683	117,683	117,683	117,683	117,683	117,683	117,683	117,683	2,353,659
Cash Outflow - Capital Investment	0	182,500	0	0	0	0	0	0	0	0	547,500
- Operating Cost	34,746	34,746	34,746	34,746	34,746	34,746	34,746	34,746	34,746	34,746	694,920
Total Cash Outflow	34,746	217,246	34,746	34,746	34,746	34,746	34,746	34,746	34,746	34,746	1,242,420
Net Cash Flow	82,937	-99,563	82,937	82,937	82,937	82,937	82,937	82,937	82,937	82,937	1,111,239

Payback Period (Years)	4.40
Net Present Value (NPV) @ 10%	282,939
Internal Rate of Return (IRR) (%)	21%
Benefit Cost (B/C) Ratio @ 10%	2

Note:

1. The family will provide other services such as labour and watch and ward.
2. Although not calculated as such, it is expected that in the second year and onwards the community will make advance arrangements for seed supply / stocking and harvest at a time when the shrimp has a higher market price therefore the net income will almost double hence the economic returns will improve accordingly

Appendix 2. Summary of Annual Costs and Returns of Fish Cage Experiment

Table 5. Economic Analysis

Item	Quantity	Rate	PKR
Estimated Return (Income)			
Fish (seabass) (kg)	153	650.0	99,450.0
Total			**99,450.0**
Capital Cost			
Cage construction	1	80,000.0	80,000.0
Total			**80,000.0**
Operating Cost			
Fish Seeds	260	155.0	40,300.0
Feed (kg)	853.0	10.0	8,530.0
Misc cost			5,000.0
Total			**53,830.0**
Total Investment Cost			
Year 1 investment			**133,830.0**
Annual Operating cost (year 2 & ahead)			**53,830.0**
Economic Analysis			
Per unit production cost / break-even cost per kg			456.4
Profit per unit			193.59
Payback Period (Years)			1.75

Table 6. Financial Analysis

Year	0	1	2	3	4	5	6	7	8	9	10
Cash Inflow - Sales	0	99,450	99,450	99,450	99,450	99,450	99,450	99,450	99,450	99,450	99,450
Cash Outflow - Capital Investment	80,000	0	0	0	0	40,000	0	0	0	0	0
- Operating Cost	0	53,830	53,830	53,830	53,830	53,830	53,830	53,830	53,830	53,830	53,830
Total Cash Outflow	80,000	53,830	53,830	53,830	53,830	93,830	53,830	53,830	53,830	53,830	53,830
Net Cash Flow	minus 80,000	45,620	45,620	45,620	45,620	5,620	45,620	45,620	45,620	45,620	45,620

Payback Period (Years)	1.75
Net Present Value (NPV) @ 10%	175,478
Internal Rate of Return (IRR) (%)	53%
Benefit Cost (B/C) Ratio @ 10%	3

Other system parameters not mentioned above

Total # of fish harvested (Seabass)	187	#
Average individual weight of fish at harvest (kg)	0.82	kg
Mortality of fish	73	#
Days of production cycle	116	days

Note:

1. The family will provide other services such as labour and watch and ward.
2. Although not calculated as such, it is expected that in the second year and onwards the community will make advance arrangements for seed supply / stocking and harvest at a time when the fish has higher market price therefore the net income will almost double hence the economic returns will improve accordingly

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