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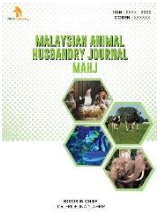

REVIEW ARTICLE

FISH FARMING PRACTICES AND DISEASE OCCURRENCE IN THE FISH FARMS OF DHANUSHA DISTRICT, NEPAL

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ABSTRACT

Dhanusha is one of the leading fish producing districts in Nepal and the fish farming is increasing in the district to establish the district as a 'Fisheries center'. However, with the increasing fish farming and intensity, a number of diseases find their way to the farm which may hinder the progress of fish farming. Present study was carried out to assess the fish farming practices and the disease occurrence across the fish farms of Dhanusha district. Questionnaire-based personal interviews were conducted with 64-fish farmers selected from all over the district using simple random sampling. Majority of the respondents were males (89.1%), in the active age group of 30-50 years (71.9%), with average experience of more than 15 years (39%) in fish farming. The widely adopted farming system was Carp polyculture, however, some of the farmers also culture other species like Pangas, African catfish, Rupchand, Puntius etc. Only earthen ponds were common with water depths of 5-7 ft (54.7%). Majority of the respondents relied on private hatcheries (34.4%) for fish seeds and the most common stocking size was fingerlings (42.2%) and fry (29.7%). The major source of information and technical support for the farmers were successful farmers (82.8%) and government offices (73.4%). Approximately 65.6% of the farmers had received trainings on fish production and disease management. The most common feed materials were mustard oil cake (100%); rice bran (96.9%) and commercial pellet feed (54.7%). Cattle dung (87.5%); poultry manure (28.1%) and Urea/DAP (95.3%) were the major fertilizers used by the farmers. The most prevalent fish disease was Argulosis (96.9%), Lernaea (90.6%) and EUS (85.9%), but asphyxiation (82.8%) caused the reportedly highest mortality of 346.1±305.5 Kg/ha. Similarly, the most susceptible species to disease was Naini (65.6%) followed by silver carp (49.0%) and bighead carp (34.0%), while the least infected species was Grass carp (0.8%). Winter (70.3%) was reported to be the main season for the occurrence of fish diseases in Dhanusha district. The average B/C ratio in pond aquaculture in the study area was 1.36.

KEYWORDS

Polyculture, Pangas, Hatcheries, Argulosis, Lernaea, Nain

1. INTRODUCTION

Aquaculture generally refers to controlled farming of aquatic organisms, like fish, mollusks, crustaceans and aquatic plants, etc under controlled system of management. It involves rearing process such as regular stocking, feeding, pond management and protection from predators etc that tends to enhance production thereby achieving significant economic returns. The stocked cultivated may be either individual or corporate ownership. And, this contribution to food security and economic growth if, includes only the rearing of fish and related species under respective ownership and systematic management is recognized as fisheries. Almost all fish produced are consumed as food in Nepal, recognizing it as the cheapest source of animal protein providing arrays of important nutritional and health benefits. It is acclaimed to be the prime source of lean protein and healthy fats in Nepal (T. B. Gurung, 2016). A nation with a wide range of agroecological types, Nepal is situated between the latitudes of 28°N and 84°E. Its terrain ranges from southern plains that are less than 60 meters above sea level to the Himalayas, which are located above the latitude of 4800 meters above sea level (WorldData, 2020). Consequently, Nepal has an agrarian economy that supports a diversity of agricultural methods and crop production, thereby leading to food security (Bhusal et al., 2021). Similarly, aquaculture may be able to utilize 7,900 km of irrigation canals in the country besides almost 6,000 river systems, streams, lakes, ponds, and other abundant water resources scattered across 500,000 hectares of Nepal. Aquaculture in Nepal provides 1.13% and 4.18%, respectively, to the overall GDP and AGDP (T. B. Gurung, 2014). With a growth rate of 14.3%, which is greater than that of other agricultural sectors' growth rate of 7.17 %, it is one of the sectors of Nepal's economy that is expanding the quickest. The majority of the "pond" or warm-water fish production takes place in the southern part of the country-the Terai region, where 94% of the fish ponds are located. Bara, Dhanusha, Siraha, Morang, Sunsari, Kapilvastu and Rupandehi are the major districts where fish farming is done in large scale (CFPCC, 2021).

The Terai area has greater levels of both fish production and consumption (Koirala et al., 2021). The yearly fish output is 104,623 Mt with a productivity of 5.32 T/ha overall, and 6734 Mt with a productivity of 5.20 T/ha alone in Dhanusha district. Similarly, there was a total of 2846 fish ponds, producing 6734 Mt. Kg yearly. Within the district, a fish farm takes up 1295 hectares of space (PIU, 2020). Since the fish farming in Dhanusha is polyculture type and is getting more intensive in scale, relative occurrence and transmission of disease are also anticipated to rise (Pradhan et al., 2016). With growing area and a growing number of farmers engaged in commercial fish farming, it is one of the biggest fish farming districts of Nepal. The Prime Minister of the Agriculture

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Modernization Project just proclaimed Dhanusha to be a "Fish Superzone" in the year 2016. They also stated that diseases if left unattended and uncured may cause huge loss to fish farmers and may decrease the overall fish yield. A number of governmental and non-governmental organization are working to uplift the fisheries sector in Dhanusha (PIU, 2020). Responsive planning for development of this sub-sector is vital for increasing the production. Information on production and system and associated health management issues form a good base for planning and development in this sector. Considering the fact mentioned above, this study is designed to access the fish production systems adopted, and the underlying issues of diseases and pests in the fish superzone of Dhanusha. This study will help to identify the fish farming practices, occurrence of diseases and the existing health management practices adopted by the farmers in Dhanusha district.

2. Literature Review

2.1 Aquaculture in Nepal

Since ancient times, fish has played a significant role in Nepalese cuisine. Fish culture has historically made some localities and/or ethnic groups well-known. For instance, the Majhi, Tharu, Kewat, Mallah, Mukhiya, Das, Kahar Lodh, Mahar, Magar Kumal, and Gupta tribes were among the indigenous people who relied on catching and eating fish as well as other aquatic creatures like ghunghi, crabs, and others from surrounding water sources for a long time (T. Gurung, 2003).

A very recent development in Nepal, nevertheless, is commercial aquaculture. Using seeds of Indian major carp imported from India, it was started on a modest scale in ponds in the middle of the 1940s. The introduction of the foreign species common carp marked the beginning of additional growth in the 1950s (*Cyprinus carpio*). As a result of its breeding accomplishments in the 1960s, carp monoculture was pushed, and the private sector was extremely impressed. The proportion of aquaculture in the nation's fish output is steadily increasing. However, significant improvement was made in the 1970s with the introduction of three exotic Chinese carp species viz., grass carp (*Ctenopharyngodon idella*), bighead carp (*Aristichthys nobilis*), and silver carp (*Hypophthalmichthys molitrix*). Their ability to reproduce successfully in captivity has significantly advanced aquaculture in Nepal (FAO, 2016). Similar to this, effective trials of induced breeding of three economically significant indigenous large carps—Rohu (*Labeo rohita*), Mrigal (*Cirrhinus mrigala*), and catla (*Catla catla*)—were conducted in our nation (Gurung, 2003). This achievement served as the impetus for the development of the carp polyculture method, which is used to produce carp in ponds with seven other kinds of fish. Many farmers were motivated by this method since it significantly enhanced productivity per unit area and economic rewards. Beginning in the 1980s, the Aquaculture Growth Project, funded by the Asian Development Bank (ADB) and the United Nations Development Program (UNDP), directed the official or legal development of this technique. There are now 19 such development and research institutes operating around the nation for the development of aquaculture, which was recently established by the government of Nepal (UNO, 2020).

Over the years, pond aquaculture has been developed as the most viable and prominent aquaculture production system in Nepal. Carp polyculture in ponds is by far the most common and viable aquaculture production system adopted in Nepal which, in 2020/78 made up about 90 percent of the total pond aquaculture. Similarly, the share of pond fisheries is 88.12 percent of total national fish production of 83,623 Mt. The major part of the pond fish production takes place in the southern part of the country-the Terai plain, where 90.12 percent of the fish ponds are located. These ponds cover over 97 percent of the total water surface area and account for over 86 percent of the total pond fish production in the country. In the fiscal year 2020/21, the average fish yield from pond aquaculture was 5.40 tons/ha in Terai plain, that exceeded the national average of 5.3 tons/ha *i.e.,* twice the average yield in the hills and mountains combined (CFPCC, 2021). The key to the growing popularity of the system in terai is the warmer climatic conditions with suitable edaphology, which are conducive to faster and higher fish growth (Gurung, 2003).

Approximately 232 of the 252 fish species in Nepal, many of which are tiny indigenous species (SIS), are the result of the finfish biodiversity (Shrestha et al., 2019). Numerous research support the claim that SIS normally provide communities around the country with substantially greater nutritional values (Pulkkinen et al., 2010). They can be found living upto the heights of up to 4,000 meters above sea level. However, Rohu, *Labeo rohita*, Catla/Bhakur, *Catla catla*, and Mrigal, *Cirrhinus mrigala,* are the three indigenous main carps that currently control the nation's aquaculture production system. Studies have also been conducted on the commercial production of three highly prized native cold water fish species, including the delicacy asala (*Schizothorax spp.*), katle (*Acrossochielus spp*.), and mahseer (*Tor spp*) (T. Gurung, 2003). Additionally, asala is a popular fish species for sun drying and processing across the eastern highlands of Nepal, Mahseer is also well-known for sports fishing (Bhusal et al., 2021). Genetic research and mass production have been pushed over all of the country's major river systems (PIU, 2020) . Along with these, species like the Nile tilapia (*Oreochromis niloticus*), Java barb (*Barbonymus gonionotus*), and giant river prawn (*Machrobrachium rosenbergii*) have recently been studied to determine the viability and potential of their commercial production in Nepal with the help of neighboring nations (S. Jha et al., 2018).

Carp polyculture in ponds and lake enclosures; cage culture of herbivorous carps like silver and bighead carp; rice-fish culture with common carp; and the comprehensive method of carp polyculture in ghols are the major aquaculture techniques used in Nepal. These aquaculture production methods are divided into groups based on the output and input levels of the production process. In all aquaculture production systems across the nation, farming practices have evolved over time from extensive to semi-intensive to intensive (Bhusal et al., 2021).

Aquaculture has evolved as one of the fastest growing agricultural subsectors in Nepal. The current total national fish production is 104,623 Mt of which 20% contributes from capture fisheries while 80% is from aquaculture (CFPCC, 2021). Nearly 600,000 people now have direct jobs thanks to the expansion of aquaculture to 55 districts around the nation. The yearly per capita fish consumption has increased dramatically between 1981/82 and 2017/18, rising from 330 g to 3.39 Kg, but it is still quite low when compared to the global average of 16 Kg per capita. The demand for fish is highest in the winter and at its lowest in the summer months of Jestha, Asar, and Shrawan (Gurung, 2016).

2.2 Fisheries in National Economy

Agriculture accounts to only 23.9 percent of total GDP of the nation while nearly two third of the population depends upon agriculture for daily livelihood which makes it a backbone of national economy. Currently, aquaculture contributes to about 1.13 percent of national gross domestic product (GDP) and about 4.18 percent on agricultural gross domestic product (AGDP). Similarly, the economic growth of agriculture sector is 2.7 percent (MoAD, 2019).

2.3 Fish Production Status in Dhanusha District

Dhanusha district is well-known as the hub for fish farming since ancient times. It is because the district has the just climate and adequate temperature as well as water resources for fish farming. The production of fish in Dhanusha district is 6734 Mt from an acreage of 1295 ha, with an average productivity of 5.2 Mt/ha (MoAD, 2021).

2.4 Fish Production Systems in Nepal

2.4.1 Traditional fish farming in Nepal

In Nepal, traditional fishing has a really long history and is carried out by different indigenous methods *viz* using cast net, gill net, loop, line and hook and basket. However, some unconventional fishing has emerged in recent years such as by using explosives, electricity and poison. This is potentially destroying the aquatic life indiscriminately (Sharma, 2008). In the1980s, people engaged in fisheries were estimated to be about 80,000 (Swar & Fernando, 1980). The recent dramatic increase in the population engaged in capture fishery probably reflects the unemployment due to increased population in the country. Water bodies in Nepal are usually uncontrolled and unregulated for local access, and usually, the poorest most deprived people are known to harness nearby natural resources such as water bodies or forest for their livelihood. However, rivers and few natural water bodies have yet been managed in such a way and most remain a “free-for-all” A few lakes in the mid-hills have been stocked with cultivable carp for increased production as strategies to reduce the fishing pressure on thinly populated native species without losing the fisher’s employment and income opportunities, until measures for conservation practices of locally vulnerable species are developed (Sharma, 2008).

2.5 Improved Fish Production Technology

The aquatic microclimate is deliberately altered as part of ethical control and maintenance to promote fish output. This has been linked to pond aquaculture, the primary aquaculture method responsible for more than 95% of all aquaculture, while exotic carp account for up to 70% of this pond culture (T. Gurung et al., 2018). Similarly, (Salau et al., 2014) reported that improved fish production technology of fish should inculcate:

- Improved techniques in pond constructions and maintenance.
- Introduction of modern fish hatchery equipment
- Provision of inlet and outlet device in ponds
- Introduction of improved fish species for the optimum yield
- Aerated containers for transporting the fingerlings to reduce stress and mortality
- Techniques to improve water quality in fish
- Fertilization and liming of fish ponds
- Fish preservation and storage techniques
- Prevention and control of fish disease
- Controls of predators in fish pond
- Techniques of hatchery and fingerlings production.

Similarly, with the increasing demand of land and water in fisheries, a colloquial approach of integrated farming is getting realized. The foundation of integrated farming is the idea that by combining two or more production systems, farm profits may be maximized. The production of a greater variety of agricultural products, an increase in cash incomes, an improvement in the quality and quantity of agricultural products, a decrease in pollution, and a more effective exploitation of resources that would otherwise go unused are all benefits of this synergistic approach to agriculture that combines livestock and fish farming. Fish feed and pond fertilizers account for around 60% of the expenditures associated with fish cultivation. The well-considered integration of fish production with other suitable agricultural methods can significantly lower these expenses (Dhawan & Sehdev, 2006).

In order to fetch optimum fish growth and development, regular feeding, at required time is necessary. In general, the suggested supplementary feeding rate is: 14 Kg/ha rice bran; 7 Kg/ha oil cake; and 17 Kg/ha grass and aquatic weeds. Daily feeding rates should be 4-5% of the fish biomass in the water body, adjusted every fortnight based on observed fish growth (Tacon & De Silva, 1997). The recommended rates of application for organic and inorganic fertilizers in an aquaculture pond are 3928 Kg/ha per 6 months, along with goat and poultry manures as organic sources of fertilizers. Additionally, 560 Kg/ha of lime throughout the year is also recommended to buffer the soil pH and for healthy ponds (Saru et al., 2021). It is advised to apply an additional 250 Kg/ha of lime throughout the growing season. In order to keep the algal biomass in the ponds, the water body must also be fed often with both organic and inorganic fertilizers as well.

The stances of pond management lie in maintenance of the production ponds or other ponds to an optimum condition that is conducive to successful growth and development of fish. According to an article published Michigan State University (Travis, 2002). Some of the practices of pond management involves:

Pre stocking pond management such as management of aquatic weeds; drying or dewatering the ponds; pond sterilization, liming and manuring etc.

Post stocking pond management involves regular feeding of fish; maintaining proper water quality; liming and manuring; continuous monitoring for disease and/or discomfort symptoms, pond water test etc.

Contrarily, the traditional methods of fish harvesting include Ring seine, Stake net, Chinese dip net, cast net, Shore seine, Trammel net, Mini trawls, Gill nets, Hook and line, traps and pots. However, the modern methods of fish harvesting include Trawling, Purse seining, Gill net, Hook and line mechanized, Jigging and Trolling lines, the most common being manual drag net (TNAU, 2009).

2.6 An Account of Major Fish Diseases

Rodgers et al., concluded the fact that translocation of live aquatic species posed a greater risk of spread of infection than moving dead goods (Rayamajhi et al., 2017). The potential of pathogen transmission, disease invasion, and subsequent outbreaks of disease in the current aquaculture systems increases with the introduction of new exotic fish species to aquaculture (Faruk et al., 2004). With the increased fish farming and intensification, the occurrence of different diseases is also increasing. Research conducted in the highland lakes and water bodies of Nepal, particularly in Trishuli, Begnas, and Mirmi, revealed that Epizootic Ulcerative Syndrome was the most prevalent illness affecting common carp fish. The most troublesome parasite in carp production at the time, Trichodina, was found to cause issues in both private and public farms, including Begnas and Mirmi, as well as in the bulk of the fisheries domains across the nation. Fin rot, which causes fin degradation in common carp, silver carp, and bighead. Neodox was demonstrated to be very efficient when used with Formalin (150 ppm).

It also described a number of problems with Nepali fish farms managing fish health, including a lack of assistance, a lack of technical know-how, poor treatment techniques, and a lack of suitable diagnostic facilities and the proper use of them (Shrestha et al., 2019). According to (D. V. C. Jha et al., 2016), the central Terai area of Nepal, including Dhanusha, Mahottari, Sarlahi, Bara, etc., suffered greatly from fish infections. Following EUS in terms of frequency were argulosis, red spot, tail and fin rot, and nutritional issues. According to reports, winter and the first few weeks of summer were when diseases were most common (Jha et al., 2018).

3. Materials and Methods

3.1 Study Area

The study was conducted across the fish superzone of Dhanusha District, Madhesh province, Nepal. Its elevation ranges from lower tropics, below 60 masl to 1000 masl. Dhanusha district covers an area of 1,180 km^2 and has a population of 838,084. The total arable area in the district is reported to be 76,531 ha (MoAD, 2019). Commercial fish farmers and were taken under consideration for the survey and hence were pre-requisitely included in sampling. There was a total of 150 fish farmers registered in fish superzone, Dhanusha. Based on Roscole's rule of thumb (1975), 64 actively involved fish farmers were selected from all over the district through simple random sampling without replacement (Memon et al., 2020). Survey was conducted from February 2022 to April 2022.

3.2 Data Collection

During the survey, primary data were collected based on semi-structured pre-tested interview schedule through personal interviews both on-farm and during their office visits. The questionnaire emphasized on the socioeconomic background of the respondents; fish farm details, aquacultural practices, disease occurrence, fish production and storage after harvesting and marketing channel. Focus Group Discussion was conducted among the 15 farmers during checklist preparation as well as Key Informant Interview (KII) was conducted with the representatives of local stakeholders, head farmers, extension officers, local leaders and chief of the community-based organizations etc for the cross-verification of the data. Simultaneously, secondary data were collected from PMAMP annual reports, research study, published articles, research papers and publications of NARC, AKC, FHRDTVC, CFPCC etc.

3.3 Data Analysis Technique

Both the qualitative and quantitative analyses were conducted using software like MS-Excel and the SPSS (Version 23). Descriptive analysis was employed for the variables like family size, educational status, size of landholding, various pond management practices like liming stocking, pond sanitation, fertilization and occurrence, severity and management of fish diseases etc. The obtained information was presented in the form of tables, graphs, charts and bar diagrams.

3.4 Scaling and Indexing:

Problems faced by respondents on fish production were ranked with the use of index. Scaling techniques, which provides the direction and extremity attitude of the respondent towards any proposition was used to construct index. The intensity of problems and measures were identified by using eight-point scaling technique using scores of 1.0, 0.8, 0.6, 0.4 and 0.2. The formula given below was used to find the indexing

$$I_{prob} = \sum S_i F_i / N$$

Where,

I_{prob} = Index value for intensity

S_i = Scale value of ith intensity

F_i = Frequency of ith response

N = Total number of respondents

On the basis of ranking of each problem by the respondents, final index value thus obtained conveyed the severity of each of the farmer's problems. Similar tactics were applied for scoring the severity of fish

diseases as observed across the fish farms. Moreover, the aspects of strength, weakness, opportunity and threat of fish farming were also analyzed on the basis of ranking of responses thus obtained from the farmers.

4. Results and Discussion

4.1 Socio-Demographic Characteristics

During the present study, it was found that mainly males (89.1%) were involved in fish farming in Dhanusha district. With the evident sex ratio of 100:95 (Female: Male), this clearly demonstrated poor participation of women in aquaculture in the study area. The age of the respondents varied between 26 to 74 years (Figure 2) with the average age of 40.2± 11.9 years.

Most of the respondents (74 %) had acquired secondary-level education whereas only 8 % of the respondents lacked any formal education. As per the survey, most of the older respondents were uneducated, as they acquired the enterprise as family occupation since a very young age. However, the young entrepreneurs were found to be generally educated. The respondents in the present heterogeneously belonged to different ethnic groups *viz.,* Yadav (20.3%), Sah/Teli (18.8%), Mukhiya (15.6%), Malah (13.5%), Mandal (6.2%), Koiri (6.2%), Brahman (6.2%), Muslims (4.8%) Paswan (3.1%) and others (5.3%) respectively performed fish farming. Although fisheries originally belonged to Mallah and Mukhiya, the participation of other casts in this industry seems dominating. The rising involvement of ethnic groups like Yadav, Kewat and Teli is due to their greater control in total population of the district (UNO, 2020). The main occupation of the respondents was found to be aquaculture, however some of them were found to be involved in other agricultural operations (10.9%), as well as services (10.9%).

These socio-demographic characteristics are in correspondence with the study done by Koirala et al in Dhanusha district (Koirala et al., 2021)

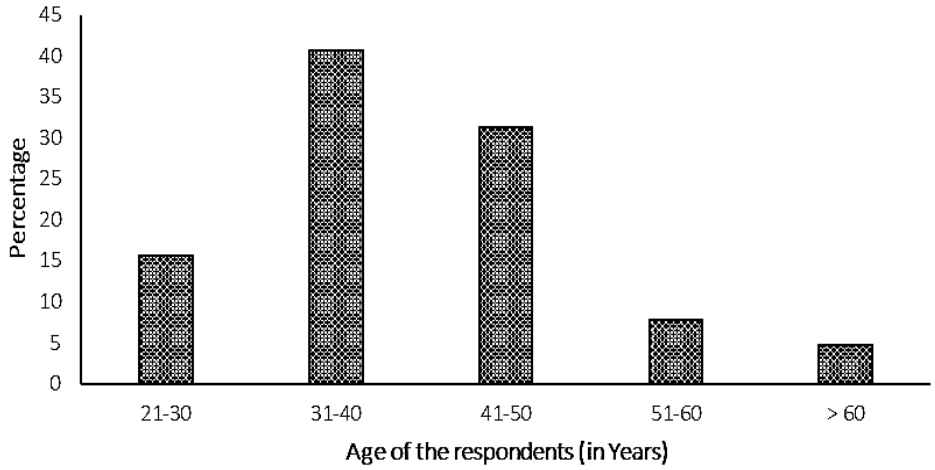

Figure 1: Distribution of the respondents based on their age.

4.2 Aquaculture Practices in The Study Area

4.2.1 Fish Culture System

Altogether, data from 64 fish farmers were analyzed. Farmers in the study area mostly followed the carp polyculture system (90.62%) *ie* rearing of seven major carps, while 9.38% of the respondents reared other species along with the carp polyculture. Rohu, Naini, Bhakur, Silver carp, Bighead carp, Common carp and Grass carp were the major fish species under cultivation, while minor species included Pangas, Rupchand, African catfish, Black carp and other local species such as Bhuna, Mohi, Patara, Golhi, Chaguni, Pothia, Budhuna etc. However major carp species was found much dominant due to their good production and feasible market. The culture system recorded during present study is similar to the results demonstrated by (Koirala et al., 2021).

Moreover, 23.44% of the respondents were found to be involved in integrated system of fish farming of which livestock-fish (40%); vegetable-fish (27%); banana-fish (13%); duck-fish (13%) and poultry-fish (7%) were the major kinds of integration observed. Consequently, most of the respondents practicing bund plantation (40%) with trees and banana reported severe shading effect, leading to lack of dissolved oxygen.

4.2.2 Farm Details of the Study Areas

From the study, three types of land holding were evident *viz* self-owned (15.6%); leased (18.8%) and both (65.6%). Similarly, the average land area held by the respondents for fish farm was found to be 7.1 ha, whereas the maximum and minimum land holdings were 56.7 ha and 0.5 ha respectively.

All the production ponds in the study area were earthen, with average depth of 5 to 7 feet (54.68%). In the study areas, majority of the ponds were found to be aged: less than 10 years (48%); 10-20 years (31%); 20-30 years (11%). Moreover, there were ponds as old as 50-100 years (6%) and above 100 years (3%).

This shows that construction of new ponds is increasing which might be due to subsidies provided by different programs like 'Mission Fish' and 'PMAMP' (Mulei et al., 2021). Contrary to this, the occurrence of ponds as old as 100 years owe to an apparently long history of fish farming in this district.

4.2.3 Irrigation and Drainage

The fish farms were found to use water from different sources like deep boring (51.6%), shallow tubewell (42.2%), and rivers and canals (6.2%). Most of the farmers (97%) were found to drain their ponds at least once a year or at two years interval. The common methods of pond drainage were: water sharing (23%), irrigation (38%), discharge into the fallow lands (20%), river/canal drain (9%) and others (6%).

These findings are in relevance to the findings of the study done by (Koirala et al., 2021) as well as(Saru et al., 2021).

4.3 Pond Inputs

4.3.1 Fish Seed and Stocking

In the study areas, all sizes of fish were stocked for production of fish *viz* fry (29.6%); fingerlings (18.8%) and yearlings or older (9.4%). Fries were reported, mostly to be stocked for production of Chhadi fish, whereas advance fingerlings or older seeds are stocked to ensure rapid harvest during the time of high demand. The average stocking density of fish in carp polyculture was found to be 37212 fry/ha and that of pangas monoculture was 6500 fry/ha. Since the farmers aim at production and marketing of Chhadi fish, extremely high stocking of Rohu and Naini were evident i.e., 50000 fry/ha. The least rate of stocking was of Bhakur *i.e.,* 127 fry/ha.

4.3.2 Source of Fish Seed

From the study, it was found that the fish farmers procured fish seeds from private hatcheries (34%); government hatchery (25%); own hatcheries (11%) and both private as well as government hatcheries (30%). The only government hatchery in Dhanusha is located at Fisheries Human Resource and Technology Validation Center (FHRTVC)- Janakpur. Majority of the fish hatcheries are located in Shahidnagar, Bateshwor and Hanshapur areas.

Most of the respondent farmers in the study area stocked fish seeds during Chaitra/Baisakh (56.3%) month followed by Jestha/Asar (27.2%), Shravan/Bhadra (11.7%), and Magh/Falgun (5.8%). This is due to the

surplus availability of seeds across the hatcheries during the month of Chaitra/ Baisakh (Aryal et al., 2020).

4.3.3 Feed Management in The Fish Ponds

Feed and feeding are essential components of fish farming since they account for about 40% of total cost of production (Koirala et al., 2021). According to this survey, 73.4% of respondents utilize only feed that is produced on farms, such as rice bran-mustard cake (2:1), rice bran-mustard cake-soybean meal (3:2:1), rice bran-mustard cake-wheat meal (3:2:1), and/or mustard cake-corn meal (1:2). The remaining 26.56% of respondents utilized synthetic feeds in addition to farm-based feeds. Salt (1% of feed) and feed additives were also utilized by the respondents (Figure 2).

The average amount of feeds per serving was reported to be 26.6(±13.1) Kg/ha with feeding frequency of 5.4 per week. The study revealed that 73.43% of the respondents feed once a day (morning only); 18.8% feed twice a day (i.e., morning and evening) and remaining 7.8% of the respondents feed 2-3 times a week. Similarly, the most common methods of feeding were sack placement (79.6%); spilling (12.5%) and pole placement (7.8%). No farm had demand feeder in operation. In particular, spilling was the most common feeding method across the large ponds wherein the feed materials were simply broadcasted into the ponds. However, (Zhou et al., 2018) reported that mechanical feeder to be the most efficient method of controlled feeding of the fish.

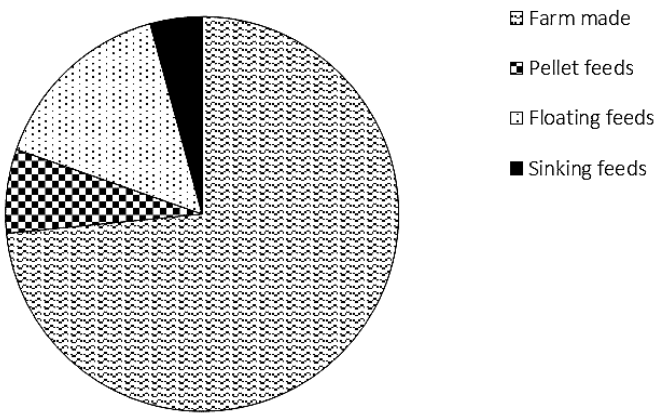

Figure 2: Types of feed used by the fish farmers in Dhanusha district

The study done by Subedi et al., (2019) also stated that locally formulated mash feed was the most common fish feed type, which contained rice bran and mustard oil cake (RB+MOC) as the key ingredients. However, they reported that the feed formulation of RB+MOC+SOB to be the most economically profitable. Similarly, the average feed used per hectare of pond area was only 4.99 t ha-1 i.e., significantly lower than the recommended feeding (Subedi et al., 2019). It was reported to be due to lack of sound knowledge and understanding in fish nutrition and daily feed requirement. This might be the cause for comparatively low production of fish. Most of the farmers in the study area were not found to feed fish scientifically, in accordance to the body weight of fish in the pond. They rather dumped feeds into the ponds as long as fish went on consuming. This posed significant losses of feeds into the pond, popularly known as "feeding the ponds."

4.4 Status of Liming and Fertilization of Ponds

4.4.1 Fertilizer Management Status

Most respondents used organic manures as well as synthetic fertilizers in the fish ponds but with variations between the species farmed and the farming season. It may be due to the fact that majority of the respondents reared livestock and poultry thereby facilitating frequent incorporation of cattle dung in the fish ponds (@400±246.4 Kgha-1 and 3.42±4 times per year) (Singh et al., 2007). However, use of poultry and goat manures were scanty (1.86±4.4 times a year) i.e., preferably in winter season, as reported by majority of the farmers . The purpose of using poultry dung was to promote the growth of maggots rather than as a feed.

Simultaneously, the average application rates (Kgha-1) of urea and DAP were 33.1±19.4 and 40.1±16.8 respectively. Similarly, the farmers in the study area preferred heaping (91%) to broadcasting (9%) as the method of manures application.

4.4.2 Liming Status

Similarly, the farmers (98.4%) used lime in their ponds for maintaining pH and as a pest and disease control measure. Most of the respondents (85.9%) used Agricultural lime because of its easy access and low cost followed by Quicklime (14.06%). The average frequency of application of lime was 1.43 times a year.

Ponds that used organic manure reported relatively more fish deaths compared to those using commercial fertilizers and were however not significantly higher (Figure 3). This is also related to the findings of (Mulei et al., 2021) in the fish farms of Nyeri county, Kenya. However, use of lime effectively controlled various fish diseases as stated by Faruk et al., (2004).

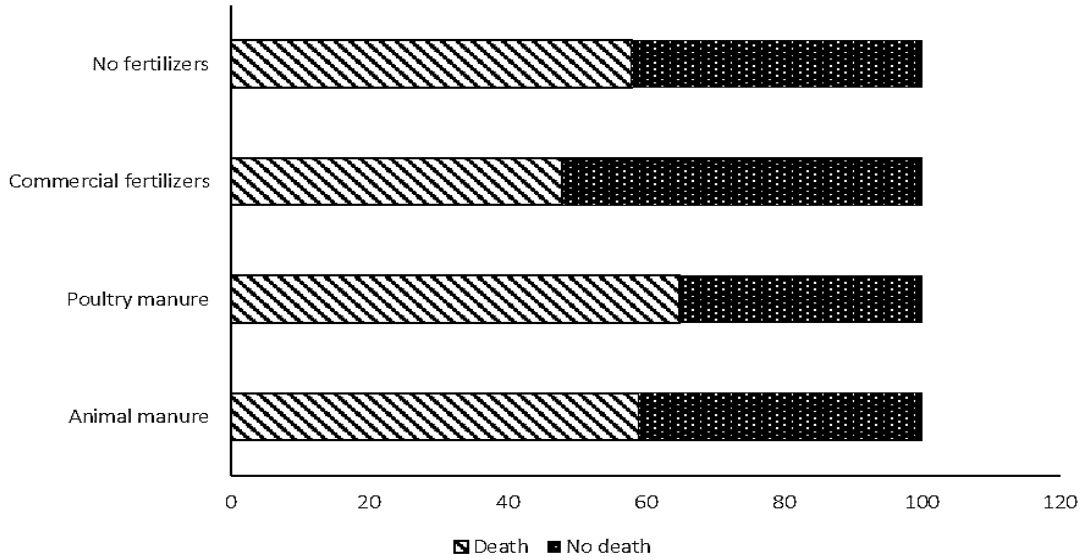

Figure 3: Correlation of fertilizer application and relative fish mortality

4.5 Fish Health and Diseases

In this study, more than 50% of the farmers reported poor growth, odd swimming, and feed refusal. More than 25% of those polled reported seeing fish floating on the water. Fish are naturally active, therefore behavioral changes like body color, floating or sinking, anorexia or refusing feed etc., were the most obvious and frequent signs of sickness. From the results, it is evident that 76% of respondents were able to identify behavior of fish that were associated with deaths. However, only the respondents, as low as 35.93% were able to identify clinical signs of disease that were associated with deaths of fish. This clearly associated with insufficient knowledge and awareness of fish farmers about the specific fish diseases. With 47% of respondents reporting fish fatalities in their ponds, it was found that farmers were careful to note any deaths in their ponds. They claimed that the number of fatalities varied among farmed fish species.

4.5.1 Clinical Signs of Disease Observed by Fish Farmers

According to the study, majority of the fish farmers (76%) reported some form of disease symptoms in their fish ponds. Farmers mentioned a number of diseases and conditions which they could recognized morphologically. The most prevalent clinical signs of disease were argulus (97%), lernaea (91%), EUS (86%), spots (75%), gill and fin rots (72%) and asphyxiation (83%). Other conditions like scale erosion, pop eyes, dropsy, mouth reddening, hemorrhagic eyes, rectal protrusion and malnutrition were also mentioned by the farmers but with lower incidences (Figure 4).These findings are in accordance to the conclusions reported by Jha et al., (2016).

4.5.2 Status of Disease Severity on different Fish Species

According to the study, the most susceptible fish species to disease was Naini followed by silver carp, Rohu and Bighead carp (Table 1). Other species were also found susceptible but the rate was very low. In this regard, the study done by Jha et al., (2016) reported that central Terai region was the most afflicted by fish diseases, where EUS, argulosis, red spots and tail and fin rot were the serious diseases. The most susceptible species to diseases was silver carp followed by Naini, Bhakur, Rohu and pangas in pond aquaculture of Bangladesh (Hasan et al., 2013).

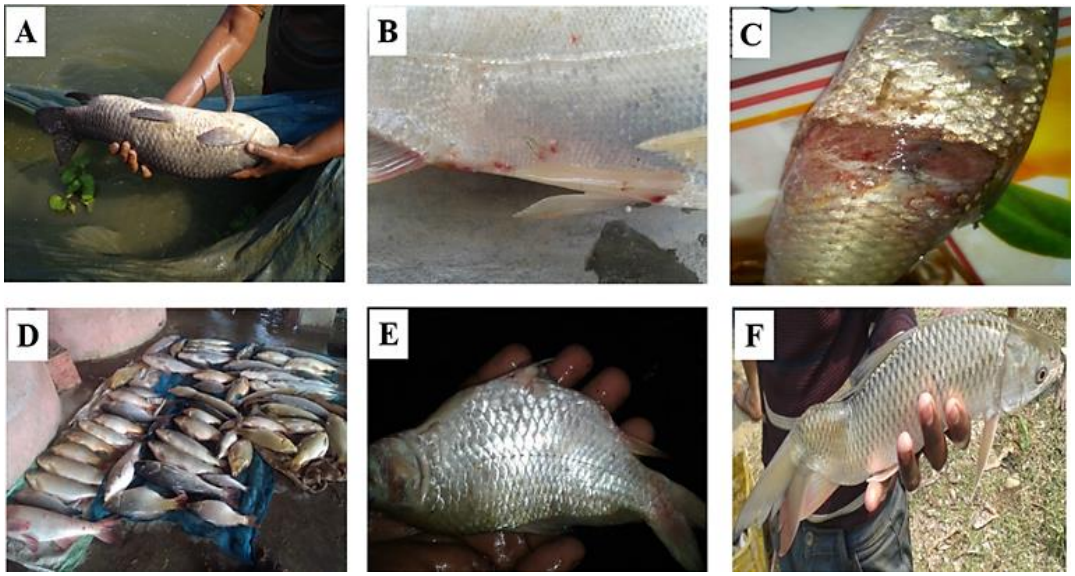

Figure 4: Diseased fishes from on-farm observation in Dhanusha district: (a) Rohu (Labeo rohita) with argulus in body and fins; (b) Silver carp (Hypophthalmichthys molitrix) with Lernaea; (c) Naini (Cirrhinus mrigala) exhibited EUS on abdomen; (d) Fishes reported dead due to Asphyxiation; (e) Common carp (Cyprinus carpio) with dropsy; (f) Naini (Cirrhinus mrigala) suffering from malformation.

Table 1: Status of Fish Affected by Different Diseases as Reported by Farmers during Household Surveys in Dhanusha

S.N.	Name of Disease	% Fish Affected								Total	Average
		Rohu	Naini	Silver Carp	Bighead carp	Common Carp	Grass Carp	Bhakur	Pangas		
1	Learniasis	0.0	19.2	100.0	13.6	0.0	0.0	8.6	0.0	141.4	17.7
3	EUS	28.6	57.1	0.0	0.0	0.0	0.0	14.3	0.0	100.0	12.5
4	Fin rot/gill rot	28.8	14.3	8.6	20.0	20.9	5.7	0.0	0.0	98.2	12.3
5	Pop eyes	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	1.3	0.2
6	Dropsy	0.0	0.0	0.0	0.0	3.6	0.0	0.0	0.0	3.6	0.5
7	Rectal protrusion	0.0	0.0	0.0	0.0	4.1	0.0	0.0	2.9	7.0	0.9
8	Spots	5.7	19.0	8.6	1.0	0.0	0.0	0.0	0.0	34.3	4.3
9	Asphyxiation	10.0	25.0	0.0	0.0	0.0	0.0	0.0	10.4	45.4	5.7
10	Enlarged jaw	0.0	0.0	2.3	3.0	0.0	0.0	0.0	0.0	5.3	0.7
11	Scale erosion	0.0	13.9	1.0	0.0	0.0	0.0	0.0	0.0	14.9	1.8
12	Fish Malformation	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	12.5
13	Ammonia/Nitrate toxicity	1.3	5.9	23.0	3.0	0.0	0.0	0.0	3.2	36.4	4.6
14	Others	4.0	5.8	2.7	0.0	0.0	0.0	0.0	0.0	12.5	1.6
Total		89.8	274.5	160.5	83.5	40.4	11.4	25.7	16.5		
Average		6.4	19.6	11.5	6.0	2.9	0.8	1.8	1.2		

4.5.3 Status of Fish Mortality

Of the disease affected fishes, the mortality due to asphyxiation was found to be the highest, *i.e.,* 346.15±305.47 Kg/ha (Table 2). Species-wise mortality was found to be not significant in the study areas. Likewise, black spot disease was found to be the reason for about 70% loss of fry of bighead and silver carp in Bardiya district in the study carried out by T. Gurung, (2011). He also reported that there was a 10-15% annual loss of fish output and about 30-40% annual loss of fish seeds owing to multiple factors. This was worth the annual loss of approximately Rs 1.5 billion in Nepal.

Table 2: Status of Fish Mortality by Different Diseases in Dhanusha

S.No.	Kinds of diseases	Average Mortality(kg/ha)
1	Parasite (Argulus/ Learnaea)	68±26.5
3	Fin rot/tail rot	42.3±35.2
4	Dropsy	83.3±44.3
5	Aeromonas Infection	95±76.4
6	Asphyxiation	346.2±305.4
7	Unidentified disease	246±136.1

4.5.4 Seasonal Distribution of Fish Disease

In the study areas, the fish diseases were distributed throughout the seasons viz winter (70%), summer (14%) and all-round the year (16%). In particular, gill and fin rots were more common in the winter while asphyxiation and associated problems were more common in the summer, which increased the rate of mortality. Similarly, argulosis was evident all-round the year. This finding concurs with those of Jha et al., (2016) such that the occurrence of fish diseases was higher in winter and on-set of summer season than other times of the year (Jha et al., 2016). Similar conclusions were drawn by in a study conducted in pond aquaculture of Bangladesh Faruk et al., (2004).

4.5.5 Fish Disease Management

In context of Dhanusha, farmers looked forward to other experienced farmers in order to ask for advice when for fish health management suggesting and disease treatment. It was found that 57.8% of the farmers "control" the disease whereas 26.5% of them "Prevent" the diseases and 15.6% of the respondents "Eradicate" the disease. The foremost step to disease management, as practised was, pond water manupulation via recirculation (84.4%), net dragging (15.6%) and altered feeding and manuring (76.6%) that was reported to be an effective control of physiological disorders like asphyxiation and malnutrition. Additionally, the chemical approach was also in practic*e* via use of lime, potassium permangnate, antibiotics, copper sulphate and pesticides. Likewise, there was extensive uses of chemicals like Super killer (5-8 ml/ha); Clinar (240ml/ha) and Cifex (2.5ltr/ha) against Argulus/Fin rot, Lernaea and EUS respectively. Similarly, tail and fin rot disease was reported to be successfully controlled by the use of granulated fabric dyes. However, more elaborte studies are recommended to ensure the efficacy of the dyes against fish diseases.

In this context, some prior studies reported that formalin (150 ppm) was effective against gill rot (Shrestha et al., 2019). Similarly, it was reported that the combined efficacy of Ciphalexin (80 mg/Kg of feed) and Kohrsolin-TH (900 ml/ha) was 97.7 percent for controlling EUS infection in carp species (Rai et al., 2014). However, the use of products sucha as DO Max, Aqua Fresh, Toximar, Clinar, Cifax, Totavet, and Malathion as treatment against fish disease, under the recommendations from local Agro-veterinary vendors, was reported to be unspecified and/or unsafe (D. V. C. Jha et al., 2016).

4.6 Ownership and Treatment of Fishing nets

Usage of drag nets (98.9%) for harvesting fish in the study areas was a common practice in Dhanusha district. The average net-sharing tendency among the farmers was 40.62%. Reported fish deaths were high in Dhnushadham and Mithila municipalities, where the highest percentage of shared nets was reported, but not statistically significant different ($p > 0.05$ chi-square).

Net treatment was reported to be quite unrecognized practice in the study areas. This was due to two common reasons *viz.,* lack of awareness of its importance and the large size of the drag net itself. However, some of the common practices of net treatment as reported are: net washing only (31.3%); Sun drying (42.2%); Washing+Sun drying (20.3%); chemical disinfection (3.2%) and salt treatment (3.1%).

A significant association between mortality and sharing of nets was found in the study conducted by Mulei et al., (2021). The use of salt and disinfectants for net treatment was indicated as being more effective than washing and sun drying in terms of preventing the spread of diseases.

4.7 Status of Extension Services in Fish Farming

4.7.1 Sources of Inspiration to Initiate Fish Farming

The majority of respondents reported to rely for information regarding fish farming, upon fellow successful farmers (82.81%) followed by extension agents (9.50%) and from training (7.69%). Of all respondents, the majority of fish farmers in the study area undertook fish farming as inspired by successful farmers (61.75%), followed by the mass media (14.38%), 13.87% due to the establishment of PMAMP and other offices. Additionally, 10% of the respondents mentioned the problem of unemployment as their primary motivation for turning to fish farming.

Almost all the municipalities had well- established fish farmers. They were found to be the icon for general people to start the fishery enterprise in the first place. Similarly, the establishment of offices like PMAMP (fish superzone); AKC and FHRDTVC with provision for subsidy and technical assistance had also attracted farmers into fish farming. Meanwhile, there also lied the condition of unemployment and lack of labours for agriculture in Dhanusha, thereby triggering fish farming in this district.

4.7.2 Disease- Related Extension Services

In order to control the prevalence of diseases, the majority of respondents (76.8%) relied on experienced farmers, while only 23.2% of the respondents acknowledged the help of government institutions. PMAMP in general, aims to meet the needs of the farming community and other related stakeholders (such as service providers, farming entrepreneurs, rural youths, agricultural sector officials, agro-service agencies, etc.) by making current information and services about PMAMP activities available to them through the various delivery channels that are close by. All of these stakeholders should use Agriculture Result Monitoring Information System (ARMIS) to help them make rational decisions to increase farm production and revenue while also receiving appropriate monitoring information from government and policy-making officials. This was potentially attributed to lack of cooperation among related institutions as well as lack of manpower and technology within the institutions. Similar results were shown in the study done by Jha et al., (2016).

4.8 Fish Production and Marketing

4.8.1 Fish Production

Fish production also varied considerably with culture system and management factors. Average annual fish production from 64 respondents was 1561.81 Mt. The highest production of Chhadi of Rohu and Naini (639.4 Mt), followed by Silver carp (285.4 Mt), Bighead carp (247.8 Mt) common carp (149.01 Mt), table rohu (78.24 Mt), grass carp (56.67 Mt) and the least was of Bhakur (43.6 Mt).

This result is in proximity to the study done by (Koirala et al., 2021), *i.e.,* the maximum production of Chhadi fish (500 Mt) was obtained followed by that of Silver carp (254.2 Mt) and bighead carp (220.7 Mt).

4.8.2 Cost and Return on Fish Farming

In this study, average cost of fish production was calculated per unit hectare of the pond considering both variable cost and fixed cost (table 3). Similarly, the cost of feed was found to be highest with 62.58% of total cost. Likewise, cost of pond construction was found to be highest among the fixed cost with share of 8.19 % of total production cost (Figure 6).

Similar findings were obtained by Subedi et al., (2019) upon the study of feed economics, *i.e.,* the expenditure on feeds alone contributes to more than half of the total cost of production . However, (Koirala et al., 2021) stated that the cost of feed alone constitutes only 37.46% of total cost of production in pond aquaculture system of Dhanusha district.

Table 3: Status of Cost and Return from Fish Farming in Dhanusha

Particulars	Amount (NRs.)	Percentage
Total variable cost	1300000	64.5%
Total fixed cost	715000	35.5%
Total subsidized fixed cost	286000	14.2%
Total cost	2015000	1.0%
Total subsidized cost	1236000	0.6%
Total fish production (Mt/ha)	5.62	
Average price of fish (NRs. / Kg)	300	
Total Revenue (NRs. /ha)	1686000	
Total subsidized cost (NRs.)	1236000	
Gross return (NRs.)	1686000	
Total Benefit (NRs.)	450000	
B:C Ratio	1.36	

4.8.3 Marketing Channel Used by the Fish Farmers

The research indicates that the farmers didn't employ any particular marketing channels. The study found that the majority of farmers purchase agricultural inputs from local markets (57.8%), distant markets (32.4%), as well as from India (9.2%). The open border with India allowed for the more affordable importation of equipment, fertilizers, and feed supplies. However, the majority of the inputs were purchased domestically.

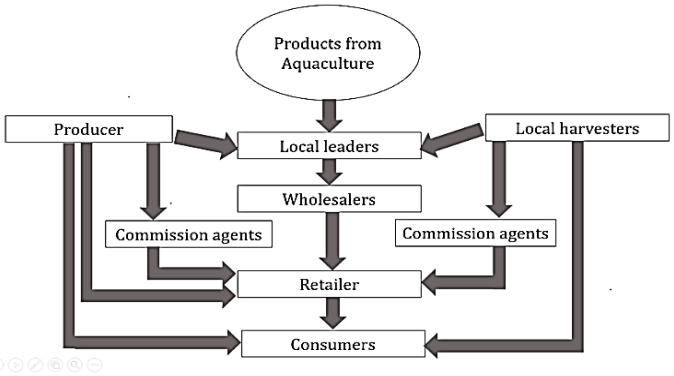

Figure 5: Fish Market Channel of Dhanusha district

Similar to this, local farmers in the study region sold their catch at daily or weekly fish markets. The majority of the harvest was sold in the local markets and within the district to various wholesalers, retailers, or directly to the consumers using various marketing strategies. Large quantities of Chhadi fish are also sold simultaneously at far-off markets like Lahan, Sarlahi, Biratnagar, Dharan, and Kathmandu. According to the study, Producer-Wholesaler -Consumer channel sales accounted for 54.70% of sales made by the respondents, followed by Producer-Wholesaler-Retailer-Consumer channel sales (28.10%). It was discovered that the dhalta system and unpredictable fish marketing channels were the main market problems in this district's fisheries industry. Moreover, Chaudhary et al., (2021) as well as Koirala et al., (2021) independently stated that it was extremely difficult for smaller farmers to compete in the market due to trader monopolies, open borders, road restrictions and a lack of market intelligence.

4.9 Farmers' Satisfaction from Fish Farming

From the study, it was reported that 50% of the farmers were satisfied for having fish farming as major occupation. However, only 37.20% of the respondents were found to be satisfied with respect to the extension services offered by the government offices. Furthermore, young entrepreneurs reported higher level of satisfaction than older ones. This might be due to higher adaptability to competition among the youths. However, an elaborative study is needed to be done to fully understand this tendency among the farmers and the institutional cooperation.

4.10 SWOT Analysis of Fish Farming in Dhanusha district

The aspects of strength, weakness, opportunity and threat of fish farming involves strength and weakness as internal factors whereas opportunity and threats as external factors. According to the study, greatest strength of fish farming in Dhanusha was reported to be the higher price and profitability of fish followed by suitable agro-climate and utilization of marginal lands onwards. Similarly, the foremost weakness thus reported was Market mafia such as *dhalta* system and inappropriate pricing followed by unavailability of quality inputs and so on. Additionally, the best opportunity reported was availability of marginal lands followed by potential for production of quality seeds and feedstuffs, women empowerment via employment in fish farming and promoting research and development. Meanwhile, the foremost threat reported was uncertain shortage of feeds and fertilizers followed by disease related productivity dip, leading to market shutdown due to potential pandemic and lastly, climate change with potential natural disasters (Table 4).

Table 4: SWOT Analysis of fish farming in Dhanusha district

Rank	Strength (S)
1.	Higher price and higher profit
2.	Suitable agro-climate
3.	Utilization of marginal lands
4.	Increasing support and subsidy in Fisheries sector by the Government
5.	Higher and quick return on investment
6.	Collaboration of Modern technologies along with indigenous knowledge and skills
7.	Availability of quality extension team in every zone and super zones
Rank	Weakness (W)
1.	Market: Pricing; Dhalta system
2.	Unavailability of healthy seeds
3.	Prevalent diseases
4.	Poor mechanization and cold chain unavailability
5.	Technical assistance lagging behind
6.	Biased subsidy system
7.	Traditional tools and technologies- Fish as Neglected Farming practice
Rank	Opportunity (O)
1.	Availability of marginal lands
2.	Potential for production of quality seeds, and feed ingredients
3.	Women employment and empowerment
4.	Strengthening market and marketing policy
5.	Use of media, e-marketing and online learning
6.	Industrialization approach via canning, salting etc.
7.	Promotion of modern machineries pond management technologies
8.	Research and development
Rank	Threat (T)
1.	Shortage of Feeds and fertilizers
2.	Disease related productivity dip
3.	Market shutdown due to potential pandemic
4.	Flood and Wild cultivars mixing up
5.	Exploitation of fertile lowlands
6.	Dependency on subsidy and its misuse
7.	Climate change and natural disasters

5. Conclusion

Fish farming in Dhanusha was mostly traditional pond-based carp polyculture, which was controlled by young and educated farmers. The supply of feeds and fertilizers was found to be less than recommended at greater stocking rates. Argulus, Lernaea and EUS were found to be serious fish disease whereas Naini and silver carp were the most susceptible fish species in Dhanusha district. However, highest damage of fish was reported due to Asphyxiation followed by EUS. The most popular method of disease control was liming and/or pond drying. Potash, salt, and numerous other insecticides including Malathion were also claimed to have been used. The average production of fish in the study areas was estimated to be 4.49 Mt/ha with the B/C ratio of 1.36. The major strength of fisheries herein, was the availability of suitable climate and topography, whereas the chief weakness was the lack of knowledge and poor extension services in relation to fish production and disease management in Dhanusha district.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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