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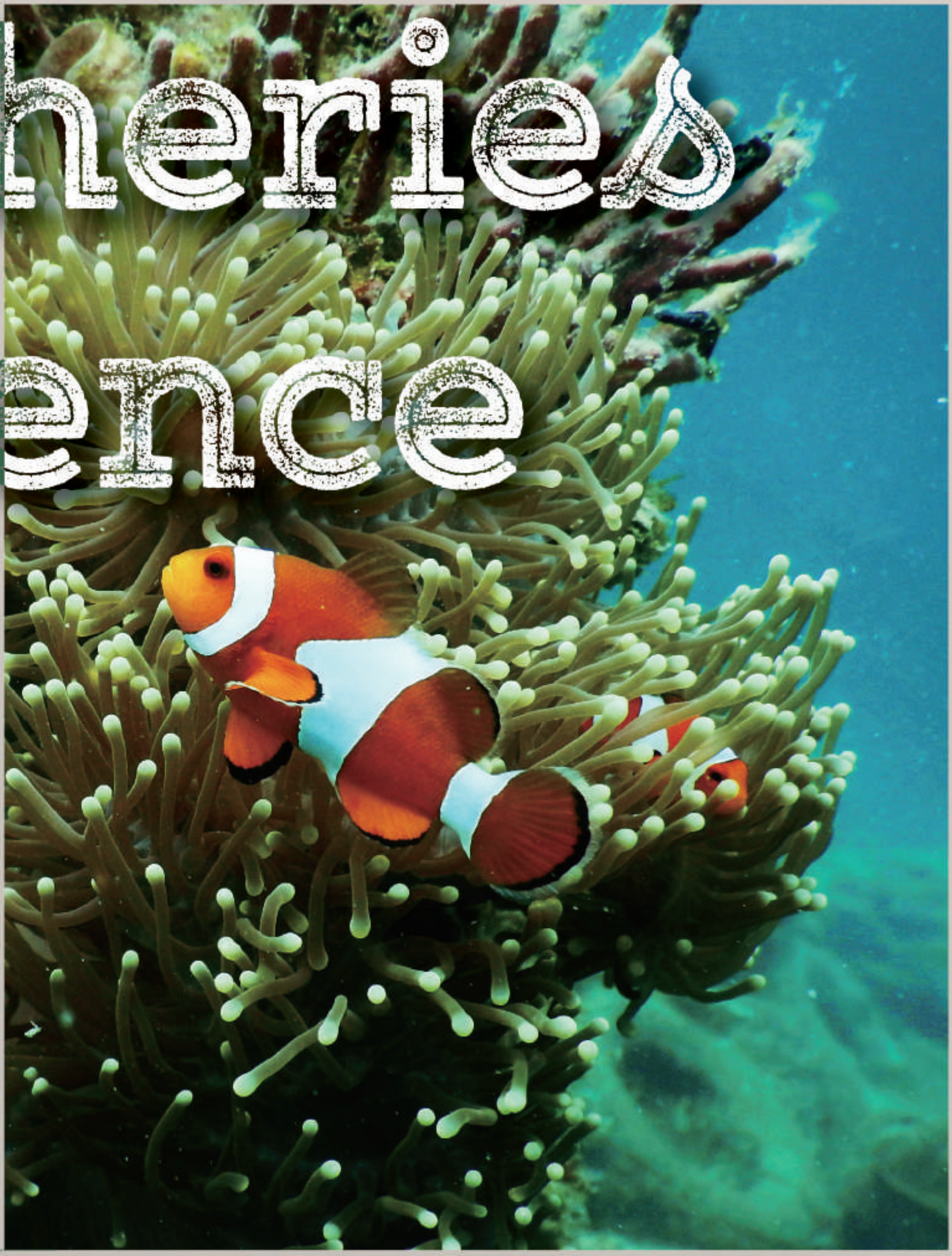

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ARTICLE

AQUAM——A Decision Support Software for Fish Farm Management

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ABSTRACT

In this paper, a software for management and decision support in a fish farm is presented. The software called AQUAM is dedicated to fresh water fish farms. Its aim is to make an efficient management of resources through planning, monitoring, analysis and decision support. Successful planning and management requires the integration of data related to ponds, fish species, fish growth, water and energy and economic analysis. AQUAM computes farm budgets relating various costs and returns in order to determine short and long term profitability. A simulation of the profit, as a function of the fish holding density, is performed with AQUAM. The data used in the simulation are from a fish farm of semi-intensive type, located in the region Danube Delta, at village Jurilovca, Tulcea county, Romania. The fish species that were taken into account were carp and sanger.

1. Introduction

The worldwide harvest of fish has stagnated at around 79 million tons per year and is not expected to rise[1]. At the same time the demand for fish products has continued to rise. The result is a fast-growing aquaculture industry with the highest growth rates in the animal food-producing sector, which had an average annual growth rate of 8.8% up until 2004[2]. With 5.8 percent annual growth rate since 2010, aquaculture continues to grow faster than other major food production sectors. In 2016, aquaculture production increased by 4 million tones over the previous year. By 2030, the world will eat 20 percent more fish (or 30 million tones live equivalent) than in 2016. Aquaculture production is projected to reach in 2030 at 109 million tones, a growth rate of 37 percent over 2016. Aquaculture (also known as aqua farming) is the farming of aquatic organisms such as fish, crustaceans, mollusks and aquatic plants. It involves cultivating freshwater and saltwater populations under controlled conditions. It is different from commercial fishing, which is the harvesting of wild fish.

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The ability of the aquaculture farmer to manage these resources including the know-how, water, capital and time, to the best advantage, for achieving his goals, will determine the performance of the farm. The term „farm management" is used by different people to convey different concepts. Aqua culturists often tend to consider it as the overall technical operation of the farm and supervision of day-to day activities. Good farm management expertise is often considered to have the same value as the practical experience in application of aquaculture technologies in the field. Proper and timely maintenance of the farm and of its installations, successful methods of brood stock manipulation, breeding, seed production, stocking, feeding, disease and pest control, proper water management, including the maintenance of water quality, harvest and marketing are the major elements of this concept of management. The science of farm management was recently applied to aquaculture. It is based on the concept of a farm as a business and consists in the application of scientific laws and principles to the conduct the farm activities.

The managerial activities can be divided in three categories[3,4]: (a) Strategic planning——long-term planning to direct future activities based on available knowledge, (b) Implementation——conversion of plans into reality, (c) Control——measuring process performance and comparing it to standards. Due to the diversity of skills, a farm manager has to have different areas of particular interest: (1) production, (2) marketing, and (3) finance[5]. While production is the most basic area, marketing is also important. Since profit maximization is a common goal in business it is important to keep in view the current market price of the produced product. Furthermore, financial activities require management decisions on capital acquisition and financial funds need to be available on demand[5]. By means of data bases the farm manager is able to compare the actual outcome of the production process with the average performance data[6]. A successful farmer will combine the different areas of management to achieve a maximum overall result.

To manage fish farm have been developed Decision Support Systems - DSS. However, DSS and data analysis cannot completely replace the manager's activities of decision making. They can help the manager to make rational decisions.

Decision support systems provide software for collecting, organizing, and analyzing the information in a consistent manner. Decision support tools can capture current state-of-the-art knowledge of system dynamics, processes, and interactions, and organize these in manner that allows manager a convenient ability to understand the system.

A broad range of aquaculture decision support systems was developed. Some of them have taken into account environmental impacts such as those for selecting and licensing aquaculture sites[7-14] and for planning nutrient removal[15]. Others are used for designing aquaculture facilities[16], managing hatchery production[17], forecasting aquaculture products[18], facilitating aquaculture research and management[19], and evaluating economic impact[20]. In[21] are developed a decision support tool for cage aquaculture. It covers various activities starting from classifying a site, selecting the best site from several site alternatives, calculating a sustainable holding density from a chosen site, and finally performing an economic appraisal of a site.

The 'FISHBASE' system is a comprehensive database system about fish information and it is available for scientific research and teaching. It was supported by the European Committee. The FISHBASE had been exploited by International Center of Aquaculture Resource Management (ICARM), Food and Agriculture Organization (FAO) and other partners.

In this paper, we present a software for management and decision support in an aquaculture fish farm. The software is called AQUAM and is dedicated to fresh water fish farms for the efficient management of resources through planning, monitoring, analysis and decision support. Successful planning and management requires the integration of data related to ponds, fish species, fish growth, water and energy and economic analysis. AQUAM computes farm budgets relating various costs and returns in order to determine short and long term profitability. A simulation of the profit as a function of the fish holding density is performed with AQUAM. The data used in the simulation are from a fish farm of semi-intensive type, located in the region Danube Delta, at village Jurilovca, Tulcea county, Romania. The fish species that were taken into account were carp and sanger.

2. AQUAM——A Decision Support Software for Fish Farm Management

2.1 Overview

According to the *Operational Program for Fisheries, Romania 2014-2021*, Romania has an exclusive economic zone of 25,000 km² at the Black Sea and a coastline of 250 km. The hydrographic network has an area of 843,710 ha, which represents approximately 3% of the total area of the country. The production capacity of Romanian fisheries sector includes: 400,000 ha of natural lakes (including the Danube Delta) and reservoirs, 84,500 ha of fish farms, 15,000 ha of nurseries, 66,000 km of rivers, of which 18,200 km are in the mountains and 1,075 km is the Danube river[22].

Romanian fisheries sector includes aquaculture, marine

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fishing and inland fishing activities as well as processing and marketing activities. However, the most important activity is aquaculture in fresh water, followed by fishing in inland waters[22].

Currently, more than 70,000 hectares of landscaped pools are used in Romania for semi-intensive aquaculture. These production capacities are considered a great advantage in view of developing the aquaculture industry in Romania. However, they should be re-orientated and upgraded in order to increase productivity per unit area. Despite the development of aquaculture in Romania, the development of management software systems has been slow. Information flows have been partially identified; data were not included in large databases. Exploitation and analysis of existing data is partial. There are a few simple applications for accounting or for tracking the production. This situation had motivated the interest for developing a software for the fish farms management, adapted to the existing conditions from Romania. In this paper is presented a software called AQUAM for fish farm management and decision support. The use of the computer software for decision support in a fish farm has advantages compared to the conventional operating farms. The major advantages are connected to: (1) increasing the fish farm performances: higher profit and production, (2) decreasing of the efforts, (3) reducing the water and energy losses and (4) increasing the quality of management.

The main resources in a farm are the material resources and the financial resources. AQUAM takes into consideration the main resources (material and financial) in a fish farm. Examples of resources considered are: ponds, fish species, staff, feed, water, energy, money, etc. The system manages resources in a dynamic manner, taking into account the time parameter. AQUAM calculate financial indicators and indicators of economic performance.

The structure, data base, models base, modules and links between modules are shown in the software system architecture AQUAM (Figure 1). The database contains a structured information about the fish farm. The models base contains bio-economic models and a minimum risk model. In this paper one of the bio-economic models is presented.

The minimum risk model was presented in [23,24].

The AQUAM modules are: Fish Farm Information, Planning, Monitoring and Analysis.

The module Fish Farm Information contains important information about fish farm:

(1) General information: name and address of the fish farm, total area (land and water), legal consideration;

(2) Ponds of the fish farm: number, name, water area, mean depth;

(3) Fish species raised in the fish farm: name, age, scientific name, caracteristics, etc.;

(4) Technical equipments from the fish farm: name, number, caracteristics;

(5) Products of the fish farm: fresh fish, frozen fish, etc.;

(6) Suppliers for seeds, feed: name, address, phone and fax number, email, caracteristics;

(7) Buyers: name, address, phone and fax number, email;

(8) Staff: permanent and mobile staff, studies, etc.

This information is stored in the AQUAM database and is used in other modules of the AQUAM software. An important aspect in a management of a fish farm is elaboration of an efficient production plan. In the Planning module are considered: fish density planning, feeding planning, aeration and water schedule, annual and monthly costs estimation, incomes and budget estimation. Depending on the estimated plan the expected profit will be computed. Based on a bio-economic model a profit simulation is realized. An important module is the monitoring (tracking) module. The monitoring is realized for feeding, aeration and water, annual and monthly costs, incomes and budget, profit and losses. Costs can be tracked monthly. Revenues come mainly from selling fish. A realized budget and profit are calculated in this module. An analysis refers to profit and production analysis.

The planning, monitoring and analysis are realized for various levels of detail. For planning and monitoring the level of detail refers to all or selected species and all or selected age. The analysis of the level of detail refers to a period of time (in years), all or selected species and all or selected age. The link between the database, the models, modules AQUAM and the manager is provided by the component "User Interface".

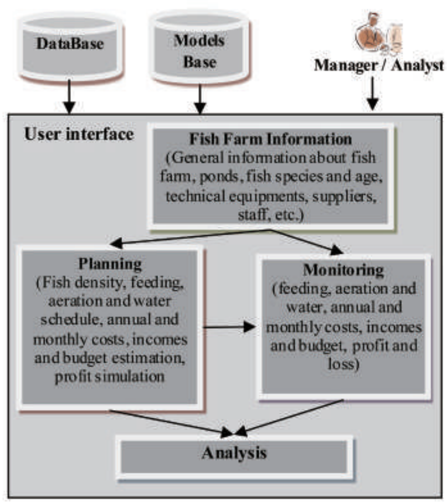

Figure 1. The System Architecture of AQUAM

2.2 Profit Simulation

The bio-economic model is presented in Table 1 and Table 2. In Table 1 are presented the inputs in the model and in Table 2 the equations of the model. In Figure 2 the costs, profit and return of an investment in a fish farm of semi-intensive type are computed. The date come from a fish farm located in the region Danube Delta, at village Jurilovca, Tulcea county, Romania.

Table 1. Inputs in the bio-economic model

Name	Measure unit	Symbol
Mean fish seed weight	Kg	FWS
Holding density at harvest	Kg/ha	HD
Ponds surface	Ha	PV
Survival rate of fish seed	percent	SR
Mean fish weight at harvest	Kg	FW
FCR (food conversion ratio)	-	FCR
Seed cost	Euro/kg	SC
Feed cost	Euro/kg	FC
Other costs	Euro	AC
Interest rate for borrowed funds to cover the cost	percent	IRC
Fish price at harvest	Euro/kg	FPH

Table 2. Profit and return of the investment calculation

Name	Measure unit	Sym-bol	Formula
Holding density at harvest	Nr. of fish/ha	HDN	HDN=HD/(FW-FWS)
Total weight of fish	Kg	WH	WH = HD x PV
Total fish bio-mass	Nr. of fish	BH	BH =WH/FW
Number of seed	Nr. of seed	NS	NS = BH/SR
Feed needed to produce biomass at harvest	Kg	FN	FN = FCR x WH
Total costs for seed	Euro	TSC	TSC = SC x NS x FWS
Total costs for feed	Euro	TFC	TFC = FC x FN
Total cost	Euro	TC	TC = (TSC + TFC + AC) (1 +IRC/100)
Break-even price	Euro/kg	BEP	BEP = TC/WH
Revenue	Euro	REV	REV = FPH x WH
Profit	Euro	PRO	PRO = REV – TC
Return of the investment	percent	ROI	ROI = 100 x (PRO/TC)

Suppose that exists a functional dependence between the fish survival rate *SR* and the fish holding density *HD*, that is $SR=f(HD)$. Note that the function f should be decreasing since the higher will be the fish holding density *HD*, the lower will be the fish survival rate *SR*. Suppose that the function is strictly convex and not monotone. Then the profit *PRO* will be a non-monotonic strictly concave function of *HD*. Consequently, *PRO*, as a function of *HD*, will have a unique maximum. Denote by HD_{opt} the fish holding density that maximizes the profit. The graph of the profit *PRO* as a function of holding density *HD* is displayed in Figure 3.

Note that at the beginning, the profit is increasing as the holding density increases. There exists an optimal holding density HD_{opt} for which the profit attains its maximum. If the holding density is greater than the optimal holding density HD_{opt} the profit begin to decrease. This is explained by the fact that higher fish densities imply higher risks.

In the case $f(HD) = \frac{k}{k + HD}$, $k > 0$, k constant, the profit *PRO* is a polynomial of degree two of the holding density *HD*.

The dependence of *SC* and *HD* is displayed, for our example, in Figure 4. The profit simulation is realized for carp and sanger species.

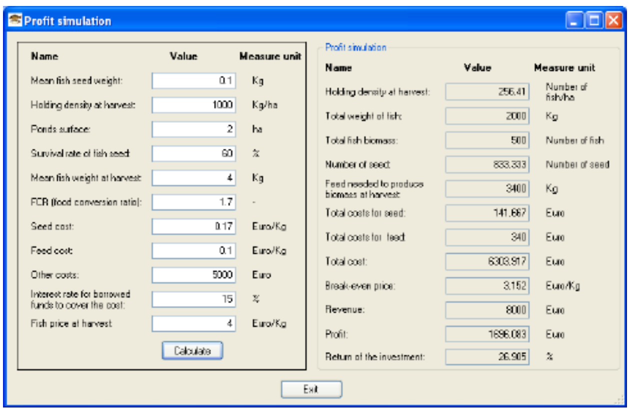

Figure 2. Costs, profit and return of the investment

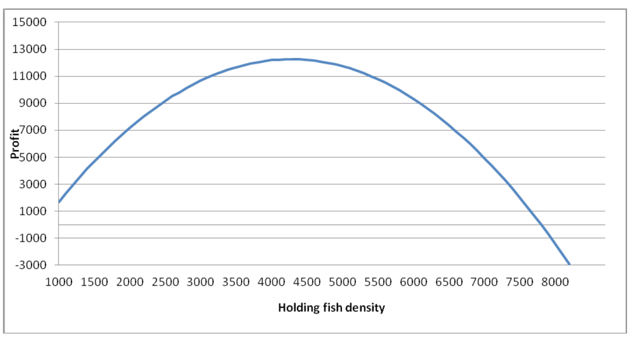

Figure 3. The profit as a function of fish holding density

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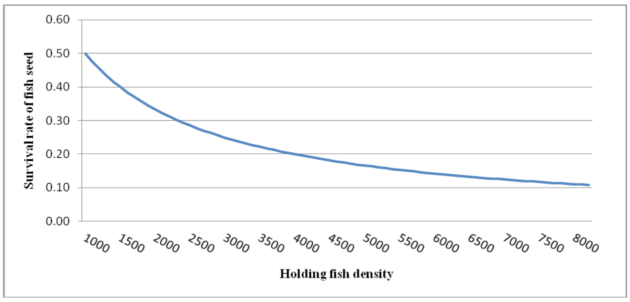

Figure 4. The fish survival rate *SR* as a function of the holding fish density – *HD*

3. Conclusion

The number of software applications for fish farms has increased in the last few decades. In the paper a software application, called AQUAM, for fish farm management is presented. The software system architecture shows the structure, data base, models base, modules and links between modules. A simulation of the profit as a function of the holding density is performed with the software AQUAM. The simulation is based on a bio-economic model that supposes that there exists a functional dependence between the fish survival rate *SR* and the fish holding density *HD*. The data used for the simulation come from the Jurilovca fish farm. Farm managers have recognized the advantages of using decision-support tools for farm management and decision planning. The use of such a system has many advantages for fish farmers. It allows him to obtain higher profits and production, to reduce the labor costs, and make optimal decisions.

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ARTICLE

Prevalence of Ectoparasitic Infestation in Indian Major Carps During Winter at Different Blocks of South 24-Parganas District, West Bengal, India

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ABSTRACT

The study was carried out to find the prevalence of ectoparasites in carp species specifically Indian Major Carps (IMC) during the post monsoon season (November'16 to March'17). Four groups of ectoparasites viz. myxozoan, ciliophoran, monogenean and crustacean were recorded from a total 500 number of carp species like, *Labeo rohita, Catla catla, Cirrhinus mrigala and Labeo calbasu* collected from different ponds of selected blocks of South 24-Parganas district of West Bengal. The highest prevalence (64.8%) of infestation had been recorded by Myxozoans and the lowest was by Monogeneans (4.8%). The highest and lowest ectoparasitic prevalence in carp was observed in *L. rohita* (32.9%) and *C. catla* (27.3%). Beside these, lower temperature (Average 19.3℃), low pH (Average 6.9) and marginal level of dissolved oxygen (Average 6.0ppm) were also created an unfavorable condition for parasitic infestation during this season. At the end of this experiment it was concluded that disease occurrences due to ectoparasites was high in winter with some key factors like temperature, pH and dissolved oxygen (DO).

1. Introduction

Disease is now a primary constraint for culture of many aquatic species which creates a negative effect both in economic and social development[1]. The increase in production of culture system, increases the potentiality of disease out-break. Other than marketing concern, the biggest challenges that were faced by the fish farmers; to control many biotic and abiotic factors, which influence fish rearing and aquaculture operations. It is well known that, the entire water area of West Bengal supports the potential fish farming compared to the other states of this country; and this high production rate in West Bengal was always lead by South 24-Parganas district till date. Freshwater aquaculture depends mainly on carp culture practices that account for around 80% of the total inland fish production according to Sanyal *et, al*. (2016)[1]. This district was attributed as a potential source of Carp farm-

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ing. It was only with the three main Indian Major Carps *viz*., Catla (*Catla catla*), Rohu (*Labeo rohita*) and Mrigal (*Cirrhinus mrigala*) that contributes a lion's share in total fish production of West Bengal.

The parasitic community of fishes, show considerable variation with the environmental conditions in which fish live[2]. Hence it is assumed that fluctuation of environment has been attributed to many disease outbreaks[3,4]. Certain environmental conditions are more conducive to disease among which water temperature is one of the important criteria associated with disease outbreak. It was observed that the prevalence of the disease was more in the winter season[5] than the other months of the year. The physiological and biological features of the host, affect the composition of parasite[6]. Fish parasites cause the significant loss to wild and cultured IMCs. Large-scale mortality of IMCs often occurs in ponds and tanks due to stocking and environmental stress, followed by parasitic afflictions. Heavily ecto-parasitic or endo-parasitic infested fishes, showed interruption in normal growth and development. Mainly these parasites, feed either from the digested content of the host's intestine or the host's own tissue[7]. Parasites cause deterioration in the food value of affected fishes and may even result in their mortality. It not only disturbed the supply of protein but also brings about a bad impact on our socio- economic condition[8]. It was already said that there was a direct relation between disease outbreak among fishes and environmental factors. Low pH, lower temperature reduces the buffer capacity of water and that badly affects the pond ecosystem. Furthermore, the incidence of infection is accentuated by the low dissolved O_2 and relatively high CO_2 value in shallow waters, affecting the usual relationship between the invading parasites and the fish[9], which in turn causes stress to the fish and that leads to fishes more susceptible to diseases and parasites. As, it's already mentioned that the parasitic prevalence was more in the winter season[5] than the other seasons of the year. This study was conducted with an intention to prove this and so the field work and experiments were planned about the ectoparasitic infestation of IMC during the winter season in the selected blocks of South 24-Parganas with some key factors like temperature, pH and DO.

2. Methodology

2.1 Fish species and Study Area

Study was carried out on Catla (*Catla catla*), Rohu (*Labeo rohita*), Mrigal (*Cirrhinus mrigala*) and Kalbose (Labeo calbasu). The five blocks that were chosen - Joynagar-II [22^{0}10'28.68"(N), 88^{0}27'07.06."(E)], Budgebudge-II [22^{o}27'54" (N), 88^{o}10'06" (E)], Canning-I [22^{0}20'46.05" (N), 88^{0}40'16.94" (E)], Bhangore-I [22^{0}30'02" (N), 88^{0}29'03.9" (E)] and Sonarpur [22^{0}26'33.48"(N), 88^{0}33'47.92."(E)] of South 24-Parganas District, West Bengal, as per the total production and IMC production rate, availability of culture area.

2.2 Sample Collection

From the selected five Blocks, 125 numbers of each species were collected from November'2016 to March'2017. A total of 500 species of Catla (*Catla catla*), Rohu (*Labeo rohita*), Mrigal (*Cirrhinus mrigala*) and Kalbose (*Labeo calbasu*) were screened for the experiment of juvenile stage (Average 250 – 400 gm weight). The samples were collected once in every month on a regular basis from every selected farm. The methods for collection and preservation of the samples for parasitic examination were followed as described by Soota, 1980[10]. Live host or freshly dead specimen were randomly sampled and collected. The fishes were examined immediately after collection. Prior to collect the affected fish samples, its behavior and clinical signs were recorded.

2.3 Parasitic Study

The length and body weight of the fishes along with date and site of collection of specimens were recorded. The gills, fins, scales and operculum were removed with least damage and placed on separate Petri-dishes containing distilled water and examined. Each of the four gills of both sides was examined separately. The gills and body surface were checked thoroughly for any attached parasites. The dorsal, pectoral, pelvic, anal and caudal fins were placed in separate petri-dishes. Each fin was thoroughly examined; scales of each side were scrapped out along with the mucus and taken separately for examination. Microscopic examinations were done & photomicrographs of ecto-parasites were taken using Olympus microscope (model no. BX51, made of Japan) with in-built digital camera (top view version 3.5). The gill, body, and tail fin smear were prepared on grease free clean slides with a drop of 0.85% NaCl solution and air dried. The India ink method[11] were followed to identify the myxozoan spores and for permanent slide preparation; the air-dried smears were stained with Giemsa stain. The Ciliophoran parasites were subjected to silver impregnation following the method of Klein (1958)[12]. The Monogeneans were removed on to clear slides with a fine niddle and kept in a drop of water and covered with cover slip. They were fixed in glycerol alcohol (90 parts of 70% ethyl alcohol and 10 parts of glycerol), stained in Borax carmine and finally mounted in glycerine jelly. Phenotypic characterization of all Proto-

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zoans, Monogeneans, Digeneans, and Nematode parasites were studied as described by Soulsby (1982)[13].

2.4 Prevalence Study

The Parasitic prevalence was estimated with the aid of Parasitic Frequency Index (PFI) which was calculated by taking the percentage of the number of hosts infected by an individual parasite species against the total number of hosts examined in a particular area under investigation. Prevalence was estimated following the formulae proposed by Margolis *et, al*. (1982)[14].

$$\text{Prevalence } (\%) = \frac{\text{Total number of infected fishes}}{\text{Total number of fish host examined}} \times 100$$

According to Srivastava'1980[15], the frequency index were further classified into rare (0.1-9.9%), occasional (10-29.9%), common (30-69.9%) and abundant (70-100%).

Determination the Severity of infection was characterized for assigning numerical qualitative value to severity grade of infections, surface infestations and disease syndrome severity, through the following scale by Lightner'1993 [16]:

Table 1. The Scale by Lightner'1993

Disease Syndrome Severity	Remarks
0.5	Non infective
1	Mild
2	Moderate
3	Infective
4	Excessive

2.5 Study of Water Quality

The three main water quality parameters (*viz*, water temperature, pH and dissolved oxygen) which are related to fish health were measured as prescribed by Kumar *et, al*.'2010[17], of each sampling ponds during the whole study period. All parameters were checked during day time, water temperature was measured by mercury thermometer, pH was measured by Pen pH meter and DO was measured by *NICE* Water Testing Kit (For the estimation of DO).

3. Results

Four groups of ectoparasites were identified, *viz*., myxosporeans, ciliophorans, monogeneans and crustaceans (Fig. 1). Among the Myxozoans group, *Myxobolus* sp. scored highest as per Parasitic Frequency Index (PFI) (Table 2). A dominating prevalence pattern was observed which represented "abundant" (Table 2) for *Myxobolus* sp. According to frequency index classification by Srivastava'1993[15], it was found throughout the experimental season, November, 2016 to March, 2017. Prevalence of myxoboliosis were seen highest (Table 3) in *Labeo rohita* (PFI, 78.2%) among the IMCs while it has shown lowest prevalence in *Catla catla* (PFI, 68.8%). The Block Bhangore-I (Table 5) showed highest prevalence (PFI, 75.5%), while Canning-I showed lowest prevalence (PFI 67.3%).

Prevalence of *Thelohanellus* sp. (57.2 %) kept "common" trend throughout the experimental period (Table 2). This myxozoan was abundant in *Labeo rohita* (PFI 61.2%, Table 3) and lowest prevalence in *Catla catla* (55.0%). In the block wise experimental data (Table 5), *Thelohanellus* sp. showed highest prevalence in Bhangore-I (PFI, 58.8%) and lowest in Canning-I (PFI, 56.2%). The average PFI percentage of myxozoan infection throughout the experimental period was 64.8%, which was abundant according to Srivastava'1993[15] (Table 2).

Throughout the study, only two ciliophoran specimen were found i.e. *Trichodina* sp. and *Ichthyophthirius* sp. and among these, *Trichodina* sp. were found to be more common (PFI 28.5%) while *Ichthyophthirius* sp. were rare in appearance (PFI 5.1%) throughout the experimental season (Table 2). *Trichodina* sp. were more abundant in Bhangore-I (PFI, 62.3%) and rarest in Sonarpur (PFI 7.3%, Table 5); *Ichthyophthirius* sp. were also rare in Bhangore-I (PFI 9.8%) and minimum in Canning-I, (PFI 4.1%, Table 5). As per affected fish species prevalence report (Table 3), between these two ciliophorans, *Trichodina* sp. was more common in *Labeo rohita* (PFI 30.2%) and minimum in *Labeo calbasu* (PFI 26.4%). On the other hand *Ichthyophthirius* sp. were absent in *C. catla* and it showed highest prevalence in *L. rohita* (PFI 8.1%) and lowest in *L. calbasu* (PFI, 4.6%). *Trichodina* sp. and *Ichthyophthirius* sp. were absent in Budgebudge II and Jaynagar II respectively.

In whole experimental period (November, 2016 to March, 2017), monogeneans showed rare occurrence (Table 2) according to Srivastava'1993[15]. The average prevalence of Monogeneans was 4.8%. Among the Monogeneans only *Dactylogyrus* sp. (PFI 7.5 %) and *Gyrodactylus* sp. (PFI 2.1%) were observed and they were referred rare as per parasitic pevelance report. *Dactylogyrus* sp. showed highest prevalence (Table 5), in Bhangore-I (PFI 12.5%) and low in Jaynagar-II (PFI 7.6%). This parasite was absent in Budgebudge-II. While *Gyrodactylus* sp. was absent in both in Joynagar-II and Budgebudge-II. *Gyrodactylus* sp. showed highest prevalence in Bhangore-I (PFI 5.7%, Table 5) and lowest in Canning-I (PFI 2.2%). In our study it was seen that both of these Monogeneans showed highest prevalence in *Labeo calbasu* (PFI for *Dactylogyrus* sp. and *Gyrodactylus* sp. were 8.7% and 3.2% respectively, Table 3) and lowest in *Catla catla*. Prevalences were 7.9% & 2.3% in *Dactylogyrus* sp, and *Gyrodactylus* sp. for *Cirrhinus mrigala* respectively (Table 3).

Beside the monogeneans, the crustaceans like *Argulus* sp., *Lernaea* sp. and *Ergasilus* sp. confirmed their prevalence (Table 2). *Ergasilus* sp. (PFI 10.2%) just reached within the boundary of occasional while *Argulus* sp. (PFI 49.9%) and *Lernaea* sp. (PFI 31.3%) were common. The average PFI value of crustacean ectoparasites was 30.4%, which denote that in winter season crustacean parasitic prevalence was common (Table 2). *Ergasilus* sp. showed highest prevalence in *L. calbasu* (18.2%, Table 3) which was occasional and *Argulus* sp. showed highest prevalence in *L.rohita* (53.8%) which was common according to frequency index by Srivastava'1993[15]. In the surveillance report it was observed that Bhangore-I indicated highest prevalence result for *Ergasilus* sp. (PFI 18.9%, Table 5), *Lernaea* sp. (PFI 43.6%), and *Argulus* sp. (PFI 79.2%). These crustaceans parasitic diseases were completely absent in Canning-I and except argulosis, the other two types were absent in Jaynagar-II (Table 5).

Severity grade of infections was calculated according to Lightner'1993 [16]. In myxozoans, it was observed that severity of infection was 'moderate' in both *Myxobolus* sp. and *Thelohanellus* sp. following Lightner'1993[16]. In case of ciliophorans (*Trichodina* sp. and *Ichthyophthirius* sp.) and monogeneans (*Dactylogyrus* sp. and *Gyrodactylus* sp.), both were showed as 'non-infective'. Among crustaceans, *Ergasilus* sp., *Argulus* sp. and *Lernaea* sp. were illustrated as 'non-infective', 'moderate' and 'mild' respectively.

Statistical analysis (Table 4) by two way ANOVA revealed that there was significant differences ($P<0.05$, df=8) in PFI (%) values of different fish species in relation to different parasites. Similarly there was significant differences ($P<0.05$, df=3) in PFI (%) among the parasites in relation to different fish species. Statistical analysis (Table 6) by two way ANOVA also revealed that there was significant differences ($P<0.05$, df=8) in PFI (%) values of parasites in relation to different places. Similarly there was significant differences ($P<0.05$, df=4) in PFI (%) values of different places in relation to different parasites.

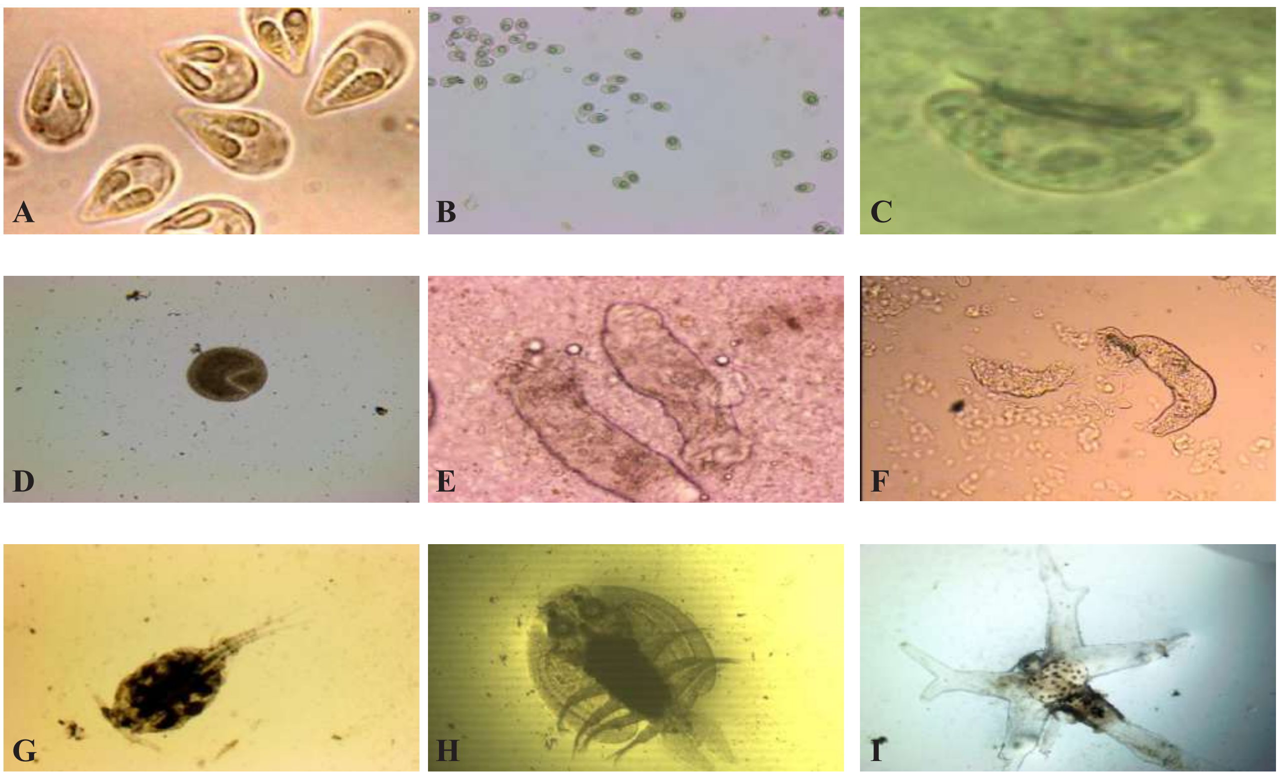

Figure 1. Identified Ectoparasites——myxosporeans , ciliophorans, monogeneans and crustaceans; A) *Myxobolus* sp., B) *Thelohanellus* sp., C) *Trichodina* sp., D) *Ichthyophthirius* sp., E) *Dactylogyrus* sp., F) *Gyrodactylus* sp., G) *Ergasilus* sp. (Copepod stage), H) *Argulus* sp., I) *Lernaea* sp.

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Table 2. Prevalence & severity of infection for individual ectoparasites in IMC species from Nov.'16 to Mar'17

Myxozoans	PFI (%)	Severity of infection	Ciliophorans	PFI (%)	Severity of infection	Monogeneans	PFI (%)	Severity of infection	Crustacean	PFI (%)	Severity of infection
Myxobolus sp.	72.3 ± 11.3	2	*Trichodina* sp.	28.5 ± 15.4	0.5	*Dactylogyrus* sp.	7.5 ± 2.1	0.5	*Ergasilus* sp.	10.2 ± 29.9	0.5
Thelohanellus sp.	57.2 ± 6.1	2	*Ichthyophthirius* Sp.	5.1 ± 21.8	0.5	*Gyrodactylus* sp.	2.1 ± 2.6	0.5	*Argulus* sp.	49.9 ± 7.3	2
									Lernaea sp.	31.3 ± 22.6	1
Average PFI	64.8			16.8			4.8			30.4	

Table 3. The average (%) of PFI of IMC from Nov'16 to March'17

Name of the Parasitic Groups		Name of the affected Indian Major Carp							
		Labeo rohita		*Labeo calbasu*		*Catla catla*		*Cirrhihus mrigala*	
		PFI%	Site of infection	PFI%	Site of infection	PFI%	Site of infection	PFI%	Site of infection
Myxosporean	*Myxobolus* spp.	78.2	Gill, Fins	71.8	Gill, Fins	68.8	Fins	70.3	Gill
	Thelohanellus spp.	61.2	Gill, Fins	56.2	Gill	55.0	Fins	56.4	Fins
Ciliophorans	*Trichodina* spp.	30.2	Body, Gill	26.4	Body, Gill	27.5	Gill	29.7	Body, Gill
	Ichthyophthirius spp	8.1	Body, Gill	4.6	Body	0.0	-	7.4	Body, Gill
Monogeneans	*Dactylogyrus* spp.	8.1	Gill	8.7	Gill	5.3	Gill	7.9	Gill
	Gyrodactylus spp.	2.9	Body, Fins	3.2	Body, Fins	0.0	Body	2.3	Body
Crustaceans	*Ergasilus* spp.	18.1	Gill	18.2	Gill	11.5	Gill	17.0	Gill
	Argulus spp.	53.8	Body, Operculum, Fins	48.9	Body	46.9	Body, base of the Pectoral and Dorsal Fins	49.8	Body, Operculum, Fins
	Learnaea spp	35.4	Body, in some times Anal part of body.	31.3	Body	30.5	Body	28.0	Body, in some times base of the pectoral fins.
Avg.% PFI		32.9		29.9		27.3		29.9	Avg. % of Total PFI 30.0

Table 4. Two way ANOVA of PFI (%) values for Parasites in relation to different fishes from Nov'16 to March'17

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Parasites	20093.41222	8	2511.676528	758.6979317	6.27E-27	2.355081
Fish	141.9852778	3	47.32842593	14.29641853	1.5E-05	3.008787
Error	79.45222222	24	3.310509259			
Total	20314.84972	35				

Table 5. The average percentage of PFI, in different selected Blocks of South 24-Parganas from Nov'16 to March'17

Name of Parasite / Block Name		Joynagar-II	Budgebudge-II	Bhangore-I	Canning-I	Sonarpur	
Myxosporeans	*Myxobolus* sp.	73.8	71.8	75.5	67.3	73.2	
	Thelohanellus sp.	56.9	57.3	58.8	56.2	56.9	
Ciliophorans	*Trichodina* sp.	27.9	0.0	62.3	16.7	7.3	
	Ichthyophthirius sp	0.0	5.2	9.8	4.1	5.4	
Monogeneans	*Dactylogyrus* sp.	7.6	0.0	12.5	9.3	8.6	
	Gyrodactylus sp.	0.0	0.0	5.7	2.2	2.8	
Crustaceans	*Ergasilus* sp.	0.0	8.3	18.9	0.0	3.6	
	Argulus sp.	16.4	31.4	79.2	0.0	72.2	
	Learnaea sp.	0.0	16.2	43.6	0.0	33.8	
Avg. % of PFI		20.3	21.1	40.7	17.3	29.3	**Avg. of Total** 25.7

Table 6. Two way ANOVA of PFI (%) values for Parasites in relation to different places from Nov'16 to March'17

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Parasites	25604.4404	8	3200.55506	17.174949	1.42E-09	2.244396
Places	3226.82578	4	806.706444	4.328981	0.006536	2.668437
Error	5963.20622	32	186.350194			
Total	34794.4724	44				

The three main water quality parameters, water temperature, pH and dissolved oxygen which are related to fish health were measured of each sampling ponds during the whole study period. All parameters were checked during day time. The temperature was almost same in all the places (average 19.3^{o} C). DO was 6.5 ppm in Bhangore-I which was highest other than four blocks; however, average was 5.96ppm which was marginal. The pH was also low (average 6.9) which also badly affects the pond ecosystem.

Table 7. Average water quality parameter of selected different Blocks from Nov'16 to March'17

Block Name Parameter	Joynagar-II	Budgebudge-II	Bhangore-I	Canning-I	Sonarpur	Avg. of Parameters
Temperature (℃)	19.2	19.3	19.3	19.2	19.2	19.3
Dissolve Oxygen (ppm)	5.9	5.2	6.5	5.8	6.3	6
pH	6.9	7.1	6.5	7.3	6.6	6.9

4. Discussion

The influence of parasites in relation to the seasons had been described by many researchers. The occurrence of Myxozoans, Ciliophorans, and Crustacean were found more or less in all seasons, but it reached peak during the winter and spring season[18,19], because in this season fishes become more susceptible to diseases due to low immunity power for the sudden change in water temperature. This study is in agreement with the reference cited above. Maximum disease prevalence was found in *L. rohita*, because of its low immunity power than other carp species. *L. rohita* made a gap with other carp species (Table 3), while *C. catla* remained in the bottom end. These results were similar with the works of others [18,20], who worked on disease occurrence as per seasonal variations. It can be mentioned that, according to the average PFI estimation of all aggregating data of affected carp specimen (30.0%, Table 3) and selected block wise prevalence result (25.7%, Table 5), the prevalence can be attributed as “occasional” or tends to “common” in the post monsoon season. In this regard it can be said that in winter season as fish species became weak due to temperature drop, it made them more susceptible to disease.

It was observed that the highest prevalence of parasites were in December and January, this study was done following Basu and Haldar, (2004)[21], when the ambient temperature was below 25ºC [18]. The result was supported strongly by this reference where throughout the experimental period, the average temperature, pH and DO were 19.3^{0}C, 6.9 & 6 respectively. The suitable temperature for development throughout their life cycle and reproduction were estimated 24-28^{0}C, [22] which was not in agreement with the present observations. It was assumed that poor water quality, DO, low pH and low temperature were the key factors for invention of this ectoparasite.

In this study it was observed that each sampling aquatic water bodies showed average pH value 6.9 (Table 7) which is lower than the acceptable limit for aquaculture pond. Average highest & lowest pH value were 7.3 (Canning I) and 6.5 (Bhangore I). It was noted that Canning-I indicated low disease prevalence than other districts (Table 5). So, it could be concluded that this low pH value beside the low temperature were one more major factor for bringing several parasitic diseases [18].

There were several reasons behind the low pH value in our selected aquatic water bodies;, like high stocking density, algal bloom, aquatic weed; besides these biological phenomenons other important observations were connection of community drain line with aquaculture ponds, unwanted human interventions in the pond which produces decomposition, degrading animals and their parts were also present in some ponds and these were the main causes regarding aquatic pollution. These affected the average DO level which was at 6 ppm (Table 5) and that was lower than the marginal limit for aquaculture pond.

According to the surveillance report, the prevalence of the parasites reached comparatively high in the month of December and comparatively low in the month of March. It may be due to organic load in the culture ponds which

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induces bio-ecological stress and made fish more susceptible to this parasitic infection. It is evident from the available literature that parasitic diseases caused significant damage not only in stocking system but also caused damage in nursery and rearing systems of carp, catfish and others [23]. Beside these poor environmental condition, malnutrition was observed in several blocks specially Sonarpur & Canning-I. Most of the water bodies that were affected by the parasitic diseases were having high organic load as well as high stocking density and poor quality of aquatic environment.

5. Conclusion

To draw a conclusion from this study, this can be said that the post monsoon season, i.e. winter, along with the lower temperature, low pH, marginal level of DO harness to create a favorable environment for the ectoparasitic infestations, specially myxoporeans and *Argulus* sp. Due to this poor aquatic environmental temperature, fish reduces metabolic activities, which in turn also made the fishes more susceptible during the winter period towards parasitic infestations. More in depth research is needed to be carried out for studying on parasites diseases of fishes and other biotic factors.

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ARTICLE

The Potential for Homestead Pond Polyculture of Tilapia and Carps in Coastal Bangladesh

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ABSTRACT

A fishers' women-led Participatory Action Research (PAR) was conducted in 30 homestead ponds to assess the potential for polyculture of Tilapia (Oreochromis niloticus) and major carps Rohu (Labeo rohita) and Catla (Catla catla) in two coastal fishing villages of Bangladesh. Three treatments, namely T1 (Tilapia 200 fish per decimal; 1 decimal=40 m2), T2 (Tilapia 200+ Rohu 32+ Catla 8 fish per decimal) and T3 (Tilapia 200+ Rohu 8+ Catla 32 fish per decimal), each with 5 replicates, were tried in Hossainpur and Anipara villages. Formulated commercial Mega-feed was applied to the ponds twice daily at an initial rate of 10% body weight (bw)/day of Tilapia down to 4% bw/day throughout the culture period. The water quality parameters of ponds including transparency, salinity and dissolved oxygen significantly varied among treatments except temperature and pH and remained within optimum range for carp polyculture except salinity. The survival rate, harvesting weight and yield of Tilapia were significantly highest in T1 (85.63±05%, 258.59±18.76 g & 11073±805 kg/ha, respectively) in Anipara and lowest in T3 (75.63±0.37%, 136.97±10.63 g & 5180±406 kg/ha, respectively) in Hossainpur. The gross fish production was the significantly highest in T1 (11354±806 kg/ha) of Anipara and lowest in T1 (6325±227 kg/ha) of Hossainpur. Statistically, the highest net return (866,627±84874 BDT/ha) was found in T1 of Anipara and lowest in T3 (279,389±46104 BDT/ha) of Hossainpur with a significantly higher benefit-cost ratio (BCR) obtained in T1 (3.26±0.20) for Tilapia and lower in T3 (1.58±0.10) for polyculture Tilapia and carp of Hossainpur. Therefore, it may be concluded that Tilapia production in small homestead coastal ponds has a higher potential than its mix with carps in polyculture for generating food and supplemental income opportunity for coastal fishers' women in Bangladesh.

1. Introduction

Aquaculture is the fastest growing food producer in the world over the last century[1] and Bangladesh ranked 5th position as per aquaculture production[2]. Inland capture and culture systems have contributed 83.72% to the total fish production (3.68 million metric tons) in 2014-2015[3]. The aquaculture sector plays an important role in the socio-economic

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development[4,5], nutrition supply[6], employment generation, poverty alleviation[7] and foreign exchange earnings[8] of the country. There are 4 million small homestead ponds[9] used for multiple purposes, such as bathing, washing and watering livestock; that are located close to their homestead[10]. The majority of homestead ponds are used for semi-intensive polyculture of fast growing fish species, particularly of major Indian and Asian carps, Rohu (Labeo rohita), Catla (Catla catla), Mrigal (Cirrhinus cirrhosus), Silver (Hypophthalmichthys molitrix), Grass carp (Ctenopharyngodon idella) and Common carp (Cyprinus carpio)[11]. It is widely believed that polyculture increases the productivity of the aquaculture system by efficient utilization of ecological resources within the environment[12,13]. Stocking of two or more complimentary fish species can increase the maximum standing crop of a pond by utilizing a wide range of available food items and the pond volume[12,14,15,16].

Tilapia (Oreochromis niloticus), one of the fast growing cultivable food fish species[17], in recent years, has become one of the most popular commercial aquaculture species[18] due to its fast growth, tasty flavour, good resistance to poor water quality and disease[19], and tolerance of a wide range of environmental conditions[20]. It offers a unique opportunity to poor people in developing countries, both as cultured species in household-pond systems in subsistence, and in commercial fisheries. It is also an important source of food[21], nutrition to subsistence farming households[22], and the sale of surplus production can provide additional income[23,24].

In the homestead pond aquaculture of Bangladesh, culture of tilapia has been promoted in small, seasonal roadside ditches and multiple ownership ponds for poor marginal farmers. The appropriate combination of culture species, densities and feeding strategies are the key to success in homestead pond aquaculture[15,25]. Though polyculture technologies of carps with many non-carp species are evolving in Bangladesh, the literature available on tilapia polyculture with carps in homestead ponds is scanty. However, most observations suggest that the farmers stock tilapia in their homestead ponds as an additional species to carps[26].

Although about 4.27 million households in rural Bangladesh own at least one homestead pond[8,9], fish culture in these ponds is still a new concept for the coastal fishers' households, who rely on Hilsa shad capture fisheries in the Southern coastal districts. The research presented here is aimed at exploring the fact if aquaculture might be a suitable option for alternative income generation activity for the fishers' households during Hilsa fishing ban periods, imposed from November to January, in a 40 km Andharmanik River Sanctuary, Kalapara, Patuakhali. If yes, what proposition of species combination will be appropriate for the coastal hypo-saline ponds? The target beneficiaries for this intervention were selected amongst the resource poor homestead pond owners in two fishing communities of Anipara and Hossainpur villages, located in the Kalapara Upazila, Patuakhali.

ECOFISH-Bangladesh project has been working in all coastal districts focusing on improvement of the livelihoods of the fishing households through helping women's access to finance and technologies. The fishers' women have been motivated on Hilsa fish conservation, compliance of different fishing rules and regulations, impacts of illegal fishing and using illegal gears, and potential for improvement of socio-economic condition by alternate income generation activities (AIGAs). They have been also trained in different AIGAs such as homestead pond aquaculture, vegetables cultivation, livestock rearing, pebbles making, etc. and received relevant livelihood supports from the project. In a Participatory Action Research (PAR) approach, the fishers' women involved in the Hilsa Shad Conservation Group (HCG) were provided with basic pond aquaculture training and empowered in managing their own ponds to relieve their male counterparts get involved in net repairing and other on-farm agricultural activities. Two hypotheses were tested to explore i) if there is any difference in fish production between only Tilapia monoculture and Tilapia and carp polyculture; and ii) if there is any difference in fish production between two neighbouring villages under the same management regime, where pond size, depth and environmental parameters are different.

2. Materials and Methods

2.1 Location and Duration of Experiment

The experiment was carried out from September 20, 2015 to March 18, 2016 (180 days) in 30 homestead ponds located in two fishing villages (Anipara and Hossainpur) in the Kalapara Upazila (an administrative unit equivalent to sub-district), Patuakhali district (Figure 1). Ponds were selected randomly from a list of 150 ponds in the study sites. Pond size, water area, water depth and key environmental parameters of all selected ponds were estimated before setting up the experiment. Ponds, in two villages, have slight variation in salinity regimes, but all are hypo-saline.

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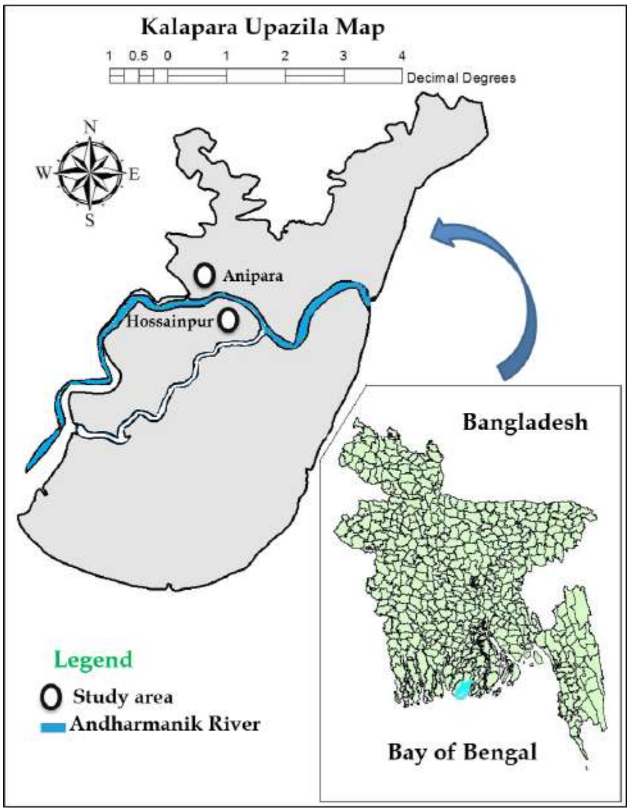

Figure 1. Location of the experimental sites

Anipara and Hossainpur are the two villages along the northern and southern side of the Andharmanik River sanctuary, respectively; the pond size, depth and environmental parameters are different. Pond areas in the studied villages varied from 10 to 14 decimal and mean depth of the ponds varied from 1.96 to 2.70 m (Table 1). In all ponds of the two villages, the depth of water column varied during culture period due to evaporation and rain, being at their maximum depth by the end of monsoon rain period.

2.2 Design of the Experiment

The research design consisted of three treatments, namely T_1 (Tilapia 200 fish per decimal; 1 decimal=40 m^2), T_2 (Tilapia 200+ Rohu 32+ Catla 8 fish per decimal) & T_3 (Tilapia 200+ Rohu 8+ Catla 32 fish per decimal) in Hossainpur and Anipara, each with five replicates. Before starting the experiment, all ponds were drained, dried and limed with powdered $CaCO_3$ at 1 kg/decimal. The ponds were filled up with rain. After 7 days of liming, the ponds were fertilized with 240 g/decimal urea and 116g/decimal triple super phosphate (TSP). The stocking was done on September 20, 2015.

2.3 Sources of Fingerlings

Fingerlings of GIFT (Genetically Improved Farmed Tilapia) and carps (Rohu and Catla) were collected from Sikder Nursery, Kalapara Upazila under Patuakhali district. Both the Tilapia fry and carp fingerlings were carried out from nursery to the experimental ponds in oxygenated polyethylene bags. The fingerlings of Tilapia, Rohu and Catla were on average 6.8 cm, 22.1 cm and 7.6 cm in length and 6.6 g, 22.1 g and 6.3 g in weight, respectively.

2.4 Selection of Feed

Mega floating feed (commercially produced in Bangladesh) was selected for the present experiment. This pellet feed was examined and found to have appreciable water stability and high nutritive value. The different types of "Mega Feed"[27] with proximate composition are nursery feed (crude protein-36.15%, lipid-12.24% & carbohydrate-23.48%), starter feed (crude protein-33.41%, lipid-12.10% & carbohydrate-28.48%), and grower feed (crude protein-30.11%, lipid-11.26% & carbohydrate-31.43%).

Table 1. Pond characteristics (mean±SE) in two villages

Characteristics	Anipara			Hossainpur		
	T_1	T_2	T_3	T_1	T_2	T_3
Pond area with dike (dec)	12.20±2.17	14.00±2.00	14.20±1.64	10.70±2.41	10.00±1.87	11.00±2.55
Water surface area (dec)	9.40±2.19	11.00±1.41	11.20±1.10	8.20±1.64	10.00±7.40	8.40±1.82
Pond depth (m)	2.13±0.28	1.96±0.06	2.03±0.10	2.60±0.27	2.19±0.17	2.70±0.61
Maximum water depth in monsoon (m)	1.60±0.11	1.55±0.07	1.58±0.08	1.74±0.08	1.59±0.13	1.62±0.13
Minimum water depth in winter (m)	1.30±0.00	1.10±0.00	1.20±0.00	1.08±0.11	0.98±0.04	1.04±0.09
Pond area receiving direct sunlight (dec)	8.00±1.22	9.00±1.41	8.40±0.89	5.80±1.48	5.00±1.00	5.40±0.89

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2.5 Feeding Strategy

Fingerlings were fed at the rate of 10% of body weight at the beginning of the experiment. The feeding rate was gradually reduced to 6% and 4% of the body weight in 2nd and 3rd month, respectively. The feeds were provided two times per day, in the morning (at 9.00 AM) and in the afternoon (at 4.00 PM). The feeds were dispersed by hand or pot broadcasted over the pond water.

2.6 Water Quality Parameters

Water quality parameters like temperature, water transparency, dissolved oxygen, pH and salinity were measured at fortnightly intervals, always at around the same hour (9.00 AM). Temperature, dissolved oxygen, pH and salinity were analyzed on the spot using a Multi Parameter detection device (Model No. HACH 40d, HACH Instruments Ltd, USA) and transparency was measured using a Secchi disc.

2.7 Sampling of Fish

Growth of fish under different stocking combinations was assessed by recording the rate of growth in terms of gain in length (cm) and in weight (g) of fish at fortnightly intervals. The fishes were sampled using a seine net and weighed with a portable digital balance to adjust feeding amounts. The length and weight were recorded by random sampling of 40 Tilapia, 20 Rohu and 20 Catla fish. Weight was taken with a digital top loading balance (TANITA-5 kg x 1 g) and length with a measuring scale. All data were recorded in a note book and spread sheet and finally the average length and weight of fish by treatment were calculated for every sampling day.

2.8 Study of Growth and Yield of Fish

Experimental data of different treatments were collected during growth trials and evaluated by using the following parameters:

2.8.1 Weight and Length Gain

Weight and length gain of experimental fish were calculated from the following formula:

Weight gain (g) = mean final fish weight (g) – mean initial fish weight (g)

Length gain (cm) = mean final fish length (cm) – mean initial fish length (cm)

2.8.2 Specific Growth Rate (SGR% per Day)

The specific growth rate was calculated from the following formula.

$$\text{Specific growth rate } (\% / \text{day}) = \frac{(\text{Log}_e W_2 - \text{Log}_e W_1)}{T_2 - T_1} \times 100$$

2.9 Economic Analysis

A simple economic analysis was performed to estimate the net profit from different treatments. The net return (profit) was measured by deducting the gross cost from the gross income incurred per pond. The benefit cost ratio was also measured as a ratio of gross income to gross cost. The cost of inputs was calculated on the basis of whole sale market prices of 2016. The cost of Mega floating feed was BDT 38.80/ kg and 46/kg for starter and grower feeds, respectively. The selling price for Tilapia, Rohu and Catla was estimated as BDT 110/kg. Since the production period was short so Rohu and Catla did not reach marketable size and thus fetch lower price and equal to that of Tilapia.

2.10 Statistical Analysis

Experimental data were analyzed with statistical software SPSS (Statistical Package for Social Sciences) version 16. Fish data were analyzed through one-way ANOVA to test the effect of different treatments on the performance of each fish species. The survival and specific growth rate (SGR) data were normalized using the arcsine of the square root transformation. Water quality data were also analyzed through One-way ANOVA using average value of the parameter in different treatments. When a main effect was significant, the ANOVA was followed by Duncan Multiple Range Test (DMRT) at 5% level of significance.

3. Results

3.1 Water Quality Parameters

The water quality parameters of ponds including temperature, transparency, pH, salinity and dissolved oxygen significantly varied among treatments except temperature and pH (Table 2). The mean water temperature (28.44±0.23 °C) and pH (7.22±0.13) were similar among all treatments (Table 2) in both villages. The transparency was found higher in T_1 (27.11 ± 0.94 cm) of Hossainpur and lower in T_2 (19.73±0.67 cm) of Anipara. The average value of dissolved oxygen was found significantly higher in T_1 (5.43±0.15 mgl^{-1}) of Anipara and lower in T_3 (4.23±0.11 mgl^{-1}) of Hossainpur village. The mean value of salinity was found significantly higher in all the ponds of Hossainpur than the ponds of Anipara (Table 2).

3.2 Growth and Production Performance

During stocking, the average individual weights of Ti-

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Table 2. Results of ANOVA and Duncan mean multi-comparisons of water quality parameters (mean value ± SE)

Variable	Treatment						Level of Significance	p-value
	Anipara			Hossainpur				
	T_1	T_2	T_3	T_1	T_2	T_3		
Temperature (°C)	28.35 ± 0.23	28.35 ± 0.23	28.34 ± 0.23	28.44 ± 0.23	28.44 ± 0.23	28.44 ± 0.24	NS	0.998
Transparency (cm)	22.49 ± 0.80^b	19.73 ± 0.67^C	22.80 ± 0.70^b	27.11 ± 0.94^a	22.93 ± 0.73^b	22.11 ± 0.64^b	*	0.000
pH	7.22 ± 0.77	6.90 ± 0.12	7.12 ± 0.06	7.25 ± 0.12	7.17 ± 0.13	7.24 ± 0.13	NS	0.233
Dissolved Oxygen (mgl^{-1})	5.43 ± 0.15^a	4.64 ± 0.23^b	4.72 ± 0.17^b	4.69 ± 0.15^b	4.35 ± 0.12^b	4.23 ± 0.11^b	*	0.000
Salinity (ppt)	0.61 ± 0.02^b	0.61 ± 0.02^b	0.64 ± 0.02^b	0.78 ± 0.03^a	0.83 ± 0.03^a	0.81 ± 0.03^a	*	0.000

lapia, Rohu and Catla were 6.58, 22.09 and 6.31g. The initial individual weights of each fish species were not significantly different among treatments of two villages.

Tilapia showed significantly highest survival rate in T_1 (85.63±0.05 %) of Anipara. Tilapia also presented the significantly highest mean harvesting weight in T_1 (258.59±18.76 g) of Anipara and lowest in T_3 (136.97± 10.63 g) of Hossainpur (Figure 2; Table 3). Similarly, the mean value of growth rate for tilapia was significantly highest in T_1 (1.44± 0.10 g/day) of Anipara and lowest in T_3 (0.76±0.06 g/day) of Hossainpur. The SGR of tilapia was also found similar. The mean value of harvesting biomass and yield for tilapia was higher in T_1 of Anipara (11,354±806 kg/ha & 11,073±805 kg/ha) and lowest in T_3 of Hossainpur (5,429±406 kg/ha & 5,180±406 kg/ha). Finally, the production of tilapia was obtained comparatively higher from monoculture than polyculture with carps in both the villages.

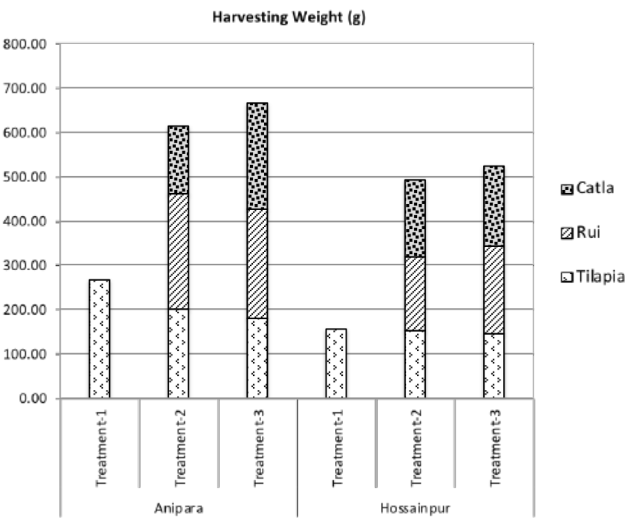

Figure 2. Harvesting weight (g) in different treatments of two villages

Rohu was presented significantly higher survival rate, harvesting weight and growth rate in T_2 (83.35±0.45 %), (263.02±49.97 g) and (1.34±0.28 g/day) of Anipara, respectively. Similarly, the SGR, harvesting biomass and the yield of rohu was significantly higher in T_2 (1.33±0.11 %/day), (1749±327 kg/ha) and (1602±327 kg/ha) of Anipara village, respectively in the polyculture composition.

Catla was affected by the polyculture composition and salinity both among the treatments in each village and between the villages. Catla presented significantly highest survival rate in T_2 (83.97±0.88 %), the highest harvesting weight in T_3 (242.34±66.46 g) from Anipara, where the ponds have comparatively lower salinity. Catla also showed significantly highest growth rate and SGR in T_3 (1.31±0.37 g/day) and (1.94±0.17 %/day) of Anipara, respectively. It was also found that the harvesting biomass (1,514±406 kg/ha) and net yield of catla (1,474.24±406.18 kg/ha) was higher in T_3 in the ponds of Anipara.

The gross production and mean yield of all fishes were significantly highest in T_1 (11,354±806 kg/ha) and (11,073±805 kg/ha) of Anipara and lowest in T_1 (6,325±227 kg/ha) and (6,058±228 kg/ha) of Hossainpur, respectively (Table 3; Figure 3). Finally, the mean value of FCR was observed higher in T_1 (0.89±0.04) of Hossainpur and lower in T_1 (0.44±0.03) of Anipara.

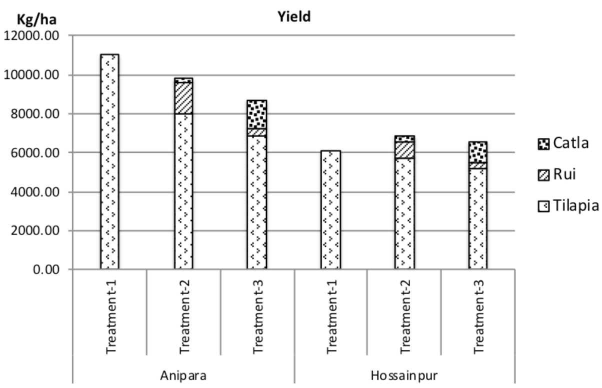

Figure 3. Average yield (kg/ha) in different treatments of two villages

3.3 Economic Analysis

Table 4 presented the ANOVA results of the income obtained by selling fish of the treatment at the prices of rural markets in Bangladesh in March, 2016. The average gross income was found significantly higher in T_1 (BDT 1,248,946±88,604/ha) of Anipara and lower in T_1 (BDT 695,725 ± 25,017 /ha) of Hossainpur (Table 4, Figure 4). Net return was found significantly higher in T_1 (BDT 866,627±84,874/ha) of Anipara and lower in T_3 (BDT

Table 3. Results of ANOVA and Duncan mean multi-comparisons for stocking weight and harvesting parameters of Tilapia, Rui and Catla (mean value ± SE)

Variable	Treatment						Level of Significance	p-value
	Anipara			Hossainpur				
	T_1	T_2	T_3	T_1	T_2	T_3		
Tilapia								
Stocking weight (g)	6.58 ± 0.0	6.58 ± 0.0	6.58 ± 0.0	6.58 ± 0.0	6.58 ± 0.0	6.58 ± 0.0	NS	1.000
Harvesting weight (g)	258.59 ± 18.76^{a}	192.97 ± 26.31^{b}	172.96 ± 23.27^{bc}	149.58 ± 6.03^{bc}	147.14 ± 7.15^{bc}	136.97 ± 10.63^{c}	*	0.000
Harvesting Biomass (kg/ha)	11354 ± 806^{a}	8261 ± 1089^{b}	7133 ± 934^{bc}	6325 ± 227^{bc}	5928 ± 288^{c}	5429 ± 406^{c}	*	0.000
Survival rate (%)	85.63 ± 0.05^{a}	82.80 ± 0.12^{b}	79.42 ± 0.15^{d}	81.04 ± 0.50^{c}	77.11 ± 0.36^{e}	75.63 ± 0.37^{f}	*	0.000
Growth rate (g/day)	1.44 ± 0.10^{a}	1.07 ± 0.15^{b}	0.96 ± 0.13^{bc}	0.83 ± 0.03^{bc}	0.82 ± 0.04^{bc}	0.76 ± 0.06^{c}	*	0.000
SGR (%/day)	2.05 ± 0.04^{a}	1.88 ± 0.08^{b}	1.83 ± 0.03^{bc}	1.76 ± 0.02^{bc}	1.75 ± 0.03^{bc}	1.71 ± 0.04^{c}	*	0.001
Yield (kg/ha)	11073 ± 805^{a}	7988 ± 1089^{b}	6872 ± 934b^{c}	6058 ± 228^{bc}	5675 ± 287^{c}	5180 ± 406^{c}	*	0.000
Rohu								
Stocking weight (g)		22.09 ± 00	22.09 ± 00		22.09 ± 00	22.09 ± 00	NS	1.000
Harvesting weight (g)		263.02 ± 49.97^{a}	245.63 ± 24.38^{ab}		164.98 ± 14.24^{b}	198.01 ± 7.65^{ab}	*	0.017
Harvesting Biomass (kg/ha)		1749 ± 327^{a}	389 ± 38^{c}		1035 ± 91^{b}	316 ± 12^{c}	*	0.000
Survival rate (%)		83.35 ± 0.45^{a}	79.29 ± 1.48^{b}		78.40 ± 0.49^{b}	79.76 ± 1.61^{b}	*	0.036
Growth rate (g/day)		1.34 ± 0.28^{a}	1.24 ± 0.14^{ab}		0.79 ± 0.08^{b}	0.98 ± 0.04^{ab}	*	0.017
SGR (%/day)		1.33 ± 0.11^{a}	1.33 ± 0.06^{a}		1.11 ± 0.05^{b}	1.22 ± 0.02^{ab}	*	0.038
Yield (kg/ha)		1602 ± 327^{a}	354 ± 38^{c}		896 ± 90^{b}	280 ± 12^{c}	*	0.000
Catla								
Stocking weight (g)		6.31 ± 00	6.31 ± 00		6.31 ± 00	6.31 ± 00	NS	1.000
Harvesting weight (g)		151.61 ± 36.96	242.34 ± 66.46		174.78 ± 16.05	183.54 ± 11.69	NS	0.445
Harvesting Biomass (kg/ha)		252 ± 60^{b}	1514 ± 406^{a}		262 ± 27^{b}	1142 ± 117^{a}	*	0.001
Survival rate (%)		83.97 ± 0.88^{a}	78.31 ± 0.66^{b}		74.87 ± 2.19^{b}	77.61 ± 1.47^{b}	*	0.003
Growth rate (g/day)		0.81 ± 0.21	1.31 ± 0.37		0.94 ± 0.09	0.99 ± 0.10	NS	0.445
SGR (%/day)		1.70 ± 0.14	1.94 ± 0.17		1.83 ± 0.05	1.86 ± 0.05	NS	0.521
Yield (kg/ha)		242 ± 60^{b}	1474 ± 406^{a}		253 ± 26^{b}	1103 ± 117^{a}	*	0.001
Total Fish Production (kg/ha)	11354 ± 806^{a}	10262 ± 1247^{a}	9035 ± 1075^{ab}	6325 ± 227^{c}	7226 ± 247^{bc}	6886 ± 435^{bc}	*	0.000
Yield (kg/ha)	11073 ± 805^{a}	9832 ± 1248^{a}	8700 ± 1074^{ab}	6058 ± 228^{c}	6824 ± 247^{bc}	6563 ± 434^{bc}	*	0.001
FCR	0.44 ± 0.03^{c}	0.56 ± 0.09^{bc}	0.63 ± 0.07^{b}	0.89 ± 0.04^{a}	0.83 ± 0.03^{a}	0.85 ± 0.06^{a}	*	0.000

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279,389±46,104/ha) of Hossainpur (Table 4). Similarly, the mean value of BCR was observed highest in T_1 (3.26±0.20) of Anipara and lowest in T_3 (1.58±0.10) of Hossainpur. Finally, the highest production and economic benefit were obtained from the monoculture of tilapia in comparatively lower saline ponds.

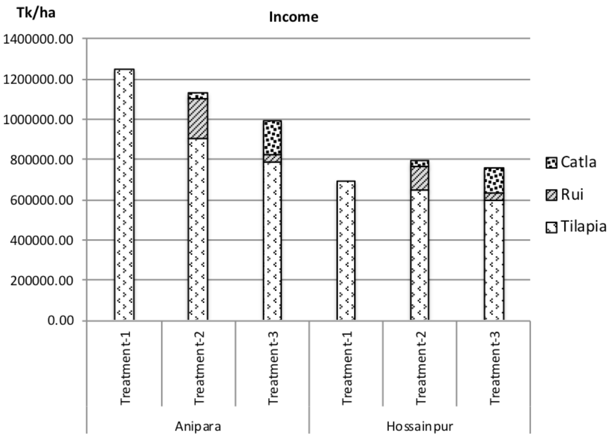

Figure 4. Average gross return (BDT/ha) in different treatments of two villages

4. Discussion

4.1 Water Quality Parameters

The growth of aquatic organisms depends on the water quality parameters of a water body[28]. Maintenance of all the factors becomes necessary for getting maximum yield from a fish pond. Good water quality is characterized by adequate oxygen, proper temperature, transparency and other environmental factors that affect fish culture[29,30].

Temperature changes affect fish metabolism, physiology and ultimately affect the production. Suitable water temperature for carp culture is between 24 and 30 ^{0}C[29]. The surface water temperature in this experiment of the ponds ranged from 26.16 to 30.35 ^{0}C which was suitable for tilapia and carps[19,30].

Transparency depends on several factors such as suspended clay particles, dispersion of plankton organisms, particulate organic matters and also the pigments caused by the decomposition of organic matters. The secchi disk transparency between 30 and 40 cm indicates optimum productivity of a pond for good fish culture[29]. The present experiment achieved much lower transparency than the optimum level in all the ponds except ponds under T_1 of Hossainpur. Since the ponds were not turbid or muddy rather greenish, this indicated the ponds were productive[29].

Water pH between 7 to 8.5 is suitable for biological productivity[29]. The pH values recorded from the ponds of two villages varied from 6.90 to 7.25, which was more or less similar to the findings of[30-32] and suitable for fish culture[29].

Dissolved oxygen of water of any culture system affects the growth, survival and physiology of fishes[33,34]. Oxygen depletion in water leads to poor feeding of fish, starvation and reduced growth either directly or indirectly[29]. The mean DO level in all the treatments of tilapia monoculture was found slightly higher compared to tilapia polyculture with carps but all observed values of DO were suitable for fish culture.

Fishes are very much sensitive to the salt concentration. Freshwater fish species generally show poor tolerance to large changes in salinity of water. Often salinity levels vary from species to species[18], the mean salinity level in this experiment ranged from 0.61 to 0.83 ppt. Tilapia can tolerate a wide range of salinity compared to Rohu and Catla that may affect the production of Rohu and Catla[20]. The overall better performance in the ponds in Anipara may have been attributed to the lower salinity even though the difference is quite low.

4.2 Growth and Production Performance

In the present research, polyculture of Tilapia and carps, Rohu and Catla was compared and contrasted against Tilapia monoculture. Each fish species stocked in the ponds has individual feeding niches and thus exerts influence on the environment in a somewhat different way, largely depending on their size and feeding regime. Tilapia utilizes natural foods organisms and detritus throughout ponds, whereas Rohu feeds in the middle column and Catla in the surface but their niches often overlaps in small homestead ponds. The productions of fishes in different treatments were found to vary among treatments due to difference in survival, growth rate and production. A variation in water quality parameters and depths of ponds between two villages were also apparent in this experiment.

Tilapia showed the highest survival rate (83.33%) due to its higher tolerance level of the variable environmental conditions[5,21] which is more or less similar with the findings of[28]. The highest weight gains of Tilapia (204.09 g) obtained in the present study was higher than[28,30,32,35]. In this study, a significant difference was observed among combined gross and net yields in different treatments. Calculated on per hectare basis over a 180- day culture period, treatment-wise highest mean gross and net production of tilapia was found in T_1 of Anipara and contributed to highest gross production among the treatments. These high gross and net were found in T_1 of Anipara might be due to proper food utilization capacity of tilapia and high survival rate of tilapia in shallow ponds[21]. Tilapia produc-

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tion in the present study was lower in comparison to[21] because the experiment was done during the winter season. However, this production was higher than those reported by[20,28,32] and in T_1, the higher production of Anipara, observed in comparison to other treatments might be due to better management practice as well as increased survival of tilapia in the low saline but deeper ponds[21].

Rohu showed the higher survival rate in different treatments. This high survival rates obtained for Rohu fish might have been due to the relatively large size of fingerlings stocked. The highest weight gains of Rohu (263 g) obtained in the present study was much higher than that of[28,30]. Calculated on per hectare basis over a 180 days' culture period, T_2 of Anipara yielded the highest total production of Rohu (1,749 kg/ha); the high gross and net yields found in Anipara may be due to proper food utilization capacity of Rohu and higher number of Rohu than Catla and also having lower salinity of ponds. Lower yield of Catla fish in the present study was found due to food competition with Tilapia in the shallow pond. The relatively similar findings on Rohu productivity were found in[36] and[37], whereas individual growth performance of Rohu was better than the Catla, as mentioned earlier the causes of higher stocking density of the species achieved higher growth in the experiment. Additionally, Rohu is an omnivore fish with preference for debris and decaying vegetation[38].

Catla showed the relatively lower survival rate in different treatments with Rohu. This lower survival rates obtained for Catla fish might have been due to the relatively lower size of fingerlings stocked in the shallow ponds and salinity of pond water. The lower production of Catla was found in almost all ponds between two treatments. Similar lower production of Catla was found in[36] and[28]. Thus, relatively lower growth of Catla in the experiment may be due to the lower production of natural food, especially zooplankton. There was a lacking of regular supply of inorganic fertilizers in the fish ponds[37]. In addition, it may be explained that the bottom feeders of benthic niches might have eaten away excess detritus from the pond as food which ultimately improved the environment for herbivorous fishes like Rohu[38]. Due to the absence of bottom feeder fish in the ponds, optimum utilization of the pond productivity may have not taken place, and there is room for inclusion of bottom feeding mrigal (Cirrhinus mrigala) /common carp (Cyprinus carpio) or freshwater prawn (Macrobrachium rosenbergii).

4.3 Economic Analysis

The statistical analysis showed that the net return and BCR values among the treatment were found significantly different (P>0.05). The highest net return and BCR obtained in T1 of Anipara (866,627 BDT/ha and 3.26, respectively) might be due to lower amount of feed used i.e. low cost feed used and relatively higher production of fishes obtained.

The present research findings revealed that the monoculture of tilapia is better than tilapia-carp polyculture in the household ponds of coastal region of Bangladesh for getting higher production and net return.

4.4 Effectiveness of Participatory Action Research Approach

Participatory action research was initiated through the training of the fishers' women. The impact of the preparatory and on-going trial monitoring training on the community level was very much effective. The design of the trial encouraged fisher's women to participate in the pond aquaculture activity with great enthusiasm. Community members eagerly waited to see the results from the research pond compared to the general pond in the two villages. Through the proper monitoring of the project personnel, it was ensured that the fishers' women were actively participated for feeding and health checking till the final harvesting. However, the overall outcomes of the on-farm research were felt positive. Since ECOFISH-Bangladesh project is a mostly development project, research in development approach would be suitable for carrying out demand-led research that would both produce science outputs and develop technologies for scaling up.

4.5 The Impacts

This experiment has exposed some insights into the promotion of aquaculture in the coastal areas of Bangladesh. Generally, many ponds of this area are very shallow with a maximum depth of approximately 1m. When a pond is shallow, the stocking capacity is very limited, water retention capacity is low and the pond is prone to drying out, this limits the period of production. This is particularly a problematic in this area where a substantial proportion of the ponds are rain-fed[39]. Many of the cultured species in Bangladesh are phytophagus[8], which means they are reliant on photosynthetic production, which, in the turbid waters of many Bangladeshi ponds, cannot take place at greater depths[40].

It is clear that now households with a pond are financially better off than those without. It will be interesting to investigate exact impact of the pond ownership on household nutrition by comparing the nutritional status of pond owning households against those without having a pond. Now, they are able to take the challenges to culture the

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fishes as an alternative livelihood options for their family consumption and households' nutrition.

5. Conclusion

In this participatory action research fishers' women have been empowered and their capacity in pond aquaculture has been tremendously developed. Between two sets of culture systems in two villages, the growth and production of fish was higher in Ainipara village ponds than those of Hossainpur. Exact reason for this difference is difficult to reveal from a single piece of research, however water salinity and pond depth may cause this difference. Pond water salinity was lower and pond depth was higher in Anipara. Tilapia monoculture was found the best performed technology among all ponds that was also shadowed by a relatively lower production in Hossainpur ponds. Polyculture of Tilapia-carp with higher number of Rohu showed better performance in the ponds of Hossainpur. Since Catla is zooplankton feeder and feeds on surface it may have competed with tilapia to some extent and may reduce the growth of tilapia. Rohu, in other side, is more robust in its dietary diversity and feeds on phytoplankton at the pond column and thus may not have directly affected the niche of tilapia neither its growth. Overall, tilapia monoculture is the suitable technology for coastal ponds, however tilapia-carp polyculture with rohu may be considered suitable considering the desire of the fishing households for polyculture instead of only tilapia monoculture.

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REVIEW

Seaweed Biodiversity and Temperature Fluctuations of Calatagan Bay, Verde Island Passage

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ABSTRACT

Changes in seaweed biodiversity reflect ecological changes and management of coastal communities. Calatagan Bay is a tourism, agriculture and aquaculture hotspot fronting the Verde Island Passage, touted to be the global center of marine biodiversity. Detection of stressors through monitoring is the key in the proper management of the area. This study surveyed existing seaweed species of the coast, and contrasted it with reported species in the area together with fluctuations in sea surface temperatures for the past two decades, contrasted with the local knowledge and perspectives of local coast-dwellers. Seaweed along the coast were collected from a representative area of 50 km2 with species identification based on morphology and pigment. Ten species that were previously unreported were found while fourteen previously reported species were no longer observed. *Caulerpa*, *Kappaphycus* and *Sargassum*, all with known market demands, were the dominant genera. Sea surface temperature data from local weather stations and the NOMADs database indicate significant warming events from June 1998 to present, with peak sea surface temperature at 31.9oC. Focused group discussions with local communities indicate increased incidences of ice-ice disease, and issues with the uncontrolled use of fertilizers of neighboring farms contaminating their coastal fronts.

1. Introduction

Seaweeds are macro benthic marine algae that contribute in the marine primary production on the shallow portion of seas and oceans while providing habitats for benthic communities[1]. Seaweeds are named after the dominant photosynthetic pigment, which could be red, brown, green and blue-green algae[1]. Underwater, it is distributed from the lower intertidal to the shallow subtidal zones of the marine environment. Their ability to adapt to the condition of the habitat results to the differences in their vertical and horizontal distribution. Thus, some species are only seen in the sheltered bays and coves while some are limited to the rocky exposed along the shore or margins of the reef.

Several species are found in a variety of intergrading environments. The presence or absence of species in a habitat is therefore the result of the combined and synergistic effects of various physico-chemical factors[1]. A major contributor to the species success and abundance is sea surface temperature[2]. Changes in subtidal vegetation, including increase in morphologically simple warm water

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varieties as well as expansion of non-indigenous species have been noted in waters that have experienced at least 1°C of warming[2-4].

Due to its strong market potential and high market importance, seaweed farming in the Philippines accounted for 69% of the total aquaculture production[5], making it an important economic activity to lessen poverty in the rural areas. In 2016, the Department of Environment and Natural Resources identified Calatagan, Batangas as one of the potential farming sites for seaweeds with its existing biodiversity in macroalgae (Table 1). In the almost three decades of studies documenting the biodiversity in the area, recorded threats included substratum loss[6], low irradiance and low salinity in certain sites where farming was being considered[7], fungal contamination and disease[7-9], and increase in sea surface temperature due to climate change[7-11]. Records of existing species are also limited by the scope of the studies performed and the most recent assessment of biodiversity in the area was done in 2012[12]. It was noted in this study that research on seaweeds has transitioned to applied and commercial applications. It has also resulted to alterations in biodiversity brought about by efforts to contribute to the seaweed trade and industry.

Table 1. Published reports on found seaweed species in Calatagan, Batangas, Philippines

Species	Reports of incidence
Caulerpa lentillifera [10,13]	1999; 2014
Ceramium mazatlanense [9]	2017
Eucheuma denticulatum [13]	1999
Gayliella flacida [9]	2017
Gelidiella acerosa [13]	1999
Kappaphycus spp.	
K. alvarezii [9,11,13]	1999; 2016; 2017
K. striatum [7,11]	2010; 2016
Sargassum spp.	
S. siliquosum [8,10,14]	1985, 2006, 2014
S. paniculatum [8,10,14]	1985, 2006, 2014
S. abbottiae [8]	2006
S. baccularia [8]	2006
S. cinctum [8]	2006
S. crassifolium [8]	2006
S. cristaefolium [8]	2006
S. feldmanii [8]	2006
S. gracillimum [8]	2006
S. hemiphylum [8]	2006
S. ilicifolium [8]	2006
S. kushimotense [8]	2006
S. oligocystum [8]	2006
S. polycystum [8]	2006
S. turbinaroides [8]	2006

In this study, sea surface temperatures from 1985 to present were mapped and compared with rapid biodiversity assessment of seaweed species in towns along the Calatagan coast facing the Verde Island passage to test if observable warming in the coastal waters of the area has occurred and if this has affected the species present in the region. The data collected were supplemented by focused group discussions with local experts, seaweed farmers and occupants of households fronting the coast to assess other perceived factors that affect the growth and trade of seaweed in Calatagan, Batangas.

2. Methods

2.1 Collection of Materials and Species Identification

Initial collection of macro algae was coordinated with the local community via the Seaweed Farm of ELFARCO. Sampling took place from September to November, where the southwest monsoon is affecting the coast. This study was unable to survey existing species during the northeast monsoon. Preliminary collection was performed with the assistance of a local diver at 13.81667 N and 120.60357 E. Additional sampling was performed at 13.83991 N and 120.59661 E, 13.84748 N and 120.58719 E, and at 13.85542 N and 120.59405 E. A 2-km radius from the deployment point was done to search for isolates. All samples encountered within 360° of a circle with a 2-km radius were recorded and three to five representative samples were collected per putative species. In the absence of a clear reference to set expectations for existing algal typologies in the area, different morphologies were used as basis for collection but no quantitative method for abundance was performed. Additional samples were taken to verify the preliminary species identification, especially for samples with highly similar morphologies, to accommodate for histological analysis in the laboratory. The isolates were gathered for local identification and compared in the standard collections archive of seaweeds by the farm (Figure 1). qGIS software was used to map the species of seaweed collected along the coast per genus[15].

Figure 1. Sampling sites along the Calatagan beach fronting the Verde Island passage

2.2 Morphological Analysis for Species Identification

The collected samples, upon return to the laboratory, were analysed based on morphological characters. The analysis utilized discrete and continuous characters of the sampled organisms. Species identification was done based on morphological traits. The morphological traits included the characters of the frond, gas bladder, stipe, blade, & holdfast[16]. Verification of species identification was performed by experts from ELFARCO and the Philippine National Museum of Natural History.

2.3 Collection of Temperature Data and Tracking of Temperature Changes

Sea surface temperatures (SST) of the area from 1985 to present were collected from the NOMAD database[17]. Ground-truthing of data was based on data collected by local weather stations and temperature collections during dates of sampling. Averages and standard deviations were computed using R software and transmuted to a monthly basis [18].

2.4 Determination of Local Knowledge and Perceptions

Focused group discussions (FGDs) and one-on-one interviews were performed with an expert from the ELFARCO Seaweed farm, five local farmers in the area, and seven locals who have lived along the coast of Calatagan Bay for 15 years or more. Prior informed consent was acquired from all participants prior to the execution of the discussions and interviews.

The points of inquiry for the discussions involved the participant's familiarity with the different species of seaweed in Calatagan bay, the changes they have observed along the coast in terms of water quality, environmental factors and changes in the taxa of seaweed found in the coast, their knowledge of the economic importance of the seaweeds, and their familiarity with efforts being done to maintain sustainability of local seaweed industries as well as environmental programs to protect the coast. Responses were processed in a qualitative manner and compared to the results of the biodiversity assessment and the generated SST maps.

3. Results and Discussion

3.1 Identified Species of Macroalgae and Comparison with Historical Records

Eighteen distinct species were identified from a total collection of 286 individual samples (Table 2). Ten species have been reported before and includes the commonly known genera of *Caulerpa*, *Kappaphycus* and *Sargassum* with known market demands. Of the previously reported species, however, representatives from the *Ceramium*, *Gayliella*, and *Gelidiella* genera were not found.

3.2 Greater Relative Biodiversity in Preliminary Sampling Site

Site 1 is distinguished by having three unique species. Anthropogenic factors that could be related to this observation include the presence of established seaweed farms in the area that cultivate the indicated species. The area covered by sites 1 and 2 play host to the bigger seaweed farms operated by ELFARCO, FARMC and PBMA. These organizations and cooperatives have access to trainings and grants that allow for a wider diversity of cultured species, including those that may have been introduced to improve the local seaweed industries. All the newly reported species are known as high sources of carageenan and agar and are widely cultivated across different coastal communities in the country[13]. Despite the wider scale of operations in sites 1 and 2, they only account for 1% of the total production of the region[19]. Greater contributions are acquired from smaller backyard operations that dominate sites 3 and 4 take advantage of predominant species in the area. This makes the stakeholders in sites 3 and 4 more vulnerable to uncontrollable challenges of climate, and also the proximity to major drainage points of nearby sugarcane farms[20].

Table 2. Identified species of seaweed along Calatagan Bay, relative locations, and local names

Species	Location	Local name	PR*
Caulerpa lentillifera	All sites	Lato	Yes
C. sertularoides	All sites	Pakpak manok	No
C. rasimosa	Preliminary site (Site 1)	Rasimosa	No
Eucheuma spinosum	All sites	Guso	No
Gracilaria arcuata	Sites 1-2	Grasilarya	No
G. firma	All sites	Taliptip	No
G. salicornia	Sites 1-2	Grasilarya	No
Halimeda discoidea	Site 1	Halimeda	No
Halimenia durvillaei	Sites 1-2	Halimenya	No
Kappaphycus striatum	All sites	Sakol	Yes
Laurencia flexilis	Site 1	Lawrensya	No
Padina japonicum	All sites	Abaniko	No
Sargassum cristaefolium	Sites 1-3	Sargasum	Yes
S. oligocystum	Sites 1-3	Sargasum	Yes
S. paniculatum	All sites	Sargasum	Yes
S. polycystum	Sites 1-3	Sargasum	Yes
S. siliquosum	All sites	Sargasum	Yes
S. turbinaroides	Sites 1-3	Sargasum	Yes

Notes: *PR - previously reported

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Limitations in sampling intensity include accessibility of the area due to weather conditions. Sampling was done during a season dominated by trade winds where water turbulence is minimal and farming is expansive. The season lasts from November to May. The southwest monsoon, on the other hand, dominates the area for the rest of the year and the strong winds lead to turbulent waters that disrupt farming practices. The sampling intensity for the study covers approximately 70% of the total Calatagan coast facing the Verde Island Passage. Previously reported species that were not found could be limited by environmental conditions that include higher salinity along the Southern coasts which may be favoured by *Ceramium mazatlanense*[21] and *Gelidiella acerosa*[22].

All three previously reported species that were no longer found during the most recent collection have been reported to prefer cooler waters ranging from 0°C to 25°C, with optimal conditions at 12°C to 15°C[1,2,23].Attributing the distribution or presence of seaweed species to SST would benefit from an overview of the temperature changes in the coast in the past 30 years. It is to be noted, however, that sampling intensity may account for their absence in this survey. Regular thorough monitoring of the coast can provide a more accurate picture of the fluctuations of seaweed species in the area.

3.3 Local Knowledge Highlight Environmental and Anthropogenic Factors Affecting Seaweed Biodiversity

Five similar local names are associated to the species of *Sargassum*, and three to *Gracilaria*. All species of *Caulerpa*, *Eucheuma*, *Kappaphycus*, and Padina have corresponding local names as well. Together with feedback from the participants in the FGD, these species may prove to be the true industrially-valued local species in the area. The other species may have been introduced through workshops and in established farms. Locals are not as familiar with species that are not farmed prior to trainings as they are typically ignored or removed from near-shore areas to make way for the growing of cultivated species, fishing and other local activities.

The most common issue encountered by the locals include the recurring occurrence of ice-ice disease. This disease typically affects the genera of *Kappaphycus* and *Eucheuma*, and results to the whitening and hardening of seaweed tissue due to the over-production of organic substance as a result of stress[24,25]. Ice-ice disease is often attributed to changes in salinity, sea surface temperature, and light intensity. The secretion of organic substances by the seaweeds also attract the growth of pathogens that speed up the development of the morphological abnormalities attributed to ice-ice[24]. The local communities share the concern on the warming of sea surface temperatures and how it would lead to more frequent occurrences of this issue. They believe it is also aggravated by the run off from the local farms that result to eutrophication. Low dissolved oxygen levels and acidification have been attributed to eutrophication[26,27]. This has led to massive fish kills, and though very little to no reports on this in Calatagan, Batangas, this has certainly affected fish ponds and lakes in the region.

4. Conclusion

This study has allowed for the documentation of ten species of seaweed that were previously unreported in the area. Of higher concern is the apparent disappearance of fourteen species. It is suggested that agricultural and environmental groups invest on regular biodiversity monitoring on the area in order to create a more concrete database of species in the area. The information presented in this paper only takes into consideration samples collected during the southwest monsoon during the cooler times of the year. Species that are dominant and prolific during the warmer times of the year and when the currents are affected by the northeast monsoon is also needed.

Data on the fluctuations of the biodiversity in the area is still too little to be correlated with temperature. Considering the information that can be acquired through regular surveys, and the ecological and industrial importance of the site, a closer monitoring of the biodiversity in the area should be considered of prime importance. Local practices that affect the health of the marine ecosystem must be evaluated. Enforcement of environmental laws must be ensured. The local Fertilizer and Pesticide Authority are encouraged to look into the claims of the local community and enforce Presidential Decree 1144 that penalizes the excessive use of fertilizers in coastal communities.

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ARTICLE

The Importance of Involving Stakeholders and Scientists in the Management of Marine Fisheries

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ABSTRACT

In recent years there has been increasing concern over the state of fish stocks, especially those that support key fisheries and supply food to many consumers. There is also concern over the state of aquatic environments, and the effects of climate change. Fisheries management is controlled by government agencies, often cooperating with similar agencies from other nations. This paper deals with the need for expert advice on fisheries, involving fishers as well as scientists. Mention is made of a Fisheries Partnership set up in Europe, bringing fishers and scientists together with other stakeholders to discuss the problems of managing fish stocks. The partnership was especially successful in improving relationships between fishers and scientists, and made significant improvements to some fish stock assessments. European Regional Advisory Councils were later established to play a similar role. They are providing significant advice on fisheries, but they do not yet play a key role in actual management. It is important to consider how stakeholders and scientists can become more actively involved in fisheries management. There is a crucial need to develop new, more participatory ways of managing fisheries.

1. Introduction

Many fisheries around the world are in a state of crisis. Catches are falling and the state of some stocks is extremely poor. Many fish stocks are being heavily exploited, and some are severely depleted. Despite these problems, in some areas of the sea fishing capacity continues to be heavy, and the level of exploitation of fish stocks remains high. Many stocks are not safe, and in some cases they are close to collapse. FAO (The Food and Agriculture Organization of the United Nations) publishes information every year on the state of fish stocks from around the World [1].

I was involved in the management of the North Sea fish stocks, as the Director of Fisheries Research for Scotland. I also served as the chairman of the North Sea Fisheries Partnership, and the Rapporteur for the North Sea Advisory Council. More recently I reported on a conference on Best Practice in World Fisheries, organised by the the Blue Marine Foundation and The Fishmongers' Company [2]. The purpose of this conference was to look at how countries around the world managed their fisheries and to consider what lessons the United Kingdom might learn from their experience and apply to its own waters in the event of leaving the EU and its Common Fisheries Policy (CFP). After leaving the EU the United Kingdom will need to develop its own system for managing fishing in its waters, while continuing to have international cooperation

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in fisheries policy, particularly with the EU and Norway. This paper considers the importance of involving stakeholders, as well as scientists in the management of marine fisheries.

Each fish stock is an inherently self-renewing resource, capable of being managed in a sustainable way, but such stocks are very easily over exploited. Many fish are mobile and widely distributed, and cannot be managed by any individual fishing community or nation. With free access to a fishery, the number of fishing vessels increases, catching technology and efficiency improves, and the resource may come under severe pressure. A race for fish can develop where many fishers from a number of nations are chasing too few fish. Fish are then removed through fishing at a rate faster than they can reproduce themselves. Fishermen are living off the natural capital of the resource, rather than the interest. The management of fishing activities exploiting such fish stocks is difficult and fragile, and the stocks themselves end up in a state of decline.

Fishing also has an impact upon marine ecosystems. Trawling for fishes, and dredging for invertebrates like scallops, crabs and lobsters, may degrade habitats and destroy flora and fauna. The removal of organisms other than fishes, either deliberately, or as a by-catch, may affect their abundance and diversity. Fishing can also have an impact upon charismatic fauna, such as seabirds and marine mammals, evoking strong public concern. Noise from fishing vessels and their trawls, and from other human activities, may also have adverse effects upon marine wildlife by changing the soundscape or acoustic scene. Sound is really important to fishes, and other marine animals including invertebrates. Extraneous sounds, termed noise, can damage them physically, and also change their behaviour; making them leave the locations where they live, cease spawning, and change their migratory behaviour [3]. Noise may also interfere with the detection of sounds that have biological importance. Many fishes communicate using sounds, especially when they are spawning [4]. A balance has to be struck between fisheries and other human activities, and the state of the aquatic environment.

Fisheries management is highly dependent upon scientific advice [5]. Scientists are needed to assess the condition, location and degree of separation of fish stocks, and to examine the effects that fishing has upon the stocks. It is also necessary to monitor the state of the marine environment, and examine interactions between fish and other animals, including marine mammals and invertebrates. Fisheries science is especially important for supporting management and includes science for stock assessment, the evaluation of impacts, and the allocation of resources. A major issue, discussed at the recent conference, includes how best to obtain the scientific data [1]. For example, in monitoring catches it is important to do some of this from fishing vessels, either by making use of human observers or using video/electronic means for data gathering. Data collection by the industry itself can be very important, and can be facilitated by familiarising fishers with the science. Decision-making must include stakeholder involvement, transparency and accountability.

Fisheries managers are civil servants, aided by their own technical experts. They often interact with civil servants from other countries in the management of the fisheries. This can sometimes result in disagreements as a result of political differences, and may influence management adversely. It is especially important that fisheries managers also involve and consult the stakeholders actually involved in fishing – including the fishers themselves – as they can also provide especially useful advice.

To maintain fish stocks in a sustainable state, governments and international agencies have often placed strong controls upon the operation of the fisheries. Output controls are imposed to regulate the quantities and sizes of fish landed through quotas and minimum landing sizes. However, because the stocks are often caught in mixed fisheries, where productivity varies between stocks, simply introducing restrictive catch limits on depleted stocks does not always result in reduced fishing pressure on those stocks that are either at risk or depleted, because fishers continue to fish for the more productive stocks, and discard fish from those stocks for which they do not have available quota [6]. It is important to monitor the discarding of fish. Input controls are sometimes introduced to restrict access to the fishery through: licences which limit the number of boats; regulations that confine fishing to particular fishing gears; restrictions upon the capacity of vessels; limitations on days spent at sea; and the closure of some areas of the sea. Imposition of these controls brings particular problems for fishers, and others involved in the fishing industry [5]. It is important that stakeholders should be consulted, and their views taken into account, before such controls are imposed.

There is often a loss of faith in the procedures adopted for governing or regulating fisheries. It is crucial to deal with the need for the reform of fisheries management through the involvement of stakeholders, including the fishers themselves, others engaged in the fishing industry, environmental interests, independent marine scientists, and perhaps even the purchasers and consumers of fish.

2. Assessing the State of Fish Stocks

In order to ensure appropriate and effective fisheries management, there are a number of key steps that have to be

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taken. It is important to obtain valid scientific information on the state of fish stocks, and on the condition of the environment which supports them [5]. There is increasing evidence that many fish stocks are small, discrete and local, existing on a scale that is significantly smaller than those defined for management purposes. Stock definition is very important, but few resources have been available to examine fish stocks in detail. The prevention of damage to fish stocks depends on scientists being able to define local spawning populations, as heavy fishing in a particular area may eliminate small, local stocks. Fisheries management must be focussed on actual discrete fish stocks, rather than the larger fish groups living in major ocean areas.

There is a particular need to apply appropriate and effective control measures relating to individual fish stocks, that take account of the experience and knowledge of the fishers themselves. There is also a need to protect the marine environment, and especially the habitats occupied by fishes, taking account of environmental interests. Currently, advice on the state of fish stocks is provided mainly by specialist fishery scientists, working for national governments. They collaborate with one another internationally, within independent organisations like ICES (The International Council for Exploration of the Sea). Such organisations provide advice on the state of fish stocks and the management of fisheries to individual countries, and to international administrations, like the European Commission. The Commission also has its own scientific advisory organisation, the STECF (Scientific Technical and Economic Committee on Fisheries), which provides economic as well as scientific advice.

The government employees that provide scientific advice often collect their information on fish stocks from the fishes that are being landed at fishing ports [5]. They rarely go to sea on fishing boats to collect data on the fish being caught, and also to examine those fish being discarded rather than landed (usually because those fish are outside the quota limits set for individual vessels). The scientists are also interested in collecting information on the fishing effort that is being expended, such as how long a net is dragged behind the vessel before it is full. Government research vessels are used to carry out surveys of the abundance and spatial distribution of fish, including eggs, larvae, and juveniles, in order to estimate stock recruitment levels. Scientific activities are usually based within government laboratories, controlled by civil servants [5]. It can be useful for such scientists to collaborate with fishers, and to obtain information by working on the fishing vessels themselves. In particular, this can enable them to examine the numbers of fish that are discarded, rather than landed. Collaboration between scientists and fishers can improve the data on fish catches and discards.

The condition of individual fish stocks often has to be assessed within different areas. It is especially important, however, to obtain information on genetic differences between fish stocks and their spatial distribution within an area. Information on the size and spatial distribution of genetically distinct fish stocks is especially important. The stock assessments carried out by scientists are largely based on analysis of the catches and landings of fish. Attention is focussed on the ages of the fish being caught, and how the age composition changes with time. Quite a lot of data needs to be collected over long periods to obtain valid stock assessments. It is difficult to estimate how stocks will change in the future. The state of fish stocks is always rather uncertain, and this creates difficulties for fisheries managers. It is not always easy to assess how effective earlier management decisions have been in terms of improvements to the state of fish stocks [5]. There is a need to validate the collection of data on catches and landings, and this is best achieved by involving the fishers themselves. It is especially important to promote discussion between fisheries managers, scientists, fishers, and other key stakeholders. It has been emphasised that data feedbacks are a key component to effective fishery data systems, ensuring that fishers and managers collect, have access to and benefit from fisheries data as they work towards a mutually agreed-upon goal [7].

Very little attention is currently being paid to the relationships between different fish species. Some fish prey upon other fish, and changes in the abundance of the predator will affect the prey species. A distinct example is the Atlantic cod, which preys upon fish like the sandeel, herring and sprat, and also preys upon key invertebrates like scallops, prawns, crabs and langoustines [5]. Some of the smaller fish and vulnerable invertebrates are removed by many predatory fish species. Other animals and plants may also be adversely affected by fishing. Bottom-trawling can have adverse effects upon corals, and other benthic organisms. However, some of the commercial fish species themselves are also affected by predators, including dolphins, whales, seals and even seabirds. Although fishing may deprive predators of their food, it is also the case that increases in predator abundance can have adverse effects upon the fishes themselves, and also upon the fishing industry. For example, the recent increase in the abundance of seals along the Scottish coast has resulted in a decline in salmon populations, and deterioration of the salmon fisheries in Scottish rivers [8]. It is evident that both increases and decreases in fish stocks may have adverse effects upon the aquatic environment. It is really important to follow an ecosystem-based approach to fish-

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eries management, although it is not always clear how this can be achieved.

Changes in the environment may also affect the state of fish stocks, and it is important to take environmental changes into account when carrying out fish stock assessments [5]. Currently, major changes in the ocean climate are affecting fish stocks in areas like the North Sea [9]. Some fish are changing their locations, and this is affecting the state of local fish stocks, and also the catches made by fishers at various locations. Environmental changes are also affecting the predators of fishes. For example, puffins and other seabirds are changing in numbers as a result of warming of the North Sea. It is thought that climate change is affecting sandeels, the food of puffins, severely. And increases in the number of storms may also damage the feeding behaviour of the puffins.

Some of the adverse environmental changes in the sea are introduced by humans, including pollution by chemicals and plastics, and the generation of anthropogenic noise, all of which can affect fish and other animals adversely. Heavy shipping, including cruise ships and recreational vessels, together with oil and gas exploration, drilling and dredging, and the construction and operation of offshore wind farms may all have adverse effects upon fish. It is really important to take activities that result in environmental changes into account in managing fisheries. Fish stocks may be changing as a result of impacts other than fishing, and setting targets for the SSB (Spawning Stock Biomass) must take account of such changes. Where fish stocks and other animals are being adversely affected by human activities other than fishing it is important to take those activities into account, and to regulate and restrict such activities as well as fishing itself.

In adopting management measures, and enforcing them, it is really important to involve fishers themselves, as their knowledge can be very valuable. Fishers know how some people that are fishing might avoid the control measures that are introduced by fisheries managers, and they may also be more aware of both the benefits and disadvantages of different measures, compared to the managers themselves, who are often land-based civil servants who do not go out to sea very often. It is important to enlist the aid of fishers, both in assessing the fish stocks and managing the fisheries. Fishers need to participate, together with other stakeholders, in fisheries management. They are often aware of the changes in fish stocks within the areas that they fish, and they may not agree with the views of scientists and fisheries managers, who often rely on rather poor data about the state of fish stocks. It is really important that the knowledge of fishers, and the information that they have, is used to improve fisheries management, although fisheries managers and scientists may often be reluctant to consult fishers.

3. Involving Stakeholders in the Management of Fisheries

There is a need to change the way that fisheries management is carried out. In particular, there is a need to bring stakeholders, including fishers and environmental interests, into the organisations that carry out fisheries management. It is important to involve scientists that are employed by governments, as their advice may be based on significant scientific activities, funded by the governments. However, it is also useful to obtain advice from independent scientists, as their work may be less influenced by governments and politicians, and may extend to a wider range of factors that may influence fish stocks. Such scientists can closely scrutinise and peer review the stock assessments, as they are being carried out, and can take additional factors into account, including other human activities that may influence fishing.

The involvement of a wider range of stakeholders, and the introduction of independent scientists, requires changes in the structure and organisation of management systems. At present the management systems are dominated by the bureaucrats employed by governments and international organisations. Different institutional arrangements are necessary and must be designed to improve the independence of the management systems and bring in the key stakeholders, and independent scientists. Some changes have started to be made to the management of fisheries in Europe.

4. The Establishment of Fisheries Partnerships

It is especially important to bring fishers and scientists together with other stakeholders, including environmental specialists, to discuss the problems of managing fish stocks. It is important to open a channel for fishers' own knowledge to be taken into account, and to enable stakeholders to comment on the stock assessments, in order to contribute to better decision-taking by the relevant authorities. Within Europe, such a partnership was established in the past to facilitate the improvement of advice on fisheries management. At a meeting of scientists and fishers from around the North Sea, it was concluded that the establishment of such a partnership would bring key stakeholders into fisheries management, and would help to improve the fish stock assessments and the management decisions subsequently taken [5]. The North Sea Fisheries Partnership was set up by the North Sea Commission, a group of local governments from around the North Sea

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that included local bodies from the European Union together with some others from Norway. The Partnership was set up in 2000, and scientists and fishers were involved from all the countries around the North Sea [5].

The North Sea Partnership was set up to promote co-operation between fisheries scientists and fishers from the appropriate countries. The aim was to improve scientific advice on fish stocks, using information from the fishers themselves as well as that collected by the scientists. A number of other participants were also involved, sometimes including the actual fisheries managers themselves. The Partnership proved to be very successful, and resulted in improvements in the assessment of a number of North Sea fish stocks. ICES scientists also became involved, as well as a number of independent scientists. The Partnership enabled fishers from around the North Sea to comment on whether the scientific assessments were in accord with their own experience. There is a strong case for establishing similar partnerships for fisheries areas around the World.

5. The Establishment of Regional Advisory Councils

The Partnership discussions that took place between fishers and scientists resulted in an agreement that there was a need for a permanent council, which enabled stakeholders to take part in providing advice on fisheries management. The European Commission itself had also decided that such a council was needed to bring about the involvement of stakeholders [10]. The Commission's own roadmap on reform of its Common Fisheries Policy [11], suggested the establishment of RACs (Regional Advisory Councils) to bring this about. A new regulation was agreed, and the first RAC was established for the North Sea, involving some of those fishers and scientists that were participating in the North Sea Fisheries Partnership. The Partnership provided considerable guidance to Member States and the Commission on how the RACs should operate. There are now many more RACs (now termed Advisory Councils or ACs). They provide advice to the European Commission, Member States, and the European Parliament. The structure of the ACs, and the procedures they must follow, are set out in a document from the Fisheries Council [12].

6. The Operation of the European Advisory Councils

The European Advisory Councils are essentially stakeholder-dominated organisations that provide advice to both the European Commission and Member States on fisheries management issues. This includes advice on conservation and socio-economic aspects of management, and on the actual suitability of the current rules. The Councils also contribute key information and even scientific data on fisheries management and conservation measures. They include fishing industry representatives, together with representatives of environmental organisations. They receive EU financial assistance.

In addition to the initial North Sea Advisory Council (NSAC), ACs now exist for a number of other seas, including the Mediterranean, Baltic, North-Western Waters, and South-Western Waters. They also exist for the High-Seas/Long-Distance Fleet, Pelagic Fisheries, and those engaged in Aquaculture. They have greatly enhanced the participation of fisheries stakeholders in providing advice on fisheries management. The ACs also include representatives of environmental organisations, recreational fishers, and fish buyers and sellers. The Commission and Member States are represented by "active observers" at the various meetings of the ACs, together with any scientists invited by the ACs. Unlike the original Fisheries Partnership, however, the scientists do not play a key role in the ACs, as they are present as observers rather than key members. It has been suggested by Long [13], that the ACs are really important, and that the European Commission and Parliament, and the Member States have now become convinced of the importance of obtaining advice from fishers and other stakeholders on key fisheries issues.

An example of the advice provided by an AC is that provided by the NSAC on the implementation of the Landings Obligation (LO). The LO is legislation intended to ensure that certain catches of fish, that are environmentally protected or surplus to the vessel's quota allocation, are no longer allowed to be discarded at sea; otherwise known as the 'discard ban'. Preliminary steps have introduced since 2013, but the full Landing Obligation came into force in January 2019. It is one of the most difficult issues facing the fishing industry under the CFP. The NSAC have focussed on the issue of "chokes" – species with a low quota, where the discard ban can cause a vessel to stop fishing, even if they still have quotas for other species. The NSAC have pointed out that it is crucial to define choke categories, in order to find suitable mitigation measures, and avoid wasting time and resources on exploring options that are unlikely to be helpful. They have made it clear that the problem of potential chokes in mixed fisheries has proven to be much more problematical than initially foreseen, and the species/fisheries chosen for inclusion have meant that many of the problems have been avoided rather than being addressed. They have emphasised that to some degree the full implementation of the LO will constitute a "big bang" that will have adverse effects upon some fishers. NSAC members have welcome the reduction in unwanted catches that may be provided by the LO. Concern has been expressed, however, that recent measures and sustainable/good practices applied within the context of the CFP to achieve this reduction may be overshadowed by too heavy a focus on the LO, and the generation of choke species.

The ACs are simply consultative bodies, and they have yet to play a stronger role in fisheries management. It is important to consider for many World fisheries how stakeholder representatives can become more actively involved in fisheries management, together with independent scientists.

7. The Future Involvement of Stakeholders in Fisheries Management

It has become clear that involving fishers and other stakeholders in providing advice is very important. At the moment, however, stakeholders are not actually allowed to be involved in taking management decisions. That has currently to be left to those who work for governments and other administrative bodies. It will now be important to develop procedures whereby the stakeholders, including fishers, environmental interests and independent experts, can become more involved in arriving at the conclusions that lead to particular decisions. There is an especially strong case for involving independent scientists in arriving at conclusions on: the state of fish stocks; the state of the environment and the likely impact of fishing upon it; other human activities, including pollution by chemicals, plastics and anthropogenic noise; and factors like climate change. Independent scientists may work on subjects that are outside those considered by government fisheries scientists, and they can assist in widening the breadth of knowledge.

Of course, if stakeholders are to become involved in taking fisheries management decisions, it will be necessary to ensure that appropriate representatives are selected from the stakeholder groups. There will also of course be problems in bring their different views together and reaching a consensus position. Mechanisms will need to be developed for doing this. There is, however, a real need for more participatory forms of fisheries and environmental management.

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- Contributorship

The role(s) that each author undertook should be reflected in this section. This section affirms that each credited author has had a significant contribution to the article.

1. Main Manuscript
2. Reference List
3. Supplementary Data/Information

Supplementary figures, small tables, text etc.

As supplementary data/information is not copyedited/proofread, kindly ensure that the section is free from errors, and is presented clearly.

Ⅲ. Abstract

A general introduction to the research topic of the paper should be provided, along with a brief summary of its main results and implications. Kindly ensure the abstract is self-contained and remains readable to a wider audience. The abstract should also be kept to a maximum of 200 words.

Authors should also include 5-8 keywords after the abstract, separated by a semi-colon, avoiding the words already used in the title of the article.

Abstract and keywords should be reflected as font size 14.

Ⅳ. Title

The title should not exceed 50 words. Authors are encouraged to keep their titles succinct and relevant.

Titles should be reflected as font size 26, and in bold type.

Ⅳ. Section Headings

Section headings, sub-headings, and sub-subheadings should be differentiated by font size.

Section Headings: Font size 22, bold type

Sub-Headings: Font size 16, bold type

Sub-Subheadings: Font size 14, bold type

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Ⅴ. Introduction

The introduction should highlight the significance of the research conducted, in particular, in relation to current state of research in the field. A clear research objective should be conveyed within a single sentence.

Ⅵ. Methodology/Methods

In this section, the methods used to obtain the results in the paper should be clearly elucidated. This allows readers to be able to replicate the study in the future. Authors should ensure that any references made to other research or experiments should be clearly cited.

Ⅶ. Results

In this section, the results of experiments conducted should be detailed. The results should not be discussed at length in this section. Alternatively, Results and Discussion can also be combined to a single section.

Ⅷ. Discussion

In this section, the results of the experiments conducted can be discussed in detail. Authors should discuss the direct and indirect implications of their findings, and also discuss if the results obtain reflect the current state of research in the field. Applications for the research should be discussed in this section. Suggestions for future research can also be discussed in this section.

Ⅸ. Conclusion

This section offers closure for the paper. An effective conclusion will need to sum up the principal findings of the papers, and its implications for further research.

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References should be included as a separate page from the main manuscript. For parts of the manuscript that have referenced a particular source, a superscript (ie. [x]) should be included next to the referenced text.

[x] refers to the allocated number of the source under the Reference List (eg. [1], [2], [3])

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Ⅺ. Glossary of Publication Type

J = Journal/Magazine

M = Monograph/Book

C = (Article) Collection

D = Dissertation/Thesis

P = Patent

S = Standards

N = Newspapers

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Kindly note that the order of appearance of the referenced source should follow its order of appearance in the main manuscript.

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Ⅻ. Others

Conflicts of interest, acknowledgements, and publication ethics should also be declared in the final version of the manuscript. Instructions have been provided as its counterpart under Cover Letter.

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