

Approach Towards Management of Pond Fish Culture For High Productivity

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Abstract

Fish and aquatic products are important source of animal protein for human which is fifth largest agricultural resource of world and shares 7.5% total world food production. Fish farming is an integration of selection of economical combination of varieties and effective fish farm management which serves as alternative way to utilize aquatic resources for nutritional security and economic development and also serves the purpose of biodiversity conservation. Feed is a largest input for fish production so there is need of more scientific research on the feed requirement of various types of fishes.

Keywords: Aquatic weeds, aquaculture, fishes, phytophagous fishes, pond fertilization

Introduction

Fish production is a high protein food production system which has a significant impact on nutritional security and economic growth. Fish and aquatic products are important source of animal protein for human particularly for coastal rural communities. Fisheries is an activity which is based on aquatic natural living resources which are although renewable but not infinite so need a proper management for sustainable nutritional and economic well-being of the growing world population. Aquatic living resources including fish, molluscs and seaweed, represent fifth largest agricultural resource of world after rice, forest products, milk and wheat and shares 7.5% total world food production (UNESCO-EOLSS). Overfishing and destructive fishing methods are costing the nation by depleting wild fisheries stock (Naylor *et al*, 1998). Commercial fishing should not compromise the sustainability of fisheries and responsible utilization of aquatic living resources. Over exploitation of fish resources and continuous degradation of environment had forced the emphasis on policy reform, explicit environmental and community considerations, strengthening of institution and research and training. Thus, there is need of improved management schemes and sustainable utilization of aquatic resource system. Fish farming is an integration of selection of economical combination of varieties and effective fish farm management. This not only serves as alternative way to utilize aquatic resources for nutritional security and economic development in judicious manner but also serves the purpose of biodiversity conservation. An ideal fish farm management consists of site selection of fish farm,

development of appropriate layout for fish farm and maintenance of pondtopography, soil and water resources (Figure-1).

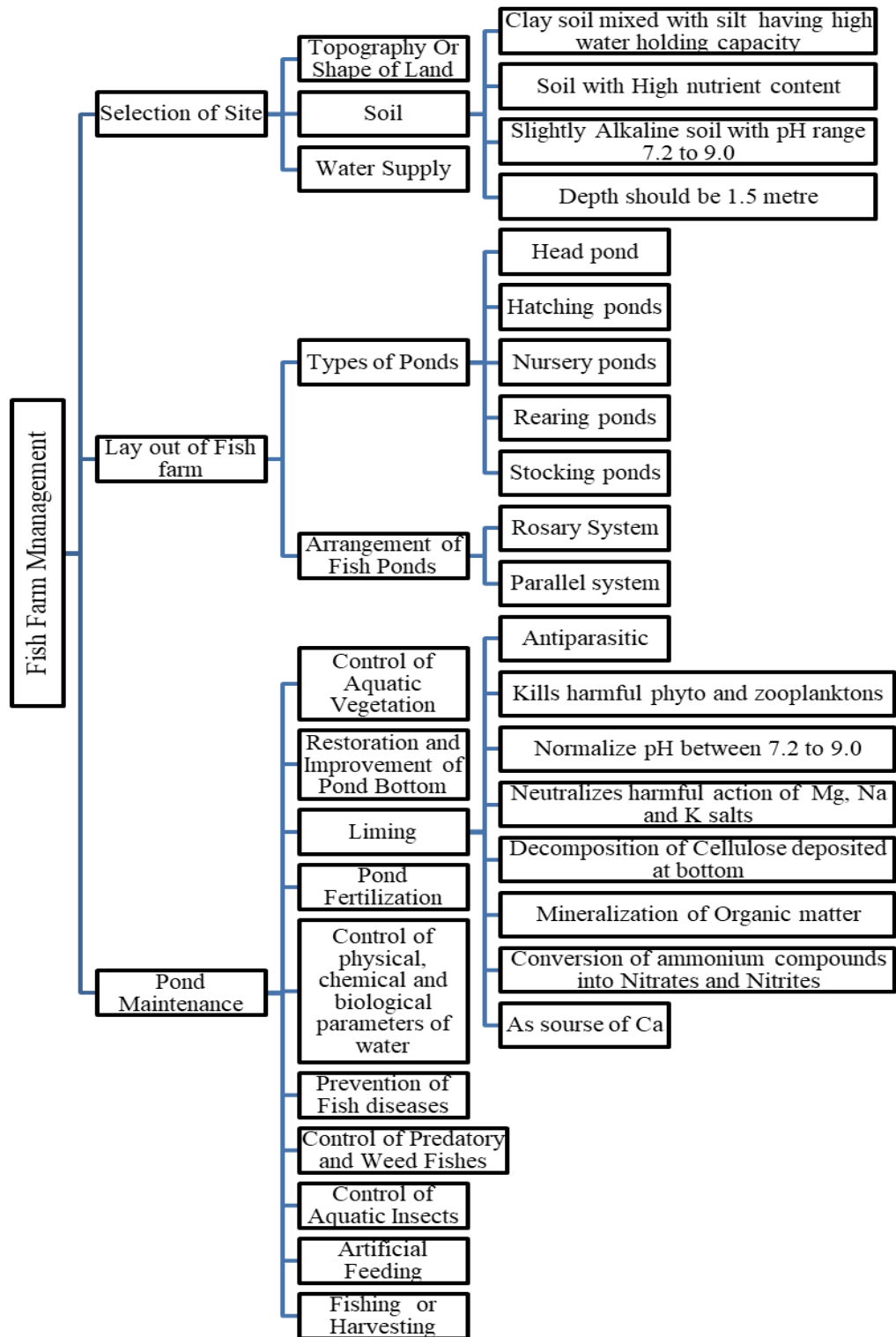


Figure-1: The concept of an ideal fish farm management practices

Topography of farm determines the number and types of ponds to be constructed. The important topographical feature of an ideal pond is the ground with a slight depression with high land on three sides and a narrow outlet on fourth side for easy evacuation and drainage. Types, characteristics and chemical conditions of soil have greater influence on pond productivity. The clay soil mixed with silt has very high-water holding capacity and is good for fish culture. A soil good for growth of crops and rich in nutrients is ideal for fish culture. Slightly alkaline soil with pH range between 7.2 and 9.0 is good for fish farming as acidic condition and too much alkalinity leads to poor yield. Availability of adequate supply of water in terms of quality and quantity is essential for fish culture and depends upon type and amount of fish to be raised in the pond. The dependable sources of water supply are lakes, reservoir, springs, rivers, canals, surface run off and wells. Muddy water should be supplied only after settling in a separate pond while the very clear water is added after pre-fertilization as it is poor in nutrients. Brown colour of water is indicator of acidic character so should be supplied after treating with lime while greenish water is rich in food for growth of fishes. Layout of fish pond consists of location, design and types of ponds. There are several categories of ponds: head pond is constructed near a perennial water to meet the water requirement of entire farm; hatching ponds, also called as spawning pond, are used for hatching of fertilized eggs and the tanks are fixed up with happa made of coarse cloth and spawn is collected in the happa where the hatching takes place; nursing pond, also called as transplantation pond, are constructed to create suitable conditions of food availability, the young fry of 3 to 5 days old are transferred from spawning ponds to nursing ponds where they grow for about 30 days; rearing ponds are used for rearing advanced fry for 2-3 months; and stocking ponds are perennial ponds and are constructed to facilitate netting.

The arrangement of fish ponds depends on the topography of land. The fish ponds are arranged either by rosary or parallel system. In rosary system the ponds are connected with one other in series so that a single channel supplies water from source to the fish pond and a drainage is connected with last pond to evacuate the excess water. One (drainage) or two (inlet and drainage) by pass channels may be connected with each pond to regulate water flow. In parallel system, all ponds of a series have separate inlets and outlets and the ponds do not overflow into each other.

Pond Maintenance

Maintenance and management of fish farm is equally important aspect of the fish culture. The principal measures adopted for effective management of pond are control of aquatic vegetation, maintenance of pond bottom, liming, pond fertilization, disease and insect-pest management, weed and predator fish management, regulation of physico-chemico-biological parameters of water, feeding and harvesting.

Control of aquatic vegetation: The aquatic vegetation or weeds are undesirable and unwanted aquatic plant which are able to grow and reproduce vigorously to disturb pond ecology and its productive potential. In India, more than 140 species have been reported as aquatic weed with high range (40-70%) weed infestation in states like West Bengal, Orissa, Bihar, Assam, Tripura

and Manipur whereas, 20-50% in other states (Philipose, 1976). Over infestation of ponds with fish may have various ill effects on fish production: lowering of water holding capacity of reservoirs; impaired flow of water in water bodies; increased mosquitoes inhabitation; increased organic matter content; high BOD (biological oxygen demand); lower oxygen level; eutrophication; reduced fish production. In addition, these are also responsible for loss of aesthetic value of aquatic ecosystem; navigation problem; impaired hydroelectricity production; damage of irrigation and drainage system; ecological imbalance, etc. Figure-2 reflects status of Kanjli wetland, a man-made wetland located in Punjab and has been recognized by the Ramsar Convention in 2002 (Reddy and Char, 2006), is under extreme infestation with water hyacinth.



Figure-2: Water hyacinth infestation in Kanjli wetland

The aquatic weeds are of various types and can be classified on the basis of their growth pattern and water-plant interaction. Philipose (1972) had grouped 56 species of aquatic weeds in marginal (20), submerged (16), emergent (11) and floating (9). The common aquatic weeds have been illustrated in Table-1 and Figure-3.

Table-1: Major aquatic weeds in aquatic ecosystem (ICID, 2002)

Families	Aquatic weeds	Families	Aquatic weeds
Alismataceae	<i>Alisma plantago</i>	Poaceae	<i>Phragmites communis</i>
	<i>Sagittaria guayanensis</i>		<i>Phragmites karka</i>
Araceae	<i>Pistia stratiotes</i>		<i>Phragmites australis</i>
Characeae	<i>Chara zeylanica</i>		<i>Panicum perpurascens</i>
	<i>Nitella hyalina</i>		<i>Paspalum fluitans</i>
Chlorophyceae	<i>Pithophora spp.</i>	Polygoneaceae	<i>Polygonum amphibium</i>
	<i>Spirogyra spp.</i>	Pontederiaceae	<i>Eichhornia crassipes</i>
Cladophoraceae	<i>Cladophora spp</i>		<i>Pontederia cordata</i>

Commelinaceae	<i>Commelina benghalensis</i>		<i>Meteranthera limosa</i>
Cyperaceae	<i>Cyperus difformis</i>		<i>Monochoria vaginalis</i>
	<i>Ipomea carnea</i>		<i>Potamogeton crispus</i>
Euphorbiaceae	<i>Ipomea hederacea</i>		<i>Potamogeton natans</i>
	<i>Ipomea aquatica</i>	Potamogetonaceae	<i>Potamogeton pusillus</i>
Holorhagaceae	<i>Myriophyllum spicatum</i>		<i>Potamogeton nodosus</i>
Hydrocharitaceae	<i>Hydrilla verticillata</i>		<i>Potamogeton pectinatu</i>
	<i>Elodea canadensis</i>		<i>Azolla imbricata</i>
Hydrocolylaceae	<i>Hydrocotyle umbellata</i>	Salviniaceae	<i>Azolla pinnata</i>
	<i>Lemna minor</i>		<i>Trapa bispinosa</i>
Lemnaceae	<i>Spirodela polyrhiza</i>		<i>Salviniaceae</i>
Lentibulariaceae	<i>Utricularia flexuosa</i>	Trapaceae	<i>Salvinia auriculata</i>
	<i>Najas minor</i>		<i>Salvinia molesta</i>
Najadaceae	<i>Vallisneria spiralis</i>		<i>Salvinia natans</i>
Nostocaceae	<i>Anabaena spp.</i>		<i>Typha angustata</i>
	<i>Nelumbo nucifera</i>		<i>Typha latifolia</i>
Nymphaceae	<i>Nymphaea alba</i>	Typhaceae	<i>Typha orientalis</i>
	<i>Nuphar lutea</i>	Zannichelliaceae	<i>Zannichellia palustris</i>
Onagraceae	<i>Jussiaea repens</i>		
	<i>Ludwigia parviflora</i>		

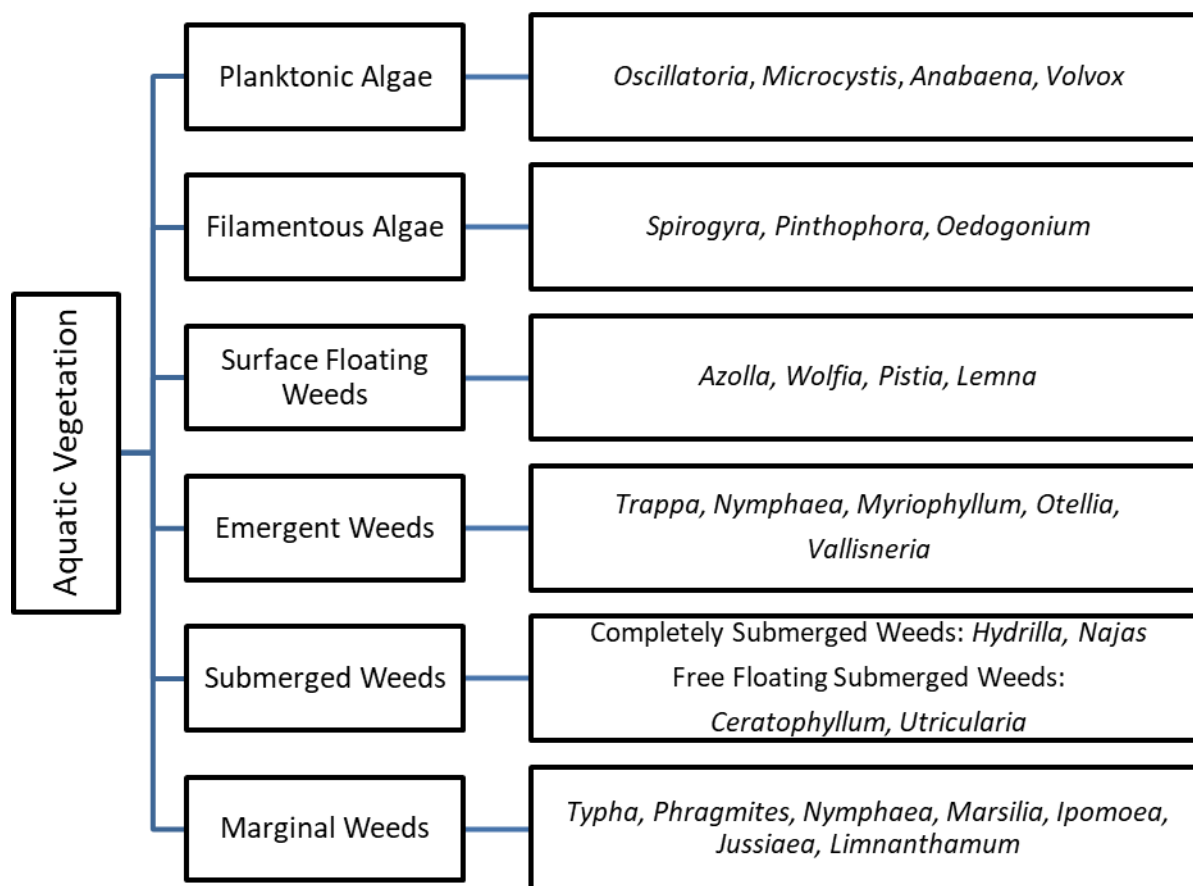


Figure-3: The different aquatic vegetation or weeds

Management of such vegetation is very important task for improving fish productivity. Application of suitable chemicals (Table-2) is always a best control for aquatic weeds which in very limited period can damage these weeds to the desirable density. However, these chemicals become lethal for aquatic life as well so its conjugation with other methods of aquatic weed management like manual, mechanical, biological and utility based control will be effective tool for improving the pond productivity (Figure-4).

Table-2: Chemical control of aquatic vegetation.

Categories of Weeds	Names of Weeds	Chemicals used
Floating Weeds	<i>Pistia, Lemna</i> and <i>Salvania</i>	Foliar spray of paraquat @ 0.02 Kg/ hectare; 2,4-D ester (MCPA) @25-40 Kg/hectare; kerosene or diesel @775-1100 litres/ hectare; mixture of Kerosene and urea in 5:1 ratio.
	<i>Eichhornia crassipes</i>	2,4-D @ 4.5-6.5 Kg/hectare.

Marginal Weeds	<i>Typha, Colocasia, Sagittaria</i>	Foliar spray of 2,4-D @ 5Kg/hectare; 2,2-dichloropropionic sodium @ 10-12 kg/hectare; Dalapan @ 25-30 kg/hectare; Amitrole @ 8 kg/hectare.
	<i>Nymphaea</i>	Spreading copper sulphate with mud on the bottom soil @ 175 kg/hectare.
Emergent Weeds	Water lily and lotus(<i>Nelumbo</i>)	2,4-D @ 1.5 kg/hectare mixed with 1 % wetting agent.
Submerged weeds	<i>Hydrilla, Najas, Potamogeton, Ceratophyllum</i>	Sodium arsenite @ 5-6ppm; CuSO ₄ alone or in combination with ammonium sulphate 50-300ppm; superphosphates @ 5000ppm.
Filamentous algae	<i>Spirogyra, Pythophora</i>	Sodium arsenite @ 5-6ppm.
Algal Boom	<i>Microcystis, Anabaena, Oscillatoria</i>	Application of CuSO ₄ @ 0.025 to 0.050 ppm; simazine @0.5-1.0 ppm.

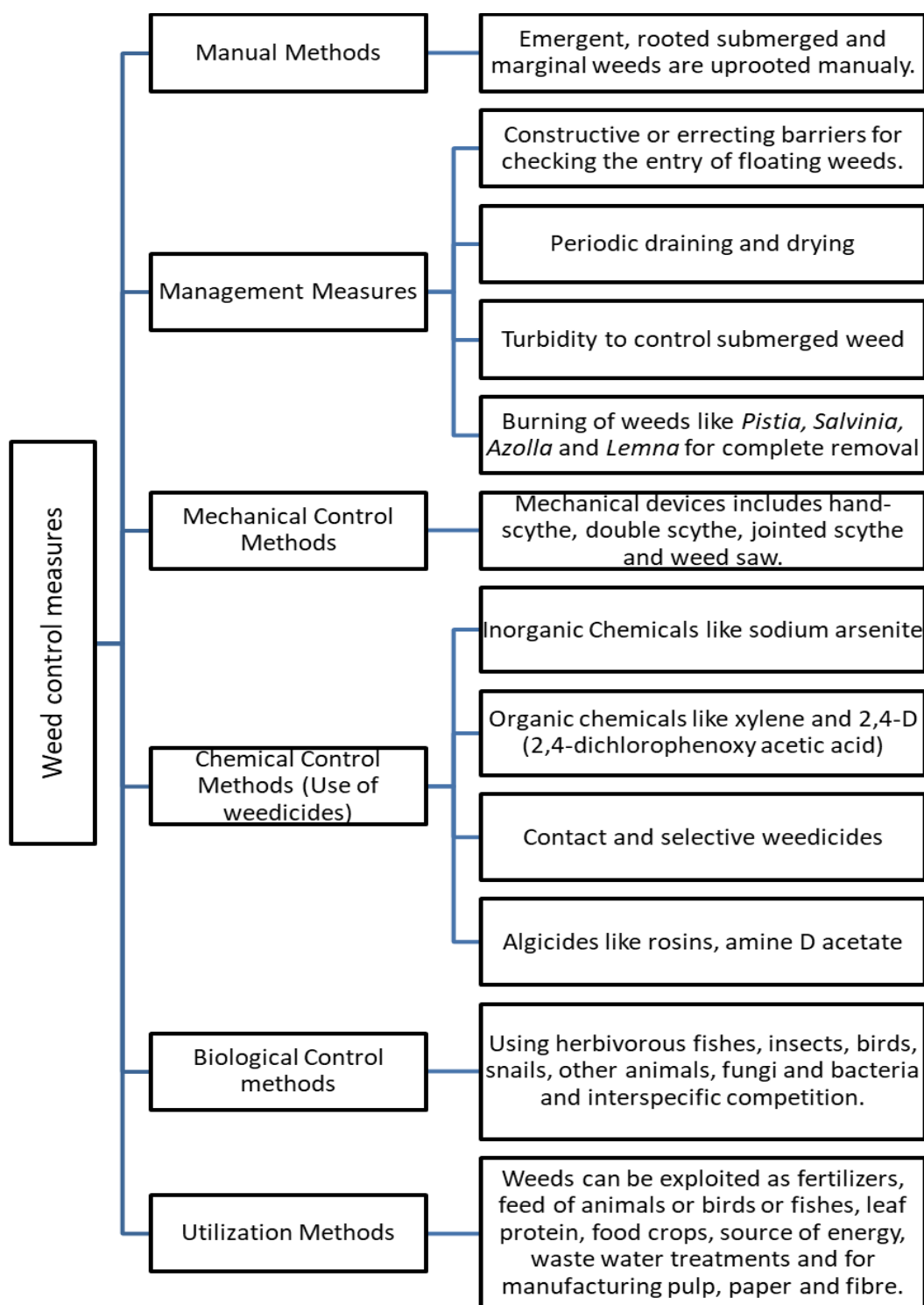


Figure-4: Management of aquatic weeds

The biological control of aquatic weeds is the most convenient, cheap and effective methods for high fish productivity and ecological safety. The phytophagous fishes which can graze over aquatic weeds are *Osphronemus goramy*(Kottelat, 2013); *Ctenopharyngodon idella* (Grass

Carp), *Oreochromis niloticus* (Shahaet *al.*, 2015); *Puntius pulchellus* (David and Rahman, 1982); *Tilapia mossambica* (*Oreochromis mossambicus*- Mozambique tilapia), *T. melanopleura*; *Cyprinus carpio* (Common carp); *Carassius carassius* (Golden Carp); *Carassius auratus* (Gold Fish); *Chanos chanos* (Milk Fish); *Colosorua bidens* (Brazilian Fish) and *Hypophthalmichthys molitrix* (Silver Carp). The phytophagous insects used to control aquatic weeds are *Galerucella nymphaeae* and *Simyra conspersa* for lilly; *Nymplula diminutalis*, *Aphis sp.*, *Hydrillia sp.* and *Bagous sp.* for *Hydrilla*; *Samea multiplicaulis*; *Cryptobagous singularis* etc (Pandey and Shukla, 2007).

The birds like swans, ducks and geese feed over algae, *Wolffia*, *Lemna* and marginal grasses. Cray fish and turtule can be effectively used to control marginal grasses and other aquatic weeds (Shah and Tyagi, 1985). The snail like *Pila globossa* can effectively control *Salvinia molesta* from water (Oyedeki and Abowei, 2012). Snails like *Marisa cornuarietis* and *Pomaca australis* can feed over submerged weeds. The fungi like *Verticillium*, *Aspergillus*, *Torula* and *Pythium* are pathogenic to *Hydrilla* while *Cercosporium*, *Cephalosporium* and *Myrothecium* are parasitic for water hyacinth (Pandey and Shukla, 2007). However, a controlled growth of vegetation in fish ponds is essential for developing a healthy pond for high economic yield.

Liming and pond bottom improvement: Restoration and improvement of pond bottom is essential to retain productivity of ponds; all the ponds are required to be drained dry once in a year. After drying, liming of pond bottom is essential to improve the pond productivity (Figure-2). The nature and the amount of liming materials applied to pond depends on physico-chemical-biological properties of soil of bottom. The various liming materials used are limestone (CaCO_3), caustic or hydrated or quicklime (CaO), slaked lime (Ca(OH)_2) and Calcium Cyanamide (CaCN_2). The most commonly used liming material is slaked lime while the most potential one is calcium cyanamide. When bottom is rich in lime no external application of lime is done as excess of Ca can combine with phosphorus to form Calcium Phosphate which is deposited to bottom of pond.

Pond fertilization: Pond fertilization is essential to enhance the carrying capacity and is aimed at developing natural food and saving artificial food. Satapathy and Nair (1990) has described a positive relation between nutrient dynamics and fertilizer application in aquatic ecosystem (Satapathy, 2010). The integrated system of pond fertilization has been represented through Figure-5. The integrated pond fertilization includes both organic and inorganic sources of nutrients. Jhingran and Ghosh (1988) and Tripathi (1990) have reported that pond fertilized with organic manures provide many times higher production than unmanured ponds. Tripathi (1990) had further reported high fish yield from the ponds fed with the biogas slurry.

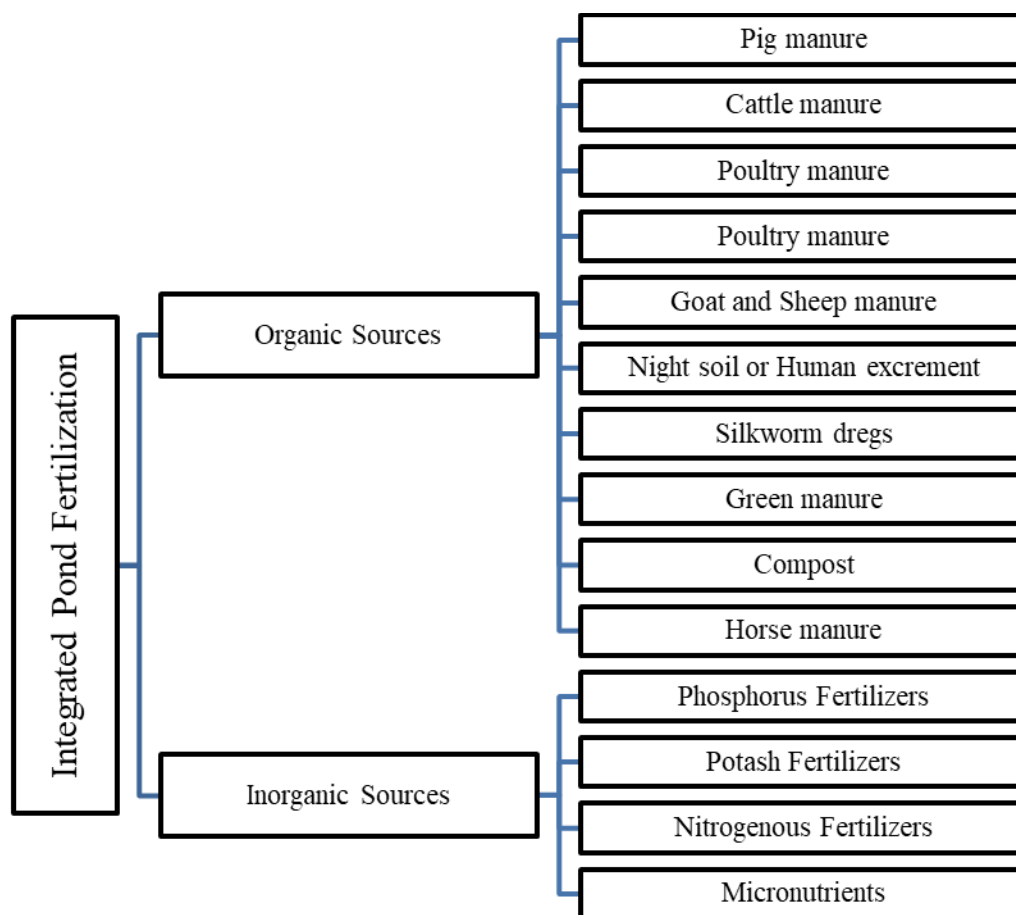


Figure-5: Pond Fertilization through integrated system

Water quality management: Water quality including physical, chemical and biological factors has significant impact over fish productivity. The various parameters of water which influence the fish culture has been described below (Figure-6) (Pandey and Shukla, 2007): A depth of 2m is congenial for high biological productivity of a pond. Longer shore line increases the vegetation and phytoplankton hence pond productivity. Movement of water favours biological productivity of pond but should not be too fast to bring unfavourable condition. Fishes are cold blooded animals which show great variability in their tolerance to temperature and are called as Eurythermal. The optimum temperature for warm water fishes ranges between 25⁰C to 32⁰C. The utilization of O₂ at 30⁰C is twice as at 20⁰C so in warm water the dissolved oxygen requirement becomes more critical than cooler water. Indian major carps can thrive well in the temperature range of 18.3 – 37.8⁰C while temperature below 16.7⁰C and above 39.5⁰C is fatal. *Cyprinus carpio* and *Anguilla japonica* can grow well in lower limits (20 – 25⁰C); *Anabas*, *Channa*, *Heteropneustes*, *Clarias* etc have high tolerance range up to 40⁰C while *Ctenopharyngodon idellus*, *Puntius javanicus* and *Tilapia mossombica* survive well in moderate range of temperature between 25 – 35⁰C. Availability of light energy to a fish pond greatly influences its primary productivity.

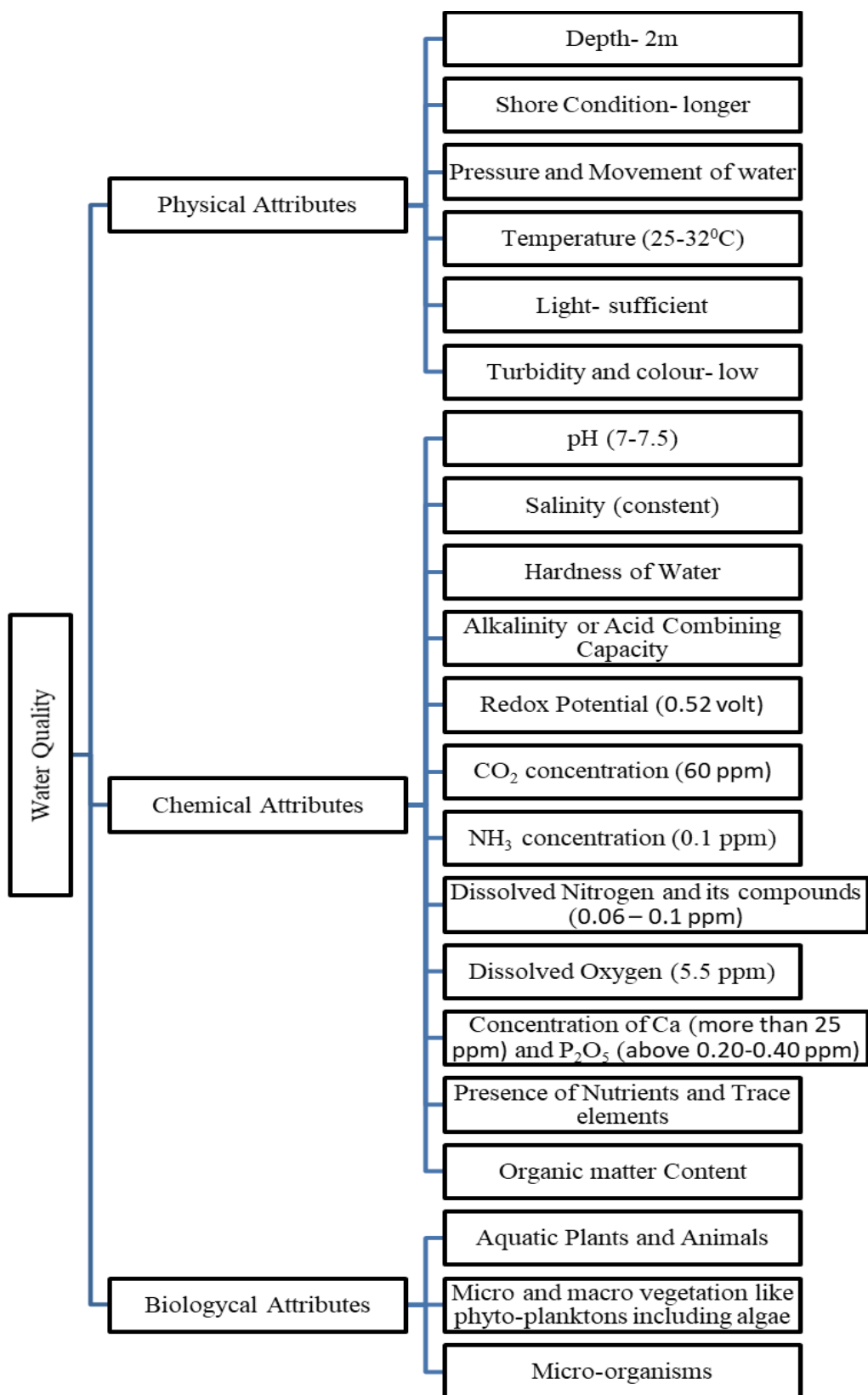


Figure-6: Physical, Chemical and Biological properties of water for successful Fish Culture

Pandey and Lakra (1997) had proposed the regulation of gonadal maturity and reproductive biology by photoperiods. Pandey and Agrawal (1988) had also observed the impact of photo-regimes on testicular and ovarian activity of *Colisa fasciatus*. Hassan *et al.* (1999) proposed that turbidity of water restricts the penetration of light and so reducing the photosynthetic activity. Thus, it acts as limiting factor for fish productivity. Jhingran (1975) proposed that turbidity due to plankton is indicator of high pond productivity while turbidity due to silt or mud is harmful to fish. Boyd (1979) had proposed use of alum for effective removal of turbidity from water and pH is adjusted by combining alum with hydrated lime. Water with pH values ranging from 6.5 to 9.0 is considered optimum for fish production with 7.0 – 7.5 as the best. Any decrease or increase in pH beyond this range results in decrease in fish production. The pH value of 4 and 11 are the acid and alkaline death points for pond fish.

Swingle (1967) reported reduced appetite; reduced growth of fishes; increased H_2S , CH_4 , Cu and other heavy metals toxicity; and increased parasitic and disease attack under acidic condition. Rahman (1992) reported the pH range of 6.5 to 7.5 is productive while Swingle (1967) observed the pH range of 6.5 to 9.0 for pond fish culture. Different fishes have different salinity acceptability. Fishes are highly sensitive to sudden changes in salinity. Small fishes are more susceptible than adult fishes to sudden changes in salinity. Swingle (1967) reported that the pond water having hardness of 15ppm $CaCO_3$ equivalent or above are satisfactory for growth of fishes. Water with hardness less than 5ppm $CaCO_3$ equivalent causes slow growth, distress and eventual death of the fishes so require liming (Hossain *et al.*, 2007). Redox potential value of 0.52 volt at $25^{\circ}C$ and 1 atm is the best value of aerated water and is suitable for fish production. Carbonates, bicarbonates and hydroxides are the main components of pond water and their concentration are expressed as total alkalinity. The calcareous water with alkalinities more than 50 ppm is most productive.

Alikunhi (1957) reported that the alkalinity range of 90 – 100 ppm corresponds to highly productive pond water while Banerjee (1967) reported 20-200 ppm of total alkalinity range for high productivity. The free CO_2 is essential to retain calcium in solution in the form of $Ca(HCO_3)_2$ and $CaCO_3$ which are called as combined CO_2 . Carbon-di-oxide in natural water is reciprocally related to acid-base relationship in the medium. CO_2 concentration naturally increases in night and decreases during day. Most of the species survive well in water containing 60 ppm CO_2 . Ammonia is product of fish metabolism and organic matter decomposition by bacteria. It exists in form of either unionized ammonia or ionic ammonium. The former is toxic to fishes but the latter is harmless. The toxic range for unionized ammonia lies between 0.6 – 2.0 ppm while the permissible concentration for fish farming is 0.1 ppm. Increase in pH of water by 1-unit results in ten times increase in proportion of unionized ammonia. Smith (1938) estimated that phosphorus and nitrogen are utilized in plankton growth at the ratio of 6:1 to 3:1. The optimum concentration of dissolved phosphate (P_2O_5) for very high pond productivity is above 0.20-0.40 ppm while the optimal limit of nitrogen is in range of 0.06 – 0.1 ppm (Bhuiyan, 1970). Ponds with more than 25 ppm of calcium is indicator of rich pond productivity. Ca is

essential for metabolic process and as structural and skeletal materials so water with poor Ca has poor productivity and absence of shrimps and molluscs. The mineral elements which are present in minute quantities in water bodies are called micronutrients or trace elements. These are Mn (present in cell walls of *Trachelomonas* alga); Mo (important for N₂ fixation by Blue Green Algae like *Anabaena*); Ni (important for green algae like *Chlamydomonas*) and Co (as growth promoter and component of vitamin-B₁₂). Other trace elements which are essential for high pond productivity includes Cu, Zn, Al, Ga and Si.

The most critical water quality is dissolved oxygen which acts as regulator of metabolic processes and as an indicator of water condition. The value of dissolved oxygen in water is influenced by temperature, atmospheric pressure, salinity of water, time duration and depth. The dissolved oxygen concentration above 5 ppm (nearly 5.5 ppm) is favourable for high pond productivity. Alikunhi (1957) stated that the dissolved oxygen range in water for successful fish culture is 5-7 ppm. Rahman *et al.* (1982) reported a range of 4 to 8.5 ppm of dissolved oxygen in pond water for high productivity. Organic matter in water bodies are produced either allochthonously or autochthonously. The allochthonous sources of organic matter are the basins and catchment area of influent streams which contain 6% crude protein with C:N ratio of 50:1 and imparts strong brown colour to water. The autochthonous source of organic matter is the decomposition of planktons which contain 24% crude protein with a C:N ratio of about 12:1 and does not impart brown colour to the water.

Presence of heterotrophic bacteria particularly the saprophytes ensures decomposition of organic matter and so are responsible for recycling of nutrients like C, N, P, S, Fe and Mn. *Closteridium pasterureum* is nitrogen fixing bacteria so will improve pond fertility. Other bacteria like *Pseudomonas*, *Mycobacterium*, *Micrococcus*, *Flavobacterium*, *Thiobacillus*, *Cladothrix* etc play important role in aquatic productivity. Zoo-planktons like protozoans, rotifers, copepods and the larval forms of crustaceans are utilized as food by many fishes while phytoplankton like flagellates, BGA (Myxophycophytes), diatoms, *Vallisnaria*, *Hydrilla*, *Utricularia*, *Anabaena*, *Volvox* etc also contributes as a good source of food for many fishes.

Fish diseases and their management: Tropical water bodies get easily polluted from unused food and decomposing organic matter so create unhygienic conditions which is favourable for introduction of diseases. Thus, fishes living in the tropical water are more susceptible and prone to diseases than fishes living in temperate water. The diseases of fish may be grouped as (i) nutritional diseases; (ii) diseases due to intrinsic factors i.e. ailments caused by environmental factors; and (iii) diseases caused by pathogens or parasites like bacteria, viruses, fungi, algae, protozoa, flukes, cestodes, nematodes and crustaceans as explained in Table-3 (Pandey and Shukla, 2007).

Nutritional diseases are either due to under nutrition or due to dietary deficiency or due to toxic effect of the diet (Table-3A). Prevention of these nutritional diseases are specific to the diseases but some common prevention practices can also be adopted which are: supply of vitamins rich and good quality food; avoiding excess of fat and salt in food; only recommended dose (should

not exceeds 2.5% of total weight of fish in pond) and ratio of supplementary food should be given; avoid over feeding; and fish should not be fed if the pond climate is too cold or too hot.

Pond environment also affect the fishes and are considered as intrinsic causes of fish diseases (Table-3B). The prevention of these ailments caused by environmental factors can be possible through hygienic maintenance and some prophylactic approaches. Hygienic maintenance includes: periodical drying and refilling with good quality water; avoid silting, weed growth, over feeding, entry of wild fishes, high stocking densities and too frequent handling and transport of pond fishes; pollution free ponds; periodical check of health of gills; and immediate removal of infected fishes. The prophylactic measures must be taken to disinfect the ponds and gears with quick lime; disinfecting fishing tools and nets with benzalkonium chloride solution (100 ppm); frequent stirring of water with poles, oars or bubble the water; disinfecting ponds having infected fish with KMnO_4 or benzalkonium chloride and giving the fish a salt bath before they are socked.

A number of pathogenic bacteria have been reported to cause severe impact on fishes so result in greater economic loss (Table-3C). Viruses containing RNA or DNA as genetic material also bring severe damage to tissues of fishes leading to death (Table-3D). These diseases cannot be easily cured, so it is essential that they must be controlled by preventing medicines. Various kinds of pathogenic fungi are known to infect the fish eggs, fry, fingerlings and adult and causes mass mortality of fresh water fish *Tilapia mossambica* (Pillai & Yvonne, 1983). The fungal inoculum grows on the non-slimy areas and penetrates into sub-cutaneous tissues to cause damage to surrounding tissues and even death. Various preventive measures and chemical treatments are used to control these diseases (Table-3E). A number of protozoan parasites are found externally on the body surface and internally in the visceral organs of fishes (Table-3F). Trematodes are also parasitic to fishes which can be categorized in two groups: Monogenetic flukes: These flukes complete their life cycle within a single host (fish). They are mostly external. Examples: *Dactylogyrus*, *Gyrodactylus* and *Diplozoon*. Digenetic flukes: These flukes complete their life cycle in two hosts including fish. They are initially external but later become internal. Examples: *Cryptocotyle*, *Diplostomium* and *Clinostomium*.

Cestodes (tape worm) like *Bothriocephalu gowkongensis* is an intestinal parasite of Chinese carp, grass carp and silver carp whereas *Ligula intestinalis* is intestinal parasite of cyprinids. Both make cysts in intestine and chock the intestine. The infected fishes can be treated with KMnO_4 solution of 4 ppm, NaCl solution of 3-5%, copper sulphate solution of 500 ppm for 2 minutes, formalin solution of 250 ppm for 1 hour and malachite green of 65-70 ppm for 10-30 seconds. The nematodes of genera *Philometra* and *Camallamus* also infect intestine of the fishes causing swelling and chocking. These diseases can be cured by dip treatment of infected fishes in 3-100000 parts of picric acid for 45-60 minutes. Leeches like *Piscicola* suck the blood and leave a wound open for secondary fungal infection. The infected fishes can be treated by dipping them in Lysol solution (0.20 ml/l of water) for 5-15 seconds, 10% NaCl solution for 20-30 min, 20% NaCl solution for 10 minutes or quick lime solution (1g/l water) for one minute. Dinoflagellates

release nerve toxin during high population level (red tide) which causes massive death to marine fishes. Crustaceans like *Argulus* spp and *Lernaea* spp are copepod crustacean parasites. These parasites are cured by treating infected fishes in 3-5% NaCl bath or in 250ppm of formalin solution for 1 hour. The pond should be drained and limed before restocking. Solution of KMnO_4 (0.2-0.3 g/gallon of water) may be added to fish pond.

Epizootic Ulcerative Syndrome, also known as cancer of fish, has been reported to various indigenous fishes. Rhabdoviruses have been identified in the blood of fishes affected with this syndrome but there may be many other causes. The syndrome is characterized with severe ulcerative skin lesions which begin with small grain to pea sized haemorrhagic spots over the body and turn into coin sized greyish spots consisting slimy central necrotic area surrounded by a zone of hyperemia. The affected fishes start rotting while still alive and even die. The most severely affected fish species are *Channa*, *Puntius*, *Carias batrachus*, *Heteropneustes fossilis* and *Mastacembalus*. For successful treatment of this disorder, fish culture pond should be made pollution free and liming of pond is carried out. Chemical mixture called CIFAX (0.01 ppm) synthesized at CIFA (Central Institute of Fresh water Aquaculture, Bhubaneswar, Orissa) helps in the healing process of the ulcerated lesions.

Control of predatory and weed fishes: The fishes which feed upon cultivable species of carp hatchlings are called predatory fishes. Example: *Amphipnous cuchia*, *Anabas testudineus*, *Ailia coila*, *A. berg*, *Bagarius bagarius*, *Clupisoma garua*, *Clarias batrachus*, *Channas striatus*, *C. marulius*, *C. stewarti*, *C. punctatus*, *C. gachua*, *Eutripychthys vacha*, *Glossogobius giuris*, *Heteropneustes fossilis*, *Mystus seenghala*, *M. aor*, *M. cavasius*, *Macragnathus aculeatus*, *Mastocembelus arnatus*, *Nandus nandus*, *Notopterus notopterus*, *N. chitala*, *Pangassius pangassius*, *Pama pama*, *Pseudociana coitor*, *Rita rita*, *Silonia silonia* and *Wallago attu* (Pandey and Shukla, 2007). The fishes which consume the aquatic vegetation to compete the cultivated fishes are called as weed fishes. Example: *Ambassis ranga*, *Aplocheilus lineatum*, *A. panchax*, *Barilius bendelisis*, *B. bola*, *B. vagra*, *Chela cochins*, *C. laubuca*, *Colisa fasciatus*, *Changasius changasius*, *Esomus danricus*, *Gudusia chapra*, *Gonialosa manniona*, *Neomacheilus zonatus*, *Osteobrama cotio*, *Oxygaster bacaila*, *O. phulo*, *Puntius ticto*, *P. conchoni*, *P. sophore*, *Rasbora daniconius*, *Setipina phasa* and *Xenentodon cancila* (Pandey and Shukla, 2007). These fishes are not suitable for efficient productivity so must be eradicated for achieving high yield from pond fish culture. The methods of eradicating predatory and weed fishes from pond are: complete dewatering of the pond followed by drying of bottom soil; complete dewatering followed by desilting of silted ponds; repeated netting of small pond with fine mesh dragnet ensures successful removal of predatory fishes and minnows; and the complete eradication of predatory and weed fishes can be achieved by using fish poisons. These fish poisons can be organophosphates like phosphamidon, thiomatin and DDVP (0,0-dimethyl-2,2-dichlorovinylphosphate); or originated from plant sources like *Derris* root powder (rotenone as active ingredient), oil cakes of *Bassica latifolia* or *Madhulica indica* (mowrin or resparin or saponin as active ingredient) @ 200-250 ppm, 1% sugarcane jaggery, seed meal of *Tamarindus*

indica @ 2000 kg/ha, *Croton tigliun*, etc. Chakraborty *et al.* (1972) had also commented on *Barringtonia acutangula* as fish poison.

Control of predatory aquatic insect: The most common predatory insects belong to orders Hemiptera (*Belostoma*, *Lithocerus*, *Nepa*, *Ranatra*, *Notonecta*, *Geris*, etc.); Coleoptera (*Cybister*, *Dytiscus*, *Gyrinus*, *Hydrophylus*, etc.); and Odonata (Dragon fly and dumsel fly). These predatory aquatic insects can be effectively controlled by using insecticides like 0.6-1 ppm gamaxene and 0.01 ppm pure gama-isomer of BHC (benzene hexaxchloride). Spraying of oil to kill the insects which come upon the surface of water to respire (Prasad, 1981). Emulsion of mustard or coconut oil and washing soap in ratio of 56:18 kg/ha has been reported from CIFRI Cuttack to kill pond insects (Pakrasi, 1953). Chatterjee (1970) had proposed use of Teepol B-300 (560 ml) in place of soap to make emulsion.

Artificial Feeding: Hora and Pillai (1962) had suggested stocking density of 78, 12,500 spawn/ha in nursery pond. The spawns start voracious feeding on zooplankton present in nusery pond. After two days of stocking artificial feed along with natural feed is given two enhance the growth of spawns. The constituents of the feed given are rice bran and oil cakes of groundnut or coconut or mustard. An artificial feed consists of a mixture of dried, powdered and sieved aquatic insects, small prawns with shrimps and pulses in ratio of 5:3:3. In both, intensive and semi-intensive aquaculture practices two-third of capture fishing are consumed by human and about one-third are used to prepare high protein fish meal. Out of this one-third is used in feed for fish production (Tacon, 1997; Tacon, 1998; Pike, 1998). All types of fin fishes require similar amount of dietary protein per unit of body weight. The compound feed of Tilapia (omnivorous) contain 15% of fish meal (Tacon, 1997). Thus, feed is a largest input for fish production and increase in fish meal and fish oil prices is reducing the profitability of fish farming (Naylor *et al.*, 2000). There is need of more scientific research on the feed requirement of various types of fishes (Lightner *et al.*, 1997) in order to substitute the fish meal and fish oil with soyabean oil seeds, meat byproduct and proteins from microbial sources (Akiyama and Tan, 1991; Tacon, 1995; Webster *et al.*, 1999).

Table-3: Various diseases and their effective management for improving fish productivity

S.No.	Bacterial Diseases	Characteristics/ Symptoms	Management
1	Infectious Dropsy (<i>Pseudomonas punctate</i>)	Accumulation of yellow coloured fluid inside the body cavity (intestinal dropsy). Ulcers on the skin and fin; deformation of backbone (ulcerative dropsy).	Complete destruction of fishes followed by draining, drying and disinfecting the pond with CaO. Dipping of infected fishes for 2 minutes in 5 mg/L KMnO ₄ solution.
2	Furunculosis of salmon (<i>Aeromonas salmonicida</i>)	Appearance of bloody boils on the skin on the visceral organs of the fishes. Bursting of furuncles spread disease.	Draining and treating the pond with slaked lime. Antibodies (intofurans or sulphonamides) enriched food.
3	Cotton mouth (<i>Fexibacteria</i>)	Presence of fungus like tufts around the mouth.	Adding antibiotics in the water. Antibiotics are:
4	Red mouth (<i>Enterobacteria</i>)	Salmonids in fresh water containing animal wastes.	Chloramphenicol 10 ppm or furnace 0.1- 0.3 ppm.
5	Tail/ fin rot (<i>Myxobacteria</i>)	White lines develop along the margins of fins which gradually extends towards the base of fins. The fin rays become haemorrhagic, brittle and destroyed completely.	Keeping the fishes for 1.5 – 2.0 minutes in 0.5% of copper sulphate solution or a bath in dilute solution of acriflavin or phenoxethol as early stage treatment.
6	Bacterial gill (<i>Myxobacteria</i>)	Colonization of damaged gills in salmonids.	Antibiotics like neomycin, chloramphenicol.
7	Tuberculosis (<i>Mycobacterium piscium</i>)	Tail or fine rot, waxy coat and ulcer on the body, nodules in internal organs and loss of weight and appetite.	Dipping of affected fishes for 1 min in 1:2000 CuSO ₄ solution for 3 to 4 days. Destruction of fishes and sterilization of ponds with KMnO ₄ .
8	Chronic lesions (<i>Nocardia</i>)	Rotting and necrotic lesions on body of salmonids.	
9	Kidney Disease of salmonids (<i>Corynebacterium</i>)	Bacterium multiplies within tissues to cause chronic damage to kidneys.	Antibiotics like neomycin, chloramphenicol etc.
10	Columnaris (<i>Chondrococcus</i> & <i>Cytophaga</i>)	Decolourized patches on the body which spread to cause loss of scales and eventual death of fresh water fishes.	Antibiotics like terramycin in artificial food. Dipping of affected fishes for 2 min in 1:2000 CuSO ₄ solution or 10-30 sec in 1:15000 malachite green solution. Destruction of fishes and sterilization of ponds with KMnO ₄ .
11	Vibriosis (<i>Vibrio anguillarum</i>)	Bacterium multiplies within skin of salmonids and produces toxins which cause anaemia.	
S.No.	Viral Diseases	Characteristics/ Symptoms	

1	VHT (RNA Virus)	Viral Haemorrhagic Septicaemia- Anaemia, pale discolouration of gills, oedema of muscles and inflammation of intestines. Sores on skin and protruding anus with haemorrhage in tissues.
2	IPN (RNA Virus)	Infectious Pancreatic Necrosis of salmonids- Damage of intestine and pancreas.
3	IHN (RNA Virus)	Infectious Haemopoietic Necrosis of salmonids- A disease complex appears in association with OSD (Oregon sockeye disease) and SRCD (sacramento river chinook disease).
4	IDC or SVC (<i>Rhabdovirus</i>)	Infectious Dropsy of Carps or Spring Viraemia of Carps- Distended abdomen and haemorrhage in skin and gills.
5	CCV (DNA Virus)	Channel Catfish Virus- Infected fishes hang vertically in water to be imbalanced. Haemorrhage of visceral tissues.

S.No.	Fungal Diseases	Characteristics/ Symptoms	Management
1	Dermatomycoses	Fine hair like tufts hanging from the infected areas, eroded and haemorrhagic fins, body cells degenerate in severity. Infected eggs tend to stick together and finally perish.	Removal of dead fishes from the pond. Draining, drying and treatment of the pond with quicklime (150-200 kg/hectare). CuSO ₄ bath of fish in 500 ppm solution for 1-2 minutes to kill fungal spores. Antibiotics (terramycin and erythromycin) supplemented food. Treatment of fish in solution containing 10-20 cc of 10% phenoxethol diluted in 1000ml of water. Quarantine regulation for nursery introduction.
2	Branchiomycoses or Gill rot	Rotting of gills and blood vessels leads to death.	
3	Systemic or Deep or internal mycoses or Ichthyophonosis	Infected fishes show swinging movement. Small spherical cysts develop in the liver, brain, kidney, gonads, etc.	
4	Skin and Kidney swelling	Hard raised swelling on the skin or in the kidney.	

S.No.	Protozoan Diseases	Characteristics/ Symptoms	Management
1	Ichthyophthiriusiasis or Ich (<i>Ichthyophthirius multifiliis</i>)	White, small spots or pimples over skin and fins. Jumping of fishes and rubbing the body with the objects in water.	Draining and liming of ponds. Daily bath of affected fishes in formalin (200-250 ppm); malachite green (1.25 ppm); methylene blue (2 ppm); acriflavin (5-10 ppm) or NaCl solution (7000 ppm). Addition of formalin (15 ppm) or malachite green (0.5 ppm) in ponds.
2	Trichodiniasis (<i>Tricodina</i>)	Skin lesions in <i>Tilapia</i> and salmonids.	
3	Whirling disease (<i>MyxosomaCeratomyxa</i>)	Protozoans penetrate the cartilage of skulls and spines in Rainbow trout and salmonids, respectively.	
4	Milky fish (<i>Henneguya</i>)	Tadpole shaped cysts with two eye spots and milky skin.	

5	Costiasis (<i>Costia necatrix</i>)	Lesions on skin, fins and gills. Grey blue film on the skin which turns to red patch. Loss of appetite and finally death. <i>Tilapia</i> is resistant to this disease.	Diseased fishes are kept in 3-5% of NaCl solution or in 1-2500 ppm formalin solution for 10-15minutes. KMnO ₄ is added to pond. Avoid overcrowding and low pH.
S.No.	Flukes	Characteristics/ Symptoms	Management
1	External fluke (<i>Gyrodactylus elegans</i>)	Bluish slime develops due to excess secretion of mucus. The colour of fish fades away and fins get torned.	Dip treatment for 3-5 minutes in 5%NaCl or 5-5000 ppm formalin solution repeated for 2-3 days. Fishes are left for
2	Gill flukes (<i>Dactylogyrus vastator</i>)	Inflammation of gills followed by complete destruction at severity leading to heavy mortality of the carps.	2-3days in water tanks containing 10 ppm of acriflavin or 2-4 ppm of methylene blue dye.
3	Yellow grub (<i>Clinostomum</i>)	The cysts are formed below the scales of infected fishes which contain worms as metacercariae of the adult fluke.	Dissecting the cyst and removing the parasites. Disinfection of wound by mercurochrome.
4	Black spot disease (<i>Cryptocotyla lingua</i>)	The cysts are formed below the skins of infected fishes which contain worms as metacercariae of the adult fluke.	Removal of secondary hosts like snails.

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