2. Review of Literature

2.1. Introduction to ornamental fish rearing

Ornamental fish production for the aquarium industry is increasing steadily throughout the world. According to Singh (2005), about 750 fresh water species are traded, among which nearly 90% are from aquaculture and 10% are collected from the wild. According to trade statistics, Asian countries dominate the world export market. Out of the figure of US $ 189.5 million of total exports in 2002, Asian countries had a share of about 60%. Singapore was the world's largest exporter contributing about 22% of total exports (**Table 1**), followed by Malaysia (9.3%), the Czech Republic (7%) and Indonesia (6.7%).

Table 1 World trade in ornamental fish (2002): share of main exporting countries (adapted from Singh, 2005).

Country	Amount of export (in US $)	% of global trade
Singapore	41.46	21.88
Malaysia	17.56	9.27
Czech Republic	13.35	7.04
Indonesia	12.65	6.67
China	9.48	5.00
United States	8.38	4.42
Japan	8.33	4.39
Philippines	6.44	3.40
Peru	6.44	3.40
Sri Lanka	5.52	2.91
Others	59.88	31.60
Total	**189.49**	**100**

Although most of the ornamental fish are exported from countries in south-east Asia, there is little information pertaining to husbandry and culture management of ornamental fish species from these countries. One of the possible reasons could be the intense competition between different fish farms, where commercial production techniques are closely guarded by the producers in this increasingly knowledge-based industry. Tay and Tan (1976), and Tay (1977) reported on cage culture of ornamental fish in earthen ponds in Singapore. However, water scarcity in Singapore, where almost half of the water comes from neighboring countries (Tan, 1988), forced fish producers to limit unrestricted use of water. Fernando and Phang (1985) documented the culture techniques of guppy, *Poecilia reticulata*, in some fish farms of Singapore, where large, shallow, cement tanks were used for breeding, grow-out of fry and juveniles, and stocking. In some farms, glass tanks were used for stocking and conditioning. However, every farm had at least one reservoir pond. Pig dung was added as fertilizer to the cement tanks and cage-net ponds in some farms to enhance the growth of natural food organisms. Fertilization of ponds with poultry excreta or pig dung has also been reported in the culture of other ornamental species (Tay and Tan, 1976). Ng *et al.* (1992) documented the water quality management in a tropical fish farm in Singapore through a discontinuous flow recirculation system, with daily 8% exchange of water. Over the years, in order to increase productivity for intensive farming, most farmers are increasingly using the water recycling system. The intension is to create an appropriate ecological and biological system, which serves to breed and farm fish in an efficient and controlled environment (Lee, 2005).

In Malaysia, significant developments in the ornamental fish culture industry took place in the 1980s, when fish farms were set up in different locations in the country (Dey, 2005). According to official statistics published by the Department of Fisheries, Malaysia, there seems to be a degree of specialization among different states in the production of fish. While producers in Penang specialize in discus, *Symphysodon discus*, farmers in Perak give emphasis to goldfish and koi carp, which is attributable to proper understanding of the culture requirements of each species and the environmental conditions of the respective state.

Compared to Asia, much more information is available on ornamental fish culture in the United States. Watson and Shireman (1996) documented ornamental fish production in Florida. Here, tropical fish are cultured primarily in outdoor earthen ponds. Relative to other aquaculture ponds, ornamental fish ponds are very small, averaging 7.62 m × 22.86 m, with a maximum depth of about 1.83 m. The pool is first pumped dry and hydrated lime is added as a sterilant. Organic fertilizers such as cottonseed meal are also added in the pond. An earlier report by Martin (1983) indicated that compared to larger ponds in Arkansas and Kentucky, ornamental fish production was higher in ponds that were smaller than 1 acre.

Tamaru *et al.* (1997) summarized the different culture systems employed in the production of ornamental fish in Hawaii. Traditionally, ornamental fish are produced in earthen ponds because the bottom soils support a healthy growth of plankton from which the fish feed on. Besides, fish culture in ponds brings down construction costs. However, earthen ponds tend to have aquatic weed problems, and because of their large size are difficult to control. Fish culture in circular tanks allows for more effective measures in controlling the rearing management. Besides, plankton concentration in 'green water' tank culture systems is comparable to earthen ponds. Cage culture in large ponds falls somewhere in between tank and pond growout culture in terms of easy management and productivity, and serves as a cost effective way to diversify production. Asano *et al.* (2003) reported that ornamental fish are typically produced in culture tanks that exchange four tank volumes of water in a day. Since 1993, the Centre for Tropical and Subtropical Aquaculture in Hawaii have produced a series of user-friendly documentations on different aspects of culture of ornamental fish. Production protocols are available for the blue gourami, *Trichogaster trichopterus* (Cole *et al.*, 1997), tiger barb, *Capoeta tetrazona* (Tamaru *et al.*, 1997), serpae tetra, *Hyphessobrycon serpae* (Cole and Haring, 1999), lemon tetra, *Hyphessobrycon pulchripinnis* (Cole *et al.*, 1999) and swordtail, *Xiphophorus helleri* (Tamaru *et al.*, 2001).

Some literature on cultural conditions of ornamental species is available from other regions of the world. In Israel, the culture of ornamental cyprinids, mainly goldfish and koi carp are growing rapidly. Large scale fish production involves fry stocking in earthen ponds where large mortality have been reported before the fish reach 1 g size (Feldlite and Milstein, 1999). In South Africa, experimental tank culture of swordtail with water exchange rates of 1.5 - 2 theoretical turnovers per hour yielded growth rates similar or better than those found under commercial conditions (Kruger, 1995; Olivier and Kaiser, 1997). In another study, survival rate and length increment of swordtail were unaffected by water exchange rates but faster water exchange promoted a more uniform size of fish (Kaiser and Jones, 1998). Vine and Kaiser (1994) reported good production of guppy under high stocking densities in culture tanks where water was replaced 4 - 5 times per hour. Kaiser *et al.* (1998) documented the diurnal water quality fluctuations in a closed recirculating system for the culture of guppy and concluded that a water exchange rate of six turnovers per hour was required to reduce the occurrence of ammonia peaks. In Europe, ornamental fish business is seasonal, with a focus on garden ponds in summer and on aquaria in the winter (Postoma *et al.*, 2004). The Czech Republic is the largest producer of ornamental fish in Europe. Typical fish productions in the Czech Republic are small basement operations. A preliminary survey showed that some producers even operate from small rooms measuring about 16 m^2, producing nearly 12000 fish per month, using modern techniques (Rana, 2004).

In India, few cities like Kolkata, Mumbai and Chennai are the most important production centres for ornamental fish (Swain, 2004). According to Dehadrai (2004), there are about 300 full time producers and 600 part time producers of ornamental fish throughout the country (**Table 2**). Nearly 90% of total export of ornamental fish from India is conducted through Kolkata airport in West Bengal (Biswas and Lepcha, 2004). According to Swain *et al.* (2003) and Mukherjee (2004), export is limited to captured indigenous fish (85%), and cultured exotic ornamental species contribute to only 15% of the total exports. One of the reasons could be that although the exotic species have been farmed on a large scale for many years, little scientific research has been conducted on their culture and trade requirements. According to trade statistics, exotic species are in most demand, both in the global (Singh, 2005) and domestic markets (Biswas and Lepcha, 2004), and proper emphasis should be given to understanding their culture requirements under tropical conditions.

Table 2 Information on number of ornamental fish units and people involved with the trade in India (adapted from Dehadrai, 2004).

Type of business	Number of units
Regular ornamental fish farms	4
Full time breeders and growers	300
Part time breeders and growers	600
Aquarium shops (large)	250
Aquarium shops (small)	1500
Ornamental fish exporters	20

2.2. Food requirements of ornamental fish

In aquaculture, food is considered the most powerful among environmental variables affecting growth and metabolism (Kinne, 1962; Beamish and Dickie, 1967; Miller *et al.*, 1988; Kaiser *et al.*, 1997; Bunnell *et al.*, 2003). A modest amount of literature is available on the nutrition and food requirements of some popular ornamental fish species.

Nayadu (1975), Dussault and Kramer (1971), and Dahlgren (1980) documented the omnivorous feeding habit of guppy, with a varied food preference of small invertebrates, insect larvae, algae and other plant material. Fernando and Phang (1985) reported the application of formulated diets in fish farms of Singapore, which included milk powder, wheat bran, wheat flour, fish meal, egg yolk, minced beef and ground dried shrimp. In some farms, supplemental live food consisting of water fleas and tubificiid worms were also added. Much emphasis is placed upon regular supplementation of diets with live food, including cladocerans such as *Daphnia* and *Moina*, and tubificiid worms (Fernando *et al.*, 1991). A dietary protein requirement of about 30 - 40% for the guppy was reported by Shim and Chua (1986). Harpaz *et al.* (2005) studied the effect of feeding guppy fry with different forms of commercial diets and concluded that the growth was considerably enhanced when the diet was presented in powdered form, compared to flakes.

Gut content analysis of the swordtail and platy, *Xiphophorus maculatus* revealed that both terrestrial and aquatic insect larvae are eaten along with phytoplankton and some micro algae (Arthington, 1989). However, the sailfin molly, *Poecilia latipinna* prefers a diet of more plant material (Dawes, 1991). Kruger *et al.* (2001 a) conducted a series of experiments to develop a diet suitable for early juvenile swordtail under intensive culture conditions and found that a diet with 45% protein content promoted growth rates and feed conversion. Supplementation of flakes with *Daphnia* resulted in improved growth rate, compared with only flake feed (Kruger *et al.*, 2001 b). Likewise, an increment in growth rate was reported in angelfish, *Pterophyllum scalare*, when *Artemia* was supplemented with a commercial trout diet (Degani, 1993). Tiger barb is generally considered omnivorous (Tamaru *et al.*, 1997). Investigations by Shiraishi *et al.* (1972) on gut contents of wild caught tiger barb showed phytoplankton, zooplankton, aquatic and terrestrial insect larvae, and plant tissue, with a strong preference for vegetative diet. The blue gourami is considered carnivorous, the natural diet being different species of invertebrates (Degani, 1990). For the pearl gourami, *Trichogaster leeri*, a dietary protein requirement between 26% and 36% was suggested by Degani and Gur (1992).

Studies on food requirements of ornamental cyprinids lay emphasis on the importance of live food. Martin (1983) reported on the supply of zooplankton to goldfish ponds by some producers in the United States and suggested a dietary protein requirement of 38% to 45% for the goldfish. Abi-Ayad and Kestemont (1994) reported an increment of growth in goldfish fed with live *Artemia*, compared to fish fed with dry diet. However, Kaiser *et al.* (2003) suggested the use of decapsulated *Artemia* cysts, compared to live *Artemia*. The effectiveness of decapsulated *Artemia* cysts in promoting growth and survival of a number of ornamental species have also been documented by Lim *et al.* (2003). Lubzens *et al.* (1987) observed that goldfish fed with rotifer, *Brachionus plicatilis*, in combination with artificial feed, showed better growth than fish fed with dry diet only. Combination of greenwater infusoria (including mainly ciliates) with artificial diets yielded better growth of rainbow shark, *Epalzeorhynchos erythrurus*, compared to fish fed with artificial feed only (McGovern-Hopkins *et al.*, 2002). Studies on koi carp by Ako and Tamaru (1999) suggested that growth rate increases with the palatability of the diet. Appelbaum *et al.* (1986) and Van Damme *et al.* (1989) reported high mortality rates of koi carp larvae and juveniles when fed with artificial diets. Experiments by Lubzens *et al.* (1987) demonstrated that relative to dry diet, supply of *Brachionus plicatilis* improved survival and growth rate in koi carp.

Management strategies of fish husbandry are likely to influence species composition and abundance of live food in the environment (Diana *et al.*, 1991; Milstein *et al.*, 1995; Garg and Bhatnagar, 1996; Akpan and Okafor, 1997; Jakubas, 2002; Mischke and Zimba, 2004), which could in turn affect the food selection by the target fish species. Two distinct types of plankton feeding behaviour are distinguished: particulate feeding and filter feeding. In nature, switching from particulate to filter feeding behaviour is a function of various factors such as prey density and the size range of available prey (Lazzaro, 1987; Dewan *et al.*, 1991; Ushakumari and Aravindan, 1992; Xie, 1999; Serajuddin, 2000). Some planktonic organisms pass undigested through the gut of planktivorous fishes. Since the fish expends energy in the capture of prey and receives no energy through assimilation in return, the fish may recognize and avoid such undesirable prey organisms. Ivlev (1961) and Vinyard (1967) reported on slightly negative electivity towards ostracods by bleak, *Alburnus alburnus*, and bluegill, *Lepomis macrochirus*, respectively. However, detailed documentation pertaining to food selection of ornamental cyprinids under tropical conditions is sparse.

2.3. Stocking density of ornamental fish

To supply the growing market, fish farmers need to keep fish at the highest sustainable stocking densities to produce a large number of fish (Olivier and Kaiser, 1997). Knowing the optimal stock density is one of the basic factors of intensive fish culture. This density should be the resultant value of the environmental requirements of a given fish species and broadly understood economic efficiency (Holm *et al.*, 1990; Kuipers and Summerfelt, 1994; Szkudlarek and Zakes, 2002). Fish stocking density is the most sensitive factor determining the productivity of a culture system as it affects growth rate, size variation and mortality (Kaiser *et al.*, 1997).

While the effect of stocking density on growth and production of food fish species has undergone intensive investigations, little scientific research has been conducted on ornamental fish species. In comparison to food fish production, the densities at which ornamental fish have been kept are rather low. In Singapore, the stocking rate have been reported to be as low as 0.02 - 0.1 fish/ L (Ng *et al.*, 1992) to less then 0.3 fish/ L (Fernando and Phang, 1985). Among other literatures available, values range from 0.4 fish/ L in angelfish (Degani, 1993) and swordtail (Mondal *et al.*, 2004) to 0.5 fish/ L for the blue gourami (Cole *et al.*, 1997). The koi carp is traditionally cultured at a density of 0.25 fish/ L in Hawaii (Asano *et al.*, 2003). However, to our knowledge, there have not been any research studies on stocking rates for koi carp production under tropical conditions.

2.4. Polyculture of ornamental fish

Polyculture is the only possible way of simultaneously producing more than one fish species from the same rearing space (Papoutsoglou *et al.*, 1992; Papoutsoglou *et al.*, 2001). The principle of polyculture is based on the fact that cultured fish species feed on different levels of food chain and environment (Milstein *et al.*, 2002). The productivity of the aquatic system is thus increased by more efficiently utilizing ecological resources within the environment. Stocking two or more complimentary fish species can increase the maximum standing crop of a pond by allowing a wide range of available food items and the pond volume to be utilized (Lutz, 2003).

Most of the literature available on the husbandry of ornamental fish suggests monoculture (Fernando and Phang, 1985; Kestemont, 1995; Asano *et al.*, 2003; Kaiser *et al.*, 2003; McGovern-Hopkins *et al.*, 2003). One of the possible reasons could be the differences in the culture period for different fish species (Watson and Shireman, 1996). While food fish producers can sell any amount of fish harvested, ornamental fish are sold by number and have to be of a minimum size to be accepted in the market (Olivier and Kaiser, 1997). Some species have a market for small individuals, and the farmer may harvest the pond after only eight to ten weeks of growout. Others may require much longer culture periods. The extreme diversity of the industry prohibits gross generalizations in this area (Watson and Shireman, 1996). Another reason could be the scarcity of documentation pertaining to behavioural compatibility and interspecific interrelationships between different ornamental species.

2.5. Organic manuring in aquaculture

Organic manures are regarded as a composite class and contain almost all the essential nutrient elements (**Table 3**) required in a pond ecosystem (Pillay, 1993; Jana *et al.*, 2001). They are known to improve soil structure and fertility (Pillay, 1993). Being less expensive compared to chemical fertilizers, organic manures are traditionally applied to fish ponds to release inorganic nutrients which stimulate the growth of plankton (Moore 1985; Schoonbee and Prinsloo, 1988; Green *et al.*, 1990; Jhingran, 1991; Yadava and Garg, 1992; Edwards *et al.*, 1996; Garg and Bhatnagar, 1996; Mahboob and Sheri, 1997, Atay and Demir, 1998; Begum *et al.*, 2003), which form the nutritious and preferred food of many aquaculture species. In addition to their importance in the ornamental aquatic sector, zooplankton is also required as a first food for most species of food fish and contributes to faster larval growth and better survival (Prinsloo and Schoonbee, 1986; Rottmann *et al.*, 1991; Pillay, 1993; Adeyemo *et al.*, 1994; Welker *et al.*, 1994; Ludwig, 1999; Sharma and Chakrabarti, 1999; Al-Harbi and Siddique, 2001). Greater abundance of plankton supports larger populations of cultured fish species (Wurts, 2004). Lin *et al.* (1997) documented that under acidic soil conditions, fertilization with organic manure (poultry excreta) resulted in significantly increased plankton production compared to inorganic (NPK) fertilizers.

Table 3 Composition of fresh manure from various animal species (after Pillay, 1993).

Components	Mixed dung	Horse dung	Cattle dung	Sheep dung	Pig dung
Water	75.0	71.3	77.3	64.6	72.4
Organic matter	21.0	25.4	20.3	31.8	25.0
Total nitrogen (N)	0.50	0.58	0.45	0.83	0.45
Proteinic nitrogen	0.31	0.35	0.28	-	-
Ammoniacal nitrogen	0.15	0.19	0.14	-	0.20
Phosphorus (P_2O_5)	0.25	0.28	0.23	0.23	0.19
Potassium (K_2O)	0.60	0.63	0.50	0.67	0.60
Calcium (CaO)	0.35	0.21	0.40	0.33	0.18
Magnesium (MgO)	0.15	0.14	0.11	0.18	0.09
Sulphuric acid ($SO_3{}^{2-}$)	0.10	0.07	0.06	0.15	0.08
Chlorine (Cl^-)	-	0.04	0.10	0.17	0.17
Silicic acid	-	1.77	0.85	1.47	1.08
Iron and aluminum sesquioxides (R_2O_3)	-	0.11	0.05	0.24	0.07

In India, cow dung is the most common organic manure applied to fish ponds and other animal wastes have not been systematically tried (Singh and Sharma, 1999). Perhaps the easy availability of cow dung in rural India has played a determining role in its wide use in aquaculture. Among other manures, chicken's is preferred worldwide because of its ready solubility and high level of nitrogen and phosphorus concentrations (Kapur and Lal, 1986; Knud-Hansen *et al.*, 1991; Singh and Sharma, 1999; Sevilleja *et al.*, 2001). With the rapid expansion of poultry husbandry during the last two decades, poultry excreta have become increasingly available in rural India. However, organic manures other than cow dung and poultry excreta are available only in pockets; hence, their utilization in aquaculture throughout India has a very limited possibility.

2.6. Effect of organic manuring on the aquatic food web

The purpose of pond fertilization is to augment fish production through autotrophic and heterotrophic pathways (Jana *et al.*, 2001). A series of complicated processes is involved between the input of manure and the ultimate output of fish in the pond ecosystem via material cycling, production of fish food organisms and energy flow (Xianzhen *et al.*, 1988; Green *et al.*, 1989; Schroeder *et al.*, 1990; Knud-Hansen and Batterson, 1994). Besides acting as the primary nutrient source, organic manure may also enhance fish production through detrital formation (Wohlfarth and Schroeder,

1979) and exert a definite impact upon the microbial-detrital food chain of the aquatic system (Rappaport and Sarig, 1978; Pillay, 1993). Radio isotopic tracer method has been employed to detect the different production pathways in manure based fish ponds (Pekar and Olah, 1998). Carbon isotope study indicated that in common carp, *Cyprinus carpio*, 50 - 70% of the carbon originated from manure food webs and 30 - 50% originated from micro algae, whereas, in crucian carp, *Carassius carassius*, only 22% carbon was contributed by the manure and 60 - 80% carbon originated from micro algal production (Xianzhen *et al.*, 1986).

The available organic pool in manured ponds is usually duplicated everyday via bacterial production (Schroeder, 1987). Heterotrophic microorganisms, necessitating some organic sources of carbon in addition to inorganic forms for growth, have a significant role in the decomposition of organic matter and production of particulate food materials from dissolved organics (Schroeder and Hepher, 1979; Jana and De, 1990). In the decomposition process, bacteria emerge as the first link between the living world and the abiotic factors (Pekar and Olah, 1990). Although actinomycetes and fungi are also known to take part in the decomposition process (Boyd, 1995), their role are much restricted compared to bacteria (Gaur *et al.*, 1995). The rate of decomposition of organic matter also varies depending upon its composition and the physico-chemical environment of the culture system. The rate of nutrient release from animal manure over time generally determines the fertilization schedule to be adopted in a given pond (Egna and Boyd, 1997). The availability of inorganic nutrients from poultry excreta was reported to be considerably higher than that from manures of pig, goat and cow (Kapur and Lal, 1986).

Upon decomposition, organic manures release inorganic nutrients that stimulate plankton growth at the base trophic level of aquatic production cycle. Qualitative and quantitative analysis of plankton showed considerable differences in species diversity and abundance between culture systems fertilized with different organic manures (Nandeesha *et al.*, 1984; Kapur and Lal, 1986; Dhawan and Toor, 1989; Singh and Sharma, 1999). Differences in plankton concentration also varied when organic manure was applied at different rates (Yadava and Garg, 1992; Garg and Bhatnagar, 1996; Lin *et al.*, 1997; Azim *et al.*, 2001; Cheikyula *et al.*, 2001). However, Hickling (1962) and Hepher (1988) have demonstrated that above a certain level, increasing fertilizer rates do not further increase plankton concentration in the culture system.

2.7. Organic manuring and fish yields

Pekar and Olah (1990) reviewed the culture results of various food fish species in organically manured systems and found that the yield varied widely depending on the type of manure used, stocking rate, geo-climatic conditions and species cultured (**Table 4**). Lin *et al.* (1997) documented that yields of nile tilapia, *Oreochromis niloticus*, varied considerably in experimental ponds manured with different rates of poultry excreta and there was a significant correlation between fish yields and the available nitrogen in the pond system. However, yields of food fish cannot be compared with ornamental fish since the later are marketed as individuals and not on the basis of harvest weight, as is the case with food fish. Besides, the marketable size of ornamental fish varies considerably from food fish. According to our knowledge, at present, there is no documentation pertaining to culture and yields of ornamental fish species in organically manured culture systems under tropical conditions.

Table 4 Fish yields from manured ponds (after Pekar and Olah, 1990).

Type of manure	Fish stocked	Stocking rate (no./ ha)	Daily yield (kg/ ha)	Reference
Cattle manure	Common carp, Chinese carp and Tilapia	9000 – 18000	32	Moav *et al.* (1977)
	Tilapia	10000	16	Collis and Smitherman (1978)
Chicken manure	Common carp, Chinese carp and Tilapia	8000 – 16000	29 – 35	Wohlfarth *et al.* (1980)
	Common carp	2100	7	Bok and Jongblood (1984)
	Tilapia	10000	4.1 – 17.7	Teichert-Coddington and Green (1990)
Duck manure	Common carp, Silver carp and Tilapia	10000 – 20000	36	Barash *et al.* (1982)
Pig manure	Common carp and Chinese carp	10700	17 – 22	Buck *et al.* (1979)
	Common carp and Chinese carp	18000	40	Shan *et al.* (1985)
	Chinese carp and Tilapia	15500	36	Behrends *et al.* (1983)

2.8. Limitations of organic manuring

Pond fertilization through organic manuring is meant to boost fertility of pond water where nutrient concentrations are often too low to support desirable fish yields (Lin *et al.*, 1997). Fertilization also concomitantly affects water quality with positive or negative consequences to fish survival and growth. It is a well established fact that one of the most essential attributes towards the success of any aquaculture practice is the maintenance of appropriate water quality in the culture system (Diana *et al.*, 1997). However, pond fertilization using high amounts of organic manure can lead to reduced water quality including severe depletion of dissolved oxygen and generation of H_2S, methane and ammonia (Chattopadhyay and Mandal, 1980; Wong *et al.*, 1982; Batterson *et al.*, 1989; Green *et al.*, 1989; Boyd, 1990; Singh *et al.*, 1991), causing stress to impairment of normal metabolism in fish (Wong *et al.*, 1979), and even death of young fish larvae (Yip and Wong, 1977). Fish mortality has also been attributed to spikes in un-ionized ammonia in ponds receiving a combination of inorganic (urea) and organic fertilizers (poultry excreta) in high doses (Teichert-Coddington *et al.*, 1992). Besides, stress in fish due to reduced water quality can ultimately lead to exhaustion and disease (Francis-Floyd, 1990). Since ornamental fish, unlike food fish, are sold as individuals and have to be visually attractive to be accepted in the market, stressed or exhausted fish may be aesthetically unattractive to potential customers.

Primary production in excessively fertilized ponds can limit light penetration (Hepher, 1962). Pond fertilization using high amounts of animal wastes are known to have caused noticeable harm to the environment (Quines, 1988), by proliferating the growth of pathogenic bacteria like *Aeromonas* sp. and *Pseudomonas* sp. in the waterbody (Hojovec, 1977; Sugita *et al.*, 1985a; Jinyi *et al.*, 1987; Iger *et al.*, 1988; Okaeme and Olufemi, 1997). Also, organic manure are known to have caused *Aeromonas punctata* and *Saprolegina parasitica* epizootics in rohu, *Labeo rohita* and common carp (Toor *et al.*, 1983). Since ornamental fish are not consumed, public health may not be directly affected by ornamental fish cultured in manured systems. However, manures should be applied judiciously so that fish health is not negatively affected.

2.9. Some farmer-friendly aquaculture management techniques with emphasis to Indian conditions

Specific pond management techniques need to be developed to create the best environment for the fish, while utilizing animal wastes that can sustain productivity at low cost. Fertilization with manure with water exchange, have proved to be more effective than manured systems without water exchange, in maintaining better water quality and lower mortality rates in common carp (Chakrabarti and Jana, 1990), and Indian Major Carps, rohu and mrigal, *Cirrhinus mrigala* (Chakrabarti and Jana, 1998).

Introduction of live zooplankton has been investigated as an alternate to pond fertilization for increasing yields of several food fish species while avoiding water quality deterioration (Jana and Pal, 1987). However, as also mentioned earlier, literature on ornamental fish rearing under Indian conditions is scanty. As the present trend among ornamental fish producers is to utilize information generated from food fish aquaculture (Watson and Shireman, 1996), experiments on supply of exogenous zooplankton could be investigated with ornamental fish species.