1. Introduction

1.1. General introduction

Ornamental fish can be defined as attractive and colourful fish of peaceful nature that are kept as pets in confined spaces of an aquarium or a garden pool with the purpose of enjoying their beauty for fun and fancy (Dey, 1996). The soothing effect of aquariums in helping to relieve some of the pressures of modern urban life have helped, in part, to make ornamental fish keeping a popular pastime and an important commercial activity. Fish keeping is today the world's most popular hobby after photography and ornamental fish are the most popular pets in the world (Singh, 2005). As such, production of animals for the aquarium hobbyist trade is rapidly increasing. The ornamental aquatic sector has shown overall expansion since 1985, and until 1996, the annual growth rate in the world trade of ornamental fish was about 14% (Dawes, 2002). Although there was a periodic depression in the late 1990's (Olivier, 2000), the new millennium has ushered very promising resurgence. A conservative estimate of the annual wholesale value of the current world trade puts it at more than US $ 1 billion. Some 1.5 billion fish are traded yearly with a retail value of at least US $ 6 billion (Singh, 2005). The value of the entire industry, when non-exported product, wages, retail sales and associated materials are considered has been estimated at US $ 15 billion (Subasinghe, 2005).

Unfortunately, the ornamental aquatic sector in India is still in a state of hibernation. The country exported about US $ 0.7 million worth of ornamental fish during 2003-04 (Bojan, 2005), which is virtually negligible in the international scenario. The domestic market, however, is rapidly expanding, with a current turn over of Rupees 150 million (US $ 3.5 million) and an annual growth rate of 20% (Bhattacharjya and Choudhury, 2004; Dehadrai, 2004). There is a great potential for expansion of ornamental fish trade, both in India and abroad.

About 70% of India's population lives in villages and 90% of its rural population depend on agriculture and allied activities like fish capture/aquaculture for their livelihood (Radheyshyam, 2001). With her enormous natural and human resources, which could be mobilized for aquaculture activities, India could become a major player in the international ornamental fish market through a properly planned approach. Establishment of an ornamental fish culture industry has long been felt to be one means to diversify the aquaculture sector in India, and would enable Indian producers to win

market share, both locally and internationally. According to an estimate by Swain and Jena (2002), the country has the potential to increase the export of ornamental fish to about US $ 30 million every year within the next decade. The key to realizing this opportunity is the development of aquaculture technology suited to Indian conditions. Diversification of aquaculture has been given a focused attention in the country's 10th Five Year Plan with special emphasis on ornamental fish culture (Tripathi, 2004). Thus a new dimension is added to fisheries research in the country and researchers need to document commercial production techniques of various ornamental fish species to meet the burgeoning demand.

1.2. Key areas identified for research

The ornamental fish industry in India can be divided into two major sectors: (i) exotic fresh water species (this is the largest sector and includes both coldwater and tropical fish); and (ii) indigenous fresh water species (includes both coldwater and tropical fish of Indian origin) (Jha and Barat, 2005). There is also a very small sector catering to marine ornamental species. The indigenous ornamental fish market is completely capture based, while the exotic species are cultured. However, the production of exotic ornamental fish is mostly restricted to a few metropolitan cities like Kolkata, Mumbai and Chennai (Swain, 2004), and absence of proper technology has acted as a barrier for expansion of ornamental fish culture throughout the country.

A visit to some of the top ornamental fish production units of West Bengal state in India during 2001, and discussions with the producers/farmers threw open some avenues that could be researched upon. Further deliberations with aquaculture experts resulted in pointing out specific questions that were to be dealt during the study.

It was felt, that the culture technology for exotic ornamental fish under tropical conditions in India needs to be standardized. Different types of management regimes would be systematically tried to find suitable culture conditions for optimal fish production. Koi carp (*Cyprinus carpio*) was selected as a model species for the study. Also, the fact that the culture of koi carp is rapidly growing in India, and farmers were keen to know the culture techniques for the fish played an important role in its selection. Another reason for the selection of this fish was the easy availability of koi carp larvae throughout the year in Jalpaiguri district of North Bengal, the place of our study.

A common approach for increasing fish production in ponds is the direct application of fertilizer, which enhances production of plankton, a natural food item for fish (Jhingran, 1991; Chakrabarti and Jana, 1998; Ansa and Jiya, 2002; Kadri and Emmanuel, 2003). Pond fertilization practices using animal wastes are widely used in many countries to sustain productivity at low cost (Pekar and Olah, 1990; Fermin, 2001; Gupta and Noble, 2001; Tripathi and Sharma, 2001; Majumder *et al.*, 2002). Manure usage at different rates may significantly influence water quality and assist in defining the optimal conditions for continuous culture of plankton. However, the use of organic manure in ornamental carp production systems has not been documented and the application rate needs to be standardized.

Ornamental fish culture in India is practiced in particularly two types of culture systems: earthen ponds and concrete tanks. Since most farmers in India cannot afford aeration facilities, water exchange is used as an alternative to maintain water quality in the tanks. It was felt, that the effect of different water exchange regimes on water quality and koi carp production in organically manured tanks should be documented. To supply the growing market, fish farmers need to keep fish at the highest sustainable stocking densities to produce a large number of fish, hence the stocking density for koi carp also needs to be optimized.

The koi carp has a market for individuals above 4 g, and require only about 10 - 12 weeks of growout to attain the marketable size. As such, ornamental fish producers have the opportunity to harvest three to four crops throughout the year (during different seasons). In the tropical plain lands of North Bengal, pond water temperature falls below 20^{0}C for only three months in a year, that is, mid-November to mid-February. There are several reports on the influence of water temperature on the feeding activity, metabolism, growth and production of fish (Weatherley, 1990; Shrestha, 1999). It was felt, that the influence of the growth period or season on koi carp production has not been documented and requires detailed investigation.

There are some reports on organic manuring leading to depletion of dissolved oxygen, high biological and chemical oxygen demand, and generation of H_2S, methane and ammonia (Boyd, 1982; Wong *et al.*, 1982; Singh *et al.*, 1991). The resultant stress can ultimately lead to exhaustion, disease and mortality in fish (Francis-Floyd, 1990). However,

without directly applying organic manures, if the benefits of organic manuring, namely, live plankton could be channeled to fish culture tanks or ponds from other sources, environmental conditions in the fish culture systems would not be reduced. Since ornamental fish ponds in India are much smaller compared to other aquaculture ponds (measuring about 7 m × 20 m, with an average depth of 0.6 - 1.0 m), there are more opportunities to control environmental conditions in ornamental fish ponds by employing similar management techniques. It was felt, that introduction of live zooplankton could be explored as an alternate to direct organic manuring for increasing ornamental fish yields while avoiding water quality deterioration.

Any management applied would have a different effect on the interactions of water quality, phytoplankton and zooplankton, with respect to earthen ponds and concrete tanks. This could lead to differences in fish production in both systems. It was felt, that the effect of different management protocols on water quality, plankton abundance, and koi carp production in earthen ponds and concrete tanks should be compared.

The feeding habit and food preferences of koi carp in tropical conditions and its effect on fish production warrant proper documentation. The role of heterotrophic bacteria in the aquatic food web and its effect on fish yield are poorly documented (Moriarty, 1987). According to our information, there have been no research studies on the abundance of heterotrophic bacteria in ornamental fish ponds in India. Besides, freshwater fish in Indian ponds most commonly suffer from bacterial diseases such as, various kinds of skin ulcerations, albinoderma, erythroderma, furunculosis, and verticle-scale disease, primarily caused by *Aeromonas* sp. and *Pseudomonas* sp. (Das, 2004). Hence, bacteriological parameters, particularly the isolation and total counts of *Aeromonas* sp. and *Pseudomonas* sp. in koi carp ponds also demands detailed investigation.

One interesting aspect that regularly came up during the discussions was whether koi carp could be polycultured. Ornamental fish are mostly monocultured for reasons described later. Pond culture has presented the opportunity to polyculture ornamental carps, particularly, species like koi carp and goldfish, *Carassius auratus*, that have a similar marketable size (> 4.0 g) and require a similar culture period of 10 - 12 weeks to attain the marketable size, could be stocked together to optimize the utilization of available resources. However, further work on the impacts of polyculture on the overall culture

performance of each species is necessary. Behavioural studies on the interspecific interrelationships are one tool for evaluation. It was felt that the behavioural responses of koi carp and goldfish stocked in mono- and polyculture combinations should be compared to assess their behavioural compatibility. In addition, the growth and food selection of koi carp and goldfish raised in monoculture and polyculture combinations require detailed investigation.

Based on the above-mentioned needed avenues of research in ornamental fish farming, a research project entitled, "Effect of different management regimes on the survival and growth of exotic ornamental fish, koi carp (*Cyprinus carpio* L.), under tropical conditions", was initiated in February, 2002, to document the following objectives.

1.3. Objectives of the present investigation

- ✓ To study the effect of different application rates of organic manures (cow dung and poultry excreta) on the production of ornamental fish (koi carp).
- ✓ To document the effect of different water exchange regimes on koi carp production in organically manured tanks.
- ✓ To investigate the effect of different stocking densities on koi carp production.
- ✓ To explore the possibility of supplying exogenous zooplankton against direct organic manuring in fish culture systems in maintaining better culture environment and high koi carp production.
- ✓ To examine the seasonal influence on koi carp production.
- ✓ To compare koi carp production in earthen ponds and concrete tanks.
- ✓ To observe the feeding habit and food selection of koi carp.
- ✓ To monitor the growth responses of heterotrophic bacteria, along with the development of *Aeromonas* sp. and *Pseudomonas* sp. in koi carp ponds.
- ✓ To compare the behavioural responses of koi carp and goldfish stocked in mono- and polyculture combinations, for assessing their behavioural compatibility.
- ✓ To evaluate and compare the growth and food selection of koi carp and goldfish raised in mono- and polyculture combinations.

The nucleus of the present study, is therefore, likely to depict a better understanding on the cultural requirements of the koi carp (*Cyprinus carpio*) under tropical conditions.