IMPACT OF CAGE CULTURE ON WATER QUALITY PARAMETERS IN POONDI RESERVOIR, TAMIL NADU

Thesis submitted in part fulfillment of the requirements for the Degree of
Master of Fisheries Science in Aquatic Environment Management
to the Tamil Nadu Fisheries University, Nagapattinam

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CERTIFICATE

This is to certify that the thesis entitled "**Impact of cage culture on water quality parameters in Poondi Reservoir, Tamil Nadu"** submitted in partial fulfillment of the requirements for the degree of Master of Fisheries Science in **Aquatic Environment Management** to the Tamil Nadu Fisheries University, Nagapattinam is a record of bonafide research work carried out by **Mrs. P. Anusuya devi, MFT 1306 (AEM)** under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or similar titles or prizes and that part of the thesis has been published in peer reviewed journal(s) and copy / copies appended.

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Dedicated to My Husband, My Family members and My dear Teachers

ABSTRACT

Title : Impact of cage culture on water quality parameters in Poondi reservoir, Tamil Nadu

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The present investigation was carried out in Poondi reservoir, Thiruvallur district Tamilnadu to assess the water and sediment quality characteristics at the cage and control sites, where in cage culture has been already initiated by the state Fisheries Department. The water samples were collected once in fifteen days at a depth of 0.5m, 1.0m and 1.5 m in the cage site and 0.5m and 1.5m in the control site. Thisstudy was carried out for a period of 8 months from September, 2014 to April, 2015. The various physico-chemical parameters such aswater temperature, pH, dissolved oxygen (DO), salinity, hardness, alkalinity, ammonia-N (NH_3-N), nitrite-N (NO_2-N), nitrate-N (NO_3-N), phosphate- P (PO_4-P), sulphate, chemical oxygen demand (COD), biological oxygen demand (BOD), total suspended solids (TSS) and total dissolved solids (TDS) were analyzed in the water samples. The collected sediment samples were analyzed for their characteristics such aspH, electric conductivity, total organic carbon, total nitrogen and available phosphorous.

The total plate count (TPC) and feacal indicator bacteria such as *E.coli* and faecal streptococci were also assessed fortnightly in the water samples.Water temperature values ranged from 26 to 34.9ºC in cage culture site at Poondi reservoir. The hardness values ranged from 49.04 to 260.26 mg/l as $CaCO_3$.The alkalinity values ranged from 14 to 160 mg/l at cage and control sites. There was no significant difference in temperature, pH, dissolved oxygen and hardness value between cage and control sites ($P>0.05$). The dissolved oxygen values ranged from 4.00 to 6.00mg/l at cage and control sites. The sulfate concentration was found within the limit as prescribed by BIS (2003).The nutrients such as ammonia and nitrate concentrations were found slightly higher at cage site compared to control sites and the values increased towards the depth. The COD values ranged from 8.00 to 75mg/l and the BOD values ranged from 0.3 to 3.05mg/l at cage and control sites. The total suspended solids were found higher at cage site than control site, due to increased suspended matters. All the water quality parameters analysed were observed within the permissible range for fish culture and drinking purpose. In the sediment samples, lowpH was observed at cage culture site and might be due to the decomposition of organic matter. The EC value ranged from 2.81 to 55.99mS/cm and found higher at cage site. TOC values ranged from 0.47 to 3.33%both at cage and control site. The total sediment nitrogen value was found higher at control site. The available phosphorous values ranged from 5.97 to 29.85mg/100g. The total plate count (TPC) was higher at cage site during rainy season. The faecal indicator bacteria such as *E. coli* and feacal streptococci were undetectable, which indicates the reservoir water is safe for drinking purpose.The optimum water and sediment quality characteristics observed at cage culture site clearly showed that the small cage farming in the reservoir does not have major environmental impacts on the water and sediment quality.

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(**P. ANUSUYA DEVI**)

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I. INTRODUCTION

Cage culture of fish is one of the proven methods of aquaculture. Cage culture is being looked up as an opportunity to utilize existing inland water sources with great production potential to enhance production from inland open waters and posed as an answer to the rising demand for animal protein in the country (Karnatak and Kumar, 2014). To maintain the world per capita fish consumption at the current 19.1 kg by 2025, an addition of 62 million tons of aquatic products will be required and much of it will have to come from inland waters including reservoirs (Petr, 2007). Cage culture is seen as an alternative means of aquaculture for landless fish farmers (Dasuki et al., 2013). Cage aquaculture has certain advantages over other aquaculture systems that are potentially important in terms of uptake by rural poor and landless people. Cage culture can contribute to the livelihood of people through employment, income generation, poverty alleviation and provision of low-cost fish protein, ensuring food security. In addition, cage culture can also ensure rural equity, balanced regional development, gender equity through employment of rural women and men.

Cage culture is commonly practiced worldwide in both freshwater and marine environments, including open ocean, estuaries, lakes, ponds and reservoirs (Beveridge, 1987, Huang et al., 2012). As caged fish are generally fed with high protein diets, wastes derived from feed are either directly or indirectly released into the surrounding environment, causing accelerated eutrophication in the receiving waters (Beveridge, 1984; Ackefors, 1986; Lin, 1990).

Gooley et al. (2000) reported that cage culture in freshwater normally causes the increasing amount of nutrients in the sediments and water pollutants. Relatively small portion of the organic matter and inorganic nutrients in feed applied to cages is transformed to fish biomass. Wastes

from cages are freely released into the environment, potentially interacting with the entire water body. Intensive cage culture, when unregulated, can cause severe environmental problems (Lu, 1992; FAO/NACA, 1995; Santiago, 1995; Beveridge et al., 1991, 1997; Beveridge and Phillips, 1993). During the fish cage culture, a large amount of waste matter is being brought into the water directly. The ecological balance of the aquatic ecosystem was disrupted and resulted in eutrophication in areas where the cages were located and even entire lakes. As cage aquaculture becomes more prevalent, the problem of water pollution caused by the input of artificial feeds will certainly become more serious (Guo and Li, 2003).

It is estimated that for every ton of fish production in cage culture, 132.5 kg of nitrogen and 25.0 kg of phosphorus are released into the environment (Islam, 2005). This nutrient availability is usually as a result of wastes from cage culture, consisting of uneaten food faecal matters and urinary products, which are released directly into the environment. This could result in hydrobiological problems such as eutrophication, alterations in fish growth and changes in benthos population and diversity. The ability of the environment to assimilate or decompose the nutrients varies greatly according to local conditions of depth, hydrography, water exchange and sediment type. The intensive system may be harmful to the water quality, given limitations in the capacity to neutralize the metabolites, CO_2 and ammonia released by the fish as well as the excess of fish rations (Sipauba- Tavares, 2000).

Furthermore, for tilapia cage culture it was reported that 81 -90 % of carbon is lost from the cages to the surrounding environment (Gondwe et al., 2011). For a reservoir, where there is not much exchange of water, accumulation of these wastes potentially results in water quality deterioration such as eutrophication and anoxic water as reported in lake Cirata in Indonesia (Hayami et al., 2008). Several studies have reported that nitrogen and phosphorous released from

fish cage can affect chemical parameters of sediment (Beveridge, 1996; Porrello et al., 2005; Kullman et al., 2007).

Extensive studies on the ecological aspects and fisheries of certain reservoirs in Tamilnadu such as Mettur, Bhavanisagar, Sathanur, Aliyar and Thirmoorthy have already been made by several workers (Ganapati, 1955; Sreenivasan, 1969; Selvaraj, 2000 and Murugesan et al., 2003). Reservoir plays a major role in drinking water, agricultural use, fishery and electricity production, so protection of water quality is a very important issue and it should be kept at acceptable levels (Venkatesharaju et al., 2010). However, the environmental impact of cage culture is often ignored and rarely subjected to study. There are no reports directly on the environmental impact of cage culture on the water quality of reservoirs of Tamilnadu. Poondi reservoir (also known as Sathiyamoorthy reservoir) is one, which is constructed across the Kortalaiyar river in Thiruvallur district of Tamilnadu and it supply drinking water for Chennai city.

In this context, the present study is proposed on "Impact of cage culture on water quality parameters in Poondi Reservoir, Tamil Nadu" with the following objectives.

1. To analyze the water quality parameters at point and non-point sources of cage culture unit in Poondi reservoir.

2. To analyze the sediment quality characteristics at point and non-point sources of cage culture unit.

3. To assess the total microbial load and faecal coliform population in the reservoir with respect to the progress in cage culture system.

4. To assess the overall impact of cage culture on the reservoir environment.

5.II. REVIEW OF LITERATURE

Aquaculture has been a fast growing industry because of significant increases in demand for fish and seafood throughout the world (Cao et al., 2007) and it is accounted for 46% of total food fish supply (Nyanti et al., 2012). Cage aquaculture is getting increasing important worldwide due to the increasing demand for fish protein as well as due to the stagnant supply from wild catch (Yee et al., 2012). Freshwater cage culture is an important industry as it provides a source of protein and fulfills the high market demand for freshwater fishes (Nyanti et al., 2012). Although cage culture is often seen as an avenue to increase fish production and provides employment opportunity, unplanned expansion of such practices, particularly when not taking into account environmental consequences of nutrient loading, could result in negative impacts, not only on cage culture operations, but also on the capture fisheries of such water bodies (Abery et al., 2005).

CIFRI has conducted many case studies on cage culture practices in Indian reservoirs. In India, Natarajan et al. (1979) conducted carp (*C. catla, L. rohita, L. bata and C. mrigala)* spawn rearing experiments in floating cages suspended in lentic waters. Kohli (2003) conducted a series of cage culture experiments in three reservoirs viz., Walwan reservoir, Lonavala, Powai lake, Mumbai and Halali reservoir, Bhopal. There are a few reports available on the stocking density and production details on the cage culture in Indian waters. Kumariah et al. (1986) reported net production of 0.92 to 1.6 kg/m^3/month in tilapia cage culture.

Kumariah et al. (1991) obtained a net production of 0.7 kg/m^3 /month by stocking silver carp at 15 fish/m^3. Das (2012) conducted cage culture study in Dahod reservoir,

Bhopal and suggested that the raising of fingerlings from cages is profitable. Potential of cage culture in Indian reservoir was reviewed recently by Karnatak and Kumar (2014).

The main impact of cage aquaculture is the increase in the load of N, P and organic matter that enrich water and underlying sediment (Alabaster, 1982). For sustainable development of fisheries in lakes, it is essential to reduce the impact of cage culture to retain acceptable water quality conditions in the lake (Guo and Li, 2003). The increasing nutrient loading in the reservoir and the consequent deterioration of water quality could also result in other indirect influences on cage fish, in particular raising the stress levels, and therefore increasing susceptibility to diseases (Abery et al., 2005). However, in order to be environmentally responsible, it is fundamental to study and monitor the impacts of the activity on the environment (Mallasen et al., 2012).

2.1 Environmental impact of cage culture

The environmental impact of waste generated from cage culture is an increasing issue of concern around the world. Cage culture is usually performed in small water bodies such as fish ponds and reservoirs, which are often used for plant irrigation (Gorlach-Lira et al., 2013). The impacts of fish cage farming include increased nutrient levels, organic sediment matter and turbidity and decreased secchi depth, dissolved oxygen levels and pH (Beveridge 1984; Phillips, 1985; Pitta et al., 1999).

The amount of waste produced by a cage farm will depend on a number of factors such as stocking density, feeding regime and feeding rate because these three factors together determine the total amount of feeds to be used (Cao et al., 2007). Several studies have reported that there was apparent deposition of organic-rich particulate matter in the form of uneaten feed, fish feces and metabolic wastes of fish in cage farming (Gowen and Bradbury, 1987; Hall et al., 1990; Findly and Watling, 1997; Chen et al., 2000;

Karakassis et al., 2000). During intensive cultivation in net cages, large amounts of organic matter from feedstuffs used in feeding and from fish excreta, are directly released in the aquatic environment (Santos et al., 2009). Caged fish are generally fed with high protein diets, wastes derived from feed are either directly or indirectly released to the environment, causing accelerated eutrophication in the receiving waters (Beveridge, 1984; Ackefors, 1986; Lin, 1990). As a result of nutrient load, an increase in phytoplankton proliferation, particularly Cyanobacteria, has been reported and it represents a growing problem in ecosystems such as reservoirs (Borges et al., 2010).

High organic loading from fish farming activities could cause deterioration of water quality in cage culture systems and environment (Arulampalam et al., 1998). The drop in water transparency, pH and dissolved oxygen were most probably due to the introduction of the cages (Mhlanga, 1994). Guo and Li (2003) reported increased nutrient levels such as nitrogen and phosphorus in the water column and sediment layers, influence on biota changes due to the release of organic matter from a fish farm in a Chinese lake.

Gooley et al. (2000) reported that cage culture in freshwater normally causes the increasing amount of nutrients in the sediments and water. Portion of these nutrients are dissolved or become sedimented. Sediment nutrients accumulate on the bottom of the reservoir under cages and can create considerable oxygen demand. In conditions of low water levels or changing weather conditions to occur throughout the water column along with high concentration of toxic substances, such as NH_3-N, NO_2-N and H_2S (Wu, 1995; Findy and Watling, 1997). This mixing can result in fish kills of cage fish and wild fish stocks (Abery et al., 2005). Fish kills are frequently results in poor water quality due to nutrients enrichment that cause algal bloom and crush which leads to oxygen depletion and accumulation of toxic

products such as H_2S (Abery et al., 2005; Yee et al., 2012). Marte et al. (2000) showed that an increasing amount of units of cage culture with over feeding leads to the deterioration of water quality.

The development of anaerobic condition under cage sites may lead to the accumulation of toxic nitrogen compounds and eventually resulted in the depletion of dissolved oxygen (Jiwyam and Chareontesprasit, 2001). Fish in cages are feed with pellets either twice or thrice a day. Excess feed and waste are directly released into the water body. It is estimated that for every ton of fish produced in cage culture, 132.5 kg of nitrogen and 25.0 kg of phosphorus are released into the environment (Islam, 2005). Gondwe et al. (2011) reported that carbon and nutrients loss from tilapia fish cages in Lake Malawi ranged from 81-91% for carbon, 59-80% for nitrogen and 85-92% for phosphorus.

For a reservoir where there is not much exchange of water, accumulation of these waste potentially result in water quality deterioration and leads to eutrophication and anoxic condition (Hayami et al., 2008). The high fish densities, along with the high feeding rates, often reduce dissolved oxygen and increase ammonia concentration in and around the cage, especially if there is no water movement through the cage. The crowding in cages promotes stress and allows disease organisms to spread rapidly. Predation can be a problem if cages are not constructed or managed properly. Terrapines, snakes, otters, raccoons and fish-eating birds will take fish or damage cages unless precautions are taken (Masser, 2008; Karnatak and Kumar, 2014).

2.2 Physico-chemical parameters of water sample

Water quality is an important integral part of any aquaculture system. It plays a major role in fish health and any deterioration in water quality causes stress to fish and brings about diseases (Arulampalam et al., 1998). Each water quality factor interacts with and influences the other parameters, sometimes in complex ways (Joseph et al., 1993). A good water condition is a necessity for the survival and growth of fish since the entire life process of the fish wholly dependent on the quality of its environment (Bolorunduro and Abdullah, 1996).

Poor water quality can result in low profit, low product quality and potential human health risks. Success, however, of the new aquaculture businesses greatly depended upon the suitability of the reservoir's water quality, its water quality variabilities, pollution and seasonal climatic and mixing events occurring in the new aquatic ecosystem (Soemarwoto et al., 1990).

Fish in the cultivation systems of floating cages are fed by external inputs, meaning a constant input of nutrients (nitrogen-N and phosphorus-P), proteins and carbon (Tacon and Forster, 2003) that, depending on the scale, can result in deterioration of water quality. Water quality management is a key ingredient in a successful fish culture practice (Joseph, 2009). Thus, water quality is the determining factor on the success or failure of an aquaculture operation. The quality of water in any ecosystem provides significant information about the available resources for supporting life in that ecosystem. Good quality of water resources depends on a large number of physico-chemical parameters. Assessing and monitoring of these parameters is essential to identify the magnitude and source of any pollution load (Thirupathaiah et al., 2012).

2.2.1 Water temperature

Water temperature is controlling factor for all aquatic life. All biological and chemical processes in an aquaculture operation are influenced by temperature. It is one of the most important external factors which influence fish production. At temperatures above or below optimum, fish growth is reduced and mortalities may occur at extreme temperatures (Joseph et al., 1993). Boyd (1982) reported that the range of water temperature from 26.06 to 31.97°C is suitable for warm water fish culture. Research has shown that a temperature range between 25 and 32°C is ideal for tropical fish culture (Bolorunduro and Abdullah, 1996). Siti-zahrah et al. (2004, 2008) reported that the water temperature above 30°C causes high mortality rate in the cage culture of tilapia in Tasik Kenyir reservoir in Malaysia. Mondal et al. (2010) recorded an average temperature of 21.38°C in tilapia cage culture in Thailand.

Zanatta et al. (2010) recorded an average temperature of 23.58°C in Jurumirim reservoir, Brazil in tilapia cage culture system. High water temperature in most of the water bodies are experienced due to the low water level, high air temperature and clean atmosphere (Thirupathaiah et al., 2012). Jiwyam (2012) recorded an average water temperature of 26.81°C from tilapia cage culture in Thailand. Nyanti et al. (2012) reported that the temperature decreases as depth increases in cage culture of the Batang Ai Hydroelectric dam reservoir, Sarawak, Malaysia.

2.2.2 pH

Hydrogen ion concentration plays a significant role in the productivity of a reservoir. Normally pH range from 6.4 to 8.3 is favourable for fish growth (Robert et al., 1940). The pH limit for protection of aquatic life is 6.0 to 8.5 (ISI, 1974). Hepher and Pruginin (1981) reported that this value ranging from 6.5 to 9.0 is good for fish culture. The pH

may drop in fish cage culture because of waste deposits (Beveridge, 1984; Pitta et al., 1999 and Demir et al., 2001). Higher value of pH (7.8 to 8.8) was recorded in Halali reservoir during summer months by Jiwyam and Chareontesprasit (2001).

This might be due to increased photosynthetic activity and decomposition of allochthonous matter present in the lake which increases the nutrient concentration at higher temperature, input of sewage and agricultural waste are also responsible for higher values of pH in water. Food decomposition and breathing release carbon dioxide, which reacts with the water and produces carbonic acid and hydrogen ions, acidifying the medium (Mallasen et al., 2012).

Nyanti et al. (2012) reported the decrease in pH towards the increasing depth due to decaying organic matter especially from the vegetation which were not removed prior to impoundment and contributions from feed and waste from the cage culture. Yee et al. (2012) reported the lower pH value corresponded with low dissolved oxygen and high BOD values due to the oxygen consumption during the breakdown of organic matter from excess feed and fish waste. The slightly lower pH values attributed to respiration of aquatic animals and to the decomposition of organic matter from uneaten feed and fish excrement.

2.2.3 Dissolved Oxygen (DO)

Dissolved oxygen is an important parameter in water quality assessment and reflects the physical and biological processes prevailing in the water. DO concentration of 5 mg/l throughout the year in the reservoir is productive for fish culture (Tarzwall, 1957; Banerjee, 1967). The DO values indicate the degree of pollution in water bodies (Amankwaah et al., 2014). It is important in the production and support of life. It is also necessary for the decomposition and decay of organic matter. Higher range of dissolved

oxygen was recorded during rainy season due to mixing of water by heavy wind action and mixing of monsoon rains.

DO has been attributed a great significance as an indicator of water quality especially the magnitude of eutrophication. DO concentration in water is mainly dependent upon temperature, dissolved salts, velocity of wind, pollution load, photosynthetic activity and respiration rate (Tamot et al., 2008). The lower DO at some aquaculture sites is mainly caused by consumption of DO by microorganisms in decomposition of organic matter (Yee et al., 2012).

Oxygen levels never fell below 4.0 mg/l, which is considered to be the critical level for tropical fish rearing (Mallasen et al., 2012). Massive plankton growth can cause problems of DO depletion at night and the production of ammonia and other toxins (Soemarwoto et al., 1990). Nsonga (2014) reported that the level of DO of 6.5 mg/l or above 5 mg/l is the ideal level for warm water fishes. It has been reported that oxygen depletion in water surrounding cages is due to the respiration of the caged fish (Cornel and Whoriskey, 1993). Swingle (1969), Neill and Bryan (1991) and Daniel et al. (2005) stated that the DO concentrations below 3.5 mg/l is undesirable for fish farming. Boyd (1998) concluded that the desired concentration of dissolved oxygen range in the water is 5 to 15 mg/l. The self-pollution of cage culture activities resulting in fish kills has been reported in Lake Taal, Philippines in summer months where wind conditions are low, resulting in low oxygen (Yambot, 2000). Rani et al., (2004) reported lower values of dissolved oxygen in summer season due to higher rate of decomposition of organic matter and limited flow of water in low holding environment due to high temperature. Karnatak and Kumar (2014) reviewed that localized water quality problems, particularly

low dissolved oxygen, are common in cage culture. Low dissolved oxygen within cages may not affect other organisms in the lake, pond or stream.

2.2.4 Salinity

Salinity is a measurement of the ionic composition of water. Saline water usually consists of four major cations, calcium, magnesium, sodium, potassium and four major anions, bicarbonate, carbonate, sulphate and chloride along with some minor elements.

Salinity of inland waters is extremely variable, dictated by the flux of ions within the water body. Salinity is a fundamental water quality parameter monitored by ecologists in both freshwater and marine because of its influence on biota. Most aquatic organisms are adapted to only a narrow range of salinity, beyond which they cannot maintain their osmotic and ionic balance. In freshwater systems, problems associated with raising salinity have become a major environmental concern, with drinking and agricultural water supplies in some regions being rendered unusable without costly desalinization. Freshwater fishes exhibit a wide range of tolerance to salinity. Salinity not only affects osmoregulation, but also influences the concentration of unionized ammonia. Many commercially important species (Channel catfish, Tilapia) survive and grow well in the slightly salty water (Joseph et al., 1993).

2.2.5 Hardness

The hardness of water is mainly governed by the content of calcium and magnesium salts, largely combined with bicarbonates and carbonates (temporary hardness) with sulphates, chlorides and other anions of minerals (permanent hardness) (Jiwyam and Chareontesprasit, 2001). One degree of hardness equals 17 ppm $CaCO_3$. Soft water refers to water with 0 to 75 ppm $CaCO_3$ and has lowest buffering capacity. Moderately hard water has 75 to 150 ppm $CaCO_3$. Hard water has 150 to 300 ppm $CaCO_3$ and very hard

water had a concentration of $CaCO_3$ greater than 300 ppm, which has the highest buffering capacity (Boyd, 1990; 1998). Hujare (2008) reported higher total hardness during summer than rainy and winter season.

The increase in hardness can be attributed to the decrease in water volume and increase in the rate of evaporation at high temperature (Thirupathaiah et al., 2012). Hardness value of more than 15mg/l is required for optimum health of warm water fishes (EPA, 1973; Jhingran, 1988). Lucas and Southgate (2012) reported that the hardness value more than 50 mg/l is desirable for tilapia culture.

2.2.6 Alkalinity

The total alkalinity is the sum total of carbonates and bicarbonates alkalinity. Water with a high alkalinity is more strongly buffered than water with a low alkalinity. Moreover, bicarbonates can act as a storage area for surplus carbon dioxide, thus carbon dioxide will not be limited during photosynthesis. This will then ensure that there will be a continuous supply of oxygen in the system. The recommended level of alkalinity for freshwater system is 5-500 mg/l (Lawson, 1995). Boyd (1982) advocated that total alkalinity should be more than 20mg/l in fertilized ponds as fish production increases with increase in total alkalinity. Bicarbonates are mainly responsible for variation of total alkalinity concentration. Total alkalinity may be used as tool for the measurement of productivity and conditions of water bodies (Jiwyam and Chareontesprasit, 2001). Tamot et al. (2008) reported that the alkalinity ranged from 90 to 160 mg/l in Halali reservoir and the reservoir water could be considered as nutrient rich.

Sugunan (2011) reported that alkalinity value of Indian reservoir water ranged from 40 to 240 mg/l. Jiwyam (2012) reported the alkalinity value of 156.75±19.16 mg/l in Nile

tilapia cage culture. Lucas and Southgate (2012) considered that the alkalinity value more than 20mg/l in water is desirable for tilapia culture.

2.2.7 Ammonia-N (NH_3-N)

It is the principal nitrogenous waste produced by aquatic animals, via metabolism and is excreted across the gills (Cao et al., 2007). Ammonia was higher at fish culture site due to feces released by the fish (Nyanti et al., 2012). Ammonia strongly influences the dynamics of the dissolved oxygen in water, since 4.6 mg of oxygen is needed to oxidize 1.0 mg of ammonia. Ammonia levels between 3 and 4 mg/l may be toxic for tropical fish (Boyd, 2001). Swingle (1969), Neill and Bryan (1991) and Daniel et al. (2005) concluded that ammonia concentration of more than 0.2 mg/l is undesirable for fish farming. Safe concentration of ammonia for freshwater fish is less than 0.05 mg/l (Lawson, 1995). Chen (1988) stated that the ammonia value lower than 1 mg/l in pond water was acceptable for pond fish culture. Boyd (1998) suggested that the ammonia value less than 0.1 mg/l is the desired concentration for fish culture system.

Ammonia concentration of 0.02 mg/l is required for optimum health of warmwater fish culture (EPA, 1973 and Jhingran, 1988). Lucas and Southgate (2012) suggested the ammonia concentration of less than 1 mg/l is desirable for tilapia culture. Some reports showed that the ammonia concentration ranging from 0.01 to 1.15 mg/l in the cage culture system (Eglal et al., 2009; Zanattaet al., 2010; Mallasen et al., 2012; Nyanti et al., 2012; Gorlach-Lira et al., 2013). Karnatak and Kumar (2014) reviewed that the high fish densities, along with the high feeding rates, often reduce dissolved oxygen and increase ammonia concentration in and around the cage, especially if there is no water movement through the cage.

2.2.8 Nitrite-N (NO_2-N)

Nitrite is a by-product of oxidized NH_3 or NH_4^+, an intermediary in the conversion of NH_3 or NH_4^+ into NO_3. This process is completed through nitrification which is done by the highly aerobic, gram-negative, chemoautotropic bacteria found naturally in the system. The conversation is quick, thus high nitrite concentrations are not commonly found. However, if high levels do occur, it can cause hypoxia, due to deactivation of haemoglobin in fish blood, a condition known as the "brown blood disease" (Lawson, 1995). According to Boyd (1998), the desired concentration of nitrite in the water is less than 0.3mg/l in aquaculture. There were studies reported that the concentration of nitrite-N ranged from 0.001 to 0.28 mg/l in the cage culture systems (Siti-zahrah et al., 2008; Eglal et al., 2009; Mondal et al., 2010; Jiwyam, 2012; Gorlach-Lira et al., 2013. Nyanti et al. (2012) reported that the nitrite concentration at cage stations was higher than control due to the contribution from fish waste and excess feed. It is found that increasing pH, low dissolved oxygen and high ammonia can increase its toxicity.

2.2.9 Nitrate-N (NO_3-N)

Nitrate is formed through nitrification process, i.e. oxidation of NO_2 to NO_3 by the action of aerobic bacteria. Nitrate not taken up directly by aquatic plants is denitrified in anaerobic sediments (Furnas, 1992). Boyd (1998) reported the desired nitrate concentration for the aquaculture is 0.2 to 10 mg/l. Surface water can also be contaminated by sewage and other wastes rich in nitrates. Higher concentration of nitrate in drinking water is toxic (Umavathi et al., 2007).

As per the Environmental Protection Agency (EPA), the maximum contaminant level (MCL) of nitrate concentration is 10 mg/l for drinking water (Self and Waskom, 2008). Runoff from refuse dumping sited and farming activities affect nitrate concentration

greatly in receiving waters. The fertilizers used on farms, through leaching and surface runoff into the stream during heavy rainfall could also contributed to the high levels of nitrate in receiving streams (Rao, 2011).

2.2.10 Phosphate-P (PO_4-P)

Phosphate is one of the important nutrient and limiting factor in the maintenance of reservoir fertility. It is recognized as the principle factor produced by the fish farm that has an effect in the lake environment (Jones and Lee, 1982; Ketola, 1982; Kelly, 1992; Guo and Li, 2003). The primary route by which phosphorus enters the aquatic environment from cage farming is through the feed administered to the fish (Gavine et al., 1995). A large number of cages in area can exceed the carrying capacity of the aquatic environment, which may cause problems by high levels of phosphorus (Mallasen et al., 2012).

Kelly (1992; 1993) reported that the accumulation of decomposited solid waste releases labile phosphorus to the water column. Boyd (1998) reported that desired concentration of phosphate in the water is in the range of 0.005 to 0.2 mg/l. As phosphorus is a limiting nutrient in tropical freshwater, it forms a major factors contributing to the cost of production (Barik et al., 2001). Santos et al. (2012) reported the acceptable value of phosphorus was 0.025 mg/l for Nile Tilapia. The phosphate concentration as per WHO standard is 2.5 mg/l for drinking water (Amankwaah et al., 2014).

2.2.11 Sulfate (SO_4^{2-})

Sulfate is a constituent of total dissolved solid (TDS) and may form salts with sodium, potassium, magnesium and other cations. It is not a toxicant in the category of heavy metals,

pesticides or other toxic natural or manmade substances, but rather is a common salt necessary for life at some concentrations. It is usually diluted in the water body rather quickly and is non-bioaccumulative. According to Boyd (1998), sulfate concentration of 5 to 100 mg/l is desirable for the freshwater aquaculture systems. In Northern and Central Illinois streams, sulfate levels ranged from 30 to 150 mg/l in streams without significant human-induced sulfate sources (IDNR, 2009). Sulfate is widely distributed in nature and may be present in natural waters in concentrations ranging from a few to several thousand milligrams per liter (APHA, 2012).

2.2.12 Chemical Oxygen Demand (COD)

Chemical oxygen demand is an indicator of organics in the water, usually used in conjunction with biological oxygen demand (BOD). COD is a measure of the oxygen equivalent of the organic matter content if a sample that is susceptible to oxidation by a strong chemical oxidant (APHA, 1995). The COD is widely used as a measure of the susceptibility to oxidation of the organic and inorganic materials present in water bodies and in the effluents from sewage and industrial plants (Chapman, 1996). Thus the COD is a reliable parameter for judging the extent of pollution in water. The COD of water increases with increasing concentration of organic matter and inorganic matter (Boyd, 1981). Garg et al. (2010) reported that COD ranged from 3.60 to 17.40 mg/l in Ramsagar Reservoir.

2.2.13 Biological Oxygen Demand (BOD)

Biological oxygen demand is a very important parameter in estimating the pollution status of the water body. BOD itself is not a pollutant and exercises no direct harm but it may cause an indirect harm by reducing DO concentration levels detrimental to fish life and other

beneficial uses. BOD represents that fraction of dissolved organic matter which is degraded and easily assimilated by bacteria. BOD indicates the presence of biodegradable organic matter quantitatively, which consumes DO from water. The higher values of BOD produce obnoxious smell and unhealthy environment. A higher value of BOD is due to favourable environmental conditions for microbiological activities at higher temperature (Tamot et al., 2008).

BOD is directly linked with decomposition of dead organic matter present in the lake and hence the higher values of BOD can be directly correlated with pollution status and has an inverse relation with DO concentration. The BOD values were observed between 0.0 and 4.0 mg/l in Hathaikheda reservoir in Bhopal (Namdev et al., 2011). Tamot et al. (2008) reported that the BOD value ranged from 3.2 to 6.8 mg/l in Halali Reservoir. High values of BOD usually near the bottom of the cage aquaculture site where nutrients and organic matter from the fish, excess feed and waste accumulated, which resulted in high oxygen demand and in dry season, when water temperature increases, the rate of decomposition increases (Yee et al., 2012).

2.2.14 Total Suspended Solids (TSS)

Total suspended solid is an indicator of the amount of erosion that took place nearby or upstream. This parameter would be the most significant measurement as it would depict the effective and compliance of control measures.

Yi et al. (2004) reported that the TSS values were 87.2 mg/l in the upstream water, 125.8 mg/l in the middle stream and 86 mg/l in the downstream water in Mekong River, Vietnam. A large accumulation of suspended solids will reduce light penetration; thereby suppress

photosynthetic activity of phytoplankton, algae and macrophytes. Higher value of TSS in the cage culture site was due to the fish excretion and excess fish feed (Boyd, 2004).

2.2.15 Total Dissolved Solids (TDS)

Total dissolved solidsare the solids present in the water in the dissolved state. It consists of inorganic salts and dissolved materials. Garg et al. (2010) reported that TDS value from 166.37 to 239 mg/l in Ramsagar reservoir in Madhya Pradesh. Sawant and Chavan (2013) recorded the maximum total dissolved solid values of 172.66 mg/l during summer season owing to loss of water due to evaporation and concentration of salts in the water.

2.3 Sediment Characteristics

The main impacts of cage aquaculture are the increase in the concentration of N, P and organic matter that enrich water and underlying sediment (Cao et al., 2007). The greatest accumulation of solid wastes occurs directly under cages and alters the sediment quality by increasing nutrient load. The transfer of nutrients from overlying water to the sediment is governed by sedimentation of particulate material adsorption of nutrients by the sediment and the direct uptake by assimilation from the water column (Troell and Berg, 1997).

Several studies have reported that nitrogen and phosphorus discharged from fish cage can affect chemical parameters of sediment (Beveridge, 1996; Zhang et al., 2004; Yan, 2005; Porrello et al., 2005; Kullman et al., 2007). The nutrient loading and sedimentation model were indicating that the cage culture operations probably are a major contributor of large inputs of nutrients into the reservoirs. Portions of these nutrients are dissolved or become sedimented. Sediment nutrients accumulate on the bottom of the reservoir under cages and

can create considerable oxygen demand. This mixing can result in fish kills of cage fish and wild fish stocks (Abery et al., 2005).

2.3.1 pH

As in water, pH of soil is also one of the critical factors affecting productivity (Roshan, 2009). Soil pH is a measure of soil acidity or alkalinity. It is an important indicator of soil health. It affects crop yields, crop suitability, plant nutrient availability and soil micro-organism activity which influence key soil processes. Soils with high clay and organic matter content are highly able to resist a drop or rise in pH and have a greater buffering capacity. Under anaerobic condition the decomposition of organic matter is slow and the products of decompositions are mainly reduced compounds and short chain fatty acids thus making the soil strongly acidic. Soil pH also influences transformation of phosphorus into available forms and controls the adsorption and release of essential nutrients at the soil-water interface (Roshan, 2009; Pandey et al., 2013). Roshan (2009) considered that a slightly alkaline pH is favourable for fish culture for soil and Pandey et al. (2013) reported that soil pH of 6.5 to 8.5 is best range for fish culture.

If the soil is not naturally buffered, it reduces the rate of bacterial action influencing productivity of the pond. Sugunan (2011) reported soil pH from 6.0 to 8.8 in Indian Reservoirs.

2.3.2 Electrical Conductivity

Electrical conductivity is a measure of water capacity to convey electric current. It signifies the amount of total dissolved salts (Dahiya and Kaur, 1999). The high EC levels could also be attributed to the high levels of TDS because EC is a function of TDS which determines the quality of water (Tariq et al., 2006). There is a positive relationship between electrical conductivity and total dissolved solids (Garg et al., 2010).

High conductivity values may be an indicator of an eutrophication process. Rainfall is responsible for diluting the ions present in the water; therefore, conductivity levels decreased during the wet season and in the dry season, these values increased (Mallasen et al., 2012). Nyanti et al. (2012) reported the increased EC values towards the increasing depth due to the accumulation of fish waste such as urine and feces as well as uneaten feed and their products of decomposition especially at the deeper part of the reservoir.

2.3.3 Total Organic Carbon (TOC)

Organic carbon in freshwaters arises from living material (directly from plant photosynthesis or indirectly from terrestrial organic matter) and also as a constituent of many waste materials and effluents.

Consequently, the total organic matter in the water can be a useful indication of the degree of pollution, particularly when concentrations can be compared upstream and downstream of potential sources of pollution, such as sewage or industrial discharges or urban areas. Alpaslan and Pulatsu (2008) reported that the TOC values in Rainbow trout cage culture site were from 5.41 to 8.59 % and in control site from 4.38 to 8.49 % in Kesikkopru reservoir, Turkey. Garg et al. (2010) suggested that the bottom sediment with 1.5 to 2.5 %

organic carbon is productive. In Indian reservoirs, Total Organic Carbon values were ranged from 0.6 to 3.2 % (Sugunan, 2011).

2.3.4 Total Nitrogen (TN)

Most reservoirs being used for fish culture, the main sources of nutrients especially N and P derive mostly from fish waste and the uneaten feeding stuff. The accumulation of organic matter and the decomposition of feed stuff in the bottom sediment play an important role in relation to oxygen consumption of the fish in cages and surrounding area. The accumulation of nitrogen compounds within the settled sediments could take place from time to time and some amounts could have been used for growth by some biotic creatures such as water plants and others (Bhatnagar and Devi, 2012). Jiwyam and Chareontesprasit (2001) reported total nitrogen values with from 0.032 to 0.254 % in cage site and from 0.075 to 0.336 % in control site at KhonKaen reservoir, Thailand. Cao et al. (2007) reported a value of 681mg/l total nitrogen in cage culture in Dahonghu Reservoir, China.

Alpaslan and Pulatsu (2008) studied on cage culture of rainbow trout at Kesikkopru reservoir, Turkey and reported the total nitrogen values from 0.26 to 0.44 % in cage site and from 0.21 to 0.34 % in control site.

2.3.5 Available Phosphorus (AP)

Phosphorus tends to accumulate in the sediments at a higher level than that of organic matter and nitrogen (Bhatnagar and Devi, 2012). The supply of phosphorus and nitrogen to the sediment could possibly depend upon the sink of phytoplankton from water reservoirs and some parts of them may have been adsorbed through the clay surface. Phillips (1985) found that phosphorus in the bottom sediment accumulate up to 58.7 % in the lake.

According to Beveridge (1984, 1996), each kg of cultivated fish provides about 0.023 kg of available phosphorus to the environment, where residual food is the main source of this waste. Barik et al. (2001) reported that the available phosphorus in sediment was ranged from 0.04 to 1.64 mg/100g in freshwater system. Available phosphorus should be in the range of 4.7 to 6.2 mg/100g soil for high biological productivity (Garg et al., 2010) and phosphorus availability in Indian reservoirs ranged from 0.47 to 6.2 mg/100g (Sugunan, 2011).

2.4 Microbial Quality

Microorganisms plays an important function in water bodies, since they participate in the transformation of nutrients in the environments, nutrition of animals which may affect various parameters of water quality such as dissolved oxygen, pH and ammonia (Moriarty, 1997).

In case of heavy rainfall, the microbial loads of running waters may suddenly increase substantially and reach reservoir bodies very quickly (Kistemann et al., 2002). Physico-chemical parameters of the water such as pH, nutrients and presence of toxic compounds may influence the density of bacterial populations. The importance of the microbial population in the reservoirs used for fish farming and irrigation can be resumed by its influence on the amount and diversity of bacteria in the fish during capture, handling and processing, as well as in the microbial contamination of food produced in agriculture under irrigation (Gorlach-Lira et al., 2013). Coliform bacteria can survive longer in freshwater than seawater due to the lower salinity (Davies and Evison, 1991). Heavy rainfall resulted in an increase in the number of coliform bacteria in both water and sediment samples (Goyal et al., 1977). The extent of faecal contamination may change seasonally with temperature, rainfall

and other influences. Total coliforms are used as indicators of water quality because they are easy to detect and quantify and used as indicators of faecal pollution.

Relatively high numbers of bacteria observed in the reservoir reflect the nature of the cultivation of fish in net cages, which uses considerable volumes of alimentary inputs in the reduced area, with consequent releases of high quantities of alimentary residues and metabolites to the environment that can strongly influence the microbiological quality of water. Furthermore, the high temperature of the water observed in the tropics and the neutral and alkaline pH are favorable for the growth of bacteria (Gorlach-Lira et al., 2013). Entero-pathogens, such as *Escherichia coli*, are generally present at very low concentrations in environmental waters with a diversified micro flora.

Their presence in drinking water must at least be considered as a possible threat or indicative of microbiological water quality deterioration (Rompre et al., 2002).

2.4.1 Total microbial load

The relationship between physico-chemical parameters and bacterial count attracted much of attention (Ogbondeminu and Adeniji, 1984; Guo et al., 1988; Ferguson et al., 1996). High bacterial counts were associated with low salinity, so an indirect relationship exists between salinity and bacterial density as observed in Cherai beach, Kerala (Raveendran et al., 1978), Cochin backwaters (Gore et al., 1979), Charlotte harbour estuary in Florida (Lipp et al., 2001) and in coastal waters of Italy (Caruso et al., 2000). A direct relationship occurred with the bacterial counts and ammonia in Italian coastal waters (Caruso et al., 2000). Higher counts during monsoon months may be due to low salinity, less exposure to light and temperature (Nallathambi et al., 2002). Gorlach-Lira et al. (2013) found

that the total plate count of tilapia cage culture at the Reservoir in Padre Azevedo in Brazil was ranged from $1.3x10^4$ to $67.3x10^4$cfu/100ml.

2.4.2 *E. coli*

The microorganism such as *E. coli serves* as a prime indicator of faecal pollution in water. It can grow up to 44 $^{\circ}$C and is called thermotolerant coliform (Kator and Rhodes, 1991). The U.S. Environmental Protection Agency recommends the use of *E. coli*, a member of the faecal coliform group, as an indicator organism for recreational waters in freshwater bodies (USEPA, 2000). This species is the most common coliform among the intestinal flora of warm-blooded animals and its presence might be principally associated with fecal contamination.

No *E. coli* are therefore allowed in drinking water (Rompre et al., 2002). Growth of these organisms in natural waters would compromise their use as indicators of faecal contamination, and evidence from a number of studies suggests that *E. coli* and enterococci may multiply in warm, subtropical water (Byappanahalli and Fujioka, 1998; Solo-Gabriele et al., 2000; Desmarais et al., 2002).

2.4.3 Faecal streptococci

Fecal streptococci (FS) are, in conjunction with coliform bacteria, commonly used indicators of fecal pollution. They are particularly useful indicators because they are not as widespread as coliforms and are always present in the feces of warm blooded animals (Sinton et al., 1993). Faecal Streptococci include gram positive, catalase negative, non-spore forming, facultative anaerobes associated with the gastrointestinal tracts of humans and animals (Kator and Rhodes, 1991).

Though faecal streptococci constitute 0.1% or less of the gut microbiota, they have long been considered an important indicator of faecal pollution, because of its inability to grow in seawater or in virgin soils (Venkateswaran and Natarajan, 1987). Surendraraj et al. (2009) observed that water temperature showed a negative effect on all bacterial indicator parameters analysed except *E.coli* and faecal streptococci in pond water at Thiruvankulam, Kerala. Gorlach-Lira et al. (2013) found that the site with floating net cages exhibited more contamination with faecal streptococci than other sampling sites.

III. MATERIALS AND METHODS

The present investigation was undertaken to assess the impacts of cage culture on water quality parameters in Poondi Reservoir located in Thiruvallur District, Tamil Nadu, in which cage culture has already been initiated by the State fisheries department with 12 numbers of cages. All the cages are of similar size with 4x4x3 m. This study was carried out in point source (cage site) and non-point source (control site) of cage culture for a period of eight months from September, 2014 to April, 2015.

3.1 Collection of water sample

The water samples were collected fortnightly from point and non-point sources of cage culture in Poondi reservoir, at different depths such as 0.5 m, 1.0 m and 1.5 m in the cage site and 0.5 m and 1.5 m in control site. The water samples were collected in separate clean plastic containers without any air bubbles. The containers were rinsed before sampling and tightly sealed after collection and labeled in the field. The water samples were brought to the laboratory and the physico-chemical parameters such as water temperature, pH, dissolved oxygen (DO),salinity, hardness, alkalinity, ammonia-N (NH_3-N), nitrite-N (NO_2-N), nitrate-N (NO_3-N),

phosphate-P (PO_4-P), sulfate, chemical oxygen demand (COD), biological oxygen demand (BOD), total suspended solids (TSS) and total dissolved solids (TDS) were analyzed by using standard procedure.

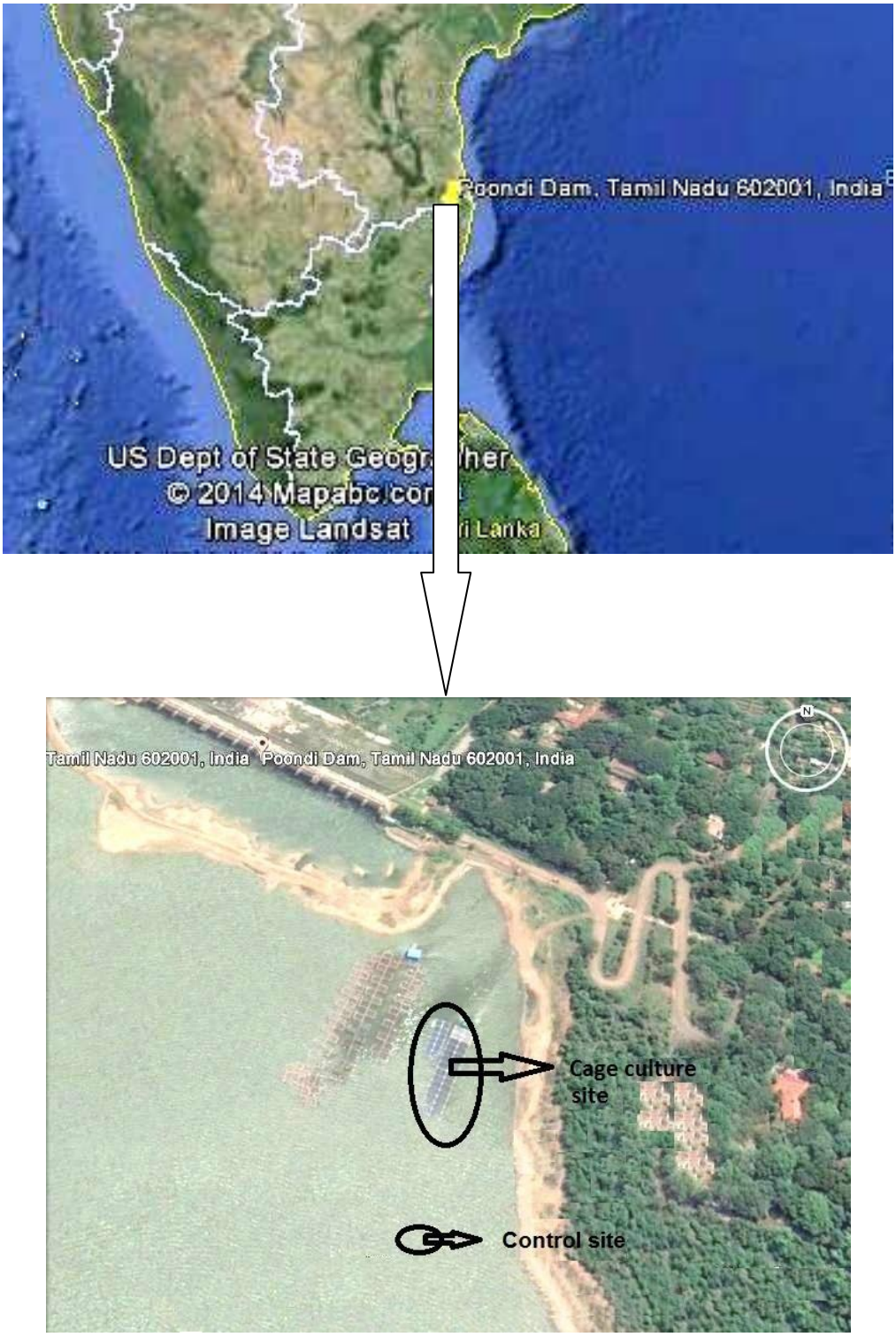

Plate 4.1. Map showing the study area

3.1.1 Analysis of physico-chemical parameters of water sample

Temperature of the water sample was measured in the field by using mercury thermometer with a range of 0 to 100 °C and 0.1°C graduations. The pH was measured by using 'ELICO' pH meter. For estimation of dissolved oxygen, the water samples were collected in a BOD bottles. The sample was fixed immediately after the collection of water and estimated adopting modified Winkler's titration method (APHA, 1995). The other parameters like salinity, BOD, COD, TDS and TSS were analyzed by adopting the standard methods (APHA, 1998). The water samples were filtered andanalyzed for their dissolved nutrients like ammonia-N (NH_3-N), nitrite-N (NO_2-N), nitrate-N (NO_3-N) and phosphate-P (PO_4-P) using Spectrophotometer (Perkin Elmer-Model) as per the procedure of APHA(1995) with each analysis done in duplicates and the mean values were taken for consideration. Sulfate in the water samples were analysed by Gravimetric method with ignition of residue (APHA, 2012).

3.2 Collection of sediment sample

Sediment samples were collected fortnightly from point and non-point sources of cage culture in Poondi reservoir with the help of snapper/grab and brought to the laboratory in the polythene bags in an insulated box. The large shells and stones were removed physically. The sediment samples were dried at room temperature for 24 h and ground well to powder by using a glass mortar (Hall, 1986). Later, the dried bulk sediment samples were sieved using a test sieve with a pore size of 250 μm and the fine fractions were collected for further analysis.

3.2.1 Analysis of sediment characteristics

The pH was measured by using 'ELICO' pH meter. The electrical conductivity was measured by 'ELICO CM 183-EC-TDS' Analyzer. The total organic carbon was analyzed by the procedure of Boyd (1995). The total nitrogen (K-Jeldahl method) and available phosphorus was estimated by standard methods (FAO, 1975).

3.3 Collection of water sample for microbiological analysis

Water samples were collected directly from cage and control sites in sterilized glass bottles and were analyzed for total plate count (TPC) and faecal indicator bacteria such as *E. coli* and faecal streptococci.

3.3.1 Total plate count

From the collected samples, 10 ml was transferred directly into 90ml physiological saline to obtain 10^{-1} dilution. From this, 10 fold serial dilutions were prepared by transferring 1ml to 9ml physiological saline. Similarly further dilutions were made. 0.1 ml of each of appropriate dilutions was pipetted to marked sterile predried petridishes in duplicate containing nutrient agar. The inoculum was spread evenly on the surface of the agar plate using a sterile spreader. The plates were counted after incubation at 37 ^{o}C for 48 h and expressed as colony forming unit (cfu) per ml.

3.3.2 Enumeration of *E. coli*

Enumeration of *E. coli* was done by using Tergitol -7 agar.0.1 ml of inoculum from the appropriate dilution was spread on the surface of agar plates using sterile spreader. The agar plates were incubated at 37 ^{o}C for 48 h.

Using a colony counter, circular, non-mucoid, flat, yellow with pinkish tinge colonies were counted and expressed as colony forming unit (cfu) per ml.

3.3.3 Enumeration of faecal Streptococci

Enumeration of faecal Streptococci was done using sterile Kenner faecal agar (KF agar) with 1 % Triphenyl Tetrazolium Chloride (TTC). 1 ml of each dilution was pipette on to prepared petridishes in duplicates and incubated at 37 ^{o}C for 48 h. Using the colony counter, the red to pink colour colonies were recorded and marked as faecal streptococcal count.

3.4 Statistical analysis

The collected data on water quality parameters, sediment characteristics and microbial analysis were subjected to ANOVA test and correlation matrix (Christenson, 1996). All the statistical analysis was performed using SPSS (version 16.0). Mean and standard deviation of collected data were calculated.

IV. RESULTS

4.1 Physico-chemical parameters of water sample

4.1.1 Water Temperature

The water temperature values recorded in cage culture and control sites are given in Fig. 4.1. The average water temperature values of cage and control sites were 29.44 ± 2.38 ºC and 29.14 ± 2.39 ºC respectively during the study period. The minimum and maximum water temperature values of 26 and 34.9 ºC was noticed in the cage culture sites at 1.5 m and 0.5 m depth and 26 and 34.3 ºC was observed in the control sites at 1.5 m and 0.5 m depth. The one way ANOVA performed with the water temperature values of cage and control sites showed no significant difference during the study period (P>0.05) and is presented in the Table 4.1. The correlation between the water quality parameters of cage site and control site are given in Table 4.2 and 4.3.

4.1.2 pH

During the study period, pH values of cage and control sites ranged from 7.53 to 8.94 and the observed values are given in Fig 4.2. The average pH value of 8.12 ± 0.46 was observed in the cage culture site and 8.15 ± 0.46 was noticed in the control site. The minimum and maximum pH values of cage culture site were 7.53 and 8.94 at a depth of 1.5 m and 0.5 m depth respectively. The minimum pH value of control site was 7.69 at a depth of 1.5 m and the maximum value of 8.84 was at 0.5 m depth. The one way ANOVA performed with the pH values of cage and control sites indicated no significant difference during the study period (P>0.05) and is presented in the Table 4.1.

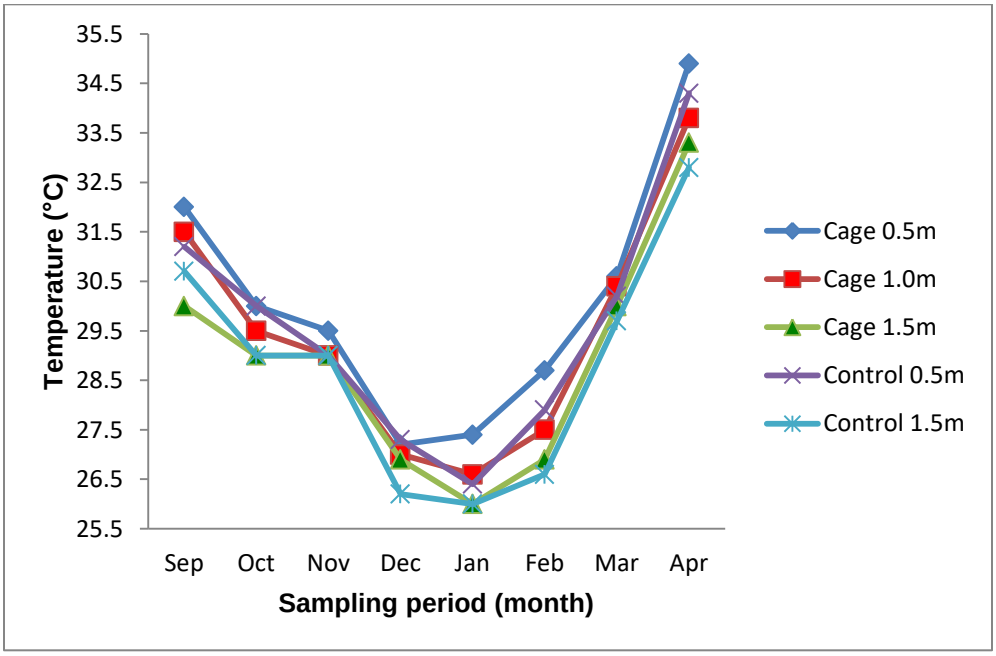

Fig. 4.1. Variation in water temperature values recorded at cage and control sites

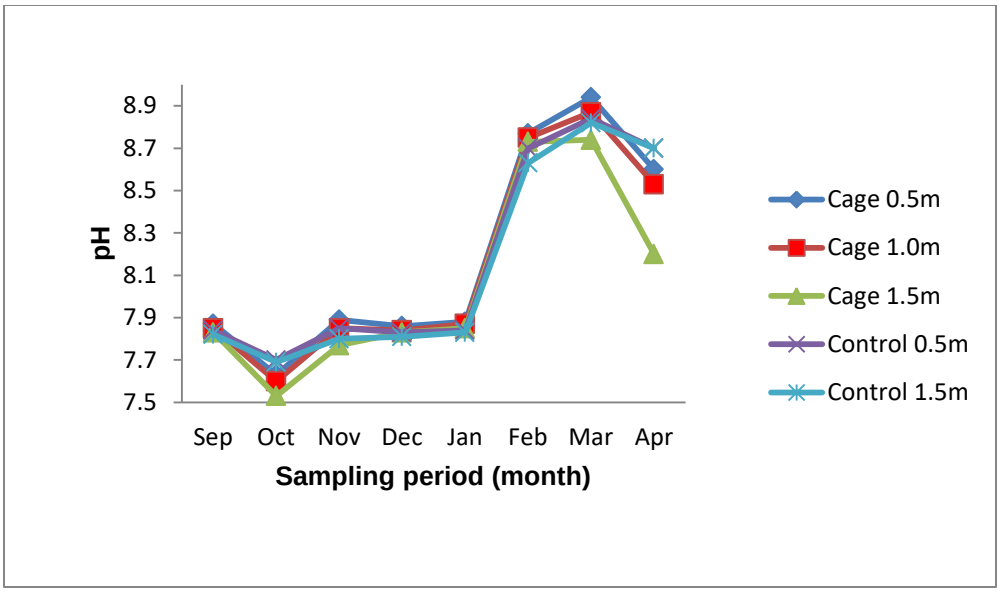

Fig. 4.2. Variation in pH values recorded at cage and control sites

4.1.3 Dissolved Oxygen

During the study period, dissolved oxygen values of cage and control site ranged from 4.00 to 6.00 mg/l. The dissolved oxygen values recorded in cage and control site are given in Fig. 4.3. The average dissolved oxygen values were 4.71 ± 0.46 mg/l in cage culture site and 4.84 ± 0.61 mg/l in control site. The maximum value of 5.73 mg/l was recorded at 0.5 m depth and the minimum value of 4.00 mg/l was recorded at 1.5 m depth in the cage culture site. The maximum value of 6.00 mg/l was recorded at 0.5 m depth and the minimum value of 4.00 mg/l was recorded at 1.5 m depth in the control site. The results of one way ANOVA showed no significant difference existed between the dissolved oxygen values of cage and control site during the study period ($P>0.05$) and is presented in the Table 4.1.

4.1.4 Salinity

The salinity values recorded both in cage and control sites are given in Fig. 4.4. The salinity values ranged from 0.1 to 0.3 ppt at cage culture sites and from 0.1 to 0.25 ppt at control sites. The average salinity value of 0.16 ± 0.06 ppt was observed in both the cage and control sites. The results of one way ANOVA showed that no significant difference existed between the salinity values of both cage and control sites during the study period (P>0.05) and is presented in the Table 4.1.

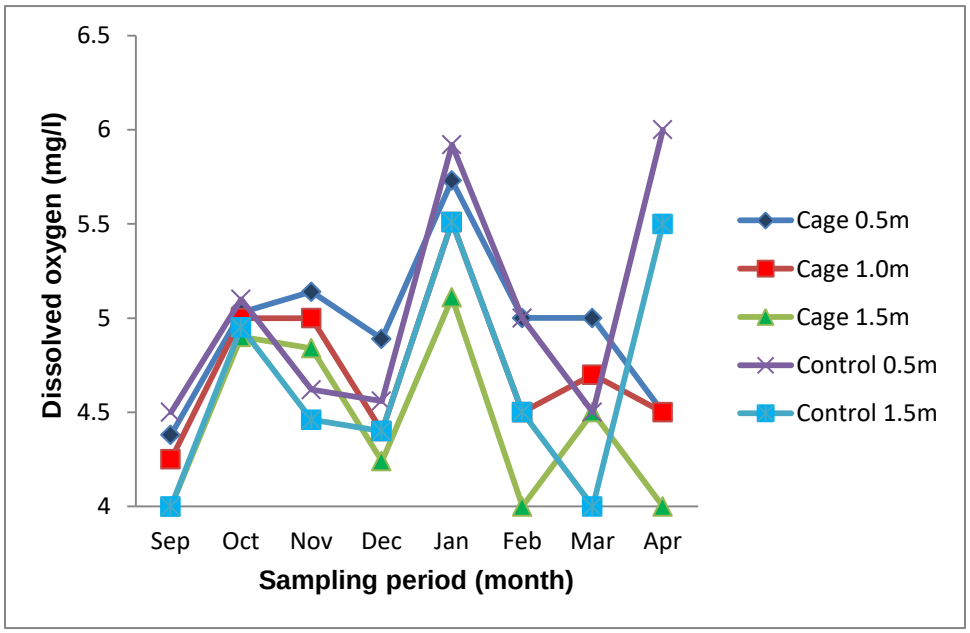

Fig. 4.3. Variation in dissolved oxygen value recorded at cage and control sites

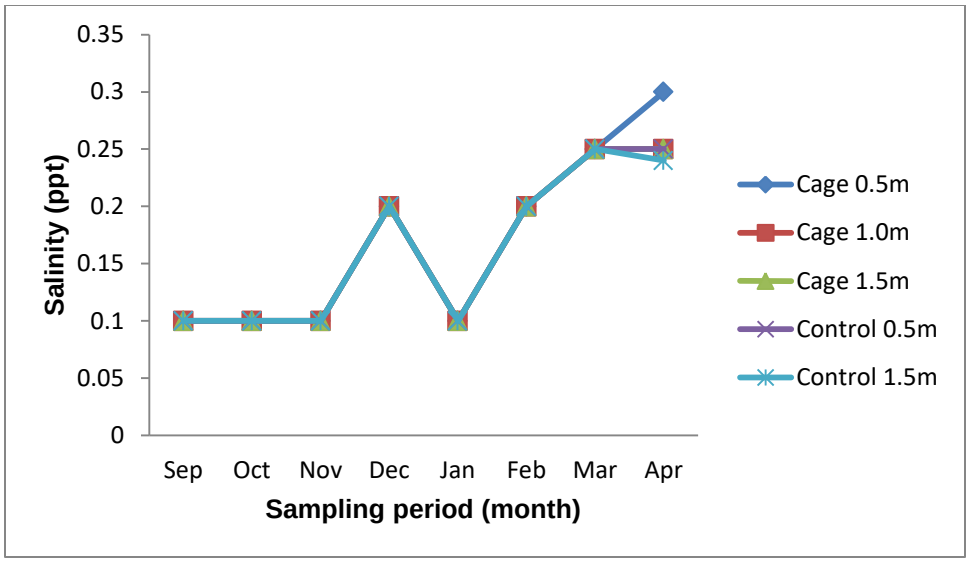

Fig. 4.4. Variation in salinity values recorded at cage and control sites

4.1.5 Hardness

The hardness values recorded in cage and control sites are represented in Fig. 4.5. The average hardness value of 150.56 ± 57.81 mg/l as $CaCO_3$ was recorded in the cage culture site and 151.64 ± 63.17 mg/l as $CaCO_3$ was recorded in the control site. The minimum and maximum hardness values of 53.05 and 244.24 mg/l as $CaCO_3$ were noticed in the cage culture site at a depth of 0.5 m and 49.04 and 260.26 mg/l as $CaCO_3$ were noticed in the control site at 1.5 m depth. The one way ANOVA performed with the hardness values of cage and control sites indicated no significant difference during the study period ($P>0.05$) and is presented in the Table 4.1.

4.1.6 Alkalinity

The alkalinity values recorded both in cage and control sites are given in Fig. 4.6. The alkalinity values ranged from 14 to 160 mg/l in cage culture site at both the depth of 0.5 m and 1.5 m and from 16 to 140 mg/l in the control site at 0.5 m depth. The average alkalinity values were 79.41 ± 52.63 mg/l in the cage site and 77.37 ± 48.31 mg/l in the control site during the study period. The one way ANOVA performed with the alkalinity values showed no significant difference between cage and control sites during the study period ($P>0.05$) and is presented in the Table 4.1.

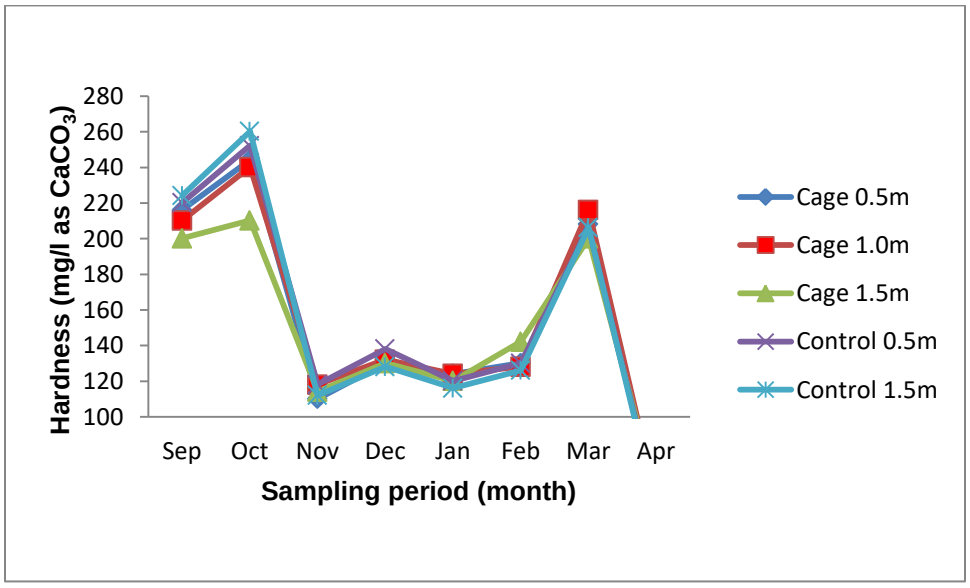

Fig. 4.5. Variation in hardness values recorded at cage and control sites

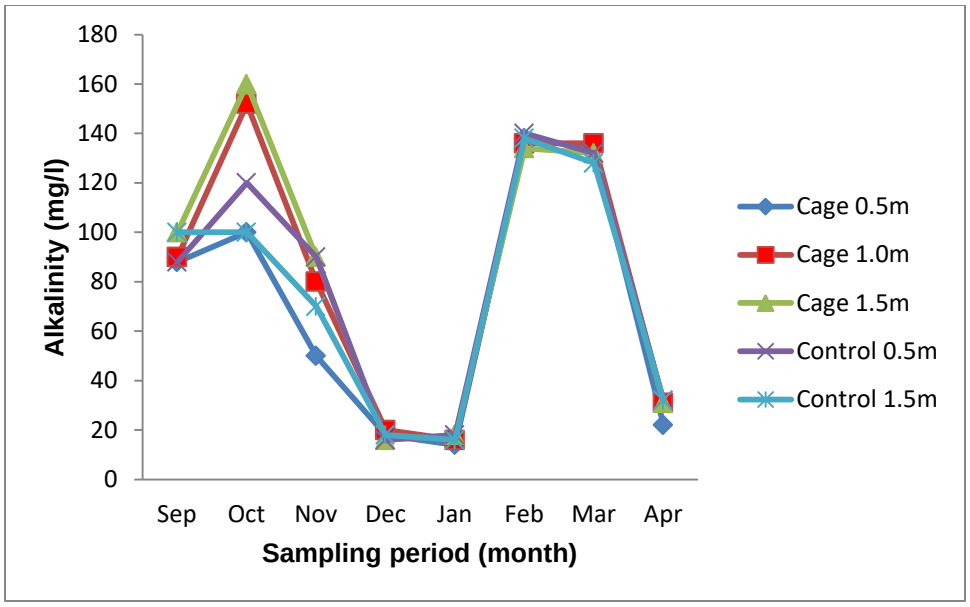

Fig. 4.6. Variation in alkalinity values recorded at cage and control sites

4.1.7 Ammonia- N

During the study period, the ammonia values ranged from 0.0010 to 1.1800 µg at. NH_3-N/l at both cage and control sites and represented in Fig. 4.7. The maximum ammonia value recorded in the cage and control sites were 1.18 µg at. NH_3-N/l and 0.65 µg at.NH_3-N/l respectively. The results of one way ANOVA indicated that no significant difference existed between the ammonia values of cage and control sites during the study period ($P>0.05$) and is presented in the Table 4.1.

4.1.8 Nitrite- N

The nitrite values recorded in cage and control sites are given in Fig. 4.8. Nitrite values ranged from 0.0201 µg at. NO_2-N/l to 0.8208 µg at.NO_2-N/l in the cage site and from 0.0184 µg

at.NO_2-N/l to 0.9285 µg at.NO_2-N/l in the control site. The results of one way ANOVA showed no significant difference between the nitrite values of cage and control site during the study period (P>0.05) and is presented in the Table 4.1.

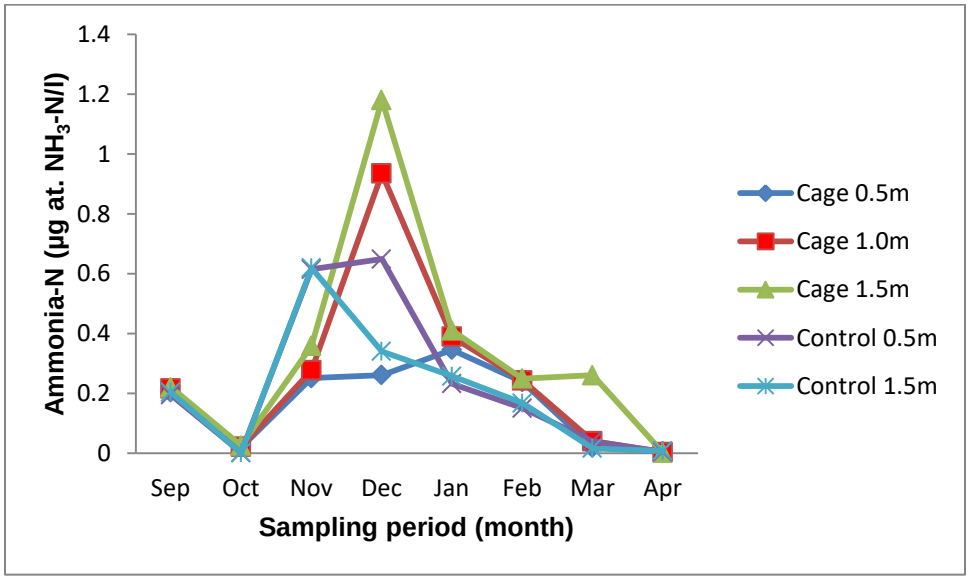

Fig. 4.7. Variation in ammonia-N values recorded at cage and control sites

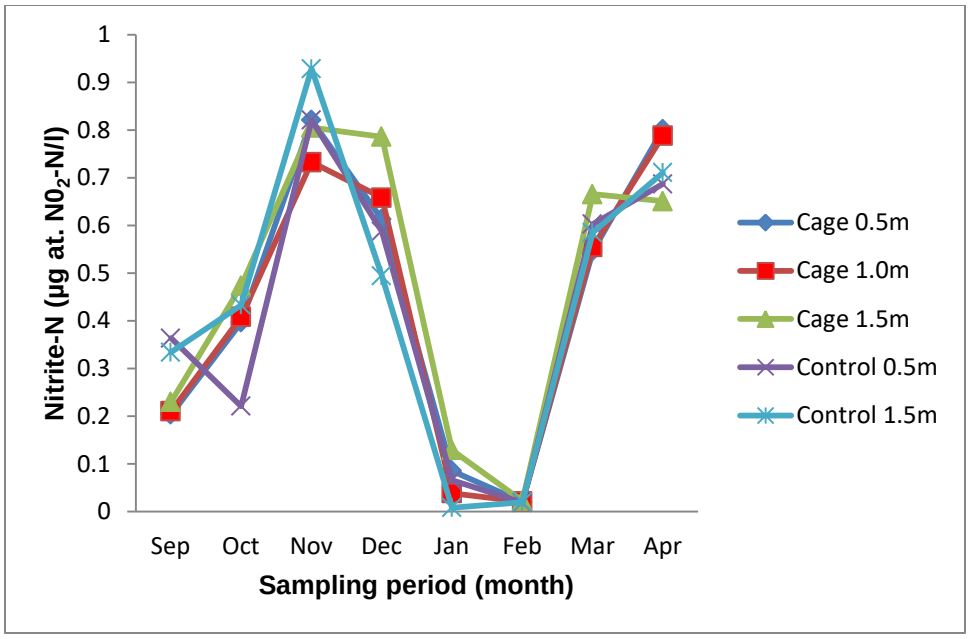

Fig. 4.8. Variation in nitrite- N values recorded at cage and control sites

4.1.9 Nitrate- N

The values of nitrate recorded in cage and control site are given in Fig. 4.9. The maximum values of 0.0912 µg at. NO_3-N/l was recorded at a depth of 1.5 m and minimum of 0.0056 µg at. NO_3-N/l was recorded at a depth of 0.5 m and 1.0 m in the cage site. The value ranged from 0.0035 µg at. NO_3-N/l to 0.0583 µg at.NO_3-N/l in the control site. The average nitrate valuesof cage and control site were 0.0362 ± 0.0289 µg at. NO_3-N/l and 0.0248 ± 0.0178 µg at.NO_3-N/l respectively during the study period. The one way ANOVA performed with the nitrate values of cage and control sites indicated no significant difference during the study period ($P>0.05$) and is presented in the Table 4.1.

4.1.10 Phosphate- P

The phosphate values recorded in cage and control site are given in Fig. 4.10. During the study period, phosphate values of cage and control site ranged from 0.7798 to 2.9173 µg at. PO_4-P/l. The average phosphate values of 1.7942 ± 0.4599 µg at. PO_4-P/l was observed in the cage culture site and 1.7816 ± 0.5615 µg at. PO_4-P/l was noticed in the control site. The maximum value of 2.2121 µg at. PO_4-P/l was recorded at a depth of 0.5m and minimum value of 1.0736 µg at. PO_4-P/l was recorded at 0.5m depth near the cage culture site. The results of one way ANOVA showed no significant difference existed between the phosphate values of cage and control site during the study period (P>0.05) and is presented in the Table 4.1.

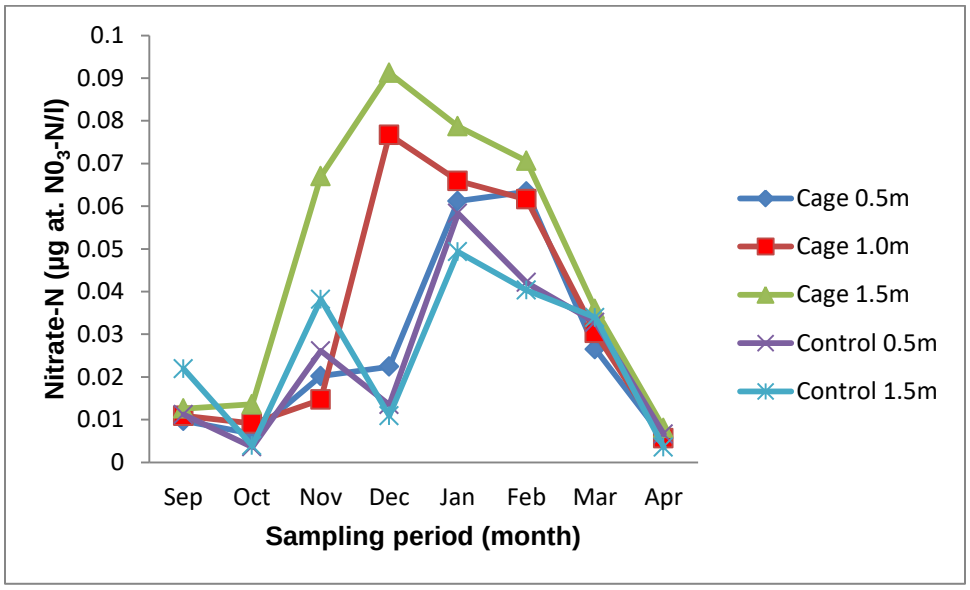

Fig. 4.9. Variation in nitrate-N values recorded at cage and control sites

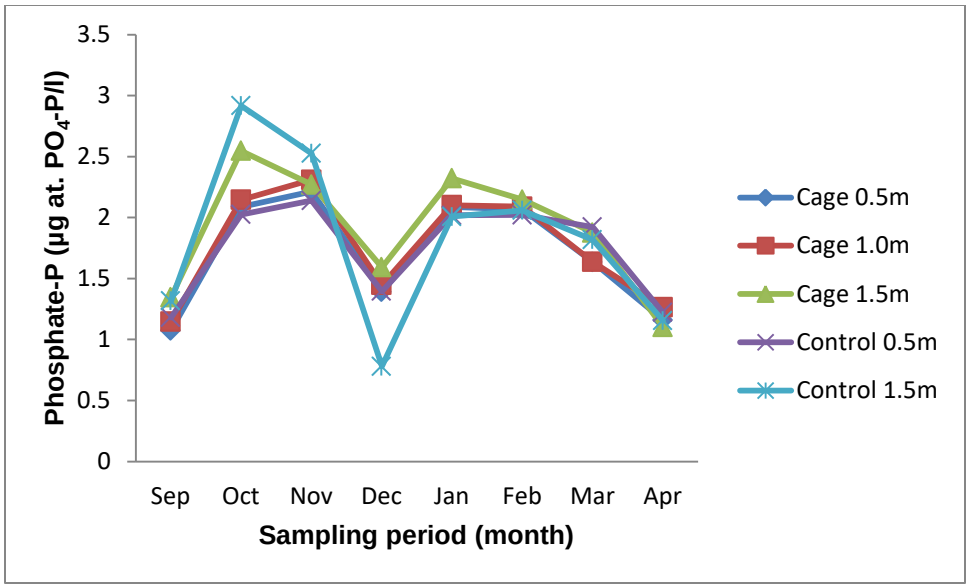

Fig. 4.10. Variation in phosphate- P values recorded at cage and control sites

4.1.11 Sulfate

The sulfate value ranged from 0.0011 to 1.2340 mg/l during the study period. The values of sulfate recorded in cage and control site are given in Fig. 4.11. The sulfate value was ranged from 0.0015 mg/l at 0.5 m depth to 1.2340 mg/l at 1.5 m depth in the cage culture site and 0.0011 mg/l at 0.5 m depth to 0.808 mg/l at 1.5 m depth in the control site. The one way ANOVA performed with the sulfate values of cage and control sites indicated no significant difference during the study period ($P>0.05$) and is presented in the Table 4.1.

4.1.12 Chemical oxygen demand

The chemical oxygen demand values recorded in cage and control site are given in Fig. 4.12. The COD value ranged from 8.00 mg/l at 0.5 m depth to 75.00 mg/l at 1.0 m depth in the cage site and from 9.00 mg/l at 0.5 m depth to 35 mg/l at 1.5 m depth in the control site. The average COD value of cage and control were 24.12 ± 14.49 mg/l and 23.12 ± 7.99 mg/l respectively. The one way ANOVA performed with the chemical oxygen demand values of cage and control sites indicated no significant difference during the study period (P>0.05) and is presented in the Table 4.1.

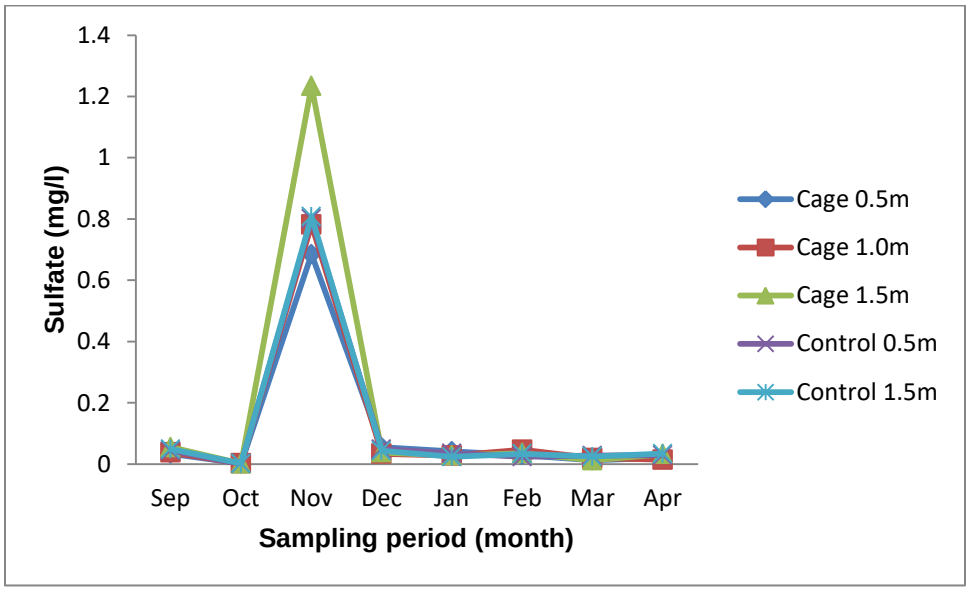

Fig. 4.11. Variation in sulfate values recorded at cage and control sites

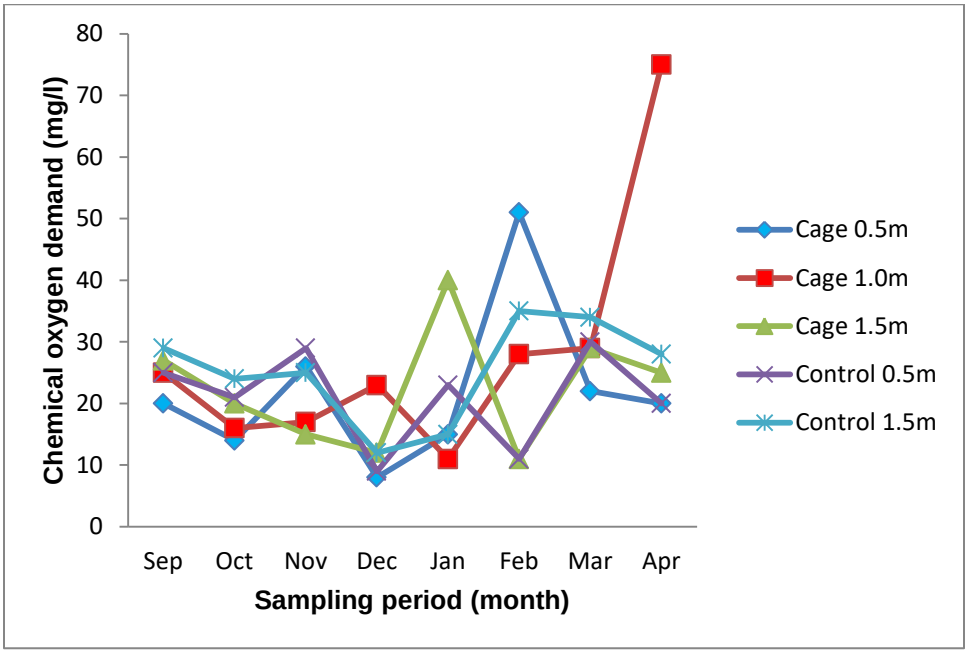

Fig. 4.12. Variation in chemical oxygen demand value recorded at cage and control

4.1.13 Biological Oxygen Demand

The values of biological oxygen demand recorded in the cage and control site are given in Fig. 4.13. The maximum value of 2.68 mg/l was observed at 1.5 m depth and the minimum value of 0.30 mg/l was observed at 0.5 m depth in the cage culture site. The minimum and maximum value of 0.61 mg/l at 0.5 m depth and 2.46 mg/l at 1.5 m depth were observed in the control site. The average value of BOD in the cage and control site was 1.63 ± 0.75 and 1.49 ± 0.52 mg/l respectively. The results of one way ANOVA showed no significant difference existed between the biological oxygen demand values of cage and control site during the study period ($P>0.05$) and is presented in the Table 4.1.

4.1.14 Total suspended solids

The total suspended solids values recorded in the cage and control site are given in Fig. 4.14. The average TSS value was 0.18 ± 0.18 mg/l in cage site and 0.15 ± 0.14 mg/l in the control site. The TSS values ranged from nil value at 1 m depth to 0.72 mg/l at 0.5 m depth in the cage site. In the control site the TSS value ranged from 0.01 mg/l at both the depths of 0.5 m and 1.5 m to 0.52 mg/l at 0.5 m depth. The one way ANOVA performed with the total suspended solid values of cage and control sites indicated no significant difference during the study period (P>0.05) and is presented in the Table 4.1.

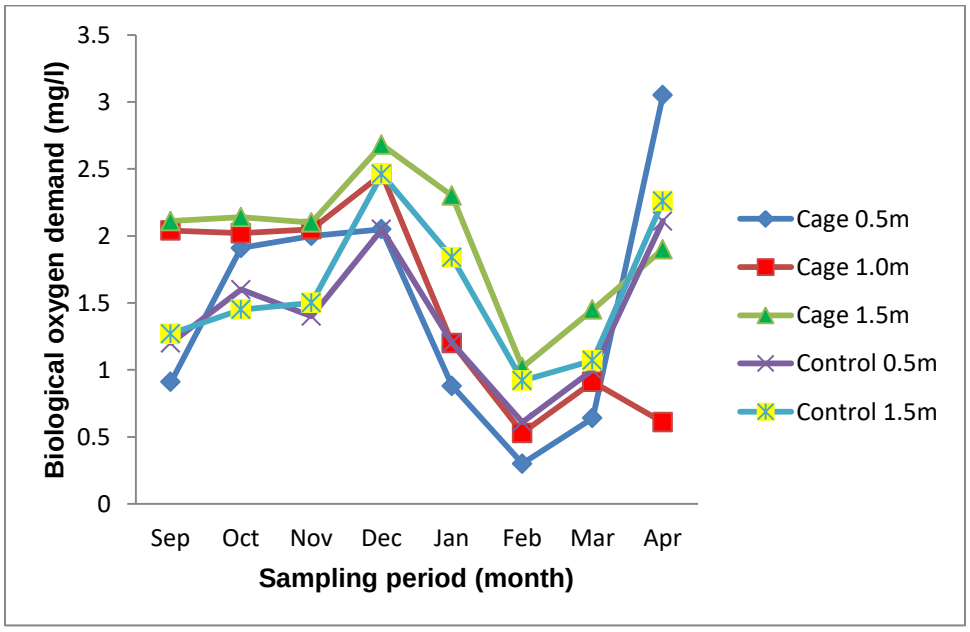

Fig. 4.13. Variation in biological oxygen demand values recorded at cage and control sites

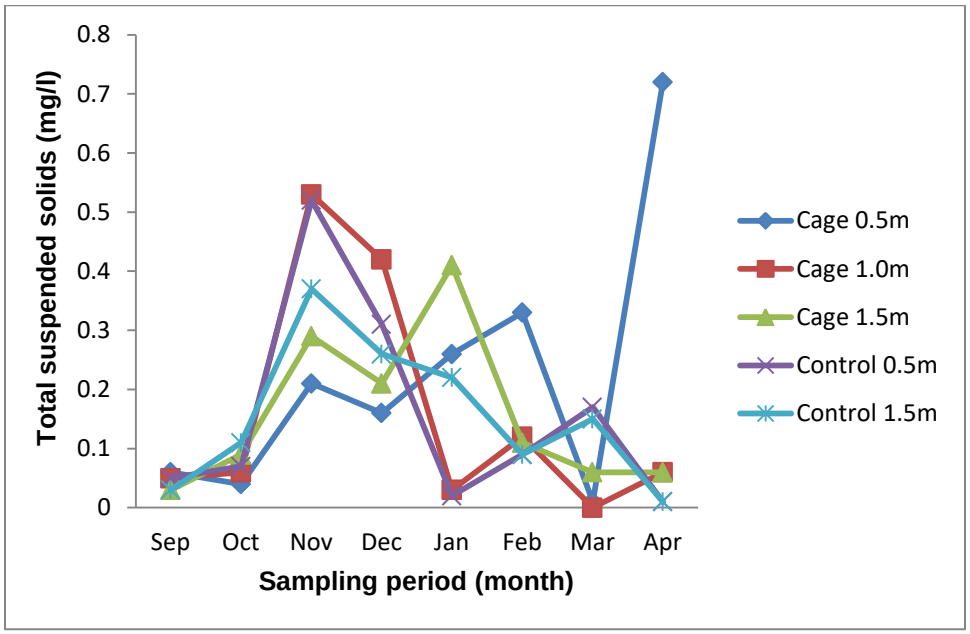

Fig. 4.14. Variation in total suspended solid values recorded at cage and control

4.1.15 Total dissolved solids

The total dissolved solids values recorded in the cage and control site are given in Fig. 4.15. The maximum value of 0.72 mg/l was observed at 0.5 m depth and the minimum value of 0.12 mg/l was observed at 1.5 m depth in the cage culture site. The TDS value ranged from 0.24 to 0.81 mg/l at 0.5 m depth in the control site. The average value of TDS was 0.36 ± 0.13 mg/l and 0.39 ± 0.16 mg/l in the cage and control sites respectively. The results of one way ANOVA showed that no significant difference existed between the total dissolved solid values of cage and control site during the study period ($P>0.05$) and is presented in the Table 4.1.

4.2 Sediment characteristics

4.2.1pH

The pH values observed in the cage and control site are given in Fig. 4.16. The soil pH value ranged from 7.07 to 7.9 in the cage culture and from 7.08 to 7.81 in the control site. The average values of cage and control site were 7.50 ± 0.29 and 7.48 ± 0.23 respectively. The one way ANOVA performed with the pH values of cage and control sites indicated no significant difference during the study period (P>0.05) and is presented in the Table 4.4.

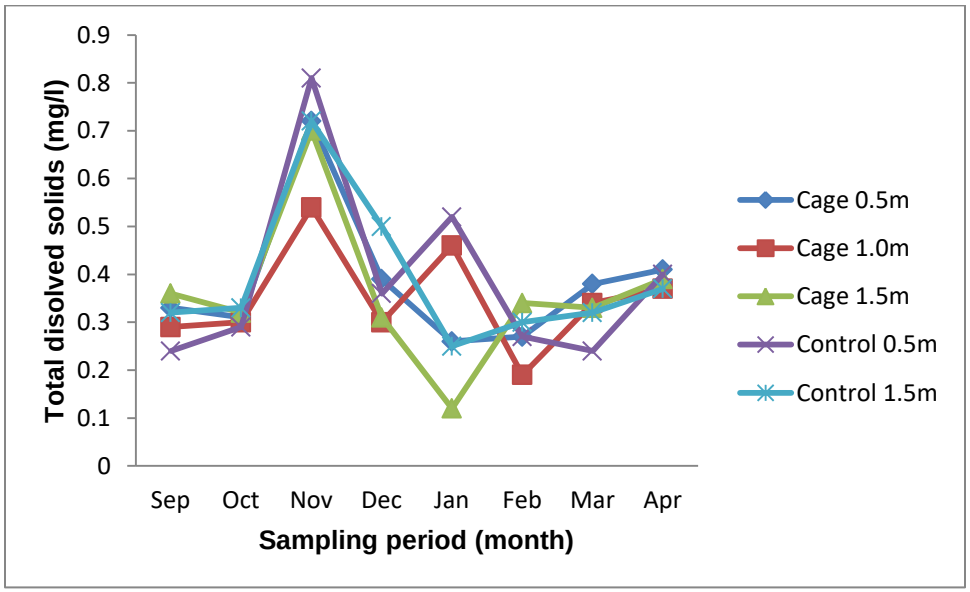

Fig. 4.15. Variation in total dissolved solid values recorded at cage and control sites

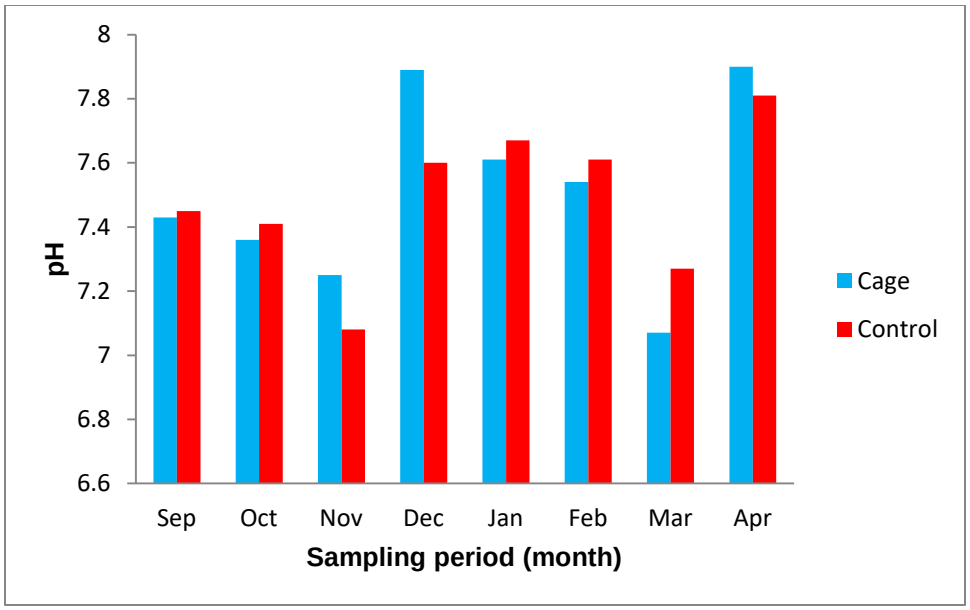

Fig. 4.16. Variation in pH values recorded at cage and control sites

Table 4.1. ANOVA table for physico-chemical parameters of water samples

Physico-chemical parameters	**Source of variation**	**Sum of square**	**Degrees of freedom**	**Mean Sum of square**	**F critical**	***P* value**
Temperature	Between Groups	8.660	4	2.165	0.362	0.834 NS
	Within Groups	209.095	35	5.974		
	Total	217.755	39			
pH	Between Groups	0.012	4	0.003	0.013	1.000 NS
	Within Groups	8.267	35	0.236		
	Total	8.279	39			
Salinity	Between Groups	0.000	4	0.000	0.014	1.000 NS
	Within Groups	0.178	35	0.005		
	Total	0.178	39			
Hardness	Between Groups	207.392	4	51.848	0.013	1.000 NS
	Within Groups	136546.066	35	3901.3		

	Total	136753.457	39			
Alkalinity	Between Groups	1091.350	4	272.83	0.098	0.982 NS
	Within Groups	97676.250	35	2790.7		
	Total	98767.600	39			
Ammonia	Between Groups	0.136	4	0.034	0.475	0.754 NS
	Within Groups	2.503	35	0.072		
	Total	2.639	39			
Nitrite	Between Groups	0.012	4	0.003	0.031	0.998 NS
	Within Groups	3.324	35	0.095		
	Total	3.335	39			
Nitrate	Between Groups	0.003	4	0.001	1.150	0.349 NS
	Within Groups	0.022	35	0.001		
	Total	0.025	39			
Phosphate	Between Groups	0.175	4	0.044	0.163	0.956 NS
	Within Groups	9.422	35	0.269		
	Total	9.597	39			

Table 4.1.cont'd

Physico-chemical parameters	**Source of variation**	**Sum of square**	**Degrees of freedom**	**Mean Sum of square**	**F critical**	***P* value**
Sulfate	Between Groups	0.024	4	0.006	0.064	0.992 NS
	Within Groups	3.205	35	0.092		
	Total	3.229	39			
DO	Between Groups	1.730	4	0.432	1.675	0.178 NS
	Within Groups	9.037	35	0.258		
	Total	10.766	39			
COD	Between Groups	262.600	4	65.650	0.415	0.797 NS
	Within Groups	5537.375	35	158.211		
	Total	5799.975	39			
BOD	Between	1.628	4	0.407	0.903	0.473

	Groups					NS
	Within Groups	15.784	35	0.451		
	Total	17.412	39			
TSS	Between Groups	0.029	4	0.007	0.231	0.919 NS
	Within Groups	1.100	35	0.031		
	Total	1.129	39			
TDS	Between Groups	0.012	4	0.003	0.123	0.973 NS
	Within Groups	0.839	35	0.024		
	Total	0.851	39			

Note: ***NS** – Non significant.

4.2.2 Electrical conductivity

The electrical conductivity values observed in the cage and control site are given in Fig. 4.17. The minimum and maximum electrical conductivity values of 2.81 and 55.99 mS/cm were noticed in the cage culture site and 4.64 and 38.56 mS/cm were noticed in the control site. The average values of electrical conductivity were 22.53 ± 17.13 mS/cm in the cage culture site and 21.92 ± 11.24 mS/cm in the control site. The results of one way ANOVA showed no significant difference existed between the electrical conductivity values of cage and control site during the study period (P>0.05) and is presented in the Table 4.4.

4.2.3 Total organic carbon

The total organic carbon values observed in the cage and control site are given in Fig. 4.18. The values of total organic carbon ranged from 0.47 to 3.33 % in the cage culture site and from 0.54 to 2.93 % in the control site. The average values of cage and control site were 2.42 ± 0.84 % and 2.37 ± 0.75 % respectively. The one way ANOVA performed with the total organic values

of cage and control sites indicated no significant difference during the study period (P>0.05) and is presented in the Table 4.4.

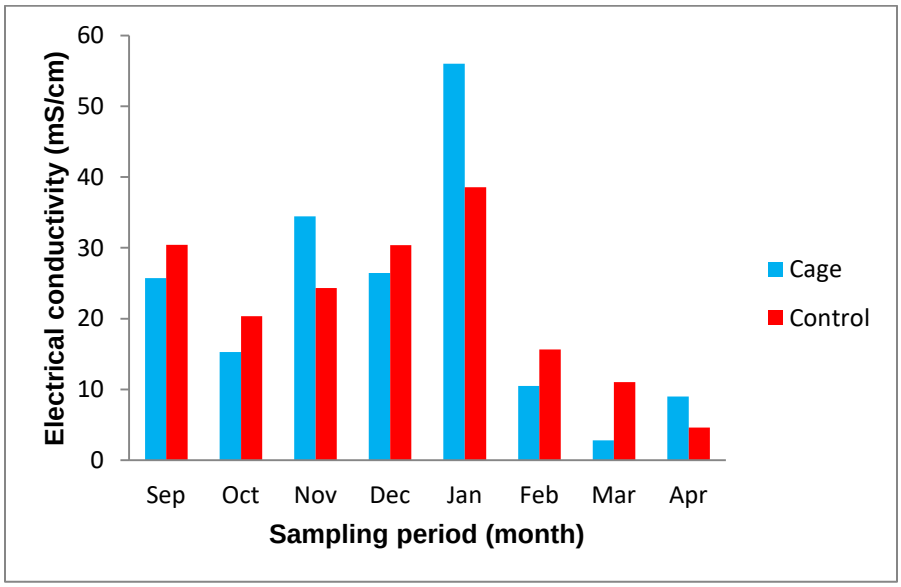

Fig. 4.17. Variation in electrical conductivity values recorded at cage and control sites

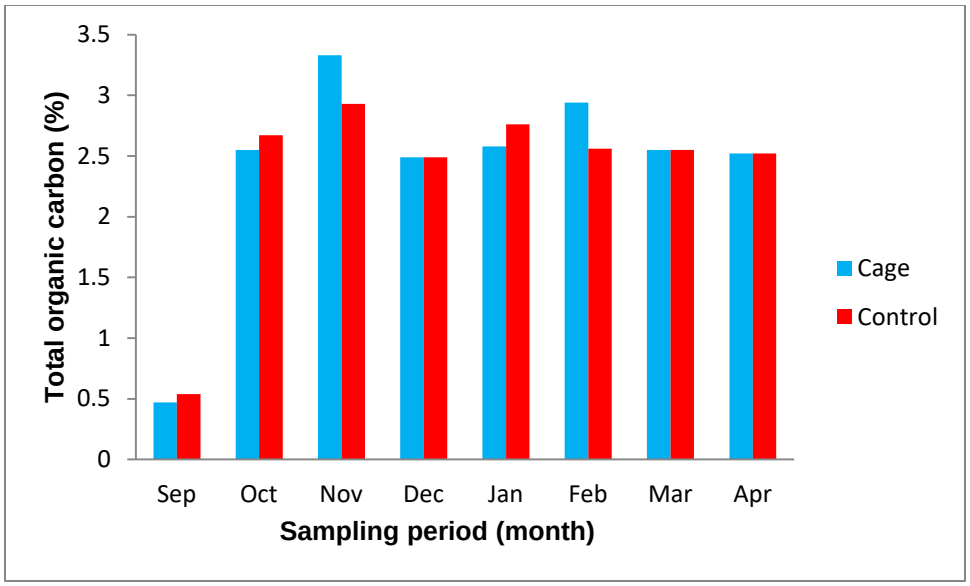

Fig. 4.18. Variation in total organic carbon values recorded at cage and control sites

4.2.4 Total nitrogen (TN)

The total nitrogen values observed in the cage and control site are given in Fig. 4.19. The values of total nitrogen ranged from 0.0054 to 0.0372 % in the cage culture site and from 0.0028 to 0.0616 % in the control site. The average total nitrogen value for cage and control were 0.0185 ± 0.0107 % and 0.0130 ± 0.0198 % respectively. The results of one way ANOVA showed no significant difference existed between the total nitrogen values of cage and control site during the study period ($P>0.05$) and is presented in the Table 4.4.

4.2.5 Available phosphorous (AP)

The available phosphorous values observed in the cage and control site are given in Fig. 4.20. The minimum and maximum values of available nitrogen were 6.14 and 29.85 mg/100g in the cage site and 5.97 and 19.38 mg/100g in the control site. The average available nitrogen value in cage and control were 14.33 ± 8.06 mg/100g and 11.88 ± 5.19 mg/100g. The one way ANOVA

performed with the available phosphorus values of cage and control sites indicated no significant difference during the study period (P>0.05) and is presented in the Table 4.4.

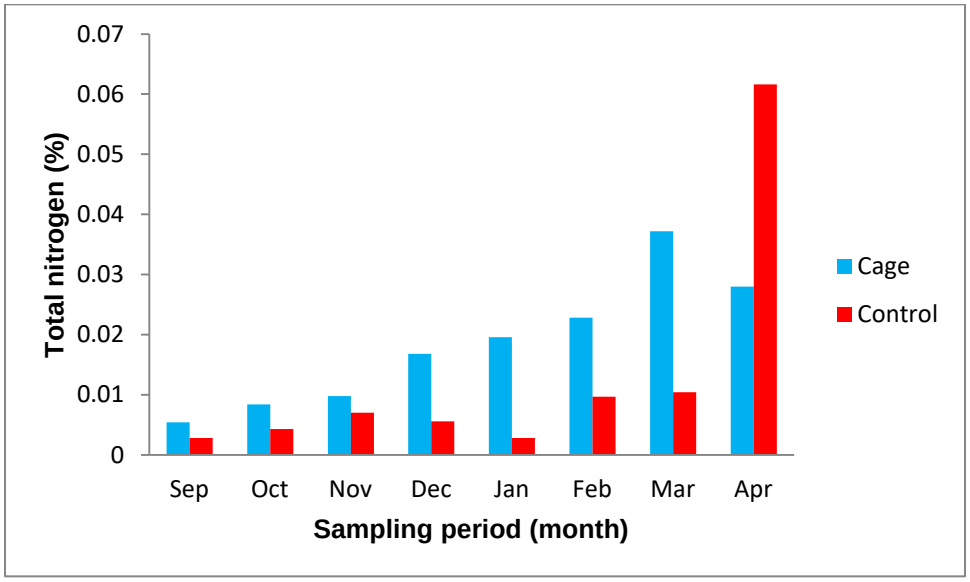

Fig. 4.19. Variation in total nitrogen values recorded at cage and control sites

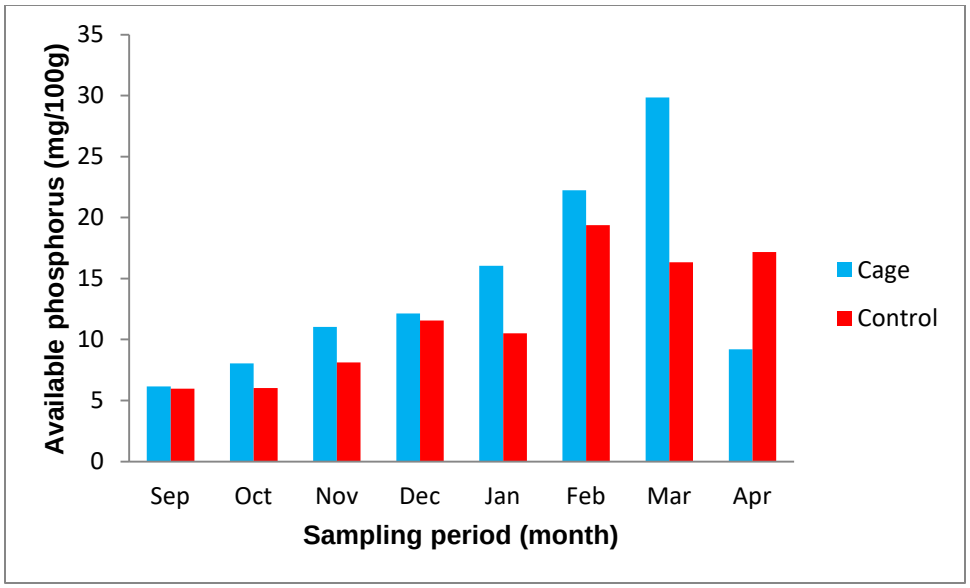

Fig. 4.20. Variation in available phosphorus values recorded at cage and control sites

Table 4.4. ANOVA table for physico-chemical parameters of sediment samples

Physico-chemical parameters	Source of variation	Sum of square	Degrees of freedom	Mean Sum of square	F critical	P value
pH	Between Groups	0.001	1	0.001	0.020	0.889 NS
	Within Groups	0.983	14	0.070		
	Total	0.985	15			
EC	Between Groups	1.482	1	1.482	0.007	0.934 NS
	Within Groups	2941.794	14	210.12		
	Total	2943.276	15			
TOC	Between Groups	0.011	1	0.011	0.016	0.900 NS
	Within Groups	8.984	14	0.642		
	Total	8.995	15			
TN	Between Groups	0.000	1	0.000	0.471	0.504 NS
	Within Groups	0.004	14	0.000		
	Total	0.004	15			
AP	Between Groups	24.044	1	24.044	0.522	0.482 NS
	Within Groups	644.301	14	46.022		
	Total	668.346	15			

Note: ***NS** – Non significant.

4.3 Microbial quality

4.3.1 Total Plate Count

The total plate count observed in the cage and control site are given in Fig. 4.21. The TPC values ranged from $0.01x10^5$ cfu/ml at 1.0 m depth to $3.4x10^5$ cfu/ml at 1.5 m depth in the cage culture site and from $0.01x10^5$ cfu/ml at 1.5 m depth to $1.7x10^5$ cfu/ml at 0.5 m depth in the control site. The results of one way ANOVA indicated that no significant difference existed between the total plate count values of cage and control site during the study period ($P>0.05$) and is presented in the Table 4.5.

4.3.2 Enumeration of *E. coli*

The *E. coli* was undetectable in the cage and control site during the study period.

4.3.3 Enumeration of Streptococci

Faecal streptococci wereundetectable in the cage and control site during the study period.

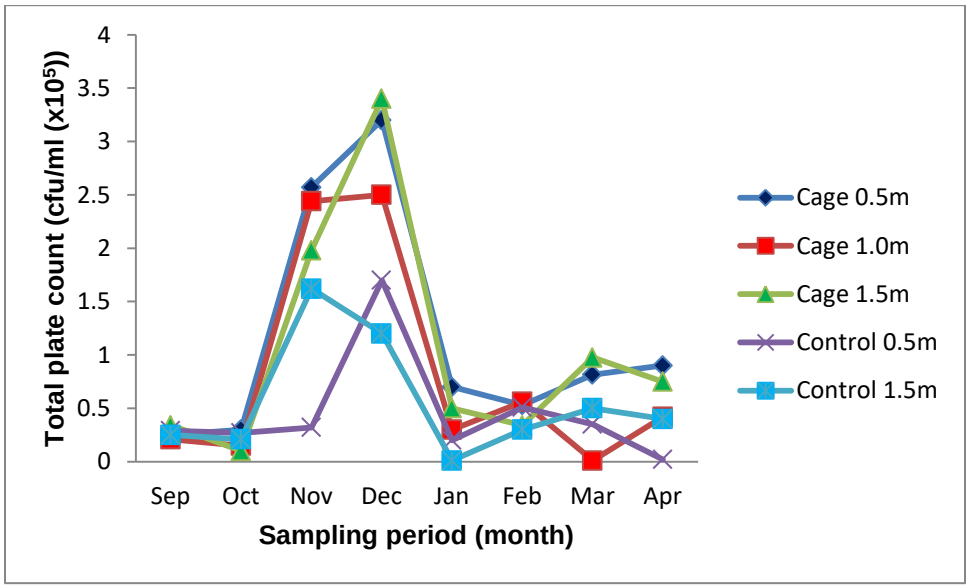

Fig. 4.21. Variation in total plate count values recorded at cage and control sites

Table 4.5. ANOVA table for total plate count in water samples

Source of variation	Sum of square	Degree of freedom	Mean square	F critical	P value
Between Groups	2.914	4	0.728	0.889	0.481 NS
Within Groups	28.680	35	0.819		
Total	31.593	39			

Note: ***NS** – Non significant.

V. DISCUSSION

5.1 Physico-chemical parameters of water sample

5.1.1 Water temperature

In the present study, water temperature values ranged from 26 to 34.9 ºC in cage culture site at Poondi reservoir. The maximum water temperature value of 34.9 ºC was recorded in the month of April, 2015 in cage culture site at 0.5 m depth, which might be due to low water level, high air temperature and clean atmosphere (Thirupathaiah et al., 2012). The minimum temperature of 26 ºC was observed in the cage culture site during the month of November, 2014 at a depth of 1.5 m. The similar observations were made by the following studies. The average temperature of 26.81 ± 1.65 ºC was recorded in Nile tilapia cage culture (Jiwyam, 2012). Nyanti et al. (2012) reported the temperature of 25.2 to 32.2 ºC in the cage culture site of Batang Ai Hydroelectric dam reservoir, Malaysia. In tilapia cage culture system, temperature ranged from 27.8 to 28.1 ºC (Gorlach-Lira et al., 2013). Dasuki et al. (2013) also reported a range of water temperature from 24.5 to 32.6 ºC in Kubanni reservoir, where African catfish cage culture had been practiced. In the present study, a negative correlation was noticed between temperature and

depth (r = -0.201) and the temperature decreased towards the depth. There is no significant difference between the values of water temperature at cage and control sites.

5.1.2pH

In the present study, pH values ranged from 7.53 to 8.94 and found within the desirable range for fish culture system.

Similar observations were made by the Tamot et al. (2008), where the pH values ranged from 7.8 to 8.8 in Halali reservoir. Dasuki et al. (2013) also observed similar pH values in the Kubanni reservoir. In red tilapia cage culture system, pH values ranged from 6.3 to 8.7 in Tasik Kenyir reservoir, Malaysia (Siti-zahrah et al., 2008). Lucas and Southgate (2012) suggested the desirable range of pH value for tilapia culture ranges from 6.5 to 8.5. In the present study, the pH values were found to decrease with depth as also reported by Nyanti et al. (2012). The pH value was slightly alkaline throughout the study period, which is most favourable for fish culture and there is no significant difference between the pH values at cage and control sites. There is a negative correlation between the values of pH and depth (r = -0.017) in the present study.

5.1.3 Dissolved oxygen (DO)

In the present study, the DO values ranged from 4.00 to 6.00 mg/l. Nyanti et al. (2012) reported the range of DO values from 0.26 to 8.45 mg/l in the Batang Ai Hydroelectric dam reservoir, Sarawak, Malaysia. The minimum DO value (4 mg/l) was observed at 1.5 m depth both in the cage and control sites. This might be due to the decomposition of organic matter and limited flow of water towards the depth. The higher DO value might be due to mixing of water by heavy wind action (Tamot et al., 2008). There is a negative correlation between the value of dissolved oxygen and depth (r = -0.461) in the present study and there is no significant difference between the values at cage and control sites.

5.1.4 Salinity

In the present study, the salinity values ranged from 0.1 to 0.3 ppt and within the desirable range for freshwater fish culture. The maximum salinity value was observed in the month of February, 2015 and the lower was observed in the month of November, 2014. There is a negative correlation between the values of salinity and depth (r = -0.037) in the present study, which might be due to the increase in temperature at the surface water. There is no significant difference in the salinity values between the cage and control sites.

5.1.5 Hardness

The hardness values of 80 to 150 mg/l were reported in cage culture at Halali reservoir (Tamot et al., 2008). It ranged from 200 to 231 mg/l in Odathurai reservoir (Murugesan et al., 2005). In the present study, the hardness values ranged from 49.04 to 260.26 mg/l as $CaCO_3$ in Poondi reservoir and these values are slightly higher than the previous reports. The higher hardness value of 183.75 mg/l was reported by Thirupathaiah et al. (2012) in lower Manair reservoir of Andhra Pradesh during rainy season. But in contrast to the above report, in the present study, lower value of 80 mg/l was reported in the month of April, 2015 may be due to pre-monsoon showers. The maximum hardness value of 150 mg/l was observed in the month of October, 2014 in control site at 1.5 m depth. There is a negative correlation between the values of hardness and depth (r = -0.037) in the cage culture site and positive correlation (r= 0.018) in the control site during the present study. There is no significant difference between the hardness values of hardness at the cage and control sites.

5.1.6 Alkalinity

In the present study, the alkalinity values ranged from 14 to 160 mg/l. The similar results were observed by Murugesan et al. (2005) in Odathurai reservoir, Tamot et al. (2008) in Halali reservoir and Sugunan (2011) in Indian reservoirs. Mondal et al. (2010) reported the average alkalinity value of 142.27 mg/l in the tilapia cage culture system. Sarkar (2011) reported the alkalinity values of Indian reservoirs between 40 and 150 mg/l. In the present study, there is no significant difference between the values of alkalinity at the cage and control sites. The minimum alkalinity value of 14 mg/l was observed in the month of January, 2015 in cage culture site at 0.5 m depth and the maximum value (160 mg/l) was observed in the month of October, 2014 at 1.5 m depth. Lucas and Southgate (2012) suggested that the alkalinity value higher than 20 mg/l is suitable for tilapia cage culture. There is a positive correlation between the values of alkalinity and depth (r = 0.115) in the cage culture site and negative correlation (r= -0.045) in the control site during the present study. This might be due to the inflow of rain water at control site.

5.1.7 Ammonia-N

In the present study, ammonia values ranged from 0.0010 to 1.1800 µg at. NH_3-N/l and the values were found slightly lower than the previous reports (Jiwyam, 2012; Nyanti et al., 2012; Gorlach-Lira et al., 2013; Nsonga, 2014). Zanatta et al. (2010) reported the slightly lower (0.052µg/l) ammonia concentration in tilapia cage culture at Jurumirim reservoir, Brazil. During the study period, the higher concentration of ammonia was found at the cage site than the control site, which might be due to the excretion of waste in the cage culture site.

There is a positive correlation between the values of ammonia and depth (r = 0.251) in the cage culture site, as evidenced from the increased ammonia concentration towards the depth. This might be due to uneaten feed and faecal deposits through the water column into the

sediment. But in the control site, negative correlation (r= -0.076) was observed between the ammonia concentration and depth.

5.1.8 Nitrite- N

In the present study the nitrite concentration ranged from 0.0080 to 0.9285 µg at. $N0_2$-N/l and these values were found slightly lower than the earlier reports in Tasik Kenyir reservoir in Malaysia (Siti-zahrah et al., 2008), sub-tropical reservoir in Brazil (Zanatta et al., 2010), in the tilapia cage culture site in Thailand (Mondal et al., 2010), the Nova Avanhandava reservoir, Brazil (Mallasen et al., 2012) and the reservoir in Padre Azevedo in Brazil (Gorlach-Lira et al., 2013).During the study period, slightly higher nitrite concentration (0.9285 µg at.$N0_2$-N/l) was observed in the control site than the cage site and there is no significant difference between the values of nitrite at the cage and control sites. There is a positive correlation noticed between the nitrite concentration and depth (r = 0.048) in the present study.

5.1.9 Nitrate-N

In the present study, the nitrate concentration ranged from 0.0035 to 0.0912 µg at. $N0_3$-N/l and this value was slightly lower than the earlier reports in theJurumirim reservoir, Brazil (Zanatta et al., 2010), Indian reservoirs (Sugunan, 2011), the Manair reservoir (Thirupathaiah et al., 2012) and Nova Avanhandava reservoir, Brazil (Mallasen et al., 2012).

The nitrate values were found slightly higher at cage site compared to control site, which might be due to the feeding activity. However, minimum nitrite value observed at cage culture site during the study period could be due to the conversion of nitrite to nitrate. The maximum concentration observed in the month of December, 2014, might be due to the excess inflow of water during the rainy season (Rao, 2011). There is a positive correlation between the nitrate concentration and depth (r = 0.291).

5.1.10 Phosphate- P

In the present study, the phosphate concentration ranged from 0.7798 to 2.9173 µg at. PO_4-P/l and the values were similar to the earlier reports in the Padre Azevedo reservoir, Brazil (Gorlach-Lira et al., 2013) and Nova Avanhandava reservoir, Brazil (Mallasen et al., 2012). The lower phosphate concentration was observed in the month of December, 2014 in the control site at 1.5 m depth. Garg et al. (2010) reported that the availability of phosphate in Indian reservoirs is very low and rarely exceeds 0.1 mg/l, except for a shorter period during monsoon season. The higher concentration was observed in the month of October, 2014 in the control site at 1.5 m depth. This might be due to the accumulation of decomposed solid waste through rainwater (Kelly 1992; 1993). There is a positive correlation between the phosphate concentration and depth ($r = 0.168$) in the present study.

5.1.11 Sulfate

In the present study, the sulfate value ranged from 0.0011 to 1.2340 mg/l. According to Boyd (1998), 5 to 100 mg/l sulfate is desirable for the freshwater aquaculture systems.

The lower level of sulfate value was observed in control site at 0.5 m depth. The higher sulfate value was observed in the month of November, both in cage and control sites, which might be due to heavy rainfall and the runoff from different sources might have added some concentration of sulfate to the water column. There is a positive correlation between sulfate and depth ($r = 0.094$). In the present study, the sulfate level was found within the prescribed limit of less than 200 mg/l for drinking water (BIS, 2003) and the water is considerably good for drinking purpose. There is no significant difference between the sulfate values at the cage and control sites.

5.1.12 Chemical oxygen demand (COD)

In the present study, the COD values ranged from 8.00 to 75 mg/l and this value was slightly higher than the report of Garget al. (2010) in the Ramsagar reservoir. There is only limited reports are available on the COD values at cage sites with respect to freshwater systems. The higher COD value was observed in the cage site than the control site might be due to the increase in the organic matter (Boyd, 1981). There is no significant difference between the COD values at the cage and control sites.

5.1.13 Biological oxygen demand (BOD)

In the present study, the BOD values ranged from 0.3 to 3.05mg/l and the value was slightly higher than the earlier reports by Yee et al. (2001) and Nyanti et al. (2012). The similar result was reported by Mondel et al. (2010) in tilapia cage culture in Thailand. The maximum BOD value was observed in the month of April, 2015 month in the cage site at 0.5 m depth.

This might be due to the maximum temperature during the summer season leading to favourable environmental conditions for microbiological activities (Tamot et al., 2008). There is no significant difference between the BOD values the cage and control sites. There is a positive correlation between biological oxygen demand and depth (r = 0.273) in the present study.

5.1.14 Total suspended solids (TSS)

In the present study, the TSS value ranged from 0.00 to 0.72 mg/l. The lower TSS value reported in the month of March, 2015 in cage culture site at a depth of 1.0 m. The higher value was observed during April, 2015 in the cage site at 0.5 m depth. This might be due to the increased suspended matter. There is a negative correlation between total suspended solids and depth (r = -0.148) in the present study. The higher TSS value found at cage site and there is no significant difference between the cage and control sites.

5.1.15 Total dissolved solids (TDS)

In the present study, the TDS value ranged from 0.12 to 0.81 mg/l. The lower value of TDS was observed in the month of January, 2015 in cage site at 1.5 m depth. The higher value was observed during the November, 2014 in the control site at 0.5 m depth. Sawant and Chavan (2013) reported the maximum TDS value of 172.66 mg/l during summer season owing to loss of water due to heat and concentration of salts present in water at the Mahagaon reservoir from Maharastra. The present result indicated the lower value at summer season and higher value at winter season.

There is a negative correlation between TDS value and depth($r = -0.077$) in the present study and there is no significant difference between the cage and control sites.

5.2 Sediment characteristics

5.2.1 pH

Sediment pH values ranged from 7.07 to 7.90 in the present study and this is within the permissible limit for fish culture (Pandey et al., 2013). The minimum pH value was observed at cage culture site. This might be due to the decomposition of organic matter which leads to reduction in the sediment pH under anaerobic condition (Roshan, 2009; Pandey et al., 2013). Sugunan (2011) reported that the pH values of Indian Reservoirs ranged from 6.0 to 8.8. There is no significant difference between the values of pH at the cage and control sites.

5.2.2 Electrical conductivity (EC)

The EC values ranged from 2.81 to 55.99 mS/cm in the present study. The lower EC value observed at cage site, this might be due to the dilution of ions present in the water and decreased dissolved solids (Mallasen et al., 2012). The higher EC value observed at cage culture might be

due to feed and faecal matter at cage site. There is no significant difference between the EC values at cage and control sites.

5.2.3 Total organic Carbon (TOC)

In the present study, the TOC values ranged from 0.47 to 3.33%. The similar values were observed by Sugunan (2011) in Indian reservoirs.

The maximum TOC value was observed in the cage site than control site which due to the increased organic matter in the cage site. There is no significant difference between the values of TOC at the cage and control sites.

5.2.4 Total Nitrogen (TN)

During the present study, total nitrogen values ranged from 0.0028 to 0.0616%. Similar result was reported in tilapia cage culture system in Khon Kaen reservoir, Thailand (Jiwyam and Chareontesprasit, 2001) and in Kesikkopru reservoir, Turkey (Alpaslan and Pulatsu, 2008). The nitrogen content of the sediment is often used as a good indicator of sediment enrichment, due to the fact that this is mostly derived from external inputs (CSIRO 2000, Telfer and Robinson, 2003). Drusilla et al., (2009) reported the high nitrogen value during monsoon might be due to agricultural runoff and also due to low adhesion of nitrates to inorganic contents of sediments. In the present study, the total nitrogen value was slightly higher at control site than the cage site, but there is no statistical difference between the cage and control sites.

5.2.5 Available Phosphorus (AP)

In the present study, the available phosphorus value ranged from 5.97 to 29.85 mg/100g. The available phosphorus value should be in the range of 4.7 to 6.2 mg/100g for high biological productivity (Garg et al., 2010). Sugunan (2011) also reported the AP value of Indian reservoirs

ranged from 0.47 to 6.2 mg/100g. In the present study, the higher phosphorus value was found at cage culture site, which might be due to the fish wastes and unconsumed feeding stuff (Jiwyam and Chareontesprasit, 2001). Holmer et al. (2002) found large accumulation of phosphorous in the sediment nearby milkfish cage farm in moderately shallow water.

There is no significant difference between available phosphorus values of cage and control sites during the present study.

5.3 Microbial Quality

5.3.1 Total microbial load

In the present study, total plate count (TPC) values ranged from $0.01x10^5$ to $3.4x10^5$ cfu/ml in the cage culture site and from $0.01x10^5$to $1.7x10^5$ cfu/ml in the control site. There is no significant difference between total microbial load at the cage and control sites during the present study.

5.3.2 *E. coli*

In the present study, *E. coli* was undetectable in the water samples throughout the study period. As per the BIS, 2003 standard *E. coli* should be zero for drinking purpose and Poondi reservoir water is found safe for drinking purpose.

5.3.3 Faecal streptococci

In the present study, faecal streptococci were undetectable, which indicates the reservoir water is safe for drinking purpose.

Since cage culture development is in its infancy stage in India, very little is known about the impact of cage culture on the environment and limited reports are available. It is clear that only the mass input of exogenous nutrients may cause negative effect on water quality. The cage

culture activity with the minimum number of cages (12 numbers) for short term duration does not have noticeable impact over the water quality at cage sites, but the long term effects are need to be monitored for the sustainability of cage farming.

The overall optimum physico-chemical properties of water and sediment in the reservoirs coupled with absence of *E. coli* and streptococci clearly indicates that the small cage farming units do not have major environmental impact on the water and sediment quality of the reservoirs.

VI. SUMMARY AND CONCLUSION

The present investigation was carried out in Poondi reservoir, Thiruvallur district Tamilnadu to assess the water and sediment quality characteristics at the cage and control sites, wherein cage culture has been already initiated by the State Fisheries Department. The water samples were collected once in fifteen days at 0.5 m, 1.0 m and 1.5 m depths in the cage site and 0.5 m and 1.5 m depths in the control site. This study was carried out for a period of 8 months from September, 2014 to April, 2015.

The minimum and maximum water temperature values of 26 and 34.9 ºC noticed during the study period. However, the high temperature in the cage site might be due to summer season. The pH value was slightly alkaline (7.53 to 8.94) throughout the study period, which is most favourable for fish culture. The dissolved oxygen values ranged from 4 to 6 mg/l and the minimum was found at 1.5 m depth, which could be due to the decomposition of organic matter and limited flow of water at deepest region. The values of temperature, pH and salinity showed negative correlation towards the depth. The salinity values ranged from 0.1 to 0.3 ppt at cage culture sites and from 0.1 to 0.25 ppt at control sites. The minimum and maximum hardness

values of 53.05 and 244.24 mg/l as $CaCO_3$ were noticed in the cage culture site and 49.04 and 260.26 mg/l as $CaCO_3$ were observed in the control site and the water is found slightly alkaline. The alkalinity values ranged from 14 to 160 mg/l in cage culture sites and from 16 to 140 mg/l in the control sites. In the present study, the higher concentration of ammonia was found at the cage site than the control site, which might be due to the excretion of waste in the cage culture site.

Nitrite values ranged from 0.0201 µg at. NO_2-N/l to 0.8208 µg at.NO_2-N/l in the cage site and from 0.0184 µg at.NO_2-N/l to 0.9285 µg at. NO_2-N/l in the control site and the values were found slightly higher at control site. The nitrate values were found to be higher (0.0912 µg at. NO_3-N/l)at cage site when compared to the control site, this might be due to the feeding activity. Phosphate values ranged from 0.7798 to 2.9173 µg at. PO_4-P/l both at cage and control site. The higher concentration observed at control site might be due to inflow of rain water, which carries nutrients. The sulfate values ranged from 0.0015 to 1.2340 mg/l in the cage culture site and from 0.0011 to 0.808l mg/l in the control site, and the values were found within the limit prescribed by BIS (2003) for fish culture and drinking purpose. The high COD value (75.00 mg/l) was observed at cage site than the control site, might be due to the increase in the organic matter. The high BOD values (3.05 mg/l) at cage culture site might be due to the high temperature during the summer season leading to the favourable environmental conditions for microbiological growth which could consume the oxygen. The total suspended solids values ranged from 0.00 to 0.72 mg/l in the cage site and from 0.01 to 0.52 mg/l at control site. The maximum value of total dissolved solids (0.81 mg/l) observed at control site, might be due to increase in the salt content during summer season.

In the sediment samples, pH values ranged from 7.07 to 7.9 in the cage culture site and from 7.08 to 7.81 in the control site. The low pH value observed at cage culture site could be due to

the decomposition of organic matter at the bottom of the cage. The high EC value (55.99 mS/cm) was noticed in the cage culture site than control site. The values of total organic carbon ranged from 0.47 to 3.33% in the cage culture site and from 0.54 to 2.93% in the control site.

The higher TOC value observed at cage site might be due to the increased organic matter. The values of total nitrogen ranged from 0.0054 to 0.0372% in the cage culture site and from 0.0028 to 0.0616% in the control site. The high amount of TN in control site might be due to the excess deposition of organic load brought by rain water inflow. The higher phosphorus value (29.8524 mg/100g) was observed at cage culture site, which might be due to the feed stuff in the cage culture site. The total plate count ranged from $0.01x10^5$ to $3.4x10^5$ cfu/ml at cage culture site and from $0.01x10^5$ to $1.7x10^5$ cfu/ml at control site. The high TPC value was observed in the cage site might be due to the influence of rain water and availability of nutrients at cage site. The *E. coli* and faecal streptococci count was undetectable at cage and control sites.

The physico–chemical parameters of reservoir water was found within the desirable limit as recommended by the Bureau of Indian Standards, 105000 (BIS, 2003) for fish culture, irrigation and drinking water. This study clearly showed that the small cage farming in the reservoir does not have major environmental impacts on the water and sediment quality. It is clear that only the mass input of exogenous nutrients may cause negative effect on water quality. The cage culture activity with the minimum number of cages (12 numbers) for short term duration does not have noticeable impact over the water quality at cage sites, but the long term effects are needed to be monitored for the sustainability of cage farming.

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Table 4.2. Correlation between water quality parameters in cage culture site

	Depth	Temp	pH	Salinity	Hard	Alk	NH_3	NO_2	NO_3	PO_4	SO_4^{2-}	DO	COD	BOD	TSS	TDS
depth	1															
Temp	-0.201	1														
pH	-0.017	0.228	1													
Salinity	-0.037	0.384	0.764**	1												
Hard	-0.037	-0.101	-0.168	-0.356	1											
Alk	0.115	0.049	0.310	-0.034	0.664**	1										
NH_3	0.251	-0.601**	-0.268	-0.084	-0.173	-0.444*	1									

NO_2	0.048	0.401	-0.075	0.347	-0.281	-0.249	0.078	1								
NO_3	0.291	-0.769**	0.083	-0.008	-0.230	-0.203	0.748**	-0.291	1							
PO_4	0.168	-0.610**	-0.190	-0.470*	0.128	0.331	0.021	-0.214	0.364	1						
SO_4^{2-}	0.094	-0.064	-0.243	-0.344	-0.248	-0.035	0.086	0.418*	0.067	0.364	1					
DO	-0.461*	-0.357	-0.269	-0.402	0.033	-0.122	-0.091	-0.143	0.131	0.597**	0.185	1				
COD	0.010	0.352	0.408*	0.296	-0.284	0.014	-0.222	0.028	-0.108	-0.163	-0.155	-0.104	1			
BOD	0.273	0.017	-0.642**	-0.160	-0.108	-0.384	0.318	0.490*	-0.083	-0.078	0.208	-0.175	-0.393	1		
TSS	-0.148	-0.033	-0.179	0.095	-0.553**	-0.408*	0.274	0.256	0.219	0.100	0.321	0.141	-0.015	0.464*	1	
TDS	-0.077	0.186	-0.160	-0.139	-0.262	-0.116	-0.071	0.571**	-0.202	0.110	0.808**	0.128	-0.206	0.201	0.123	1

Temp - Temperature; Hard - Hardness; Alk – Alkalinity

*. Correlation is significant at the 0.05 level

**. Correlation is significant at the 0.01 level

Table 4.3. Correlation between water quality parameters in the control site

	Depth	Temp	pH	Salinity	Hard	Alk	NH_3	NO_2	NO_3	PO_4	SO_4^{2-}	DO	COD	BOD	TSS	TDS
depth	1															
Temp	-0.169	1														
pH	-0.027	0.361	1													
Salinity	-0.009	0.280	0.857**	1												
Hard	0.018	-0.050	-0.292	-0.342	1											
Alk	-0.045	0.107	0.357	0.059	0.567*	1										
NH_3	-0.076	-0.439	-0.496	-0.333	-0.256	-0.347	1									
NO_2	0.031	0.505*	0.059	0.226	-0.187	-0.157	0.321	1								
NO_3	0.027	-0.585*	0.128	-0.132	-0.160	0.082	0.218	-0.423	1							
PO_4	0.075	-0.285	-0.153	-0.416	0.291	0.414	0.038	-0.103	0.374	1						
SO_4^{2-}	0.002	-0.026	-0.269	-0.355	-0.241	0.00007	0.703**	0.588*	0.167	0.347	1					
DO	-0.300	0.146	0.053	-0.009	-0.545*	-0.503*	-0.275	-0.219	0.046	0.034	-0.207	1				
COD	0.274	0.328	0.329	0.041	0.226	0.515*	-0.295	0.198	0.097	0.227	0.184	-0.305	1			
BOD	0.197	0.147	-0.268	0.127	-0.446	-0.797**	0.166	0.391	-0.552*	-0.505*	-0.025	0.301	-0.419	1		
TSS	$-1.2x10^7$	-0.379	-0.324	-0.188	-0.124	-0.108	0.815**	0.481	0.137	0.240	0.773**	-0.362	-0.130	0.136	1	
TDS	-0.007	-0.103	-0.326	-0.282	-0.396	-0.278	0.675**	0.565*	0.116	0.180	0.873**	-0.009	0.066	0.203	0.682**	1

Temp - Temperature; Hard - Hardness; Alk – Alkalinity

*. Correlation is significant at the 0.05 level

**. Correlation is significant at the 0.01 level

.