

PERFORMANCE COMPARISON OF *CYPRINUS CARPIO* (LINNAEUS, 1758) POPULATIONS REARED IN INLAND SALINE WATERS AT VARYING SALINITIES

Dissertation submitted in partial fulfillment of the requirements for the
degree of

M.F.Sc. (Fish Genetics and Breeding)

by

PHIBI PHILIP NADUVATHU, B.F.Sc

(FGB-MA7-03)

ICAR-CENTRAL INSTITUTE OF FISHERIES EDUCATION
(Deemed-to-be University Established Under Section 3 of UGC Act 1956)

**Panch Marg, Off Yari Road, Versova,
Andheri (W), Mumbai – 400 061**

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DEDICATION



Dedicated to all fish farmers

&

aquaculture professionals



भारतीय कृषि अनुसंधान परिषद
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(वि. अ. आ. अधिनियम धारा-3 के अंतर्गत विश्वविद्यालय)

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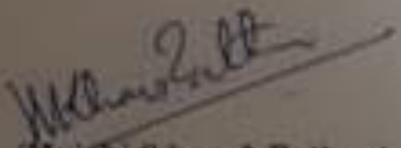
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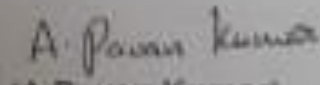
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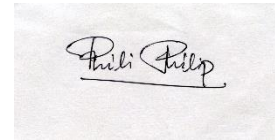

(Mujahidkhan A Pathan)
Scientist
FGB Division
ICAR-CIFE
Mumbai-61


(A Pavan Kumar)
Senior Scientist
FGB Division
ICAR-CIFE
Mumbai-61


(Satya Prakash)
Scientist
AQG Division
ICAR-CIFE
Mumbai-61

DECLARATION

I hereby declare that the dissertation entitled “**PERFORMANCE COMPARISON OF *CYPRINUS CARPIO* (LINNAEUS, 1758) POPULATIONS REARED IN INLAND SALINE WATERS AT VARYING SALINITIES**” is an authentic record of the work done by me and that no part thereof has been presented for the award of any degree, diploma, associateship, fellowship or any other similar title.

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Date: 30/08/2020

(Phibi Philip Naduvathu)

Place: Mumbai

M.F.Sc. Student

ICAR-Central Institute of Fisheries Education

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What makes life valuable is that it doesn't last forever and what makes it precious is that it ends. I realise that now more than ever and I say it today, to remind us that time is luck. Don't waste it living someone else's life. Make it count for something good. Fight for what matters to you, no matter what. It is easy to feel hopeful on a fine beautiful day, but there may be dark days ahead. There may come days where we feel all alone and that is when hope is needed the most. No matter how buried it gets or how lost we feel, we must promise to everyone who loves us that we will hold on to hope. Keep it alive. We have to be greater than what we suffer. My personal wish for everyone is to become hope. People need that! Even if we fail, what better way is there to live? Following words are never enough to express my sincere gratitude towards all those who were there for me in times of need and became a part of my life.

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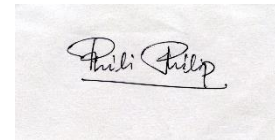
There are some blessed souls who really stood by my side and helped me to move on in life; **Sathiyarayanan, Vijay, Husain and Hafeef Roshan**; all I could say is that “God bless you abundantly”. I also want to express my unfalling affection and gratitude to **Paul Nathaniel, Bharathi S, Akash, Abu, Shahana, Kathiresan, Susitharan, Sona, Meharoof, Siju, Rameez Roshan, Velumani, Arul, Safna, Silpa, Thushar, Vishnu Nair, Syam, Srihari, Bharathi Rathinam, Sangavi** for your kind concern, care and affection.

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A rectangular image showing a handwritten signature in black ink on a light-colored background. The signature is written in a cursive style and reads "Phibi Philip".

Phibi Philip Naduvathu

सार

भारत में, लगभग 6.74 मिलियन हेक्टेयर भूमि मृदा लवणता की समस्या से बुरी तरह प्रभावित हुई है और 1.93 मिलियन किमी² क्षेत्र भू लवणीय जल से भरा हुआ है। जलीय कृषि गतिविधियों में अंतर्देशीय खारा भूजल का उपयोग करने के लिए उपयुक्त प्रौद्योगिकियों का विकास, भारत की राष्ट्रीय प्राथमिकताओं में से एक है। कॉमन कार्प, साइप्रिनस कार्पियो (लिनिअस, 1758), दुनिया के जलीय कृषि में तीसरी सबसे अधिक उत्पादित मछली है और इसे लवणता और ठंड को सहन करने के लिए जाना जाता है। हालांकि, अंतर्देशीय खारे पानी में कॉमन कार्प के वृद्धि क्षमता के अध्ययन दुर्लभ हैं। इसलिए, वर्तमान अध्ययन में कॉमन कार्प के तीन भौगोलिक स्टॉकों, आंध्र प्रदेश, कर्नाटक और तमिलनाडु के शुरुआती विकास प्रदर्शन का मूल्यांकन दो खारेपन स्तरों; कम खारा और उच्च खारा पे किया गया;। प्रारंभिक विकास प्रदर्शन का अध्ययन करने के लिए शरीर का वजन (BW), मानक लंबाई (SL) और शरीर की गहराई (BD) जैसे लक्षणों को दर्ज किया गया। संवर्धन के 1, 15 वीं, 30 वीं और 45 वीं दिन पर नमूने लिए गए थे। तीन स्टॉकों में से, कर्नाटक के स्टॉक ने सबसे अच्छा प्रदर्शन किया, इसके बाद तमिलनाडु का स्टॉक रहा। कर्नाटक स्टॉक ने क्रमशः 66.72 ± 1.1 ग्राम, 21.70 ± 0.43 सेमी और 7.37 ± 0.14 सेमी का औसत BW, SL और BD प्राप्त किया। दो खारेपन के बीच, कम खारे तालाबों में पाले गए स्टॉकों ने उच्च खारे तालाबों में पाले गए स्टॉकों की तुलना में बेहतर प्रदर्शन किया। कम खारेपन पर पाले गए कार्प स्टॉक का औसत BW, SL और BD क्रमशः 16.69 ± 0.41 ग्राम, 9.05 ± 0.16 सेमी और 2.88 ± 0.05 सेमी था। विभिन्नता और खारेपन के प्रभाव को समझने के लिए 19 मापदंडों वाले मॉर्फोमेट्रिक अध्ययन का भी उपयोग किया गया। तीन मॉर्फोमेट्रिक पैरामीटर सिर की लंबाई, आंखों का व्यास और फ्री ऑर्बिटल लंबाई; कम खारे पानी की तुलना में उच्च खारे पानी में पाले जाने वाले मछली के स्टॉकों में काफी अधिक थी। हालांकि, कॉमन कार्प में लवणता के प्रभाव को कम करने के लिए और अधिक अध्ययन किए जाने की आवश्यकता है। कुल लंबाई के साथ सभी आकार के मापदंडों का सह-संबंध अनुमान लगाया गया और यह पाया गया कि सभी आकार के मापदंडों का कुल लंबाई के साथ सकारात्मक रूप से सह-संबंध था; 8 पैरामीटर अत्यधिक सह-संबद्ध (आर > 0.9) थे, अन्य 8 मध्यम रूप से सहसंबद्ध (आर and 0.6 और < 0.9) थे और दो काफी कम सह-संबंधित थे (आर < 0.5)। अध्ययन का निष्कर्ष है कि कर्नाटक कार्प (आमुर) का स्टॉक हरियाणा के क्षेत्रों में अंतर्देशीय लवण जलीय कृषि के लिए एक अच्छा उम्मीदवार प्रजाति है। आणविक कार्य और लंबी अवधि के अध्ययन जनसंख्या आधारित प्रदर्शन भिन्नता और सामान्य कार्प में लवणता के प्रभाव के रूप में अनुकूली परिवर्तनों पर अधिक अंतर्दृष्टि और व्यापक समझ प्रदान करेंगे।

ABSTRACT

In India, nearly 6.74 million ha of land has been severely affected by the problem of soil salinity and 1.93 million km² area is laden with ground saline water. The development of suitable technologies, to utilise the inland saline groundwater for aquaculture activities, is one of the national priorities of India. Common carp, *Cyprinus carpio* (Linnaeus, 1758), is the third most-produced fish in world aquaculture and is known to exhibit salinity and cold tolerance. However, growth performance studies of common carp in inland saline water are scarce. Hence, the present study evaluated early growth performance of three geographical stocks of common carp viz; Andhra Pradesh, Karnataka and Tamil Nadu at two salinities namely, low saline (4 ± 2 ppt) and high saline (8 ± 2 ppt). Traits viz; body weight (BW), standard length (SL) and body depth (BD) were recorded to study the early growth performance. Sampling were done at 1st, 15th, 30th, and 45th days of culture age. Amongst the three stocks, the Karnataka stock performed the best, followed by Tamil Nadu stock. The Karnataka stock attained a mean BW, SL and BD of 66.72 ± 1.1 g, 21.70 ± 0.43 cm and 7.37 ± 0.14 cm, respectively. Among the two salinities, the stocks reared in low saline ponds performed better than the stocks raised in high saline ponds. The mean BW, SL and BD of common carp stocks reared at low saline was 16.69 ± 0.41 g, 9.05 ± 0.16 cm and 2.88 ± 0.05 cm respectively. The morphometric study having 19 parameters was also conducted to understand the variation and effect of salinity. The three morphometric parameters viz; head length, eye diameter and pre-orbital length were significantly higher in fish stocks reared in high saline waters than in low saline waters. The correlation of all morphometric parameters with total length was estimated and it was found that all the morphometric parameters were positively correlated with total length; 8 parameters were highly correlated ($r > 0.9$), another 8 were moderately correlated ($r \geq 0.6$ and < 0.9) and two were least correlated ($r < 0.5$). The study concludes that the Karnataka stock (Amur) of common carp is a good candidate species for inland saline aquaculture in the areas of Haryana. Molecular works and longer duration studies would provide more insights and wider understanding on the population-based performance variation and adaptive changes as an effect of salinity in common carp.

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Introduction

1. INTRODUCTION

The global fish production is estimated to have reached about 179 million tonnes in 2018, with a total first sale value estimated at USD 401 billion, of which 82 million tonnes, valued at USD 250 billion, came from aquaculture production (FAO, 2020). Aquaculture accounted for 46 percent of the total production and 52 percent of fish for human consumption. Inland aquaculture produced most farmed fish (51.3 million tonnes, or 62.5 percent of the world total), mainly in freshwater, compared with 57.7 percent in 2000 (FAO, 2020). India is the second largest aquaculture producing nation with an estimated overall production of 6.68 million tonnes, which constitutes 53% of the nation's total fish production (FAO, 2019).

Inland saline aquaculture is defined as land-based aquaculture using saline groundwater and is practised in several countries *viz.*, Australia, China, Egypt, Iraq, Mexico, USA, Pakistan, Turkey and India (Roy and Davis, 2010; Crespi *et al.*, 2011; Jarwar, 2014). Globally, species like *Penaeus vannamei*, *P. japonicus*, *P. monodon*, *Dunaliella salina* (algae) and *Crassostrea gigas* (oyster) are successfully being reared under inland saline aquaculture. In India, nearly 6.74 million ha of land has been severely affected with the problem of soil salinity and 1.93 million km² area is laden with ground saline water. These salt-affected lands are mainly spread over the states of Rajasthan, Haryana, Punjab, Gujarat, Uttar Pradesh, Delhi, Andhra Pradesh, Maharashtra, Karnataka and Tamil Nadu (Singh *et al.*, 2019; CSSRI, 2011). The development of suitable technologies for the utilisation of inland saline groundwater and inland saline soils is one of the national priorities of India (Lakra *et al.*, 2014). Salt tolerant freshwater fish species such as tilapia (*Oreochromis niloticus*), goldfish (*Carassius auratus*), riverine catfish (*Pangasianodon hypophthalmus*) etc have been tested as candidate species for inland saline aquaculture (Bhat *et al.*, 2018; Garg & Bhatnagar. 2016; Kumar *et al.*, 2017).

Common carp (*Cyprinus carpio*), is one of the most economically important freshwater species for aquaculture in the world. As one of the dominant cyprinid species, it is cultured in over 100 countries worldwide (FIGIS, 2013) and is fourth major species

produced in world after grass carp, silver carp and Nile tilapia. It accounts to 7.7 percent of total aquaculture production in 2018 (FAO, 2020). Common carp, in India, is cultured across the country and accounts for a major bulk of carp seeds produced by state hatcheries. The common carp stocks in India are thought to have originated from two introductions, in 1939 (“German” strain) and 1957 (“Bangkok” strain) (Jhingran, 1991), which have been subsequently mixed over many generations (Ayyappan *et al.* 2013). Common carp can be bred during most of the year, and thus seed production can be matched to demand, which varies according to rainfall pattern. Even though the common carp is bred all over India there is no genetic selection program to improve this species.

Common carp, though predominantly a freshwater fish is even seen in brackish waters (Riede, 2004). It is known to exhibit salinity, and cold tolerance and some studies have revealed that it can tolerate and survive up to 10 ppt salinity, but its growth is affected beyond 6 ppt (Kasim, 1983; Salati *et al.*, 2011). Singh *et al.* (2018) recorded similar observations in a study on common carp in inland saline water of Punjab. In addition to this, common carp can also withstand cold temperatures and this ability to tolerate a wide range of temperature (3-35°C) should be tested about its growth performance during winter months of North India. This could see whether the common carp can be the candidate species for winter aquaculture in inland saline areas or water.

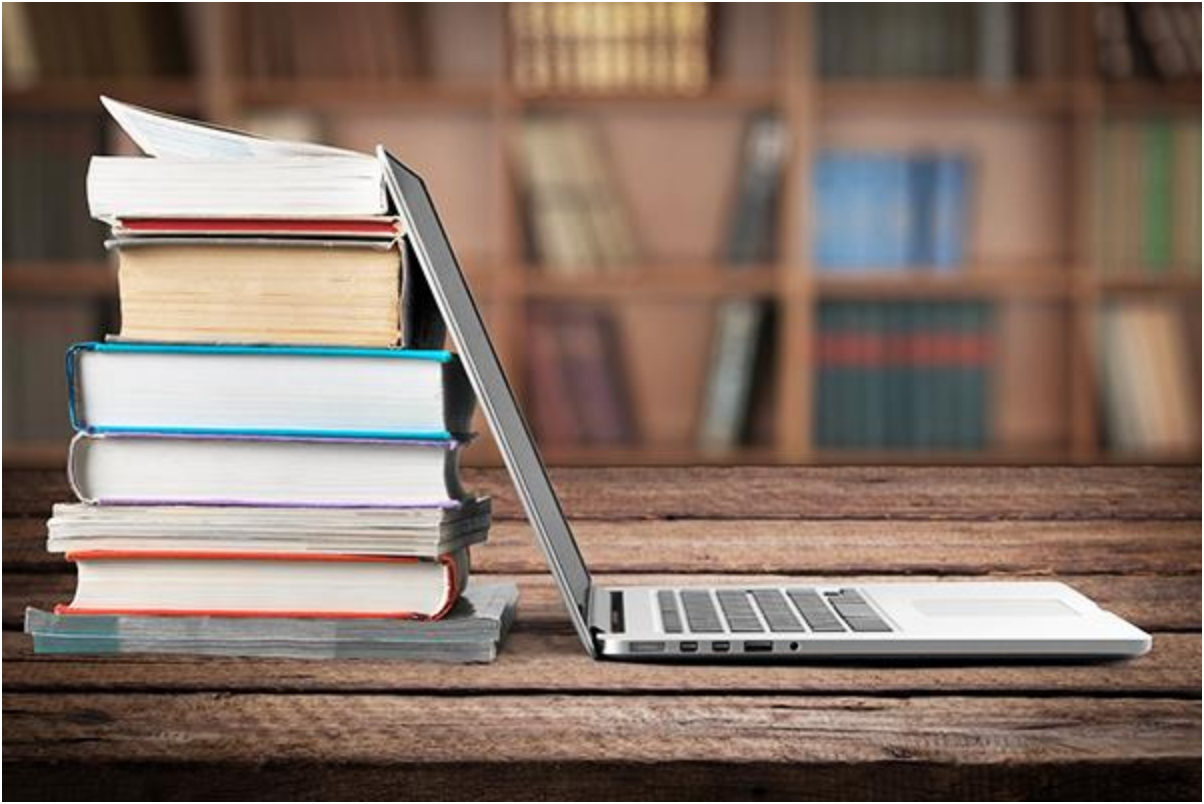
Salinity tolerance involves complex responses at the molecular, cellular, metabolic, and physiological levels. Salinity tolerance is the primary limiting environmental factor affecting growth in Inland saline water. In addition to this, to popularise the culture of common carp during severe winter months of North India, the common carp should also exhibit cold tolerance. This necessitates the development of a salinity-tolerant base population of common carp. Since the performance of the fish depends on the stocks and the environment they are cultured in, understanding the aspect of genotype and environment interactions is essential to identify the most suitable stock for a given environment. A fast-growing strain can be developed through genetic selection and breeding.

Morphometric characteristics explain the body shape aspects of the organism. In comparison to meristic characters, morphometric traits are continuous variables and depend on the size of the body. The morphometric analysis provides information on phenotypic stocks, groups of individuals with similar growth, mortality, and reproductive rates (Booke, 1981). Unlike meristic characters, which are fixed in early life, morphometric characters may be labile to environmental influences throughout life (Wainwright *et al.*, 1991). Phenotypic plasticity in morphometric characteristics may often be adaptive (Robinson and Parsons, 2002). Hence, it is interesting to study the effect of salinity on morphometric traits of common carp. This will delineate if any adaptation plasticity to saline environment exists in common carp.

With this background, the present study was conducted with the following objectives.

Objectives:

1. To compare the growth of different populations of *Cyprinus carpio* reared in varying salinities.
2. To conduct morphometric analysis of *Cyprinus carpio* populations reared in inland saline water.



Review of Literature

2. REVIEW OF LITERATURE

2.1. Aquaculture

Aquaculture is the farming of aquatic organisms, including fish, molluscs, crustaceans and aquatic plants. Farming implies any form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators etc. (FAO, 1998). With capture fishery production relatively static since the late 1980s, aquaculture has been responsible for the continuing impressive growth in the supply of fish for human consumption. Global fish production (excludes aquatic mammals, crocodiles, alligators and caimans, seaweeds and other aquatic plants) reached about 179 million tonnes (in value equivalent to USD 362 billion) in 2018 of which 156.4 million tons were used for human consumption providing a per capita apparent consumption of 20.5 kg (FAO, 2020). Aquaculture continues to be the world's fastest-growing major food production sector with an overall (production of 114.5 million tons (in value equivalent to USD 263.4 billion) and grew on average at 5.3 percent per year in the period 2001-2018.

The aquatic animal production attained another record high of 82.1 million tonnes (in value equivalent to USD 250.1 billion) in 2018 and is projected to reach 109 million tonnes in 2030. In 2017, fish accounted for about 17 percent of total animal protein and 7 percent of all proteins consumed globally. Moreover, fish provided about 3.3 billion people with almost 20 percent of their average per capita intake of animal protein. A total of 59.51 million people was engaged (on a full-time, part-time or occasional basis) in the primary sector of fisheries and aquaculture in 2018 out of which 20.53 million people are involved in aquaculture and 38.98 million in capture fisheries. It is estimated that nearly 14 percent of these workers were women (FAO, 2020). The top 5 major produced animal species in world aquaculture (in descending order of production) are Grass carp (*Ctenopharyngodon idellus*), Silver carp (*Hypophthalmichthys molitrix*), Nile tilapia (*Oreochromis niloticus*), Common carp (*Cyprinus carpio*) and Bighead carp (*Hypophthalmichthys nobilis*) and they together contribute to around 50% of world's aquatic animal food production.

India stands second among the world's leading farmed food fish producers with an overall production of 7.06 million tonnes in 2018 (FAO, 2020). Carp-oriented inland aquaculture production in India is surging ahead, unlike marine fish capture production which has been stagnating at India and at the global scenario. About 80% of the inland fish production is from freshwater aquaculture (DADF, 2017). Bulk of the carp production (70 to 75% of the total) in the country is contributed by the three Indian major carps (IMCs), namely catla (*Catla catla*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus mrigala*) followed by the exotic species, namely Common Carp (*Cyprinus carpio*), Silver Carp (*Hypophthalmichthys molitrix*) and Grass Carp (*Ctenopharyngodon idella*) that form the second important group (FAO, 2017).

2.2. Inland Saline Aquaculture

Inland saline aquaculture (ISA) can be defined as land based aquaculture using saline groundwater and it relies on the production strategies for the growth and survival of salt-tolerant freshwater species and estuarine/marine species (Allan *et al.*, 2001). Water logging, indiscriminate use of inorganic fertilizers, poor drainage and over irrigation are the main causes for salinization of soil. Sources of saline groundwater include ephemeral and permanent saline lakes, saline water extracted with coal seam gas (Coal bed methane gas industry) and saline groundwater extracted from aquifers, including shallow water tables where saline groundwater is extracted to protect the root zone of plants (Allan *et al.*, 2001). Effects of climate change causing sea level to rise, which in turn affects the dynamics of estuary systems leading to saltwater infusion into groundwater, is the latest reason for the expansion of inland saline areas (OECD, 2017).

There is about 1000 million hectares of salt affected soil spread across the world (CSSRI, 2011) in countries such as Australia, China, Denmark, Egypt, France, Germany, Hungary, India, Iraq, Israel, Italy, Pakistan, Turkey, USA etc. (Allan *et al.*, 2001; Singh *et al.*, 2013). In India nearly 9.38 million-hectare (ha) area is occupied by salt-affected soils out of which 5.5 million ha are saline soils (including coastal) and 3.88 million ha alkaline soils (Singh *et al.*, 2018).

The salt affected land and water have progressively increased, have adversely affected environment and caused serious threat for the sustainability of agricultural practices and their economic utilization. Aquaculture other than being a food-producing method, it restores habitat, replenish wild stocks and rebuild populations of threatened and endangered species (NOAA, 2019). Generally, inland saline aquaculture has some comparative advantages over coastal aquaculture such as cheap land availability, better biosecurity (as unlike open seawater the inland saline water is relatively isolated that offers better bio-security against viruses and thus more chance for the water to be disease free) and fewer issues of conflict with the competing users as they are generally located in remote areas (Gong *et al.*, 2004). So there is a growing interest and need in developing commercial ISA which is a perfectly economical, sustainable and eco-utility solution (Singhet *et al.*, 2019) and potentially can even be integrated with agriculture (Sowers *et al.*, 2005).

Countries like China,USA, Israel, Australia and Egypt have practiced aquaculture with saline-alkaline water and suitable species in land locked areas,where soil conditions and the chemical properties of available water are inhospitable for conventional food grain crops or pasture(FAO, 2018). Dwivedi and Lingaraju (1986) first attempted fish and prawn culture in ground saline waters of semi-arid regions of Haryana, India. Lakra *et al.*, (2014) have reported culture technology for commercial farming of *Penaeus monodon* and *Litopenaeus vannamei* in saline affected soils using inland ground saline water at Rohtak centre of ICAR - Central Institute of Fisheries Education, Haryana, India. Presently, 650 ha of inland saline area is used for commercial shrimp production system with a production of 1.9 tons per hectare. It is projected that utilization of ground saline water for aquaculture will increase in the coming years, and the output from such systems will also improve with the advancement of technology (Krishna *et al.*, 2019).

Inland saline water (ISW) differ in chemistry compared with coastal seawater and brackish water (Davis *et al.*, 2005). Saline surface water and groundwater often have different ionic proportionalities when compared with seawater (McNevinet *et al.*, 2004; Gong *et al.*, 2004). The salinity of the ISW ranges from 0.5 to 45 ppt (Boyd and

Thunjai, 2003; Partridge and Creeper, 2004) with high level of Ca^{2+} and Mg^{2+} resulting in high water hardness (Jana *et al.*, 2006). ISW is often characterized by imbalanced Mg^{2+} and K^+ ratios in relation to other major ions which can result in reduced growth (Gong *et al.*, 2004; Partridge *et al.*, 2004). K^+ concentration in ISW is comparatively lower to seawater, due to its adsorption onto the clay (Allan *et al.*, 2001) which could be potentially detrimental in terms of the ability to osmoregulate effectively as enzyme activity of the animals can be directly related to K^+ concentration (Burse and Lane, 1971; Zhu *et al.*, 2004). In general, except for low K^+ concentration and the imbalanced Mg^{2+} and K^+ ratios, ionic composition and concentration of other constituents in ISW is similar to the ocean water (Allan *et al.*, 2001). Inland saline waters differ from each other on spatial scale, and variations in ionic profiles may occur even in waters even derived from the same saline aquifer (Prangnell and Fotedar, 2005).

ISW is an unexploited resource for ISA (Beresford *et al.*, 2004), but adjusting the chemistry or choosing species that are tolerant to the differences is one of the major challenges against the expansion of inland saline aquaculture (Allan *et al.*, 2009). Worldwide, a range of species have been evaluated for culture in saline groundwater including euryhaline finfish like *Chanos chanos*, *Mugil cephalus*, *Etroplus suratensis*, *Lates calcarifer*, *Sparus auratus*, *Bidyanus bidyanus*, *Macquaria nooemaculeata*, *Salmo salar*, *Dicentrarchus labrax*, *Argyrosomus japonicus* (Jana *et al.*, 2006, Fielder *et al.*, 2001), crustaceans like *Penaeus monodon*, *Penaeus vannamei*, *Penaeus japonicus*, *Macrobrachium rosenbergii*, *Penaeus latisulcatus*, molluscs like *Saccostreaglomerata*, diadromous species such as salmonids (*Oncorhynchus mykiss*, *Ictalurus punctatus*) (Samochoet *et al.*, 2002) and salt-tolerant freshwater species such as *Oreochromis niloticus* and *Bidyanus bidyanus*. Some of the above-mentioned fish species like *Oreochromis niloticus*, *Carassius auratus*, *Pangasianodon hypophthalmus*, *Penaeus vannamei*, etc. have been tested as candidate species for inland saline aquaculture in India. Difficulty in sexual maturation of many fish species in ISW, lack of continuous availability of estuarine species seeds and steno thermal nature of estuarine or marine fish emphasizes the need to evaluate more species for their suitability to be cultured in ISW.

2.3. Common Carp (*Cyprinus carpio*)

2.3.1. Common carp; taxonomical classification, morphology and production

According to the binomial classification of Linnaeus (1758), Common carp belongs to the

Kingdom:Animalia

Phylum:Chordata

Class: Actinopterygii

Order: Cypriniformes

Family: Cyprinidae

Subfamily: Cyprininae

Genus: Cyprinus

Species: *C. Carpio*.

Common carp has an elongated and somewhat compressed body. It is variable in form, proportions, squamation, development of fins and colour (Spillman, 1961). The true European wild carp is brownish green on the back and upper sides, shading to golden yellow ventrally. The fins are dusky, ventrally with a reddish tinge (FAO). Lips are thick, and two pairs of barbels (shorter ones on the upper lip) are present at angle of mouth (Kottelat, M., 2001). Dorsal fin has 17 to 23 soft rays and 3 to 4 spines. Anal fin has 5 to 6 soft rays and 2 to 3 spines. Caudal fin with 3 spines and 17-19 rays and is deeply emarginated. There are 35 to 36 vertebrae present (Kottelat, M. and J. Freyhof, 2007). The posterior edge of 3rd dorsal and anal fin spines has sharp spinules. Lateral line has 32 to 38 scales (Peteri, 2004).

Common carp is the fourth most widely cultivated fish species in the world and contributes 7.7% of global aquaculture production in terms of quantity. Aquaculture production of common carp increased from 3,331 thousand tons in 2010 to 4189.5 thousand tons in 2018 which is in parallel to the increase of global aquaculture production of freshwater fishes (FAO, 2020).

2.3.2. Common carp; biology, popularity and importance

Common carp generally inhabits freshwater environments and rarely seen in brackish water environments (Barus *et al.*, 2001). The ecological spectrum of the carp is broad and thus, it can be seen in many water bodies (large) such as lakes, oxbow lakes and water reservoirs, middle and lower streams of rivers, inundated areas and shallow confined waters with slow-flowing or standing water and soft bottom sediments. It inhabits the benthopelagic regions of the water body and is potamodromous in nature (Riede, 2004). Common carps are active swimmers that can leap obstacles up to 1 meter high and negotiate torrential flows (Merrick and Schmida, 1984). The fish is very hardy and can tolerate many extreme environmental conditions such as cold winter periods, high salinity and low oxygen concentration. Best growth is obtained when water temperature ranges between 23°C and 30°C (Peteri, 2004). It can survive, grow, and even reproduce in water up to 10 ppt salinity (Singh *et al.*, 2018; Whiterod and Walker, 2006; Mangat and Hundal, 2014). The optimal pH range is 6.5 to 9.0. The species can survive low oxygen concentration (0.3 to 0.5 mg/litre) as well as supersaturation (Kailola *et al.*, 1997).

The length at first maturity (L_m) generally ranges from 25 to 36 cm (Murdy, 1997) but Asian counterparts of common carps (*Cyprinus carpio haematopterus*) are known for early maturation; which is at an age of approximately six months and sometimes at a weight below 100 g (Basavaraju *et al.*, 2003). Male carp are matured within a period that is 25 to 35 percent shorter than the females (FAO). The common carp is polygamous. A spawning female is usually followed by several males (Alikunhi, K.H., 1966). Natural spawning often occurs along the shores or in backwaters. Adults often undertake considerable spawning migration to suitable backwaters and flooded

meadows. Larvae survive only in warm water among shallow submerged vegetation (Kottelat, M. and J. Freyhof, 2007). Under tropical conditions carp breeds throughout the year and is a seasonal spawner in temperate waters (Alikunhi, K.H., 1966).

This fish possesses numerous beneficial attributes viz widely cultured, high consumer demand, hardy, tolerates both high (up to 35°C) and low water temperature (upto3°C)(Eaton and Scheller, 1996), high fecundity (42,320 – 4,16,650) and added advantage of fully sequenced genome (Xu *et al.*, 2014). Adding to this, its ability to tolerate wide fluctuations in environmental conditions (pH, temperature and salinity), broad feeding nature, high variability of quantitative traits (numerous strains), good possibilities for hybridisation, shorter generation interval, standardized breeding techniques, good availability of seeds and commercial value have made common carp a great success in world freshwater aquaculture. Owing to its economic value in aquaculture, it has been intensively studied in terms of its physiology, development, immunology, disease resistance, selective breeding and transgenic manipulation. It is considered an alternative vertebrate fish model to zebrafish (*Danio rerio*) and as an important ornamental fish species. One of its variants; Koi, is the most popular outdoor ornamental fish because of its distinctive colour and scale patterns (Xu *et al.*, 2014). A variety of *C. carpio* genome resources have been developed over the past decade, including many genetic markers, genetic maps, a BAC (Bacterial Artificial Chromosome) based physical map, a large number of ESTs and cDNA microarrays. Recently, a comparative exomic study of *C. carpio* and *D. rerio* genome has been reported, providing additional genome resourcing data for the research community (Xu *et al.*, 2014). Also, information on breeding for improved growth rate and disease resistance is available for common carp. It is a polytypic plastic species with a marked tendency to produce 'varieties' and 'races' in response to selective breeding and environmental influences.

2.3.3. Common carp: distribution and population genetics

Common carp has a very wide distribution which is from the west of Europe to the east of Asia (Kottelat and Freyhof, 2007). It evolved from its Caspian Sea ancestor and initially spread into basins of the Black and Aral seas. Under conditions of the

postglacial thermal optimum some descendants spread as far as the Danube and possibly into eastern mainland Asia (Berg, 1964). A reophilic wild population in the Danube River is strongly assumed to be the origin of the common carp (Kottelat, 1997). This population has become rare and even listed as endangered by International Union for Conservation of Nature (CITES, 2017) because of rampant introductions of the domesticated form, hybridization with domesticated stocks, East Asian congeners and their hybrids, river regulation and the elimination of floodplains. Wild stocks are only present naturally in rivers draining to the Black, Caspian and Aral Sea but it has been introduced throughout the world and exist as many different forms and strains (Kottelat and Freyhof, 2007) making it the most translocated fish in the world. Introductions of the domesticated and wild form of common carp have been practised since Roman times (Balon, 1995), as a result, it is now established in 91 countries worldwide (Casal, 2006).

There are two major documented common carp introductions that happened in India; one is the German strains introduced in 1939 and the other one is the Bangkok strain introduced in 1956 (Jhingran, 1991). Common carp individuals of these two introductions most probably formed the base population of the existing entire common carp population in the country as they have mixed over many generations (Basavaraju *et al.*, 2003) through various forms of human intervention and various environmental conditions (Bakos, 1994).

Population genetics study of common carp have showed that there are two subspecies in the world: *Cyprinus carpio carpio* from Europe and *Cyprinus carpio haematopterus* from Asia (Paaver and Gross, 1990). Also, the Asian subspecies might have sub-divided into strains from Central Asia and East/Southeast Asia through a combination of forces including geographic isolation, adaptation, accumulation of mutations and natural as well as human selection pressures (Kohlmann *et al.*, 2003). The structuring of common carp in two subspecies and the further structuring within these subspecies has indicated that some strains of common carp have evolved quite independently and thus may show different patterns of genetic variation for quantitative traits, provided there is an additive genetic basis for the traits of interest (Kohlmann *et al.*, 2003; Csizmadia *et al.*, 1995).

2.3.4. Common carp: feeding and culture practices

In general terms, common carp are omnivorous with a high tendency towards benthic macro invertebrates such as water insects, larvae of insects, worms and molluscs. Additionally, the carp consumes the stalks, leaves and seeds of aquatic and terrestrial plants and decayed aquatic plants (Merrick and Schmida, 1984). Desai and Singh (2009) found that weight gain of *C. carpio* fry was highest at 6% ration at both temperatures *i.e.*, 28°C and 32. Common carp of up to 15.4 cm total length preferentially select zooplankton (rotifers and copepods), but common carp larger than 18.9 cm total prefers benthic macro-invertebrates. Common carp size has no significant effect on phytoplankton as all sizes of common carp avoid phytoplankton consumption (Rahman *et al.*, 2009). A low abundance of benthic macroinvertebrates or a high stocking density of common carp could cause the carp to switch to its next preferred food items (zooplankton), leading to significant dietary competition with other fish which prefer zooplankton. Common carp maximize fitness not only by shifting food preference but also by modifying its feeding niche and behaviour even in the presence of superior fish, making it a valuable species not only for monoculture but also for polyculture (Rahman *et al.*, 2009). In the presence of insufficient other natural foods, the fish eats fry of other fish at high density (Weber & Brown 2011).

Common carp is known for its larger bottom–up effects (bioturbation of benthic sediment during feeding on benthic organisms) than other benthivorous fish. It releases soluble phosphorus ($\text{PO}_4^- \text{P}$), the limiting nutrient for phytoplankton growth from the pond sediments increasing the phytoplankton production. This positively influences the production of planktivorous fish. Rohu, a planktivorous fish grows better in ponds with common carp than in a monoculture (Rahman *et al.*, 2006). Therefore, the fish is commonly reared in semi-intensive polyculture ponds; where use of natural food with supplementary feeding with cereals is predominant (Hepher and Pruginin, 1981; Horváth *et al.*, 1992; Kaushik, 1993). However, in cold climate regions, especially in Europe, monoculture of common carp is more popular (Szucs *et al.*, 2007). The contribution of supplementary feeds on carp growth increment generally represents around 25–50% of total yield (Adámek *et al.*, 2012).

The bottom-up effect of common carp impacts the aerobic decomposition of organic matter and nutrient availability in the water column. If the density of common carp is not excessive, an increase in nutrient availability may enhance photosynthesis and plankton production, whereas if it is excessive, it causes dramatic ecological disruption at both the community and ecosystem levels by changing the abiotic properties of the water. Therefore, the density of common carp is a very important factor that has a great effect on the aquatic ecosystem. The critical density of common carp largely depends on its habitat. In polyculture ponds, water quality, natural food resources and fish growth are strongly affected when the density of common carp approaches more than about 1000 kg ha⁻¹(Rahman *et al.*, 2015).

2.4. Performance of common carp

Growth involves change in magnitude in terms of weight or length and thus increases in live weight or dimension against age is described as growth. Growth patterns are traditionally classified into two groups: determinate and indeterminate patterns. Most fish are indeterminate growers as they grow throughout their whole life with highly variable rates. Indeterminate growth is defined as growth that continues past maturation and may continue to the end of life (Heino and Kaitala, 1999). Growth can be a useful measure for evaluating habitat suitability and the influence of management activities on a fish species.

Growth in organisms is coordinated by the ontogenetic development that allows variability in the development rates and sizes in order to adapt to environmental conditions and thus animal size varies naturally among the individuals of same species born at the same time and place, despite growing under same environmental conditions (Magwene, 2001). Growth needs resources and trades off with other traits. Within the same species, the difference in genetic makeup often results in differed growth potential leading to different families or groups have different genetic makeup. A cohort of fish often exhibits substantial size variability (De Angelis *et al.*, 1993) and the reason for the variability could be the genetically determined target of the body size of each individual, ontogenetic developments (nutritional factors) and environmental parameters. The variability is a drawback in commercial culture and in order to reduce this, the idea of the

extent of the phenomena is essential and then it has to be investigated how growth can be promoted, through manipulations of factors that influence it (Goldan *et al.*, 1998). For poikilothermic vertebrates such as teleost fish, extrinsic factors are particularly important because many developmental processes are dependent on temperature, photoperiod and food availability (McLean and Donaldson, 1993).

The daily growth of carp can be 2 to 4 percent of body weight. Carps can reach 0.6 to 1.0 kg body weight within one season in the polyculture fish ponds of subtropical/tropical areas. Growth is much slower in the temperate zone where the fish reach the 1 to 2 kg body weight after 2 to 4 rearing seasons. Best growth is obtained when water temperature ranges between 23°C and 30°C (Peteri, 2004). The growth in common carp is influenced by the genetic factors like stock & non genetic factors like culture environment, culture method, stocking density and quality and quantity of feed provided. Stock wise variation in growth of common carp was reported by Basavaraju *et al.*, (2002). The classical and well documented approach was to relate animal weight to time through empirical equations describing growth curves. The shape of curves will vary according to the species, environment and trait (Akbas *et al.*, 1999).

Basavaraju *et al.*, (2003), conducted a series of culture performance trials for stocks of *C. carpio* obtained from Hungary (Amur and P3), Indonesia (Rajdanu), Vietnam (Selected Vietnamese and Unselected Vietnamese) and two local stocks (L-BRP and L-FRS). The completed trial's result involving pure lines indicated that the strains from Hungary and the Rajdhanu (RJ) stock from Indonesia appear to be the most promising in terms of weight at harvest, survival and gonado-somatic index.

In another study of Basavaraju *et al.*, (2012), field trials were conducted to assess the growth performance of two stocks (new breed, Amur and existing stocks) of common carp, *Cyprinus carpio* under polyculture at nine different locations of Karnataka. They observed the mean body weight of Amur stock was 583.03 ± 18.36 g for a culture period of 28 weeks and was significantly higher than that of existing stock. Amur stock registered 20.31% faster growth over the existing stock and showed consistently better growth over existing stock in all the locations. In yet another study conducted by Das (2017), evaluated the performance of common carp, Amur (Hungarian strain) introduced

in Meghalaya in 2010. The three-year studies revealed that the performance of Amur common carp is superior over the local existing breed in farmers ponds under the mid hill conditions.

Verma (2013), reared two morphs of common carp *viz* Amur and Scale carp for one year in seed farm ponds, private owned ponds and community ponds at Himachal Pradesh, India and evaluated their growth performance. Seed farm ponds were maintained scientifically with supplementary feeding and the other two pond types were not maintained scientifically. Amur carp morphs' average weight gain after 1 year of culture in seed farm ponds and private ponds were significantly higher than that of scale carp morph, but the average weight gain of scale carp morph in community pond was greater than that of Amur carp morph.

Vijayakumar *et al.*, (2019) evaluated the growth performance of Amur common carp under polyculture with Indian major carps (Catla and Rohu) in ponds integrated with and without poultry farm. After 8 months of culture, Amur common carp had the highest growth (net weight gain of 1328.7 g and length increment of 29.8 cm) compared to Catla (net weight gain of 1148.9 g and length increment of 27.9 cm respectively) and Rohu (net weight gain of 819 g and length increment of 27.1 cm respectively) in pond integrated with poultry farm, but in pond that is not integrated with poultry farm, Catla showed maximum growth (1250.8 g and length increment of 29.1 cm respectively) followed by Amur common carp (1191.69 g and length increment of 27.4 cm respectively) and Rohu (860 g and length increment of 26.09 cm respectively). The specific growth rate of Catla was the highest in ponds integrated with (2.30) and without (2.27) poultry farm followed by Amur common carp and Rohu. Rajanna *et al.*, (2019), polycultured Amur common carp, Catla and Rohu in seasonal water bodies and reported their survival rate as 82%, 78% and 62% respectively. Verma and Mandal (2018) evaluated growth performance of amur common carp and mrigal with major carps (catla, rohu, silver carp and silver barb) in polyculture system. They found that amur common carp performs better than mrigal with major carps in polyculture system and with stocking at ratio of 15% each have an improved fish production.

2.5. Inland saline aquaculture of common carp and others

According to Boeuf and Payan (2001), salinity can change the amount of energy available for body growth by altering the energetic cost for osmotic and ionic regulation. Varsamos *et al.*, (2005) reported that variations in salinity could influence several physiological processes, particularly metabolic and osmoregulatory function in fish, where a portion of the metabolic energy is spent in the osmoregulatory process. Salinity tolerance of freshwater fish varies with the species, age, size and acclimating conditions. Most of the marine animals inhabit areas of lower salinity at their younger stages (Pearse and Gunther, 1957). While most fishes are stenohaline, many euryhaline fish species tolerate great fluctuations in water salinity (Fiol and Kultz, 2007; Plaut, 1999), including acute changes on a daily basis (Swanson, 1998; Scott *et al.*, 2004). Many, but not all, fish species may be capable of adjusting or acclimation, at least in part, to these changing environmental variables through phenotypic plasticity in their responses to salinity. If environmental change exceeds the capacity of fish to respond *via* these mechanisms, genetic selection might act on these traits, allowing populations to respond *via* evolutionary adaptation (Anttila *et al.*, 2013).

Cyprinus carpio was well known as a stenohaline freshwater fish but Whiterod and Walker (2006) showcased the other dimension of the fish that can tolerate a rather wide range of salinities, even up to 12 ppt. Dwivedi and Lingaraju (1986) attempted to culture Indian major carps and common carp fingerlings, in saline ground water of 8-10 ppt salinity at Sultanpur (Haryana) during 1984-87. Indian major carps could not tolerate beyond 5 ppt, whereas, common carp could grow to a size of 550 g in less than a year and also achieved maturation. Hasan and Mohamed (2019) reared the fish at 0.1, 5, 10 & 15 ppt for 90 days and the daily growth rates were found to be 0.5, 0.36, 0.16 and 0.13 g/day, respectively which shows the fish can tolerate and even grow at 15 ppt. Garg (1996) reported that common carp could be profitably cultured up to a salinity of 5 ppt, and there was no adverse effect on the fish even when the salinity was raised to 7 ppt. Common carp from the River Murray survived direct transfer from freshwater to a salinity of 12.5 ppt and with acclimation there was 50 % survival at 15 ppt (Geddes, 1979). *Cyprinus carpio* and *Hypothalmichthys molitrix* have a lower oxygen

consumption rate and standard metabolic rate at 3 ppt salinity because they expend less energy on maintaining internal equilibrium (Qui Deyi and Qin Kejing, 1993). The salinity tolerance of common carp is similar to that of goldfish (Du Jiayin, 1986) higher than that of silver carp (Von Oertzen, 1985) and lower than those of *Tilapia zillii* (Chervinski and Zorn, 1974), *Tilapia rendalli* (Whitfield and Blaber, 1976), rainbow trout (Stickney, 1986) and *Ctenopharyngodon idella* (Chervinski, 1977). Kejing(1993) found rapid growth of carp fingerlings in 3 ppt salinity rather than at 0.5 ppt because of less energy expenditure for osmotic regulation.

Dwivedi and Lingaraju (1986) could successfully culture *Cirrhinus mrigala* in saline water of 8-10 ppt salinity at Hisar. They further reported that the gonadal maturation of the fish was fast in saline water. In general, the culture of Indian major carps could be possible in water of low salinity (5-10 ppt). Chervinski (1977) reported a poor survival, in grass carp reared in high saline waters. Grass carp is reported to tolerate 10 to 16 ppt salinity for a short period. A preliminary investigation indicated the feasibility of rearing silver and grass carp in brackish water ponds in an area unsuitable for agriculture (Chervinski, 1977). Chervinski (1984) subjected young ones of *Clarias lazera* to abrupt and gradual changes from fresh water to various salinities and observed 94% survival when the fish were transferred from freshwater to 25 ppt seawater. Rohu and Catla fry can survive up to 5 ppt but high mortality was observed when the salinity was increased to 7 ppt. High survival were obtained when fingerlings were stocked instead of fry in brackishwater ponds (Ghosh, 1971). Through fingerlings can be reared in salinities as high as 8 ppt, they found that the best growth occurred at 5 ppt in case of *Cirrhinus mrigala*.

2.6. Effect of temperature on growth of common carp

Temperature controls and limits all physiological and behavioural parameters of ectotherms (Fry, 1947). water temperature is the master abiotic factor for fish (Brett, 1971) as basal metabolic rate, swimming performances, feeding rate, growth rate, reproduction etc. are all thermally influenced (Beamish, 1981; Oyguet *al.*, 2011; Desai and Singh, 2009). Physiological performances are significantly depressed in warm water fish with declining temperatures (Fontaine *et al.*, 2007). Empirical and

experimental evidence suggests that water temperature has a major influence on aquaculture husbandry practices (Desai and Singh, 2009), the outcome of introductions (Britton *et al.*, 2010a), expression of life history traits across distribution range (Oygui *et al.*, 2011) and their distribution in habitats with altered thermal regimes (e.g., Encina *et al.*, 2008).

Across their natural range, common carp can grow faster in regions of higher temperatures and longer growing seasons, with the fastest growth recorded in equatorial populations where water temperatures remain >20°C all year. Understanding how their foraging and growth responds to temperature may provide important ecological insights that can be useful in interpreting field observations on populations in both their native and invasive range (Oyugi *et al.*, 2011). In UK, the carp have tended to live in the warmest water (about 28°C) (Alabaster and Downing, 1966) and Økland *et al.* (2003) reported on a thriving carp population in a warm African Reservoir where surface water temperatures reached 28°C. Oyugi *et al.* (2012) revealed that the foraging performance and growth rates of juvenile common carp were strongly regulated by temperature. As temperatures increased from 16°C, the values of these parameters also increased. In general, the highest growth rates were achieved at 20°C and 24°C, and the highest feeding rate at 24°C (Oyugi *et al.*, 2012). Fasting metabolic rates and maintenance energy requirements are affected by water temperature below. The resting metabolic rates at temperature below 17°C are quite low.

2.7. Morphometry

Morphometrics is the empirical fusion of geometry with biology (Bookstein, 1997) that studies the variation in the body form (shape and size) of organisms and its co-variation with other variables (Bookstein, 1985; Turan, 1999). In other words, morphometrics may be defined as a more or less interwoven set of largely statistical procedures for analysing variability in size and shape of organs and organisms (Mojekwu and Anumudu, 2015). Numerous studies have been conducted on the aspects of morphometric characters of fish. Geographical isolation, the interactive effects of the

environment, selection, genetics, and individual ontogenies produce morphometric differences within a species (Cadrin, 2000; Naeem *et al.*, 2012).

Apart from the advent of biochemical and molecular genetic techniques, the morphological variation among populations, genera, and families provide the basis for taxonomical classification (Swain and Foote, 1999). Chaklader *et al.* (2016) explained the importance of morphometric studies in taxonomic relationships and Vatandoust *et al.* (2014) studied morphological measurements of brown trout (*Salmo trutta fario*) from Caspian Sea and explained taxonomic status of the fish. Morphometric study can quantify a trait of evolutionary significance, evaluate the population structure of a species and stock (Turan, 2004; Cadrin and Friedland, 1999), providing information on phenotypic stocks, groups of individuals with similar growth, mortality, and reproductive rates (Booke, 1981). Dhanya *et al.* (2013) studied morphometric variations of *Etroplus suratensis* from two lacustrine ecosystems from Kerala. Ontogenetic changes in body shape that are particularly rapid at key life stages such as metamorphosis (from larval to juvenile body forms) can be described by morphometric analysis (Gould, 1966). Chattopadhyay *et al.* (2014) have done mouth morphometry and architecture of a freshwater catfish *Mystus vittatus* in relation to feeding habit.

Unlike meristic characters (countable), which are fixed in early life, morphometric characters are measurable, continuous variables that depend on the size of the body and is labile to variations resulting from sex, food availability, predator-prey interactions, physical parameters and other environmental influences throughout life (Dasgupta, 1991; Wainwright *et al.*, 1991). Environmental changes allow the fishes to respond adaptively by a modification in their behaviour and physiology, which leads to either death or altered performance (adaptation); which is changes in their reproduction, morphology and survival that mitigate the effects of environmental variation (Stearns, 1983). Most of the adaptations trigger phenotypic change (phenotypic or adaptive plasticity) which could be reflected as variations in morphometric parameters. The morphological differences between the benthic and limnetic forms observed in a variety of fish taxa is the perfect example (Robinson and Parsons, 2002; Robinson and Wilson, 1994).

Mokhlasur Rahman (2014) reported morphometric and meristic variations of stinging catfish *Heteropeustes fossilis* among three isolated stocks of three landmarks of Bangladesh. Other examples are the studies of several authors that reported variation between body parameter occurred due to the influence of biological (size, genetic factors) and environmental factors (temperature, turbidity, water pollution and depth of water) (Ezeafulukwe *et al.*, 2015; Ramasamy and Rajangam, 2016; Alexandra Silva, 2016; Singla, 2016).

Pathak *et al.* (2013) carried out variations in body parameters among Barred Spiny Eel, *Macrogathu spancalus* of two river systems using geomorphometrics. He illustrated the role of phenotypic plasticity to the geographical variations among the different stock. Morphological variations of *Arius jella* from five estuaries in Sri Lanka were studied by Gunawickrama (2007) and observed significant heterogeneity in morphometric characters occurring among the fish from different estuaries. These phenotypic adaptations do not necessarily result in genetic changes in the population (Ihssen *et al.*, 1981) and thus, detection of such phenotypic differences among populations cannot usually be taken as evidence of genetic differentiation. The difference in morphological characters associated with trophic specialization has also been extensively studied in Arctic char, *Salvelinus alpinus* and involves both genetic difference and phenotypic plasticity (Skulason *et al.*, 1989).

Morphometric characters are quantitative genetic traits, generally thought to be influenced by many genes of small individual effect, though some adaptive morphometric differences may be explained by relatively few genes of large size (Hatfield, 1997). The difference in morphological characters often result from changes in the timing of development events, they can be a clear indication of life history differences between groups, differences that are central to the assessment and management of exploited fish stocks (Cadrin, 2000).

2.7.1. Morphometric studies in common carp

Wild common carp is ecologically a highly plastic species and thus can thrive changing or new environments and establish new populations (Murakaeva *et al.*,

2013) and this strong adaptation to environment reflects as morphological changes. Shermadhi and Spaho (2013) studied morphometric and meristic features of common carp populations in three different lakes (Belshi, Shkodra and Prespa) of Albania. There existed defined morphometric and meristic differences among individuals of the three populations. Causes of such differences are the modification of morpho-anatomic features because of adaptations towards local environments and hybridisation with the cultivated populations.

Panicz *et al.* (2014), studied morphometric characterisation of *Cyprinus carpio*, *Carassius auratus* and their hybrids. They found that, 6 morphometric variables (pre-dorsal distance, body width, ventral fin length, distance between pectoral and anal fin) differed while 3 other morphometric traits (anal fin length, dorsal fin height and horizontal diameter of eye) didn't differ among the three analysed groups. Whereas minimum body depth and distance between ventral and anal fin didn't differ between common carp and its hybrid with gold fish and rest all parameters differed indicating hybridisation without domination of one of the parents.

Patino *et al.* (2003) used morphometric analysis to conduct a pilot study with feral common carp in Lake Mead, Nevada, suggesting that regional differences between fish from a contaminated site (Las Vegas Bay) and those from a relatively uncontaminated reference site have sex-specific effects on gonadal condition. Khalili and Amirkolaie (2010) conducted a study to determine whether genetic makeup and morphometric characteristics of common carp in the southern coast of Caspian Sea are altered by farmed fish and environment and they concluded that common carp showed morphological and biochemical differences. Environmental conditions (change in feeding categories, salinity and temperature) and hybridisation with domesticated carps may be the reasons for the variation.

Siraj *et al.* (2017) conducted morphometric analysis involving 18 morphometric parameters. About 75 samples of *Cyprinus carpio* were collected from three basins of Dal Lake, namely Hazratbal basin, Nigeen basin and Gagribal basin. Out of eighteen characters, nine characters showed high values of correlation coefficient indicating that these characters are directly proportional to each other and seven

characters showed moderate correlation coefficient. Bhat *et al.* (2016), performed a morphometric study in *Cyprinus* sp and found that out of eighteen characters in relation to total fish length, ten characters showed high values of correlation coefficient, eight characters showed moderate correlation coefficient while in percentage of head length three characters showed least correlation coefficient and four showed moderate correlation.



Material and Methods

3. MATERIALS AND METHODS

The present study was conducted at the ICAR-Central Institute of Fisheries Education, Regional Centre, Rohtak, Haryana, India.

3.1. Assembling of stocks

Three geographical locations of India viz; Karnataka, Tamil Nadu and Andhra Pradesh were chosen for collection of common carp stocks. The common carp seeds were collected from multiple hatcheries and mixed location wise. The stocks were transported to the ICAR-CIFE regional centre at Rohtak, Haryana via road, rail and air cargo following the standard protocol for fish transport. The details of different stocks collected are provided in the Table 1. The stocks were assembled twice for the experiment, the first collection was during the early onset of winter and the other one was during early onset of summer at Rohtak.

Table 1. Details of common carp populations collected for the experiment

SI No	Name of Stock	Particulars	Total Seeds	Age (Weeks)
1	Karnataka	Seeds produced from mass spawning at Fisheries Research Information Centre, Hesaraghatta, Bangalore, Karnataka, India	2300	4
2	Tamil Nadu	Nearby hatcheries and seeds produced at Erode Centre for Sustainable Aquaculture (ECeSA), Tamil Nadu Dr Jayalalithaa Fisheries University (TNJFU), Erode, TN, India.	3800	5
3	Andhra Pradesh	Nearby hatcheries at ICAR-CIFE Regional Centre, Kakinada, AP, India	2500	4

3.2. Disinfection, acclimatisation and stocking:

The transported common carp seeds were released stock wise into cement tanks of 12,000 L capacity having freshwater for acclimatisation. In total, 6 tanks (2 tanks for each stocks) were used for acclimatisation and all the tanks used were prior disinfected with 10 ppm KMnO_4 solution. All fish were given a dip treatment in 2 ppm KMnO_4 solution for 5 to 10 seconds before being released into these cement tanks. Salinity of every tanks was increased at a rate of 1 ppt per day and this was done by exchanging freshwater with inland saline water at the required level.

3.3. Experimental design

Two experiments *viz*; growth performance experiment and morphometric study experiment were conducted.

The early growth performance experiment of three geographical stocks of common carp *viz*; Andhra Pradesh, Karnataka and Tamil Nadu were carried out in ponds of dimension 20×10×1.5 m, for six weeks (April - May) at two salinities; *viz.*, the high saline and low saline. A total of six ponds; two ponds for each stocks, where one pond had high saline water and another pond had low saline water, were used for the experiment. The stocking density was 320 fries per pond.

Morphometric study were carried out FRP indoor tanks of capacity 1,500 L. A total of twelve tanks; four tanks for each stocks, where two tanks had high saline water and another two tanks had low saline water were used for the experiment. The stocking density was 40 fries per tank.

The low saline ponds and tanks were maintained at 4 ± 2 ppt and the high saline ponds and tanks were maintained at 8 ± 2 ppt. All the ponds and tanks were pre-prepared for stocking by drying and treatment with calcium hypochlorite (bleaching powder) and were also filled with waters of required salinity so that the acclimatised fish are directly transferred to experimental ponds and tanks.

3.4. Rearing and sampling

The fish were fed ad libitum twice a day (07.00 hr and 19.00 hr) with ABIS pre starter floating feed (size 2 mm, crude protein: 32 percent, fat: 4 percent and fiber: 4 percent).

In tanks, about 10 percent of water was exchanged and replenished daily. There was no water exchange in ponds but the water lost by evaporation and seepage was compensated. The salinities were maintained throughout the experiment period. Water temperature was measured twice a day at 05.00 h and 16.00 h respectively. Digital LCD portable probe thermometer was used to record the air and water temperature. Spectrophotometer (Electronics India) was used to estimate water quality parameters. Salinometer (Venus Aqua) was used to measure the salinity. 1 HP and 5 HP motor (Kirloskar) were used for pumping water to fish rearing units. The 300 watts and 500 watts water heaters were used to maintain the water temperature at required times.

The fish reared in the ponds for growth performance were sampled at an interval of every 15 days. The growth traits *viz.*, body weight, standard length and body depth were recorded at each sampling. The fish reared in tanks for morphometric studies were measured at the end of the experiment period.

3.5. Recording of traits

3.5.1. Growth performance study

The traits *viz* body weight (BW), standard length (SL) and body depth (BD) of common carp were recorded at every two weeks of culture age. Each sampling was completed within two days. The individual body weight of fish was recorded by portable digital weighing balance. Photographs of every fish were captured to record standard length and body depth. The photographs were captured using Honor 20i mobile phone rear camera (24 megapixel primary sensor with an f/1.8 aperture) in JPEG format with a resolution of 1080×2340 pixels. The standard length and body depth measurements

were retrieved later by software, ImageJ (version 1.51) developed by Wayne Rasband of National Institute of Health, USA.

3.5.2. Morphometric study

The morphometric traits of 480 fish, comprising equally from each stocks and each salinities were recorded for the study. 40 fish from each stock were taken to be reared in each salinity and this was done in duplicates. At the end of experimental period the photographs of all fish were recorded to get the values of all parameters. The photographs were captured using Honor 20i mobile phone rear camera (24 megapixel primary sensor with an f/1.8 aperture) in JPEG format with a resolution of 1080x2340 pixels. Nineteen morphometric traits viz; **TL** – Total Length, **FL** - Fork length, **SL** - Standard length, **PrePFL** - Pre pectoral fin length, **PreDFL**- Pre dorsal fin length, **PreVFL** – Pre ventral fin length, **PreAFL** - Pre anal fin length, **PFBL** - Pectoral fin base length ; **DFBL** - Dorsal fin base length, **VFBL** – Ventral fin base length, **AFBL** - Anal fin base length, **DbP&V** – distance between pectoral and ventral fin, **DbP&A** – distance between pectoral and anal fin, **DbV&A** – distance between ventral and anal fin, **MaxBD** – Maximum body depth, **MinBD** – Minimum body depth, **POL** - Post orbital length, **HL** - Head length, **ED** – eye diameter (Fig.1. and Table 2), were further retrieved using the software, ImageJ (version 1.51)

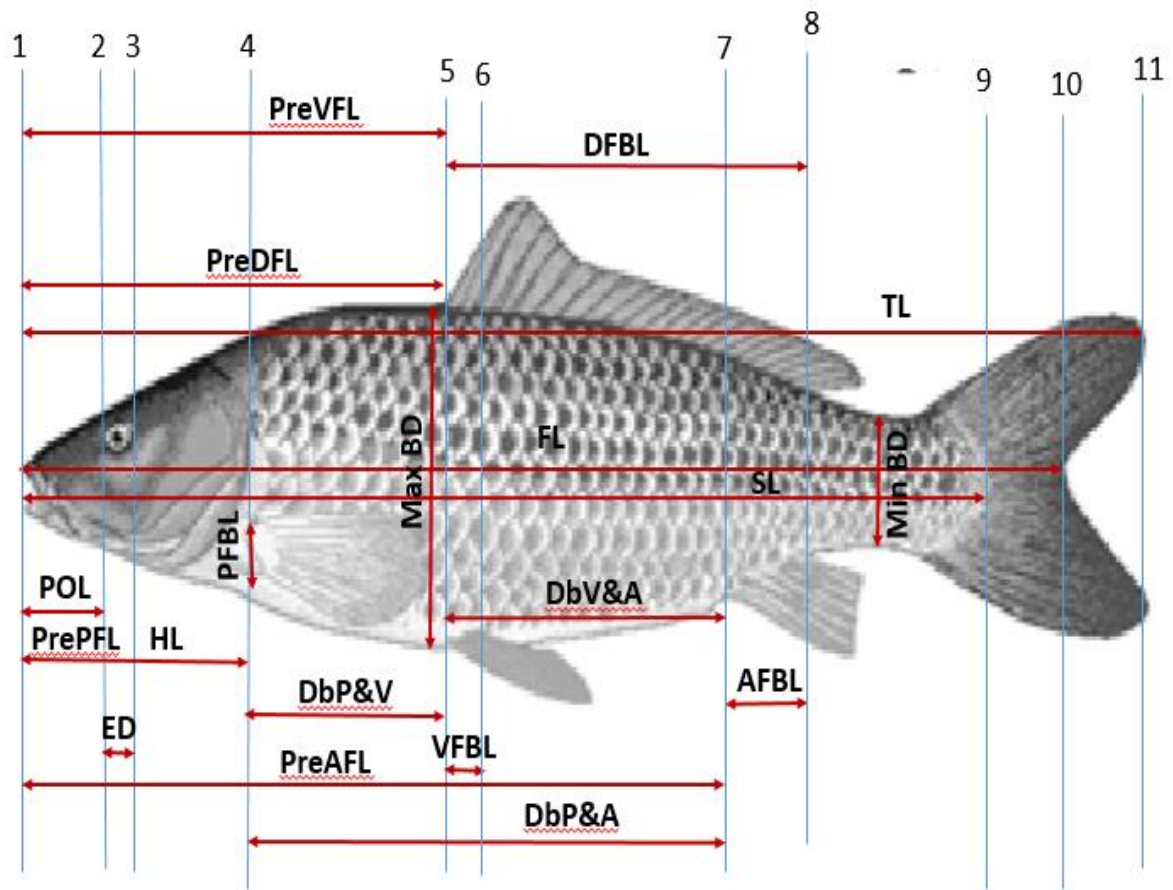


Figure 1: Morphometric measurements of *Cyprinus carpio* considered for the study. (TL – Total Length, FL - Fork length, SL - Standard length, PrePFL - Pre pectoral fin length, PreDFL - Pre dorsal fin length, PreVFL – Pre ventral fin length, PreAFL - Pre anal fin length, PFBL - Pectoral fin base length ; DFBL - Dorsal fin base length, VFBL – Ventral fin base length, AFBL - Anal fin base length, DbP&V – distance between pectoral and ventral fin, DbP&A – distance between pectoral and anal fin, DbV&A – distance between ventral and anal fin, MaxBD – Maximum body depth, MinBD – Minimum body depth, POL - Post orbital length, HL - Head length, ED – eye diameter)

Table 2: Morphometric characters used for the present study

SI No	Morphometric traits	Acronyms	Description
1	Total length	TL	Length of the fish from anterior-most tip of the snout to the posterior-most tip of the longest lobe of the caudal fin. In figure 1, it is the linear distance between 1 st and 11 th line (See figure 1).
2	Fork length	FL	Length from the snout tip to the bifurcation of the caudal fin. In figure 1, it is the linear distance between 1 st and 10 th line (See figure 1).
3	Standard length	SL	Distance between the snout tip and the base of the caudal fin rays. In figure 1, it is the linear distance between 1 st and 9 th line (See figure 1).
4	Head length	HL	Length from the tip of the snout to the posterior most margin of the operculum. In figure 1, it is the linear distance between 1 st and 4 th line (See figure 1).
5	Pre-orbital length	PreOL	Length from the tip of the snout to the anterior-most margin of the eye orbit. In figure 1, it is the linear distance between 1 st and 2 nd line (See figure 1).
6	Eye diameter	ED	The diameter of the eye orbit along the body axis. In figure 1, it is the linear distance between 2 nd and 3 rd line (See figure 1).
7	Maximum body depth	MaxBD	It is the minimum linear distance between the opposite ends of the deepest part of the body (See figure 1).
8	Minimum body depth	MinBD	It is the minimum vertical distance across the caudal peduncle (See figure 1).

9	Pre-dorsal fin length	PreDFL	The distance from the tip of snout to the origin of the base of first dorsal fin ray. In figure 1, it is the linear distance between 1 st and 5 th line (See figure 1).
10	Pre-pectoral fin length	PrePFL	The distance from the tip of snout to the origin of pectoral fin. In figure 1, it is the linear distance between 1 st and 4 th line (See figure 1).
11	Pre-ventral fin length	PreVFL	The minimum linear distance from the tip of snout to the origin of first ventral fin ray. In figure 1, it is the distance between 1 st and 5 th line (See figure 1).
12	Pre-anal fin length	PreAFL	The minimum linear distance from the tip of snout to the origin of first anal fin ray. In figure 1, it is the distance between 1 st and 7 th line (See figure 1).
13	Dorsal fin base length	DFBL	It is the minimum linear distance of the dorsal fin from the first origin of the fin to the insertion point of the fin. In figure 1, it is the linear distance between 5 th and to 8 th line (See figure 1).
14	Pectoral fin base length	PFBL	It is the minimum linear distance from the origin of the pectoral fin to the posterior-most tip of the fin (See figure 1).
15	Ventral fin base length	VFBL	It is the minimum linear distance from the origin of the first ventral fin ray to the last ventral fin ray. In figure 1, it is the minimum linear distance between 5 th and 6 th line (See figure 1).
16	Anal fin base length	AFBL	It is the minimum linear distance from the origin of first anal fin ray to the origin of the last anal fin ray. In figure1, it is the minimum linear distance between 7 th and 8 th line (See figure 1).

17	Distance between Pectoral & Ventral Fin	DbP&V	It is the minimum linear distance from the origin of first ray of pectoral fin to the origin of first ray of ventral fin. In figure 1, it is the linear distance between 4 th and 5 th line (See figure 1).
18	Distance between Pectoral & Anal Fin	DbP&A	It is the minimum linear distance from the origin of first ray of pectoral fin to the origin of first ray of anal fin. In figure 1, it is the minimum linear distance between 4 th and 7 th line (See figure 1).
19	Distance between Ventral & Anal Fin	DbV&A	It is the minimum linear distance from the origin of first ray of ventral fin to the origin of first ray of anal fin. In figure 1, it is the minimum linear distance between 5 th and 7 th line (See figure 1).

3.6. Statistical analysis

The statistical analysis was done using software Statistical Analysis Software (SAS; version 9.3). The data was initially tested for normality and the outliers were removed. The least square means and the effects of stock, salinity and stock*salinity on performance traits recorded at different culture ages was estimated by invoking the PROC GLM procedure of SAS, using following model.

$$Y_{ijk} = \mu + S_i + Sa_j + S_i * Sa_j + e_{ijk}$$

where,

μ = common mean

Y_{ijk} = record of kth fish reared in jth salinity belonging to ith stock

S_i = effect of ith stock (i= 1,2,3)

Sa_j = effect of jth salinity (j=1,2)

e_{ijk} = residual, e_{ijk} , i.i.d. $\sim N(0,1)$

The pairwise wise comparison was done by invoking Tukey's test procedure. The growth curves for mean trait value were plotted by invoking procedure PROC SGPLOT. The correlation between trait body weight and temperature was estimated by invoking PROC CORR procedure of SAS.

The least square means and the effects of stock and salinity, stock*salinity on morphometric traits recorded was estimated by invoking the PROC GLM procedure of SAS, using following model.

$$Y_{ijk} = \mu + S_i + S_{aj}(S_i) + e_{ijk}$$

where,

μ = common mean

Y_{ijk} = morphometric trait record of k^{th} fish reared in j^{th} salinity belonging to i^{th} stock

S_i = effect of i^{th} stock ($i=1,2,3$)

S_{aj} = effect of j^{th} salinity ($j=1,2$)

e_{ijk} = residual, e_{ijk} , i.i.d. $\sim N(0,1)$

The pairwise wise comparison was done by invoking Tukey's test procedure. The regression coefficient and regression curves for various morphometric traits expressed as function of total length (TL) were estimated invoking PROC REG procedure of SAS.



Results

4. RESULTS

In the present study, three geographical stocks of common carp *viz.*, Andhra Pradesh, Karnataka and Tamil Nadu were evaluated for early growth performance in ponds at two salinities namely low saline (LS) and high saline (HS). The early growth performance traits *viz.*, body weight, standard length and body depth were recorded. The sampling was done at 1st, 15th, 30th and 45th day of culture.

4.1. Frequency distribution

The number of fish observations at different sampling points *viz.*, 1st, 15th, 30th and 45th day of culture, from the three stocks *viz.*, Andhra Pradesh (AP), Karnataka (K) and Tamil Nadu (TN) reared at two salinities *viz.*, high saline and low saline are provided in Table 3. A total of 3078 observations were recorded for the three growth traits *viz.*, body weight, standard length and body depth. About 1927, 307, 366 and 478 fish observations were recorded at 1st, 15th, 30th and 45th day of culture respectively. Stock wise records include 982, 1021 and 1075 observations from the AP, K and TN respectively. There were 1532 and 1546 observations at high saline and low saline ponds respectively.

4.2. Trait: Body weight

4.2.1. Descriptive statistics

The descriptive statistics stock wise and salinity wise at different culture age *viz.*, 1, 15, 30 and 45 days are provided in the Table 4. At the 1st day of culture, the average body weight in grams along with standard error (SE) of Andhra Pradesh, Karnataka and Tamil Nadu stocks were 0.20 ± 0.002 , 0.64 ± 0.01 and 0.69 ± 0.01 respectively and at high saline and low saline the average body weights were 0.53 ± 0.01 , 0.50 ± 0.01 respectively. The Tamil Nadu stock had the highest coefficient of variation (CV) of 60.59%, followed by Karnataka and Andhra Pradesh. At the 45th day of culture, the average body weight in grams along with standard error (SE) of Andhra Pradesh, Karnataka and Tamil Nadu stocks were 18.34 ± 0.97 , 55.47 ± 1.53 , 31.40 ± 1.69 respectively and at high saline and low saline the average body weights were 24.05

± 1.12 g, 45.41 ± 1.58 g respectively. On the 45th day of culture age, Tamil Nadu stock had the highest CV of 72.46% followed by Andhra Pradesh and Karnataka. Among the two salinities the common carp cultured in low saline ponds had greater CV than high saline ponds at all culture ages. The maximum body weight of common carp recorded was 154 grams at 45th day of culture age and it belonged to Tamil Nadu stock reared in low saline ponds.

4.2.2. Variation in body weight

The stock*salinity wise variation in body weight within and between the different culture ages in common carp is represented as box plots in Fig. 2.1 to Fig. 2.4. The growth curve (Fig.3) is plotted using the mean body weight at different culture ages. The Karnataka stock reared at 4 ppt (low saline) showed the highest peak for body weight followed by the same stock reared at 8 ppt (high saline). Further, the Tamil Nadu stock reared at 4 ppt showed an upward trend after 30 days of culture age followed by Andhra Pradesh stock reared at 4 ppt.

The stock, salinity and stock*salinity wise least square means of the trait body weight at different culture ages are provided in Table 5. A total of 1927 observations were recorded for body weight at 1st day of culture age. The overall least square mean body weight was 0.51 ± 0.01 g. Among the stocks, the common carp belonging to Tamil Nadu stock had significantly higher body weight of 0.69 ± 0.01 g followed by Karnataka and Andhra Pradesh stocks. Among the salinities, there was no significant difference between body weights of common carp reared in low saline and high saline ponds. The stock*salinity comparison revealed significant differences for body weight.

A total of 307 observations were recorded for body weight at 15th day of culture age. The overall least square mean body weight was 9.85 ± 0.4 g. Among the stocks, the common carp belonging to Karnataka stock had significantly higher least square mean body weight of 16.80 ± 0.41 g followed by Tamil Nadu and Andhra Pradesh stocks. Among the salinities, the common carp reared in low saline ponds had a least square mean body weight of 11.90 ± 0.33 g and that was significantly higher than that of high saline pond. Among the stock*salinity comparisons, common carp belonging to

Karnataka stock reared in low saline pond had the significantly highest body weight of 19.79 ± 0.54 g.

A total of 366 observations were recorded for body weight at 30th day of culture age and the overall body weight least square mean was 20.32 ± 0.75 g. Among the stocks, the common carp belonging to Karnataka stock had significantly higher body weight of 33.90 ± 0.74 g followed by Tamil Nadu and Andhra Pradesh stocks. Among the salinities, the common carp reared in low saline ponds had significantly higher body weight of 24.93 ± 0.61 g. Among the stock*salinity comparisons, common carp belonging to Karnataka stock reared in low saline pond had the significantly highest body weight of 40.54 ± 1.02 g.

A total of 478 observations were recorded for body weight at 45th day of culture age and the overall least square mean body weight was 34.86 ± 1.09 g. Among the stocks, the common carp belonging to Karnataka stock had significantly higher least square mean body weight of 55.08 ± 1.26 g followed by Tamil Nadu and Andhra Pradesh stocks. Among the salinities, the common carp reared in low saline ponds had significantly higher least square mean body weight of 45.32 ± 0.99 g. Among the stock*salinity comparisons, common carp belonging to Karnataka stock and reared in low saline pond had the significantly highest least square mean body weight of 66.72 ± 1.75 g followed by the same stock reared in high saline pond. Tamil Nadu stock reared in low saline pond had a least square mean body weight of 42.81 ± 1.61 g and performed similar to Karnataka stock reared in high saline pond. Stock, salinity and stock*salinity wise Tukey-Karmer groupings of common carp body weight, at different culture ages is provided in Fig. 4.01 to Fig. 4.12.

Amongst the three stocks, the Karnataka stock performed better followed by Tamil Nadu and Andhra Pradesh stocks. The least square mean body weight of Tamil Nadu stock was significantly higher than Andhra Pradesh stock at the 1st day of culture and this initial difference remained till the end of experiment period. Amongst the two salinities, the stocks reared in low saline ponds performed better than the stocks reared in high saline ponds.

The mean sum of square (MSS) values from analysis of variance for body weight at various rearing ages is represented in Table 6. The effects of stock, salinity, and stock*salinity on body weight were estimated. At 1st day of culture age, the stock and stock*salinity had significant effect on body weight, but at 45th day of culture age the stock and the salinity had significant effect on body weight of fish.

Table 3: Pond age, stock and salinity wise frequencies

Pond Age	Frequency
1	1927
15	307
30	366
45	478
Total	3078
Stock	Frequency
AP	982
K	1021
TN	1075
Total	3078
Salinity	Frequency
Low Saline	1532
High Saline	1546
Total	3078

Table 4: Descriptive statistics for the trait body weight

1. 1st day of culture						
Group	Source	No	Mean ± SE (g)	CV	Min (g)	Max (g)
Stock	AP	640	0.20 ± 0.002	33.39	0.05	0.44
	K	645	0.64 ± 0.01	42.79	0.28	2.53
	TN	642	0.69 ± 0.01	60.59	0.27	4.76
Salinity	High saline	965	0.53 ± 0.01	69.24	0.05	2.90
	Low saline	962	0.50 ± 0.01	73.54	0.07	4.76
2. 15th day of culture						
Group	Source	No	Mean ± SE (g)	CV	Min (g)	Max (g)
Stock	AP	84	4.08 ± 0.28	64.96	0.62	12.49
	K	101	17.12 ± 0.54	31.93	4.46	30.85
	TN	122	7.80 ± 0.46	65.83	0.60	31.27
Salinity	High saline	150	7.21 ± 0.48	81.82	0.62	30.85
	Low saline	157	12.37 ± 0.57	58.55	0.60	31.27
3. 30th day of culture						
Group	Source	No	Mean ± SE (g)	CV	Min (g)	Max (g)
Stock	AP	110	9.75 ± 0.58	63.22	2.55	49.04
	K	126	34.32 ± 1.01	33.13	8.84	63.53
	TN	130	15.70 ± 0.95	69.02	1.28	66.80
Salinity	High saline	181	14.76 ± 0.84	76.91	1.93	61.18
	Low saline	185	25.76 ± 1.09	57.90	1.28	66.80
4. 45th day of culture						
Group	Source	No	Mean ± SE (g)	CV	Min (g)	Max (g)
Stock	AP	148	18.34 ± 0.97	64.82	4.19	99.40
	K	149	55.47 ± 1.53	33.73	14.52	105.46
	TN	181	31.40 ± 1.69	72.46	2.96	154.33
Salinity	High saline	236	24.05 ± 1.12	71.80	3.62	100.46
	Low saline	242	45.41 ± 1.58	54.39	2.96	154.33

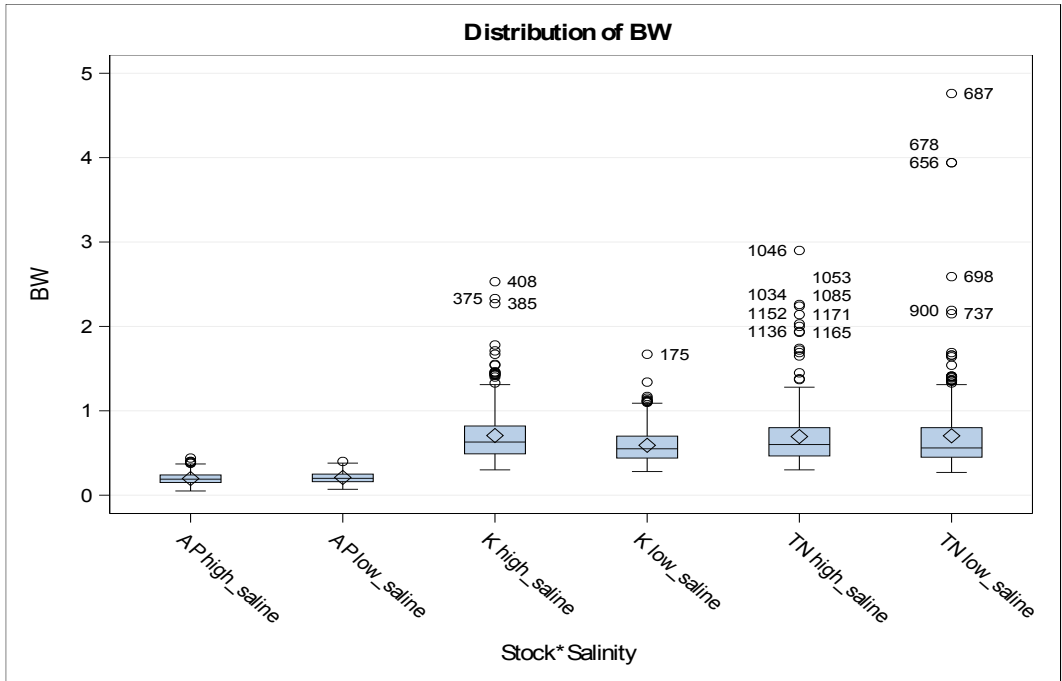


Figure 2.1: Box and Whisker plot for body weight of different stock*salinity at 1st day of pond age

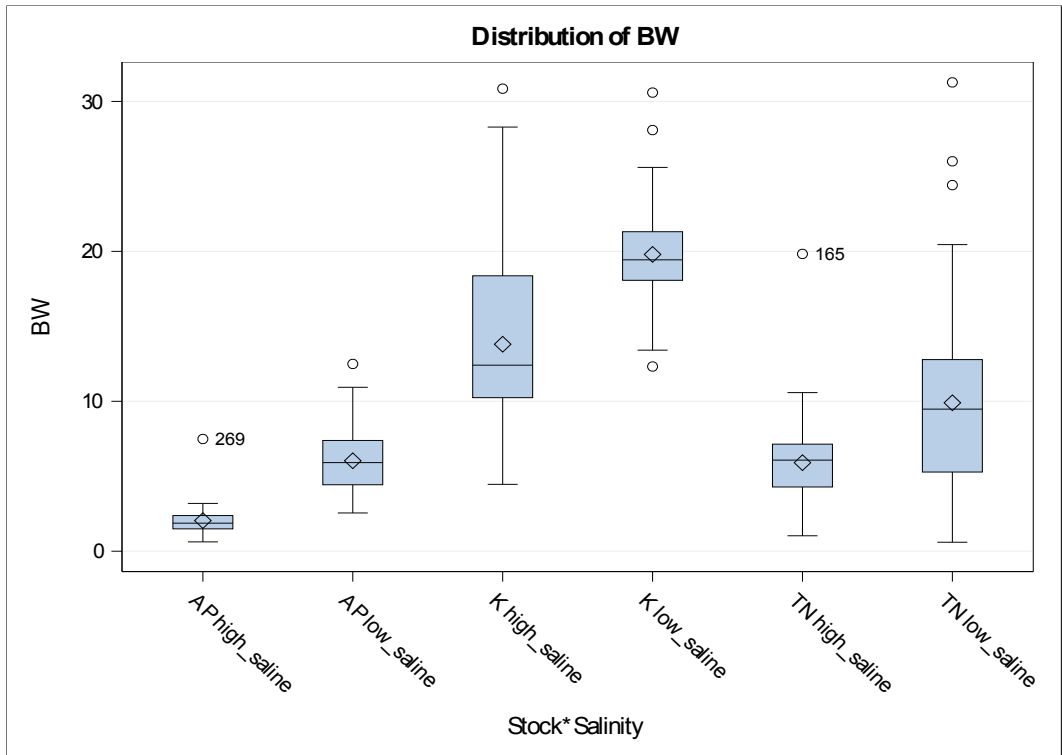


Figure 2.2: Box and Whisker plot for body weight of different stock*salinity at 15th day of pond age

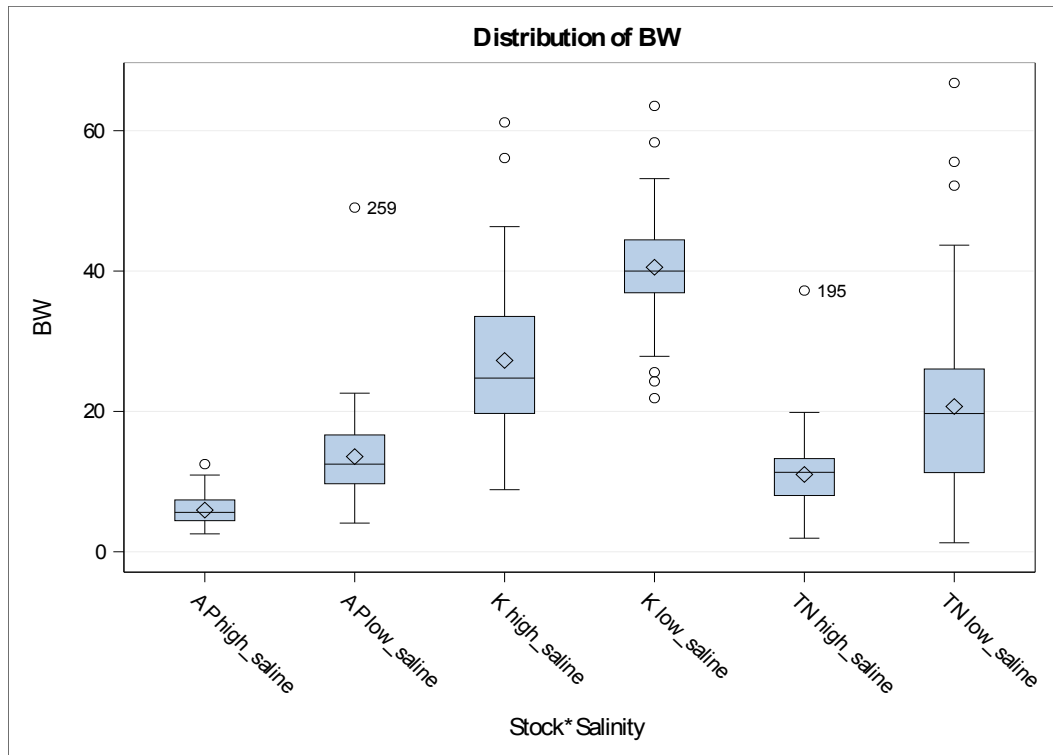


Figure 2.3: Box and Whisker plot for body weight of different stock*salinity at 30th day of pond age

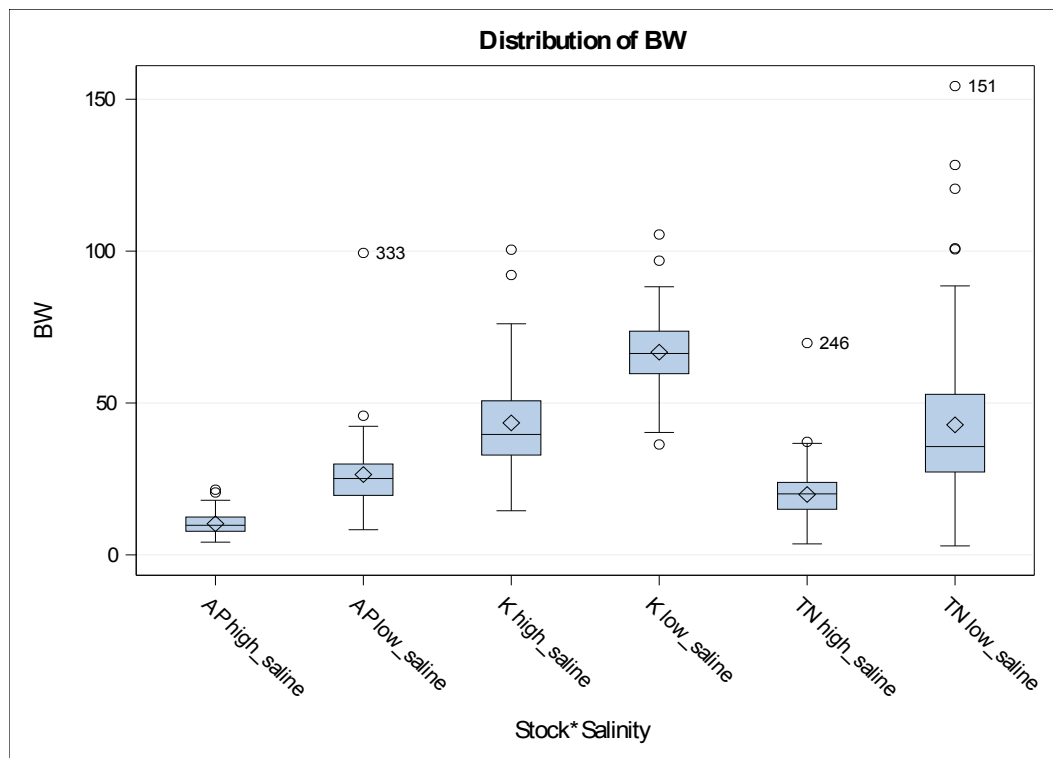


Figure 2.4: Box and Whisker plot for body weight in grams of different stock*salinity at 45th day of pond age

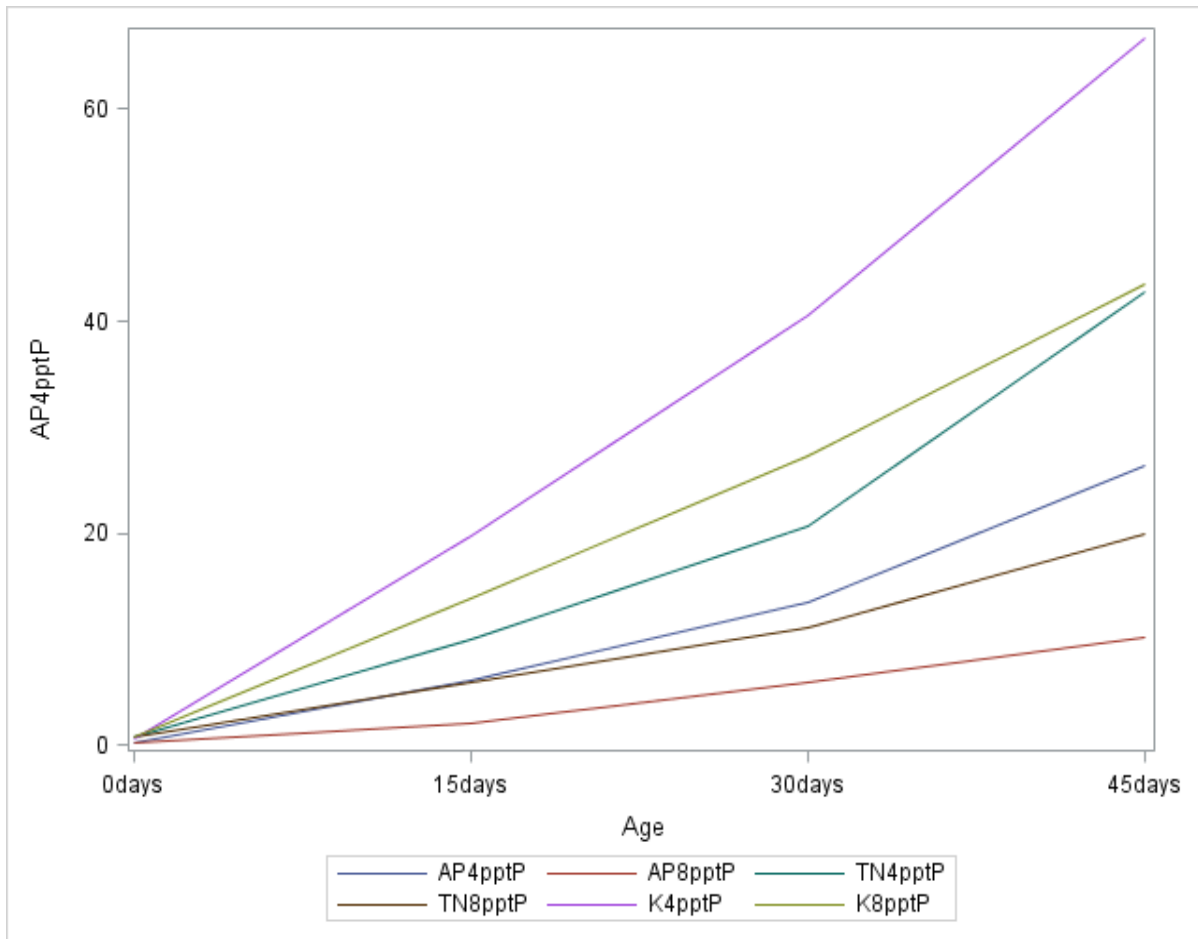


Figure 3: Least square means comparison curve for body weight of the three stocks across salinities reared in pond

Table 5: Least square means and its standard error of body weight in grams at different pond ages

Group	Source of Variation	Pond Age							
		1		15		30		45	
		N	Mean ± SE	N	Mean ± SE	N	Mean ± SE	N	Mean ± SE
Overall	-	1927	0.51±0.01	307	9.85±0.40	366	20.32±0.75	478	34.86±1.09
Stocks	AP	640	0.20±0.01 ^c	84	4.03±0.44 ^c	110	9.75±0.79 ^c	148	18.34±1.26 ^c
	K	645	0.64±0.01 ^b	101	16.80±0.41 ^a	126	33.90±0.74 ^a	149	55.08±1.26 ^a
	TN	642	0.69±0.01 ^a	122	7.90±0.37 ^b	130	15.85±0.73 ^b	181	31.34±1.14 ^b
Salinity	HS	965	0.53±0.009 ^a	150	7.25±0.34 ^b	181	14.73±0.62 ^b	236	24.52±1.01 ^b
	LS	962	0.50±0.009 ^a	157	11.90±0.33 ^a	185	24.93±0.61 ^a	242	45.32±0.99 ^a
Stock*Salinity	AP-HS	320	0.19±0.01 ^c	41	2.04±0.64 ^e	55	5.94±1.13 ^e	74	10.25±1.79 ^d
	AP-LS	320	0.21±0.01 ^c	43	6.03±0.62 ^d	55	13.56±1.13 ^d	74	26.44±1.79 ^c
	K-HS	325	0.70±0.01 ^a	45	13.80±0.61 ^b	59	27.25±1.09 ^b	72	43.44±1.81 ^b
	K-LS	320	0.59±0.01 ^b	56	19.79±0.54 ^a	67	40.54±1.02 ^a	77	66.72±1.75 ^a
	TN-HS	320	0.69±0.01 ^a	64	5.90±0.51 ^d	67	11.01±1.02 ^{de}	90	19.88±1.62 ^c
	TN-LS	322	0.70±0.01 ^a	58	9.90±0.53 ^c	63	20.70±1.05 ^c	91	42.81±1.61 ^b

Means within each group of sources of variation viz stocks (AP, K and TN), salinity (high saline and low saline) and stock*salinity (AP-HS, AP-LS, K-HS, K-LS, TN-HS, TN-LS) in the same column having different superscripts vary significantly from each other within the group ($p < 0.01$). 'N' is number of observations at each group for each pond age.

Table 6: Mean sum of squares from analysis of variance of body weight at different pond ages

Source of Variation	DF	Tank Age			
		1	15	30	45
Stock	2	47.69*	4058.07*	19005.07*	51731.68*
Salinity	1	0.47 ^{NS}	1619.84*	9448.36*	51225.53*
Stock*Salinity	2	0.86*	33.49 ^{NS}	244.35 ^{NS}	609.68 ^{NS}
EMS	NA	0.08	16.79	70.29	237.79
Error DF	NA	1921	301	360	472
R ² (%)	NA	37.01	67.21	66.36	58.69

* $p < 0.01$, NS- not significant ($p > 0.01$)

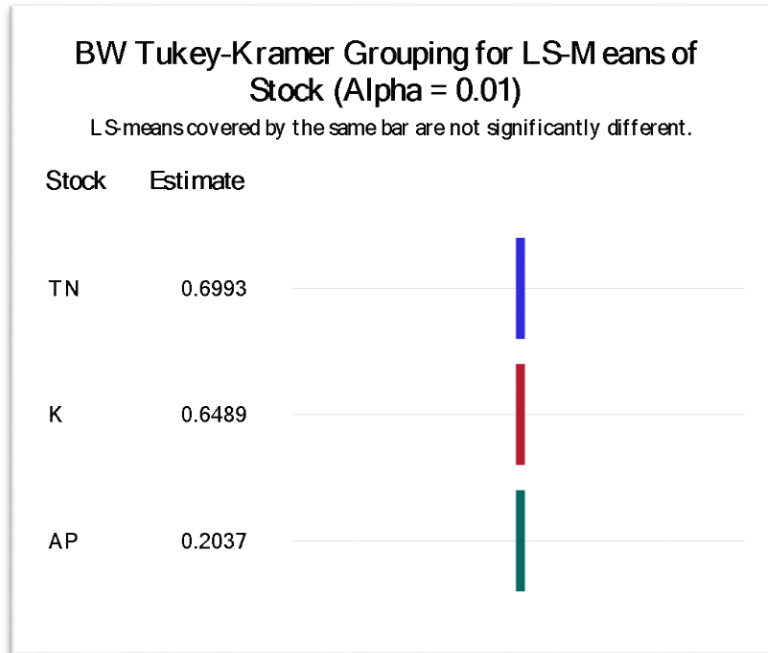


Figure 4.1: Stock wise Tukey-Kramer grouping for body weight least square means at 1st day of pond age

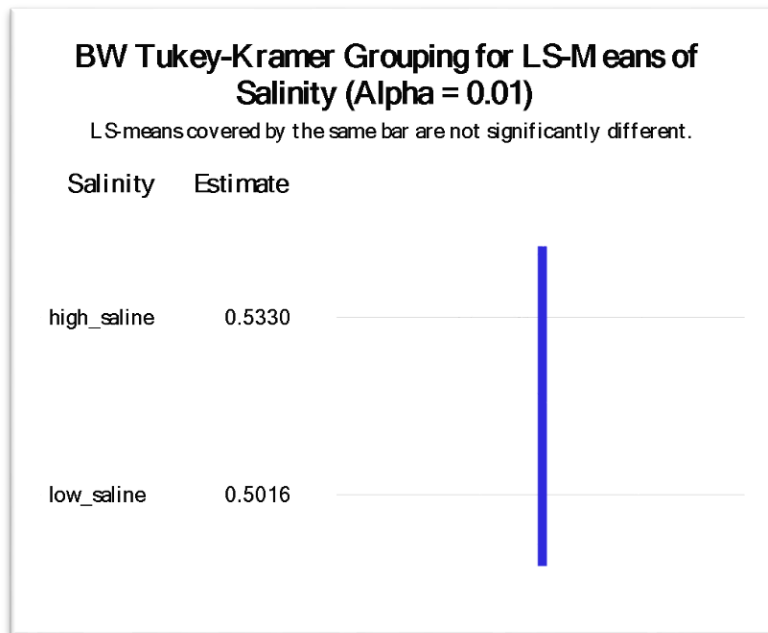


Figure 4.2: Salinity wise Tukey-Kramer grouping for body weight least square means at 1st day of pond age

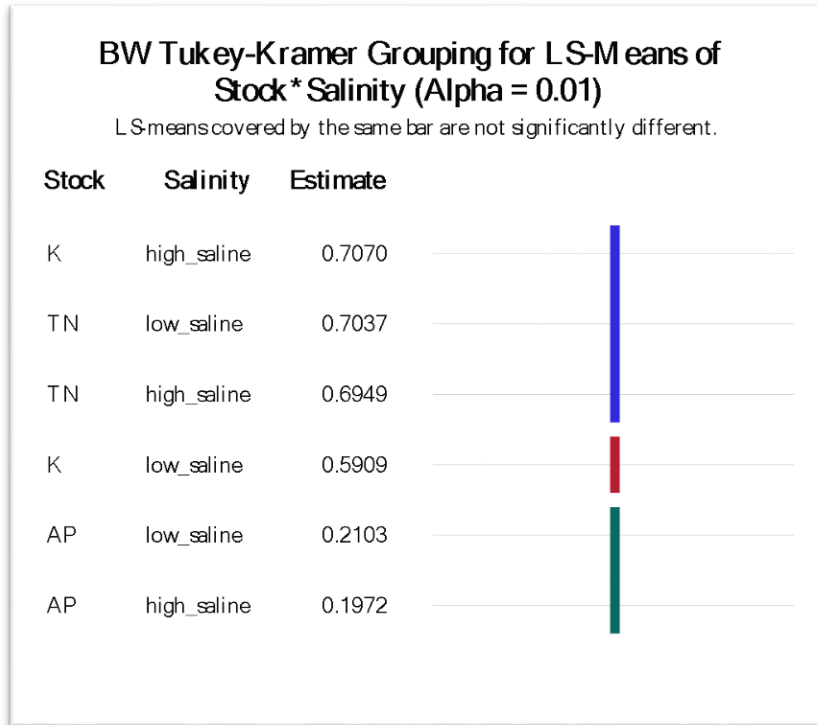


Figure 4.3: Stock*salinity wise Tukey-Kramer grouping for body weight least square means at 1st day of pond age

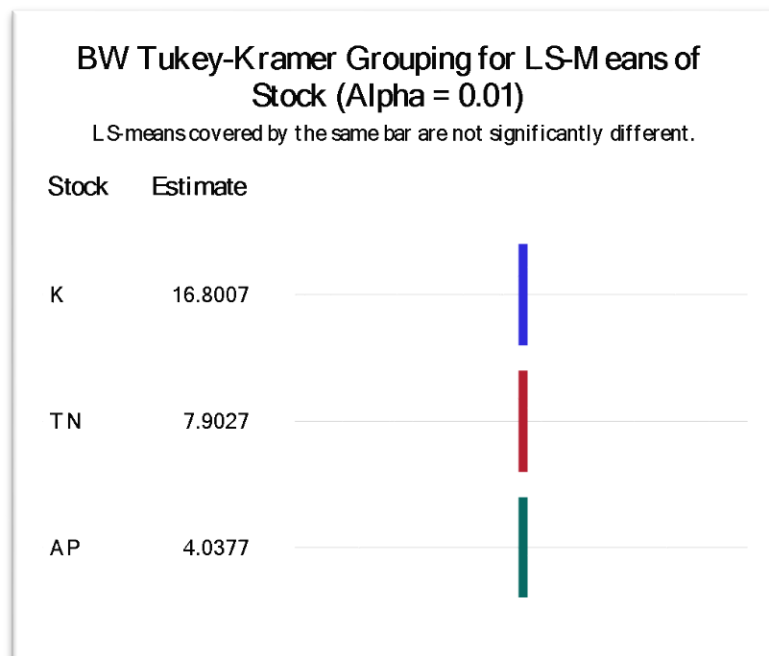


Figure 4.4: Stock wise Tukey-Kramer grouping for body weight least square means at 15th day of pond age

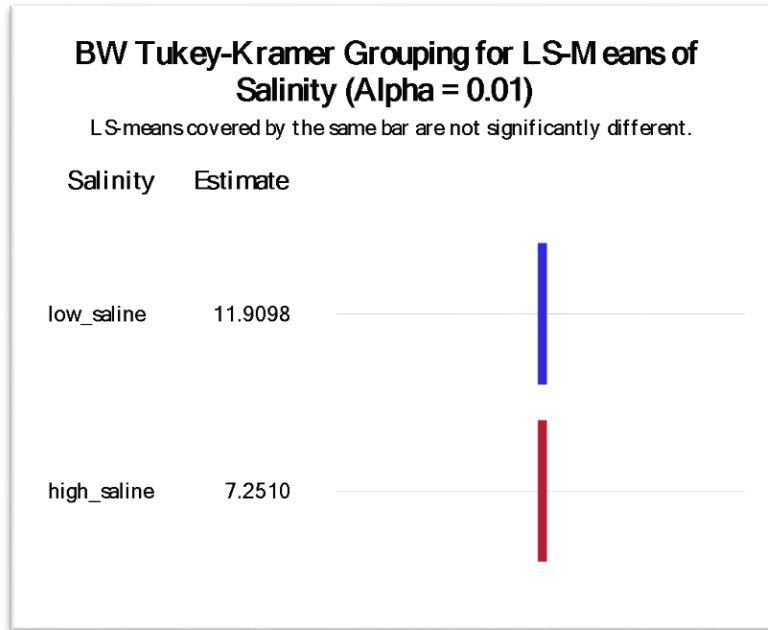


Figure 4.5: Salinity wise Tukey-Kramer grouping for body weight least square means at 15th day of pond age

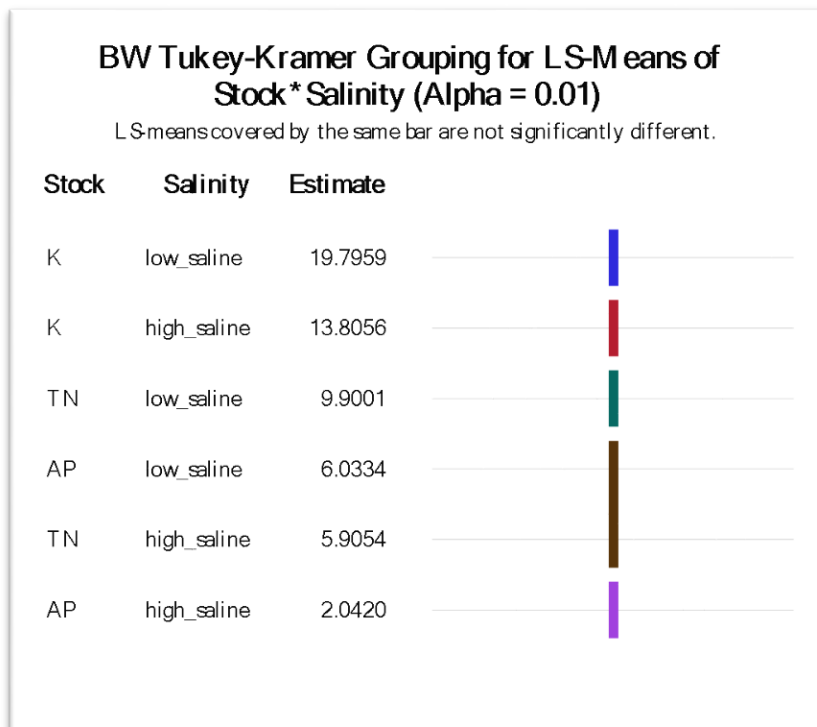


Figure 4.6: Stock*salinity wise Tukey-Kramer grouping for body weight least square means at 15th day of pond age

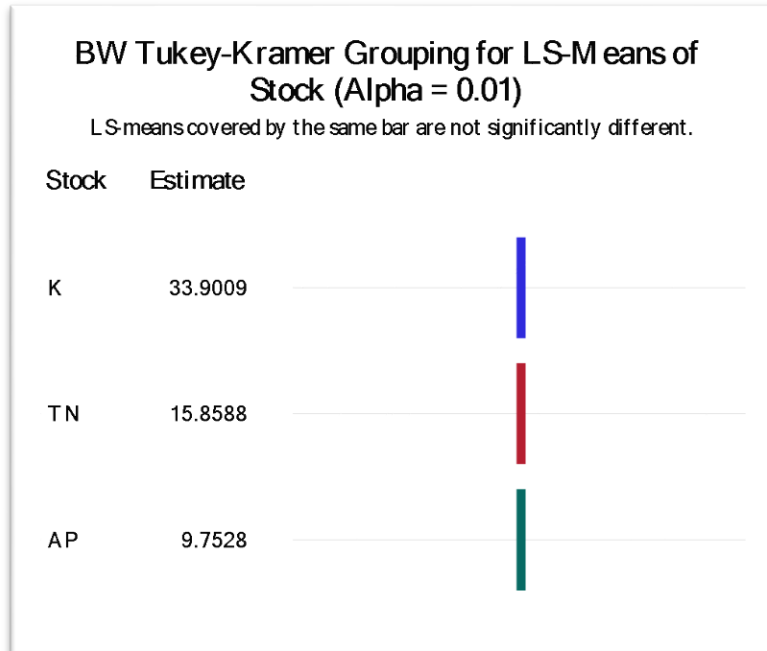


Figure 4.7: Stock wise Tukey-Kramer grouping for body weight least square means at 30th day of pond age

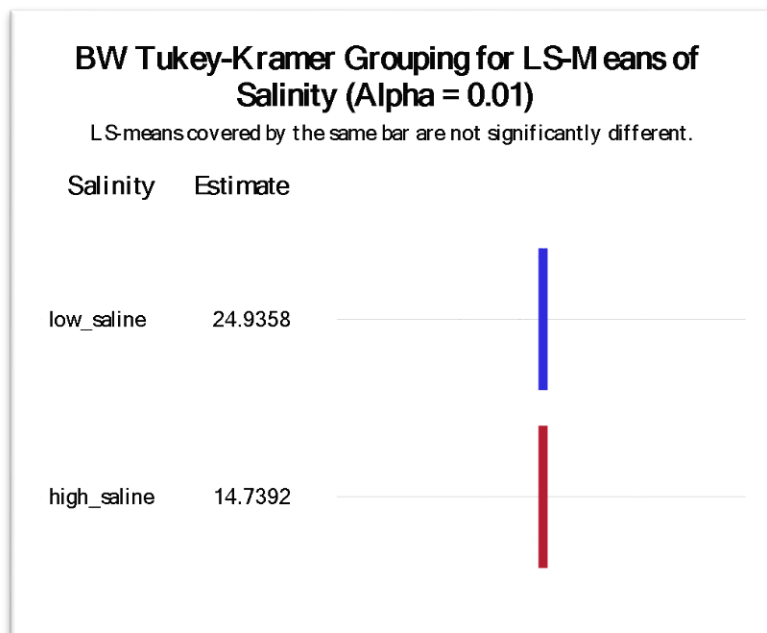


Figure 4.8: Salinity wise Tukey-Kramer grouping for body weight least square means at 30th day of pond age

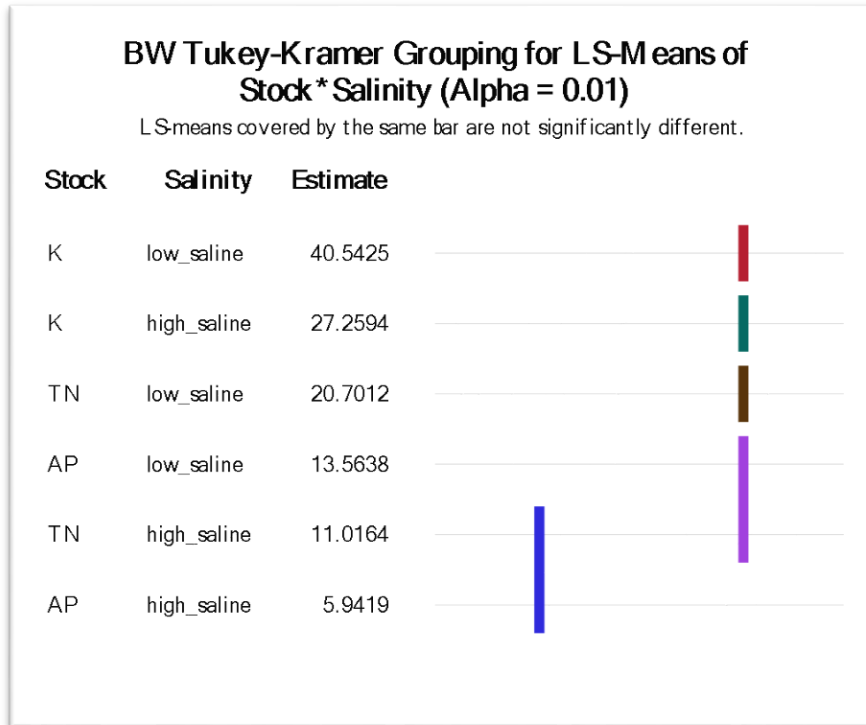


Figure 4.9: Stock*salinity wise Tukey-Kramer grouping for body weight least square means at 30th day of pond age

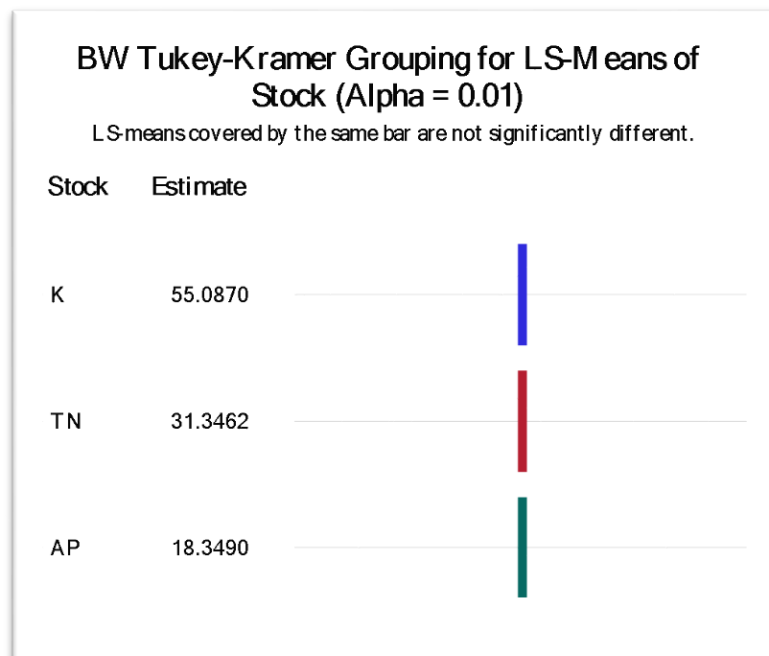


Figure 4.10: Stock wise Tukey-Kramer grouping for body weight least square means at 45th day of pond age

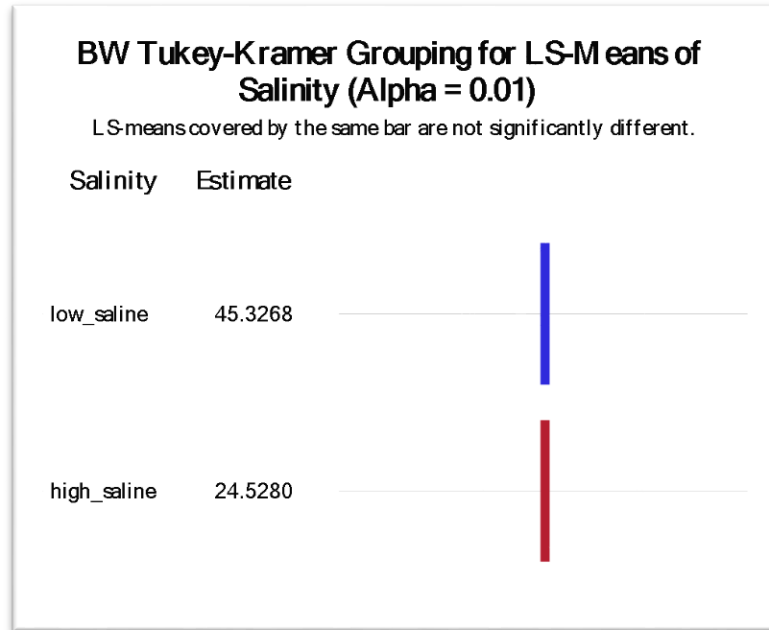


Figure 4.11: Salinity wise Tukey-Kramer grouping for body weight least square means at 45th day of pond age

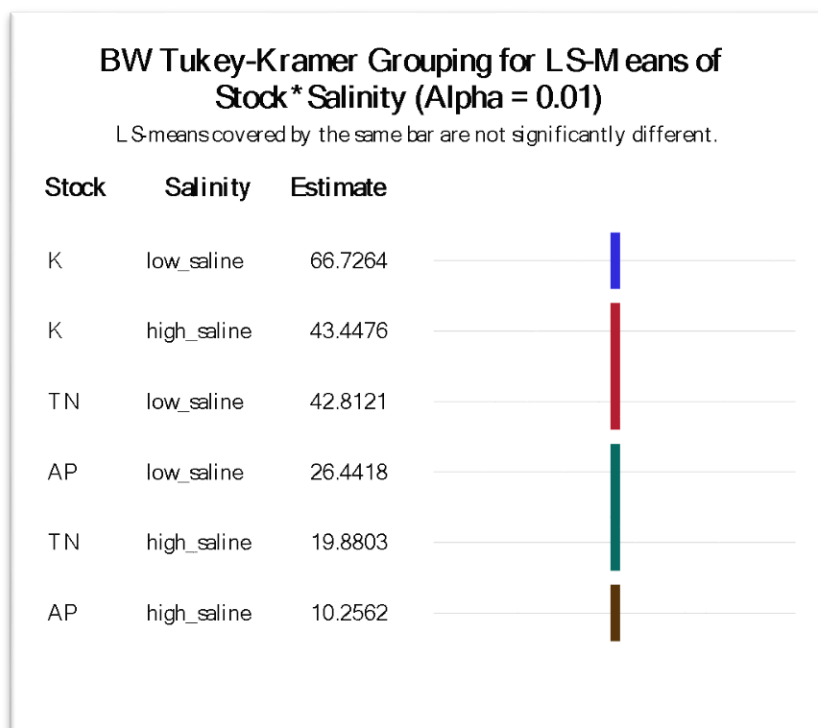


Figure 4.12: Stock*salinity wise Tukey-Kramer grouping for body weight least square means at 45th day of pond age

4.3. Trait: Standard Length

4.3.1. Descriptive statistics

The descriptive statistics for standard length in common carp, stock and salinity wise at different culture age *viz.*, 1, 15, 30 and 45 days are provided in the Table 7. At the 1st day of culture, the average standard length in centimeter along with standard error (SE) of Andhra Pradesh, Karnataka and Tamil Nadu stocks were 0.72 ± 0.009 , 2.40 ± 0.03 and 2.50 ± 0.06 respectively and at high saline and low saline the standard length were 1.94 ± 0.04 cm, 1.81 ± 0.04 cm respectively. The Tamil Nadu stock had the highest coefficient of variation (CV) of 60.86%, followed by Karnataka and Andhra Pradesh. At the 45th day of culture, the average standard length in centimeter along with standard error (SE) of Andhra Pradesh, Karnataka and Tamil Nadu stocks were 9.31 ± 0.31 , 16.20 ± 0.39 , 11.41 ± 0.52 respectively and at high saline and low saline the standard length were 9.99 ± 0.31 cm, 14.45 ± 0.41 cm respectively. On the 45th day of culture age, Tamil Nadu stock had the highest CV of 61.43 % followed by Andhra Pradesh and Karnataka. The maximum standard length of common carp recorded was 49.56 cm at 45th day of culture age and it belonged to Tamil Nadu stock reared in low saline ponds.

4.3.2. Variation in standard length

The stock*salinity wise variation in standard length within and between the different culture ages in common carp is represented as box plots in Fig. 5.1 to Fig. 5.4. The growth curve (Fig.6) is plotted using the mean standard length at different culture ages. The Karnataka stock reared at 4 ppt (low saline) showed the highest peak for standard length followed by the same stock reared at 8 ppt (high saline). Further, the Tamil Nadu stock reared at 4 ppt (low saline) showed an upward trend after 15 days of culture age. The stock wise, salinity wise and stock*salinity wise least square means of standard length at different culture age are given in table 8.

A total of 1927 observations were recorded for standard length at 1st day of culture age. The overall least square mean of standard length was 1.87 ± 0.03 cm. Among the stocks, the common carp stock belonging to Tamil Nadu and Karnataka had the highest standard length of 2.50 ± 0.04 cm and 2.40 ± 0.04 respectively followed by

Andhra Pradesh stock. Among the salinities, there was no significant difference between standard length of common carp reared in low saline and high saline ponds. The stock*salinity comparison revealed significant differences for standard length.

A total of 307 observations were recorded for standard length at 15th day of culture age. The overall least square mean of standard length was 9.85 ± 0.4 cm. Among the stocks, the common carp belonging to Karnataka stock had significantly higher least square mean standard length of 7.65 ± 0.2 cm followed by Andhra Pradesh and Tamil Nadu stocks. Among the salinities, the common carp reared in low saline ponds had least square mean standard length of 6.59 ± 0.16 cm and it was significantly higher than that of high saline pond. Among the stock*salinity comparisons, common carp belonging to Karnataka stock and reared in low saline pond had the significantly highest least square mean standard length of 9.01 ± 0.27 cm.

A total of 366 observations were recorded for standard length at 30th day of culture age. The overall least square mean of standard length was 9.26 ± 0.22 cm. Among the stocks, the common carp belonging to Karnataka stock had significantly higher least square mean standard length of 11.68 ± 0.33 cm followed by Tamil Nadu and Andhra Pradesh stocks. Among the salinities, the common carp reared in low saline ponds had significantly higher least square mean standard length of 9.98 ± 0.27 cm. Among the stock*salinity comparisons, common carp belonging to Karnataka stock and reared in low saline pond had the significantly highest least square mean standard length of 13.20 ± 0.45 cm followed by same stock reared in high saline pond.

A total of 478 observations were recorded for standard length at 45th day of culture age and the overall least square mean standard length was 12.25 ± 0.28 cm. Among the stocks, the common carp belonging to Karnataka stock had significantly higher least square mean standard length of 16.12 ± 0.41 cm, followed by Tamil Nadu and Andhra Pradesh stocks. Among the salinities, the common carp reared in low saline ponds had significantly higher least square mean standard length of 14.46 ± 0.32 cm. Among the stock*salinity comparisons, common carp belonging to Karnataka stock and reared in low saline pond had the significantly highest least square mean standard length of 18.30 ± 0.57 cm followed by same stock reared in high saline pond and Tamil Nadu

stock reared in low saline pond. The stock, salinity and stock*salinity wise Tukey-Karmer grouping of common carp standard length, at different culture ages is provided in Fig. 7.1 to 7.12.

Amongst the three stocks, the Karnataka stock performed better followed by Tamil Nadu and Andhra Pradesh stocks. The least square mean of standard length of Tamil Nadu stock was significantly higher than Andhra Pradesh stock at the 1st day of culture and this initial difference remained till the end of experiment period. Amongst the two salinities, the stocks reared in low saline ponds performed better than the stocks reared in high saline ponds.

The mean sum of square (MSS) values from analysis of variance for standard length at various culture ages is represented in Table 9. The effects of stock, salinity, and stock*salinity on standard length were estimated. At 1st day of culture age, stock and stock*salinity had significant effect on standard length. The stock and salinity had significant effect on standard length at 45th day of culture age.

Table 7: Descriptive statistics for the trait standard length

1. 1st day of culture						
Group	Source	No	Mean ± SE (cm)	CV	Min (cm)	Max (cm)
Stock	AP	640	0.72 ± 0.009	33.77	0.16	1.58
	K	645	2.40 ± 0.03	41.14	1.06	9.51
	TN	642	2.50 ± 0.06	60.86	0.95	17.11
Salinity	High saline	965	1.94 ± 0.04	69.08	0.16	10.26
	Low saline	962	1.81 ± 0.04	72.88	0.23	17.11
2. 15th day of culture						
Group	Source	No	Mean ± SE (cm)	CV	Min (cm)	Max (cm)
Stock	AP	84	5.21 ± 0.23	41.93	2.01	12.98
	K	101	7.80 ± 0.24	31.91	2.04	14.04
	TN	122	3.55 ± 0.21	65.84	0.29	14.23
Salinity	High saline	150	4.15 ± 0.19	56.93	0.44	14.04
	Low saline	157	6.59 ± 0.23	45.21	0.29	14.23
3. 30th day of culture						
Group	Source	No	Mean ± SE (cm)	CV	Min (cm)	Max (cm)
Stock	AP	110	6.90 ± 0.23	35.49	2.29	14.89
	K	126	11.78 ± 0.31	29.84	3.28	22.82
	TN	130	8.83 ± 0.43	55.66	0.59	30.43
Salinity	High saline	181	8.34 ± 0.27	44.91	1.92	27.80
	Low saline	185	10.17 ± 0.33	45.37	0.59	30.43
4. 45th day of culture						
Group	Source	No	Mean ± SE (cm)	CV	Min (cm)	Max (cm)
Stock	AP	148	9.31 ± 0.31	40.95	3.03	37.51
	K	149	16.20 ± 0.39	30.02	4.68	32.26
	TN	181	11.41 ± 0.52	61.43	0.91	49.56
Salinity	High saline	236	9.99 ± 0.31	48.73	1.66	32.26
	Low saline	242	14.45 ± 0.41	45.12	0.91	49.56

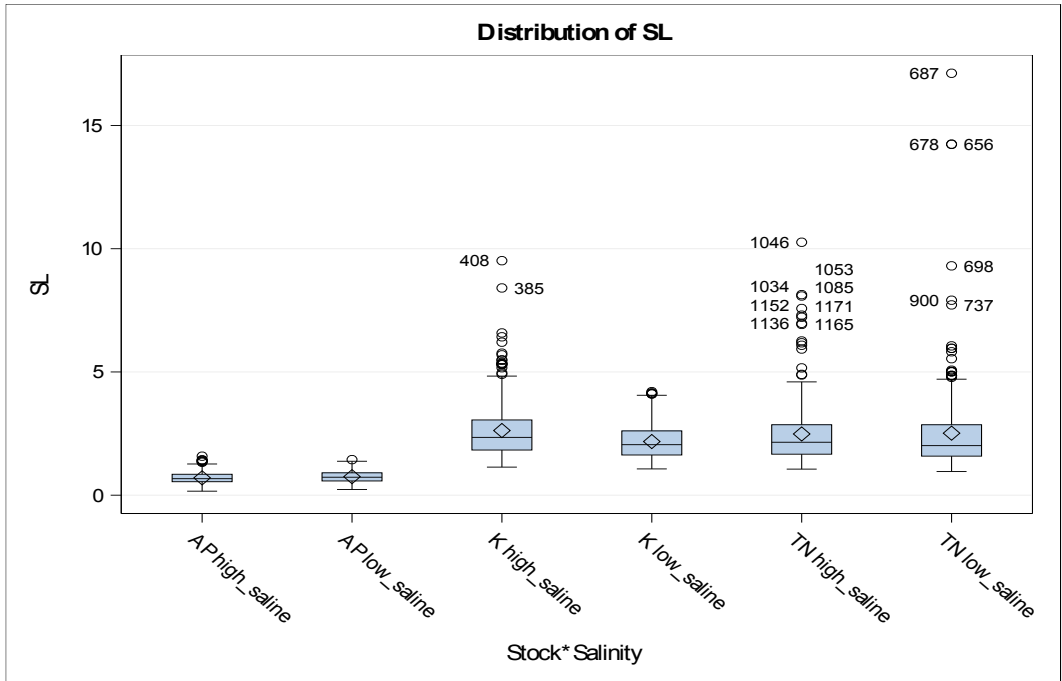


Figure 5.1: Box and Whisker plot for standard length in centimeters of different stock*salinity at 1st day of pond age

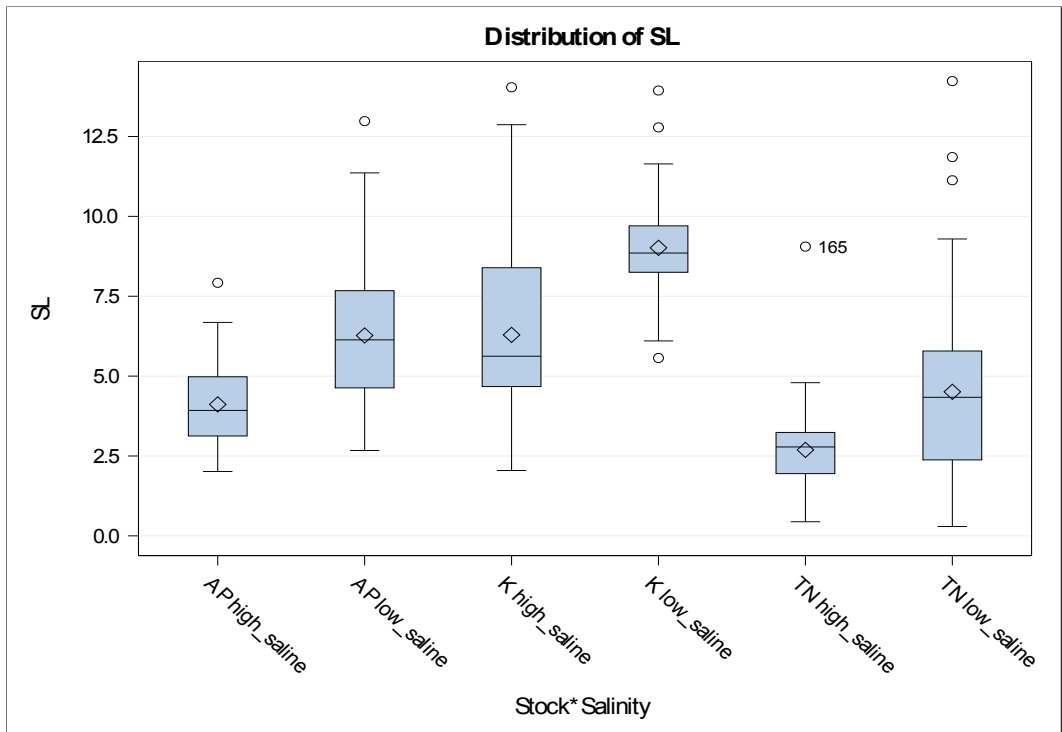


Figure 5.2: Box and Whisker plot for standard length in centimeters of different stock*salinity at 15th day of pond age

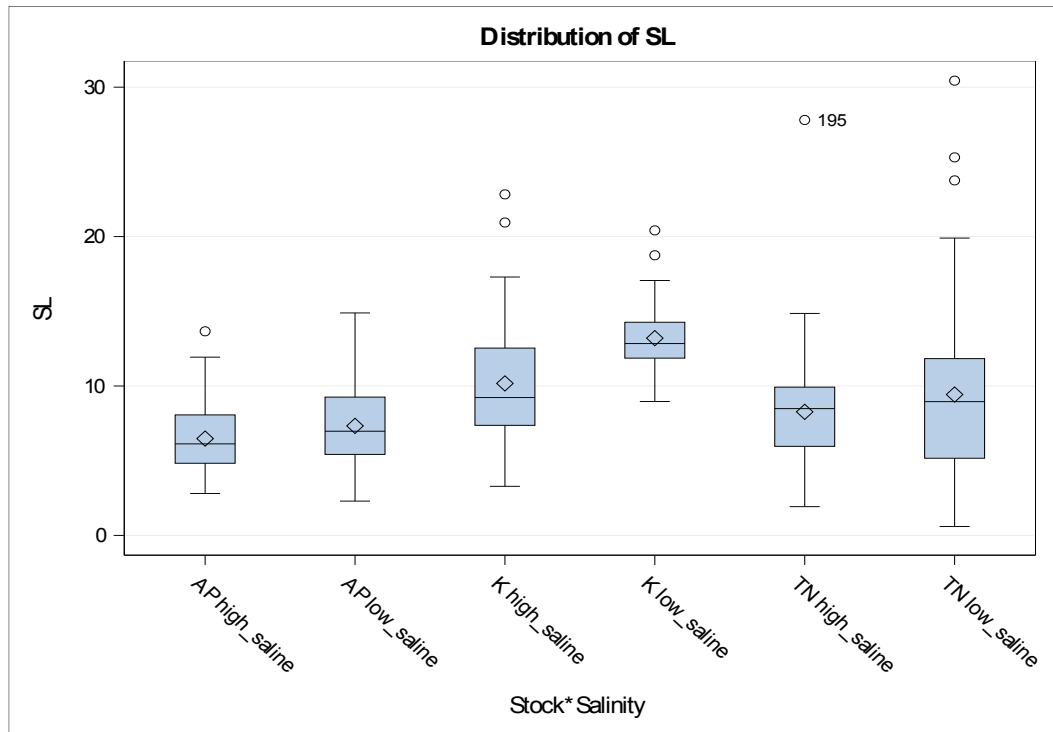


Figure 5.3: Box and Whisker plot for standard length in centimeters of different stock*salinity at 30th day of pond age

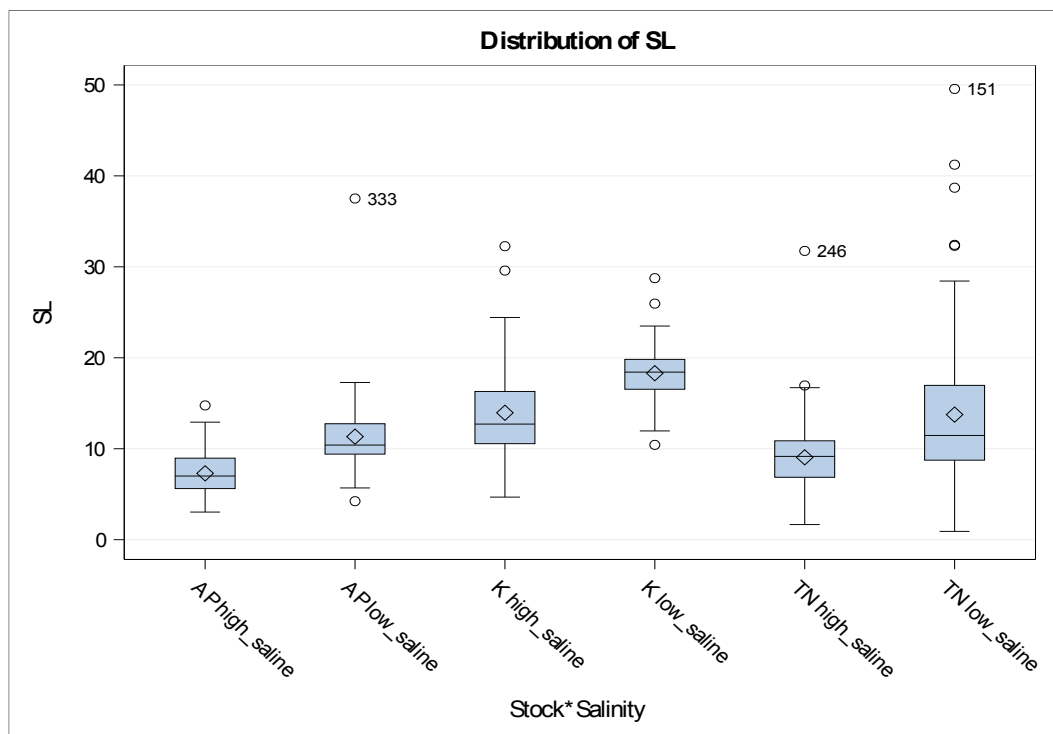


Figure 5.4: Box and Whisker plot for standard length in centimeters of different stock*salinity at 45th day of pond age

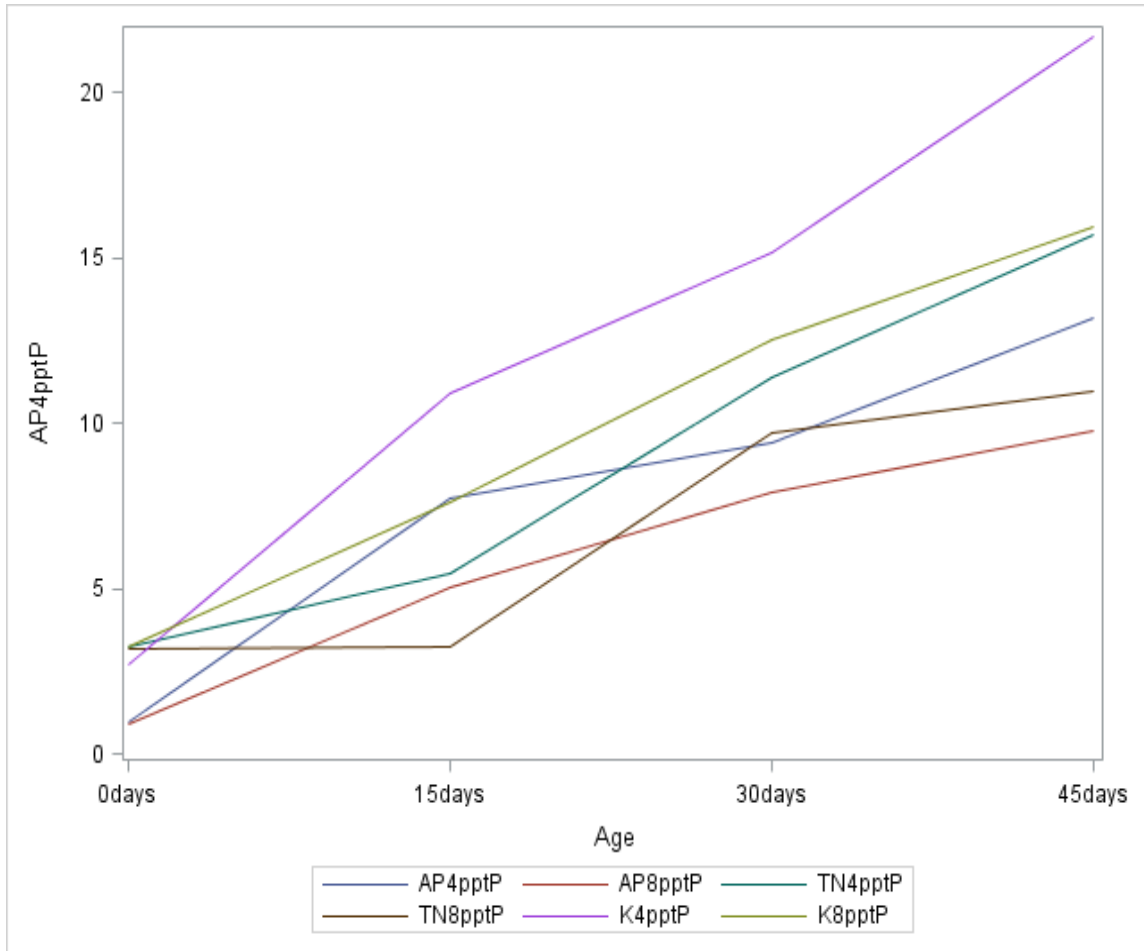


Figure 6: Least square means comparison curve for standard length of the three stocks across salinities reared in pond

Table 8: Least square means and its standard error of standard length in centimeters at different pond ages

Group	Source of Variation	Pond Age							
		1		15		30		45	
		N	Mean ± SE	N	Mean ± SE	N	Mean ± SE	N	Mean ± SE
Overall		1927	1.87±0.03	307	5.40±0.16	366	9.26±0.22	478	12.25±0.28
Stocks	AP	640	0.72±0.04 ^b	84	5.19±0.22 ^b	110	6.90±0.35 ^c	148	9.31±0.41 ^c
	K	645	2.40±0.04 ^a	101	7.65±0.20 ^a	126	11.68±0.33 ^a	149	16.12±0.41 ^a
	TN	642	2.50±0.04 ^a	122	3.59±0.18 ^c	130	8.84±0.32 ^b	181	11.40±0.37 ^b
Salinity	HS	965	1.93±0.03 ^a	150	4.36±0.17 ^b	181	8.30±0.27 ^b	236	10.10±0.33 ^b
	LS	962	1.81±0.03 ^a	157	6.59±0.16 ^a	185	9.98±0.27 ^a	242	14.46±0.32 ^a
Stock*Salinity	AP-HS	320	0.70±0.05 ^c	41	4.11±0.32 ^c	55	6.48±0.50 ^d	74	7.29±0.59 ^d
	AP-LS	320	0.75±0.05 ^c	43	6.27±0.31 ^b	55	7.33±0.50 ^{cd}	74	11.33±0.59 ^{bc}
	K-HS	325	2.62±0.05 ^a	45	6.29±0.30 ^b	59	10.17±0.48 ^b	72	13.95±0.59 ^b
	K-LS	320	2.17±0.05 ^b	56	9.01±0.27 ^a	67	13.20±0.45 ^a	77	18.30±0.57 ^a
	TN-HS	320	2.48±0.05 ^a	64	2.69±0.25 ^d	67	8.27±0.45 ^{bcd}	90	9.05±0.53 ^{cd}
	TN-LS	322	2.51±0.05 ^a	58	4.50±0.27 ^c	63	9.42±0.46 ^{bc}	91	13.75±0.53 ^b

Means within each group of sources of variation viz stocks (AP, K and TN), salinity (high saline and low saline) and stock*salinity (AP-HS, AP-LS, K-HS, K-LS, TN-HS, TN-LS) in the same column having different superscripts vary significantly from each other within the group ($p < 0.01$). 'N' is number of observations at each group for each pond age.

Table 9: Mean sum of squares from analysis of variance of standard length at different pond ages

Source of Variation	DF	Tank Age			
		1	15	30	45
Stock	2	635.62*	452.07*	685.55*	1822.22*
Salinity	1	7.24 ^{NS}	372.30*	256.12*	2252.32*
Stock*Salinity	2	12.70*	5.66 ^{NS}	42.43 ^{NS}	4.43 ^{NS}
EMS		1.10	4.30	13.80	25.81
Error DF		1921	301	360	472
R ² (%)		38.11	51.62	26.45	33.11

* $p < 0.01$, NS- not significant ($p > 0.01$)

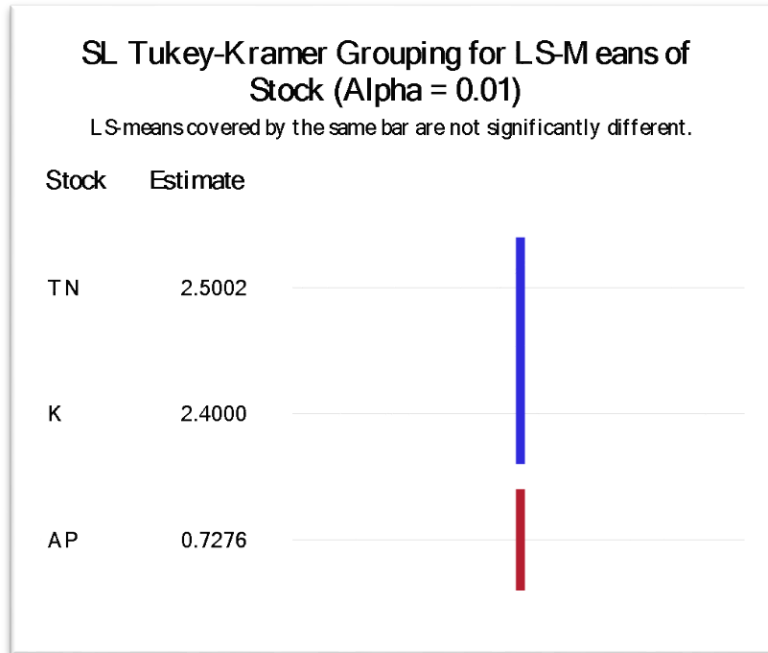


Figure 7.1: Stock wise Tukey-Kramer grouping for standard length least square means at 1st day of pond age

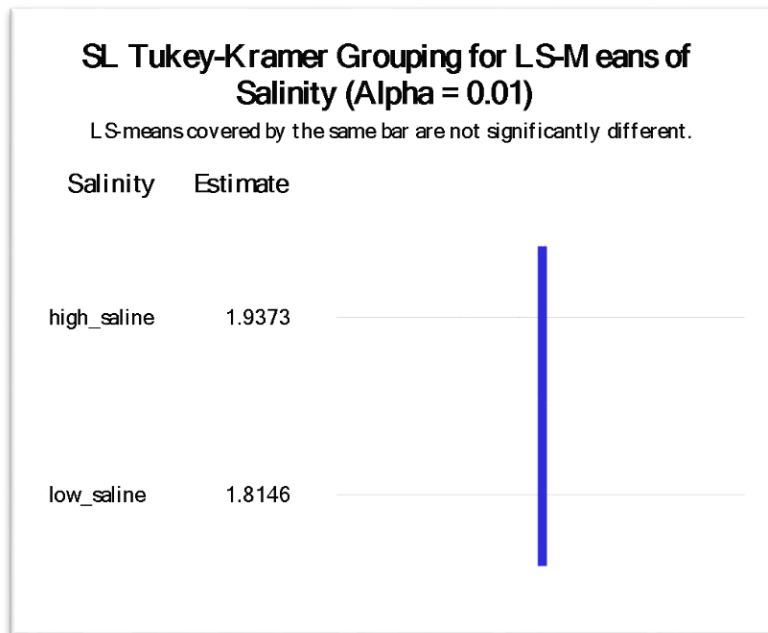


Figure 7.2: Salinity wise Tukey-Kramer grouping for standard length least square means at 1st day of pond age

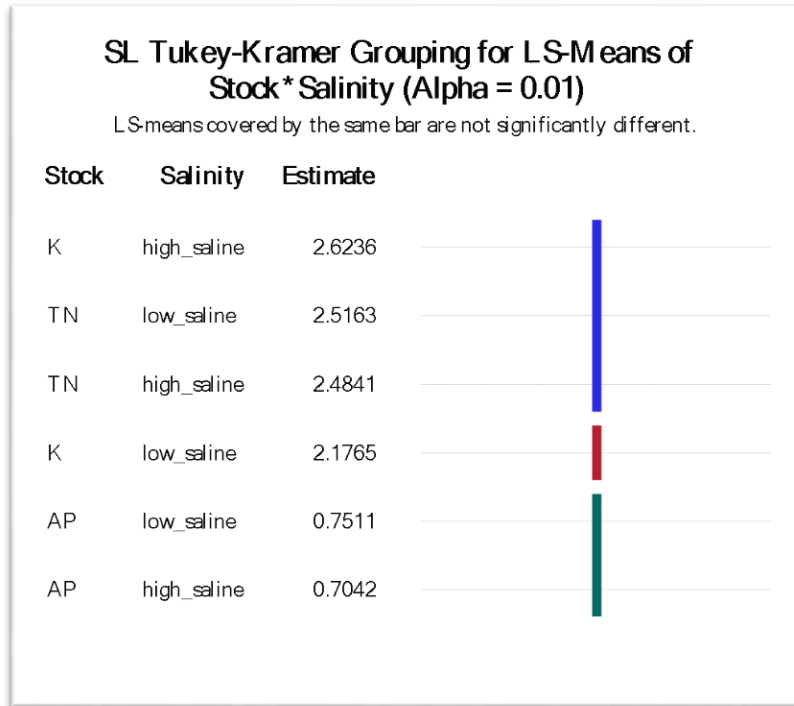


Figure 7.3: Stock*salinity wise Tukey-Kramer grouping for standard length least square means at 1st day of pond age

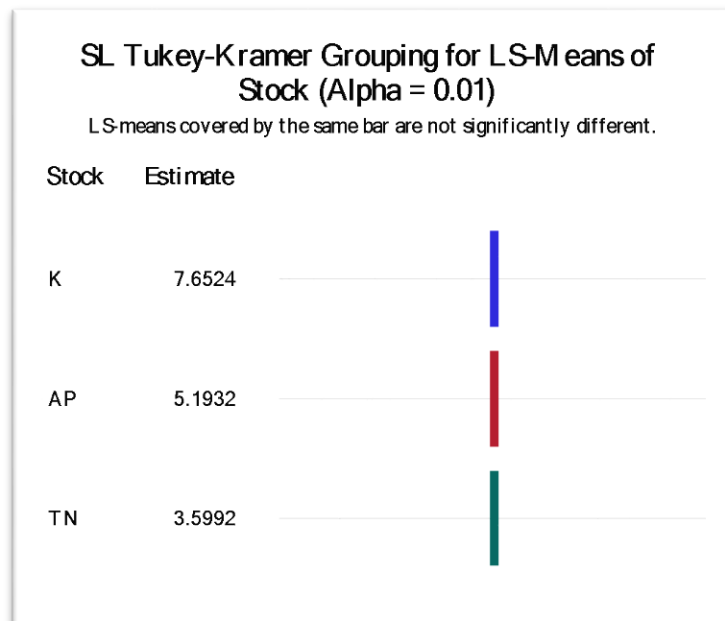


Figure 7.4: Stock wise Tukey-Kramer grouping for standard length least square means at 15th day of pond age

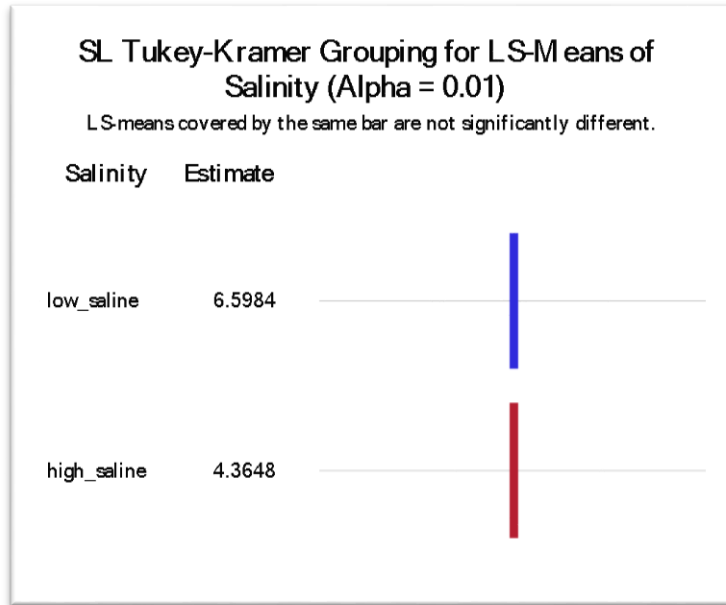


Figure 7.5: Salinity wise Tukey-Kramer grouping for standard length least square means at 15th day of pond age

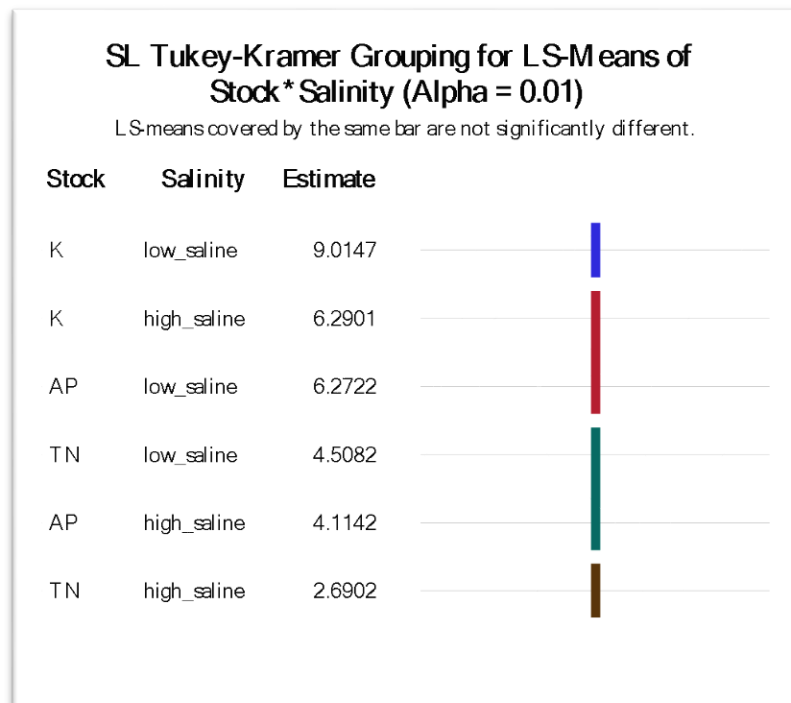


Figure 7.6: Stock*salinity wise Tukey-Kramer grouping for standard length least square means at 15th day of pond age

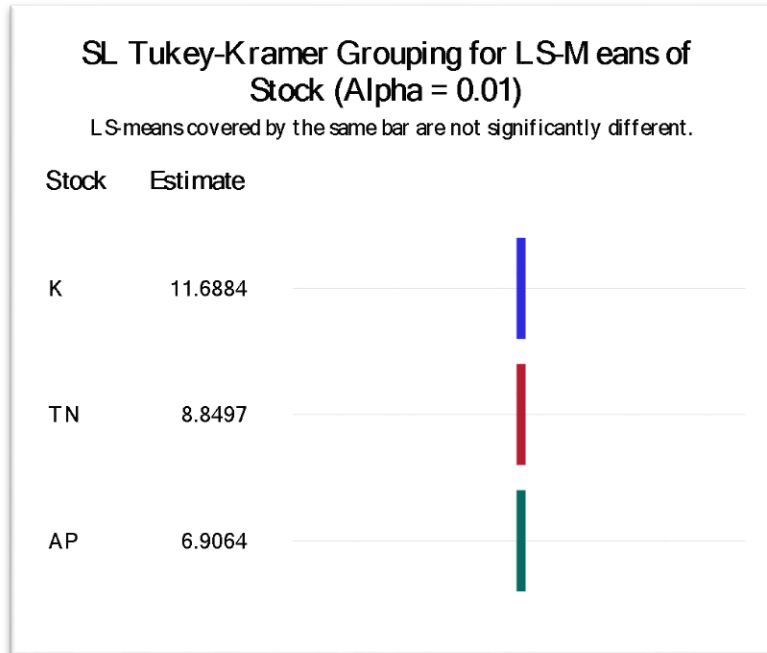


Figure 7.7: Stock wise Tukey-Kramer grouping for standard length least square means at 30th day of pond age

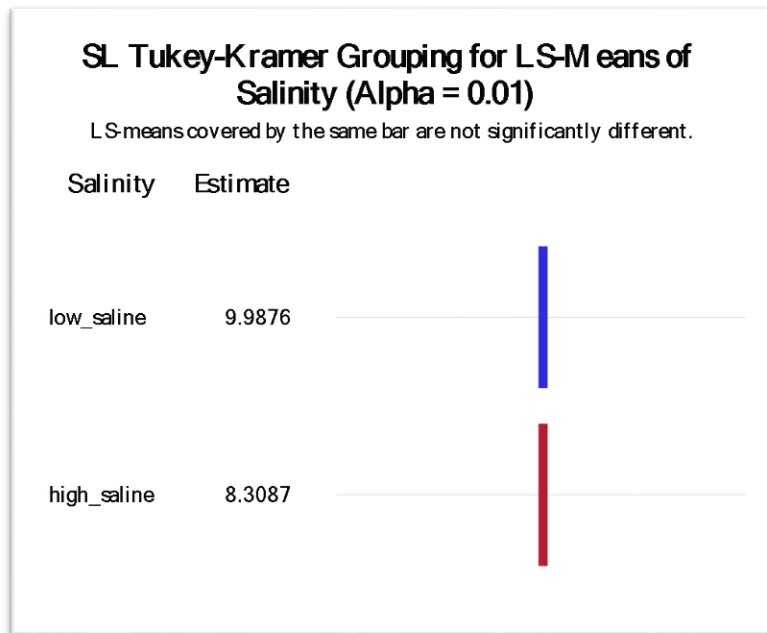


Figure 7.8: Salinity wise Tukey-Kramer grouping for standard length least square means at 30th day of pond age

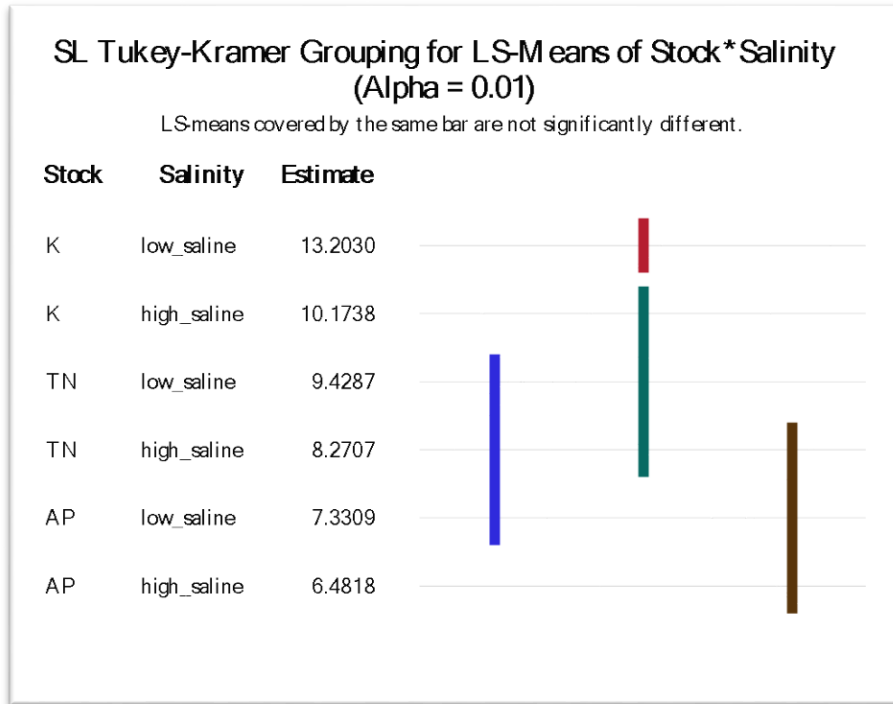


Figure 7.9: Stock*salinity wise Tukey-Kramer grouping for standard length least square means at 30th day of pond age

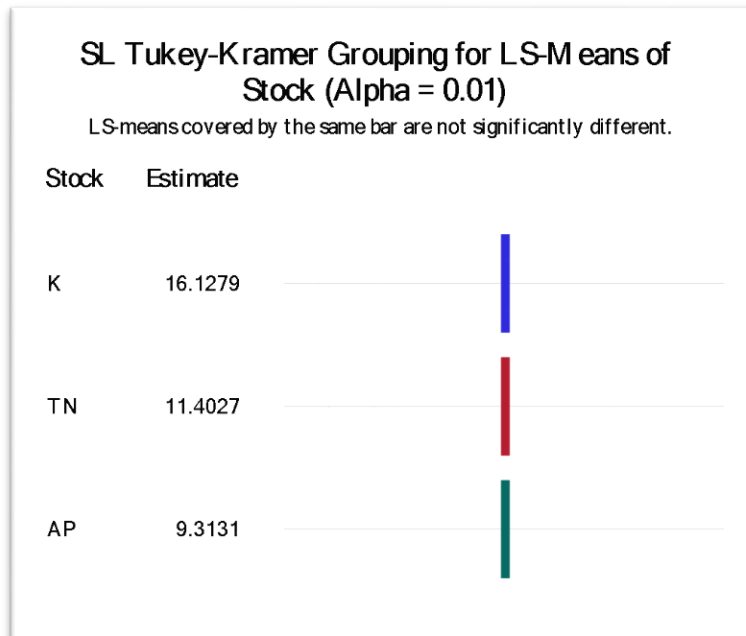


Figure 7.10: Stock wise Tukey-Kramer grouping for standard length least square means at 45th day of pond age

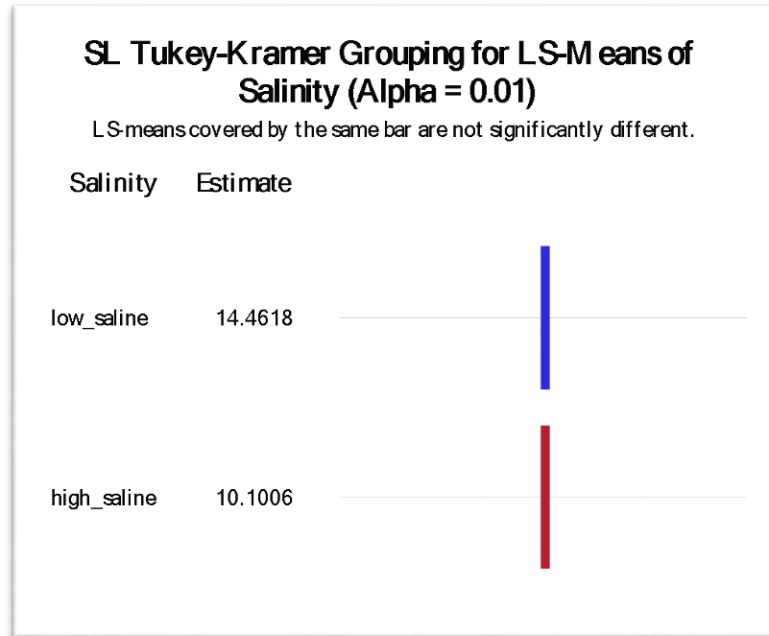


Figure 7.11: Salinity wise Tukey-Kramer grouping for standard length least square means at 45th day of pond age

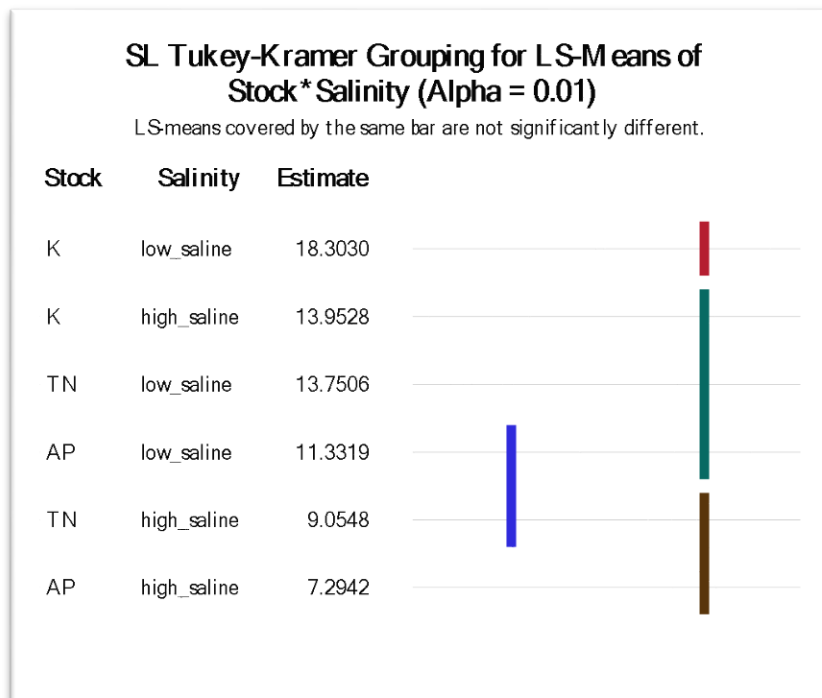


Figure 7.12: Stock*salinity wise Tukey-Kramer grouping for standard length least square means at 45th day of pond age

4.4. Trait: Body depth

4.4.1. Descriptive statistics

The descriptive statistics for body depth in common carp, stock wise and salinity wise at different culture age *viz.*, 1, 15, 30 and 45 days are provided in the Table 10. At the 1st day of culture, the average body depth in centimeter along with standard error (SE) of Andhra Pradesh, Karnataka and Tamil Nadu stocks were 0.25 ± 0.003 , 0.79 ± 0.01 and 0.87 ± 0.02 respectively and at high saline and low saline, the body depths were 0.65 ± 0.01 cm, 0.62 ± 0.01 cm respectively. At the 1st day of culture, Tamil Nadu had the highest coefficient of variation (CV) of 60.51 %, followed by Andhra Pradesh and Karnataka. At the 45th day of culture, the average body depth in centimeter along with standard error of Andhra Pradesh, Karnataka and Tamil Nadu stocks were 3.55 ± 0.11 , 6.51 ± 0.16 , 4.53 ± 0.20 respectively and at high saline and low saline the body depths were 3.93 ± 0.12 cm, 5.73 ± 0.17 cm respectively. At the 45th day of culture, the Tamil Nadu stock had highest CV of 62.30 %, followed by Andhra Pradesh and Karnataka. Among the two salinities; the common carp cultured in high saline ponds had greater CV than low saline ponds at all culture ages expect the 1st day of culture. The maximum body depth of common carp recorded was 19.92 cm at 45th day of culture age and it belonged to Tamil Nadu stock reared in low saline ponds.

4.4.2. Variation in body depth

The stock*salinity wise variation in body depth within and between the different culture ages in common carp is represented as box plots in Fig. 8.1 to Fig. 8.4. The growth curve (Fig.9) is plotted using the mean body depth at different culture ages. Karnataka stock reared at 4 ppt (low saline) showed the highest peak for body weight followed by the same stock reared at 8 ppt (high saline). Further, the Tamil Nadu stock reared at 4 ppt (low saline) showed an upward trend after 30 days of culture age followed by Andhra Pradesh stock reared at 4 ppt.

The stock wise, salinity wise and stock*salinity wise least square means of the trait body depth at different culture age are given in table 11. A total of 1927 observations were recorded for body depth at 1st day of culture age. The overall least

square mean body depth was 0.63 ± 0.01 cm. Among the stocks, the common carp belonging to Tamil Nadu stock had the significantly highest least square mean body depth of 0.87 ± 0.01 cm followed by Karnataka and Andhra Pradesh stock. Among the salinities, there was no significant difference between least square mean body depths of common carp. The stock*salinity comparison revealed significant differences for body depth.

A total of 307 observations were recorded for body depth at 15th day of culture age. The overall least square mean body depth was 2.07 ± 0.06 cm. Among the stocks, the common carp belonging to Karnataka stock had significantly higher least square mean body depth of 2.98 ± 0.08 cm followed by Andhra Pradesh and Tamil Nadu stocks. Among the salinities, the common carp reared in low saline ponds had significantly higher least square mean body depth of 2.56 ± 0.06 cm. Among the stock*salinity comparisons, common carp belonging to Karnataka stock reared in low saline pond had the significantly highest least square mean body depth of 3.50 ± 0.10 cm followed by the same stock reared in high saline pond and the Andhra Pradesh stock reared in low saline pond.

A total of 366 observations were recorded for body depth at 30th day of culture age and the overall least square mean body depth was 3.61 ± 0.09 cm. Among the stocks, the common carp belonging to Karnataka stock had the significantly highest least square mean body depth of 4.71 ± 0.12 cm, followed by Andhra Pradesh and Tamil Nadu stocks. Among the salinities, the common carp reared in low saline ponds had significantly higher least square mean body depth of 4.02 ± 0.10 cm. Among the stock*salinity comparisons, common carp belonging to Karnataka stock reared in low saline pond had the significantly highest least square mean body depth of 5.28 ± 0.17 cm followed by same stock reared in high saline pond.

A total of 478 observations were recorded for body depth at 45th day of culture age. The overall least square mean body depth was 4.84 ± 0.11 cm. Among the stocks, the common carp belonging to Karnataka stock had the significantly highest least square mean body depth of 6.48 ± 0.16 cm, followed by Tamil Nadu and Andhra Pradesh stock. Among the salinities, the common carp reared in low saline ponds had significantly

higher least square mean body depth of 5.73 ± 0.13 cm. Among the stock*salinity comparisons, common carp belonging to Karnataka stock reared in low saline pond had the significantly highest least square mean body depth of 7.37 ± 0.23 cm followed by same stock reared in high saline pond and Tamil Nadu stock reared in low saline pond. The stock, salinity and stock*salinity wise Tukey-Karmer grouping for common carp body depth, at different culture ages is provided in Fig. 10.1 to 10.12.

Amongst the three stocks, the Karnataka stock performed better followed by Tamil Nadu and Andhra Pradesh stocks. The least square mean of body depth of Tamil Nadu stock was significantly higher than Andhra Pradesh stock at the 1st day of culture and this initial difference remained till the end of experiment period. Amongst the two salinities, the stocks reared in low saline ponds performed better than the stocks reared in high saline ponds.

The mean sum of square (MSS) values from analysis of variance for body depth at various rearing ages are represented in table 12. The effects of stock, salinity, and stock*salinity on body depth were estimated. At 1st day of culture age, the stock had significant effect on body depth, whereas at 45th day of culture age the stock and the salinity had significant effect on body depth.

Table 10: Descriptive statistics for the trait body depth

1. 1st day of culture						
Group	Source	No	Mean ± SE (cm)	CV	Min (cm)	Max (cm)
Stock	AP	640	0.25 ± 0.003	36.55	0.03	0.57
	K	645	0.79 ± 0.01	38.73	0.34	3.03
	TN	642	0.87 ± 0.02	60.51	0.32	5.91
Salinity	High saline	965	0.65 ± 0.01	68.62	0.04	3.63
	Low saline	962	0.62 ± 0.01	71.93	0.03	5.91
2. 15th day of culture						
Group	Source	No	Mean ± SE (cm)	CV	Min (cm)	Max (cm)
Stock	AP	84	1.93 ± 0.09	45.97	0.47	5.08
	K	101	3.03 ± 0.09	31.86	0.80	5.44
	TN	122	1.38 ± 0.08	65.88	0.10	5.52
Salinity	High saline	150	1.56 ± 0.07	58.64	0.15	5.44
	Low saline	157	2.56 ± 0.09	45.24	0.10	5.52
3. 30th day of culture						
Group	Source	No	Mean ± SE (cm)	CV	Min (cm)	Max (cm)
Stock	AP	110	2.78 ± 0.09	37.01	0.99	6.27
	K	126	4.74 ± 0.12	29.87	1.32	9.25
	TN	130	3.22 ± 0.16	58.43	0.21	11.82
Salinity	High saline	181	3.13 ± 0.11	47.30	0.64	9.47
	Low saline	185	4.08 ± 0.13	44.31	0.21	11.82
4. 45th day of culture						
Group	Source	No	Mean ± SE (cm)	CV	Min (cm)	Max (cm)
Stock	AP	148	3.55 ± 0.11	40.96	1.19	14.52
	K	149	6.51 ± 0.16	30.78	1.89	12.94
	TN	181	4.53 ± 0.20	62.30	0.34	19.92
Salinity	High saline	236	3.93 ± 0.12	49.90	0.65	12.94
	Low saline	242	5.73 ± 0.17	46.70	0.34	19.92

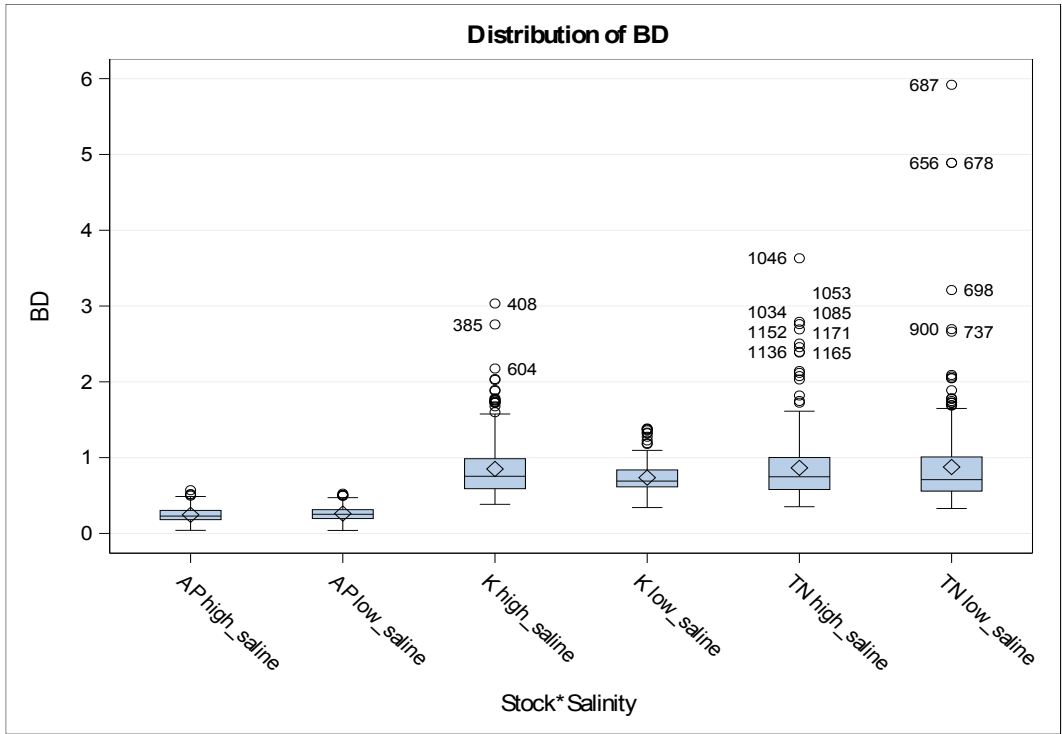


Figure 8.1: Box and Whisker plot for body depth in centimeters of different stock*salinity at 1st day of pond age

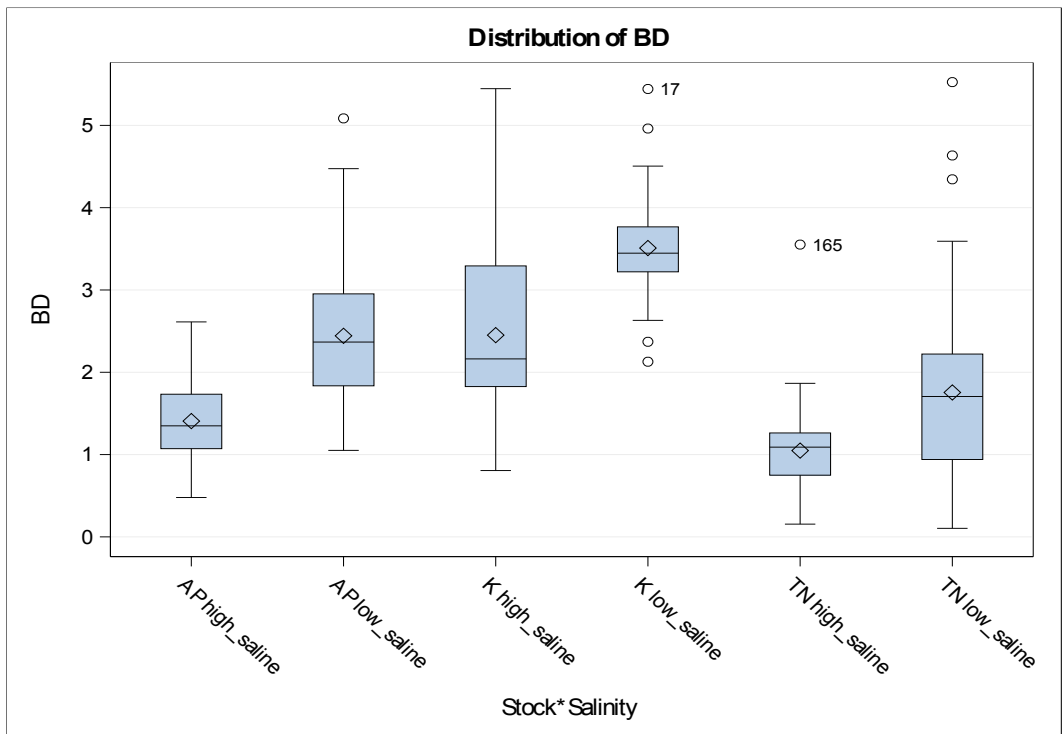


Figure 8.2: Box and Whisker plot for body depth in centimeters of different stock*salinity at 15th day of pond age

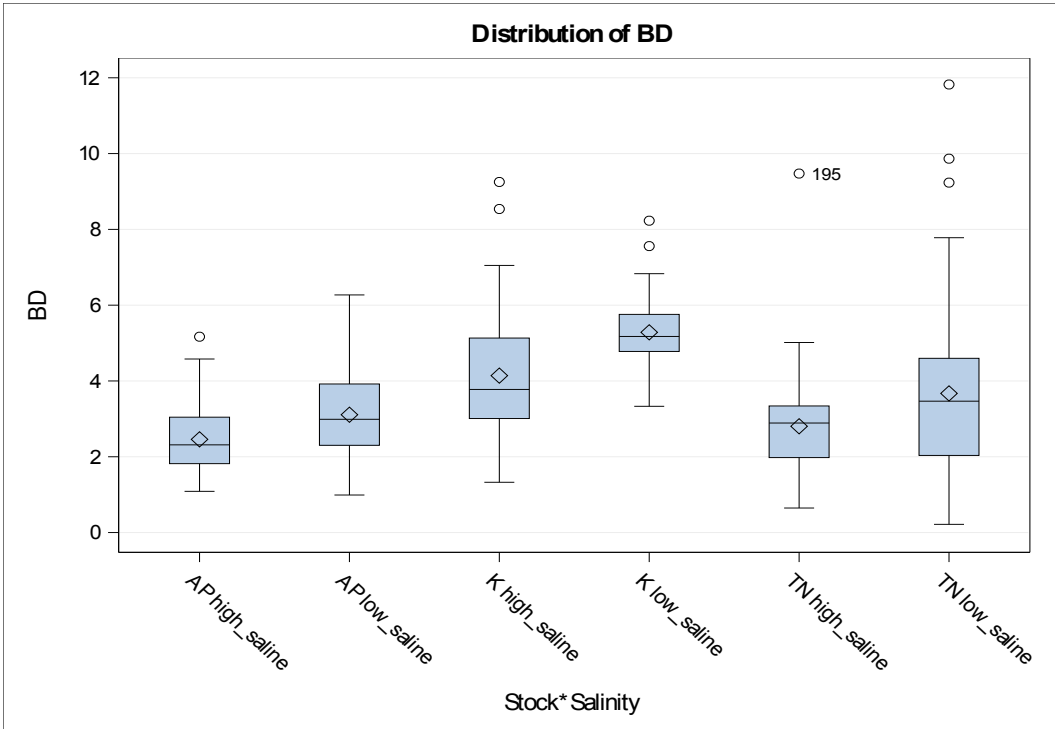


Figure 8.3: Box and Whisker plot for body depth in centimeters of different stock*salinity at 30th day of pond age

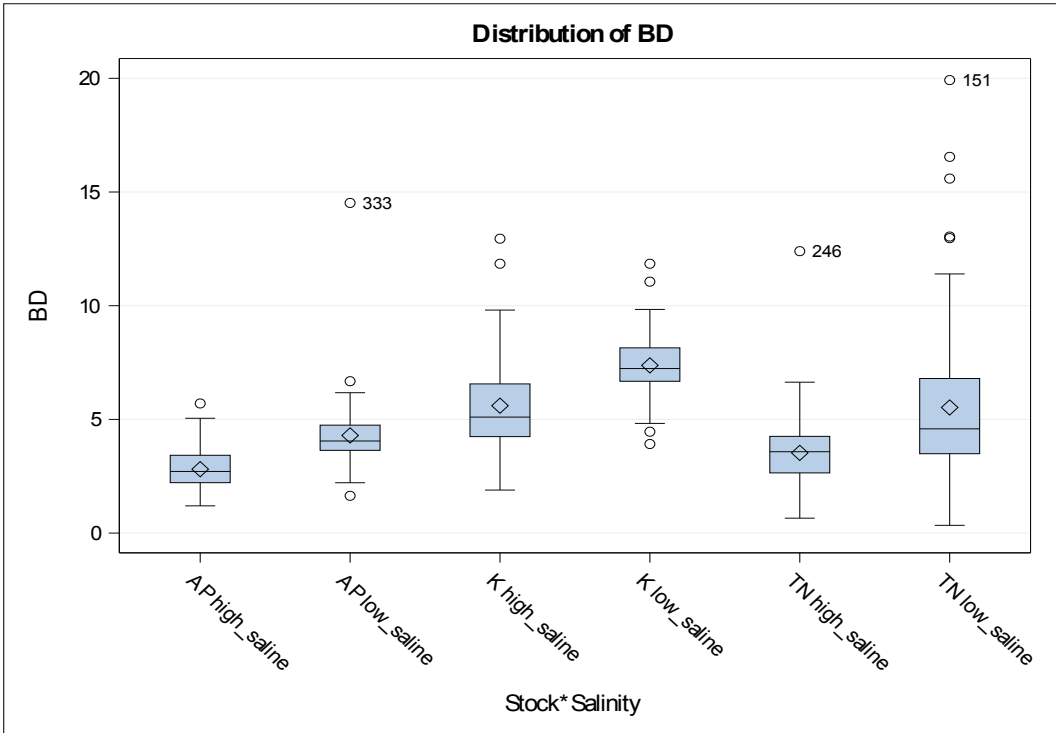


Figure 8.3: Box and Whisker plot for body depth in centimeters of different stock*salinity at 45th day of pond age

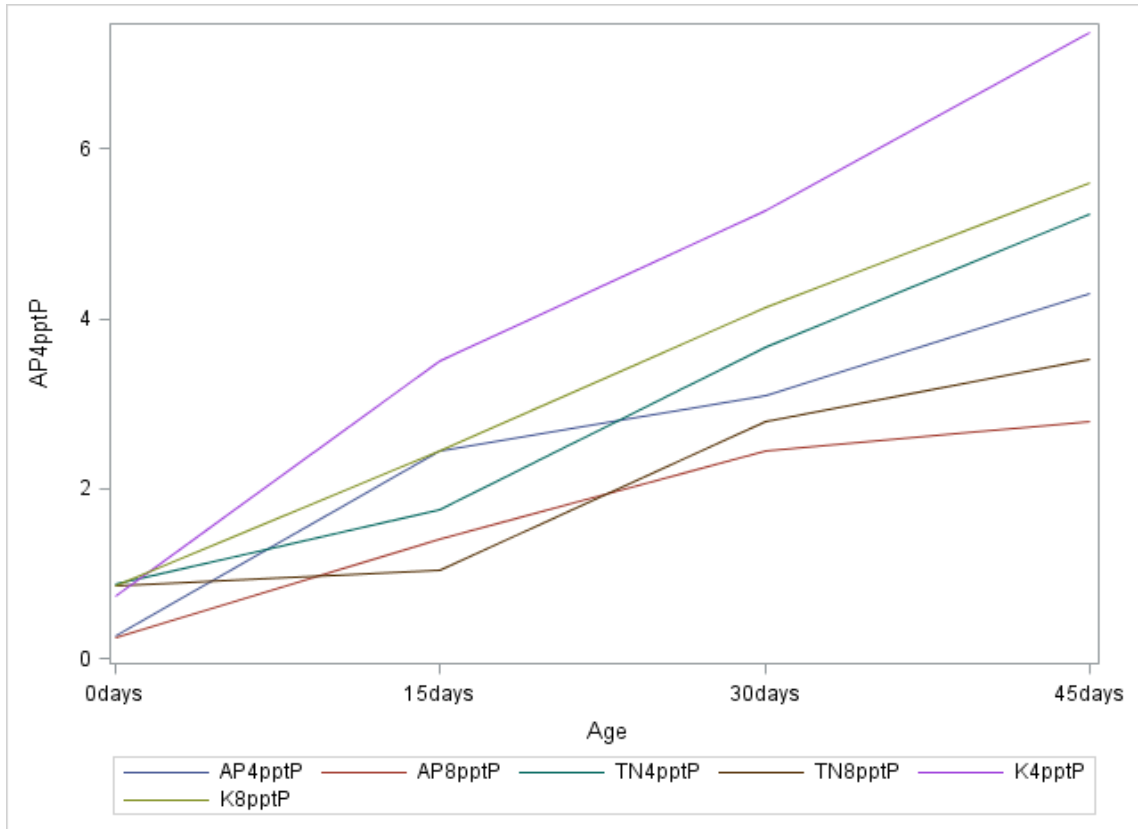


Figure 9: Growth curve plotted for fish stocks using least square mean body depths reared in pond but at different salinities

Table 11: Least square means and its standard error of body depth in centimeters at different pond ages

Group	Source of Variation	Pond Age							
		1		15		30		45	
		N	Mean ± SE	N	Mean ± SE	N	Mean ± SE	N	Mean ± SE
Overall		1927	0.63±0.01	307	2.07±0.06	366	3.61±0.09	478	4.84±0.11
Stocks	AP	640	0.25±0.01 ^c	84	1.92±0.08 ^b	110	2.78±0.13 ^b	148	3.52±0.16 ^c
	K	645	0.79±0.01 ^b	101	2.98±0.08 ^a	126	4.71±0.12 ^a	149	6.48±0.16 ^a
	TN	642	0.87±0.01 ^a	122	1.40±0.07 ^c	130	3.23±0.12 ^b	181	4.52±0.15 ^b
Salinity	HS	965	0.65±0.01 ^a	150	1.63±0.06 ^b	181	3.13±0.10 ^b	236	3.97±0.13 ^b
	LS	962	0.62±0.01 ^a	157	2.56±0.06 ^a	185	4.02±0.10 ^a	242	5.73±0.13 ^a
Stock*Salinity	AP-HS	320	0.24±0.01 ^c	41	1.40±0.12 ^{cd}	55	2.45±0.19 ^d	74	2.80±0.23 ^d
	AP-LS	320	0.26±0.01 ^c	43	2.44±0.12 ^b	55	3.10±0.19 ^{cd}	74	4.29±0.23 ^c
	K-HS	325	0.85±0.01 ^a	45	2.45±0.11 ^b	59	4.14±0.18 ^b	72	5.60±0.24 ^b
	K-LS	320	0.73±0.01 ^b	56	3.50±0.10 ^a	67	5.28±0.17 ^a	77	7.37±0.23 ^a
	TN-HS	320	0.86±0.01 ^a	64	1.04±0.10 ^d	67	2.80±0.17 ^d	90	3.52±0.21 ^{cd}
	TN-LS	322	0.87±0.01 ^a	58	1.75±0.10 ^c	63	3.67±0.18 ^{bc}	91	5.52±0.21 ^b

Means within each group of sources of variation viz stocks (AP, K and TN), salinity (high saline and low saline) and stock*salinity (AP-HS, AP-LS, K-HS, K-LS, TN-HS, TN-LS) in the same column having different superscripts vary significantly from each other within the group ($p < 0.01$). 'N' is number of observations at each group for each pond age.

Table 12: Mean sum of squares from analysis of variance of body depth at different pond ages

Source of Variation	DF	Tank Age			
		1	15	30	45
Stock	2	72.42*	69.40*	122.71*	334.03*
Salinity	1	0.40 ^{NS}	65.01*	71.42*	363.35*
Stock*Salinity	2	0.88 ^{NS}	1.06 ^{NS}	1.80 ^{NS}	2.66 ^{NS}
EMS		0.12	0.64	2.07	4.15
Error DF		1921	301	360	472
R ² (%)		37.99	52.96	30.90	35.10

* $p < 0.01$, NS- not significant ($p > 0.01$)

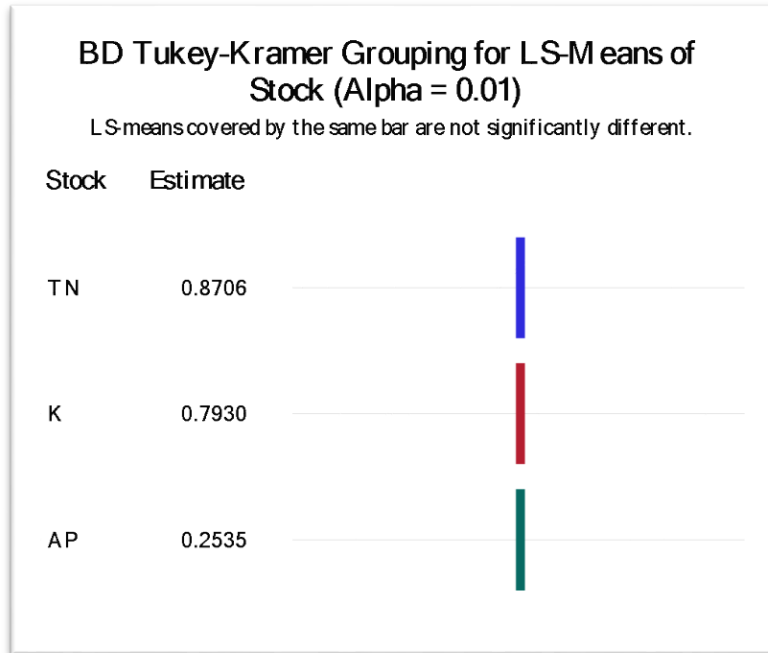


Figure 10.1: Stock wise Tukey-Kramer grouping for least square means body depth at 1st day of pond age

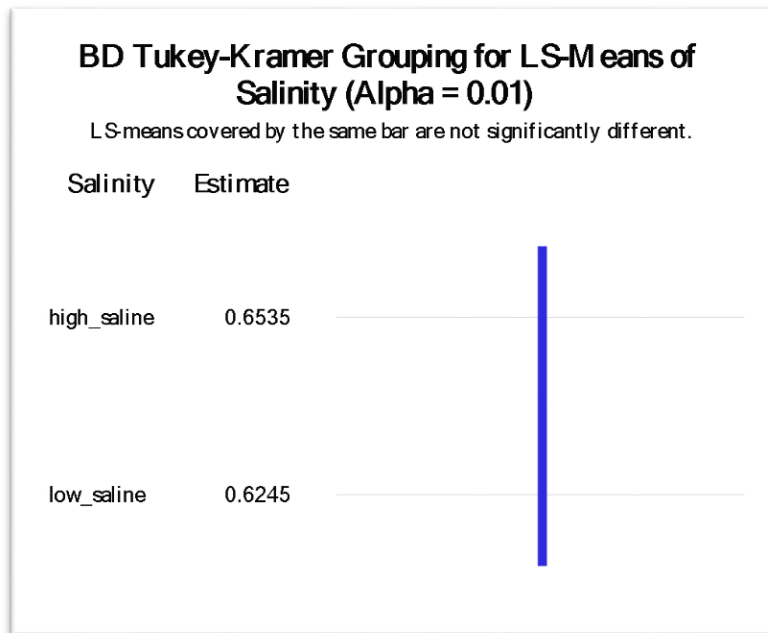


Figure 10.2: Salinity wise Tukey-Kramer grouping for least square mean body depth at 1st day of pond age

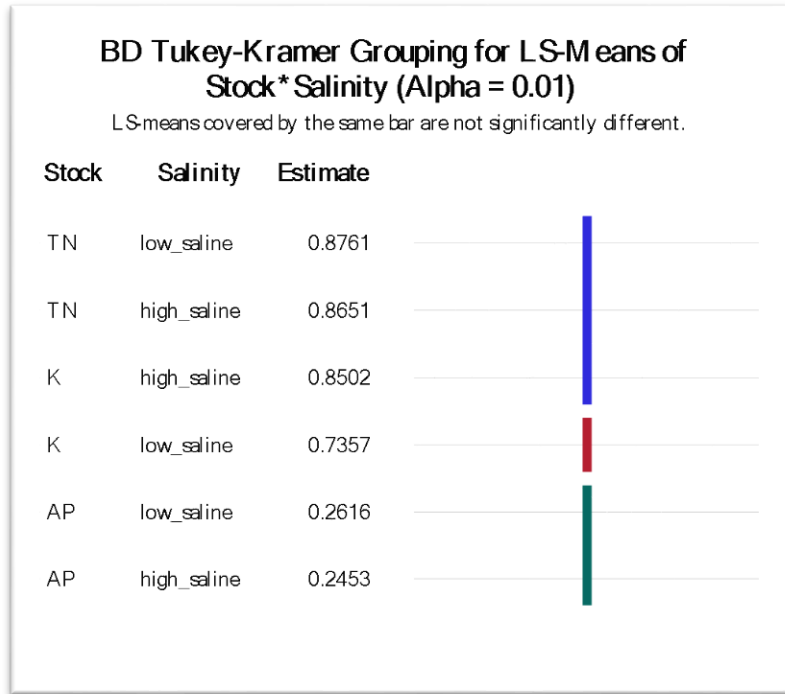


Figure 10.3: Stock*salinity wise Tukey-Kramer grouping for least square mean body depth at 1st day of pond age

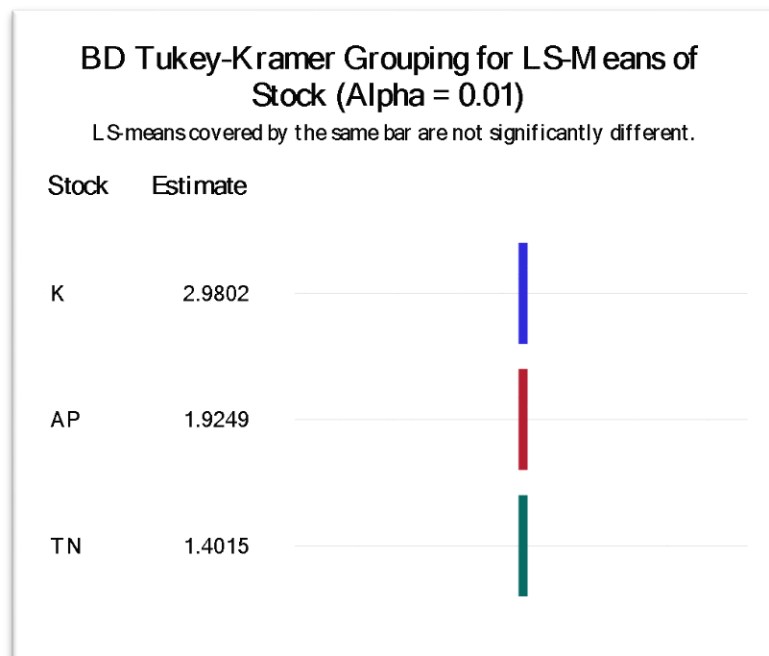


Figure 10.4: Stock wise Tukey-Kramer grouping for least square mean body depth at 15th day of pond age

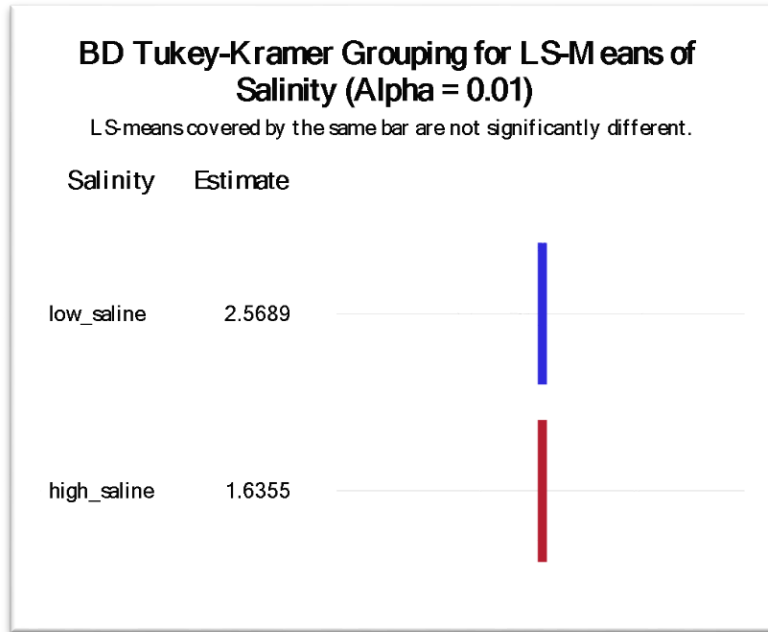


Figure 10.5: Salinity wise Tukey-Kramer grouping for least square mean body depth at 15th day of pond age

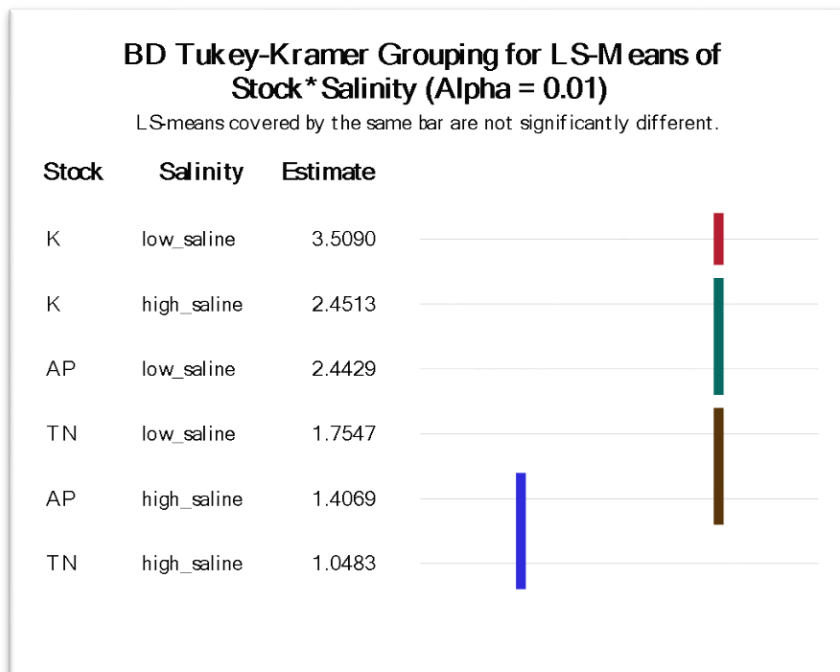


Figure 10.6: Stock*salinity wise Tukey-Kramer grouping for least square mean body depth at 15th day of pond age

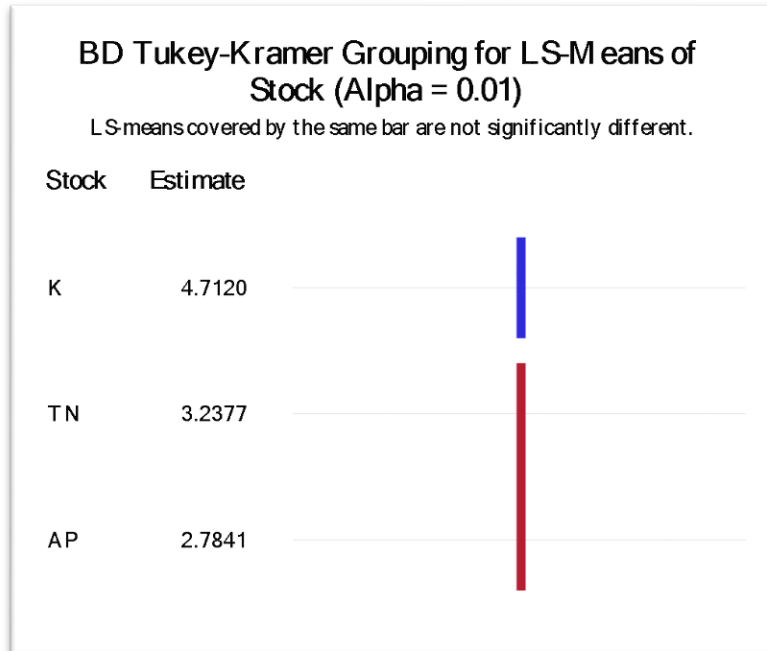


Figure 10.7: Stock wise Tukey-Kramer grouping for least square means body depth at 30th day of pond age

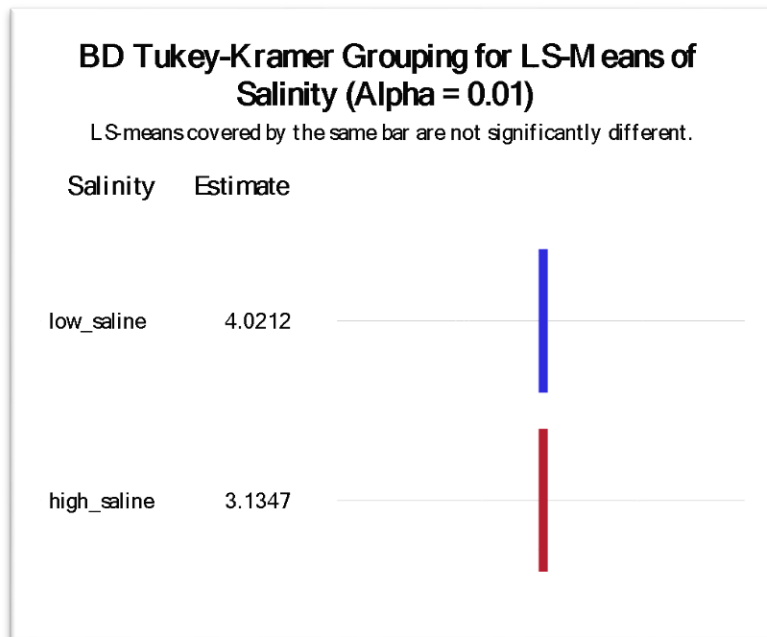


Figure 10.8: Salinity wise Tukey-Kramer grouping for least square mean body depth at 30th day of pond age

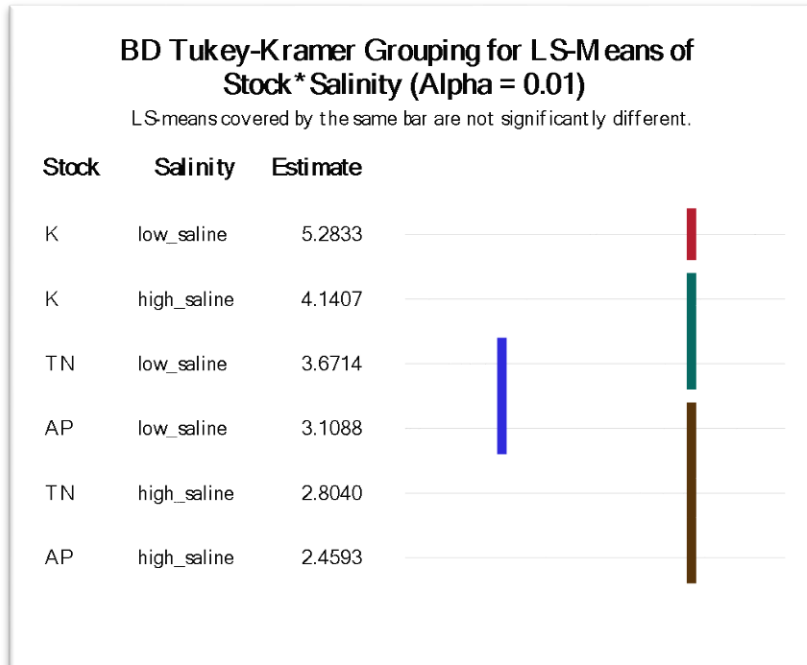


Figure 10.9: Stock*salinity wise Tukey-Kramer grouping for least square mean body depth at 30th day of pond age

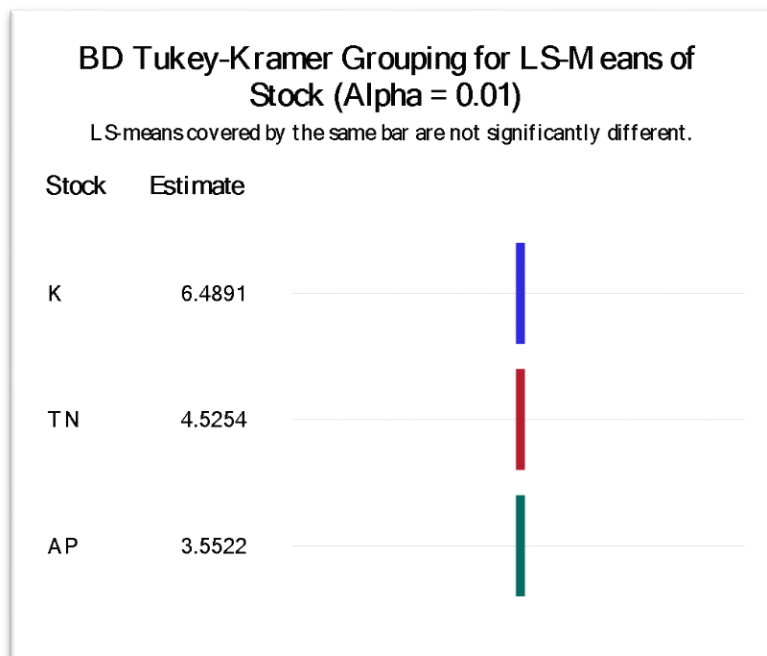


Figure 10.10: Stock wise Tukey-Kramer grouping for least square mean body depth at 45th day of pond age

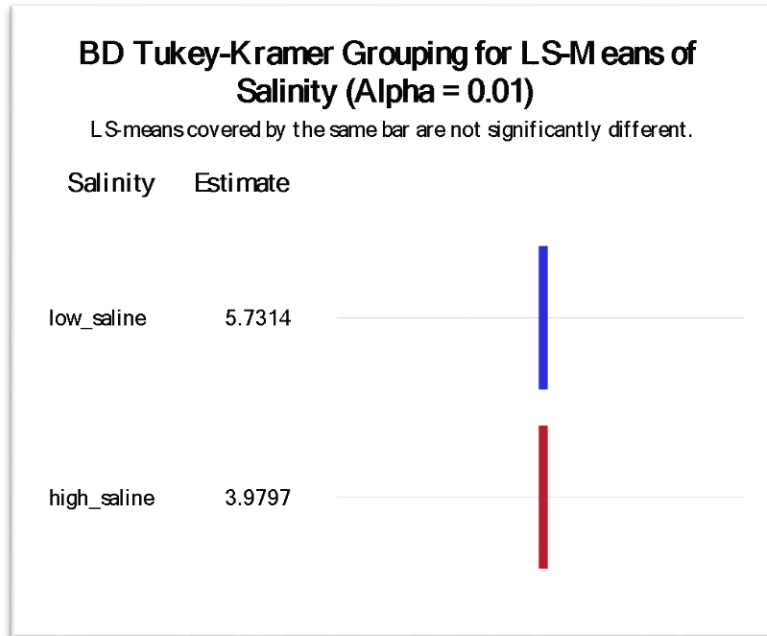


Figure 10.11: Salinity wise Tukey-Kramer grouping for least square mean body depth at 45th day of pond age

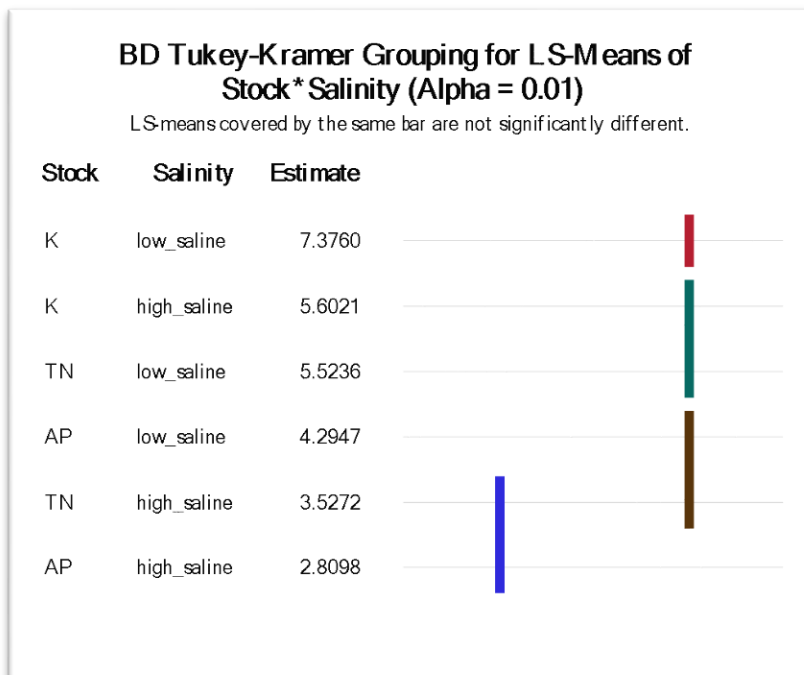


Figure 10.12: Stock*salinity wise Tukey-Kramer grouping for least square mean body depth at 45th day of pond age

4.5. Morphometric study

The morphometric study was conducted to understand variation between the fish reared at two different salinities. A total of 480 fish comprising equally from each stock were measured at the end of rearing period. A total of Nineteen morphometric traits were recorded *viz.*, **TL** – Total Length, **FL** - Fork length, **SL** - Standard length, **PrePFL** - Pre pectoral fin length, **PreDFL**- Pre dorsal fin length, **PreVFL** – Pre ventral fin length, **PreAFL** - Pre anal fin length, **PFBL** - Pectoral fin base length ; **DFBL** - Dorsal fin base length, **VFBL** – Ventral fin base length, **AFBL** - Anal fin base length, **DbP&V** – distance between pectoral and ventral fin, **DbP&A** – distance between pectoral and anal fin, **DbV&A** – distance between ventral and anal fin, **MaxBD** – Maximum body depth, **MinBD** – Minimum body depth, **POL** - Post orbital length, **HL** - Head length, **ED** – eye diameter (Figure 11).

4.5.1. Descriptive statistics

The descriptive statistics of the morphometric parameters in fish are provided in the table 13. A total of 240 common carp were reared at each salinity *viz.*; high saline and low saline. The mean value of all morphometric parameter were found comparatively lower in high saline water than in low saline, expect for head length, eye diameter and pre-orbital. The mean values (in centimeters) for head length, eye diameter and pre-orbital of fish reared in low saline waters were 1.70 ± 0.03 , 0.29 ± 0.01 and 0.40 ± 0.01 respectively and the same for fish reared in high saline waters were 1.78 ± 0.02 , 0.32 ± 0.01 and 0.43 ± 0.01 respectively. The coefficient of variation of all 19 morphometric parameters was found to be higher in fish reared in low saline waters than those in high saline water. The variation in initial and final mean of body weight and standard length across the two salinities nested in stock are provided as box plots in Fig. 12.1 to Fig. 12.2 and Fig. 13.1 to Fig. 13.2 respectively. The variation in maximum body depth, minimum body depth, head length, pre-dorsal fin length and total length within and between stocks and salinities nested in stocks are provided as box plots in Fig. 14. to Fig. 18 respectively.

4.5.2. Variation in morphometric traits

The initial and final least square mean value for body weight and standard length are provided in Table 14. A total of 480 observation were recorded for these parameters. The final overall least square mean for body weight and standard length were 4.23 ± 1.95 g and 5.46 ± 1.14 cm respectively. Initially the Tamil Nadu had the significantly highest least square mean body weight and standard length of 2.67 ± 0.53 g and 4.24 ± 0.38 cm respectively but at the end of rearing period the Karnataka stock had significantly higher final least square mean of 5.59 ± 2.27 g and 6.43 ± 1.27 cm respectively followed by Tamil Nadu and Andhra Pradesh stocks. Amongst the salinity (stock) comparisons, Karnataka stock reared in low saline water had the significantly highest least square mean body weight and standard length of 6.82 ± 2.38 g and 7.29 ± 1.003 cm respectively followed by the same stock reared in high saline waters and the Tamil Nadu stock reared in low saline water.

The least square mean of 5 morphometric parameters *viz*, maximum body depth (maxBD), minimum body depth (minBD), head length (HL), pre-dorsal fin length (preDL) and total length (TL) are provided in Table 15. The overall least square mean of maxBD, minBD, HL, preDL and TL were 2.07 ± 0.45 cm, 0.74 ± 0.30 cm, 1.73 ± 0.29 cm, 2.63 ± 0.60 cm and 7.03 ± 1.47 cm respectively. Among the stocks, the Karnataka had the significantly highest least square mean maxBD, minBD, HL, preDL and TL of 2.42 ± 0.50 cm, 0.93 ± 0.31 cm, 1.96 ± 0.26 cm, 3.14 ± 0.63 cm and 8.27 ± 1.58 cm respectively, followed by Tamil Nadu and Andhra Pradesh stock. Among the salinity (stock) comparisons, the Karnataka stock reared in low saline water had the significantly highest least square mean maxBD, minBD, HL, preDL and TL of 2.76 ± 0.44 cm, 1.03 ± 0.33 cm, 1.99 ± 0.25 cm, 3.54 ± 0.59 cm and 9.39 ± 1.38 cm respectively, followed by the same stock reared in high saline.

The mean sum of square (MSS) values from analysis of variance for bodyweight, standard length, maximum body depth, minimum body depth, head length, pre-dorsal fin length and total length at final are represented in Table 16. The effects of stock and salinity (stock) on these morphometric parameters were estimated. The stock

had significant effect on all these parameters, but the effect of salinity (stock) was significant to all the parameters except minBD.

4.5.3. Analysis of morphometric traits as function of total length

The morphometric traits are analysed as function of total length using a simple linear regression equation $Y = bX + a$ where 'Y' represents the value of morphometric trait that is expressed as function of total length and 'X' represents the value total length (TL), a and b are parameters; 'a' represents the X intercept and 'b' is the regression coefficient. The function along with the parameters for each morphometric trait in mentioned in table 17. All the traits are positively correlated with total length. The traits viz., standard length, fork length, pre-ventral fin length, pre-dorsal fin length, anal fin base length, distance between pectoral and ventral fin and maximum body depth are strongly positively correlated with total length with r value > 0.9. The regression coefficient 'b' is highest for fork length and least for eye diameter. The goodness of fit is measured by R^2 and majority of traits have R^2 value > 0.7. The traits viz., minimum body depth, eye diameter, head length and pre orbital length have a poor fit. The regression curves with 95 % confidence limits for all the traits as a function of total length is given in figures 19.1 to 19.7. The curves indicate a good fit for traits viz., standard length, fork length, pre-ventral fin length, pre-dorsal fin length, anal fin base length, distance between pectoral and ventral fin and maximum body depth.

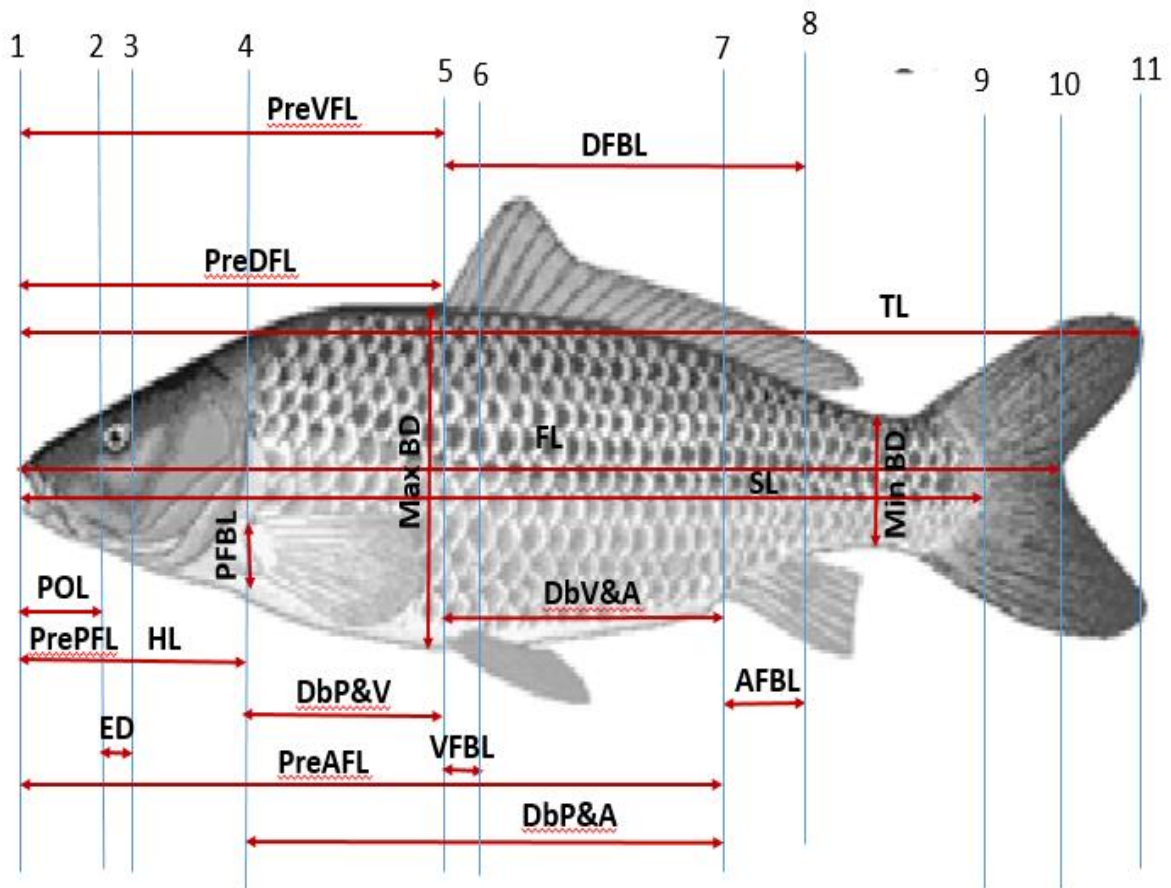


Figure 11: Morphometric measurements of *Cyprinus carpio* for the study (TL – Total Length, FL - Fork length, SL - Standard length, PrePFL - Pre pectoral fin length, PreDFL - Pre dorsal fin length, PreVFL – Pre ventral fin length, PreAFL - Pre anal fin length, PFBL - Pectoral fin base length ; DFBL - Dorsal fin base length, VFBL – Ventral fin base length, AFBL - Anal fin base length, DbP&V – distance between pectoral and ventral fin, DbP&A – distance between pectoral and anal fin, DbV&A – distance between ventral and anal fin, MaxBD – Maximum body depth, MinBD – Minimum body depth, POL - Pre orbital length, HL - Head length, ED – eye diameter)

Table 13: Descriptive statistics values of all morphometric parameters

Parameter	Source of Variation	N	Means \pm SE	CV	Minimum Value	Maximum Value
BW	Overall	480	4.23 \pm 0.13	46.11	1.29	13.04
	High saline	240	3.52 \pm 0.12	36.26	1.29	9.42
	Low saline	240	4.94 \pm 0.02	45.26	1.18	13.04
TL	Overall	480	7.03 \pm 0.09	20.84	4.38	12.11
	High saline	240	6.57 \pm 0.08	13.32	4.60	9.36
	Low saline	240	7.50 \pm 0.16	23.51	4.38	12.11
SL	Overall	480	5.46 \pm 0.07	20.82	3.54	9.25
	High saline	240	5.09 \pm 0.07	14.13	3.70	7.18
	Low saline	240	5.84 \pm 0.12	22.99	3.54	9.25
FL	Overall	480	6.45 \pm 0.09	21.95	3.89	11.38
	High saline	240	6.03 \pm 0.08	13.81	4.04	8.33
	Low saline	240	6.87 \pm 0.16	25.13	3.89	11.38
PrePFL	Overall	480	1.34 \pm 0.03	33.56	0.54	2.78
	High saline	240	1.26 \pm 0.03	26.09	0.55	2.08
	Low saline	240	1.43 \pm 0.05	37.49	0.54	2.78
PreVFL	Overall	480	2.75 \pm 0.04	22.31	1.66	5
	High saline	240	2.59 \pm 0.03	14.64	1.70	3.68
	Low saline	240	2.92 \pm 0.07	25.58	1.66	5.00
PreDL	Overall	480	2.64 \pm 0.04	22.94	1.57	4.83
	High saline	240	2.47 \pm 0.03	15.13	1.60	3.56
	Low saline	240	2.80 \pm 0.07	26.32	1.57	4.83
PreAL	Overall	480	4.58 \pm 0.06	19.76	2.93	7.87
	High saline	240	4.30 \pm 0.05	12.89	3.03	5.93
	Low saline	240	4.86 \pm 0.10	22.35	2.93	7.87
PFBL	Overall	480	1.30 \pm 0.02	27.26	0.71	2.55
	High saline	240	1.23 \pm 0.02	20.79	0.73	1.91
	Low saline	240	1.37 \pm 0.04	30.70	0.71	2.55
VFBL	Overall	480	1.86 \pm 0.03	23.88	1.10	3.45
	High saline	240	1.75 \pm 0.03	16.76	1.12	2.57
	Low saline	240	1.96 \pm 0.05	27.22	1.10	3.45
DFBL	Overall	480	2.04 \pm 0.03	25.04	1.23	3.90
	High saline	240	1.92 \pm 0.03	17.64	1.24	2.88
	Low saline	240	2.16 \pm 0.06	28.53	1.23	3.90

Parameter	Source of Variation	N	Means ± SE	CV	Minimum Value	Maximum Value
AFBL	Overall	480	4.43 ± 0.08	28.56	2.69	8.66
	High saline	240	4.14 ± 0.08	21.18	2.80	6.32
	Low saline	240	4.72 ± 0.14	32.00	2.69	8.66
DBPV	Overall	480	1.44 ± 0.02	26.30	0.82	2.81
	High saline	240	1.36 ± 0.02	19.68	0.86	2.09
	Low saline	240	1.52 ± 0.04	29.71	0.82	2.81
DBPA	Overall	480	2.82 ± 0.04	23.17	1.70	5.20
	High saline	240	2.65 ± 0.04	15.34	1.73	3.82
	Low saline	240	3.00 ± 0.07	26.55	1.70	5.20
DBVA	Overall	480	1.35 ± 0.02	27.03	0.72	2.62
	High saline	240	1.27 ± 0.02	20.33	0.75	1.96
	Low saline	240	1.42 ± 0.04	30.52	0.72	2.62
MaxBD	Overall	480	2.07 ± 0.03	21.76	1.17	3.62
	High saline	240	1.92 ± 0.03	15.58	1.17	2.83
	Low saline	240	2.23 ± 0.05	23.24	1.21	3.62
MinBD	Overall	480	0.74 ± 0.02	39.77	0.26	1.67
	High saline	240	0.71 ± 0.02	33.83	0.26	1.28
	Low saline	240	0.78 ± 0.03	43.64	0.27	1.67
HL	Overall	480	1.74 ± 0.02	16.80	1.08	2.56
	High saline	240	1.78 ± 0.02	14.54	1.16	2.55
	Low saline	240	1.70 ± 0.03	18.72	1.08	2.56
ED	Overall	480	0.30 ± 0.14	27.58	0.16	0.60
	High saline	240	0.32 ± 0.01	25.89	0.17	0.60
	Low saline	240	0.29 ± 0.01	28.94	0.16	0.50
POL	Overall	480	0.42 ± 0.01	26.49	0.22	0.79
	High saline	240	0.43 ± 0.01	24.25	0.22	0.79
	Low saline	240	0.40 ± 0.01	28.50	0.22	0.68

Table 14: Initial and final least square mean value for body weight and standard length

Group	Source of Variation	Morphometric Parameters							
		Body Weight (g)				Standard Length (cm)			
		Initial		Final		Initial		Final	
		N	Mean ± SD	N	Mean ± SD	N	Mean ± SD	N	Mean ± SD
Overall		480	1.52 ± 0.51	480	4.23 ± 1.95	480	3.40 ± 0.47	480	5.46 ± 1.14
Stocks	AP	160	0.99 ± 0.52 ^b	160	3.42 ± 1.51 ^b	160	3.07 ± 0.51 ^b	160	4.92 ± 0.76 ^b
	K	160	0.91 ± 0.43 ^b	160	5.59 ± 2.27 ^a	160	2.90 ± 0.48 ^c	160	6.43 ± 1.27 ^a
	TN	160	2.67 ± 0.53 ^a	160	3.67 ± 1.10 ^b	160	4.24 ± 0.38 ^a	160	5.11 ± 0.70 ^b
Salinity [stock]	AP_HS	80	0.89 ± 0.43 ^b	80	3.07 ± 1.33 ^c	80	2.99 ± 0.47 ^{bc}	80	5.10 ± 0.81 ^{bc}
	AP_LS	80	1.08 ± 0.59 ^b	80	3.78 ± 1.61 ^{bc}	80	3.15 ± 0.53 ^b	80	4.74 ± 0.68 ^c
	K_HS	80	0.83 ± 0.41 ^b	80	4.36 ± 1.29 ^b	80	3.01 ± 0.46 ^{bc}	80	5.39 ± 0.67 ^b
	K_LS	80	0.99 ± 0.44 ^b	80	6.82 ± 2.38 ^a	80	2.78 ± 0.48 ^c	80	7.29 ± 1.003 ^a
	TN_HS	80	2.63 ± 0.56 ^a	80	3.13 ± 0.66 ^c	80	4.17 ± 0.39 ^a	80	4.76 ± 0.50 ^c
	TN_LS	80	2.71 ± 0.49 ^a	80	4.22 ± 1.19 ^{bc}	80	4.31 ± 0.35 ^a	80	5.46 ± 0.70 ^b

Means within each group viz; stocks (AP, K and TN) and salinity [stock] (AP-HS, AP-LS, K-HS, K-LS, TN-HS, TN-LS) in the same column having different superscripts vary significantly from each other within the group ($p < 0.01$). 'N' is number of observations at each group for each pond age.

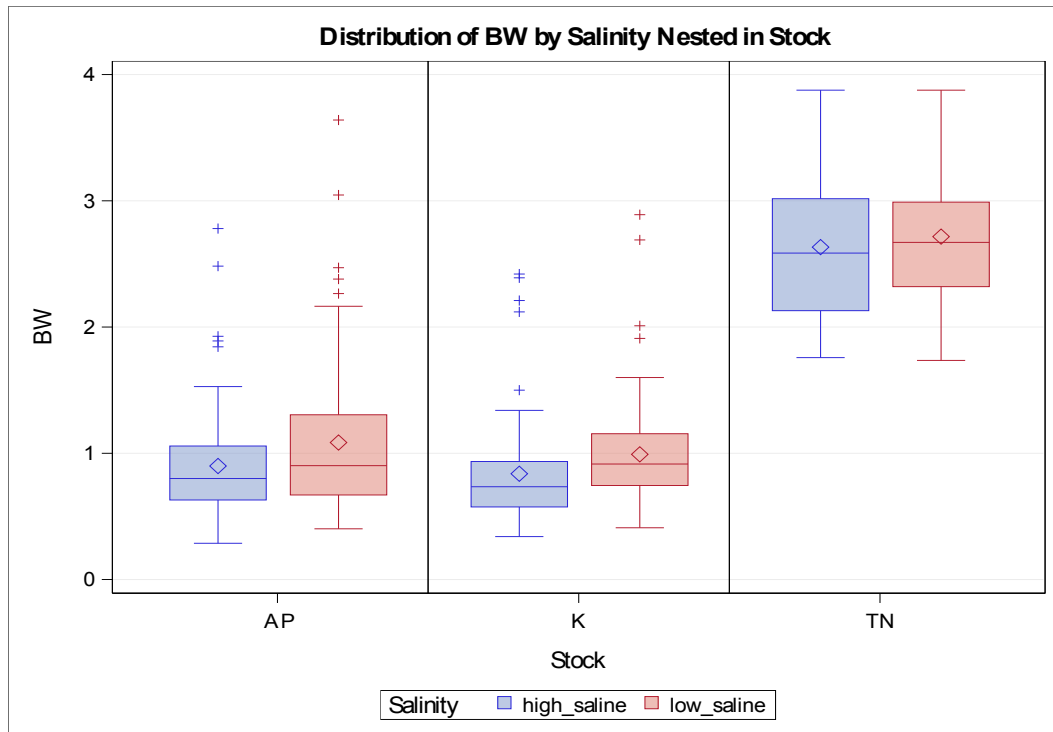


Figure 12.1: Box and Whisker plot for initial body weight across two salinities nested in stock

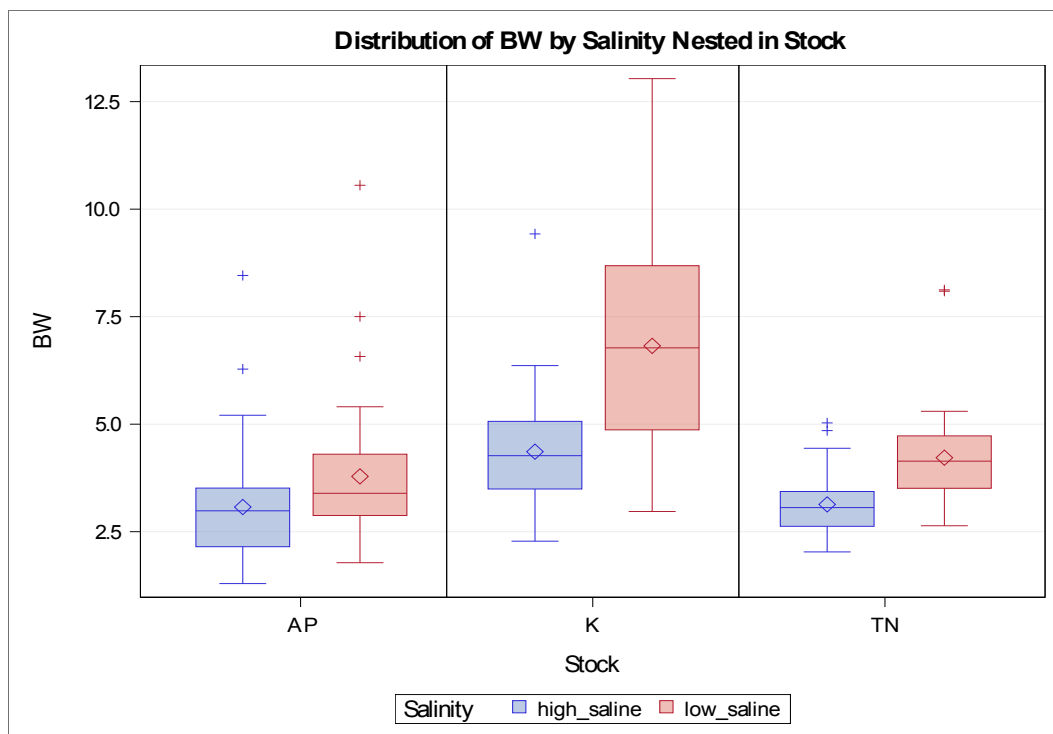


Figure 12.2: Box and Whisker plot for final body weight across two salinities nested in stock

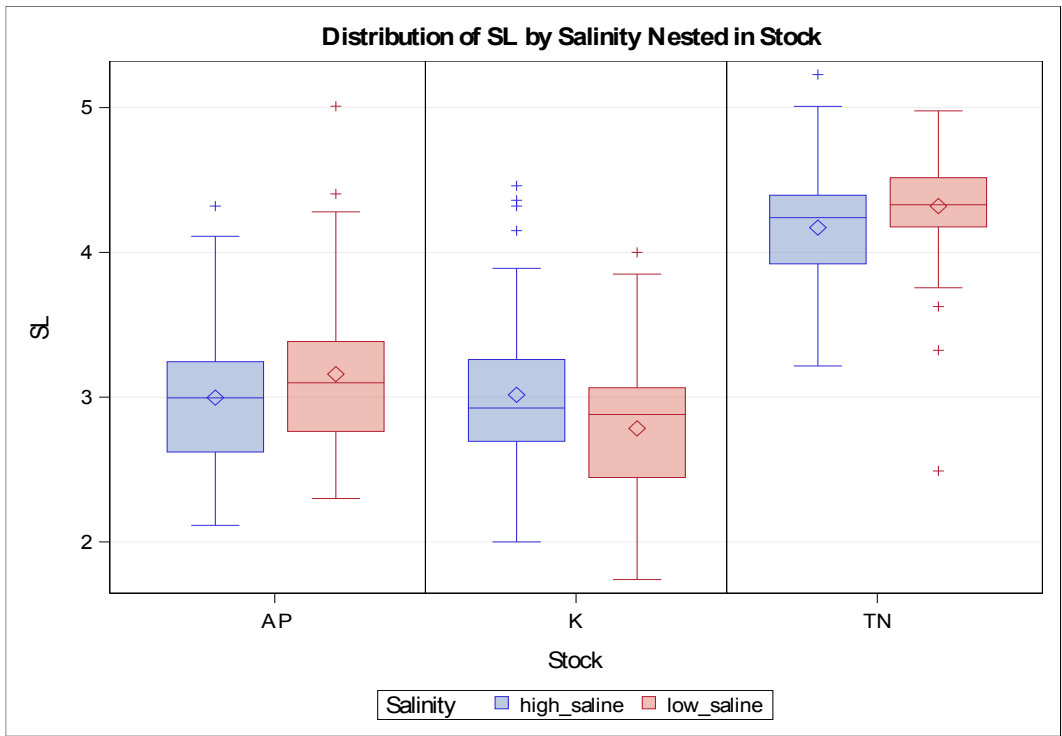


Figure 13.1: Box and Whisker plot for initial standard length across two salinities nested in stock

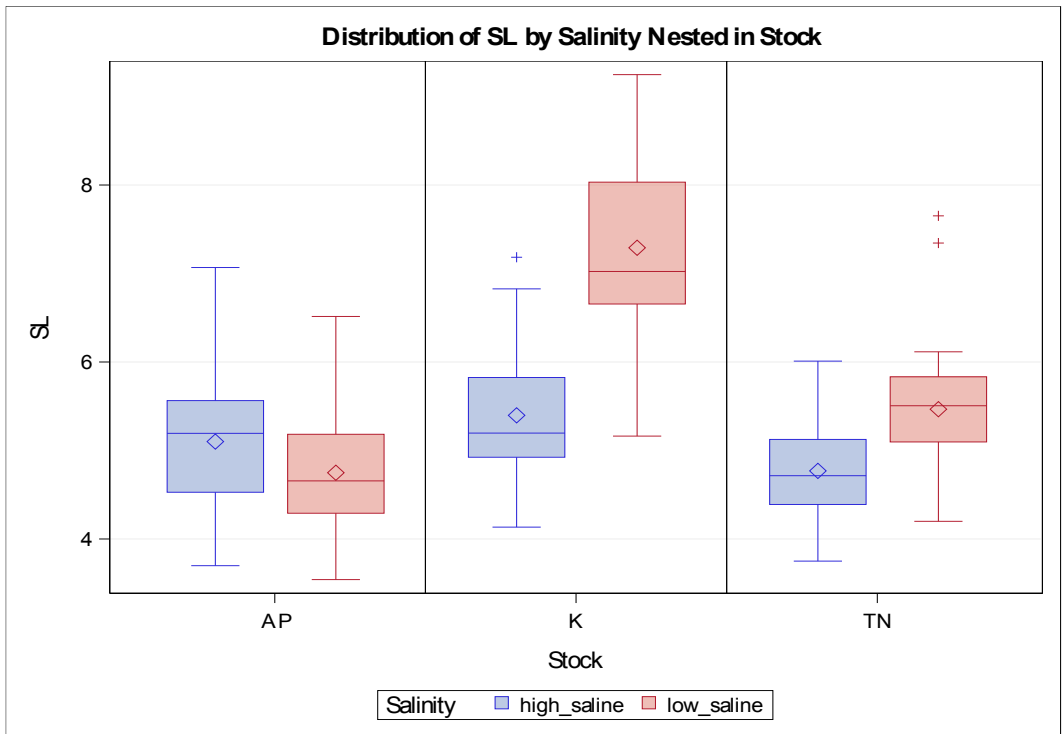


Figure 13.2: Box and Whisker plot for final standard length across two salinities nested in stock

Table 15: Least square mean values of some morphometric parameters

Group	Source of Variation	Morphometric Parameters									
		MaxBD		MinBD		HL		PreDL		TL	
		N	Mean ± SD	N	Mean ± SD	N	Mean ± SD	N	Mean ± SD	N	Mean ± SD
Overall	-	480	2.07 ± 0.45	480	0.74 ± 0.30	480	1.73 ± 0.29	480	2.63 ± 0.60	480	7.03 ± 1.47
Stocks	AP	160	1.79±0.27 ^c	160	0.59±0.21 ^b	160	1.52±0.23 ^c	160	2.26 ± 0.36 ^c	160	6.14 ± 0.90 ^c
	K	160	2.42±0.50 ^a	160	0.93±0.31 ^a	160	1.96±0.26 ^a	160	3.14 ± 0.63 ^a	160	8.27 ± 1.58 ^a
	TN	160	1.99±0.27 ^b	160	0.70±0.23 ^b	160	1.72±0.18 ^b	160	2.50 ± 0.37 ^b	160	6.67 ± 0.82 ^b
Salinity [stock]	AP_HS	80	1.79±0.30 ^c	80	0.62 ±0.19 ^c	80	1.64±0.24 ^b	80	2.33 ± 0.31 ^c	80	6.33 ± 0.94 ^c
	AP_LS	80	1.79±0.25 ^c	80	0.56±0.23 ^c	80	1.41±0.16 ^c	80	2.18 ± 0.40 ^c	80	5.96 ± 0.83 ^c
	K_HS	80	2.09±0.29 ^b	80	0.83±0.25 ^b	80	1.93±0.25 ^a	80	2.74 ± 0.37 ^b	80	7.15 ± 0.77 ^b
	K_LS	80	2.76±0.44 ^a	80	1.03±0.33 ^a	80	1.99±0.25 ^a	80	3.54 ± 0.59 ^a	80	9.39 ± 1.38 ^a
	TN_HS	80	1.85±0.21 ^c	80	0.66±0.21 ^{bc}	80	1.75±0.15 ^b	80	2.34 ± 0.27 ^c	80	6.21 ± 0.55 ^c
	TN_LS	80	2.14±0.25 ^b	80	0.73±0.26 ^{bc}	80	1.68±0.21 ^b	80	2.66 ± 0.39 ^b	80	7.13 ± 0.78 ^b

Means within each group viz; stocks (AP, K and TN) and salinity [stock] (AP-HS, AP-LS, K-HS, K-LS, TN-HS, TN-LS) in the same column having different superscripts vary significantly from each other within the group ($p < 0.01$). 'N' is number of observations at each group for each pond age.

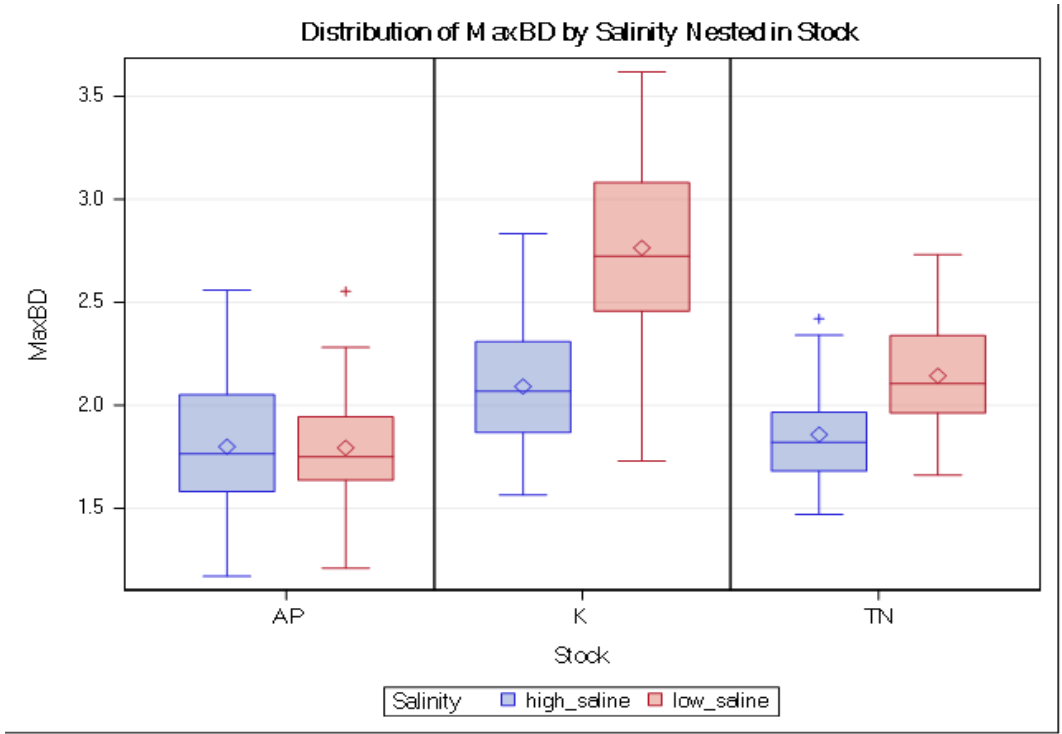


Figure 14: Box and Whisker plot for maximum body depth across two salinities nested in stock

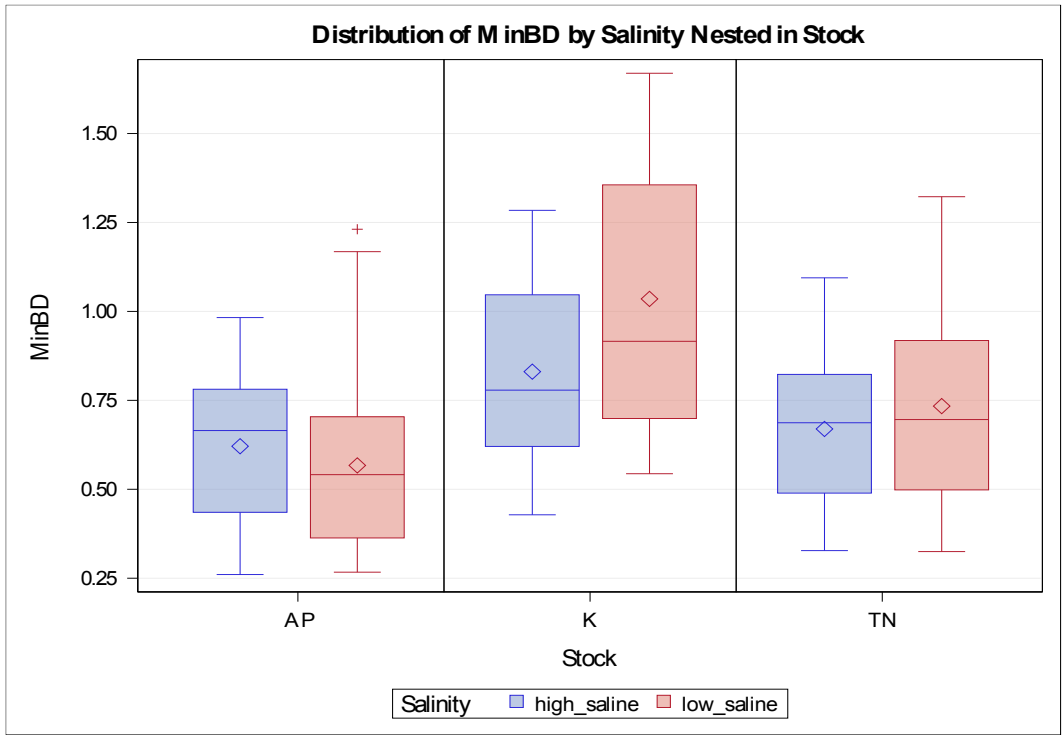


Figure 15: Box and Whisker plot for minimum body depth across two salinities nested in stock

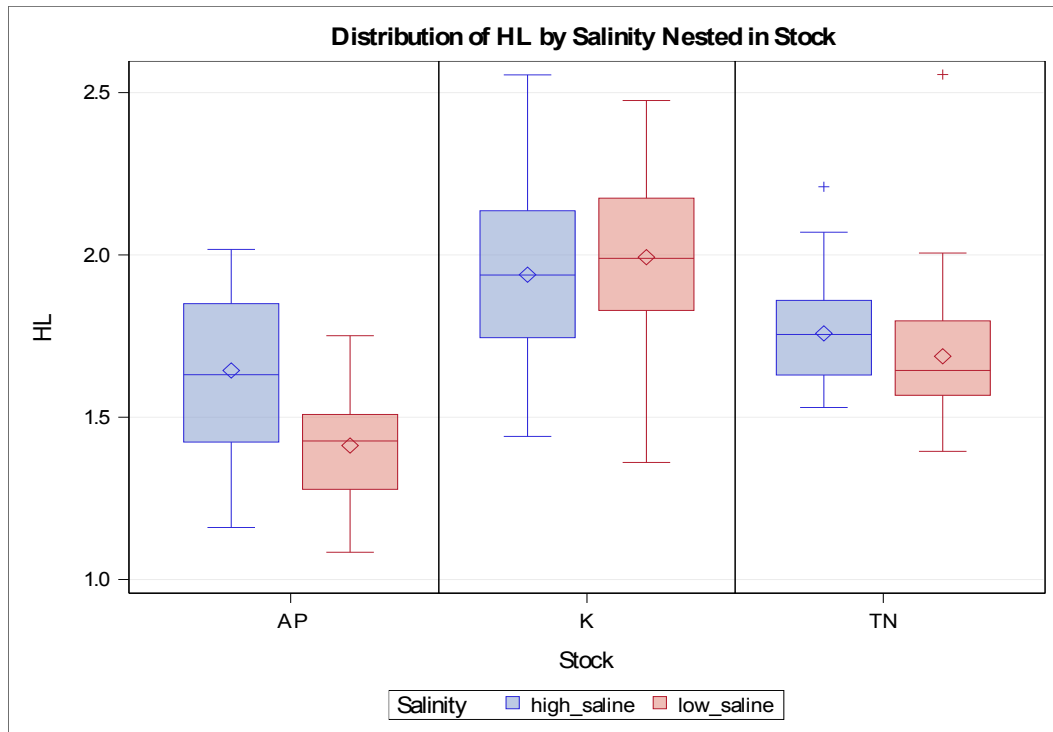


Figure 16: Box and Whisker plot for head length across two salinities nested in stock

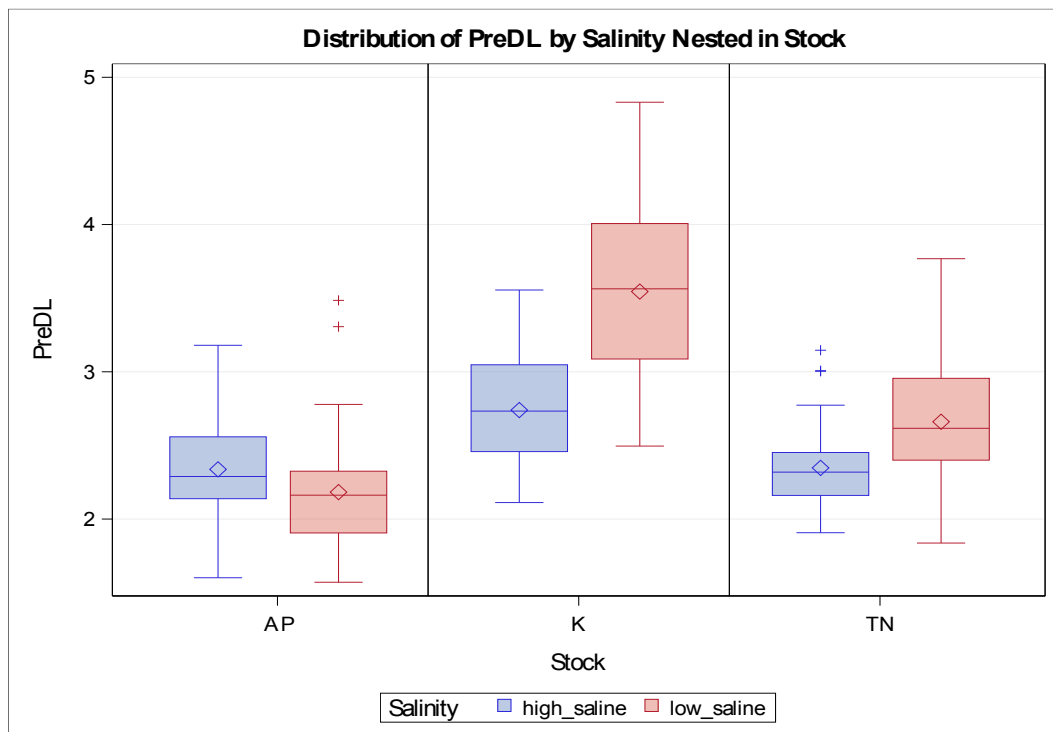


Figure 17: Box and Whisker plot for pre dorsal fin length across two salinities nested in stock

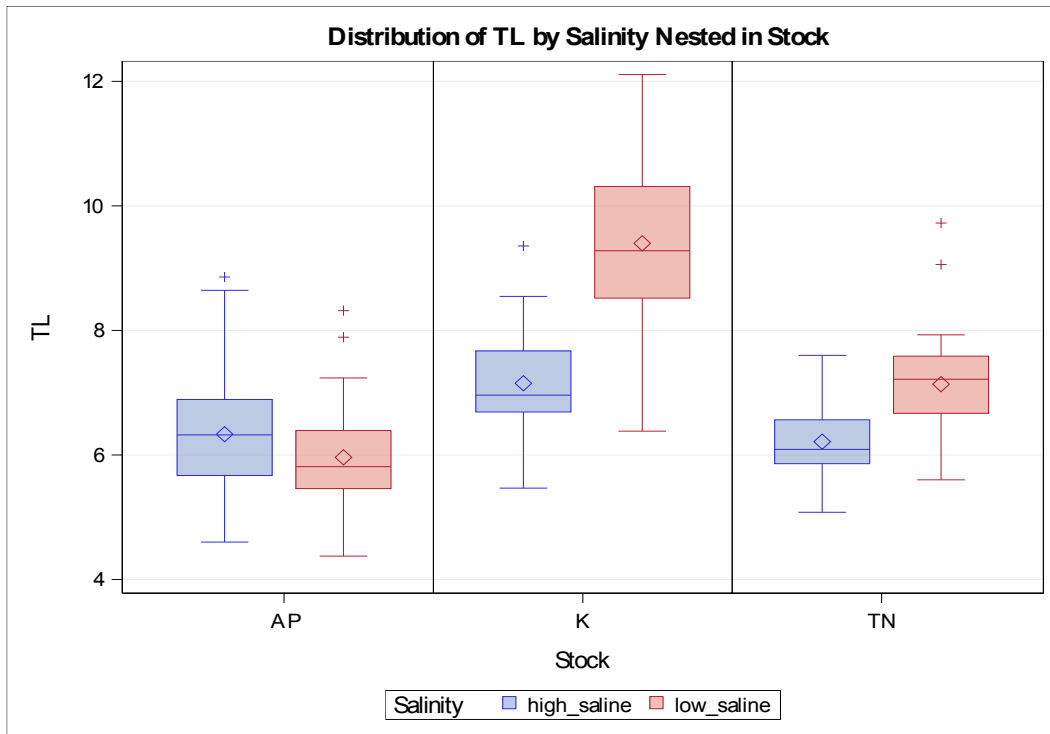


Figure 18: Box and Whisker plot for total length across two salinities nested in stock

Table 16: Mean sum of squares from analysis of variance of different morphometric parameters

Source of Variation	DF	Morphometric Parameters						
		BW	SL	MaxBD	MinBD	HL	PreDL	TL
Stock	2	111.90*	47.39*	8.30*	2.39*	3.84*	16.60*	98.17*
Salinity (stock)	3	51.61*	27.96*	3.56*	0.32 ^{NS}	0.40*	5.12*	40.26*
EMS		2.27	0.55	0.09	0.06	0.04	0.16	0.83
Error DF		234	234	234	234	234	234	234
R ² (%)		41.5	57.8	56.0	27.6	43.7	55.6	61.8

*p<0.01, NS- not significant (p>0.01)

Table 17: Regression coefficient (b) for various morphometric parameters as function of total length (TL)

SI No	Parameters	a	b	R	R ²	Y = bX + a
1	Standard Length	0.09	0.76	0.97	0.96	0.76 TL + 0.09
2	Fork Length	-0.23	0.95	0.97	0.96	0.95 TL - 0.23
3	Pre-Pectoral Fin Length	-0.31	0.23	0.76	0.58	0.23 TL - 0.31
4	Pre-Ventral Fin Length	0.03	0.38	0.91	0.84	0.38 TL + 0.03
5	Pre-Dorsal Fin Length	-0.02	0.37	0.91	0.84	0.37 TL - 0.02
6	Pre-Anal Fin Length	0.41	0.59	0.95	0.92	0.59 TL + 0.41
7	Pectoral Fin Base Length	0.04	0.17	0.73	0.54	0.17 TL + 0.04
8	Ventral Fin Base Length	0.06	0.25	0.84	0.71	0.24 TL + 0.06
9	Dorsal Fin Base Length	-0.10	0.30	0.87	0.76	0.30 TL - 0.10
10	Anal Fin Base Length	-1.05	0.78	0.90	0.81	0.78 TL - 1.05
11	Distance between Pectoral & Ventral fin	0.02	0.20	0.77	0.60	0.20 TL + 0.02
12	Distance between Pectoral & Anal Fin	-0.08	0.41	0.92	0.86	0.41 TL - 0.08
13	Distance between Ventral & Anal Fin	0.03	0.18	0.74	0.56	0.18 TL + 0.03
14	Maximum body depth	-0.01	0.29	0.96	0.93	0.29 TL - 0.01
15	Minimum Body depth	-0.06	0.11	0.56	0.32	0.11 TL - 0.06
16	Head length	0.72	0.14	0.72	0.52	0.14 TL + 0.72
17	Eye diameter	0.10	0.02	0.48	0.24	0.02 TL + 0.10
18	Pre orbital Length	0.09	0.04	0.60	0.37	0.04 TL + 0.09

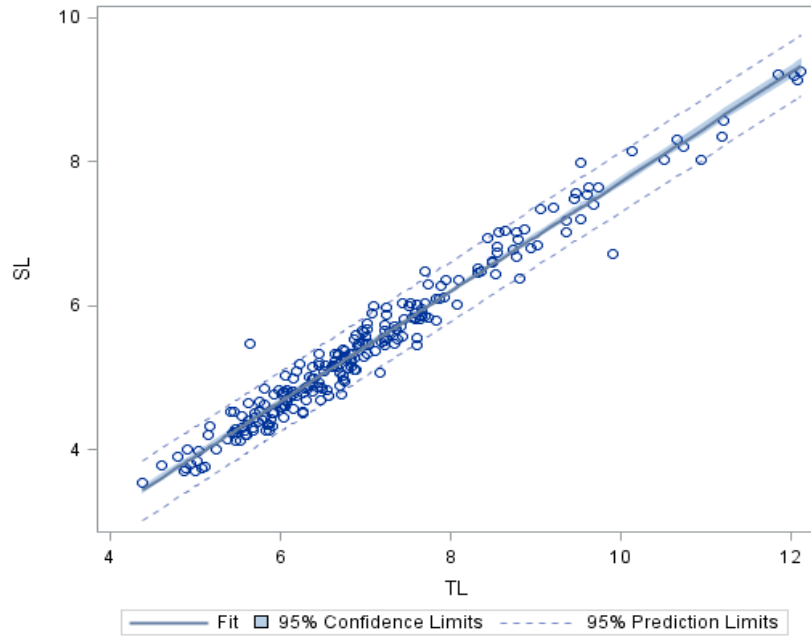


Figure 19.1: Regression curve of standard length on total length

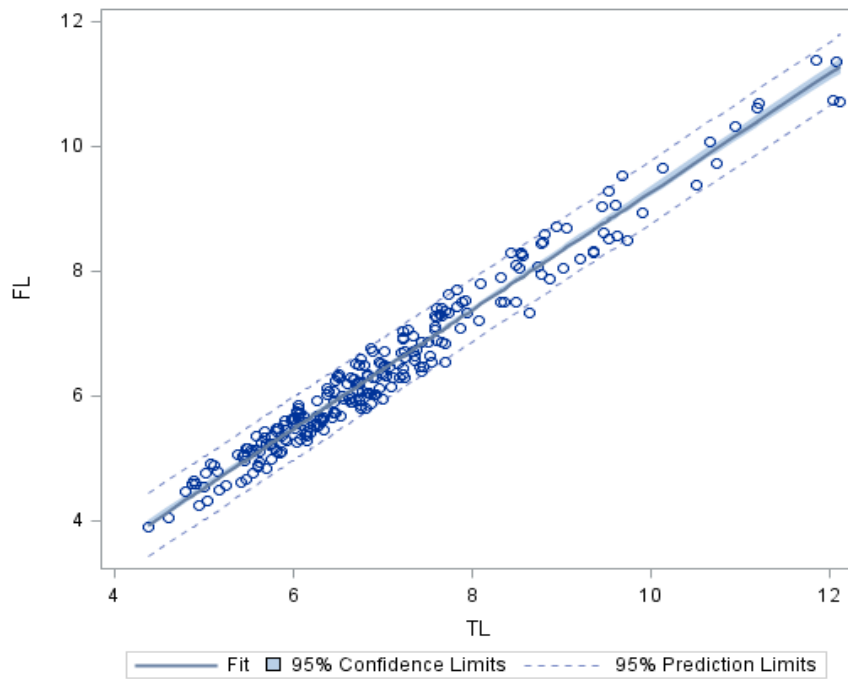


Figure 19.2: Regression curve of fork length on total length

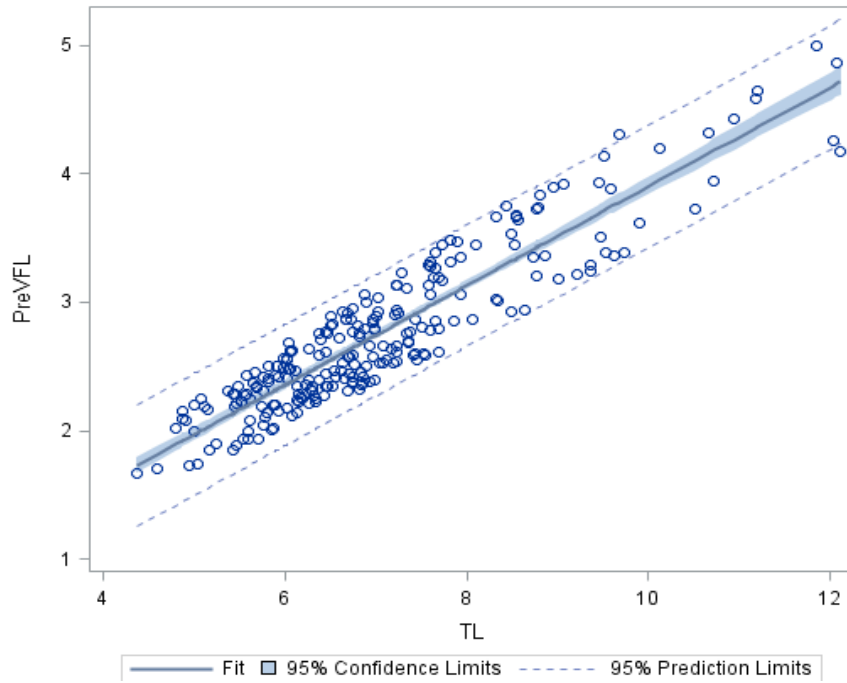


Figure 19.3: Regression curve of pre ventral fin length on total length

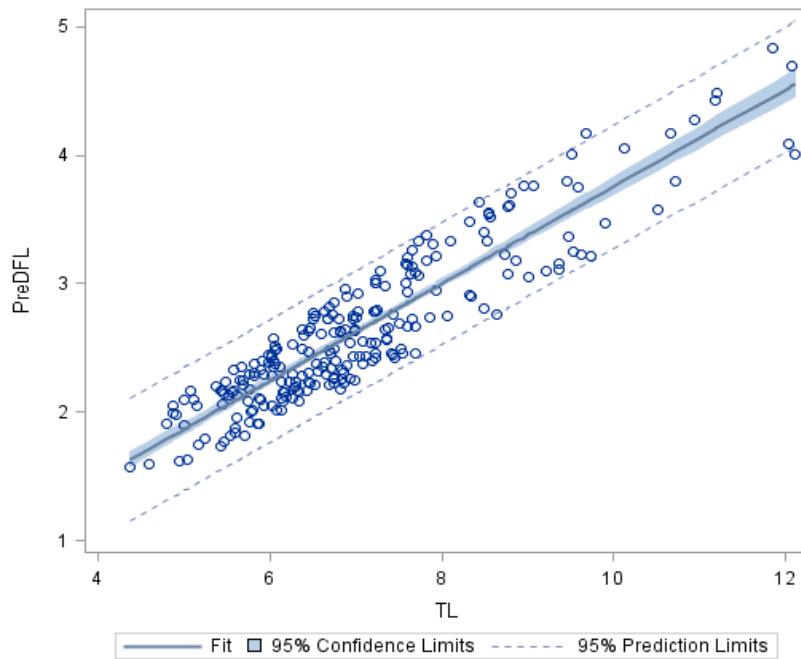


Figure 19.4: Regression curve of pre dorsal fin length on total length

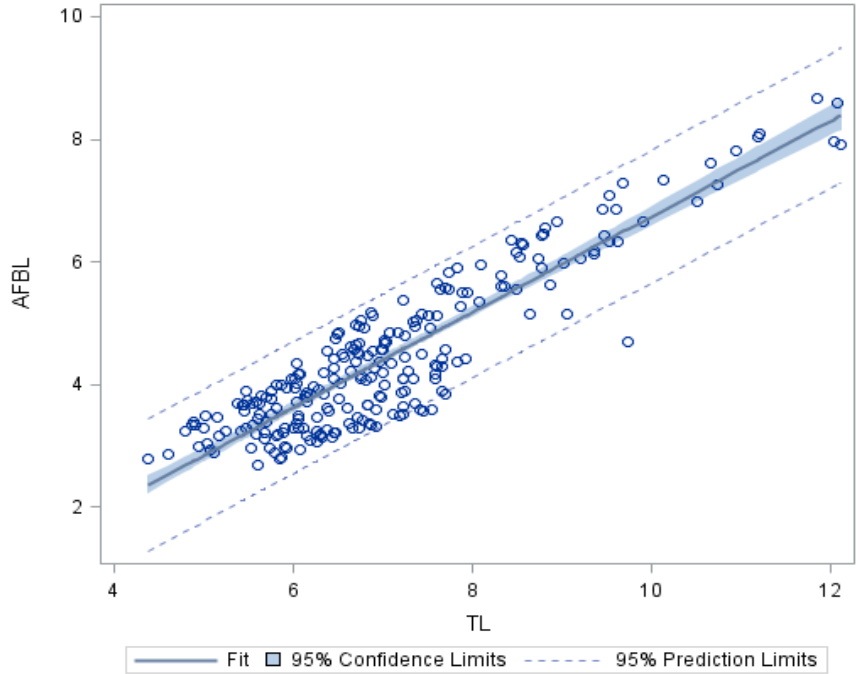


Figure 19.5: Regression curve of anal fin base length on total length

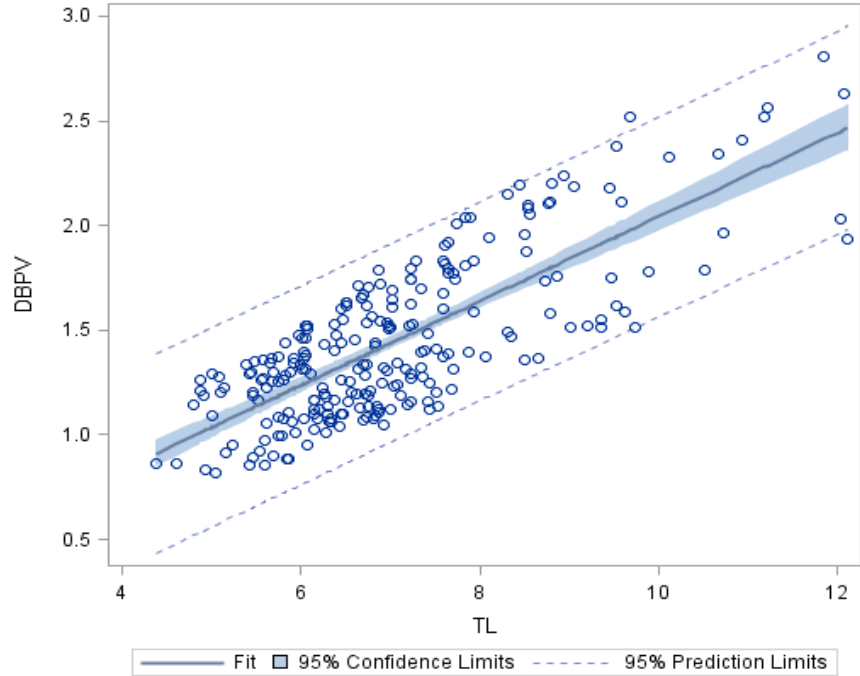


Figure 19.6: Regression curve of distance between pectoral and ventral fin on total length

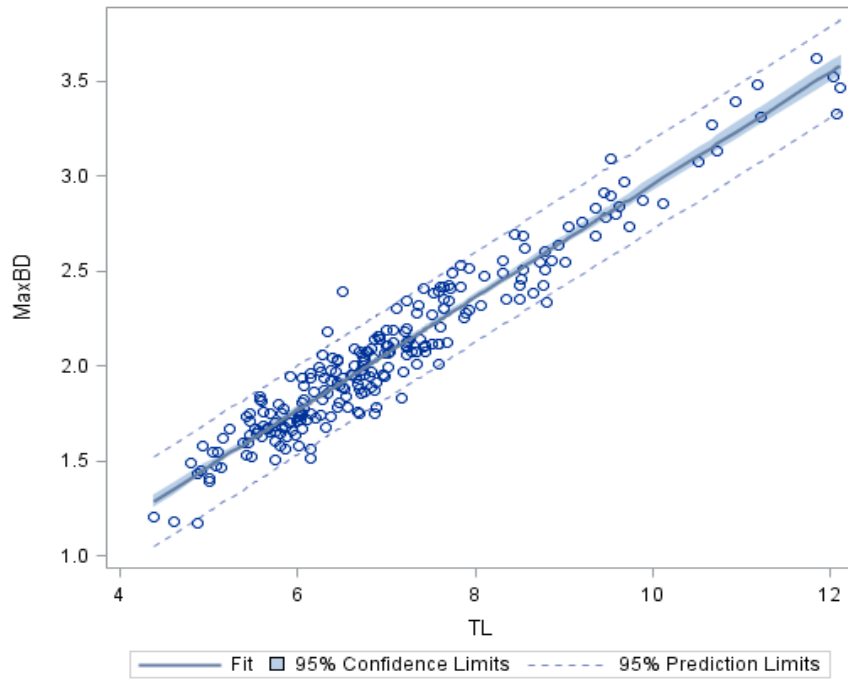


Figure 19.7: Regression curve of maximum body depth on total length



Discussion

5. DISCUSSION

The development of suitable technologies for the utilisation of inland saline ground water and inland saline soils is one of the national priorities of India (Lakra *et al.*, 2014). The inland saline ground water is unfit for agriculture activity and hence is popularly used for aquaculture. Salt tolerant freshwater fish species such as tilapia (*Oreochromis niloticus*), goldfish (*Carassius auratus*), riverine catfish (*Pangasianodon hypophthalmus*), common carp (*Cyprinus carpio*) etc, have been tested as candidate species for inland saline aquaculture. *Cyprinus carpio* (Linnaeus, 1758) is globally known commercial species for aquaculture and is known to tolerate moderate fluctuations in salinity and temperature (Whiterod and Walker, 2006). In the present study, the early growth performance of three geographical stocks of common carp was evaluated at two salinities reared in ponds. The morphometric studies were also conducted to evaluate the effect of salinity.

5.1. Performance comparison of *Cyprinus carpio*

The early growth performance of three geographical stocks of common carp *viz*; Andhra Pradesh, Karnataka and Tamil Nadu was evaluated at two salinities namely high saline and low saline ponds. The early growth performance traits recorded were body weight, standard length and body depth at 1st, 15th, 30th and 45th days of culture age. For all the three traits recorded during a culture period of 45 days, across the two salinities, the Karnataka stock cultured in low saline pond performed better followed by Tamil Nadu and Andhra Pradesh stock. The Karnataka stock of common carp attained an average body weight, standard length and body depth measuring 66.72 ± 1.75 g, 18.30 ± 0.57 cm and 7.37 ± 0.23 cm respectively. The Karnataka stock used in this study belongs to Amur strain of common carp and is known to perform better than other common carp stocks of India. The results obtained in this study are similar to other reported studies wherein the superior performance of Amur strain of common carp has been recorded. Basavaraju *et al.* (2003), conducted a series of culture performance trials for stocks of *C. carpio* obtained from Hungary (Amur and P3), Indonesia (Rajdanu), Vietnam (SV) and two local stocks (L-BRP and L-FRS). The results from the completed

trials involving pure lines indicated that the strains from Hungary and the Rajdhanu (RJ) stock from Indonesia appear to be the most promising in terms of weight at harvest, survival and gonado-somatic index. In another study of Basavaraju *et al.* (2012), field trials were conducted to assess the growth performance of two stocks (new breed, Amur and existing stocks) of common carp, *Cyprinus carpio* under polyculture at nine different locations of Karnataka. They observed the mean body weight of Amur stock was 583.03 ± 18.36 g for a culture period of 28 weeks and was significantly higher than that of existing stock. Amur stock registered 20.31% faster growth over the existing stock and showed consistently better growth over existing stock in all the locations. In yet another study conducted by Das (2017), they evaluated the performance of common carp, Amur (Hungarian strain) introduced in Meghalaya in 2010. The three year studies revealed that the performance of Amur common carp is superior over the local existing breed in farmers ponds under the mid hill conditions.

In the present study, the common carp stocks performed better at low saline ponds compared to high saline ponds. At the end of culture period the common carp stocks reared at low saline ponds attained an average body weight, standard length and body depth measuring 45.32 ± 0.99 g, 14.46 ± 0.32 cm and 5.73 ± 0.13 cm respectively. The comparative low performance in high saline ponds may be attributed to the negative effects of increase in salinity on feed conversion rate, feed conversion efficiency, protein intake, efficiency of protein utilization ratio and excess nitrogenous excretion rate, oxygen consumption rate etc. Abdel-Tawwab, (2018) investigated the impact of increased salinity (5, 10 and 15 g/L) on some growth parameters of common carp (*Cyprinus carpio*) for 12 weeks, They observed a decrease in feed conversion rate, feed conversion efficiency, protein intake and the efficiency of protein utilization slump to 21.32, 10.94 and -10.07% in the salt concentrations of 5, 10 and 15 g/L, respectively while it was 29.16% in the control treatment. Similar results were reported by Wang *et al.* (1997). They observed the food consumption, growth rate, digestibility was higher in common carp (*Cyprinus carpio* L.) fingerlings reared in low saline waters whereas the nitrogenous excretion rate and oxygen consumption rate gradually increased with increase in salinity from 0.5 to 14.5%. The earlier studies by Mangat and Hundal (2014) suggests that fingerlings of common carp, will easily adapt and tolerate culture systems

of fresh and low brackish water environments of 0 to 6 ppt salinity. Hundred percent survival were detected at 0 to 6 ppt salinity range in common carp fingerlings, subjected to salinity regimes of 0, 1.5, 3, 6, and 12 ppt for 60 days during different seasons (summer, autumn and winter).

5.2. Morphometric studies in common carp

In the present study nineteen morphometric traits of common carp were studied *viz.*, TL – Total Length, FL - Fork length, SL - Standard length, PrePFL - Pre pectoral fin length, PreDFL- Pre dorsal fin length, PreVFL – Pre ventral fin length, PreAFL - Pre anal fin length, PFBL - Pectoral fin base length ; DFBL - Dorsal fin base length, VFBL – Ventral fin base length, AFBL - Anal fin base length, DbP&V – distance between pectoral and ventral fin, DbP&A – distance between pectoral and anal fin, DbV&A – distance between ventral and anal fin, MaxBD – Maximum body depth, MinBD – Minimum body depth, POL - Post orbital length, HL - Head length, ED – eye diameter.

The morphometric traits were recorded on fish that were cultured in cement tanks for 90 days and the average values for morphometric traits obtained salinity wise were compared. The fish stocks reared in low saline tanks showed higher average values for sixteen traits than the fish stocks reared in high saline tanks. The three morphometric traits *viz.*, head length, eye diameter and pre orbital length had higher average values for fish stocks reared in high saline tanks than the fish stocks reared in low saline tanks. This observation suggests that the head length, eye diameter and pre orbital length of common carp were affected by increase in salinity. The common carp may display adaptive phenotypic plasticity as an adaptive response to cope up with the high saline environment. The phenotypic plasticity may be delineated through morphometry provided a strong response is exhibited. There are few studies in fish that have validated the phenotypic plasticity as an adaptive response. White and Angelovic (1973) observed differences in body characteristics in a study exploring the effects of low levels of gamma radiations, salinity and temperature on a teleost fish, pinfish (*Lagodon rhomboids*). The fish were exposed to salinity at 10, 20 and 30 ppt in an experiment that lasted for 45 days. They observed that the traits namely head length, eye diameter, length of last dorsal spine, first dorsal ray and second anal spine were

significantly changed by salinity alone. In yet another study by Mazarella *et al.*, 2015, concluded strong and parallel salinity-induced phenotypic plasticity in one generation of threespine stickleback. The threespine stickleback (*Gasterosteus aculeatus*) is one example system where plasticity might have played an important role in an adaptive radiation as this fish has diversified after invading freshwater lakes repeatedly from the marine habitat. They evaluated phenotypic plasticity in stickleback body shape in response to salinity in fish stemming from a wild freshwater population. The fish raised in salt water developed shallower bodies and longer jaws, and these changes were consistent and parallel across families. Similarly, common carp may also exhibit plasticity owing to its varied populations at different freshwater ecosystems around the world. Balon (1995) have documented that common carp's wild ancestor is a marine one, originated in the Black, Caspian (e.g. Anzali wetland) and Aral Sea drainages and dispersed east into Siberia and China and west as far as the Danube River (Fallahbagheri *et al.*, 2013). In our study the findings may hint towards adaptation in morphometric parameters in common carp reared in high saline environment. However, the short duration of experiment, sample size and parameters recorded may not be sufficient to delineate the effects of salinity on adaptive response and exhibition of phenotypic plasticity in common carp.

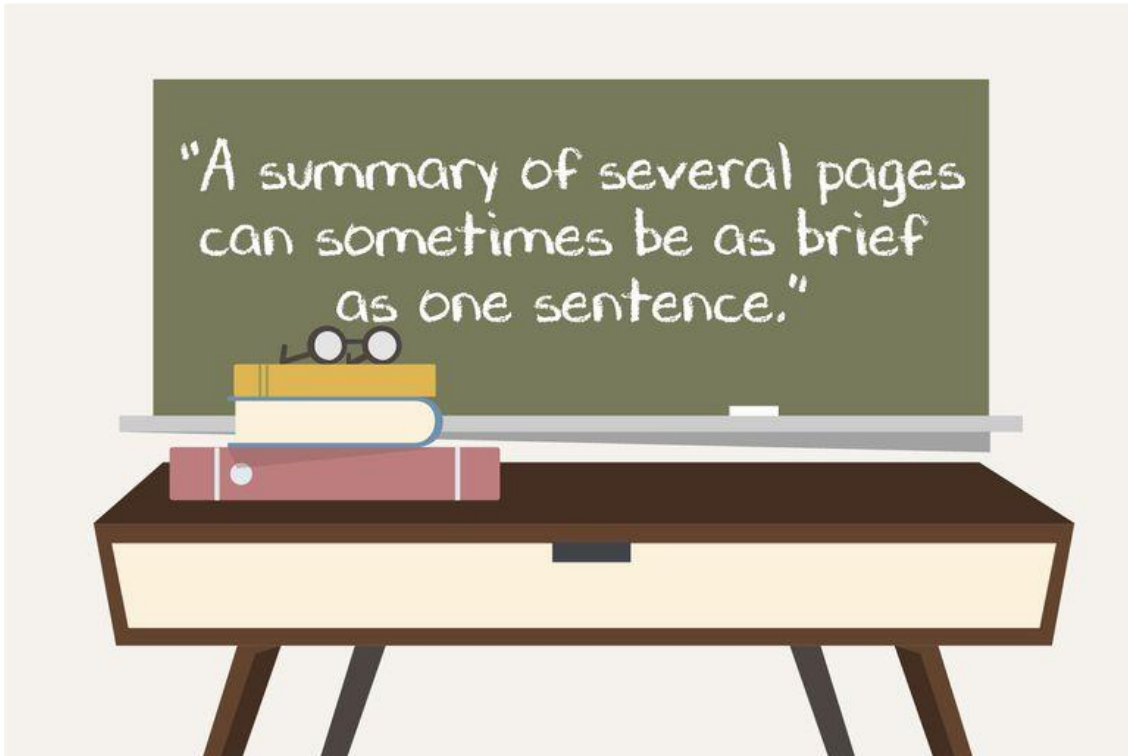
The common carp for the morphometry study was reared in cement tanks during the winter months (December to February). The initial mean body weight and standard length were 1.52 ± 0.51 g and 3.40 ± 0.47 cm respectively and the final mean body weight and standard length were 4.23 ± 1.95 g and 5.46 ± 1.14 cm respectively. The comparative very lower growth performance of common carp can be attributed to the sub optimum water temperature. The average water temperature ranged from 6°C to 15°C and a significant positive correlation of 0.71 was observed between temperature and body weight during the experiment period. Fish being poikilothermic, water temperature has significant effect on its basal metabolic rate where, lower water temperature result in reduced basal metabolic rate which in turn lower the demand for food (Kausar and Salim., 2006). Oyugi *et al.*, (2011) reported that foraging which determine growth is strongly thermal influenced and the highest growth rates in common carp were achieved at a temperature range between 20 and 24°C. Beamish (1981)

reported that added to basal metabolic rate and feeding rate; swimming performance and oxygen consumption also deviates from its optimum level in fish when they are not within their thermal range of tolerance. Khan *et al.*, (2004) observed significant difference in growth performance between *Labeo rohita* reared in outdoor tanks with average water temperature of 14.8°C and those grown in a polyhouse with average water temperature of 19.8°C.

In the present study, the morphometric traits were also analysed as function of total length using a simple linear regression equation. All the traits were positively correlated with total length. This indicates that the growth of fish in one area of the body is co-related to growth in another area of the body. The fork length and standard length had the highest value of regression coefficient whereas eye diameter and pre orbital length had the least value. Eight of the total eighteen morphometric parameters *viz*; standard length, fork length, pre-ventral fin length, pre-dorsal fin length, pre-anal fin length, anal fin base length, distance between pectoral and ventral fin and maximum body depth were strongly correlated with total length with r value > 0.9 , and indicate a better fit. The eight of the remaining ten morphometric parameters *viz*; pre-pectoral fin length, pectoral fin base length, ventral fin base length, dorsal fin base length, distance between pectoral & ventral fin, distance between ventral & anal fin and head length were moderate correlated with total length with r value ≥ 0.6 and < 0.9 . The remaining two parameters *viz*; minimum body depth and eye diameter were least correlated to total with r values of 0.56 and 0.48 respectively. Different values of correlation coefficient indicate the varying relationships of total length with the parameters. Similar results were reported by Bhat *et al.* (2016), in *Cyprinus* sp. They found that out of eighteen characters in relation to total fish length, ten characters showed high values of correlation coefficient and eight characters showed moderate correlation coefficient. While in percentage of head length three characters showed least correlation coefficient and four showed moderate correlation. Similar results were also reported by Siraj *et al.* (2017), wherein they conducted morphometric analysis involving 18 morphometric parameters in 75 samples of *Cyprinus carpio* collected from three basins of Dal Lake, namely Hazratbal basin, Nigeen basin and Gagribal basin. Amir Bashir *et al.* (2015) worked on morphometric characters of *Triplophysa marmorata* where all body parameters exhibited

positive correlation with total length. Brraich and Akhter (2015) also affirmed that the positive correlation between body parameters and total length of minor carp, *Crossocheilus latius* from a wetland in India.

In conclusion, the present study delineates the effects of stock and salinity and their interactions on performance of common carp. Amongst the three stocks, the Karnataka stock performed the best followed by Tamil Nadu stock. Amongst the two salinities, the stocks reared in low saline ponds performed better than the stocks reared in high saline ponds. It was also observed that common carp performance is severely affected by the low winter temperature during the months of December to February. The morphometric analysis revealed that, out of 19 traits studied, the increase in salinity had an effect on head length, eye diameter and pre orbital length. All the traits were positively correlated and were expressed as a function of total length in common carp and traits viz; standard length, fork length, pre-ventral fin length, pre-dorsal fin length, pre-anal fin length, anal fin base length, distance between pectoral and ventral fin and maximum body depth showed strong positive correlation to total length.



Summary

6. SUMMARY

The dream of global prosperity will be made a reality by aquaculture sector as it continues to grow faster than any other food production sector in the world. It offers food and nutritional security, promotes economic growth and employs millions of people. India's current (2018) aquaculture production of 7.06 million metric tons is the 2nd largest in the world. To maintain the high growth rate India needs to expand the aquaculture area in the country. Inland saline soils and water provide a potential resource for aquaculture.

The expansion of salt affected lands is a significant challenge that India is currently facing. The factors responsible are climate change dependent sea level surge causing saltwater infusion into groundwater, unsustainable use of chemical fertilizers, soil moisture evaporation based salts accumulation, weathering of geological substrates and absence of leaching causing soluble salts accumulation etc. The salinisation has drastically reduced the economic utility of the soil and thus developing suitable technologies for the utilisation of inland saline ground water and soils have become one of the national priorities of India. The inland saline soil is unfit for agriculture and thus it is impeccable to use such soils for aquaculture which could be a very promising, economical and sustainable solution. Common carp (*Cyprinus carpio*) could tolerate fluctuations in salinity (0-10 ppt), temperature (3-35°C) and pH (6.5 to 9) and is thus candidate species for inland saline aquaculture especially for fallow months of severe winter.

The experiment was conducted to evaluate the early growth performance of three geographical stocks of common carp reared at two salinities. Morphometric analysis was also conducted to evaluate the effect of salinity. Body weight, standard length and body depth were the traits used to compare the performance and 19 parameters were used for morphometric analysis. Common carp stocks of Karnataka, Andhra Pradesh and Tamil Nadu were chosen and were transported to Rohtak, Haryana to be reared in inland saline water. The fish were reared stock wise at two salinities viz; low saline and high saline. The common carp were reared in ponds for 45 days and in

tanks rearing was for 90 days. The sampling for growth performance study were done on 1st, 15th, 30th and 45th day of culture age and for the morphometric study it was done at the end of experiment. The common carp were reared in severe winter months in no temperature control tanks.

At 45th day of culture, the least square mean for body weight, standard length and body depth of Karnataka stock reared in pond at low saline were 66.72 ± 1.1 g, 21.70 ± 0.43 cm and 7.37 ± 0.14 cm respectively. For all the three traits recorded during a culture period of 45 days, across two salinities, the Karnataka stock cultured in low saline pond performed the best followed by Tamil Nadu and Andhra Pradesh stock. The Karnataka stock used in this study belong to Amur strain of common carp and is known to perform better than other common carp stocks of India. The common carp stocks reared in low saline ponds outperformed the high saline ponds. At 45th day of culture, the least square mean for body weight, standard length and body depth of common carp stocks reared at low saline pond were 16.69 ± 0.41 g, 9.05 ± 0.16 cm and 2.88 ± 0.05 cm respectively and high saline pond were 9.28 ± 0.42 g, 7.14 ± 0.16 cm and 2.18 ± 0.05 cm respectively. Growth performance of common carp stocks reared at low saline waters was thus significantly higher than those at high saline waters.

The average values of 19 morphometric parameters corresponding to the two salinity *viz*; low saline and high saline were compared to know the effect of salinity. The fish stocks reared in low saline waters showed significantly higher average values for sixteen traits than the fish stocks reared in high saline water. The three morphometric traits *viz*; head length, eye diameter and pre orbital length had significantly higher average values for fish stocks reared in high saline water than those reared in low saline water, suggesting these traits are affected by increase in salinity. The morphometric traits were also analysed as a function of total length using a simple linear regression equation. The regression coefficient value of fork length (0.95) and standard length (0.76) were the highest, whereas eye diameter (0.02) and pre orbital length (0.04) were the least. All the traits were positively correlated with total length. The traits *viz*; standard length, fork length, pre-ventral fin length, pre-dorsal fin length, pre-anal fin length, anal fin base length, distance between pectoral and ventral fin and maximum body depth

were strongly correlated with total length with r value greater than 0.9. In conclusion, the early performance study of common carp delineated that out of three stocks tested for performance in two varying salinities, the Karnataka stock reared at low saline pond showed better performance than any other combinations.



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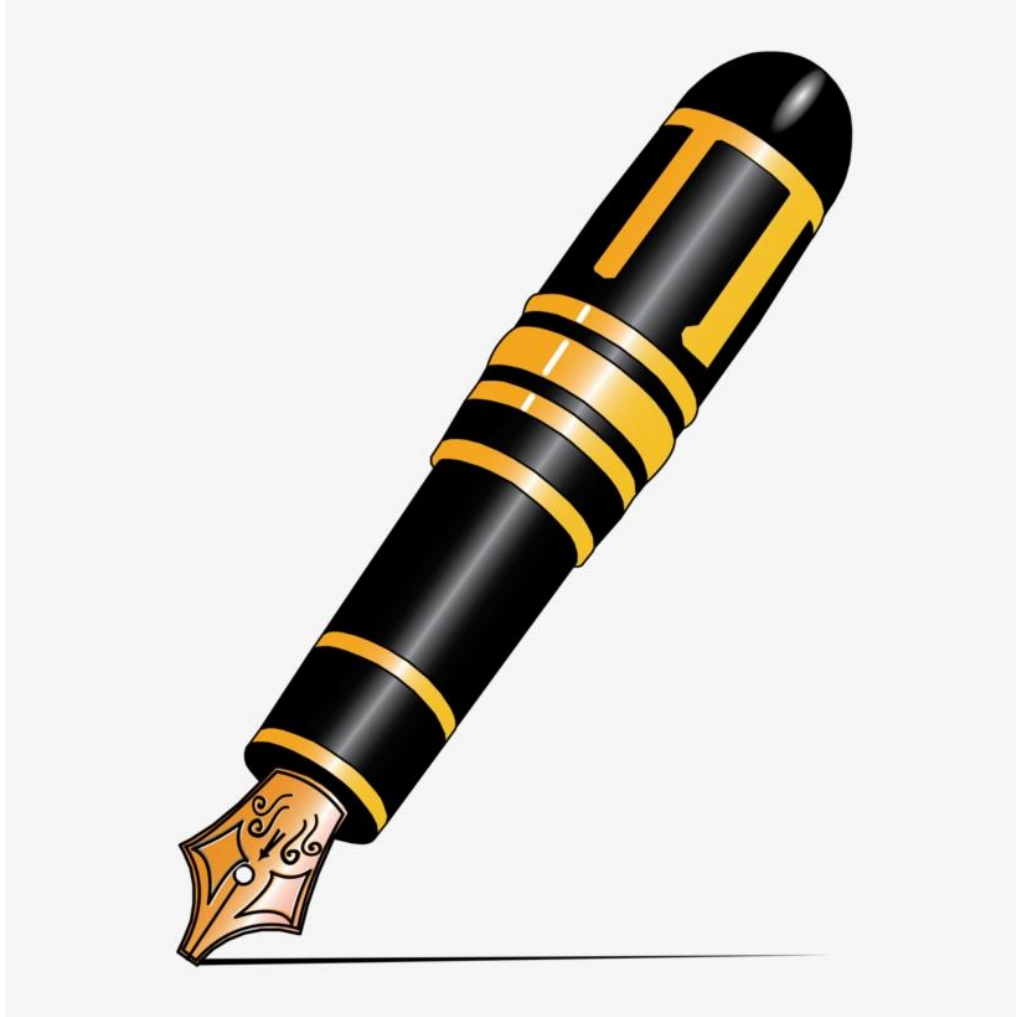
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Appendix

ABBREVIATIONS AND ACRONYMS

%	Percent
°C	Degree Celsius
‰	Parts per Thousand
ACTH	Adrenocorticotrophic Hormone
AFBL	Anal Fin Base Length
ANOVA	Analysis of Variance
AP	Andhra Pradesh
APHA	American Public Health Association
b	Breadth
DB	Body Depth
BW	Body Weight
C	Carbon
CE	Culture Environment
CIFE	Central Institute of Fisheries Education
Cl	Chlorine
CNS	Central Nervous System
CSSRI	Central Soil Salinity Research Institute
CV	Coefficient of Variation
DbP&A	Distance between Pectoral & Anal Fin
DbP&V	Distance between Pectoral & Ventral Fin
DbV&A	Distance between Ventral & Anal Fin

DFBL	Dorsal Fin Base Length
DNMRT	Duncan's New Multiple Range Test
EBT	Eriochrome Black T
ECeSA	Erode Centre for Sustainable Aquaculture
ED	Eye Diameter
EDTA	Ethylene Diamine Tetra Acetic Acid
FAO	Food and Agriculture Organisation
FL	Fork Length
FRP	Fibre Reinforced Plastic
g	Gram
GIFT	Genetically Improved Farmed Tilapia
h	Height
ha	hectare
HL	Head Length
HP	Horse Power
hr	Hour
HS	High Saline
ICAR	Indian Council of Agriculture Research
IMCs	Indian Major Carps
ISA	Inland Saline Aquaculture
ISW	Inland Saline Water
K	Potassium
kg	Kilo Gram

L	Litre
l	Length
LCD	Liquid Crystal Display
L _m	Length at First Maturity
LS	Low Saline
MaxBD	Maximum Body Depth
Mg	Magnesium
mg	Milli Gram
million hectare	mha
MinBD	Minimum Body Depth
mL	Milli Litre
MSS	Mean Sum of Squares
N	Nitrogen
Na	Sodium
nm	Nano Meter
nr	Not Recorded
OD	Optical Density
OECD	Organisation for Economic Co-operation and Development
PFBL	Pectoral Fin Base Length
POL	Pre Orbital Length
ppm	Parts Per Million
ppt	Parts per Thousand

PreAFL	Pre Anal Fin Length
PreDFL	Pre Dorsal Fin Length
PrePFL	Pre Pelvic Fin Length
PreVFL	Pre Ventral Fin Length
PUFA	Poly Unsaturated Fatty Acids
SAS	Statistical Analysis Software
SD	Standard Deviation
SE	Standard Error
SL	Standard Length
SOC	Soil Organic Carbon
SOFIA	State of World Fisheries and Aquaculture
t	Tons
TL	Total Length
TN	Tamil Nadu
TNJFU	Tamil Nadu Dr Jayalalithaa Fisheries University
USA	United States of America
USD	United States Dollar
VFBL	Ventral Fin Base Length
W	Watts
yr	Year