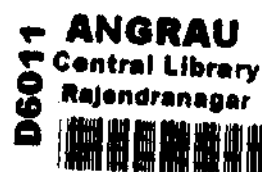


**EFFECT OF AQUACULTURE ON SOIL AND GROUND
WATER QUALITY IN NELLORE AND PRAKASAM
DISTRICTS OF ANDHRA PRADESH**

By

KEERTHI VENKAIAH



THESIS SUBMITTED TO THE
ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF

**DOCTOR OF PHILOSOPHY
IN THE FACULTY OF AGRICULTURE**

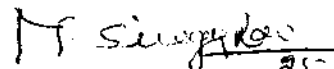
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SEPTEMBER 1999

CERTIFICATE

Mr. KEERTHI VENKAIAH, has satisfactorily prosecuted the course of research and that the thesis entitled **“EFFECT OF AQUACULTURE ON SOIL AND GROUND WATER QUALITY IN NELLORE AND PRAKASAM DISTRICTS OF ANDHRA PRADESH”** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any university.

Date: 25-9-99
Place: Hyderabad


(Dr. M. SINGA RAO)
MAJOR ADVISOR

CERTIFICATE

This is to certify that the thesis entitled "**EFFECT OF AQUACULTURE ON SOIL AND GROUND WATER QUALITY IN NELLORE AND PRAKASAM DISTRICTS OF ANDHRA PRADESH**" is submitted in partial fulfilment of the requirements for the degree of **DOCTOR OF PHILOSOPHY IN AGRICULTURE** of the Acharya N.G. Ranga Agricultural University, Hyderabad is a record of the bonafide research work carried out by **Mr. KEERTHI VENKAIAH** under my guidance and supervision. The subject of the thesis has been approved by the student's advisory committee.

No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All assistance and help received during the course of investigations have been duly acknowledged by the author of the thesis.


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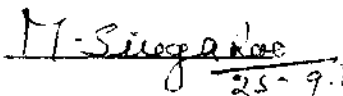
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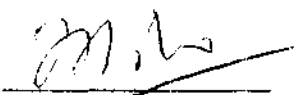
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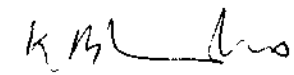
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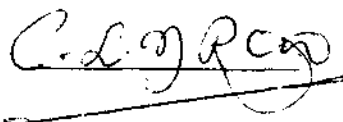
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ACKNOWLEDGEMENTS

*I thank and praise my **LORD VENKATESWARA** for the benignant blessings, grace, strength and stamina to complete this task with success.*

*I express my heartfelt gratitude to my major advisor **Dr. M. Singa Rao**, Professor of Soil Physics, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Rajendranagar, Hyderabad for the unlimited efforts and scholarly meliorations made throughout the field investigation and in preparation and presentation of research findings without which, perhaps, this stupendous task could not have been accomplished.*

*I express my esteem regard, sincere gratitude and profound thanks to **Dr. A. Prasad Rao**, Radio Tracer Agril. Chemist for his keen interest, whole hearted co-operation and constant encouragement rendered during the progress of research work and in preparation of the thesis.*

*It is with profound sincerity that I acknowledge the help and guidance given by **Dr. K. Bhaskara Rao**, Soil Physicist, Regional Agricultural Research Station, Tirupati; **Sri A. Satyanarayana**, Associate Professor, Computer Centre, ANGR Agricultural University and **Dr. C.L. Narasimha Rao**, Associate Professor, Department of Plant Physiology, College of Agriculture, Rajendranagar, Hyderabad, members of Advisory Committee for their prompt suggestions and valuable guidance rendered in the presentation of research findings.*

I also take this opportunity to express my sincere thanks to Dr. A. Sreenivasa Raju, Head, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Rajendranagar and Dr. K. Sreenivasa Reddy, Head, Department of Soil Science, S.V. Agricultural College, Tirupati and Dr. B. Lakshmi Reddy, Director of Extension, ANGR Agricultural University, for their valuable suggestions, throughout the experimentation, assistance and facilities extended in carrying out the research work.

I am indebted to Dr. P. Raghavulu, Dean of Agriculture, ANGR Agricultural University for their kind co-operation and help during the course of study.

I also take this opportunity to thank Dr. M. Suryamarayana Reddy, Associate Professor; Dr. A. Sambasiva Reddy, Associate Professor; Dr. P. Chandrasekhara Rao, Associate Professor, Dr. L.M. Rao, Associate Professor, Sri C. Ranganayakulu, Associate Professor, Dr. P. Raghava Reddy, Plant Breeder and Dr. B. Rajendra Prasad, Soil Scientist, ANGR Agricultural University for their valuable suggestions and help rendered in preparation of research findings.

I acknowledge with thanks the constant support and alacrity of my friends and colleagues Dr. K. Balakrishna Reddy, Sri P. Krishnappa, Dr. K. Sreenivasula Reddy, N. Narayana, Dr. M. Martin Luther, M. Ramakrishna, D. Rama Prasad and Dr. V. Radhakrishna Murthy.

I am thankful to all staff members of Department of Soil Science and Agricultural Chemistry, College of Agriculture, Rajendranagar especially Dr. G. Swarajyalakshmi, Dr. G.W.L. Jayakumar, Dr. B.R.C. Prasad Rao, Dr. A.V.

Samuel, Srikant Medekkar, Dr. P.R. Pawan Kumar, Dr. V. Govardhan and Sri M. Jeevarathnam Raju for their help rendered during my study.

I wish to express my deep sense of gratitude to Dr. T. Nagur, Scientist (Retd.), Sri P.H. Satyanarayana, Dr. K. Subramanyam Reddy, Dr. N. Ramavatharam, Sri D. Munirathnam, Dr. K. Sreeramula Reddy and Sri S. Satyanarayana for their help rendered in preparation of the thesis.

It is with love, I wish to express my gratitude to my father Sri Keerthi Ramaiah, my mother Smt. K. Narayanamma, for the unbounded affection, cheerful assistance and encouragement and blessings without which this task could not have been accomplished.

I express my deep sense of appreciation to my wife Kanakamma, my children Sateesh, Dinesh, my cousin brother N.V. Bruhmaiah, my sister-in-law K. Kameswaramma, my sisters, J. Ramanamma, N. Padmavathi, A. Bujjamma, my brother K. Sudhakara Rao, my brother-in-law J. Masthanaiah, A. Ram Prasad, D. Venkataramanaiah and his family members, P. Murali, A. Venkateswarlu and Prasad.

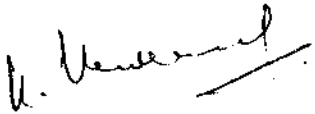
I owe special thanks to the help received from Smt. Chandra, Babu, Munirathnam, Subramanyam, Reddi Muni, S.V. agril. College, Tirupati.

I express my profound thanks to M. Samiyelu, Abdul Amzad, Mrs. M. Ramadevi, D. Yadagiri, and V. Yadagiri.

I acknowledge the help rendered by the staff of the Computer Centre Miss. K. Jayalalitha, D. Hema Nalini, T. Manjulatha, in carryingout the statistical analysis of the data.

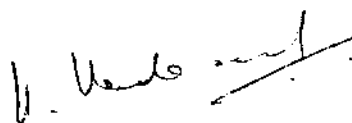
A special word of extreme thanks to my colleagues Mrs. P. Sujani, S.Sreedevi, N. Niveditha, P. Ravindra Babu, K. Prasada Rao, P. Gurumurthy, Dr. A. Sharada Devi, J. Padmaja and M. Dasharatham.

I am also thankful to Mr. K. Chandra Sekhar of Sai Baba Computers, for excellent and neat typing of the thesis.


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DECLARATION

I, **KEERTHI VENKAIAH**, hereby declare that the thesis entitled **“EFFECT OF AQUACULTURE ON SOIL AND GROUND WATER QUALITY IN NELLORE AND PRAKASAM DISTRICTS OF ANDHRA PRADESH”** submitted to Acharya N.G. Ranga Agricultural University for the degree of **DOCTOR OF PHILOSOPHY IN AGRICULTURE** is a result of original research work done by me. I, further declare that the thesis or any part thereof has not been published earlier in any manner.


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ACCUMULATION OF CARBENDAZIM
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GRAPE (Vitis vinifera L.)

Degree : Ph.D.

Faculty : AGRICULTURE

Major field of study : PLANT PATHOLOGY

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Year of submission : 1993

ABSTRACT

Field experiments were conducted for two seasons during 1986 and 1987 at Grape Research Station, Andhra Pradesh Agricultural University, Rajendranagar, Hyderabad, India to study the bioefficacy of carbendazim and thiophanate-methyl on grape anthracnose and powdery mildew on variety Thompson Seedless. The biodegradation, dissipation and accumulation of these fungicides in grape berries were also studied.

Carbendazim and thiophanate-methyl when sprayed at weekly interval at a concentration of 0.1 per cent controlled anthracnose and powdery mildew to the extent of 92.0 and 80.9 per cent, respectively. The effectiveness of these fungicides was poor in controlling powdery mildew as compared to anthracnose.

The relationship between disease control and spray interval was inversely related, while the disease control was directly related to the concentration of the fungicides. The highest cost benefit ratio was obtained by spraying 0.1 per cent carbendazim or thiophanate-methyl at one week interval for both the diseases.

The total residues of carbendazim and thiophanate-methyl were estimated colorimetrically in the fruit samples by adopting the procedure followed by Vaidya and Banerjee (1984) and Miller et al. (1977), respectively. While for bioassay method the procedure suggested by Singh and Thapliyal (1986) was used for determining the residues of carbendazim and thiophanate-methyl using Macrophomina phaseolina (Tassi) Goid. as the test fungus. The rate of dissipation of carbendazim and thiophanate-methyl was faster in longer spray interval irrespective of concentrations of fungicides used as detected by both chemical and bioassay methods. Carbendazim and thiophanate-methyl sprayed at different concentrations and different spray intervals dissipated to more than 80 per cent in 30 days. They further dissipated to below detectable level in 45 days, except in 0.2 per cent concentration sprayed at one week interval, where it dissipated to 91.33 and 90.14 per cent for carbendazim and thiophanate-methyl, respectively. The half life values at shorter spray interval were higher compared to longer spray interval due to higher initial deposits of both the fungicides. Both the chemical and bioassay methods were found equally good for determining the residues of carbendazim and thiophanate-methyl.

The different washing agents used for removing methyl benzimidazole-2-YL carbamate residues from the market samples were found to be ineffective. The conversion of thiophante-methyl to methyl benzimidazole-2-YL carbamate at higher spray concentration (2000 μ g) took longer time than lower concentrations.

Grape berries can be safely consumed 18, 13 and 11 days after last spray of 0.05 per cent carbendazim when sprayed at 1, 2 and 3-week interval, respectively. As regards thiophanate-methyl, berries can be consumed 19, 14 and 11 days after last spray when sprayed at 1, 2 and 3-week interval, respectively. A waiting period of 22, 16 and 15 days is required after last spray of 0.1 per cent carbendazim when sprayed at 1, 2 and 3-week interval, respectively, whereas for thiophanate-methyl 24, 17 and 16 days are required when sprayed at 1, 2 and 3-week interval, respectively. Similarly carbendazim 0.2 per cent when sprayed at 1, 2 and 3-week interval required 30, 20 and

17 days waiting period, respectively after last spray, whereas for thiophanate-methyl 31, 21 and 17 days were required after last spray for safe consumption of berries when sprayed at 1, 2 and 3-week interval, respectively.

Grape berries can be used for preparing juice and raisins without any waiting period after harvest since sufficient interval of atleast 30 days is available between the last spray of carbendazim or thiophanate-methyl and harvest.

INTRODUCTION

CHAPTER I

INTRODUCTION

Aquaculture, as a traditional practice, has been in existence since centuries in Thailand, India, Indonesia, Taiwan, Bangladesh, Philippines, Vietnam, Peru, Malaysia and other coastal belts in the world. It has gained its development, centuries ago in India, specially in the eastern region consisting of West Bengal, Orissa, Assam and North Bihar. A decade ago, this practice has spread to east coastal area of Peninsular India, specially Andhra Pradesh and Tamil Nadu. In India, fresh water fish farming is an age old practice while brackish water prawn farming is gaining importance only recently among the commercially active allied agricultural practices.

Commercial success of the brackish water prawn farming in Taiwan and its subsequent spread to Asian countries has resulted in the blue revolution in India. New economic policy with a thrust on the export earnings, coupled with conducive environmental conditions, and the ambience of coast line and man power, has resulted in the rapid and large scale adoption of intensive saline water based shrimp farming in India.

About 1.19 million hectares of potential area was identified for aqua farming by the Ministry of Commerce, Government of India, of which about 0.10 million hectares has already come under aqua farming.

Aquaculture is affecting the biotic and abiotic factors of the environment in three ways viz., impact of external environment on aquaculture, impact of

aquaculture on external environment and impact on aquaculture itself. Generally, aqua farming exerts considerable influence on the water and land in its vicinity. During the last few years, thousands of hectares of cultivated agricultural land along the coast line was converted to semi-intensive shrimp farms in the states of Andhra Pradesh and Tamil Nadu taking advantage of the utilizable maximum area in these two states. Intensive and over crowded shrimp farms which are mostly localised in these states resulted in creation of several environmental problems affecting normally grown crop yield in the vicinity, pollution of underground aquifers and nearby water sources and soil and disease outbreak.

Na-Sae (1989) reported that the paddy farmers, having their crops in the vicinity of shrimp farms in Thailand, incurred huge grain yield losses as the salt water from the prawn farms affected the physical and chemical properties of soil. Reports from shrimp farming in countries like Taiwan, Thailand, Indonesia and Philippines, revealed that irresponsible brackish water prawn culture which had only short term profit as its motive, has converted most of the productive agriculture land into barren land. India is the late entrant to the modern shrimp culture, which was initiated hardly about 10 years ago. The hazards of shrimp culture have been highlighted by the scientists, mass media, social organisations and public. It has been creating serious concern as evidenced by some of the studies available.

In addition to brackish water farming, fresh water fish farming, too, is adding a new dimension to the already existing pollution. The establishment of large scale fresh water fish ponds in the middle of the cultivated fields for the last one decade in coastal belt of India caused soil degradation and water pollution. Cultivated land adjoining fresh water fish culture ponds in coastal Andhra Pradesh of India rendered

unfit for cultivation. However, no systematic studies have been made to define the extent and seriousness of the problems arising due to aquaculture in relation to the characters of ground water and nature of adjoining soil properties.

Notwithstanding the adverse effects of aquaculture, it has been taken up on large scale in the recent past in Nellore and Prakasam districts of Andhra Pradesh causing soil and water pollution in alarming proportions and creating severe problem to human beings and other forms of life. Environmentalists, social organisations and the others concerned with the welfare of the society, consequently, are very much exercise over these problems.

According to Directorate of Fisheries (1996), an area of about 6534 ha under brackish water farming and 35000 ha under fish farming was existing in Nellore district of Andhra Pradesh. In Prakasam district, the prawn farming area was 2751ha.

Hence there is urgent need to quantify these adverse effects created by the upcoming aquaculture on the adjoining soils and underground water in a systematic manner. In view of the same, it has been proposed to investigate and quantify the adverse effects associated with the both brackish and fresh water aquaculture farms with the following specific objectives:

1. To study the adverse effects of aquaculture on the physical and chemical properties of the adjoining cultivated fields.
2. To analyse the influence of aquaculture on the quality of ground water in the vicinity.
3. To estimate the yield losses of the crops grown around the aquaculture ponds.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

The literature available relating to soil and water pollution due to aquaculture is very meagre. The published and unpublished available literature has been reviewed and presented under the following heads.

- 2.1 Characterization of soils of aquaculture ponds
- 2.2 Characterization of water used for aquaculture ponds
- 2.3 Characterization of soils adjoining fresh water fish culture ponds
- 2.4 Characterization of soils adjoining brackish water prawn culture ponds
- 2.5 Quality of ground water in the lands adjoining aquaculture ponds

2.1 CHARACTERIZATION OF SOILS OF AQUACULTURE PONDS

Literature available on the physical and chemical properties of soils of aquaculture ponds is presented below.

Boyd (1976) showed that the physical and chemical properties of fish pond soils varied with pond depth. However, clay and organic matter were found to be accumulated in the deeper layers of the pond.

Ayub *et al.* (1993) observed that the upper 5 cm layer of fish pond soils was more active chemically and biologically than the deeper layers and the exchange of substances between the soil and water was found to be occurring in this zone.

The physical, chemical and biological processes occurring in the pond soils would affect the water quality and several water problems in ponds originate from soils at the bottom (Boyd, 1990 and 1992). Soils with a high oxygen demand could cause low dissolved oxygen concentration in ponds and soils could remove nutrients from water in the pond (Boyd *et al.*, 1994).

Tenzing and Boyd (1994) opined that fish ponds of high rainfall subtropical regions need acidic soils (pH 4.84 - 5.71) with low alkalinity (7.9 to 34.9 mg l⁻¹ as CaCO₃) and weakly mineralized water (TDS 28 - 82 mg l⁻¹). Fish ponds at Haa in the inner Himalayan region had near neutral reaction and water contained on an average of 83.3 mg l⁻¹ total alkalinity and 170 mg l⁻¹ dissolved solids.

2.1.1 Soil reaction (pH)

Chakraborti *et al.* (1985) reported that soil pH was ranging between 7.8 and 8.6 in the *Penaeus monodon* (Tiger prawns) cultured ponds in West Bengal. Chattopadhyay and Chakraborti (1986) indicated that average pH of the brackish water and fresh water pond soils in West Bengal were 7.7 and 7.5, respectively.

Optimum range of soil pH for the *Penaeus monodon* culture was found to be between 6.5 and 7.5. Brackish water and fresh water ponds had similar average pH of 6.55 and 6.96 respectively. Soils with pH values above 7.0 were observed to be showing low exchangeable Al in comparison to Ca, Mg, K and exchangeable bases (Boyd *et al.*, 1994).

Boyd (1974) also reported that the pH values of the pond soils of the sub-tropical foot hills were below 6.0 and water of these ponds had pH values between 6.8 and 8.6.

The pH of the pond bottom soil will be remained fairly constant as it was determined by the chemical properties of soil and was not influenced daily by the changes occurring in the pH of the water column (Tenzing and Boyd, 1994).

The soil pH of fresh water fish ponds and brackish water prawn ponds at Gudavalli village of Guntur district in Andhra Pradesh varied between 7.10 and 7.50; and 7.10 and 7.75 respectively (RARS, Lam, 1995).

Adhikari *et al.* (1997) reported that the soil pH of fresh water fish ponds under red (Alfisols), laterite (Oxisols), lateritic (acid soils) and alluvial (Inceptisols and Alfisols) soils representing different districts of Orissa was found to be ranging between 7.0 and 7.9.

Vijayalakshmi (1997) studied the soil pH values in the brackish water prawn culture ponds maintained with different types of water in Nellore district of Andhra Pradesh. The pH was between 8.0 and 8.3 with sea water, 8.1 and 8.3 with water from Buckingham Canal, 8.0 and 8.2 with creek fed pond and 7.4 to 7.8 with bore well water.

Karthikeyan *et al.* (1998) reported that the pH values of the soil in the brackish water prawn culture ponds of Lingavaram village in Nellore district of Andhra Pradesh were ranging initially between 7.71 and 7.72 but at the end of the culture the range was between 6.62 and 7.32.

2.1.2 Salinity (EC)

Soil salinity status measured as electrical conductivity (EC) of the soils of brackish water ponds was found to be higher than those of fresh water ponds; the average value of brackish water being 6.9 dSm^{-1} and that of fresh water to be 3.5 dSm^{-1} . The difference was obviously due to submerged condition of the soil with brackish water (Chattopadhyay and Chakraborti, 1986).

The survey conducted in Guntur and Krishna districts of Andhra Pradesh by Narasimha Rao and Narasimha Rao (1987) revealed that the discharged water from the fresh water fish ponds was having EC of 32 dSm^{-1} . The EC value of fresh water fish ponds at Gudavalli village of Guntur district was varying between 3.14 and 16.50 dSm^{-1} (RARS, Lam, 1995).

Vijayalakshmi (1997) observed that the EC values of sea, creek, bore and Buckingham canal water fed pond soils ranged from 6.1 to 7.4; 6.5 to 7.8; 2.8 to 4.1 and 6.1 to 7.4 dSm^{-1} respectively.

2.1.3 Organic carbon

Tang and Chen (1967) observed that the productivity of brackish water increased with increase in the organic carbon content of algal pasture soils of milky fish ponds of Taiwan.

The pond soils usually showed greater concentration of organic matter than agronomic soils (Boyd, 1970 and 1974).

Nelson and Sommer (1982) observed that soils varied in their organic matter content from near 0 to 100 per cent.

Many factors affect the content of organic matter in pond soils. Within a given pond, an increase in the soil organic matter in the surface 5 cm layer is usually observed during the growing season (Boyd, 1992). Organic carbon content ranged from 0.18 to 7.20 per cent in 0-5 cm layer of Shrimp ponds (Boyd, 1992).

Optimum range of soil organic carbon in fish ponds was found to be 0.5 to 2.5 per cent. Average concentration of organic carbon for fresh water and brackish water soils was found to be almost identical. Most soils contained less than 5 per cent organic carbon and the highest concentration observed was 11.8 per cent (Boyd *et al.*, 1994).

Vijayalakshmi (1997) studied the organic carbon content in the brackish water prawn culture pond soils maintained with different types of water in Nellore district of Andhra Pradesh. It varied from 0.11 to 0.36 with sea water, 0.24 to 0.38 with creek water, 0.08 to 0.34 with water from Buckingham canal and 0.20 to 0.53 with borewell water.

2.1.4 Available nitrogen

The critical value of available nitrogen in soils of fresh water fish ponds was 25 mg 100 g⁻¹ of soil (Banerjee, 1967). Presence of organic matter was known to influence the amount of available N content of soils to a large extent.

Available N content of the soil was found to fluctuate between 6.5 and 16.3 mg 100 g⁻¹ of soil whereas the available N content with a range of 12.38 to 16.3 mg 100 g⁻¹ of soil was found to be suitable for *Penaeus mondon* (Tiger prawn). Ponds

with less than 12.3 mg of N 100 g⁻¹ of soil resulted in the production of less than 200 t ha⁻¹ crop⁻¹ (Chakraborti *et al.*, 1985).

Chattopadhyay and Chakraborti (1986) found that the available N levels were low in both brackish water pond soils in West Bengal (10.4 mg 100 g⁻¹ of soil) and fresh water pond soils (13.6 mg 100 g⁻¹ of soil).

Average N content of soils was 0.28 and 0.30 per cent in fresh water and brackish water ponds respectively. Nitrogen per cent was below 0.5 in 90 per cent of the soil samples tested. Optimum range for the available N was found to be between 250 and 750 mg kg⁻¹ soil (Boyd *et al.*, 1994).

According to Vijayalakshmi (1997), the available N content of sea, creek, bore and Buckingham canal water fed pond soils ranged from 8.2 to 17.0; 12.8 to 15.7; 12.6 to 17.4 and 4.9 to 15.3 mg 100 g⁻¹ of soil respectively.

2.1.5 Available phosphorus

Chattopadhyay and Mandal (1986) reported that the available P of fresh water pond soil ranged between 1.08 and 2.86 mg 100 g⁻¹ soil as compared to average value for brackish water soil.

Chattopadhyay and Chakraborti (1986) also reported that the available P in brackish water pond soils was higher (2.6 mg 100 g⁻¹ of soil) as compared to fresh water pond soils (1.6 mg 100 g⁻¹ soil). Soils of brackish water ponds had greater concentrations of P than that of fresh water ponds. The P concentration was less than 40 mg 100 g⁻¹ in most of the fresh water pond soils, whereas most of the brackish water ponds had more than 40 mg 100 g⁻¹ (Boyd *et al.*, 1994).

Vijayalakshmi (1997) indicated that the available P_2O_5 status of brackish water pond soils of different sources viz., sea, creek, bore and Buckingham canal water were ranging from 1.6 to 2.3, 0.8 to 1.6, 0.6 to 2.0 and 0.9 to 2.4 mg 100 g^{-1} of soil respectively in Nellore district of Andhra Pradesh.

2.1.6 Exchangeable cations

2.1.6.1 Calcium and magnesium

Calcium concentration was observed to be 3.450 and 3.539 ppm in brackish water and fresh water soils respectively. Magnesium concentration was found to be greater in soils of brackish water ponds than that of fresh water pond soil (Boyd *et al.*, 1994).

Vijayalakshmi (1997) studied exchangeable Ca and Mg content in soils of the brackish water prawn culture ponds maintained with different types of water. Exchangeable Ca was found to be between 2.75 and 7.8 c mol (P^+) kg^{-1} soil with sea water, 1.90 and 5.65 c mol (P^+) kg^{-1} soil with creek water, 5.0 and 9.0 c mol (P^+) kg^{-1} soil with bore well water and 8.9 to 11.5 c mol (P^+) kg^{-1} soil with Buckingham canal water. Similarly, exchangeable Mg content in the soil with sea, creek, bore and Buckingham canal water was found to be in the range of 8.0 to 21.5, 4.2 to 10.5, 7.4 to 22.5 and 9.0 to 15.0 c mol (P^+) kg^{-1} soil respectively.

2.1.6.2 Potassium and sodium

Sodium content of pond soils ranged from 0.9 to 3.4 me 100^{-1} g soil with an average of 1.9 me 100^{-1} g soil. Potassium was present in the least quantities ranging from 0.1 to 0.4 c mol (P^+) kg^{-1} of soil. Amount of water soluble Na in the pond soils

increased with increase in EC and decreased with the distance from the main estuary (Chattopadhyay and Mandal, 1986).

Boyd *et al.* (1994) found that the exchangeable K and Na concentrations were greater than in soils of brackish water ponds than those of fresh water ponds.

According to Vijayalakshmi (1997), the exchangeable Na content of sea, creek, bore and Buckingham canal fed pond soils ranged from 5.21 to 10.21, 9.73 to 19.15, 2.17 to 5.37 and 7.8 to 10.56 c mol (P⁺) kg⁻¹ soil respectively.

2.1.7 Available micronutrients

Vijayalakshmi (1997) studied the status of DTPA extractable micronutrients in brackish water prawn culture pond soils fed with sea, creek and bore water in Nellore district. The copper content was found to be between 1.6 and 3.0 µg ml⁻¹ with sea water, 0.39 and 1.8 µg ml⁻¹ with water from creek, 0.3 to 0.8 µg ml⁻¹ with bore water and 0.28 to 0.52 µg ml⁻¹ with Buckingham canal water. The Mn content of sea, creek, bore and Buckingham canal fed pond soils ranged from 7.3 to 15.2, 4.7 to 8.0, 2.9 to 5.0 and 4.8 to 7.2 µg ml⁻¹ respectively. The zinc content varied between 0.2 to 2.5 µg ml⁻¹ with sea water, 0.25 to 0.39 µg ml⁻¹ with creek water, 0.21 to 0.37 µg ml⁻¹ with canal water and 0.36 to 0.70 µg ml⁻¹ with water from Buckingham canal.

2.2 CHARACTERIZATION OF WATER USED FOR AQUACULTURE PONDS

Quality parameters of water like pH and salinity have been studied both for main source and also under ponded condition. It is observed that the properties of

water in the source and under ponded conditions are not exactly similar but were varying. Literature available on this aspect is presented below.

2.2.1 pH

It is one of the most important quality parameter that affects the growth of prawns.

Extremely low pH could create stress to the shrimps resulting in the soft shell and poor survival. Moderately low pH had no effect on survival but it could have adverse effect on the growth. After 26 days of exposure to pH 6.45 in the presence of inorganic carbon of more than 26 mg l⁻¹, *Penaeus mondon* post larvae survival was 100 per cent but their growth was reduced by 40 per cent probably as a result of CO₂ poisoning (Wickins, 1976).

The pH could also increase the percentage of unionized ammonia, which is considered to be more toxic form of ammonia (Colt and Armstrong, 1981).

Law (1988) recommended pH 7.5 to 8.5 for the culture of *Penaeus mondon* in Malaysia.

Narasimha Rao and Narasimha Rao (1987) observed that pH of fresh water fish pond sample collected from Vuyyur of Krishna district was 7.7.

Chen (1995) reported that pH value of waters in the prawn ponds ranged from 7.8 to 8.4. Relatively low values were recorded during monsoon months whereas higher values were observed in the pre monsoon months. Optimal pH was found to be ranging from 8.0 to 8.5 for *Penaeus mondon*.

pH of fish pond water of Polavaram in Prakasam district was 8.24 whereas it was 5.6 in Gudavalli village of Guntur district in Andhra Pradesh (RARS, Lam, 1995).

Water collected from different sources and ponds in Nellore district revealed that the pH ranged from 8.0 to 8.3 in the water and it was 8.1 to 8.5 when the same sea water fed to pond and both showed a decreasing trend with increasing crop duration. Similarly the pH of creek water ranged from 7.7 to 8.2 but it was 8.0 to 8.4 when it was fed to the pond (Vijayalakshmi, 1997).

Karthekeyan *et al.* (1998) reported that pre project pH values of different prawn culture pond water of Lingavaram village of Nellore district varied between 6.8 and 7.7 and post project pH values varied between 7.9 and 8.1.

2.2.2 Salinity (EC)

Electrical conductivity as a single factor, played an important role in prawn farming as it was responsible for many functions such as metabolism, growth, osmotic behaviour and reproduction.

High mortality and poor growth rates of *Penaeus monodon* juveniles were observed at salinities lower than 10 ppt (Cawthorne *et al.*, 1983). Direct influence of salinity was observed on the growth of *Penaeus monodon* (Subramanyam 1973, Verghese *et al.*, 1975; Liao 1977 and Chakraborti *et al.*, 1985)

Chakraborti *et al.* (1985) reported that both temperature and salinity tended to increase from January to June-July but temperature tended to remain high from June to August but the salinity dropped rapidly. Chakraborti *et al.* (1987) observed

that the salinity considerably high (18.7 per cent salts) in the month of June but dropped sharply to 8.1 per cent with advent of monsoon continuing at the same level upto December. Normal growth of *Penaeus mondon* was observed to be maintained between 15 and 30 ppt salinity range (Chen, 1976 and 1985).

Similarly, Boyd (1989) observed that the ideal salinity range for growth and development of Tiger prawns was between 15 and 25 ppt. Similar observation was also made by Chen (1995). Boyd (1995) also observed that sea water had a salinity of 30-35 ppt but the estuarine water at the salinity from near to zero to more than 30 ppt. However, Allan *et al.* (1995) observed that the average salinity of the pond water for optimum growth of *Penaeus mondon* was 30.5 per cent with a range of 28.7 to 34.5 per cent.

Three types of water sources were utilized for the brackish water prawn culture in Nellore district viz., underground saline water through filter points, water from Buckingham canal and sea water. The underground water having salinity of 4 to 7 ppt was mainly used for prawn culture in Nellore district where water is being drawn from 30 to 100 feet depth. The salinity of brackish water of Buckingham canal was ranging from 17 to 34 ppt depending upon its depth and connection with sea (Raghava Reddy *et al.*, 1994).

The salinity of pond water in Nellore, Killai and Tuticorin varied between 12 and 35 ppt while that of four ponds at Visakhapatnam and one pond at Srikali ranged from 18 to 28 ppt (NEERI, 1995). It was further noticed that three ponds in Visakhapatnam and one pond in Srikali were having salinity in the range of 7.2 to 9.0 ppt and one pond in Srikali exhibited salinity of 35 to 38 ppt.

Krishna Pillai (1995) studied the mean monthly salinity values for six ponds in different months and ranged from 26.9 to 36.0 per cent. Only in Palk Bay it was 30.65 per cent in January. In December, salinity ranged from 24.8 to 23.6 per cent, whereas in Polk Bay it was 29.08 per cent. In January, salinity ranged from 26.8 to 40.9 per cent, in March it was from 35.9 to 58.5 per cent and in August, it was 90.4 per cent. The variation in salinities was mainly due to varying amounts of rainfall received during the North-East monsoon. High salinity was observed due to evaporation during summer.

Vijayalakshmi (1997) studied the salinity of different sources of water used for prawn culture and that of the ponds from these sources. EC ranged from 32.4 to 40.5 ppt in the sea water while the corresponding pond water showed an EC of 29.22 to 43.74 ppt. The EC of creek water and the corresponding pond water varied from 34.86 to 41.0 ppt and 25.98 to 34.55 ppt respectively. Similarly in the case of bore water and in the pond it varied from 9.73 to 17.01 ppt and 11.80 to 20.25 ppt respectively. The salinity of Buckingham canal water and in the pond it ranged from 20.32 to 39.28 ppt and 18.48 to 27.60 ppt respectively.

2.3 CHARACTERIZATION OF SOILS ADJOINING FRESH WATER FISH CULTURE PONDS

It is generally observed that the water in the aquaculture ponds has a significant influence on the properties of soils adjacent to the pond. It could be noticed that these effects get nullified beyond certain lateral distance. Properties like soil structure, aeration, salinity, available major nutrients have been studied in these soils. Available literature is presented below.

2.3.1 Soil reaction (pH)

Satyanarayana *et al.* (1986) reported that pH of cultivated soils adjoining the fish ponds ranged from 7.50 to 7.75 as the distance from the fish pond increased from 0 to 50 meters.

Narasimha Rao and Narasimha Rao (1987) observed that pH of soil profile in the rice fields of Vuyyur of Krishna district affected by fresh water fish ponds ranged from 7.7 to 8.5.

pH of soils adjoining fresh ponds of Gudavalli village of Guntur district ranged between 7.10 to 7.75 (RARS, Lam, 1995).

2.3.2 Salinity (EC)

Satyanarayana *et al.* (1986) reported that the salinity problems were spread over a large area within a few years if the fish ponds were maintained with improper drainage.

The adverse effects of salinity due to fish ponds was less in the rice fields which were separated by small irrigation channel from the fish ponds (Satyanarayana *et al.*, 1986).

Satyanarayana *et al.* (1986) reported that EC of the soil in the adjoining cultivated fields of fish ponds decreased from 16.50 dSm⁻¹ to 3.14 dSm⁻¹ as the distance from the fish ponds increasing from 0 to 50 meters. They also observed that due to high level of water in the fish ponds, the effluents along with the water

reaches the adjacent fields through the bunds of fish ponds, resulting in the occurrence of salinity making the fields unfit for cultivation upto 50 meter distance.

An area of about 22.75 acres of different farmers around the fish ponds were affected with salinity and were found to be unfit for cultivation (Satyanarayana *et al.*, 1986).

Survey results revealed that the effluent water discharged from fish ponds was having EC of more than 32 dSm^{-1} while the EC of the adjoining soil ranged from 3 to 16 dSm^{-1} . Further, it was observed that due to spread of this effluent water on the surrounding cultivated fields, the physico-chemical properties were also found to be adversely affected (Narasimha Rao and Narasimha Rao, 1987).

Narasimha Rao and Narasimha Rao (1987) studied the salinity of soil profiles of rice fields adjoining the fish ponds and in the profiles located away from the fish ponds in Vuyyuru area of Krishna district. EC of soil profile of rice fields situated at lower elevation about one feet adjoining fish ponds was found to be varied between 5.16 and 9.24 dSm^{-1} . In the soil profile situated at higher elevation adjacent to fish ponds, the EC of the soil ranged from 2.04 to 6.77 dSm^{-1} whereas EC of profile soils situated far away from fish ponds showed 0.82 to 1.56 dSm^{-1} .

The surface soil samples collected from the fields of Vuyyur in Krishna district adjacent to the fish pond had an EC of 66 dSm^{-1} (Narasimha Rao and Narasimha Rao, 1987). They also reported that salinity in the surface soil samples was also observed to vary in the same study with distance. The intensity of salinity decreased from 6.60 to 3.84 dSm^{-1} as the distance from the fish pond increased from

0 to 150 m. Similarly, in the case of cultivated soils, EC decreased from 16.5 to 3.14 dSm⁻¹ as the sampling distance increased from 10 to 40 m from the pond (Narasimha Rao and Narasimha Rao, 1987).

2.3.3 Available major nutrients

Narasimha Rao and Narasimha Rao (1987) studied the N, P and K status of soil profiles situated at the lower and higher elevation of fish ponds. At lower elevation, N content was found to vary between 140 and 330 kg ha⁻¹. Similarly available P₂O₅ and K₂O ranged from 28 to 40 and 181 to 346 kg ha⁻¹ respectively. Available nitrogen, phosphorus and potassium in the soil profile situated at higher elevation of fish ponds were found to vary between 154 and 380; 18 and 38 and 151 and 313 kg ha⁻¹ respectively.

2.4 CHARACTERIZATION OF SOILS ADJOINING BRACKISH WATER PRAWN CULTURE PONDS

Soils just adjacent to brackish water ponds are generally observed to be adversely affected in their productivity due to deterioration in their properties. The adverse effects decreased as the distance from the pond increases and after some distance, the adverse effects are not noticed. Available literature on the variation in the soil properties adjoining brackish water ponds is reviewed hereunder.

2.4.1 Soil reaction (pH)

The pH of profile soil samples adjacent to brackish water prawn culture ponds in Prakasam district and observed the pH increased with an increase in depth of soil and the values varied between 7.57 and 7.93. Similar trend was also

observed in the normal soil profiles and the values ranged from 7.25 and 8.22 (RARS, Lam, 1995).

The survey conducted in Prakasam district by the Scientists of Regional Agricultural Research Station, Tirupati (1997) revealed that the pH of affected and unaffected mango soils due to brackish water prawn culture ponds varied between 7.6 and 8.4; and 6.8 and 7.1 respectively.

The pH value of soil samples in the vicinity of the aqua farm before starting of the brackish water prawn culture was found to be ranging between 7.44 and 7.67 whereas at the end of the culture, it ranged from 7.80 to 8.05 (Karthikeyan *et al.*, 1998).

2.4.2 Salinity (EC)

Soil salinisation can be expected to increase in the soils adjoining the brackish water prawn culture ponds as majority of shrimp farms discharge saline effluent into the canals. There is also seepage of salt water from ponds, as most ponds are raised above the surrounding land (and water table), which also contribute to salinisation of surrounding soil and water.

Na-Sae (1989) reported that the cultivated rice fields around the prawn farms were spoiled in southern part of Thailand.

Soil salinity of rice fields adjacent to the prawn ponds was increased due to continuous pumping of brackish water from Buckingham canal and underground saline water, specially into the ponds located on the western side of the Buckingham canal and due to subsequent lateral or horizontal percolation (Raghava Reddy *et al.*,

1994). They also reported that rice fields were getting salinised due to letting out of brackish water adversely affecting the crop productivity.

Salinity of profile soil samples adjoining prawn ponds in the affected mango orchard decreased with an increase in depth upto 80 cm (3.47 to 2.64 dSm^{-1}) as compared to the EC of profile soils located nearer to healthy trees (0.248 to 0.186 dSm^{-1}) in the unaffected area (RARS, Lam, 1995).

Banchong (1995) reported that the rapid growth of coastal aquaculture in South East Asia resulted in salinity intrusion. Further, he confirmed that the development of shrimp culture caused soil salinisation.

Continuous shrimp farming resulted in salinisation of land and water resources in Taiwan, Thailand, Indonesia and Philippines (Algarswami, 1995).

Mango orchards nearer to the brackish water prawn culture ponds were affected due to seepage of effluents from the pond leading to the surface soil salinity building (3.4 dSm^{-1}) and sub-surface soil salinity (2.6 dSm^{-1}) (RARS, Lam, 1995).

The EC of affected soil samples nearer to prawn culture ponds showed high salt content ranging from 3.6 to 5.0 dSm^{-1} which is the toxic level for orchard crops whereas the unaffected field far away from the prawn pond showed negligible EC of 0.08 dSm^{-1} (RARS, Lam, 1995).

The survey report (RARS, Lam, 1995) clearly indicated that the light textured soils of mango and sapota orchards which were nearer to prawn ponds showed high EC as compared to the soils away from the ponds. Lateral seepage

from the prawn ponds might have resulted in salt build up and continuous stagnation of this water in the ponds leading to conversion of cultivated soils into saline soils.

Shrimp farming caused spread of salt into the land around shrimp farms. The spread of salt has expanded as the duration of the farming time increased and affected the rice farming, fruits and other plantations. The spread of salts into rice fields from the shrimp pond has been reported to be within 40 m around shrimp ponds. Electrical conductivity, sodium chloride content, sulphate content and exchangeable sodium percentage were higher at all depths upto 120 cm. The surface soil accumulated sodium at hazardous level to plants like long pod bean, pepper, mung bean, soybean, peanut, mango and lime. In inner gulf region (Sanut Sakhon Province), it was found that increase of salt in soil near shrimp farming area was affected 8 per cent of the agriculture and causing either death of plants or lower plant population (Banchong, 1995).

2.4.3 Chemical properties of soils

The organic carbon content of soils affected in mango orchards near to brackish water prawn culture ponds was less and did not indicate specific trend due to prawn culture (RARS, Lam, 1995).

Available potassium of soil in mango orchards adjacent to prawn culture ponds was higher as compared to normal soils of mango orchards (RARS, Lam, 1995).

Profile soils of affected mango orchards had high exchangeable Mg ($17.5 \text{ c mol (P}^1\text{) kg}^{-1}$) followed by Ca ($3.5 \text{ c mol (P}^1\text{) kg}^{-1}$), Na ($4.56 \text{ c mol (P}^1\text{) kg}^{-1}$) and

K ($0.26 \text{ c mol (P}^{\text{'})} \text{ kg}^{-1}$) but the profile soil in healthy mango orchards recorded lower exchangeable Mg (RARS, Lam, 1995).

Karthikeyan *et al.* (1998) observed that the chloride content of soils in and around brackish water prawn culture ponds in Nellore district was found to vary between 5.026 and 9.386 mg g^{-1} before start of the culture, but the same ranging between 6.126 and 16.850 mg g^{-1} after harvest of the culture.

Total hardness of the soils in and around aqua farm in Nellore district was varied from 0.5196 to 1.244 mg g^{-1} before start of the culture and the same varied from 0.5300 to 1.680 mg g^{-1} after the harvest. The total alkalinity varied between 0.2129 and 0.6223 ; and 0.2454 and 0.6494 mg g^{-1} before start of the culture and after harvest of the culture respectively (Karthikeyan *et al.*, 1998).

2.5 QUALITY OF GROUND WATER IN THE LANDS ADJOINING AQUACULTURE PONDS

Ponding of either fresh or brackish water for aquaculture was generally observed to effect the quality of underground water due to deep percolation and seepage of ponding water along with dissolved salts. Available literature is reviewed hereunder.

According to Phillips *et al.* (1993), surface water flows might be effected either by temporary blockage or permanent division of canals causing potential effects of aquaculture and quality of water in the wells around the aquaculture farms. Direct discharge of the effluent and pond seepage will also affect the quality of water.

Pumping of fresh water from underground aquifers for intensive shrimp farming had resulted in salt water intrusion and salinisation of fresh water aquifers. The seepage of salt water into the water table surrounding shrimp ponds had been reported to cause salinisation of fresh water supplies in several countries including Bangladesh (Mahmood, 1986) and Indonesia (Cholik and Pennomo, 1987).

However, in Thailand, the results of water quality survey during October 1992 to March 1993 in the coastal areas of southern part indicated that although the amount of effluent water was large, the effects of shrimp culture on the environment were minimal (Somehat and Paitoon, 1993).

2.5.1 pH

pH of water samples collected from drain channel of brackish water prawn ponds, tank water and dug out pond water adjoining prawn ponds in Karedu village of Prakasam district was 7.7, 7.8 and 7.4 respectively (RARS, Tirupati, 1997).

Karthikeyan *et al.* (1998) reported that pH of the samples collected before start of the culture from different locations in Nellore district around prawn ponds showed an increasing trend and ranged from 6.9 to 7.2 and from 7.3 to 8.5 respectively thereby showing increased alkalisation.

2.5.2 Salinity (EC)

Subramanyam (1973) reported that the intensity of salinity was increased with the decrease in distance from the rivers and the sea coast.

In the coastal saline areas, particularly in the deltaic areas, the soils became saline due to the intrusion of sea water, high water table and salinity of ground water (Yadhav *et al.*, 1979).

Raghava Reddy *et al.* (1994) reported that the salinity of bore well water increased upto 12 ppt within a span of three months in Govindapalli village in Kota mandal of Nellore district as the prawn ponds were located adjacent to the bore wells.

The quality of water in many of the villages was adversely affected due to indiscriminate digging of brackish water prawn culture ponds. A survey on the effect of brackish water prawn culture on the quality of underground water revealed that the tank water used for drinking earlier got deteriorated and showed an EC of 23.5 dSm^{-1} due to seepage of effluents from the brackish water ponds (RARS, Lam, 1995).

EC of water in the dug out pit adjacent to brackish water prawn culture pond in Karedu village of Prakasam district was 27 dSm^{-1} (RARS, Tirupati, 1997).

Karthikeyan *et al.* (1998) reported that before start of the culture and after harvest of the culture, EC values of underground water collected from different locations of Nellore district around brackish water prawn culture ponds. The values varied between 0.650 and 1.376 dSm^{-1} ; and 0.920 and 1.580 dSm^{-1} respectively.

Thus the present review have shown that the salts of the impounding water in the ponds, whether under fresh water or brackish water, makes the soils saline. The ponds adversely affect the properties of the adjoining soils, the extent of which

depends on the source and time of sampling in relation to the occurrence of rains. The review also revealed that the adverse effects of the ponded water continue and are spreading into the adjoining lands but the distance beyond which the adverse effects cause is not uniform and appears to be governed by the land local characteristics including land properties of the existing soils.

No information is available on the extent of reduction in the productivity of the adjoining lands of the aquaculture farms through couple of references indicate complete loss of crop in the immediate vicinity of the ponds.

MATERIALS & METHODS

CHAPTER III

MATERIALS AND METHODS

The development of aquaculture has both positive and negative impacts on the environment in general and on agriculture in particular. A positive impact is that it increases efficient utilisation of coastal agricultural area adding better income to the farming community. On the other hand, it reduces the availability of agricultural land by its conversion into ponds and by damaging the adjoining cultivable lands. Construction of aquaculture ponds causes environmental degradation and reduction of land productivity by salinizing. The present investigations were carried out during 1995-96 and 1996-97 in order to characterize the physical and chemical properties of soils adjoining the aquaculture ponds and to assess the quality of ground water upto one kilometer away from the aquaculture ponds. The methods adopted and materials used in the study are presented in this chapter.

3.1 LOCATION

The study was carried out in six different locations of Nellore and Prakasam districts of Andhra Pradesh. The locations selected for fresh water fish culture ponds were in Rebala, Kovur and Purini villages of Nellore district, and the locations selected for the three brackish water prawn culture ponds were in Karedu-1 and Karedu-2 villages of Prakasam district and Kolladinni village of Nellore district. These locations are shown in the Fig. 1a & 1b, and ponds are shown in plates 1a & 1b and 2a & 2b.

NELLORE AND PRAKASAM DISTRICTS IN ANDHRA PRADESH

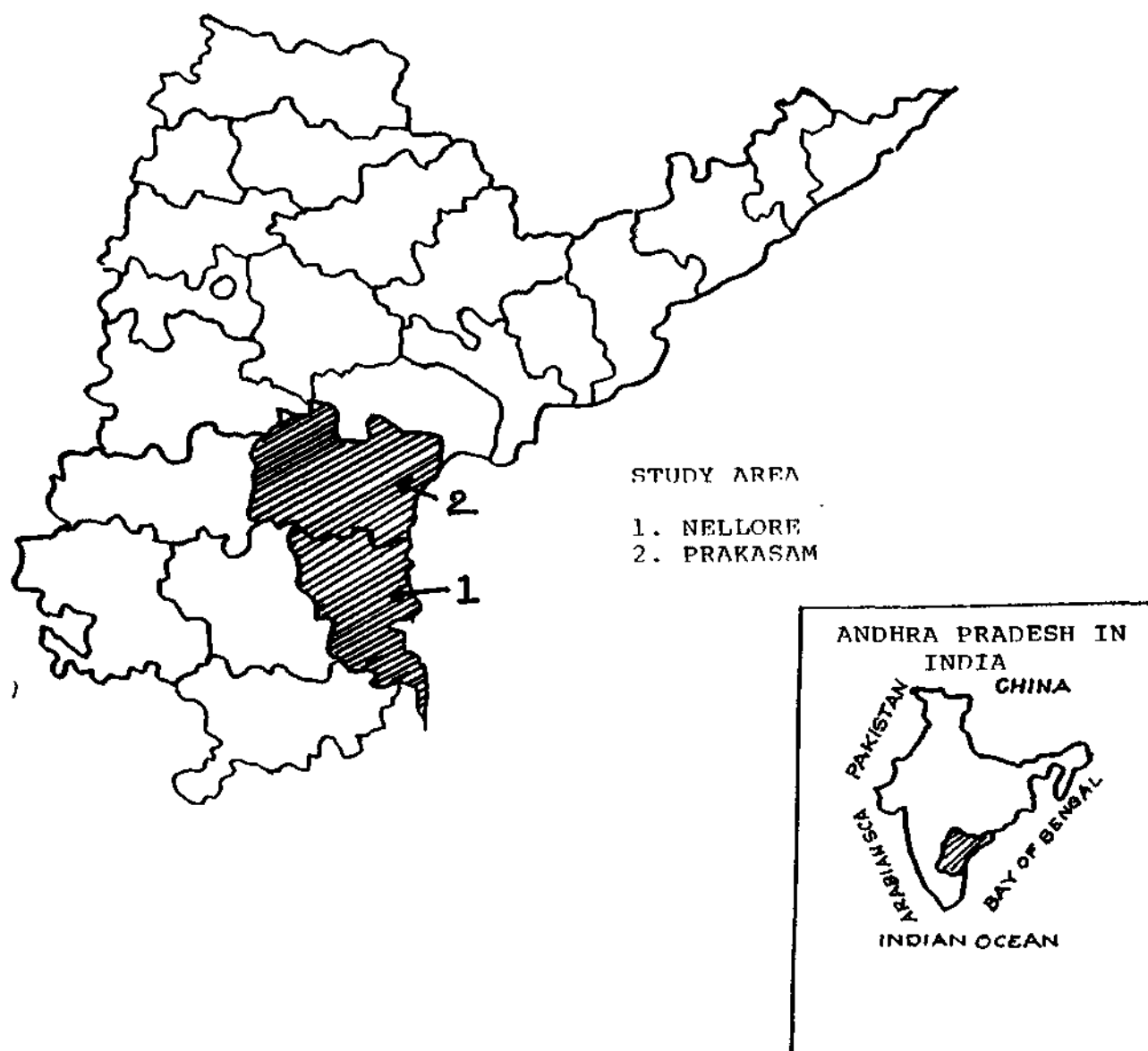


Fig 1a: Locations of study area

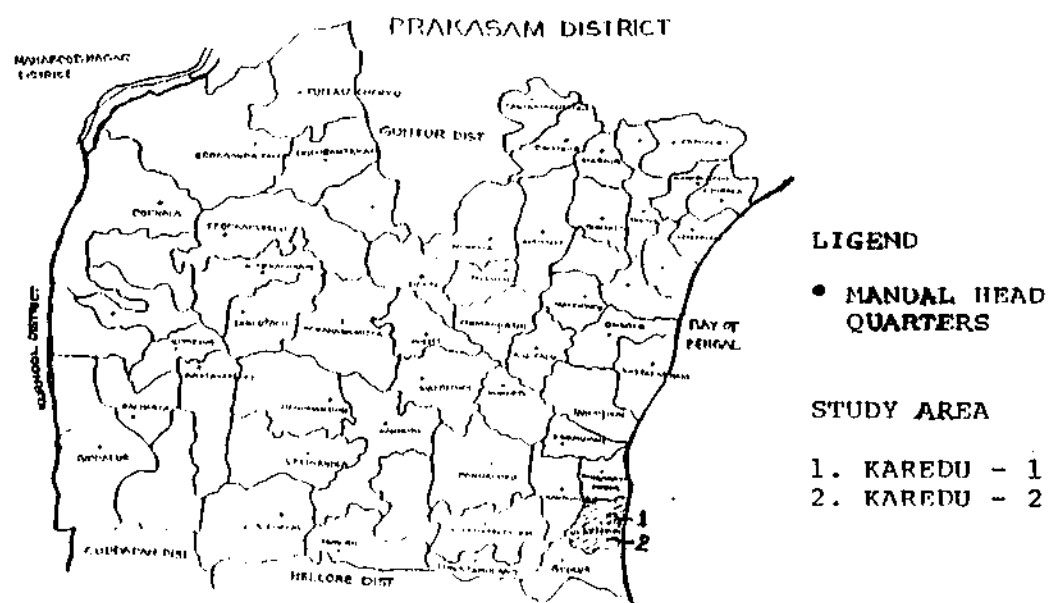
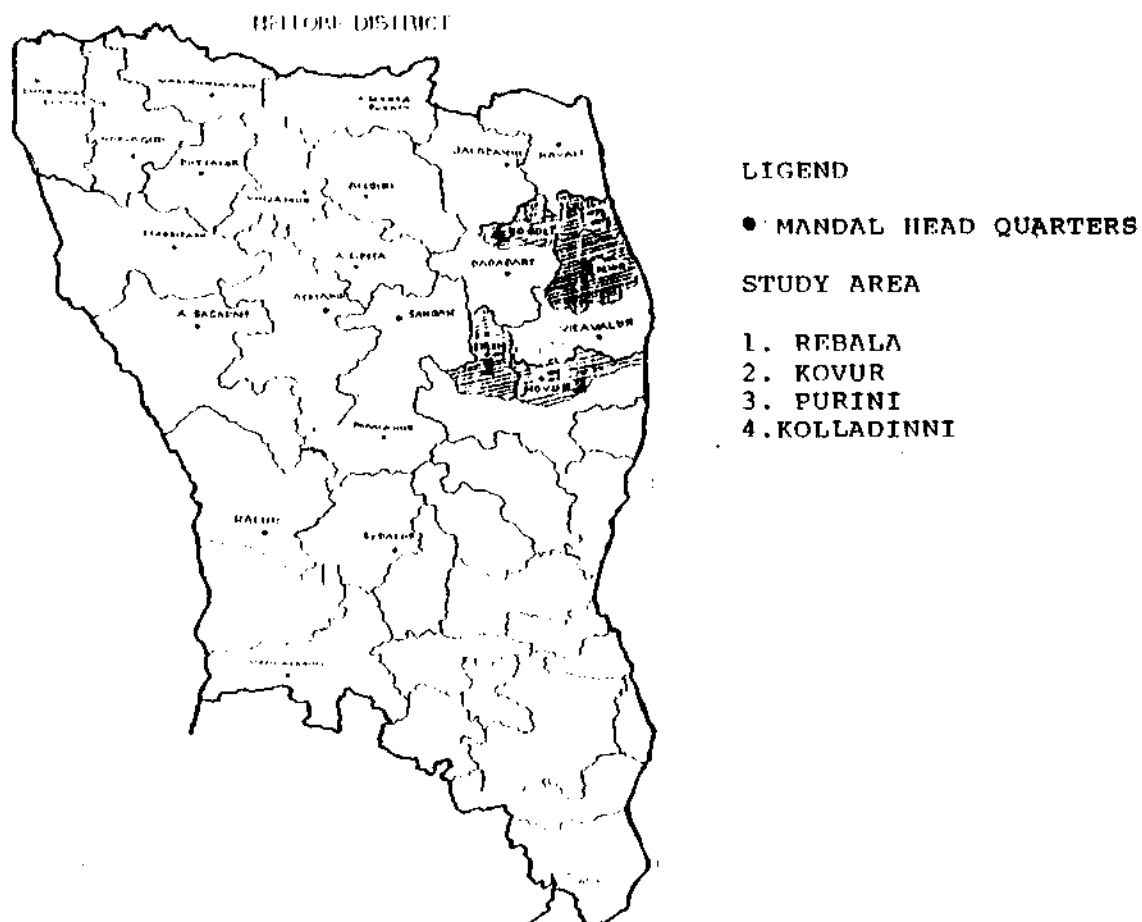


Fig 1b: Locations of study area.



Plate 1a: Fresh water fish culture ponds at Kovur



Plate 1b: Fresh water fish culture pond at Purini

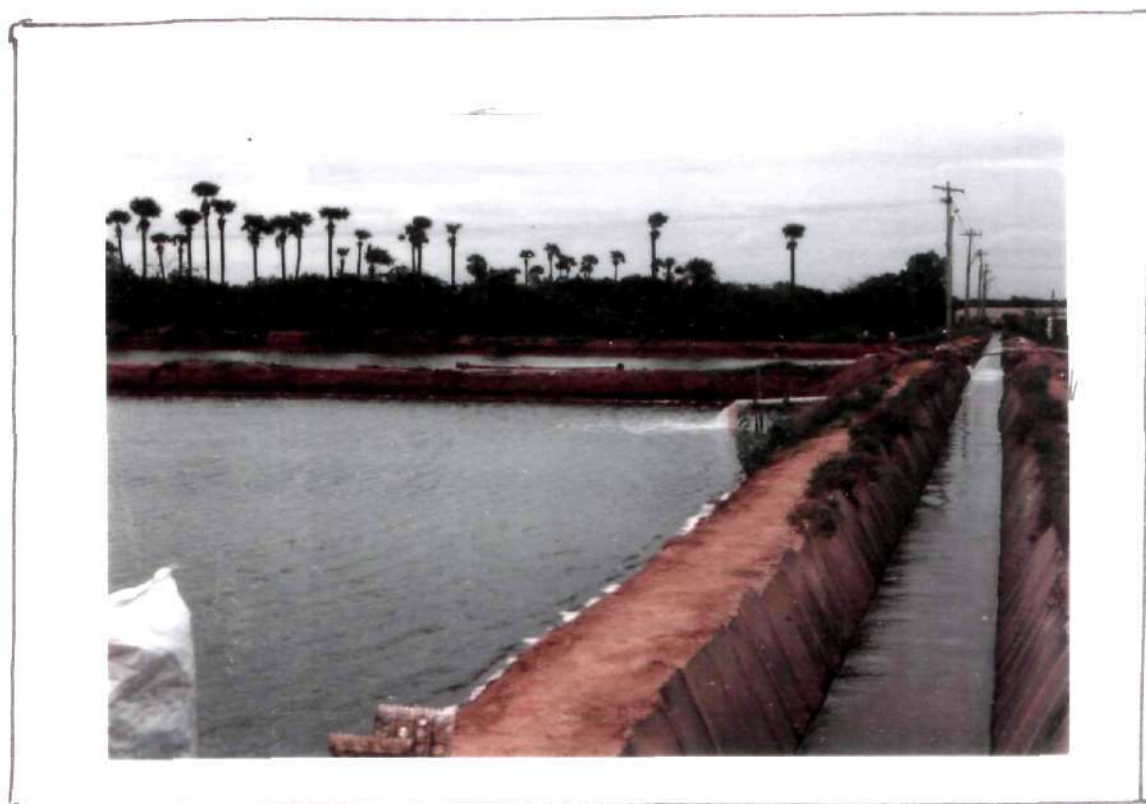


Plate 2a: Brackish water prawn culture pond at Karedu-I

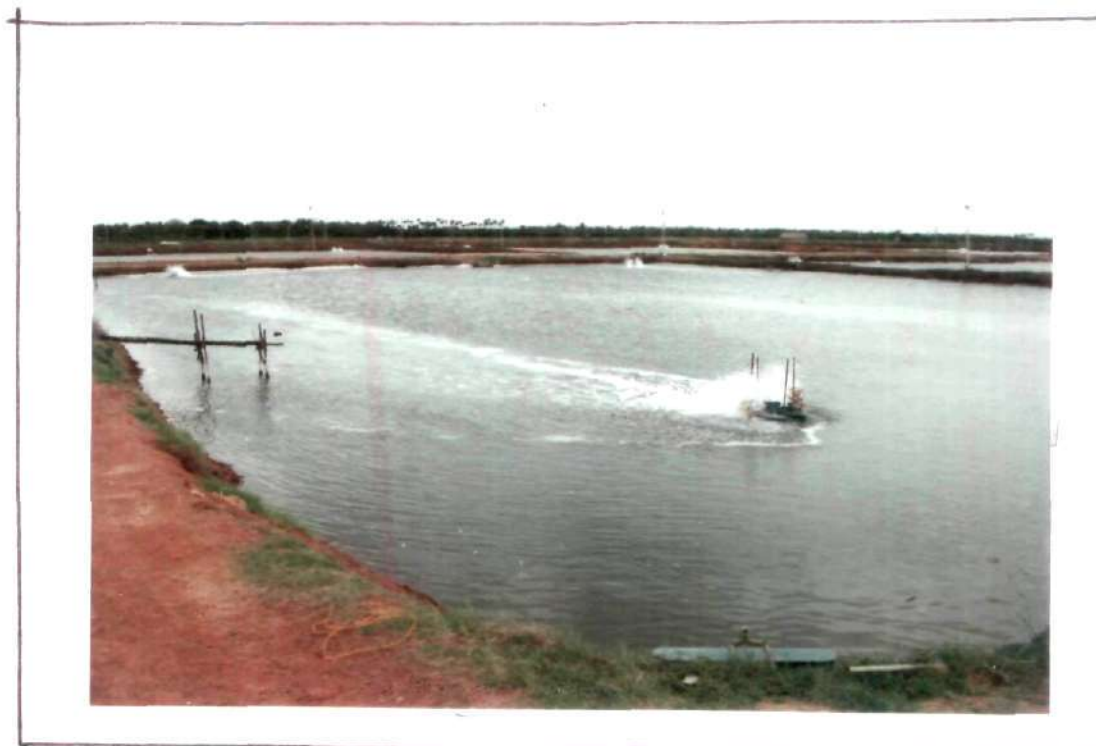


Plate 2b: Brackish water prawn culture pond at Kolladinni

3.2 WEATHER DATA IN NELLORE AND PRAKASAM DISTRICTS DURING THE STUDY PERIOD

The meteorological data on mean minimum and maximum temperatures, number of rainy days, rainfall and evaporation pertaining to Nellore and Prakasam districts from January 1995 to December 1997 are furnished in Appendix I and II.

3.3 COLLECTION OF SOIL SAMPLES

Soil profile samples were collected in the adjoining fields of fresh water fish culture ponds and brackish water prawn culture ponds at the beginning, middle of the culture and end of the culture at O (adjacent to pond), 25, 50, 100, 200, 400 and 600 meters away from the ponds. At each location, the soil samples were collected at 0-15, 15-30, 30-60 and at 60-90 cm depths. The total number of soil samples collected during the study period was 1008. Details about the soil samples collected at different locations are given in the Table 1.

3.4 COLLECTION OF WATER SAMPLES

Water samples from different sources adjoining the fresh water fish culture ponds in Rebala, Kovur and Purini villages and brackish water prawn culture ponds in Kolladinni village of Nellore district and Karedu-1 and Karedu-2 villages of Prakasam district were collected upto a lateral distance of about one km from the pond at the time of starting and harvest of the culture during 1995-96 and 1996-97. The details of water samples collected for the study given in the Table 2. The locations from where selected wells/filter points/ponds/hand pumps adjoining fresh and brackish water ponds are falling are depicted in Figs.2 to 7.

Table 1: Details of aquaculture ponds selected and date of samples collected for the study.

S. No.	Name of the district	Name of the Mandal	Name of the village	Type of culture	Duration of the culture		Area of the pond (acres)	Age of the pond (years)	Date of collection of soil samples
					From	To			
1.	Nellore	Butchireddy-palem	Rebala	Fresh water fish culture	<u>1995-96</u>		22	9	12-8-1995 15-12-1995 15-5-1996
					12-8-95	15-5-96			
					<u>1996-97</u>				
					30-7-1996	25-4-1997			
2.	Nellore	Kovur	Kovur	Fresh water fish culture	<u>1995-96</u>		18	10	2-8-1995 7-12-1995 10-5-1996
					2-8-1995	9-5-1996			
					<u>1996-97</u>				
					8-8-1996	7-5-1997			
3.	Nellore	Allur	Purimi	Fresh Water fish culture	<u>1995-96</u>		17	8	10-8-1995 15-12-1995 15-5-1996
					10-8-1995	12-5-1996			
					<u>1996-97</u>				
					25-7-1996	15-4-1997			
									25-7-1996 10-11-1996 15-4-1997

Table 1 contd...

S. No.	Name of the district	Name of the Mandal	Name of the villages	Type of culture	Duration of the culture		Area of the pond (acres)	Age of the pond (years)	Date of collection of soil samples
					From	To			
4.	Nellore	Bogollu	Kolladinni	Brackish water prawn culture ponds	<u>1996</u> 2-2-1996	15-7-1996	24	2	2-2-1996
					<u>1997</u> 25-1-1997	5-7-1997			19-4-1996 15-7-1996
									25-1-1997 10-4-1997 5-7-1997
5.	Prakasam	Ulavapadu	Karedu-1	Brackish Water Prawn Culture ponds	<u>1996</u> 9-2-1996	2-7-1996	22	2	9-2-1996 24-4-1996 2-9-1996
					<u>1997</u> 2-2-1996	8-7-1996			2-2-1996 17-4-1996 8-7-1996
6.	Prakasam	Ulavapadu	Karedu-2	Brackish Water Prawn Culture ponds	<u>1996</u> 5-2-1996	1-7-1996	20	2	5-2-1996 16-4-1996 1-7-1996
					<u>1997</u> 25-1-1997	30-5-1997			25-1-1997 30-3-1997 20-5-1997

Table 2: Details of ground water samples collected at different lateral distances from the aquaculture ponds.

Village	Fresh/brackish water pond	Water source	Distance from the pond (m)	Water table (ft)
Rebala	Fresh water pond	Well	10	35
		Filter point	58	40
		Filter point	98	40
		Filter point	389	35
		Filter point	505	45
		Filter point	600	35
		Filter point	1010	40
Kovur	Fresh water pond	Filter point	8	55
		Filter point	88	55
		Filter point	199	45
		Filter point	380	50
		Filter point	500	55
		Filter point	770	55
		Filter point	930	45

Table 2 contd....

Village	Fresh/brackish water pond	Water source	Distance from the pond (m)	Water table (ft)
Purini	Fresh water pond	Hand pump	25	15
		Well	55	20
		Well	100	20
		Hand pump	220	16
		Hand pump	285	12
		Hand pump	330	15
		Well	825	22
		Well	940	25
Karedu-1	Brackish water pond	Filter point	10	52
		Pond	188	12
		Pond	295	12
		Well	590	22
		Filter point	780	50
		Hand pump	885	19
		Filter point	1000	50

Table 2 contd...

Village	Fresh/brackish water pond	Water source	Distance from the pond (m)	Water table (ft)
Karedu-2	Brackish water pond	Filter point	22	55
		Pond	158	10
		Filter point	338	60
		Filter point	500	65
		Filter point	820	56
		Filter point	990	55
		Filter point	1200	60
Kolladinni	Brackish water pond	Filter point	34	30
		Well	156	25
		Well	240	25
		Well	390	25
		Hand pump	720	20
		Well	920	25
		Hand pump	1025	20

Fig. 2 : Location of well/filter points adjoining fresh water
fish culture ponds at Rebala.

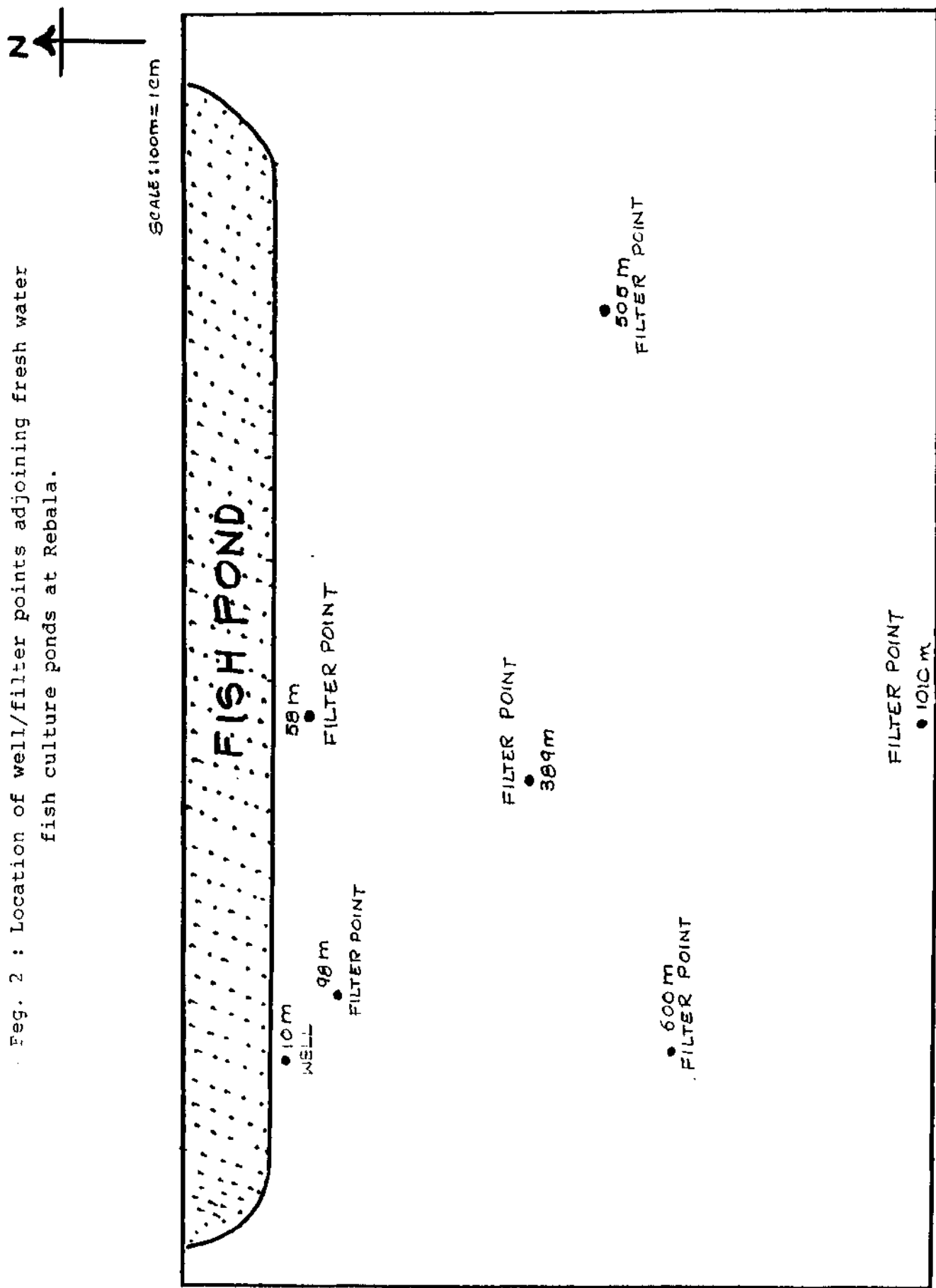


Fig. 3: Location of filter points adjoining fresh water fish culture ponds at Kovur.

N
SCALE: 100m = 1cm

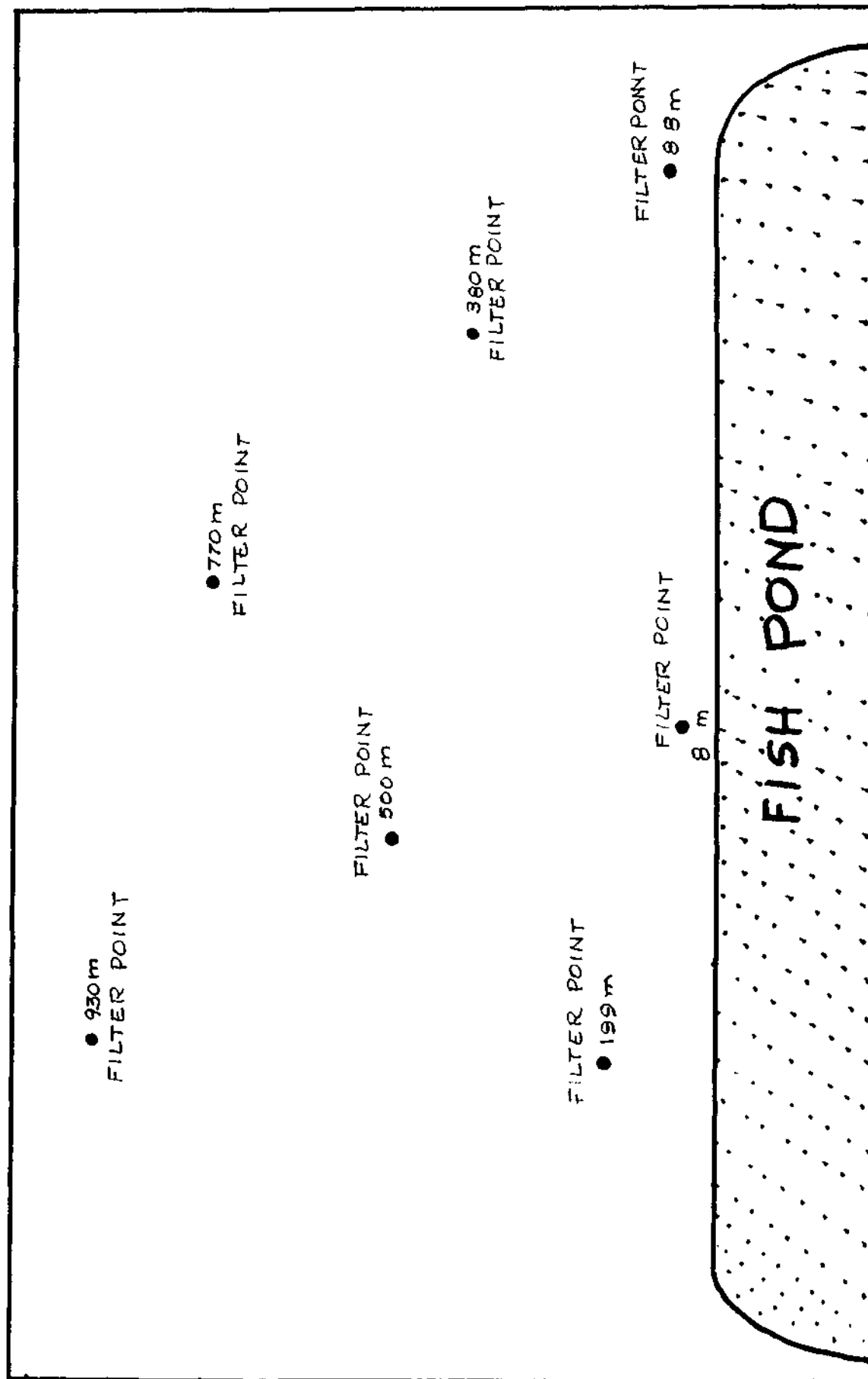


Fig.4 : Location of wells/Hands Pumps adjoining fresh water fish culture ponds at Purini.

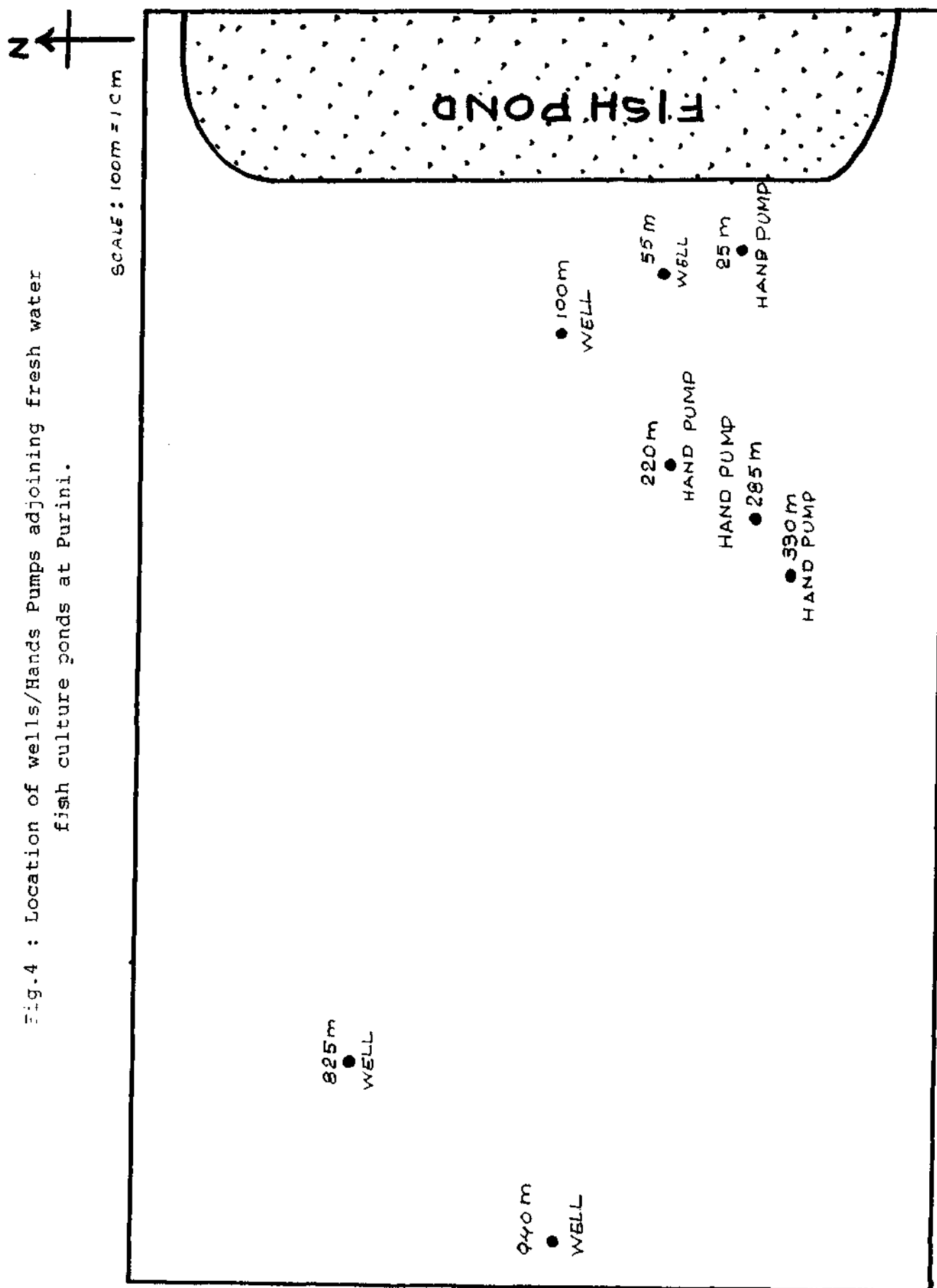


Fig. 5: Location of Filter points/ Ponds/Hand Pump adjoining brackish water
Prawn culture ponds at Karedu-1.

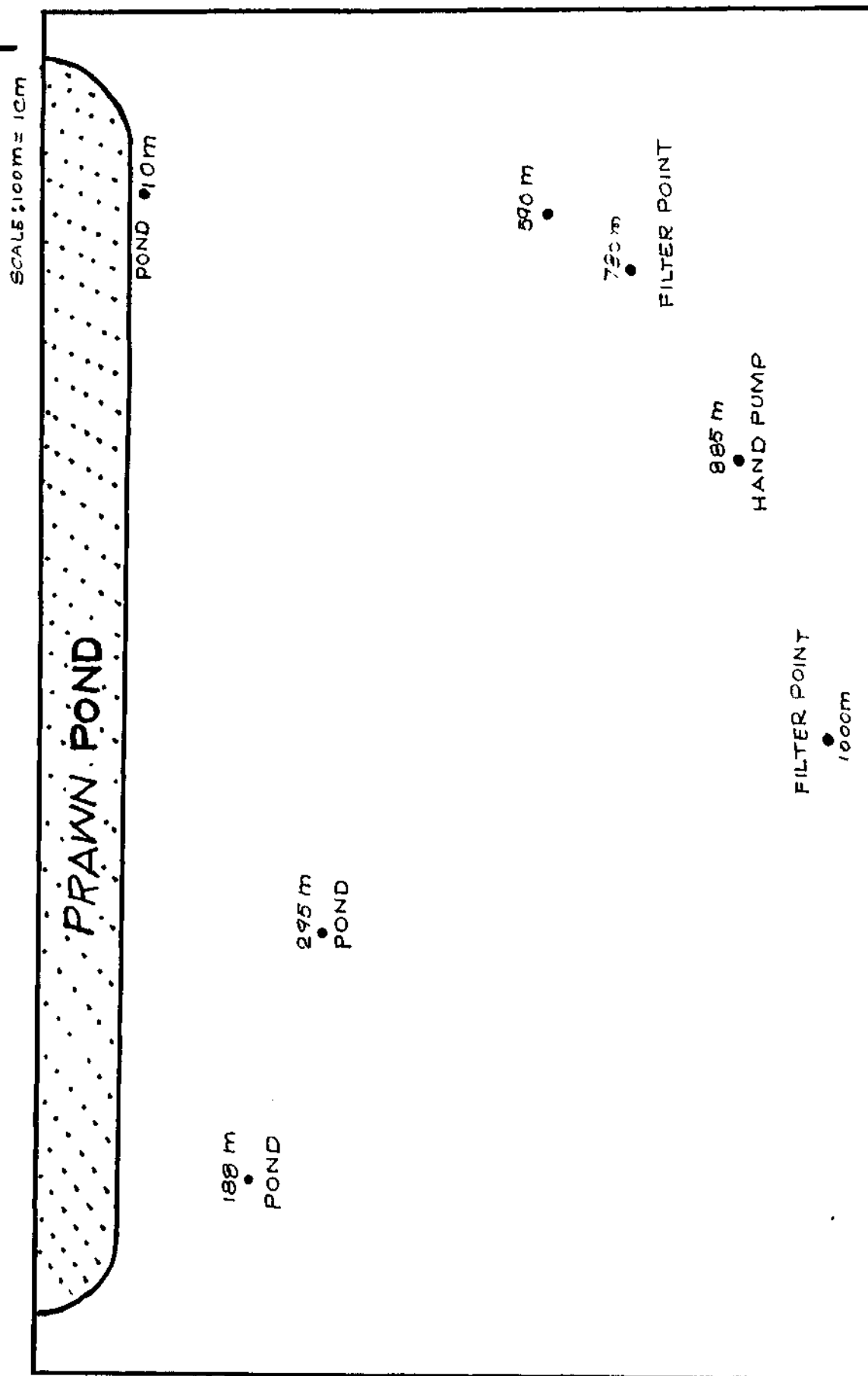
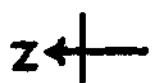


Fig.6 : Location of filter points/pond adjoining brackish water
Prawn culture ponds at Karedu-2.



SCALE : 100m 1 cm

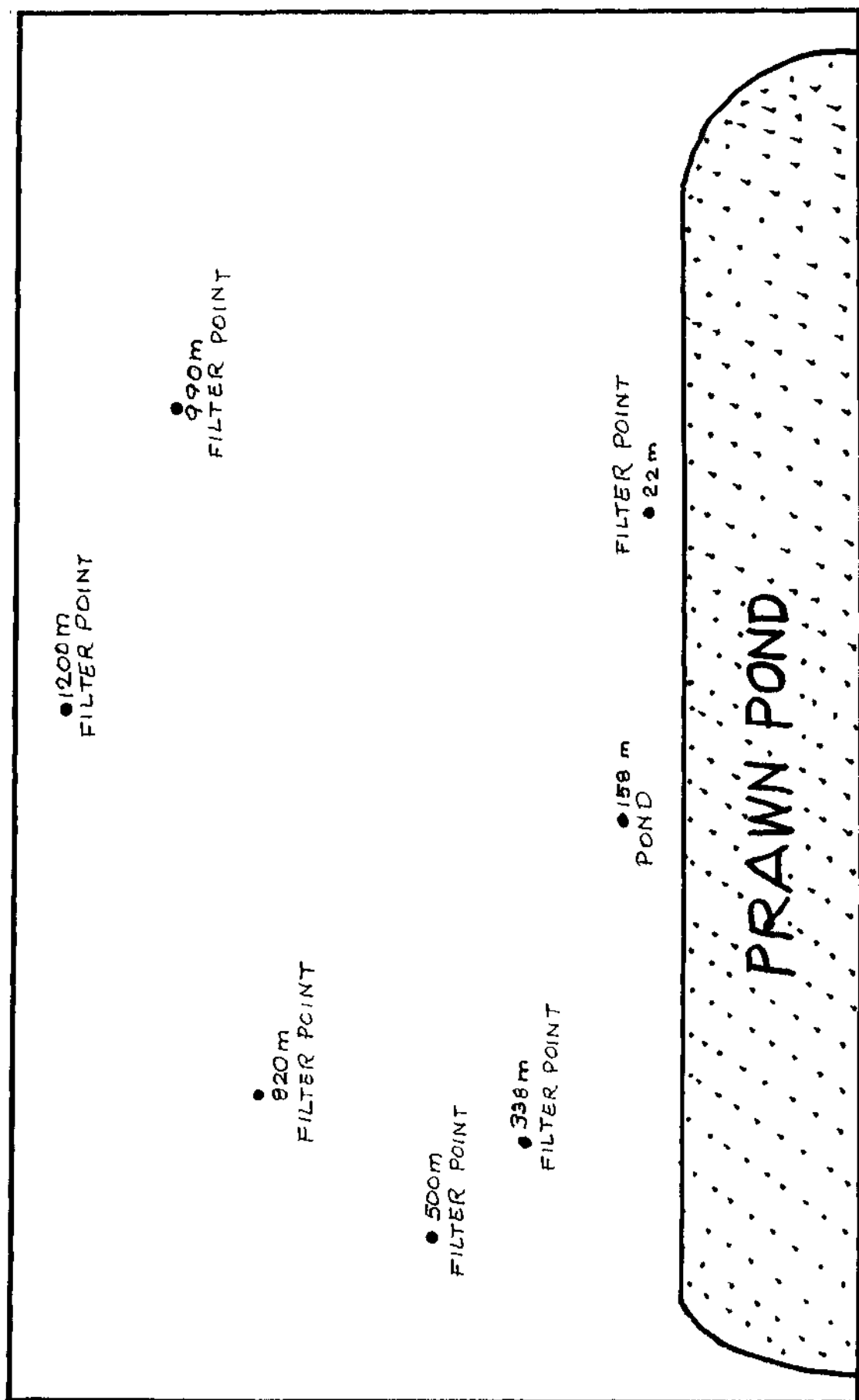
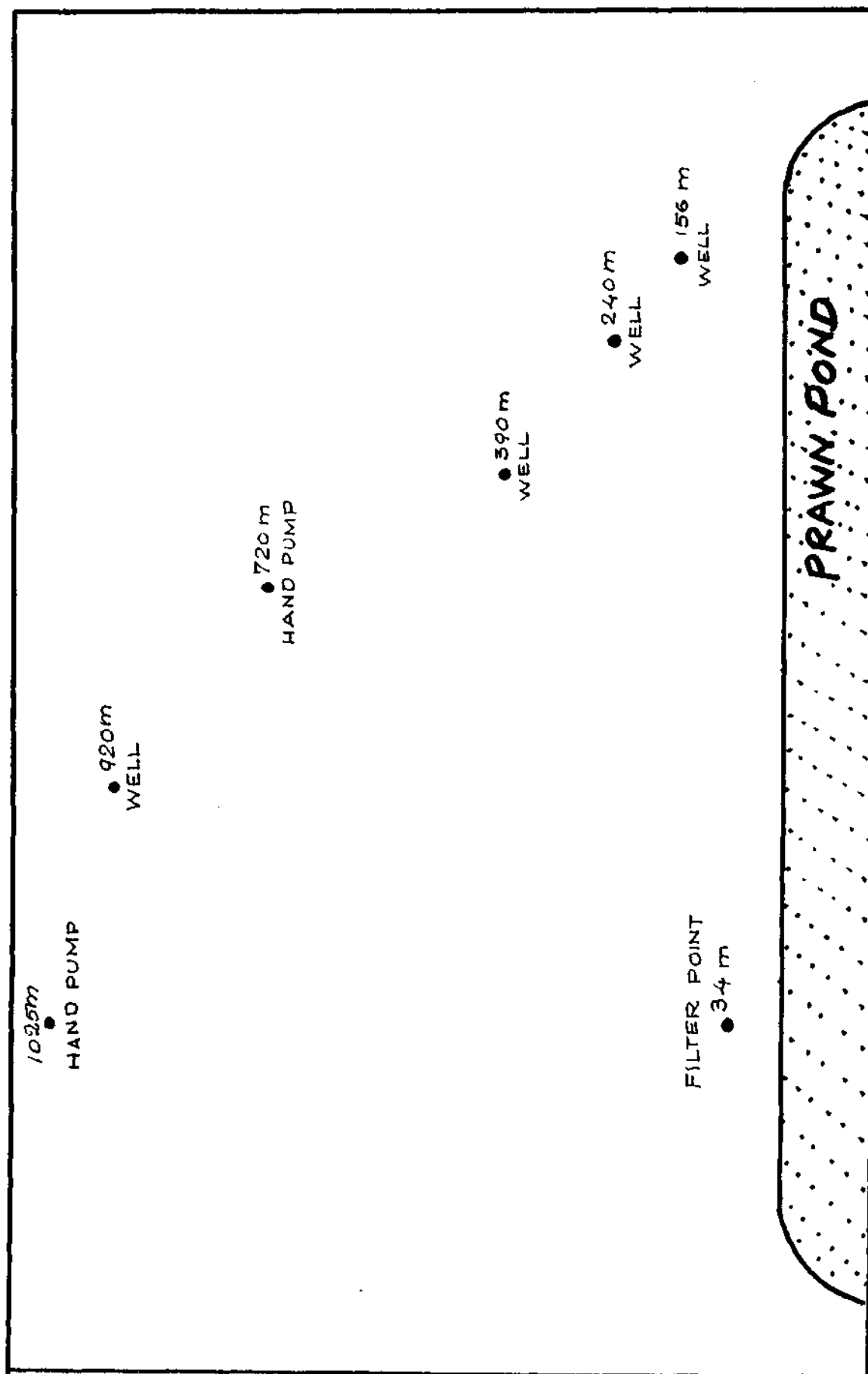
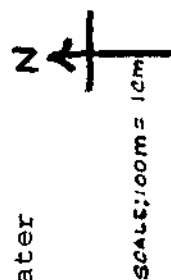


Fig.7 : Location of wells/filter point/ Hand pumps adjoining brackish water
Prawn culture ponds at Kolladinni.



3.5 METHODS OF SOIL ANALYSIS

Methods of analysis followed in the study are presented below.

3.5.1 Mechanical Analysis of Soil

The soil samples were analysed for sand, silt and clay fractions by International pipette method (Black, 1965).

3.5.2 Bulk Density of Soil

Bulk density of soils was estimated by core method and expressed as Mg m^{-3} as per the procedure outlined by Blake and Hartge (1986).

3.5.3 Hydraulic Conductivity of Soil

The hydraulic conductivity of undisturbed soil samples was estimated in the laboratory as per the procedure outlined by Klute and Dirksen (1986) and the results were expressed in cm hr^{-1} .

3.5.4 Infiltration Rate

Infiltration rates were measured in the fields with double ring infiltrometer method following variable head method outlined by Bouwer (1986) and results were expressed in cm hr^{-1} .

3.5.5 Soil Structural Indices

For the determination of soil structure, undisturbed natural clods were collected from the field and analysed for water stable aggregates (aggregates > 0.25

mm in diameter) by Yoder's wet sieving method as per the procedure outlined by Kemper and Rosenaur (1986).

3.6 CHEMICAL PROPERTIES OF SOILS

3.6.1 Soil Reaction (pH)

Soil reaction was measured with pH meter in 1:2 ratio soil water suspension using glass electrode (Jackson, 1967).

3.6.2 Electrical Conductivity (dSm^{-1})

The electrical conductivity was estimated in 1:2 soil water extract using electrical conductivity bridge (Jackson, 1967).

3.6.3 Soil Organic Carbon

Soil organic carbon was estimated by Walkley and Black's method as given by Jackson (1967).

3.6.4 Available Nitrogen

The available N content in the soil samples was estimated by alkaline permanganate method (Subbiah and Asija, 1956).

3.6.5 Available Phosphorus

Available phosphorus was extracted using Olsen's extract (0.5 M sodium bicarbonate of pH 8.5) followed by the development of blue color using ascorbic acid method given by Watanabe and Olsen (1965).

3.6.6 DTPA extractable Micronutrients

The content of DTPA extractable micronutrients viz., Fe, Mn, Zn and Cu in soil was estimated using 1:2 soil extract ratio (Lindsay and Norvell, 1978). The concentration of each nutrient was estimated using atomic absorption spectrophotometer (Model 170-0036, Hitachi, Japan) at an air pressure of 1.6 kg cm⁻² using acetylene gas.

3.6.7 DTPA Extractable Heavy Metals

The content of DTPA extractable heavy metals viz., cadmium, chromium, nickel and lead in soil were estimated using 1:2 soil - extract ratio using atomic absorption spectrophotometer (Model 170-0036, Japan) at an air pressure of 1.64 kg cm² using acetylene gas.

3.6.8 Water Soluble Ions

3.6.8.1 Calcium and magnesium

Water soluble calcium and magnesium were estimated volumetrically in soil water extract (1:2) using rapid EDTA titration method (Vogel, 1978).

3.6.8.2 Sodium and potassium

Sodium and potassium were estimated in soil water extract (1:2) using flame photometer (Systronics model 121) as described by Jackson (1967).

3.6.8.3 Carbonates and Bicarbonates

The concentration of carbonate and bicarbonate ions in soil water extract (1:2) were estimated by titrating the soil water extract with standard sulphuric acid using phenolphthalein and methyl orange (Piper, 1966).

3.6.8.4 Chlorides

The concentration of chlorides in soil water extract (1:2) was estimated volumetrically by titrating the water extract with standard silver nitrate using potassium chromate as indicator (Reitemeier, 1943).

3.6.8.5 Sulphate

The concentration of sulphate ions was estimated in the soil water extract (1:2) by turbidometric method at wavelength 440 nm using spectronic 20 Bausch and Lomb spectro photometer (Massoumi and Cornfield, 1963).

3.7 WATER ANALYSIS

The water samples collected from open wells/filter points/hand pumps/ponds adjacent to fresh and brackish water aquaculture ponds and the pond water were analysed in the laboratory following the procedures indicated below.

3.7.1 pH

The pH of water was measured using glass electrode pH meter (Jackson, 1967)

3.7.2 Electrical Conductivity

The electrical conductivity was measured with conductivity bridge (Jackson, 1967).

3.7.3 Calcium and Magnesium

The calcium and magnesium were estimated volumetrically using EDTA rapid titration method (Vogel, 1978).

3.7.4 Sodium and potassium

The sodium and potassium contents were estimated with the aid of flame photometer (Systronics model 121) as described by Jackson (1967).

3.7.5 Carbonates and Bicarbonates

The concentration of carbonates and bicarbonate ions were estimated by titrating the water with the standard sulphuric acid using phenolphthalein and methyl orange as indicators, respectively (Piper, 1966).

3.7.6 Chloride

The concentration of chloride in water was estimated volumetrically by titrating the water with standard silver nitrate using potassium chromate as indicator by Mohr's method (Reitmeier, 1943).

3.7.7 Sulphate

The concentration of sulphates were estimated by turbidometric method at wavelength 440 nm using spectronic 20 Bausch and Lomb Spectrophotometer (Massoumi and Cornfield, 1963).

3.7.8 Fluorides

The concentration of Fluoride ions was estimated by Fluoride meter (ELICO make model EL-325) using reagent solution (RGT) and standard fluoride solution supplied by ELICO Private Limited, Hyderabad.

3.7.9 Boron

Boron was estimated by colorimetric method using carmine solution (Hatcher and Wilcox, 1950).

3.7.10 Nitrate Nitrogen

The nitrate nitrogen was estimated using the sulphanilamide NED method as given by Joseph (1994).

3.7.11 Chemical Oxygen Demand (COD)

Chemical oxygen demand was estimated as per Boyd (1978).

3.7.12 DTPA extractable micronutrients

The concentration of micronutrients viz., Zn, Fe, Mn and Cu in the water samples were estimated using atomic absorption spectrophotometer.

3.7.13 DTPA Extractable Heavy Metals

The concentration of heavy metals viz., cadmium, chromium, nickel and lead in water were determined using atomic absorption spectrophotometer (Model 170-0036, Japan) at air pressure of 1.6 kg cm² using acetylene gas.

3.8 YIELD

Yield of rice crop in the farmers fields adjoining the fresh water fish culture and brackish water prawn culture ponds selected for the study was recorded in different seasons occurring during 1995-96 and 1996-97. Yield of mango and sapota grown in the farmers fields adjoining brackish water prawn culture pond in Karedu-1 and Karedu-2 villages of Prakasam district was recorded in the years of 1995, 1996 and 1997. The yield of rice was recorded in the fields situated at 25, 50, 100, 200, 400 and 600 meters from the ponds. In case of rice crop, yield was recorded by taking 12 squaremeter area of the crop at randomly selected 4 places at each distance and calculated the grain yield per hectare. In case of mango and sapota, yield was recorded per tree by taking randomly selected four trees individually, for each distance. The details of yield recorded in the farmers fields adjoining to fresh water fish culture and brackish water prawn culture ponds are given in the table 3.

3.9 SATATISTICAL ANALYSIS

The data collected on various aspects were subjected to statistical analysis by adopting 3 factorial randomized block design (7 x 4 x 3 and 7 x 2 x 3) the first factor being distances the second factor being depth of soil sample collected and third factor being sampling periods. The first factor was at 7 levels the second factor was

at 4 and 2 levels and third factor was at 3 levels. Significant interactions alone were presented. The data were analysed statistically as per method given by Snedecor and Cochran (1975).

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Table 3: Duration and yield of the crops growing in the sampled adjacent to fields of aquaculture ponds in Nellore and Prakasam districts (1995-97).

S. No	Place	Nature of pond	Season	Variety	Duration	
					From	To
Nellore district						
1.	Rebala	Fresh water fish culture	Late <i>kharif</i>	CR 1009	10-9-95	18-1-96
			Summer	CR 1009	24-3-96	22-6-96
			Late <i>kharif</i>	CR 1009	13-9-96	16-1-97
			Summer	CR 1009	22-3-97	23-6-97
2.	Kovur	Fresh water fish culture	Late <i>kharif</i>	CR 1009	2-9-96	23-1-97
			Summer	NLR 30491	5-4-96	10-8-96
			Late <i>kharif</i>	CR 1009	10-9-97	22-1-97
			Summer	NLR 30491	10-4-97	15-8-97
3.	Purini	Fresh water fish culture	Late <i>kharif</i>	CR 1009	25-9-95	10-2-96
			Summer	NLR 30491	14-3-96	10-7-96
			<i>Rabi</i>	CR 1009	5-10-96	16-3-97
			Summer	NLR 30491	23-3-97	20-7-97
4.	Kolladinni	Brackish Water Prawn Culture	<i>Rabi</i>	IR 20	14-10-95	17-2-96
			<i>Rabi</i>	IR 20	10-10-96	13-2-97
Prakasam district						
5.	Karedu-1	Brackish Water Prawn Culture	--	Mango (Benishan)	Yield recorded in the years 1995,96 & 97.	
6.	Karedu-2	Brackish Water Prawn Culture	--	Pala sapota	Yield recorded in the years 1995,96 & 97.	

RESULTS

CHAPTER IV

RESULTS

entitled *The Project* "Effect of Aquaculture on Soil and Ground Water Quality in Nellore and Prakasam Districts of Andhra Pradesh" involved survey of soil and ground waters to find the influence of water in the aquaculture ponds on the properties of soils, quality of waters in the aquifers and on the yield of crops in the adjoining fields of the ponds. Results obtained in these studies are presented in this chapter.

4.1 CHARACTERIZATION OF WATERS IN THE AQUA-CULTURE PONDS

Water samples were drawn from fresh water fish culture ponds of Rebala, Kovur and Purini villages and brackish water prawn culture ponds of Karedu-1, Karedu-2 and Kolladinni villages at the starting of the culture and at the time of harvest during 1995-96 and 1996-97; and were analysed for pH, EC, Ca, Mg, Na, K, CO_3 , HCO_3 , Cl, SO_4 , $\text{NO}_3\text{-N}$, B, F, Cr, Pb, Ni, Cd, Fe, Mn, Zn, Cu and COD. The data are presented in Tables 4 and 5.

4.1.1 Water Quality in the fresh water fish culture ponds

4.1.1.1 pH

From the data presented in Table 4, it could be noticed that the water has high alkalinity with pH ranging from 8.03 to 8.50. The mean pH of Kovur (8.29) and Purini (8.34) was generally high as compared that of Rebala (8.20). The pH slightly decreased at the harvest of the culture compared to the start of the

culture by about 0.17 to 0.3 units in Kovur and Purini ponds in both the years of study, while in case of Rebala the pH increased by about 0.07 units in the first year and by about 0.25 units in the second year.

4.1.1.2 Salinity (EC)

The salinity as indicated by EC ranged from 1.294 to 2.480 dSm⁻¹ (Table 4). The mean EC of different ponds was varying in the order of Purini (2.280 dSm⁻¹) > Kovur (1.832 dSm⁻¹) > Rebala (1.790 dSm⁻¹). In general salt concentration in the pond waters was more at the harvest of the culture in all the three ponds compared to the start of the culture in both the years. The increase was more in case of Rebala in both the years compared to the other two places. The EC values were more in the 1996-97 compared to 1995-96 both after start of the culture and at the harvest of the culture in all the three places.

4.1.1.3 Cationic composition

The concentration of the major cations in the aquaculture ponds varied in the following order Na > Ca > Mg > K (Table 4). The Na concentration was many times more than that of calcium.

The Na concentration ranged between 9.6 and 18.8 c mol l⁻¹. Its content in the different ponds was varying in the order of Purini (16.65 c mol l⁻¹) > Rebala (12.90 c mol l⁻¹) > Kovur (10.95 c mol l⁻¹).

The Ca content ranged between 2.1 and 5.3 c mol l⁻¹. Kovur waters were having relatively higher Ca (4.6 to 5.3 c mol l⁻¹) followed by that of Rebala (2.1 to 4.3 c mol l⁻¹) and Purini (2.3 to 2.9 c mol l⁻¹) in that order.

The Mg content in the ponds ranged between 1.1 and 2.7 c mol l⁻¹. The Purini waters (2.1 to 2.6 c mol l⁻¹) were having generally higher Mg content followed by that of Kovur (2.0 to 2.3 c mol l⁻¹) and Rebala (1.1 to 2.7 c mol l⁻¹).

The K content was varying between 0.10 to 0.50 c mol l⁻¹. The K content was generally higher in Purini (0.25 to 0.50 c mol l⁻¹) and Rebala (0.04 to 0.12 c mol l⁻¹). Culturing increased the cationic concentration in both the years of study at all the three locations. The concentration of all the cations were more in the second year compared to the first year of study. The build up of Na was generally higher as compared to that of Ca, Mg and K.

4.1.1.4 Anionic composition

The concentration of CO₃, HCO₃, Cl and SO₄ ions in the pond water were analysed and the data are presented in Table 4. The data revealed that no CO₃ ions were present at all the places studied. The Cl ions were generally higher (5.6 to 13.0 c mol l⁻¹) with a mean of 9.97 c mol l⁻¹ followed by HCO₃ (6.9 to 11.5 c mol l⁻¹) with mean of 9.16 c mol l⁻¹ and SO₄ (0.20 to 0.50 c mol l⁻¹) with a mean of 0.38. Culturing generally increased the concentration of Cl, HCO₃ and SO₄ at all the locations except in Kovur waters during the second year wherein the concentration of SO₄ decreased from 0.50 to 0.30 c mol l⁻¹.

4.1.1.5 Nitrate nitrogen (NO₃-N)

The NO₃-N content varied between 0.045 to 4.2 mg l⁻¹ showing a very large variation (Table 4). Its content was several times higher in Kovur waters (3.5 to 4.2 mg l⁻¹) followed by that of Rebala (0.42 to 0.56 mg l⁻¹) and Purini (0.045

to 0.062 mg l⁻¹) culturing generally decreased the nitrate nitrogen content in the waters of Rebala and Kovur but in waters of Purini, the trend was reverse. The mean NO₃-N tended to increased by about 0.06 mg l⁻¹ in the first year and 0.01 mg l⁻¹ in the second year.

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4.1.1.6 Boron (B)

The boron content varied between 0.55 to 0.95 mg l⁻¹ in the ponds water (Table 4). It was higher in the waters of Rebala (0.77 to 0.95 mg l⁻¹) closely followed by that of Purini (0.72 to 0.92 mg l⁻¹) and were lower in Kovur (0.55 to 0.65 mg l⁻¹). Boron content in pond water increased during the culture period. The extent of increase ranged from 0.05 in Kovur during first year to a maximum 0.17 mg l⁻¹ during second year in Purini.

4.1.1.7 Fluoride (F)

The fluoride content varied between 0.31 to 0.77 mg l⁻¹ (Table 4). It was higher in Rebala (0.68 to 0.77 mg l⁻¹) followed by Purini (0.55 to 0.67 mg l⁻¹) and Kovur (0.31 to 0.37 mg l⁻¹) waters.

4.1.1.8 Heavy metals

The ponded water contained considerable amount of heavy metals as could be noticed from data presented in Table 4. The contents of Cr and Pb were generally higher than that of Ni and Cd. The Pb varied from 10 to 45 µg l⁻¹ closely followed by Cr content (5.5 to 62.0 µg l⁻¹). The Cr and Pb were generally higher in the waters of Purini followed by that of Kovur and Rebala. The Ni content was

varying from 5.0 to 13.0 $\mu\text{g l}^{-1}$ during the study period and its content was generally higher in Purini (9.0 to 13.0 $\mu\text{g l}^{-1}$) followed by Kovur (5.5 to 7.5 $\mu\text{g l}^{-1}$) and Rebala (5.0 to 7.0 $\mu\text{g l}^{-1}$). The Cd content was varying from 3.0 to 22.0 $\mu\text{g l}^{-1}$ in the waters during the study period. Its content was generally higher in the Purini (12.0 to 22.0 $\mu\text{g l}^{-1}$) and Rebala (3.0 to 5.2 $\mu\text{g l}^{-1}$). Culturing in general increased the heavy metal content during the study period. The extent of increase being generally higher in the case of Cr and Pb specially in the waters of Purini. All the heavy metals were more in the second year of study compared to the first year.

4.1.1.9 Micronutrients

The ponded water also contain considerable amounts of micronutrients viz., Zn, Fe, Mn and Cu (Table 4). Among these nutrients, Fe was highest (90.0 to 182.0 $\mu\text{g l}^{-1}$) followed by Mn (29.0 to 79.0 $\mu\text{g l}^{-1}$) and Zn (25.0 to 110.0 $\mu\text{g l}^{-1}$). The Cu content varied from 4.0 to 20.0 $\mu\text{g l}^{-1}$.

Fe content was higher in the waters of Purini (150.0 to 182.0 $\mu\text{g l}^{-1}$) followed by that of Kovur (120.0 to 150.0 $\mu\text{g l}^{-1}$) and Rebala (90.0 to 150.0 $\mu\text{g l}^{-1}$).

The Zn content was higher in Purini waters (90.0 to 110.0 $\mu\text{g l}^{-1}$) followed by that of Kovur (70.0 to 89.0 $\mu\text{g l}^{-1}$) and Rebala (25.0 to 45.0 $\mu\text{g l}^{-1}$).

The Mn content was higher in the waters of Rebala (50.0 to 79.0 $\mu\text{g l}^{-1}$) followed by that of Purini (59.0 to 75.0 $\mu\text{g l}^{-1}$) and Kovur (29.0 to 45.0 $\mu\text{g l}^{-1}$). Culturing in general increased concentration of all the micronutrients during the study period. The extent of increase being higher in the case of Fe followed by

Table 4 : Chemical composition of fresh water in the aqua culture ponds

Place	Year	Time of sampling	pH	EC		c mole l ⁻¹						
				dSm ⁻¹	Ca	Mg	Na	K	CO ₃	HCO ₃	Cl	SO ₄
Rebala	1995-96	Start of the culture	8.03	1.294	2.1	1.1	9.60	0.10	-	6.90	5.60	0.35
		Harvest of the culture	8.10	1.894	4.3	2.1	12.39	0.12	-	9.00	9.40	0.35
	1996-97	Start of the culture	8.20	1.710	2.7	1.7	12.65	0.04	-	7.90	8.70	3.50
		Harvest of the culture	8.45	2.260	2.9	2.7	16.94	0.05	-	10.50	11.30	0.49
		Mean for start of the culture	8.12	1.502	2.4	1.4	11.13	0.07	-	7.40	7.15	0.35
		Mean for harvest of the culture	8.23	2.077	3.6	2.4	14.67	0.09	-	9.75	10.35	0.42
Kovur	1995-96	Start of the culture	8.20	1.790	3.0	1.9	12.90	0.08	-	8.58	8.75	0.43
		Harvest of the culture	8.45	1.760	4.6	2.0	10.50	0.20	-	7.90	9.40	0.20
	1996-97	Start of the culture	8.20	1.845	4.9	2.2	11.10	0.25	-	8.30	9.70	0.35
		Harvest of the culture	8.35	1.802	4.8	2.1	10.90	0.20	-	8.00	9.30	0.50
		Mean for start of the culture	8.15	1.920	5.3	2.3	11.30	0.27	-	8.40	10.20	0.30
		Mean for harvest of the culture	8.40	1.781	4.7	2.1	10.70	0.20	-	7.95	9.35	0.35
Purini	1995-96	Start of the culture	8.18	1.883	5.1	2.3	11.20	0.26	-	8.35	9.95	0.33
		Harvest of the culture	8.29	1.832	4.9	2.2	10.95	0.23	-	8.15	9.65	0.34
	1996-97	Start of the culture	8.42	2.120	2.6	2.3	16.00	0.30	-	10.50	10.20	0.30
		Harvest of the culture	8.25	2.320	2.8	2.6	17.30	0.50	-	11.50	11.30	0.40
		Mean for start of the culture	8.50	2.200	2.3	2.1	14.50	0.25	-	10.20	11.50	0.32
		Mean for harvest of the culture	8.20	2.480	2.9	2.6	18.80	0.27	-	11.00	13.00	0.45
		Start of the culture	8.46	2.160	2.5	2.2	15.25	0.28	-	10.35	10.85	0.31
		Harvest of the culture	8.23	2.400	2.9	2.6	18.05	0.39	-	11.25	12.15	0.43
		Mean	8.34	2.280	2.7	2.4	16.65	0.33	-	10.80	11.50	0.37
		General mean	8.27	1.967	3.5	2.2	13.50	0.21	-	9.16	9.97	0.38

Table 4 Contd

Place	NO ₃ -	Heavy metals (µg l ⁻¹)						Micro nutrients (µg l ⁻¹)					COD mg l ⁻¹
		B	F	Cr	Rb	Ni	Cd	Zn	Fe	Cu	Mn		
Rebala	0.56	0.77	0.77	5.5	10.0	5.0	3.0	25.0	90.0	10.0	50.0	140	
	0.42	0.88	0.77	5.9	12.0	6.5	4.5	30.0	100.0	14.0	60.0	220	
	0.48	0.79	0.68	5.9	12.0	5.9	3.9	35.0	120.0	15.0	65.0	135	
	0.42	0.95	0.70	6.5	13.0	7.0	5.2	45.0	150.0	20.0	79.0	210	
	0.52	0.78	0.73	5.7	11.0	5.5	3.5	30.0	105.0	12.5	57.5	138	
	0.42	0.92	0.74	6.2	12.5	6.8	4.9	37.5	125.0	17.0	69.5	215	
	0.47	0.85	0.73	6.0	11.8	6.1	4.2	33.8	115.0	14.8	63.5	176	
Kovur	4.01	0.65	0.35	15.0	25.0	5.5	7.5	70.0	130.0	5.5	29.0	180	
	3.5	0.65	0.36	19.0	30.0	7.5	10.5	80.0	145.0	7.0	35.0	210	
	4.2	0.55	0.31	20.0	20.0	5.0	8.0	75.0	120.0	4.0	30.0	140	
	3.6	0.35	0.37	24.0	25.0	6.5	12.0	89.0	15.0	5.0	45.0	189	
	4.1	0.60	0.33	17.5	22.5	5.3	7.5	72.5	125.0	4.8	29.5	160	
	3.35	0.65	0.37	21.5	27.5	7.0	11.3	84.5	147.5	5.5	40.0	200	
	3.83	0.63	0.35	19.5	25.0	12.3	9.5	78.5	136.3	5.2	34.8	180	
Purini	0.045	0.72	0.55	45.0	35.0	9.0	15.0	95.0	150.0	10.0	59.0	105	
	0.051	0.85	0.60	55.0	40.0	12.0	20.0	110.0	175.0	15.0	65.0	130	
	0.052	0.75	0.65	50.0	30.0	10.0	12.0	90.0	165.0	12.0	60.0	115	
	0.062	0.92	0.67	62.0	45.0	13.0	22.0	105.0	182.0	18.0	75.0	125	
	0.049	0.74	0.60	47.5	32.5	9.5	13.5	92.5	157.5	11.0	59.5	110	
	0.057	0.89	0.69	58.5	42.5	12.5	21.0	107.5	178.5	16.5	70.0	128	
	0.053	0.81	0.62	53.0	39.3	11.0	17.3	100.0	168.0	13.8	64.8	119	
	1.490	0.76	0.57	26.2	25.3	7.3	10.3	70.8	139.8	11.3	54.3	66	

that of Mn and Zn. It was least in the case of Cu. The concentration of micronutrients in waters, in general, was more in the year 1996-97 compared to 1995-96.

4.1.1.10 Chemical oxygen demand (COD)

The COD in the pond water ranged from 105 to 220 mg l⁻¹ (Table 4). It was generally higher in the case of Rebala waters (140 to 220 mg l⁻¹) followed by that of Kovur (140 to 210 mg l⁻¹) and Purini waters (105 to 130 mg l⁻¹). Culturing in general increased the COD during the study period.

The increase being maximum in the case of Rebala water (80 mg l⁻¹) during first year and least in Purini water (10 mg l⁻¹) during second year.

4.1.2 WATER QUALITY IN THE BRACKISH WATER PRAWN CULTURE PONDS

4.1.2.1 pH

From the data presented in Table 5, it could be noticed that the pH of waters was ranging from 7.70 to 8.25. The pH of Karedu-1 and Karedu-2 was generally higher as compared to that of Kolladinni.

The pH slightly increased by about 0.10 to 0.15 units at the harvest of the culture compared to the start of the culture during both the years of study in Kolladinni water, while in the case of Karedu-1 the pH increased by about 0.07 units in the first year and 0.15 units in the second year. The pH increased by about 0.15 units in the first year and 0.5 units in the second year in the case of Karedu-2.

4.1.2.2 Salinity (EC)

The salinity as indicated by EC ranged from 41.05 to 49.80 dSm⁻¹ (Table 5). The EC of different ponds was varying in the order of Karedu-2 (48.6 dSm⁻¹), Karedu-1 (48.0 dSm⁻¹) and Kolladinni (42.54 dSm⁻¹). Culturing in general increased the salt concentration in brackish water prawn culture ponds. The trends of variations are similar in both the years.

4.1.2.3 Cationic composition

The major cations (Table 5) in the aquaculture ponds varied in the order of Na (358 c mol l⁻¹) > Mg (69.7 c mol l⁻¹) > Ca (21.0 c mol l⁻¹) > K (18.0 c mol l⁻¹). The Na concentration was many times higher than that of Mg.

The Na concentration was varying between 325 to 389 c mol l⁻¹. Its content in different ponds was varying in the order of Karedu-2 (374 c mol l⁻¹) and Karedu-1 (367 c mol l⁻¹) and Kolladinni (358 c mol l⁻¹).

The Ca content was varying between 15.0 to 25.0 c mol l⁻¹. Karedu-2 waters were having relatively higher Ca (20.5 to 25.0 c mol l⁻¹) closely followed by that of Karedu-1 (21.0 to 24.0 c mol l⁻¹) and Kolladinni (15.0 to 19.5 c mol l⁻¹) in that order.

The Mg content in the ponds was varying between 60 to 80 c mol l⁻¹. The Karedu-1 waters were having generally higher Mg content with mean of 75.3 c mol l⁻¹ followed by that of Karedu-2 (65.5 to 75.5 c mol l⁻¹) with a mean of 69.8 mol l⁻¹ and Kolladinni (60.0 to 68.5 c mol l⁻¹) with mean of 64.1 c mol l⁻¹.

The Na concentration was varying between 325.0 to 389.0 c mol l⁻¹. Its content in different ponds was varying in the order of Karedu-2 (374 c mol l⁻¹) > Karedu-1 (367.3 c mol l⁻¹) and Kolladinni (334 c mol l⁻¹).

The K content was varying between 10.2 to 23.0 c mol l⁻¹. The K content was generally higher in Karedu-1 (19.5 to 23.0 c mol l⁻¹) followed by that of Karedu-2 (18.2 to 23.0 c mol l⁻¹) and Kolladinni (10.2 to 13.0 c mol l⁻¹). Culturing uniformly increased the cationic concentration in both the years of study at all the three locations. The build up of Na was generally higher as compared to that of Mg, Ca and K.

4.1.2.4 Anionic composition

From the data presented in Table 5, it is noticed that Cl ions were generally higher (331 to 386.5 c mol l⁻¹) with a mean of 365 followed by SO₄ (70.0 to 90.0 c mol l⁻¹) with a mean of 83.0. HCO₃ (5.4 to 16.6 C mol l⁻¹) with a mean of 12.2 c mol l⁻¹ and CO₃ (1.1 to 4.5 c mol l⁻¹) with a mean of 3.2.

Culturing generally increased the concentration of Cl, SO₄, HCO₃ and CO₃ at all the locations studied.

4.1.2.5 Nitrate nitrogen (NO₃-N)

NO₃-N content varied between 0.415 to 0.840 mg l⁻¹ (Table 5). Its content was generally higher in Karedu-1 (0.690 to 0.840 mg l⁻¹) with a mean of 0.746 followed by Karedu-2 (0.615 to 0.720 mg l⁻¹) with a mean of 0.694 and least was found in Kolladinni (0.415 to 0.495 mg l⁻¹) with a mean of 0.460. Culturing generally increased the nitrate nitrogen content at all the three locations studied.

4.1.2.6 Boron (B)

The boron content varied between 2.7 to 3.7 mg l⁻¹ in the pond water. Its content was more in the water of Karedu-1 (3.4 to 3.7 mg l⁻¹) with a mean of 3.6 closely followed by that of Karedu-2 (3.2 to 3.5 mg l⁻¹) with a mean of 3.4 and were lower in Kolladinni (2.7 to 3.0 mg l⁻¹) with a mean of 2.85.

4.1.2.7 Fluorine (F)

Fluorine content varied between 0.61 to 0.90 mg l⁻¹ (Table 5). Its content was generally higher in the Karedu-2 waters (0.75 to 0.90 mg l⁻¹) with a mean of 0.81 followed by waters of Kolladinni (0.70 to 0.75 mg l⁻¹) with a mean of 0.72 and least was in Karedu-1 (0.61 to 0.65 mg l⁻¹) with a mean of 0.64.

4.1.2.8 Heavy metals

The pond water also contained considerable amounts of heavy metals as could be noticed from the data presented in Table 5. Among the heavy metals, the contents of Cr was higher as compared to that of Pb, Ni and Cd and lowest was Cd. The Cr varied from 1.12 to 2.7 mg l⁻¹ with a mean of 1.77 followed by Pb (0.5 to 1.60 mg l⁻¹) with a mean of 1.01 and Ni (0.39 to 0.81 mg l⁻¹) with a mean of 0.55 and Cd (0.10 to 0.29 mg l⁻¹) with a mean of 0.26. Cr content was generally higher in Kolladinni waters (1.5 to 2.7 mg l⁻¹) with a mean of 2.10 mg l⁻¹ followed by Karedu-2 (1.55 to 1.90 mg l⁻¹) with a mean of 1.77 and Karedu-1 (1.12 to 1.80 mg l⁻¹) with a mean of 1.52. Pb content was generally higher in Karedu-1 (0.90 to 1.60 mg l⁻¹) with a mean of 1.25 followed by Karedu-2 (0.85 to 1.2 mg l⁻¹), with a mean of 1.02 and Kolladinni (0.50 to 1.30) with a mean of 0.91. Ni content was generally higher

in Karedu-2 (0.45 to 0.81 mg l⁻¹) with a mean of 0.70 closely followed by Karedu-1 (0.45 to 0.80 mg l⁻¹) with a mean of 0.63 and Kolladinni (0.39 to 0.60 mg l⁻¹) with a mean of 0.49. Cd content was generally higher in Karedu-2 (0.22 to 0.29 mg l⁻¹) with a mean of 0.26 and closely followed by Karedu-1 (0.17 to 0.27 mg l⁻¹) with a mean of 0.21 and Kolladinni (0.10 to 0.16 mg l⁻¹) with a mean of 0.14. Culturing in general increased the heavy metal content in all the samples during the study period. The extent of variation being generally higher in the case of Cr and Pb in the waters of all the samples.

4.1.2.9 Micronutrients

The brackish water in the ponds also contained considerable amounts of micronutrients viz., Zn, Fe, Mn and Cu. Among the nutrients, Fe was higher (0.35 to 0.55 mg l⁻¹) with a mean of 0.43 followed by Cu (0.08 to 0.24 mg l⁻¹) with a mean of 0.15, Mn (0.08 to 0.17) with a mean of 0.12 and Zn (0.05 to 0.17 mg l⁻¹) with a mean of 0.11.

Fe content was almost similar in the waters of Karedu-1 (0.40 to 0.47 mg l⁻¹) with a mean of 0.44, Karedu-2 (0.35 to 0.55 mg l⁻¹) with a mean of 0.41 and Kolladinni (0.35 to 0.49 mg l⁻¹) with a mean of 0.43.

Cu content was higher in the waters of Karedu-2 (0.17 to 0.24 mg l⁻¹) with a mean of 0.20 followed by Karedu-1 (0.12 to 0.18 mg l⁻¹) with a mean of 0.15 and Kolladinni (0.07 to 0.10 mg l⁻¹) with a mean of 0.09.

Mn content was higher in the waters of Karedu-1 (0.15 mg l⁻¹) followed by Karedu-2 (0.14 mg l⁻¹) and Kolladinni (0.11 mg l⁻¹).

Table 5: Chemical compositions of brackish water in the aqua culture ponds

Place	Year	Time of sampling	pH	EC dSm ⁻¹	c mole l ⁻¹							
					Ca	Mg	Na	K	CO ₃	HCO ₃	Cl	SO ₄
Karedu-1	1995-96	Start of the culture	8.13	48.10	23.5	76.0	362	19.5	3.5	14.0	374	87.5
		Harvest of the culture	8.20	48.50	24.0	80.0	364	22.0	4.3	13.7	377	89.0
	1996-97	Start of the culture	8.10	47.50	21.0	68.0	365	21.0	3.7	13.3	373	83.0
		Harvest of the culture	8.25	49.50	21.5	77.0	378	23.0	4.5	14.5	386	89.5
	Mean for start of the culture	8.12	47.80	22.3	72.0	363	20.3	3.6	13.7	374	85.3	
	Mean for harvest of the culture	8.23	49.00	22.8	78.5	371	22.5	4.4	14.1	382	89.3	
Karedu-2	1995-96	Mean	8.18	48.00	22.5	75.3	367	21.4	4.0	13.9	378	87.3
		Start of the culture	8.10	48.00	24.0	75.5	362	18.2	3.2	14.3	375	85.5
	1996-97	Harvest of the culture	8.25	49.80	25.0	69.0	381	23.0	3.9	16.6	387	90.0
		Start of the culture	8.15	47.00	20.5	65.5	363	20.4	3.5	10.5	369	82.0
	Harvest of the culture	8.20	49.50	24.0	69.0	389	23.0	3.7	14.8	385	90.0	
	Mean for start of the culture	8.13	47.50	22.3	70.5	363	19.3	3.4	12.4	372	83.8	
Kolladinni	1995-96	Mean for harvest of the culture	8.23	49.70	24.5	69.0	385	23.0	3.8	15.7	386	90.0
		Mean	8.18	48.60	23.4	69.8	374	21.2	3.6	14.1	379	87.0
	1996-97	Start of the culture	7.70	41.05	15.0	60.0	325	10.2	1.1	5.4	331	70.0
		Harvest of the culture	7.85	43.05	18.0	65.0	340	12.0	1.3	7.0	347	77.0
	Start of the culture	7.75	42.05	16.5	63.0	330	11.0	1.4	9.1	335	74.0	
	Harvest of the culture	7.85	44.00	19.5	68.5	339	13.0	1.7	13.3	345	78.0	
		Mean for start of the culture	7.73	41.55	15.8	61.5	328	10.6	1.3	7.3	333	72.0
		Mean for harvest of the culture	7.85	43.50	18.8	66.8	340	12.5	1.5	10.2	346	77.5
		Mean	7.79	42.54	17.3	64.2	334	11.6	1.4	8.7	340	74.8
		General mean	8.04	46.52	21.0	69.7	358	18.0	3.2	12.2	365	83.0

Table 5 contd

Place	Heavy metals (mg l ⁻¹)					Micro nutrients (mg l ⁻¹)						
	NO ₃ -N	B	F	Cr	Pb	Ni	Cd	Zn	Fe	Cu	Mn	COD
	mg l ⁻¹											
Karedu-1	0.690	3.4	0.61	1.12	0.90	0.45	0.17	0.05	0.40	0.12	0.09	1750
	0.745	3.7	0.65	1.65	1.51	0.75	0.19	0.08	0.45	0.16	0.14	1790
	0.710	3.5	0.63	1.50	1.00	0.50	0.20	0.07	0.44	0.14	0.10	1990
	0.840	3.7	0.64	1.80	1.60	0.80	0.27	0.09	0.47	0.18	0.13	2020
	0.700	3.5	0.62	1.31	0.95	0.48	0.19	0.06	0.42	0.13	0.01	1870
Karede-2	0.793	3.7	0.65	1.70	1.56	0.78	0.23	0.85	0.46	0.17	0.14	1905
	0.746	3.6	0.64	1.52	1.25	0.63	0.21	0.07	0.44	0.15	0.12	1888
	0.695	3.2	0.80	1.70	0.90	0.45	0.24	0.10	0.35	0.17	0.11	2010
	0.745	3.3	0.90	1.90	1.20	0.72	0.29	0.12	0.55	0.21	0.15	2150
	0.615	3.4	0.75	1.55	0.85	0.50	0.22	0.14	0.39	0.18	0.12	2100
Kolladinna	0.720	3.5	0.78	1.70	1.12	0.81	0.27	0.17	0.45	0.24	0.17	2201
	0.655	3.3	0.78	1.63	0.88	0.48	0.23	0.12	0.37	0.18	0.12	2055
	0.733	3.4	0.84	1.80	1.16	0.77	0.28	0.15	0.50	0.23	0.16	2176
	0.694	3.5	0.81	1.71	1.04	1.02	0.26	0.13	0.41	0.20	0.14	2115
	0.415	2.9	0.70	1.50	0.50	0.40	0.10	0.09	0.35	0.07	0.08	1820
General mean	0.495	3.0	0.71	2.20	1.12	0.60	0.17	0.13	0.45	0.09	0.12	1890
	0.475	2.7	0.72	1.90	0.70	0.39	0.14	0.11	0.40	0.08	0.09	1695
	0.485	2.8	0.75	2.70	1.30	0.55	0.16	0.15	0.49	0.10	0.14	1798
	0.445	2.8	0.71	1.70	0.60	0.40	0.12	0.10	0.38	0.08	0.09	1758
	0.49	2.9	0.73	2.50	1.21	0.58	0.17	0.14	0.47	0.10	0.13	1844
	0.460	2.85	0.72	2.10	0.91	0.49	0.14	0.12	0.43	0.09	0.11	1801
	0.636	3.3	0.72	1.77	1.01	0.55	0.26	0.11	0.43	0.15	0.12	1935

Zn content of pond waters was generally higher in Karedu-2 (0.10 to 0.17) with a mean of 0.13 closely followed by Kolladinni (0.09 to 0.15 mg l⁻¹) with a mean of 0.12 and Karedu-1 (0.05 to 0.09 mg l⁻¹) with a mean of 0.07.

Culturing in general increased concentration of all the micronutrients during the study period. The extent of increase being higher in the case of Fe followed by Zn, Mn and Cu. The micronutrient content in the pond water in general was more in the second year of study compared to the first year.

4.2 EFFECT OF AQUACULTURE PONDS ON THE QUALITY OF GROUND WATERS

Effect of aquaculture ponds on the quality of ground water was assessed by drawing samples from wells/ponds/hand pumps/filter points located at varying lateral distances from the pond approximately upto a distance of 1 km. The samples were collected both at start of the culture and at the time of harvest of the culture during 1995-96 and 1996-97 are analysed for pH, EC, Ca, Mg, Na, K, CO₃, HCO₃, Cl, SO₄, NO₃-N, B, F, heavy metals viz., Cr, Pb, Ni, Cd, micronutrients viz., Zn, Fe, Cu, Mn, and COD. The mean data are presented in Tables 6 to 11 and depicted in Figs. 9 to 21. The zero distance in the figures indicate the data pertaining to pond waters.

4.2.1 Effect of fresh water fish culture

From the data presented in Tables 6 to 8 and illustrated in Figs. 8 to 14 it could be noticed that the properties of ground water around the fresh water fish culture ponds were affected at different locations and distance of sampling from the

pond and time of sample collection, the extent of which varied with the nature of the property.

4.2.1.1 pH

From the data presented in Tables from 6 to 8 and depicted in Fig. 8 it could be noticed that the pH of ground water was generally higher at Rebala followed by Purini and Kovur. It was varying in the order of Rebala (8.29 to 8.81) > Purini (8.0 to 8.15) > Kovur (7.56 to 7.91). In general culturing did not increase the pH at all three locations. Higher pH of ground water was obtained upto 10 m lateral distance from the pond in the case of Rebala and upto 100 m in the case of Purini. In the case of Kovur, pH was not influenced due to fresh water fish culture.

4.2.1.2 Salinity (EC)

The data on electrical conductivity of ground water presented in Tables from 6 to 8 and illustrated in Fig.8, indicated that salinity of ground water was generally higher at purini followed by Rebala and Kovur. It was varying from 1.793 to 5.183 dSm⁻¹ at Purini, from 1.080 to 2.460 dSm⁻¹ at Rebala, from 1.368 to 1.935 dSm⁻¹ at Kovur. The EC, in general was higher at the time of harvest of the culture as compared to that at the start of the culture at all three locations sampled. However, the difference in the salinity between the start and harvest of the culture was relatively higher at Purini followed by Rebala and Kovur. The adverse effects of salinity of ground water continued upto 330 m at Purini. These were observed only upto 10 m at Rebala. The ground water was not appreciably influenced due to fresh water fish culture at Kovur (1.368 to 1.935 dSm⁻¹).

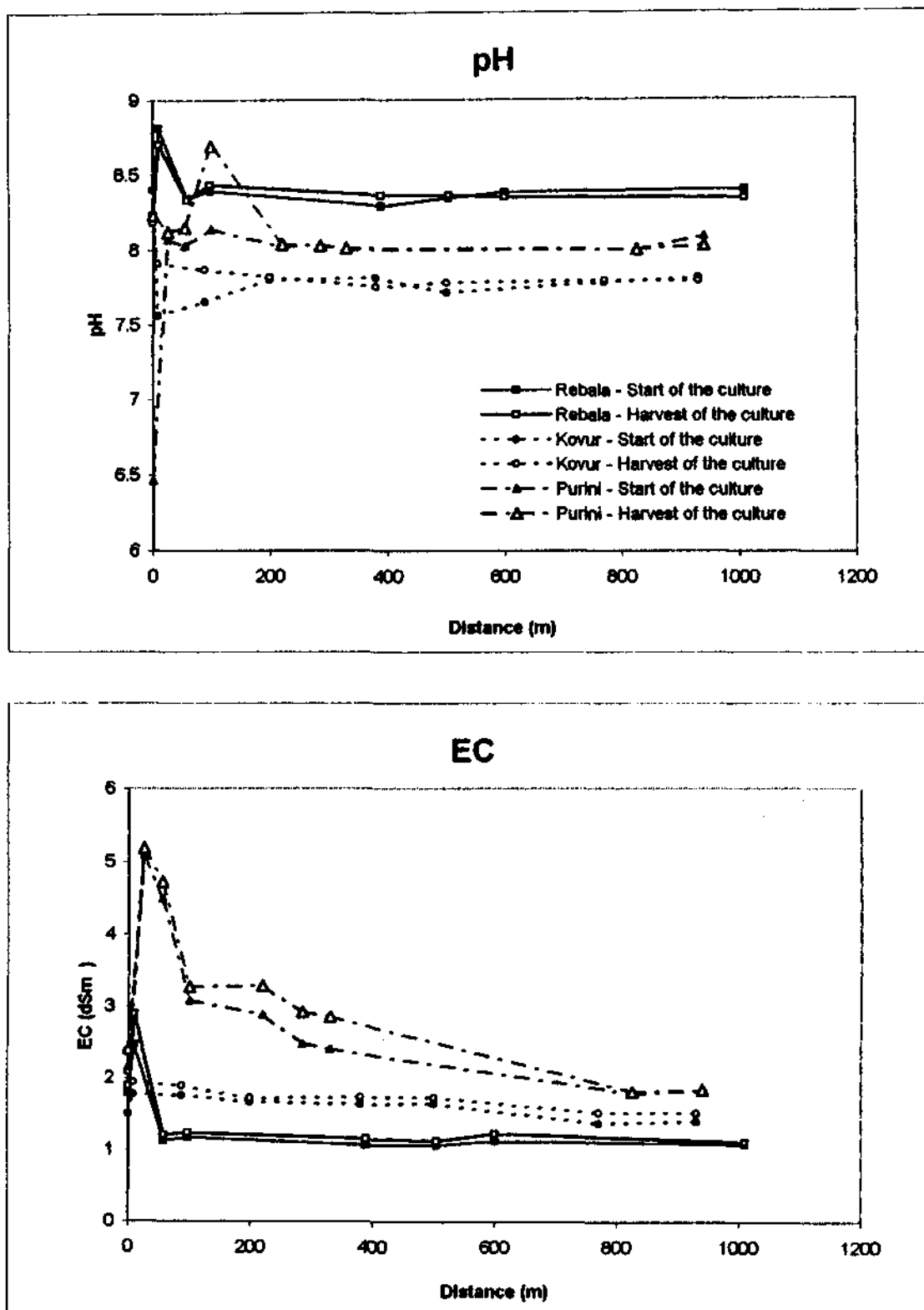


Fig. 8: Influence of fresh water fish culture on pH and EC of ground waters at different distances from the ponds

The salt build up as indicated by EC in the ground waters at Purini ranged from 3.356 dSm^{-1} at 25 m distance from the pond to a minimum of 1.023 dSm^{-1} at 330 m from the pond as compared to salinity at 940 m, which was taken as control. The salt accumulation at Rebala was highest magnitude with EC being higher by 1.780 dSm^{-1} at 10 m distance from the pond to a minimum of 0.012 dSm^{-1} at 305 m distance from the pond as compared to the salinity in ground waters at 1010 m from the pond. The salt content at Kovur was the maximum of 0.420 dSm^{-1} at 8 m distance from the pond to a minimum of 0.215 dSm^{-1} at 500 m from the pond as compared to the same at 930 m from the pond.

The ^{rise} in the salt content as indicated by EC in ground waters at Purini was observed to be highest 5.183 dSm^{-1} at 25 m from the pond to a minimum of 1.813 dSm^{-1} at 825 m from the pond. The magnitude of salt accumulation in ground waters was next highest at Rebala, the maximum being 2.89 dSm^{-1} at 10 m distance from the pond. It was the minimum of 1.110 dSm^{-1} at 1010 m from the pond. The salt accumulation was least at 8 m (1.935 dSm^{-1}) from the pond at Kovur and it was minimum of 1.513 dSm^{-1} at 930 m from the pond.

4.2.1.3 Cationic composition

The amount of cations in the underground water varied in the following order: $\text{Na} > \text{Ca} > \text{Mg} > \text{K}$ (Tables from 6 to 8 and Fig.9).

4.2.1.3.1 Calcium (Ca)

The higher Ca content of ground waters continued upto 220 m at Purini and upto 88 m at Kovur. At Rebala, however no specific trend of variation

was noticed. The Ca content of ground waters was varying in the order of Purini (1.50 to 5.65 c mol l⁻¹) > Kovur (2.80 to 5.0 c mol l⁻¹) > Rebala (1.50 to 2.55 c mol l⁻¹) (Tables 6 to 8 and Fig.9). In general, it was higher at the time of harvest of the culture (1.55 to 5.70 c mol l⁻¹) as compared to the start of the culture (1.50 to 5.65 c mol l⁻¹) at all the three locations studied. The Ca content was more in the water resources which are closer to the ponds.

4.2.1.3.2 Magnesium (Mg)

The Mg content (Tables 6 to 8 and Fig.9) was higher in the immediate neighbourhood of the ponds and it was less as the distances from the ponds increased. The Mg content in the ground water was varying in the orders of Purini (1.05 to 7.6 c mol l⁻¹) > Kovur (1.05 to 2.75 c mol l⁻¹) > Rebala (1.10 to 2.05 c mol l⁻¹). It was higher at the harvest of the culture as compared to start of the culture at all three locations. However, the difference in Mg content between the start of the culture and harvest of the culture was relatively higher at Purini followed by Kovur and Rebala. The higher Mg content continued upto 100 m at Purini and only upto 10 m at Rebala. At Kovur, however, the Mg content was not influenced by ponding with fresh water.

4.2.1.3.3 Sodium (Na)

The Na content (Tables 6 to 8 and Fig.9) of ground water was varying in the order of Purini (14.70 to 37.9 c mol l⁻¹) > Rebala (7.13 to 21.88 c mol l⁻¹) > Kovur (8.93 to 11.48 c mol l⁻¹). In general, the Na was uniformly higher at the harvest of the culture as compared to the same at the start of the culture at all the

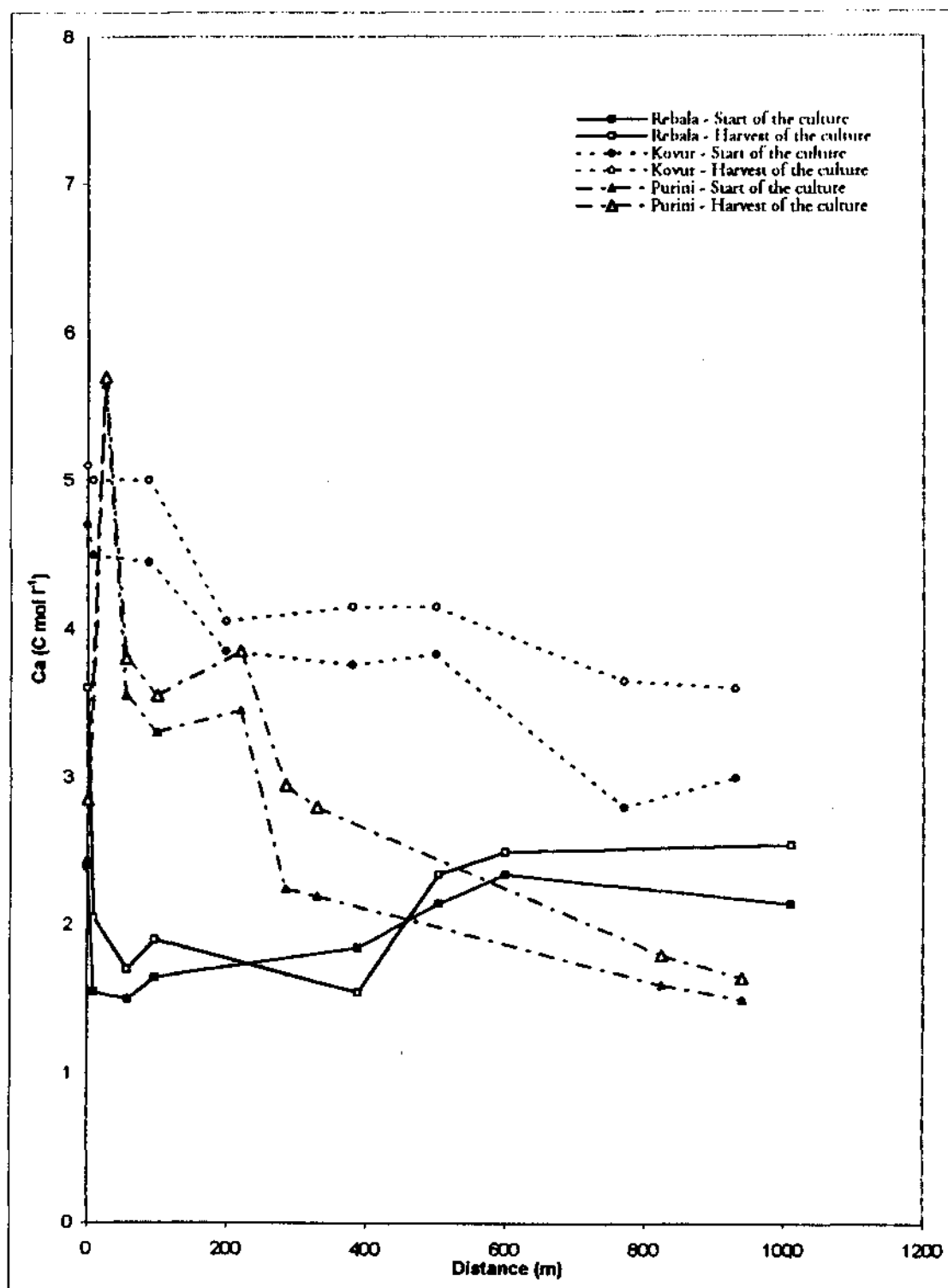


Fig.9 (a): Influence of fresh water fish culture on Ca content of ground waters at different distances from the ponds.

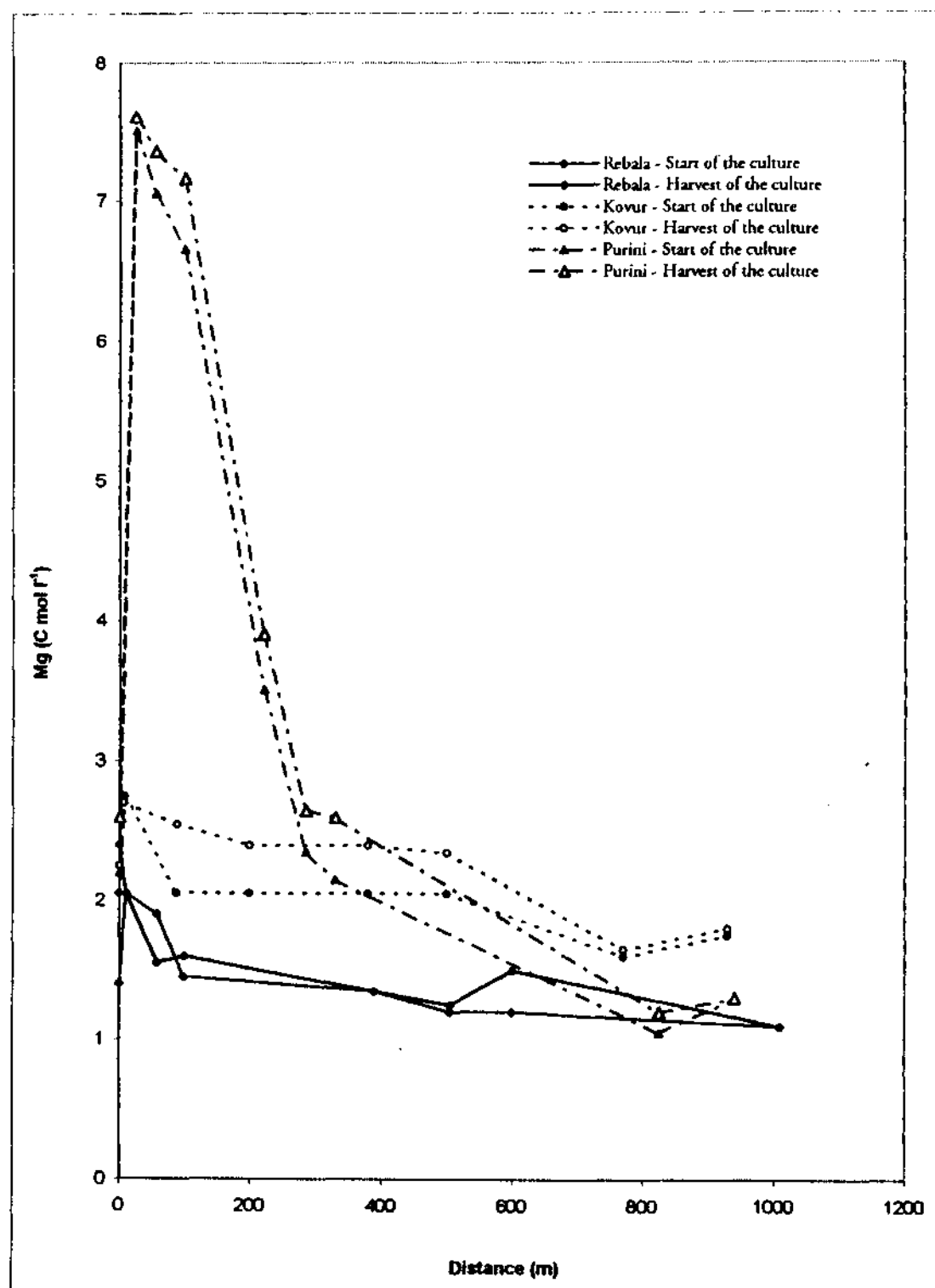


Fig. 9 (b): Influence of fresh water fish culture on Mg content of ground waters at different distances from the ponds.

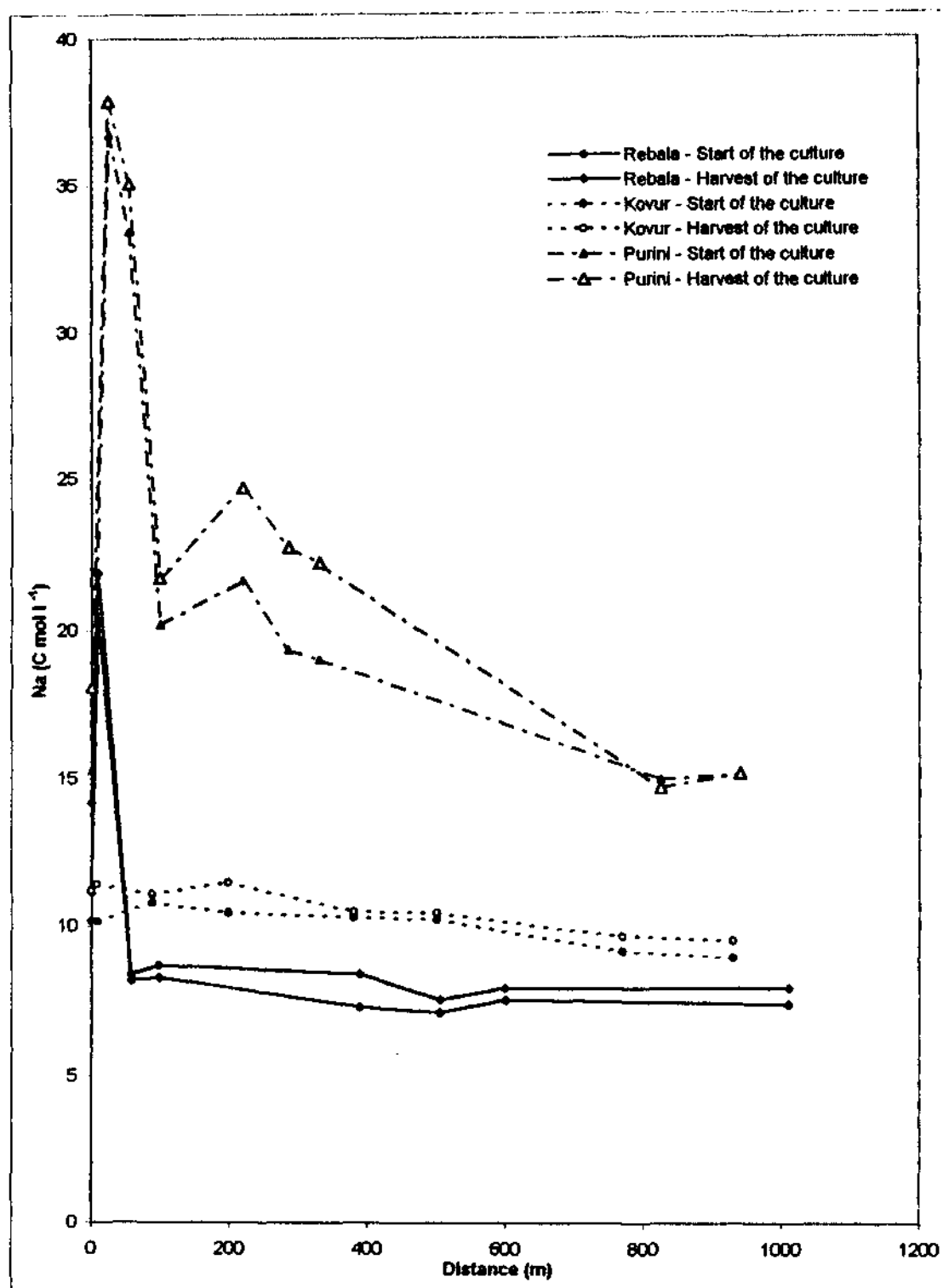


Fig. 9(c): Influence of fresh water fish culture on Na content of ground waters at different distances from the ponds.

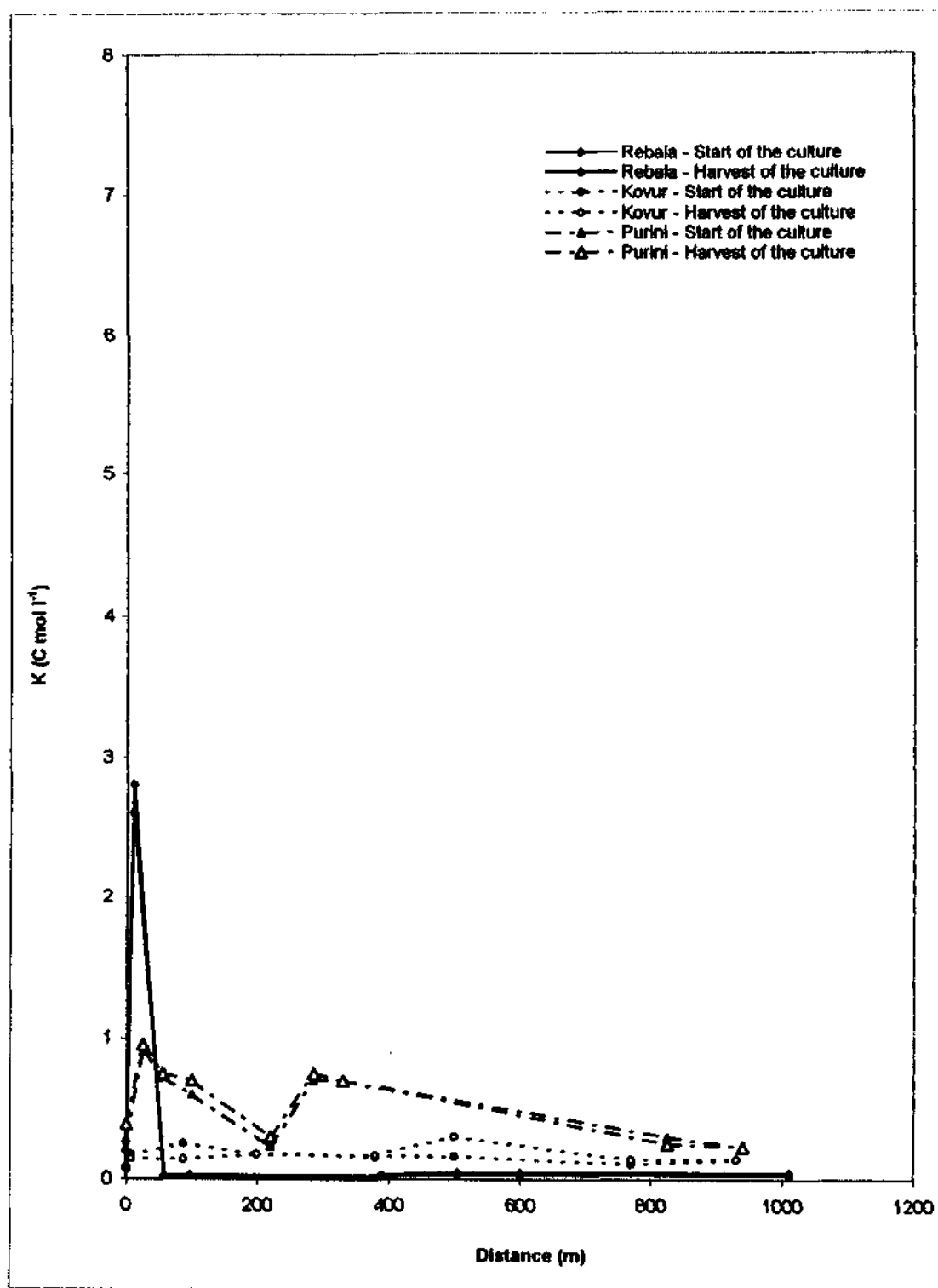


Fig. 9 (d): Influence of fresh water fish culture on K content of ground waters at different distances from the ponds.

three locations. However, the difference in Na content between the start of the culture and harvest of the culture was relatively higher at Purini followed by Rebala and Kovur. The higher content of Na continued upto 330 m at Purini and upto 10 m at Rebala. However, fish culture did not influence the ground water especially at Kovur.

4.2.1.3.4 Potassium (K)

The K content in the ground water (Tables 6 to 8 and Fig.9) was varying in the order of Rebala (0.025 to $2.60 \text{ c mol l}^{-1}$) > Purini (0.23 to $0.95 \text{ c mol l}^{-1}$) > Kovur (0.11 to $0.18 \text{ c mol l}^{-1}$). In general, the K was higher at the harvest of the culture as compared to the same at the start of the culture at all the locations sampled except at Rebala. The higher K continued upto 330 at Purini and upto only 10 m at Rebala but the K was almost identical during the study period at Kovur.

4.2.1.4 Anionic composition

4.2.1.4.1 Carbonates (CO_3)

In the ground waters studied chlorides were dominating (3.93 to $34.73 \text{ c mol l}^{-1}$) followed by HCO_3 (5.70 to $16.30 \text{ c mol l}^{-1}$) and SO_4 (0.12 to $1.90 \text{ c mol l}^{-1}$). No carbonate could be detected in the ground water sample at all the three locations studied (Tables 6 to 8 and Fig.10).

4.2.1.4.3 Bicarbonates (HCO_3)

The bicarbonate content (Tables 6 to 8 and Fig. 10) of ground waters was varying in the order of Purini (10.00 to 16.30 c mol l^{-1}) > Rebala (5.70 to 13.85 c mol l^{-1}) > Kovur (6.05 to 8.1 c mol l^{-1}). Bicarbonates were higher at the harvest of the culture as compared to the same at the start of the culture at Purini only. Higher HCO_3 content continued upto 55 m at Purini and only upto 10 m at Rebala. It was not influenced by fish culture at Kovur during the study period.

4.2.1.4.3 Chlorides (Cl)

From the data presented in Tables 6 to 8 and illustrated in Fig. 10, it could be noticed that the Cl^- content of ground waters at the three locations studied was varying in the order of Purini (7.18 to 34.73 c mol l^{-1}) > Rebala (3.93 to 14.35 c mol l^{-1}) > Kovur (7.35 to 10.70 C mol l^{-1}). In general, Cl content was higher at the time of harvest of the culture as compared to the start of the culture at all the locations sampled. The chloride content in general, in the wells near to the fish ponds was many times more compared to the far away places. The higher Cl content in the under ground waters continued upto 330 m at Purini and upto only 10 m at Rebala. At Kovur, its content did not vary much during the sampling period.

4.2.1.4.4 Sulphates (SO_4)

The SO_4 content of ground waters was varying in the order of Purini (0.20 to 1.90 c mol l^{-1}) > Kovur (0.20 to 0.70 c mol l^{-1}) > Rebala (0.12 to 0.75 c mol l^{-1}) (Tables 6 to 8 and Fig. 10). In general, its content in the ground waters was higher at the time of harvest of the culture as compared to that at the start of the

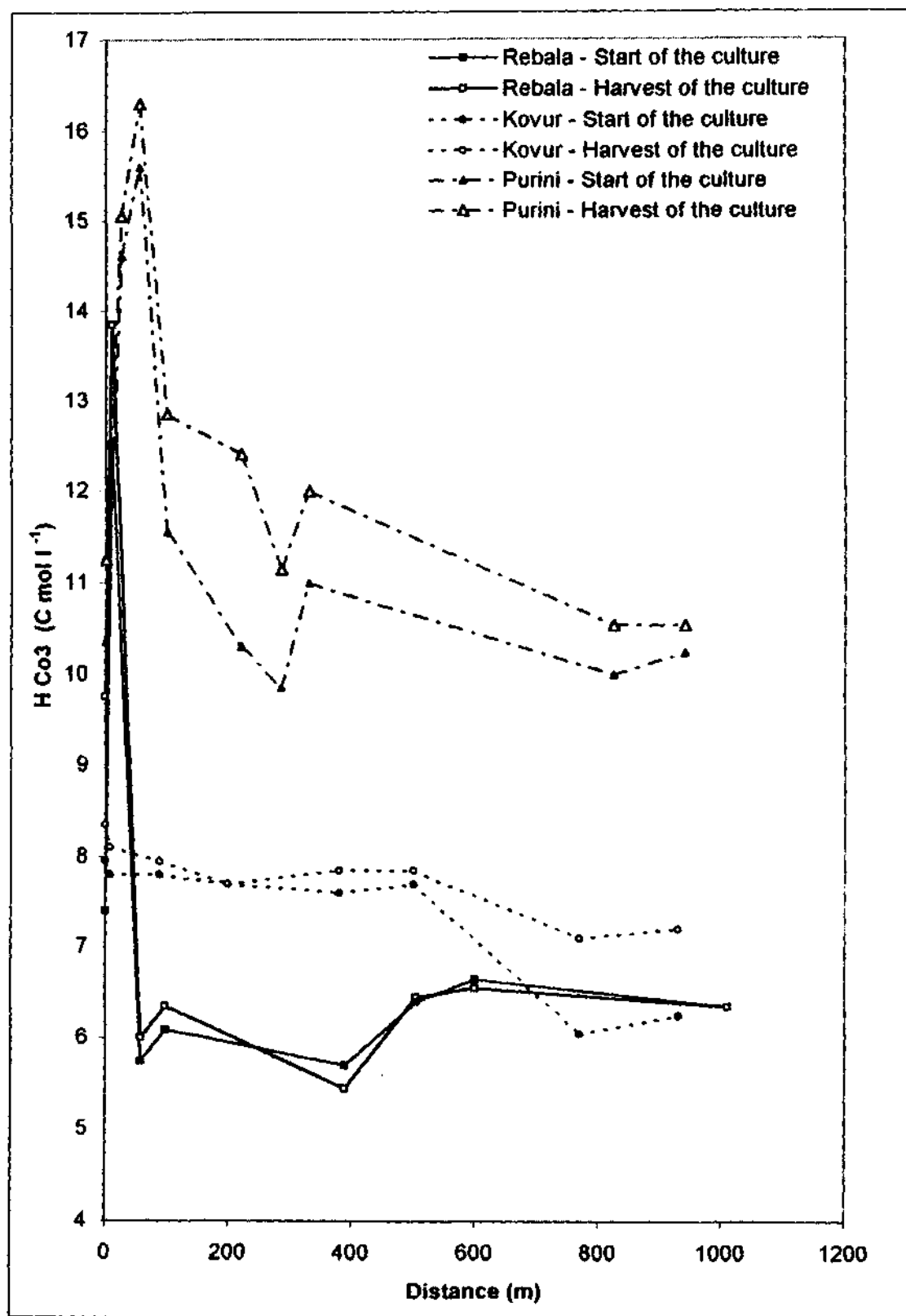


Fig.10(a): Influence of fresh water fish culture on HCO_3^- content of ground water at different distances from the pond.

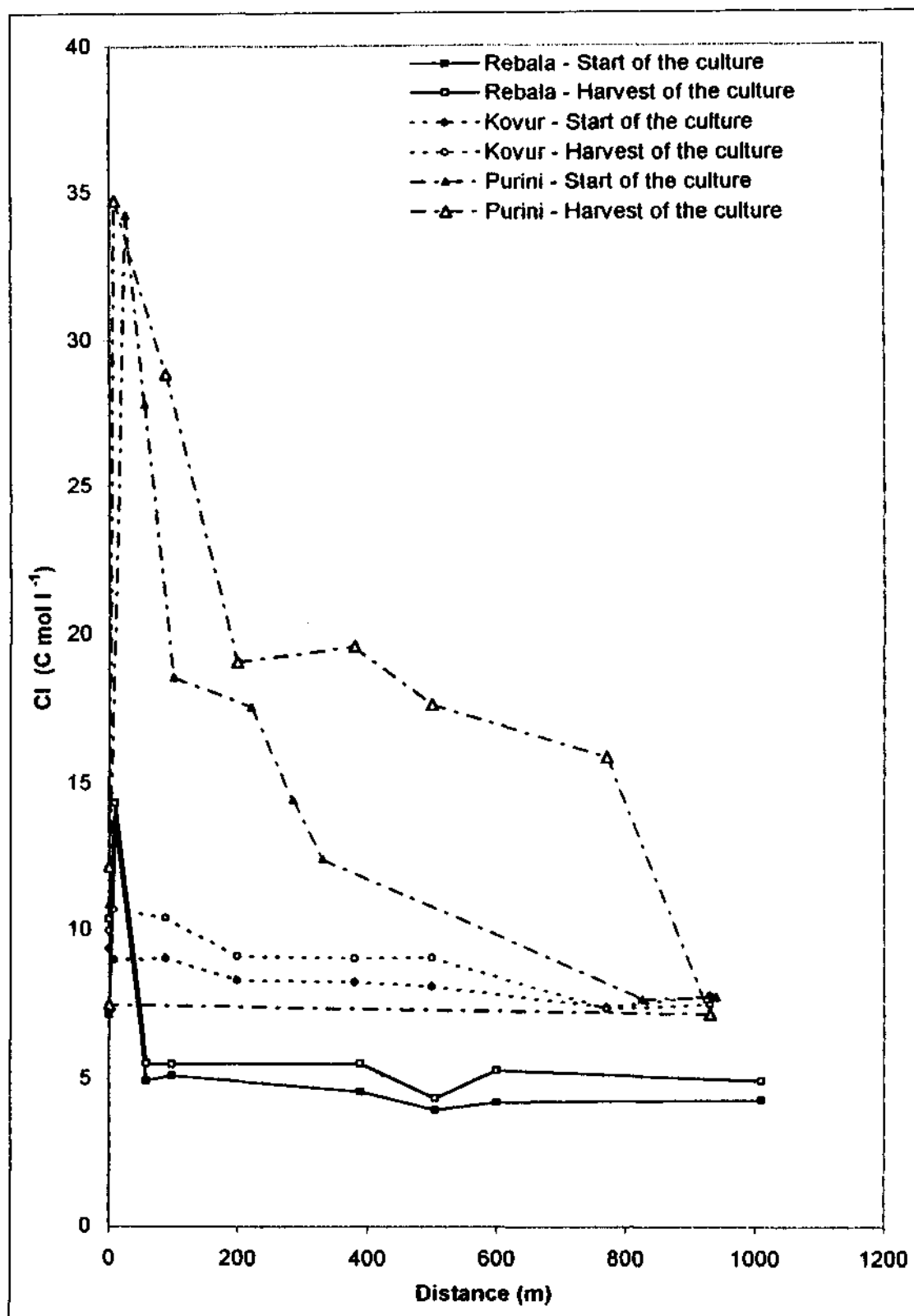


Fig.10(b): Influence of fresh water fish culture on Cl content of ground water at different distances from the pond.

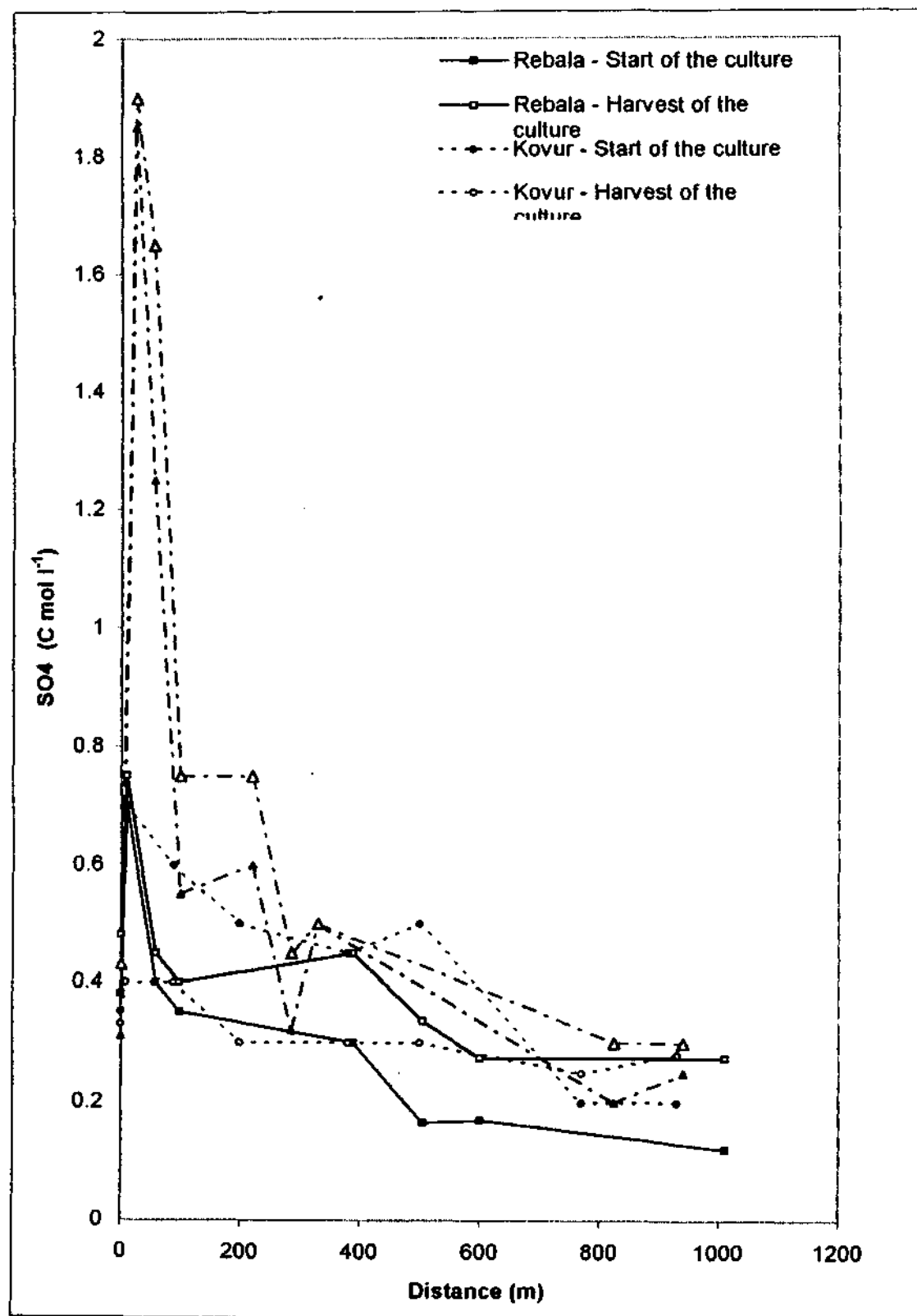


Fig.10(c): Influence of fresh water fish culture on SO_4 content of ground water at different distances from the pond.

culture at all the three locations. The concentration of sulphate in the ground water closer to the ponds was highest and it decreased with increase in distance from the pond. The higher SO_4 content in the ground waters continued upto 220 m and 10 m at Purini and Rebala respectively from these corresponding ponds. Its variation did not follow any specific trend at Kovur.

4.2.1.5 Nitrate nitrogen ($\text{NO}_3\text{-N}$)

A wide variation in $\text{NO}_3\text{-N}$ content (Tables 6 to 8 and Fig.11) in ground waters was observed among the three locations studied. Its content was much higher (2.85 to 4.2 mg l^{-1}) at Kovur compared to that at Rebala and Purini. At Rebala its content was slightly higher (0.13 to 0.43 mg l^{-1}) as compared to that at Purini (0.00315 to 0.0042 mg l^{-1}).

At Rebala, the $\text{NO}_3\text{-N}$ was significantly influenced only upto a distance of 10 m by the time of culture harvest. At Purini, the ground waters were almost unaffected by the presence of aquaculture pond.

4.2.1.6 Boron (B)

From the data presented in Tables to 8 and illustrated in Fig.11, it could be noticed that the B content of ground waters was very much higher in the immediate vicinity of the pond at Rebala upto a distance of 10 m (2.87 mg l^{-1}). Beyond 100 m and upto 500 m, the B content in under ground water of Purini was generally higher than Rebala and Kovur. However beyond 330 m, the B content was higher in Rebala waters as compared to that of Purini and Kovur waters. Culturing in general increased the boron content at Purini. At other locations i.e., at

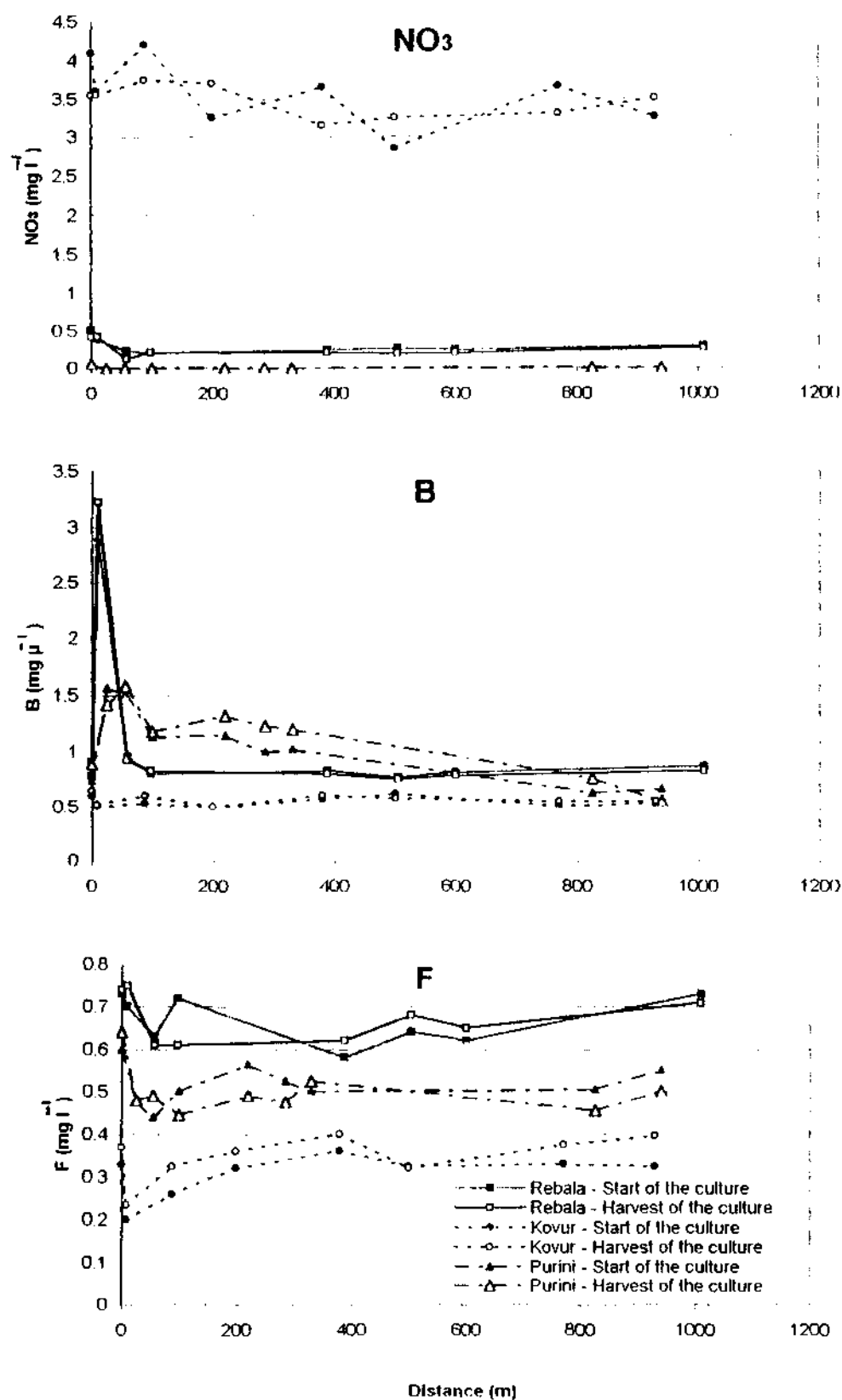


Fig. 11: Influence of fresh water fish culture on NO_3 , B and F content of ground waters at different distances from the pond.

Kovur and Rebala, B did not vary between starting of the culture and harvest of the culture

4.2.1.7 Fluoride (F)

The fluoride content of ground waters was generally higher at Rebala (0.58 to 0.75 mg l⁻¹) followed by that of Purini (0.44 to 0.39 mg l⁻¹) and Kovur (0.20 to 0.40 mg l⁻¹) (Tables 6 to 8 and Fig.11). Ponding of water generally decreased the F content in the immediate vicinity of the pond upto 58 m, 88 m and 55 m at Rebala, Kovur and Purini respectively

4.2.1.8 Heavy metals

From the data presented in Tables 6 to 8 and depicted in Fig.12, it could be noticed that the content of Pb and Cr at the locations studied compared to that of Cd and Ni, the pond water contained relatively higher amount of the heavy metals at all three locations studied thereby indicating that the fish culture found to be potential source of pollution of ground water.

4.2.1.8.1 Lead (Pb)

Lead content of ground water was generally higher at Purini (8.80 to 9.75 ug l⁻¹) followed by that of Rebala (5.70 to 6.35 ug l⁻¹) and Kovur (4.55 to 5.20 ug l⁻¹) (Tables 6 to 8 and Fig.12b) Its content did not vary during the culture period at all the locations studied

4.2.1.8.2 Cadmium (Cd)

Cadmium content at Purini was higher in the pond water compared to that of ground waters (Tables 6 to 8 and Fig. 12d). Its content was relatively higher in the ground waters of Rebala as compared to that of Kovur. The Cd was not detectable in the ground waters at Purini. Its content was generally higher in the waters of Rebala (1.05 to 1.5 $\mu\text{g l}^{-1}$) as compared to that of Kovur (0.75 to 0.9 $\mu\text{g l}^{-1}$).

4.2.1.8.3 Chromium (Cr)

The trend of variation of chromium content is generally the same as compared to that of Pb (Tables 6 to 8 and Fig. 12e). Pond waters contained higher quantity of Cr compared to the ground waters. Its content was generally higher in Purini and Rebala ground waters (4.0 to 5.25 $\mu\text{g l}^{-1}$) as compared to that of Kovur (2.45 to 3.35 $\mu\text{g l}^{-1}$).

4.2.1.8.4 Nickel (Ni)

The trend of variation in its content was the same as that of the other heavy metals excepting that its content was relatively lower as compared to Pb and Cr but higher as compared to that of Cd (Tables 6 to 8 and Fig. 12f). Its content was neither significantly differed at the different locations of sampling or by culturing. The higher content in the ponded water as compared to that of ground waters only indicates the potential danger of the ground water to getting contamination in course of time.

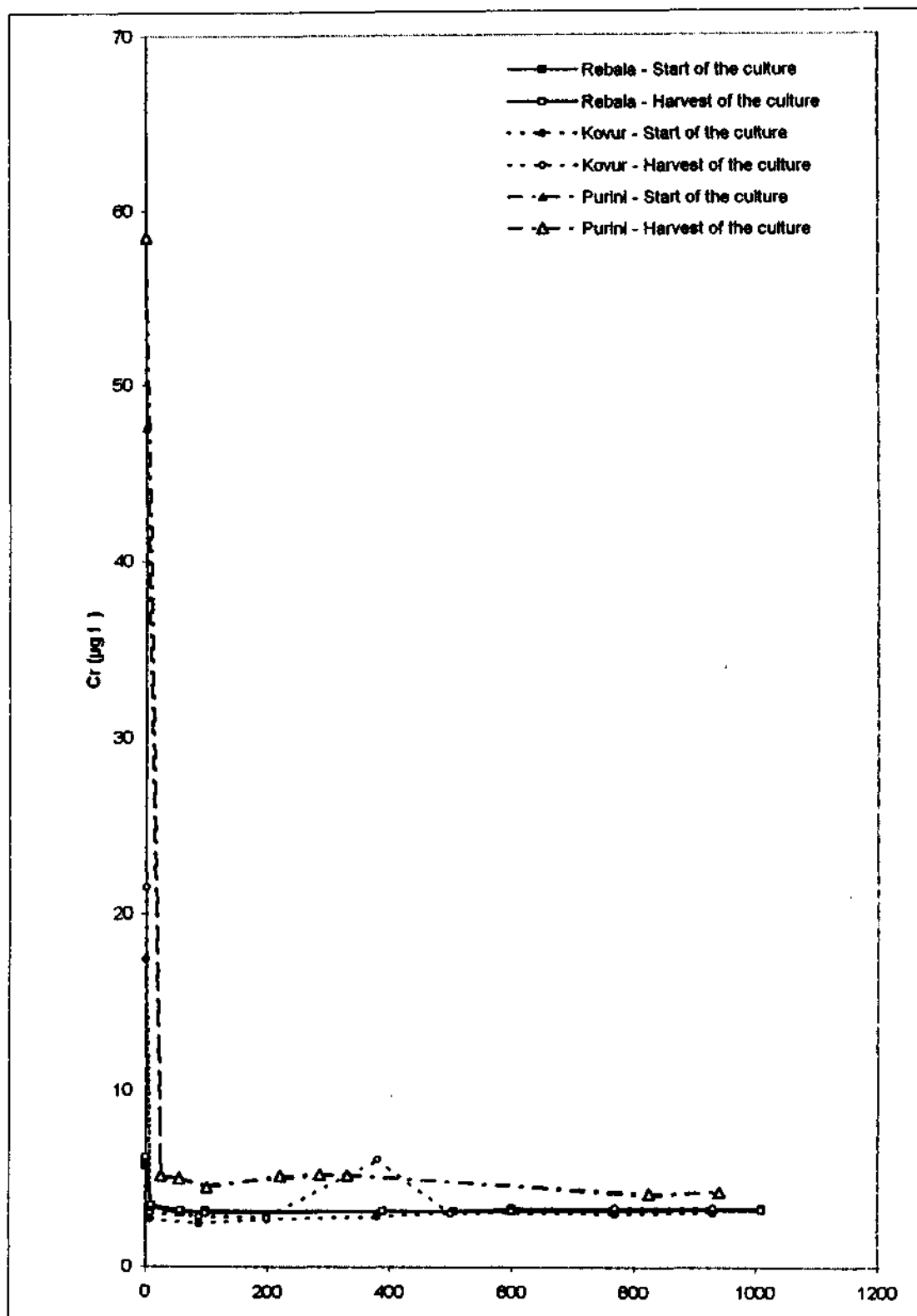


Fig.12(a): Influence of fresh water fish culture on Cr content of ground waters at different distances from the ponds.

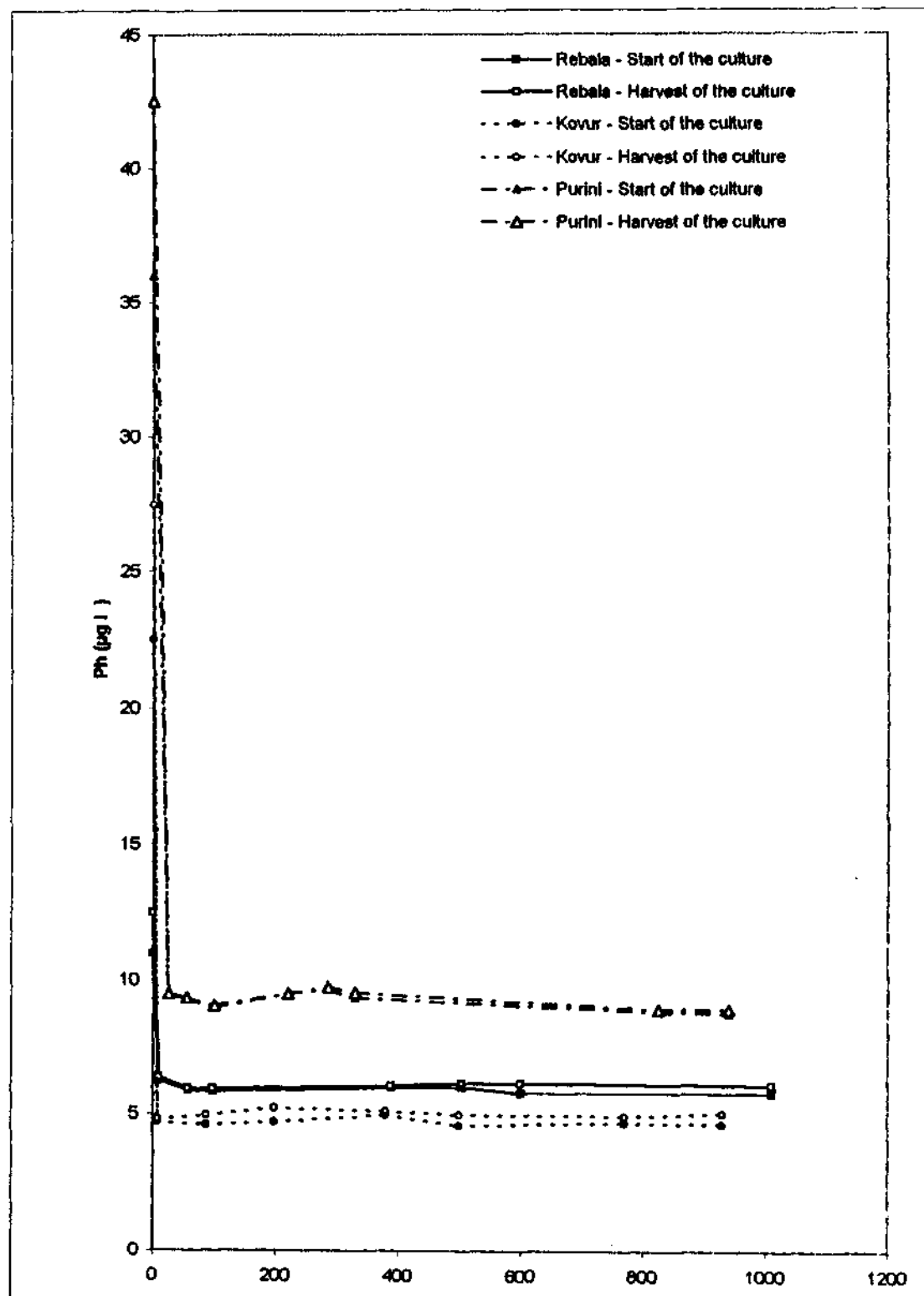


Fig.12(b): Influence of fresh water fish culture on Pb ground waters at different distances from the ponds.

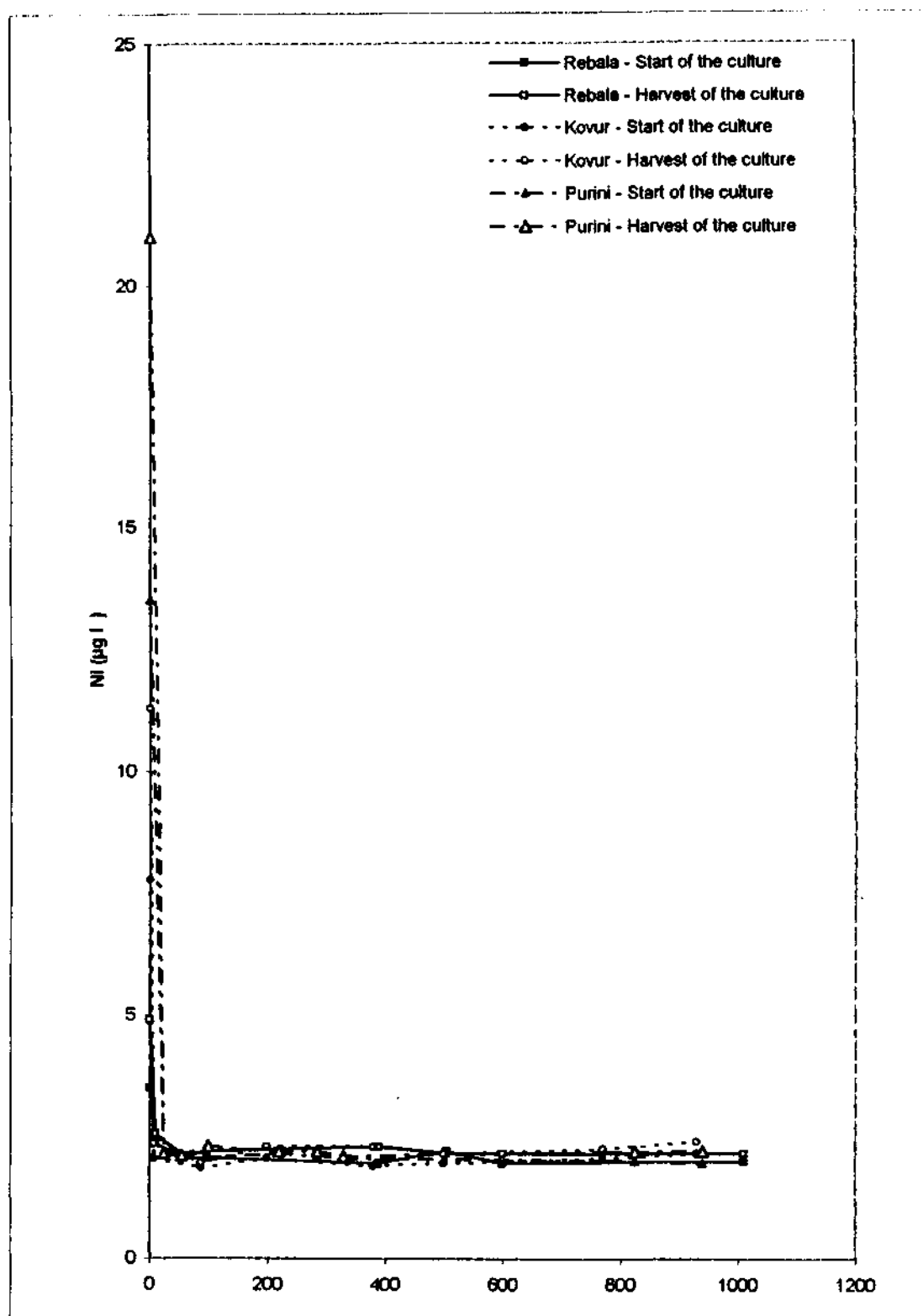


Fig.12(c): Influence of fresh water fish culture on Ni content of ground waters at different distances from the ponds.

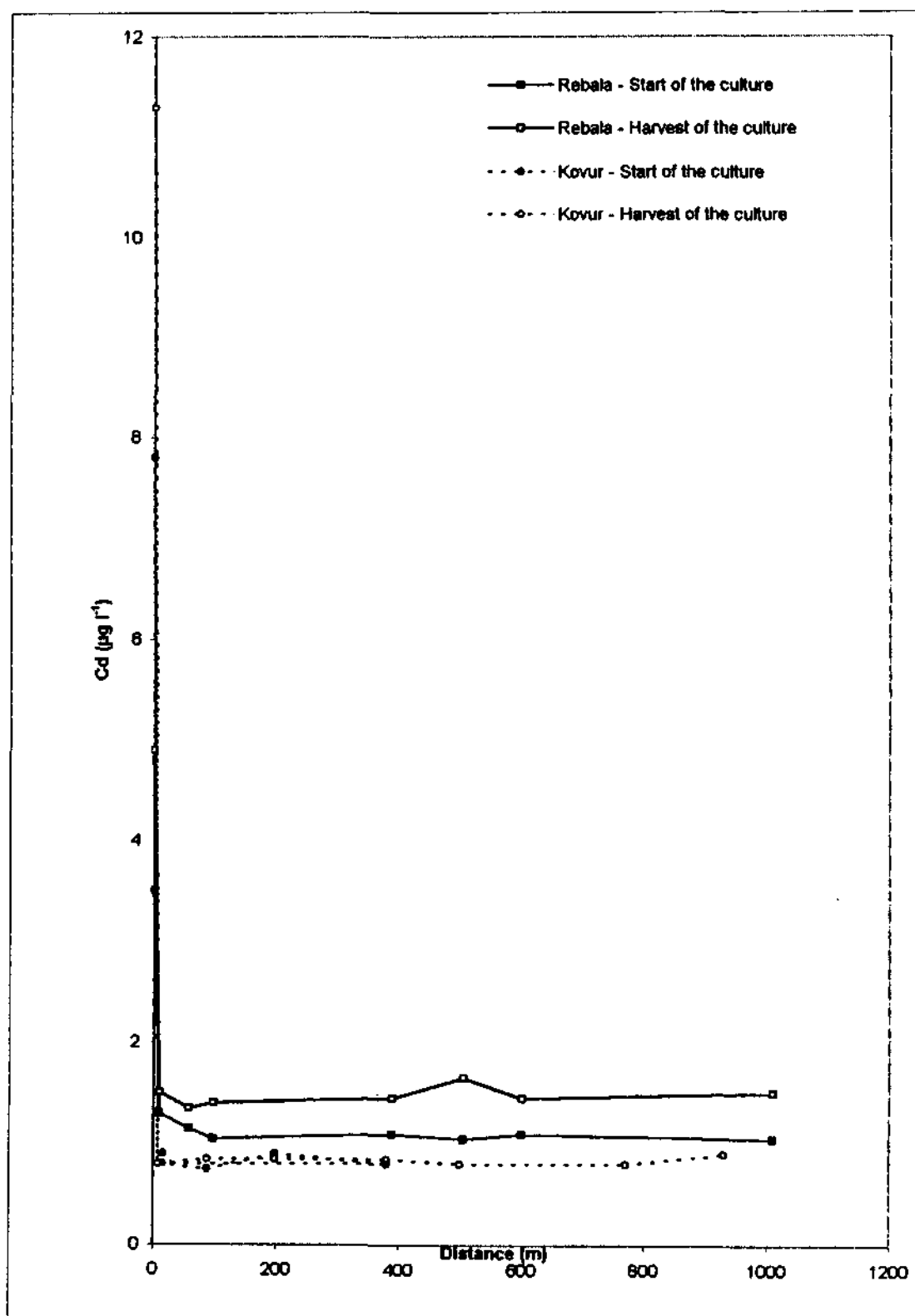


Fig.12(d): Influence of fresh water fish culture on Cd content of ground waters at different distances from the ponds.

4.2.1.9 Micronutrients

Micronutrients in the ground water varied in the following order: Fe (31.5 to 90.5 $\mu\text{g l}^{-1}$) > Zn (9.0 to 36.5 $\mu\text{g l}^{-1}$) > Mn (7.75 to 36.5 $\mu\text{g l}^{-1}$) > Cu (2.5 to 6.0 $\mu\text{g l}^{-1}$) (Tables 6 to 8 and Fig. 13).

4.2.1.9.1 Iron (Fe)

From the data presented in Tables 6 to 8 and illustrated in Fig. 13 it could be noticed that the Fe was generally higher at Purini (35.0 to 90.5 $\mu\text{g l}^{-1}$) followed by Rebala (32.0 to 63.0 $\mu\text{g l}^{-1}$) > Kovur (30.0 to 36.5 $\mu\text{g l}^{-1}$). In general Fe was higher upto 330 m at Purini compared to that of Rebala and Kovur. The difference in its content at the start of the culture and at the harvest of the culture was negligible at Kovur and Rebala. At Purini, however, it tended to slightly increase by the time of harvest as compared to that of start of the culture. Iron content was more in the pond water compared to the ground water. At Purini the Fe content in the ground waters was more in the immediate vicinity of the pond and it gradually decreased with the increase in the distance.

4.2.1.9.2 Zinc (Zn)

Zinc content in the pond water was more compared to the ground waters at all the three locations studied (Tables 6 to 8 and Fig. 13). Its content in the ground waters was generally higher at Purini (11.5 to 40 $\mu\text{g l}^{-1}$) followed by Kovur (14.0 to 18.0 $\mu\text{g l}^{-1}$) and Rebala (9.0 to 13.5 $\mu\text{g l}^{-1}$). In general, the Zn was uniformly higher at the harvest as compared to the start of the culture at all the three locations sampled. However, the difference between the start of the culture and harvest of the

culture was small and negligible at all the three locations of the study. Zinc content in the ground water was more in the wells near the ponds particularly at Purini and it decreased with the increase in distance. It did not vary much at Rebala and Kovur with distance.

4.2.1.9.3 Manganese (Mn)

Manganese content in the pond water was more compared to ground water at Rebala and Kovur (Tables 6 to 8 and Fig.13). Its content in the ground waters was gradually higher at Rebala (11.5 to $36.5 \mu\text{g l}^{-1}$) followed by Purini (11.0 to $34.5 \mu\text{g l}^{-1}$) and Kovur (7.5 to $10.75 \mu\text{g l}^{-1}$). In general, the Mn was uniformly higher at the harvest as compared to the start of the culture at all the three locations studied. However the difference between the start of the culture and harvest of the culture was small and negligible at all the three locations of the study. Manganese content in the ground water was more near the ponds and it decreased with the increase in distance at Purini, whereas in case of Rebala, the higher Mn in ground water was noticed at 10 m distance from the pond only. It did not vary much at Kovur.

4.2.1.9.4 Copper (Cu)

Copper content of fish pond waters was much more higher than the ground waters. In the ground waters it was noticed only at Rebala while the same was not detectable quantity at Kovur and Purini (Tables 6 to 8 and Fig.13). It was higher ($5.0 \mu\text{g l}^{-1}$) at 10 m at Rebala. Beyond 10 m, the Cu content was almost identical during the study period.

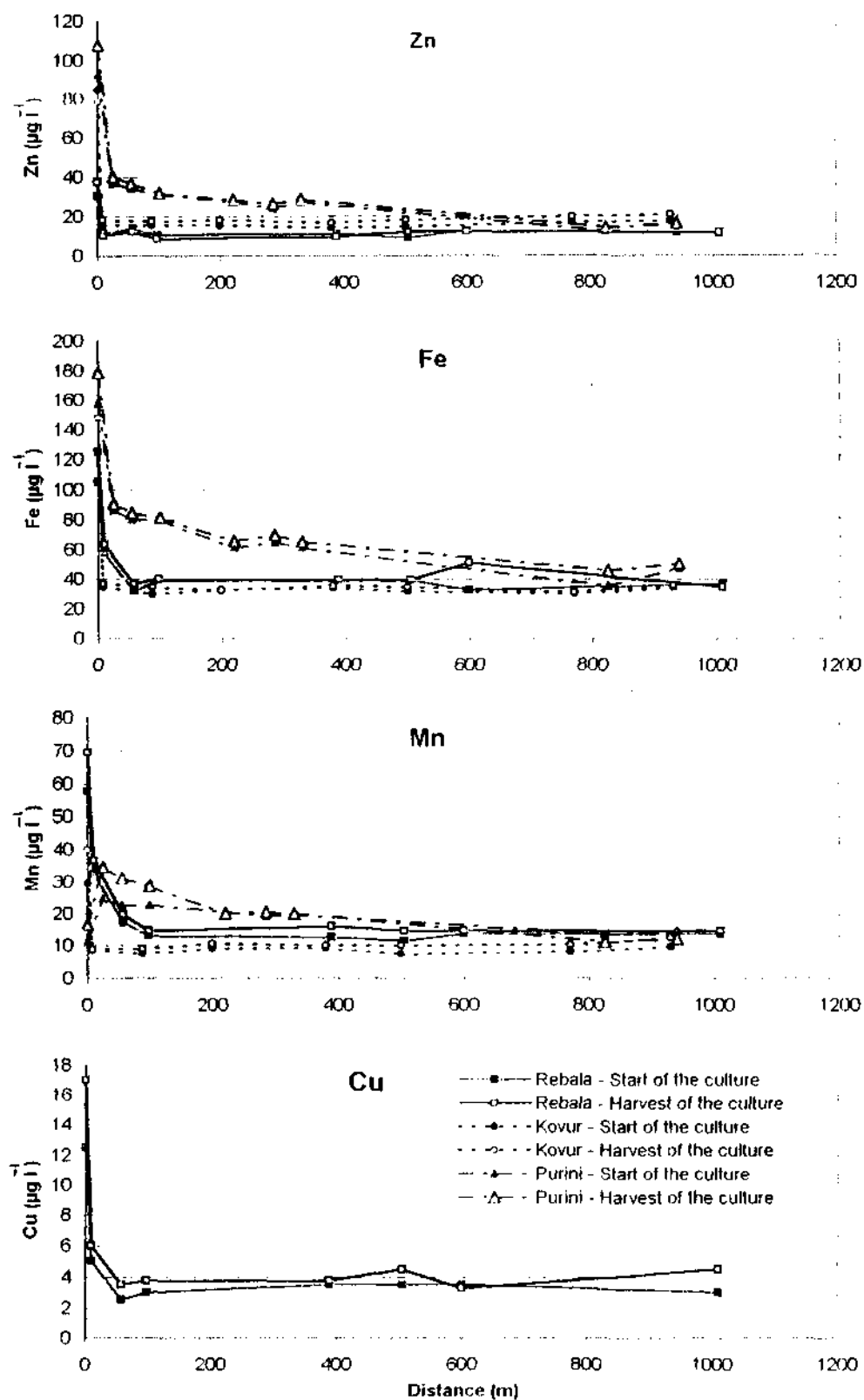


Fig. 13: Influence of fresh water fish culture on Zn, Fe, Mn and Cu content of ground waters at different distances from the ponds.

Table 6 : Mean chemical composition of ground water adjoining fresh water fish culture ponds of Rebala

Distance from the pond (m)	pH	EC (dSm ⁻¹)	Cations (c mol l ⁻¹)			Anions (c mol l ⁻¹)				
			Ca	Mg	Na	K	CO ₃	HCO ₃	Cl	SO ₄
Start of the culture (Mean of 1995-96 and 1996-97)										
0 (Pond water)	8.23	1.781	2.40	1.40	11.13	0.070	-	7.40	7.15	0.38
10	8.81	2.460	1.55	2.05	20.30	2.600	-	7.50	13.50	0.70
58	8.34	1.120	1.50	1.90	8.20	0.025	-	5.75	4.95	0.40
98	8.39	1.164	1.65	1.45	8.30	0.026	-	6.69	5.10	0.35
389	8.29	1.065	1.85	1.35	7.32	0.030	-	5.70	4.56	0.30
505	8.34	1.061	2.15	1.20	7.13	0.050	-	6.40	3.93	0.17
600	8.38	1.120	2.35	1.20	7.55	0.045	-	6.65	4.20	0.17
1010	8.40	1.108	2.15	1.10	7.39	0.045	-	6.35	4.27	0.12

Distance from the pond (m)	NO ₃ -N	B (mg l ⁻¹)	F	Heavy metals (µg l ⁻¹)				Micro nutrients (µg l ⁻¹)				COD (mg l ⁻¹)
				Cr	Pb	Ni	Cd	Zn	Fe	Cu	Mn	
Start of the culture (Mean of 1995-96 and 1996-97)												
0 (Pond water)	0.52	0.78	0.73	5.70	11.00	3.50	3.50	30.0	105.0	12.5	57.5	13.8
10	0.38	2.87	0.70	3.35	6.20	2.35	1.30	11.5	57.5	5.0	32.5	78.5
58	0.24	0.96	0.63	3.05	5.85	2.05	1.15	13.5	31.5	2.5	17.0	8.0
98	0.21	0.80	0.72	3.15	5.80	2.05	1.05	10.5	39.0	3.0	13.5	9.5
389	0.25	0.83	0.58	3.15	5.95	1.95	1.10	11.0	39.0	3.5	12.5	8.5
505	0.27	0.77	0.64	3.15	5.95	2.20	1.05	9.0	39.0	3.5	11.5	9.5
600	0.25	0.82	0.62	3.30	5.75	1.95	1.10	12.5	32.0	3.5	13.5	11.0
1010	0.30	0.87	0.73	3.30	5.70	2.00	1.05	11.5	36.5	3.0	13.5	11.0

Table 6 Contd.....

Distance from the pond (m)	pH	EC (dSm ⁻¹)	Cations (c mol l ⁻¹)				Anions (c mol l ⁻¹)			
			Ca	Mg	Na	K	CO ₃	HCO ₃	Cl	SO ₄
Harvest of the culture (Mean of 1995-96 and 1996-97)										
0 (Pond water)	8.20	1.883	3.60	2.40	14.17	0.090	-	9.75	10.35	0.48
10	8.70	2.890	2.05	2.05	21.88	2.800	-	13.85	14.35	0.75
58	8.33	1.205	1.70	1.55	8.40	0.028	-	6.60	5.53	0.45
98	8.43	1.235	1.90	1.60	8.70	0.028	-	3.35	5.50	0.40
389	8.36	1.150	1.55	1.35	8.40	0.025	-	5.45	5.53	0.45
505	8.36	1.123	2.35	1.25	7.55	0.035	-	6.45	4.33	0.34
600	8.35	1.225	2.50	1.50	7.95	0.030	-	6.55	5.30	0.28
1010	8.34	1.110	2.55	1.10	7.93	0.033	-	6.35	4.93	0.28

Distance from the pond (m)	NO ₃ -N	B (mg l ⁻¹)	F	Heavy metals (µg l ⁻¹)				Micro nutrients (µg l ⁻¹)				COD (mg l ⁻¹)	
				Cr	Pb	Ni	Cd	Zn	Fe	Cu	Mn		
Harvest of the culture (Mean of 1995-96 and 1996-97)													
0 (Pond water)	0.42	0.92	0.74	6.20	12.5	4.90	4.90	37.5	125.0	17.00	69.5	215.0	
10	0.43	3.23	0.75	3.45	6.4	2.55	1.50	10.0	63.0	6.00	36.5	96.0	
58	0.13	0.93	0.61	3.20	5.9	2.10	1.35	12.0	36.5	3.50	19.5	9.5	
98	0.22	0.83	0.61	3.05	5.9	2.20	1.40	8.5	40.0	3.75	14.5	10.5	
389	0.22	0.80	0.62	3.15	6.9	2.30	1.45	9.5	39.5	3.75	16.0	11.5	
505	0.20	0.75	0.68	3.20	6.1	2.15	1.65	12.0	39.5	4.50	14.5	9.5	
600	0.21	0.79	0.65	3.15	6.1	2.15	1.45	12.0	51.0	3.25	14.5	11.0	
1010	0.27	0.83	0.71	3.25	6.0	2.15	1.50	11.5	34.5	4.50	14.5	11.5	

Table 7: Mean chemical composition of ground water adjoining fresh water fish culture ponds of Kovur

Distance from the pond (m)	pH	EC (dSm ⁻¹)	Cations (c mol l ⁻¹)				Anions (c mol l ⁻¹)			
			Ca	Mg	Na	K	CO ₃	HCO ₃	Cl	SO ₄
Start of the culture (Mean of 1995-96 and 1996-97)										
0 (Pond water)	8.40	1.502	4.70	2.05	10.17	0.20	-	8.0	9.35	0.35
8	7.56	1.770	4.50	2.75	10.15	0.17	-	7.8	9.00	0.70
88	7.65	1.753	4.45	2.05	10.80	0.25	-	7.8	9.05	0.60
199	7.80	1.660	3.85	2.05	10.45	0.18	-	7.7	8.30	0.50
380	7.81	1.637	3.76	2.05	10.30	0.16	-	7.6	8.25	0.45
500	7.71	1.640	3.83	2.05	10.23	0.16	-	7.7	8.10	0.50
770	7.78	1.368	2.80	1.60	9.15	0.11	-	6.1	7.40	0.20
930	7.81	1.394	3.00	1.75	8.93	0.14	-	6.3	7.80	0.20

Distance from the pond (m)	NO ₃ -N	B	F	Heavy metals (µg l ⁻¹)				Micro nutrients (µg l ⁻¹)				COD (mg l ⁻¹)
	(mg l ⁻¹)			Cr	Pb	Ni	Cd	Zn	Fe	Cu	Mn	
Start of the culture (Mean of 1995-96 and 1996-97)												
0 (Pond water)	4.10	0.60	0.33	17.5	22.5	7.8	7.8	84.5	125.0	ND	29.5	16.0
8	3.60	0.51	0.20	2.7	4.7	2.1	0.8	15.5	34.5	ND	8.5	6.0
88	4.20	0.53	0.26	2.5	4.6	1.9	0.8	15.5	29.5	ND	7.5	4.5
199	3.25	0.50	0.32	2.7	4.7	2.1	0.9	15.5	32.5	ND	9.0	6.5
380	3.65	0.57	0.36	2.9	5.0	1.9	0.8	14.0	33.5	ND	9.3	6.5
500	2.85	0.62	0.33	3.1	4.6	2.0	0.8	14.5	31.5	ND	7.8	7.5
770	3.64	0.51	0.33	3.0	4.7	2.1	0.8	16.5	30.0	ND	8.0	5.0
930	3.25	0.54	0.33	3.1	4.6	2.2	0.9	17.5	34.0	ND	9.5	5.0

Table 7 Contd.....

Distance from the pond (m)	pH	EC (dSm ⁻¹)	Cations (c mol l ⁻¹)				Anions (c mol l ⁻¹)			
			Ca	Mg	Na	K	CO ₃	HCO ₃	Cl	SO ₄
Harvest of the culture (Mean of 1995-96 and 1996-97)										
0 (Pond water)	8.18	2.077	5.10	2.25	1.20	0.26	-	8.35	9.95	0.33
8	7.91	1.935	5.00	2.70	11.40	0.15	-	8.10	10.70	0.40
88	7.87	1.889	5.00	2.55	11.10	0.14	-	7.15	10.40	0.40
199	7.82	1.718	4.05	2.40	11.48	0.18	-	7.70	9.10	0.30
380	7.75	1.730	4.15	2.40	10.48	0.17	-	7.85	9.05	0.30
500	7.78	1.729	4.15	2.35	10.45	0.30	-	7.85	9.07	0.30
770	7.79	1.515	3.65	1.65	9.65	0.14	-	7.10	7.35	0.25
930	7.79	1.513	3.60	1.80	9.50	0.15	-	7.20	7.75	0.28

Distance from the pond (m)	NO ₃ -N	B	F	Heavy metals (µg l ⁻¹)				Micro nutrients (µg l ⁻¹)				COD (mg l ⁻¹)
	(mg l ⁻¹)			Cr	Pb	Ni	Cd	Zn	Fe	Cu	Mn	
Harvest of the culture of (1995-96 and 1996-97)												
0 (Pond water)	3.35	0.65	0.37	21.50	27.50	11.30	11.30	78.5	147.5	5.5	40.00	200.0
8	3.55	0.53	0.24	3.05	4.80	2.35	0.80	18.0	36.5	ND	8.75	7.0
88	3.75	0.61	0.33	2.85	4.95	1.95	0.85	17.5	34.5	ND	8.75	5.5
199	3.70	0.50	0.36	2.80	5.20	2.30	0.85	18.0	32.5	ND	10.50	4.5
380	3.15	0.61	0.40	3.10	5.10	2.30	0.85	16.5	35.0	ND	10.00	6.0
500	3.25	0.58	0.43	3.05	4.95	2.15	0.80	18.0	34.0	ND	10.00	7.0
770	3.30	0.55	0.38	3.50	4.90	2.35	0.80	19.5	31.0	ND	10.75	7.0
930	3.50	0.55	0.40	3.35	5.00	2.40	0.90	20.5	35.5	ND	12.50	6.5

Table 8 : Mean chemical composition of ground water adjoining fresh water fish culture ponds of Purini

Distance from the pond (m)	pH	EC (dSm ⁻¹)	Cations (c mol l ⁻¹)				Anions (c mol l ⁻¹)			
			Ca	Mg	Na	K	CO ₃	HCO ₃	Cl	SO ₄
Start of the culture (Mean of 1995-96 and 1996-97)										
0 (Pond water)	8.46	2.160	2.45	2.20	15.25	0.25	-	10.35	10.85	0.31
25	8.07	5.090	5.65	7.50	6.75	0.90	-	14.00	34.25	1.85
55	8.03	4.490	3.55	7.05	33.43	0.72	-	15.60	27.80	1.25
100	8.14	3.090	3.30	6.65	25.20	0.60	-	11.55	18.55	0.55
220	8.02	2.810	2.45	3.50	21.65	0.23	-	10.30	17.55	0.60
285	8.04	2.475	2.25	2.35	19.33	0.70	-	9.85	14.45	0.32
330	8.00	2.400	2.20	2.15	19.00	0.70	-	7.00	12.43	0.50
825	8.00	1.793	1.60	1.05	15.00	0.30	-	10.00	7.68	0.20
940	8.09	1.825	1.50	1.30	15.15	0.23	-	10.25	7.75	0.25

Distance from the pond (m)	NO ₃ -N	B (mg l ⁻¹)	F	Heavy metals (µg l ⁻¹)				Micro nutrients (µg l ⁻¹)				COD (mg l ⁻¹)	
				Cr	Pb	Ni	Cd	Zn	Fe	Cu	Mn		
Start of the culture (Mean of 1995-96 and 1996-97)													
0 (Pond water)	0.0490	0.74	0.60	47.50	36.00	13.50	ND	92.5	157.5	11.0	11.0	123.0	
25	0.0039	1.56	0.48	5.05	9.45	2.15	ND	36.5	36.5	ND	24.5	34.5	
55	0.0032	1.52	0.44	5.05	9.30	2.05	ND	34.0	80.0	ND	22.5	31.5	
100	0.0042	1.13	0.50	4.60	8.95	2.05	ND	31.0	79.5	ND	22.5	7.0	
220	0.0032	1.42	0.57	5.05	9.50	2.15	ND	27.0	60.5	ND	20.5	16.5	
285	0.0042	1.00	0.53	5.15	9.65	2.15	ND	24.0	64.5	ND	19.0	15.5	
330	0.0030	1.03	0.50	5.25	9.35	2.05	ND	27.0	61.0	ND	19.5	15.5	
825	0.0032	0.63	0.51	4.00	8.80	2.00	ND	12.0	35.0	ND	13.5	9.5	
940	0.0035	0.66	0.55	4.30	8.75	1.95	ND	11.5	47.5	ND	14.5	9.0	

Table 8 Contd.....

Distance from the pond (m)	pH	EC (dSm ⁻¹)	Cations (c mol l ⁻¹)				Anions (c mol l ⁻¹)			
			Ca	Mg	Na	K	CO ₃	HCO ₃	Cl	SO ₄
Harvest of the culture (Mean of 1995-96 and 1996-97)										
0 (Pond water)	8.23	2.400	2.85	2.60	18.05	0.39	-	11.25	12.15	0.43
25	8.12	5.183	5.70	7.60	37.90	0.95	-	15.05	34.73	1.90
55	8.12	4.720	3.80	7.35	35.07	0.75	-	16.30	28.85	1.65
100	8.19	3.275	3.55	7.15	21.75	0.70	-	12.85	19.08	0.75
220	8.04	3.290	3.85	3.90	24.70	0.30	-	12.40	19.60	0.75
285	8.03	2.920	2.95	2.65	22.70	0.75	-	11.15	17.65	0.45
330	8.01	2.280	2.80	2.60	22.23	0.70	-	12.00	15.90	0.50
825	8.00	1.813	1.80	1.20	14.70	0.25	-	10.55	7.18	0.30
940	8.03	1.840	1.65	1.36	15.18	0.23	-	10.50	7.48	0.30

Distance from the pond (m)	NO ₃ -N	B (mg l ⁻¹)	F	Heavy metals (µg l ⁻¹)				Micro nutrients (µg l ⁻¹)				COD (mg l ⁻¹)
				Cr	Pb	Ni	Cd	Zn	Fe	Cu	Mn	
Harvest of the culture (Mean of 1995-96 and 1996-97)												
0 (Pond water)	0.0570	0.89	0.64	58.5	42.50	21.00	ND	107.5	178.5	ND	16.5	128.0
25	0.0035	1.42	0.48	5.2	9.50	2.15	ND	40.0	90.5	ND	34.5	33.0
55	0.0032	1.58	0.49	5.0	9.35	2.10	ND	36.5	84.5	ND	31.0	31.0
100	0.0035	1.58	0.45	4.5	9.05	2.30	ND	31.5	81.0	ND	38.5	38.5
220	0.0039	1.32	0.49	5.2	9.50	2.20	ND	28.0	65.5	ND	20.0	15.5
285	0.0048	1.23	0.48	5.3	9.75	2.20	ND	26.0	69.5	ND	20.5	14.5
330	0.0035	1.20	0.53	5.2	9.55	2.10	ND	28.5	65.0	ND	20.0	15.5
825	0.0042	0.76	0.46	4.2	8.90	2.20	ND	14.0	46.0	ND	11.0	8.0
940	0.0033	0.55	0.50	4.3	8.90	2.20	ND	16.0	50.5	ND	12.0	8.0

4.2.1.10 Chemical Oxygen Demand (COD)

The data presented in Tables 6 to 8 and illustrated in Fig.14 indicated that the COD of fish pond water was many times more than the ground waters. COD was generally higher at Purini as compared to the same at Rebala and Kovur. The higher COD was noticed at 10 m (78.5 mg l^{-1}) at Rebala. At Kovur, adverse effects were not felt to any appreciable lateral difference. COD did not vary much during the culture period at Kovur and Rebala while there was slight increase at Purini at a lateral distance of 100 m.

4.2.2 Effect of brackish water prawn culture

From the data presented in Tables 9 to 11 and depicted in Figs.15 to 21 it could be noticed that the property studied were affected in all the locations to a certain distance from the pond. The extent of which varied with nature of the property.

4.2.2.1 pH

The pH of ground water (Tables 9 to 11 and Fig.15) was generally higher at Karedu-2 (7.65 to 7.98) followed by Karedu-1 (7.45 to 7.98) and Kolladinni () in that order. The pH was generally higher at the time of harvest as compared to that at the start of the culture at all the three locations studied. However, the difference in pH between the start of the culture and harvest of the culture was relatively higher at Karedu-2 followed by Karedu-1 and Kolladinni in that order. Higher pH of ground waters continued upto 338 m in the case of Karedu-2, upto 295 m in the case of Karedu-1 and 390 m at Kolladinni.

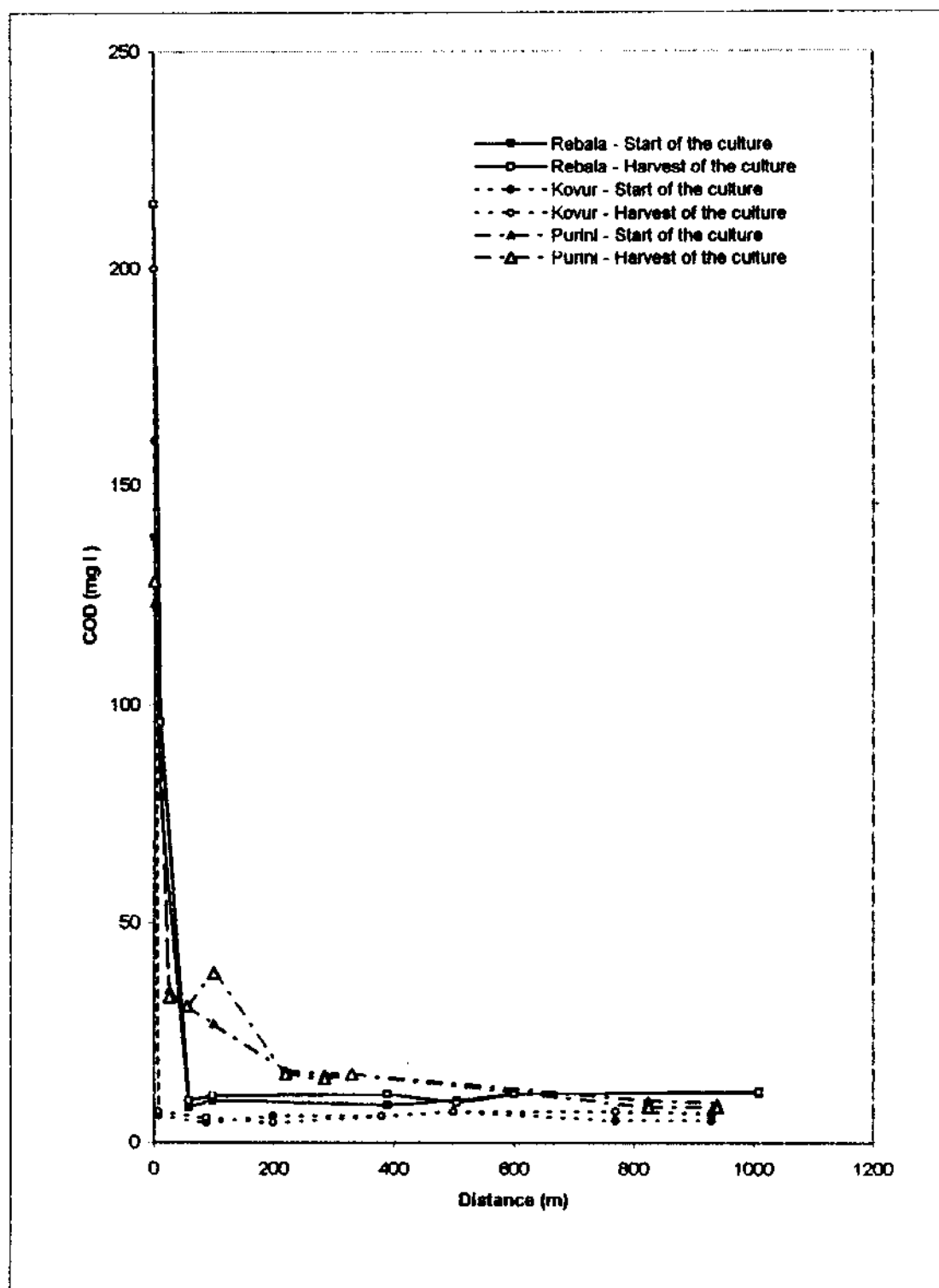


Fig.14: Influence of fresh water fish culture on COD of ground waters at different distances from the ponds.

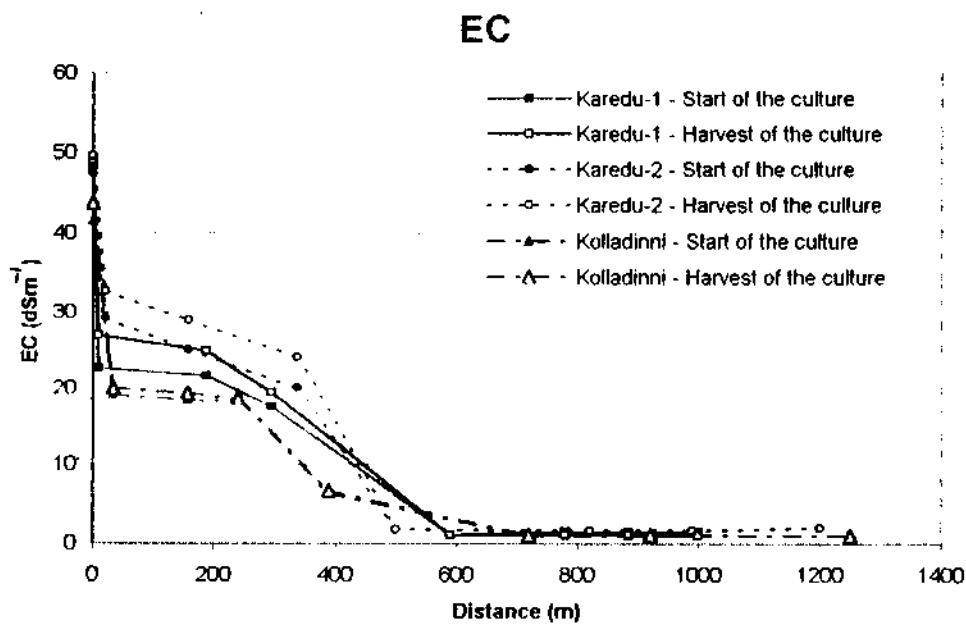
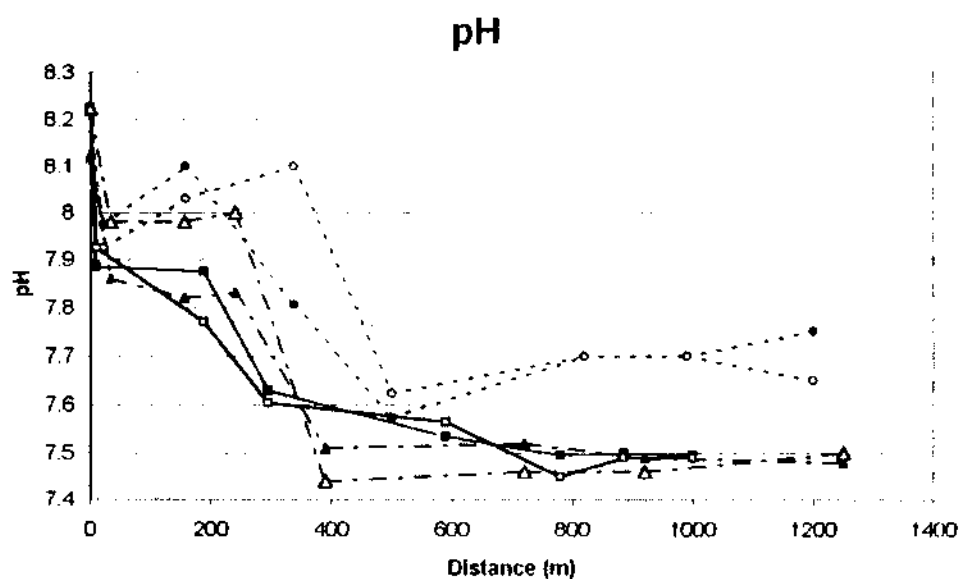


Fig. 15: Influence of brakish water prawn culture on pH and EC of ground waters at different distances from the ponds.

4.2.2.2 Salinity (EC)

From the data presented in Tables 9 to 11 and depicted in Fig.15 it could be noticed that the salinity as indicated by EC was generally higher at Karedu-2 followed by Karedu-1 and Kolladinni in that order. The salinity of the pond water at the three locations was varying in the order of Karedu-2 (1.53 to 32.70 dSm^{-1}) > Karedu-1 (1.03 to 27.0 dSm^{-1}) > Kolladinni (0.962 to 19.96 dSm^{-1}). The EC was higher at the time of harvest of the culture as compared to start of the culture at all the three locations studied. However, the difference in the salinity between the start of the culture and at the harvest of the culture was relatively higher at Karedu-2 followed by Karedu-1 and Kolladinni in that order. Prawn culture salinized the ground waters continued upto about 338 m in the case of Karedu-2, upto 320 m at Karedu-1 and upto 390 m in case of Kolladinni.

The salt accumulation in ground waters was highest at Karedu-2 (30.94 dSm^{-1}) at 22 m from the pond. It was low (22.39 dSm^{-1}) at 338 m from the pond. The salt accumulation was next in abundance (25.971 dSm^{-1}) at 10 m distance from the pond at Karedu-1 and it was low (18.389 dSm^{-1}) at 295 m from the pond. The salt accumulation was relatively low at Kolladinni. The EC was 18.918 dSm^{-1} at 34 m from the pond and was 5.618 dSm^{-1} at 390 m from the pond.

4.2.2.3 Cationic composition

The major cations in the ground water varied in the order $\text{Na} > \text{Mg} > \text{Ca} > \text{K}$. The Na concentration was many times higher than that of calcium (Tables 9 to 11 and Fig.16).

4.2.2.3.1 Calcium (Ca)

The data presented in Tables 9 to 11 and depicted in Fig.16, indicated that the Ca content of ground waters was generally higher at Kolladinni followed by Karedu-2 and Karedu-1. It was varying in the order of Kolladinni (1.28 to 19.35 c mol l^{-1}) > Karedu-2 (3.35 to 18.75 c mol l^{-1}) > and Karedu-1 (1.80 to 11.25 c mol l^{-1}). The Ca content was higher at the time of harvest as compared to start of the culture at all the three locations sampled in both the years. However, the difference in Ca between start of the culture and harvest of the culture was relatively higher at Kolladinni followed by Karedu-1 and Karedu-2 in that order while the higher Ca of ground waters continued upto 390 m in the case of Kolladinni, 295 m in the case of Karedu-1 and 338 m at Karedu-2.

4.2.2.3.2 Magnesium (Mg)

From the data presented in Tables 9 to 11 and depicted in Fig.16, it is noticed that Mg was generally higher at Karedu-2 followed by Kolladinni and Karedu-1. It was varying in the order of Karedu-2 (1.35 to 23.30 c mol l^{-1}), Karedu-1 (1.50 to 24.65 c mol l^{-1}) and Kolladinni (1.45 to 31.0 c mol l^{-1}). The Mg was higher at the time of harvest as compared to the start of the culture at all the three locations studied. However, the difference in Mg between the start of the culture and harvest of the culture was relatively higher at Kolladinni followed by Karedu-1 and Karedu-2. Higher amount of Mg was observed upto 338 m in the case of Karedu-2, 390 m in the case of Kolladinni and 295 m at Karedu-1, because of brackish water in the aquaculture ponds.

4.2.2.3.3 Sodium (Na)

Sodium content in the waters was almost same at Karedu-1 and Karedu-2 followed by Kolladinni (Tables 9 to 11 and Fig.16.). It was varying in that order of Karedu-2 (8.2 to 26.8 c mol l⁻¹), Kolladinni (5.0 to 164.0 c mol l⁻¹) and Karedu-1 (5.4 to 234.0 c mol l⁻¹).

In general, the Na was higher at the time of harvest as compared to the start of the culture at all the three locations sampled. However, the difference in Mg between the start of the culture and harvest of the culture was relatively higher at Karedu-1 followed by Karedu-2 and Kolladinni in that order. Higher Na was observed upto 338 m in the case of Karedu-2, 295 m in the case of Karedu-1 and upto 390 m at Kolladinni compared to the other distances away from the ponds.

4.2.2.3.4 Potassium (K)

The data presented in the tables 9 to 11 and depicted in Fig.16, indicate that K content of ground waters was varying in the order of Karedu-2 (1.35 to 8.85 c mol l⁻¹) > Karedu-1 (0.75 to 2.45 c mol l⁻¹) > Kolladinni (1.05 to 1.98 c mol l⁻¹). In general, higher K was found at the time of harvest as compared to the start of the culture at all the locations. However, the difference in K between the start of the culture and harvest of the culture was relatively higher in the case of Karedu-2. Higher K was found from the pond upto 338 m at Karedu-2, upto 295 m at Karedu-1 and upto 390 m at Kolladinni.

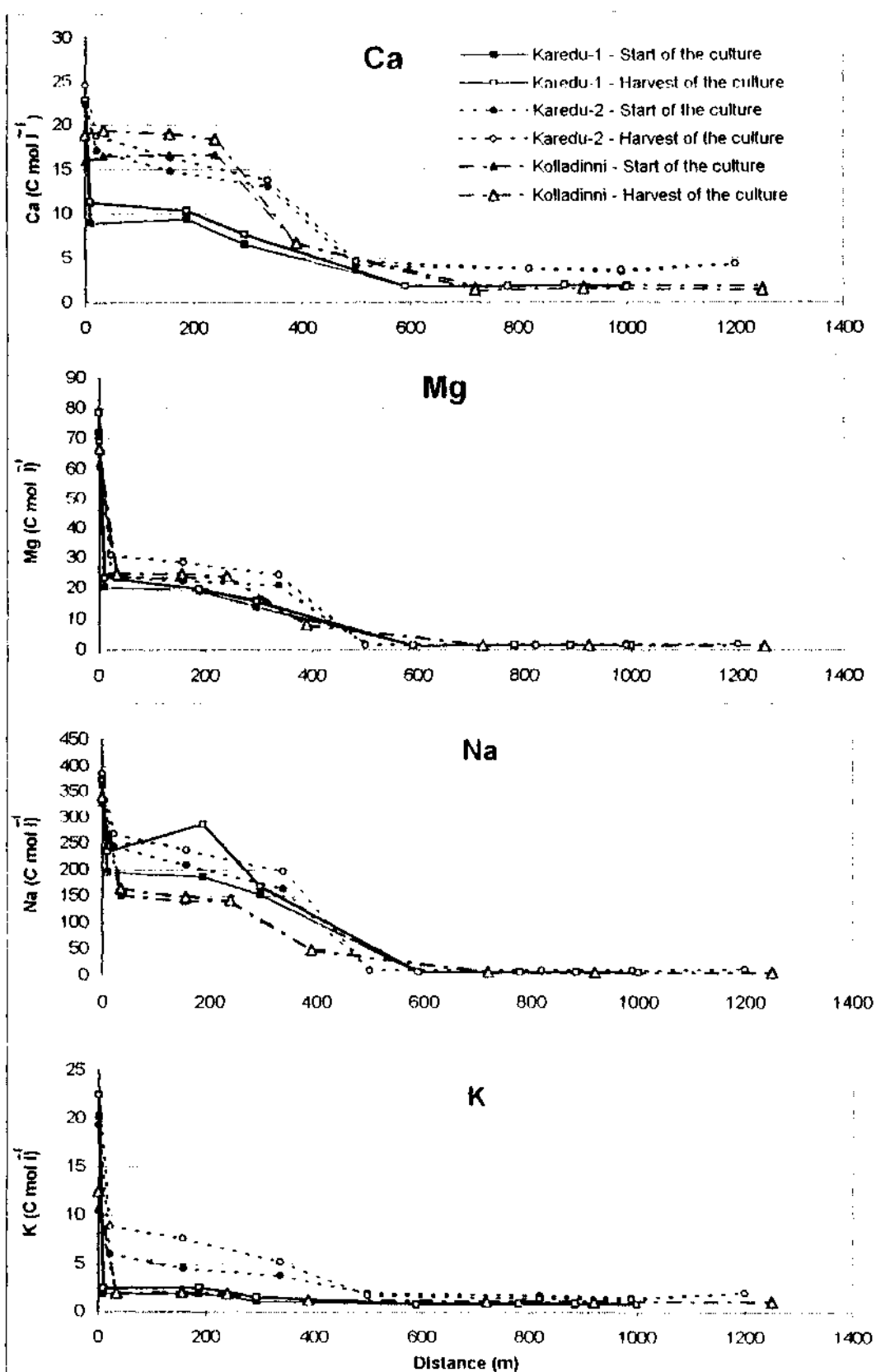


Fig. 16: Influence of brackish water prawn culture on Ca, Mg, Na and K content of ground waters at different distances from the ponds.

4.2.2.4 Anionic composition

The major anions in the ground waters varied in the order, $\text{Cl} > \text{HCO}_3 > \text{SO}_4 > \text{CO}_3$. The Cl concentration was many times higher as compared to that of other anions (Tables 9 to 11 and Fig.17).

4.2.2.4.1 Carbonates (CO_3)

Carbonates in the ground waters were generally higher at Karedu-1 (0.50 to 2.30 c mol l^{-1}) followed by Karedu-2 (0.20 to 0.85 c mol l^{-1}) and Kolladinni (0.10 to 1.5 c mol l^{-1}). (Tables 9 to 11 and Fig.17). The higher carbonates at the time of harvest were found as compared to that at start of the culture at all the three locations studied. However, the difference in carbonate content of water between the start of the culture and harvest of the culture was relatively higher at Karedu-1 followed by Karedu-2 and Kolladinni. Higher concentration of carbonates upto 295 m in the case of Karedu-1, upto 338 m at Karedu-2 and upto 395 m at Kolladinni was noticed in the ground water.

4.2.2.4.2 Bicarbonates (HCO_3)

The bicarbonate content in the ground water (Tables 9 to 11 and Fig.17). It was varying in the order of Karedu-2 (3.0 to 17.2 c mol l^{-1}) > Karedu-1 (4.0 to 10.75 c mol l^{-1}) > Kolladinni (5.2 to 8.5 c mol l^{-1}). It was uniformly higher at the time of harvest as compared to the start of the culture at all the three locations sampled. However, the difference in HCO_3 concentration between the start of the culture and harvest of the culture was relatively higher at Karedu-1 followed by Karedu-2 and Kolladinni. Higher quantities of carbonates in ground waters was

observed upto 338 m at Karedu-2, 295 m at Karedu-1 and 390 m at Kolladinni from the brackish water ponds.

4.2.2.4.3 Chlorides (Cl)

From the data presented in Tables 9 to 11 and illustrated in Fig.17, it could be inferred that the chloride content of ground water was extremely higher at Karedu-2. It was varying in the order of Karedu-2 (11.80 to 299.75 c mol l^{-1}) > Karedu-1 (4.75 to 260.0 c mol l^{-1}) > Kolladinni (3.95 to 185.5 c mol l^{-1}). It was higher at the harvest of the culture compared to the start of the culture at all the three locations. However, the difference in chloride between the start of the culture and harvest of the culture was relatively higher at Karedu-2 followed by Karedu-1 and Kolladinni. Ponding of saline water resulted in higher chloride content of ground water upto 338 m at Karedu-2, 295 m at Karedu-1 and 390 m at Kolladinni.

4.2.2.4.4 Sulphates (SO_4)

The concentration of sulphates (Fig.17 and Tables 9 to 11) in the ground water was varying in the order of Karedu-2 (0.3 to 9.0 c mol l^{-1}) > Karedu-1 (0.13 to 5.65 c mol l^{-1}) > Kolladinni (0.15 to 4.75 c mol l^{-1}). The brackish water in the ponds of shrimp culture resulted in higher SO_4 content of ground water continued upto 338 m at Karedu-2, 295 m at Karedu-1 and 390 m at Kolladinni from the pond. The sulphate content was higher at the time of harvest as compared to start of the culture at Karedu-2 but such trend was not noticed at Karedu-1 and Kolladinni.

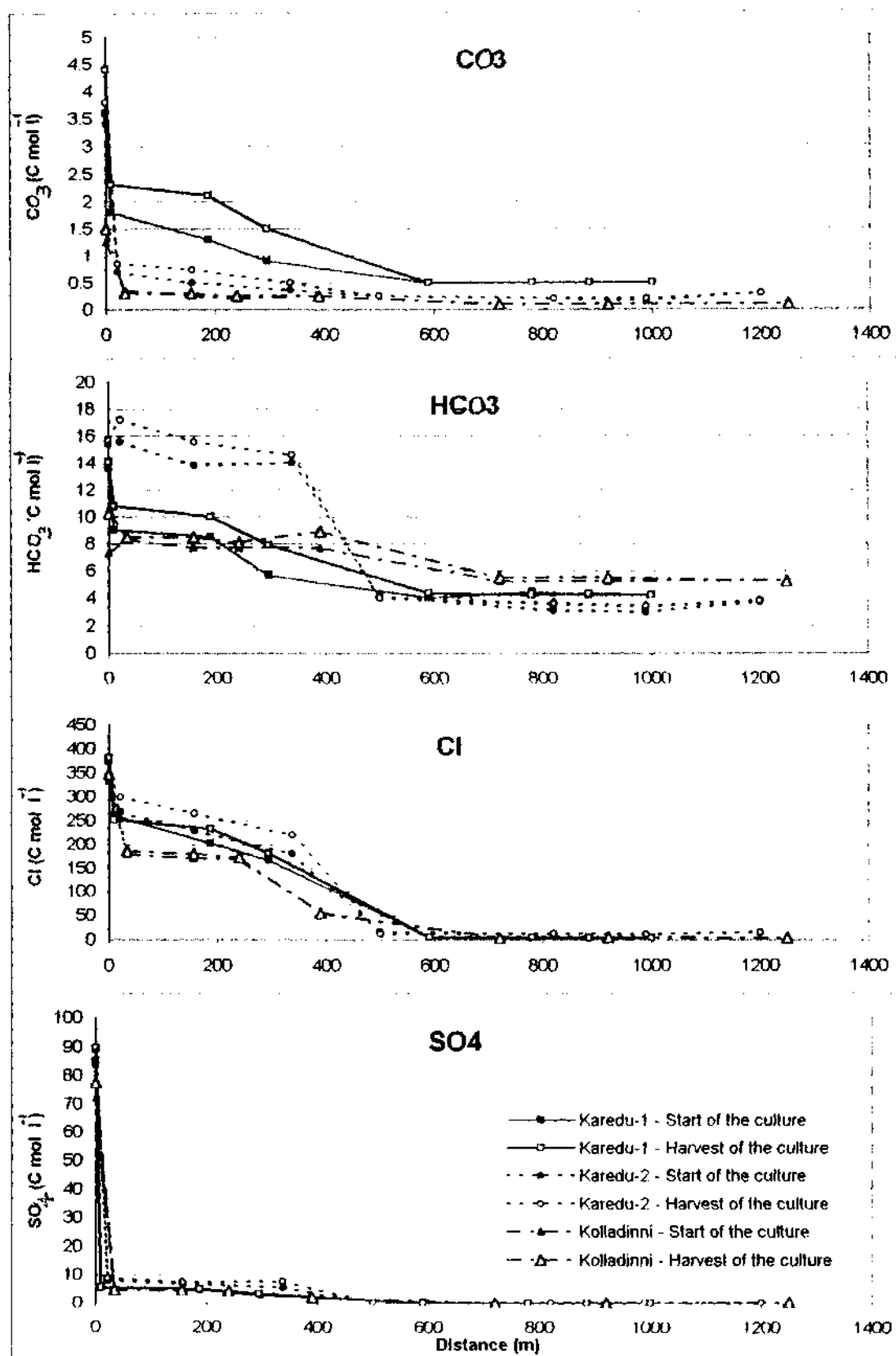


Fig. 17: Influence of brackish water prawn culture on CO_3 , HCO_3 , Cl and SO_4 of ground waters at different distances from the ponds.

4.2.2.5 Nitrate nitrogen ($\text{NO}_3\text{-N}$)

The data presented in Tables 9 to 11 and illustrated in Fig.18, revealed that NO_3 was generally higher at Kolladinni followed by Karedu-1 and Karedu-2. It was varying in the order of Kolladinni (2.25 to 4.60 mg l^{-1}) > Karedu-1 (0.185 to 0.353 mg l^{-1}) > Karedu-2 (0.135 to 0.390 mg l^{-1}). It was higher at harvest of the culture as compared to the start of the culture at Kolladinni only and at other places there was not much difference. The NO_3 content at Kolladinni was in the increasing order with the increase in distance from the pond upto 390 m and decreased again beyond 720 m . There was not much variation due prawn culture was observed on $\text{NO}_3\text{-N}$ content of ground water at other locations.

4.2.2.6 Boron (B)

The boron content in ground water was very higher near the ponds and it gradually decreased with the distance from the ponds (Tables 9 to 11 and depicted in Fig.18). The B in ground water was varying in the order of Karedu-2 (0.45 to 3.15 mg l^{-1}) > Karedu-1 (0.38 to 3.1 mg l^{-1}) > Kolladinni (0.37 to 2.9 mg l^{-1}). It was uniformly higher at the time of harvest as compared to start of the culture at all the three locations. However, the difference in boron between the start of the culture and harvest of the culture was relatively higher at Karedu-2 followed by Karedu-1 and Kolladinni. The higher values of B continued upto 600 m in the case of Karedu-1, 500 m in the case of Karedu-2 and 390 m at Kolladinni.

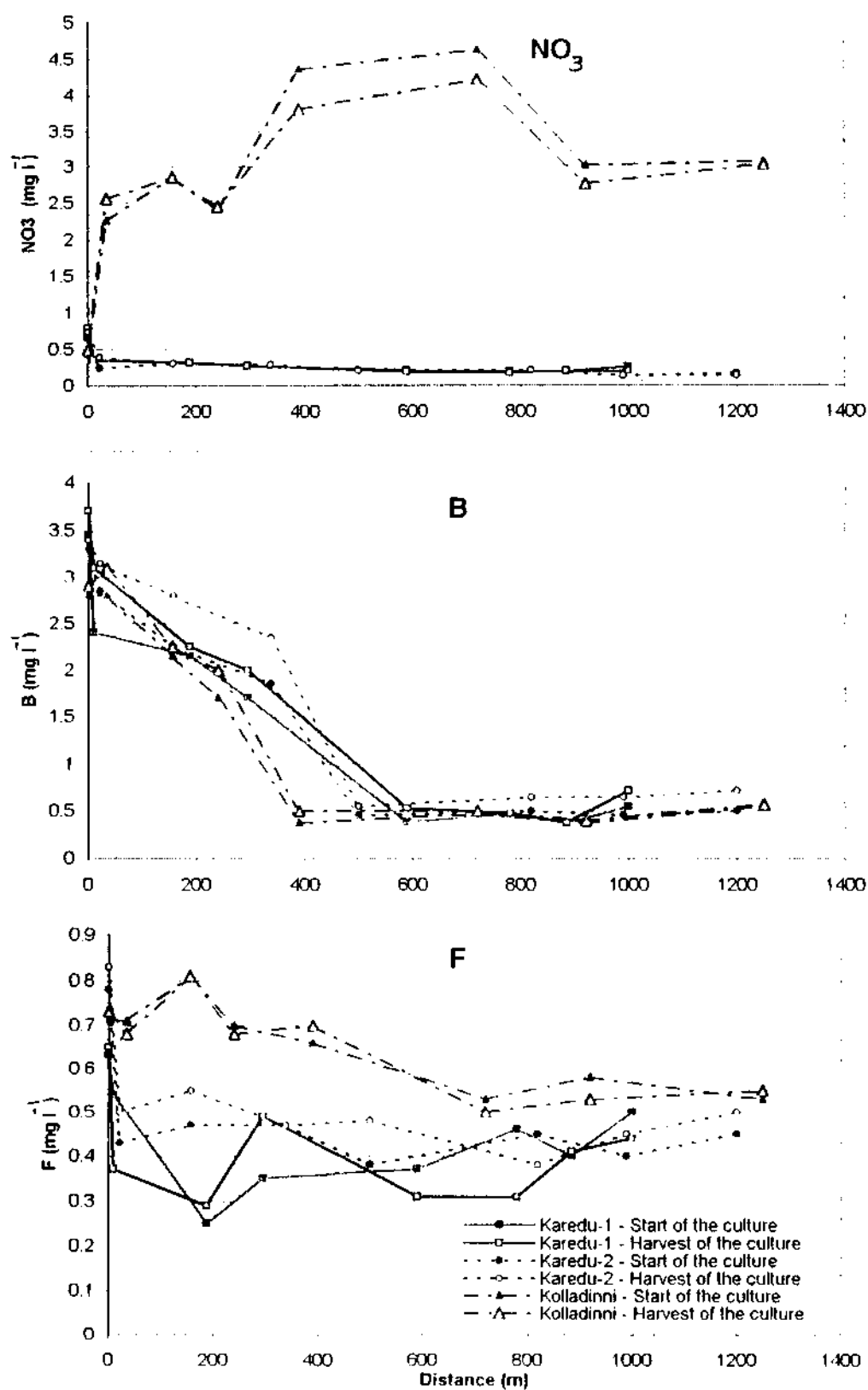


Fig. 18: Influence of brackish water prawn culture on NO_3 , B and F of ground waters at different distances from the ponds.

4.2.2.7 Fluoride (F)

At Kolladinni the F content of ground water was generally higher (Tables 9 to 11 and Fig.18) followed by Karedu-2 and Karedu-1. It was varying in the order of Kolladinni (0.50 to 0.75 mg l^{-1}) > Karedu-1 (0.31 to 0.42 mg l^{-1}) > Karedu-2 (0.35 to 0.5 mg l^{-1}). No specific trend of variation due to brackish water prawn culture pond on the F content of ground water was observed during the study period.

4.2.2.8 Heavy metals

From the data presented in Tables 9 to 11 and depicted in Fig.19 it could be noticed that, the content of Cr and Pb were relatively higher compared to that of Ni and Cd. In general pond water contained relatively higher amount of heavy metals at all the three locations studied compared to normal waters thereby indicating the ponded water to be the potential source of pollution in the areas of aquaculture with brackish water.

4.2.2.8.1 Chromium (Cr)

Among the three locations studied chromium content was higher at Kolladinni followed by Karedu-1 and Karedu-2 in that order (Tables 9 to 11 and Fig.19). It was varying between 0.002 to 0.63 mg l^{-1} at Kolladinni, 0.002 to 0.375 mg l^{-1} at Karedu-1 and from 0.0025 to 0.68 mg l^{-1} at Karedu-2. The Cr was higher at the harvest of the culture as compared to start of the culture at all the three locations studied in both the years. However, the difference in Cr between the start of the culture and harvest of the culture was relatively higher at Kolladinni followed

by Karedu-2 and Karedu-1. Higher amounts of chromium in ground water was observed due to brackish water in the ponds upto 390 m at Kolladinni, 295 m at Karedu-1 and 338 m at Karedu-2.

4.2.2.8.2 Lead (Pb)

The lead content in the ground waters was varying in the order of Kolladinni (0.005 to 0.31 mg l^{-1}) > Karedu-1 (0.002 to 0.14 mg l^{-1}) > Karedu-2 (0.0025 to 0.13 mg l^{-1}) (Tables 9 to 11 and Fig.19b) It was slightly higher at the harvest of the culture as compared to start of the culture at all the three locations studied in both the years. Higher quantity of Pb in the ground waters continued upto 240 m at Kolladinni upto 295 m at Karedu-2 and upto 338 m at Karedu-1 from their respective ponds

4.2.2.8.3 Nickel (Ni)

The Ni content of ground water (Tables 9 to 11 and Fig.19c) was varying in the order of Kolladinni (0.007 to 0.150 mg l^{-1}) > Karedu-1 (0.0045 to 0.10 mg l^{-1}) > Karedu-2 (0.0055 to 0.047 mg l^{-1}). It was higher at the harvest of the culture as compared to start of the culture at Karedu-2 and Karedu-1. However the difference in Ni was relatively higher at Karedu-2 followed Karedu-1 but difference at Kolladinni was negligible. The higher Ni continued upto 338 m in the case of Karedu-2, 295 m in the case of Karedu-1 and 390 m at Kolladinni from their respective ponds.

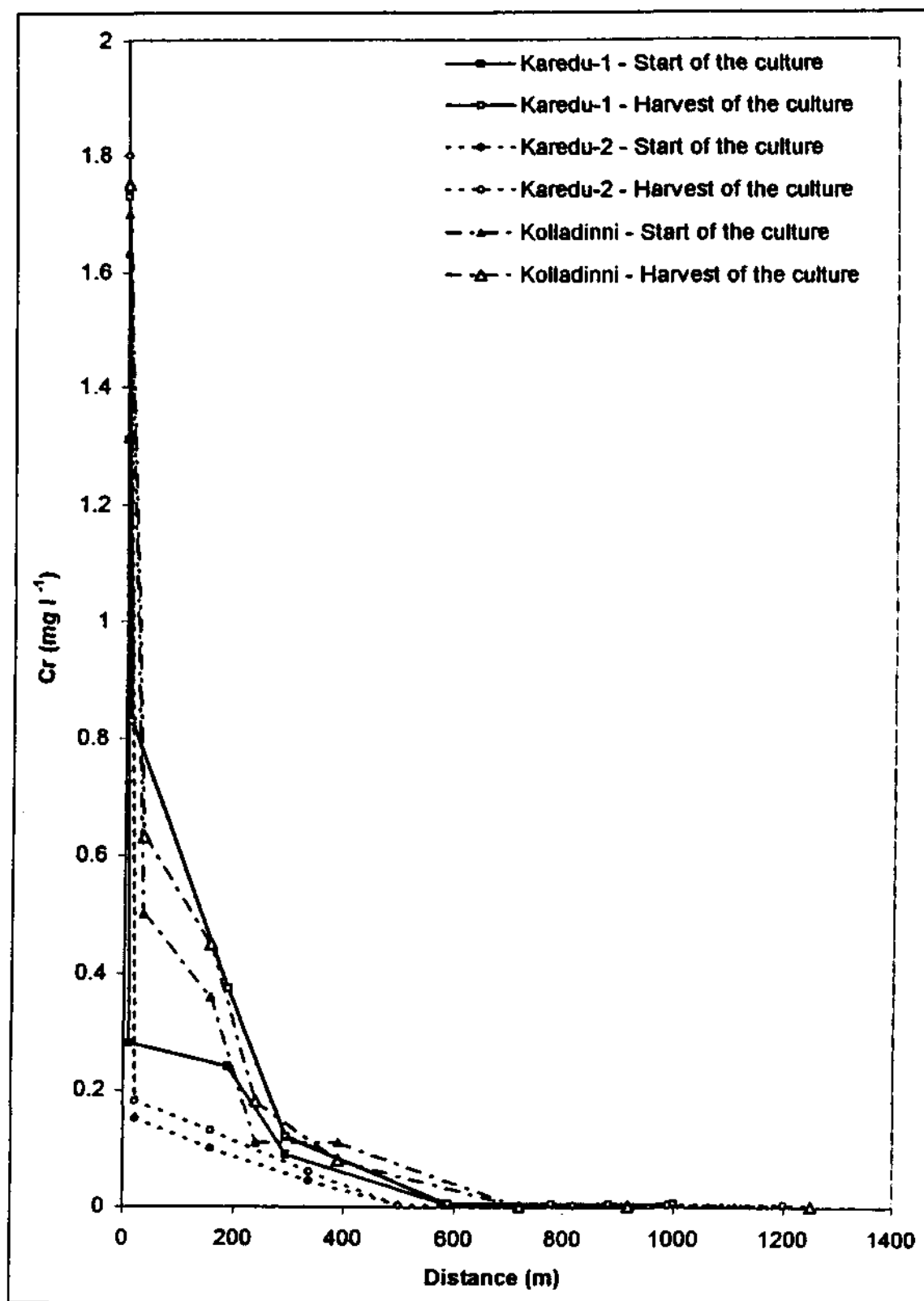


Fig. 19(a): Influence of brakish water prawn culture on Cr content of ground waters at different distances from the ponds.

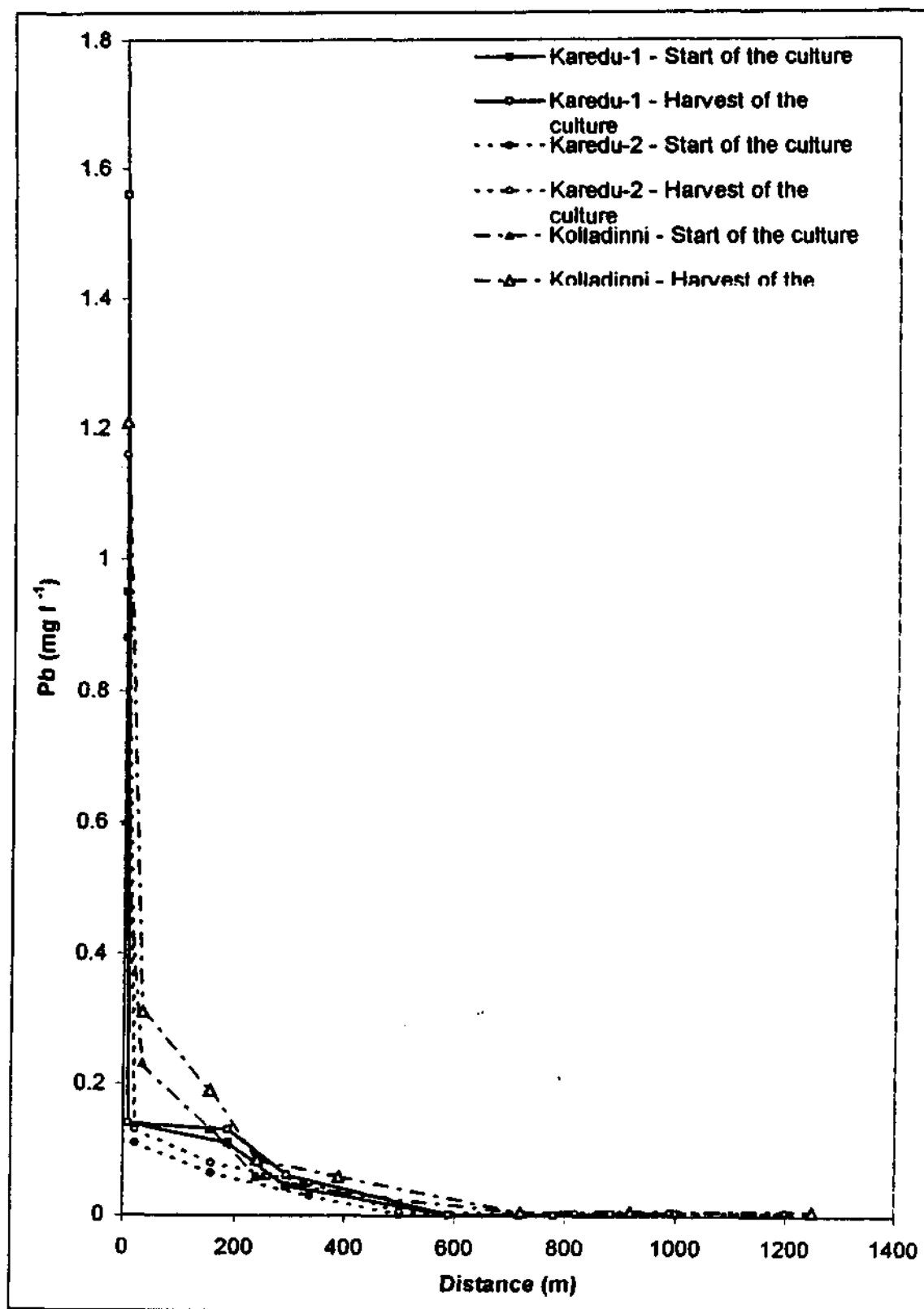


Fig. 19(b): Influence of brakish water prawn culture on Pb content of ground waters at different distances from the ponds.

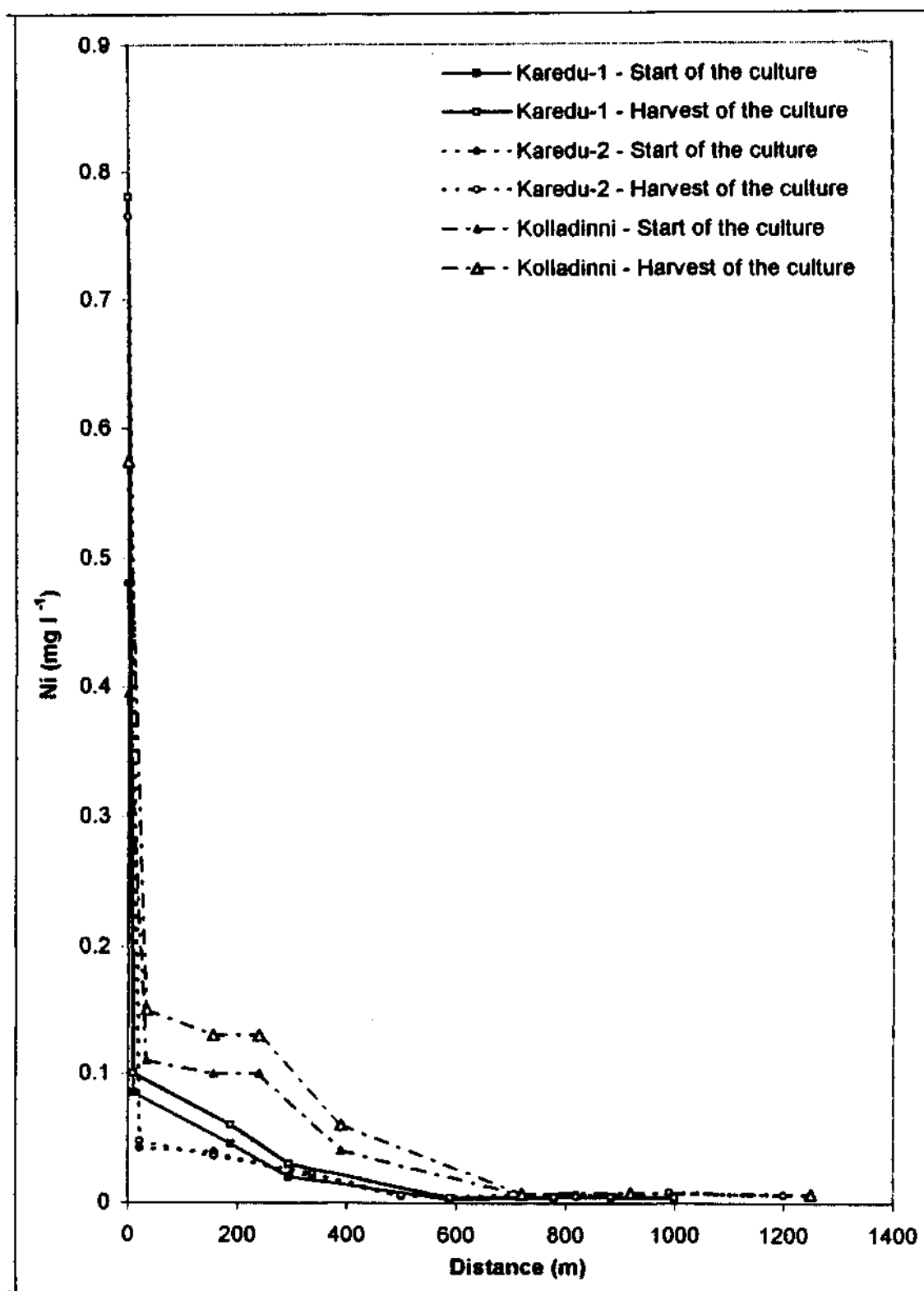


Fig. 19(c): Influence of brakish water prawn culture on Ni content of ground waters at different distances from the ponds.

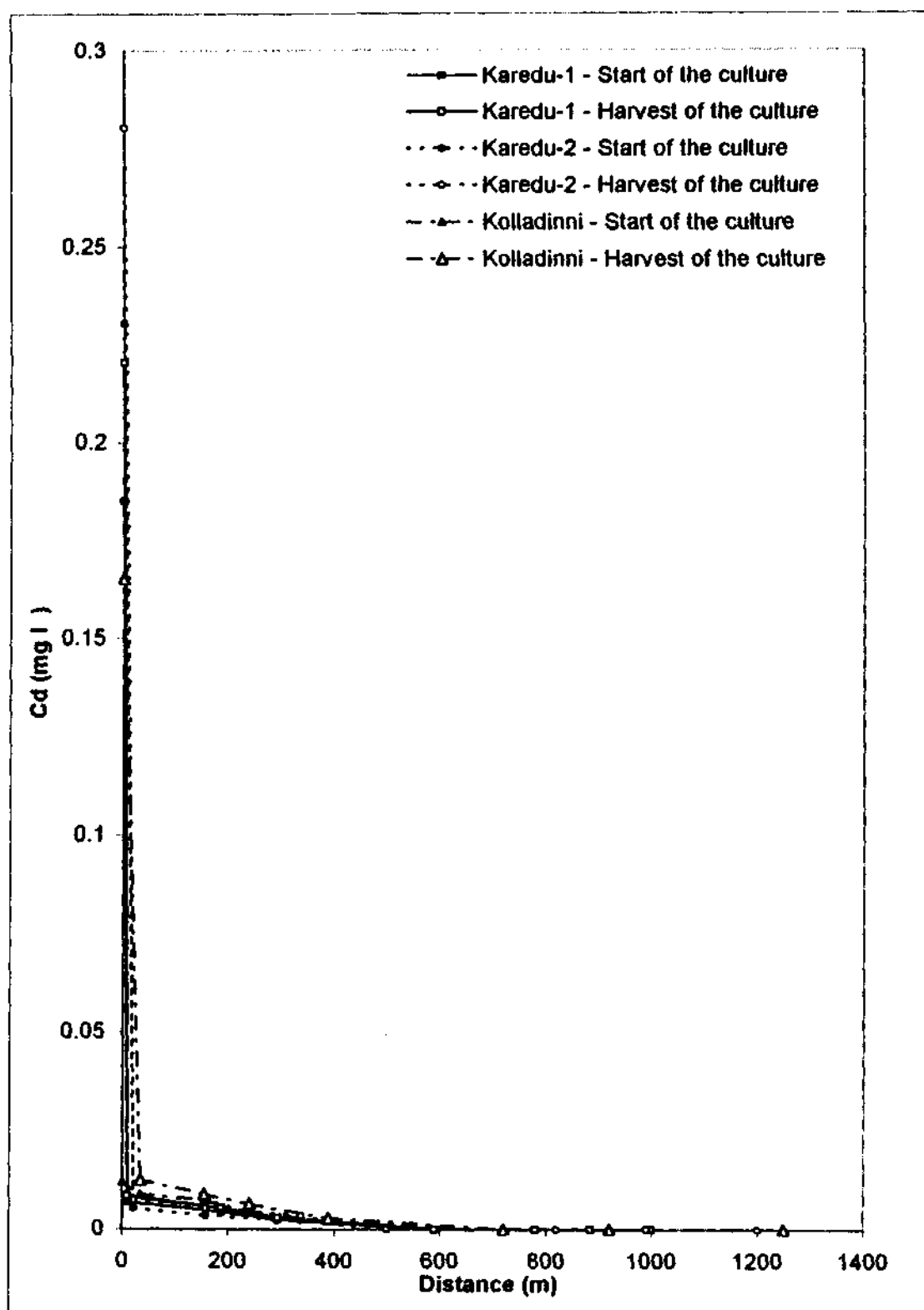


Fig. 19(d): Influence of brakish water prawn culture on Cd content of ground waters at different distances from the ponds.

4.2.2.8.4 Cadmium (Cd)

The cadmium content of ground water was generally higher in the immediate neighbourhood of pond at all the three locations sampled (Tables 9 to 11 and Fig.19). While the higher Cd was noticed upto 295 m at Karedu-1, 338 m at Karedu-2 and upto 390 m at Kolladinni. Beyond the above distance, no Cd was detected during the study period. The culturing did not influence the Cd content of ground water.

4.2.2.9 Micronutrients

The data on micronutrients in the ground waters is presented in tables 9 to 11 and Fig.20, varied in the order: Fe (0.16 to 0.28 mg l^{-1}) > Zn (0.005 to 0.057 mg l^{-1}) > Mn (0.007 to 0.039 mg l^{-1}) > Cu (0.0045 to 0.0255 mg l^{-1})

4.2.2.9.1 Zinc (Zn)

The Zn content of ground water was varying in the order of Kolladinni (0.005 to 0.057 mg l^{-1}) > Karedu-2 (0.010 to 0.037 mg l^{-1}) > Karedu-1 (0.0055 to 0.0385 mg l^{-1}). It was higher at the harvest of the culture compared to the start of the culture at all the three locations. The difference in Zn between the start of the culture and harvest of the culture was relatively higher at Kolladinni followed by Karedu-1 and Karedu-2. It was higher immediate neighbourhood of the shrimp ponds and it decreased with distance from the pond increased. The higher Zn continued upto 390 m in the case of Kolladinni, 295 m in the case of Karedu-1 and upto 338 m at Karedu-2 (Tables 9 to 11 and Fig. 20).

4.2.2.9.2 Iron (Fe)

The Fe content in the ground water (Tables 9 to 11 and Fig.20) was varying in the order of Kolladinni (0.045 to 0.28 mg l⁻¹ > Karedu-1 (0.020 to 0.145 mg l⁻¹) > Karedu-2 (0.030 to 0.125 mg l⁻¹). In general, the Zn was higher at the harvest of the culture as compared to start of the culture at all the three locations sampled. However the difference in Fe content was relatively higher at Kolladinni followed by Karedu-2 and Karedu-1. Iron content is very high in the immediate neighbourhood of the ponds and its concentration decreased as the distance from the pond increased. Higher Fe content was continued upto 390 m in the case of Kolladinni, 338 m at Karedu-2 and 295 m at Karedu-1 from the ponds.

4.2.2.9.3 Manganese (Mn)

Manganese content of ground water (Tables 9 to 11 and Fig.20) was relatively higher in the immediate neighbourhood of pond as compared to that far away from the pond at all the locations sampled. It was varying in the order: Karedu-1 (0.0075 to 0.033 mg l⁻¹ > Karedu-2 (0.0085 to 0.029 mg l⁻¹) and Kolladinni (0.007 to 0.039 mg l⁻¹). Higher content of Mn continued upto 295 m at Karedu-1, 338 m at Karedu-2 and 390 m at Kolladinni.

4.2.2.9.4 Copper (Cu)

The Cu content (Tables 9 to 11 and Fig.20) was varying in the order of Kolladinni (0.006 to 0.0255 mg l⁻¹ > Karedu-1 (0.006 to 0.017 mg l⁻¹) > Karedu-2 (0.005 to 0.0175 mg l⁻¹). It was higher at harvest of the culture as compared to the start of the culture at all three locations sampled. However the difference in Cu

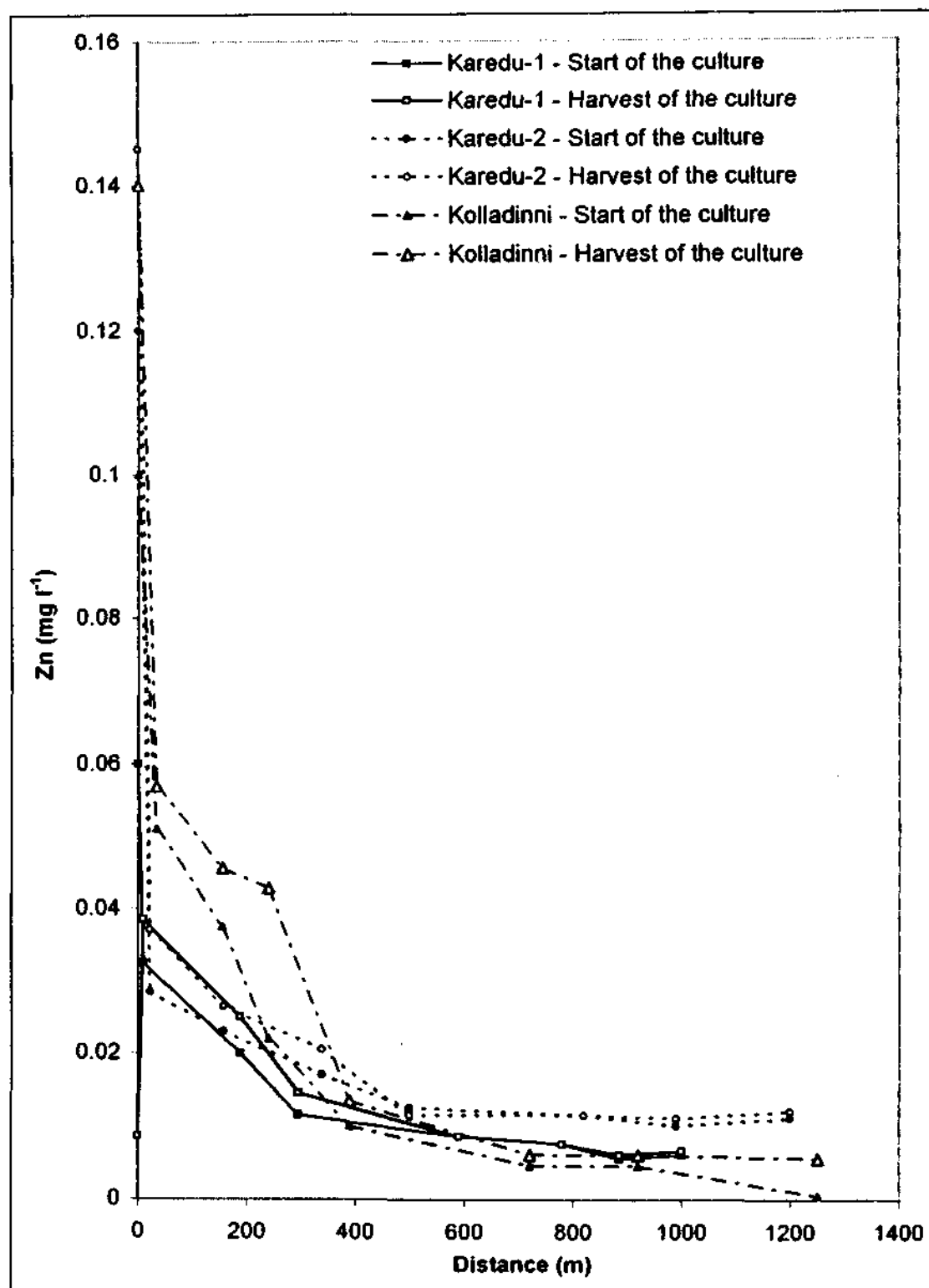


Fig. 20(a): Influence of brakish water prawn culture on Zn content of ground waters at different distances from the ponds.

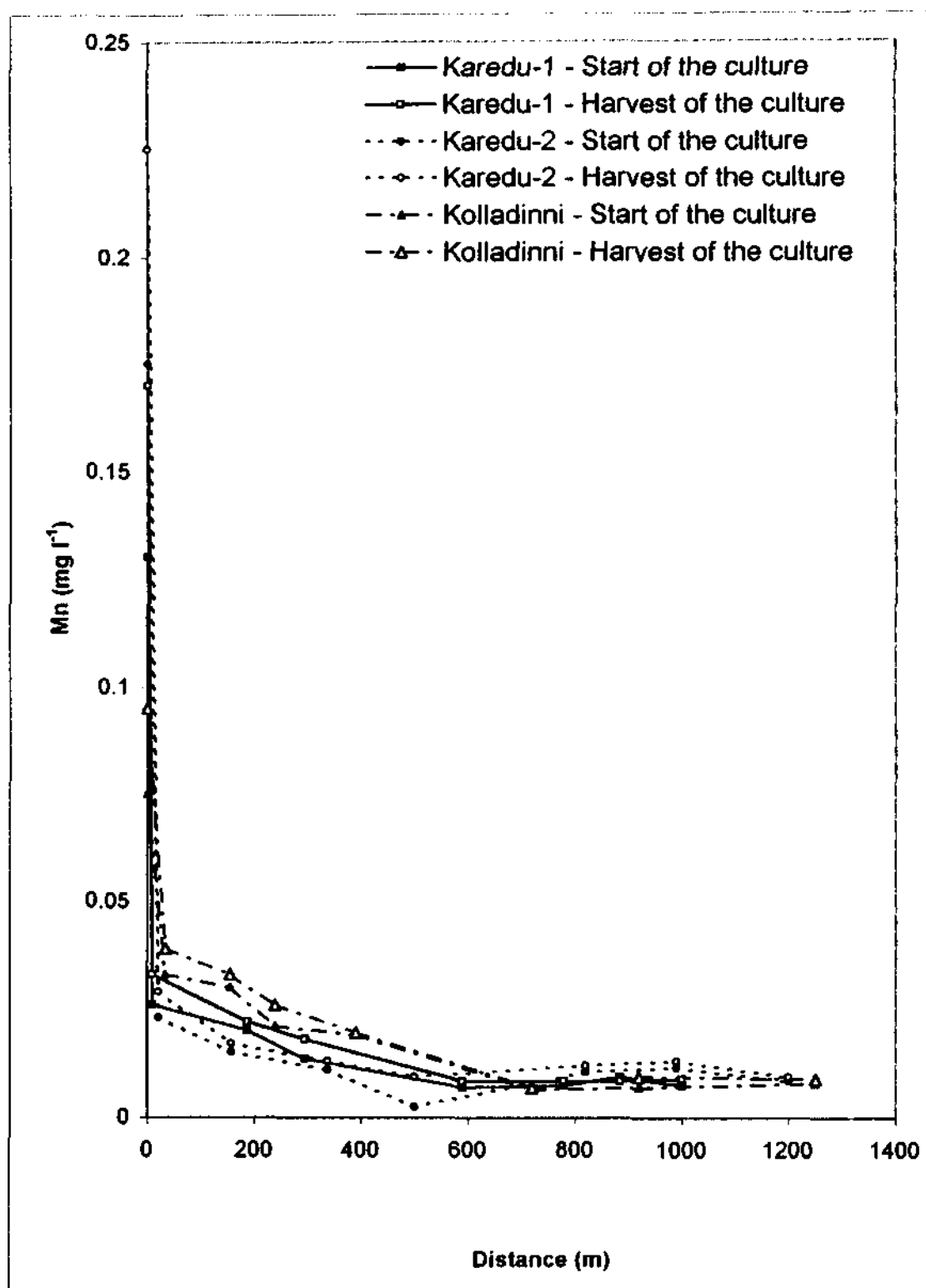


Fig. 20(b): Influence of brakish water prawn culture on Fe content of ground waters at different distances from the ponds.

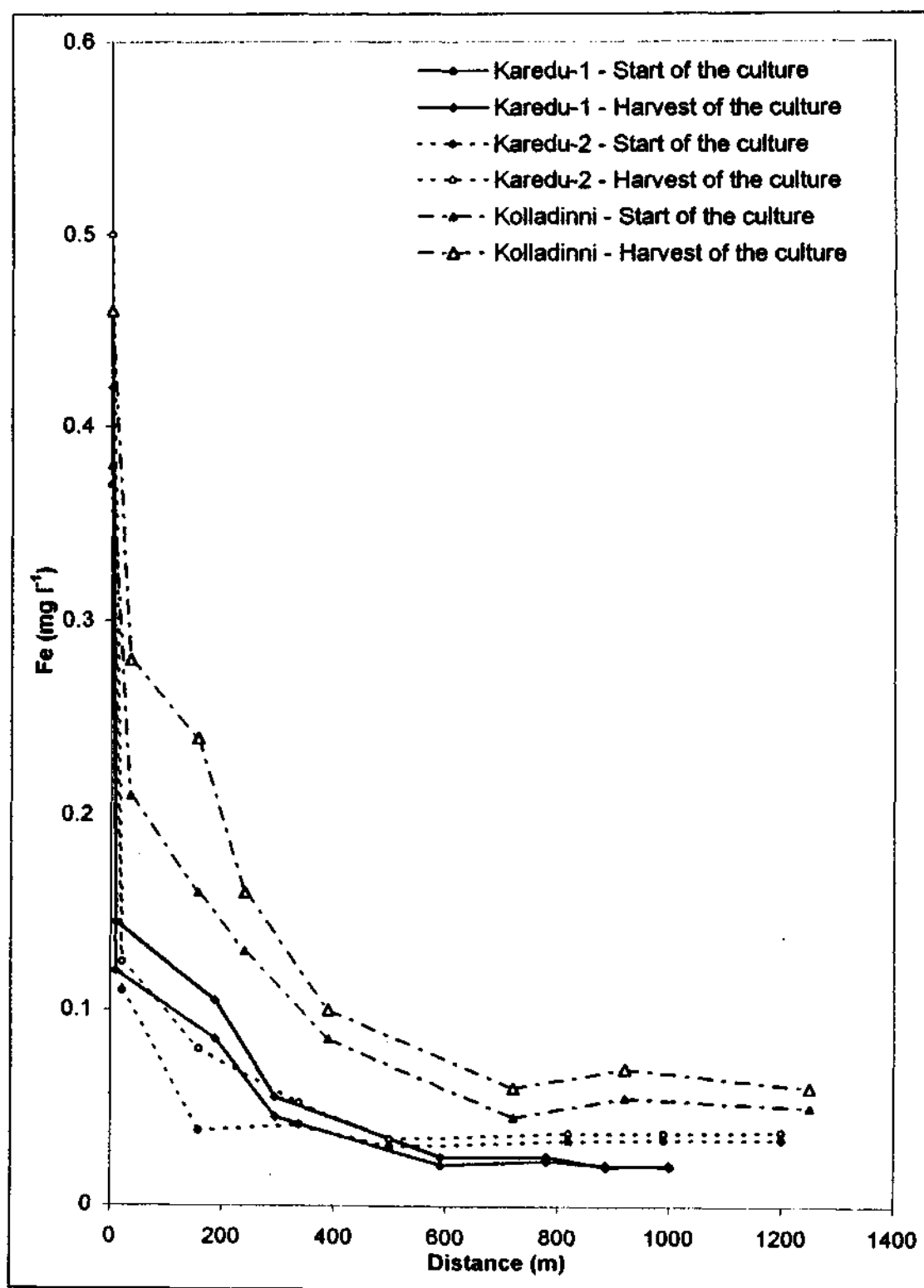


Fig. 20 (c): Influence of brackish water prawn culture on Mn content of ground waters at different distances from the ponds.

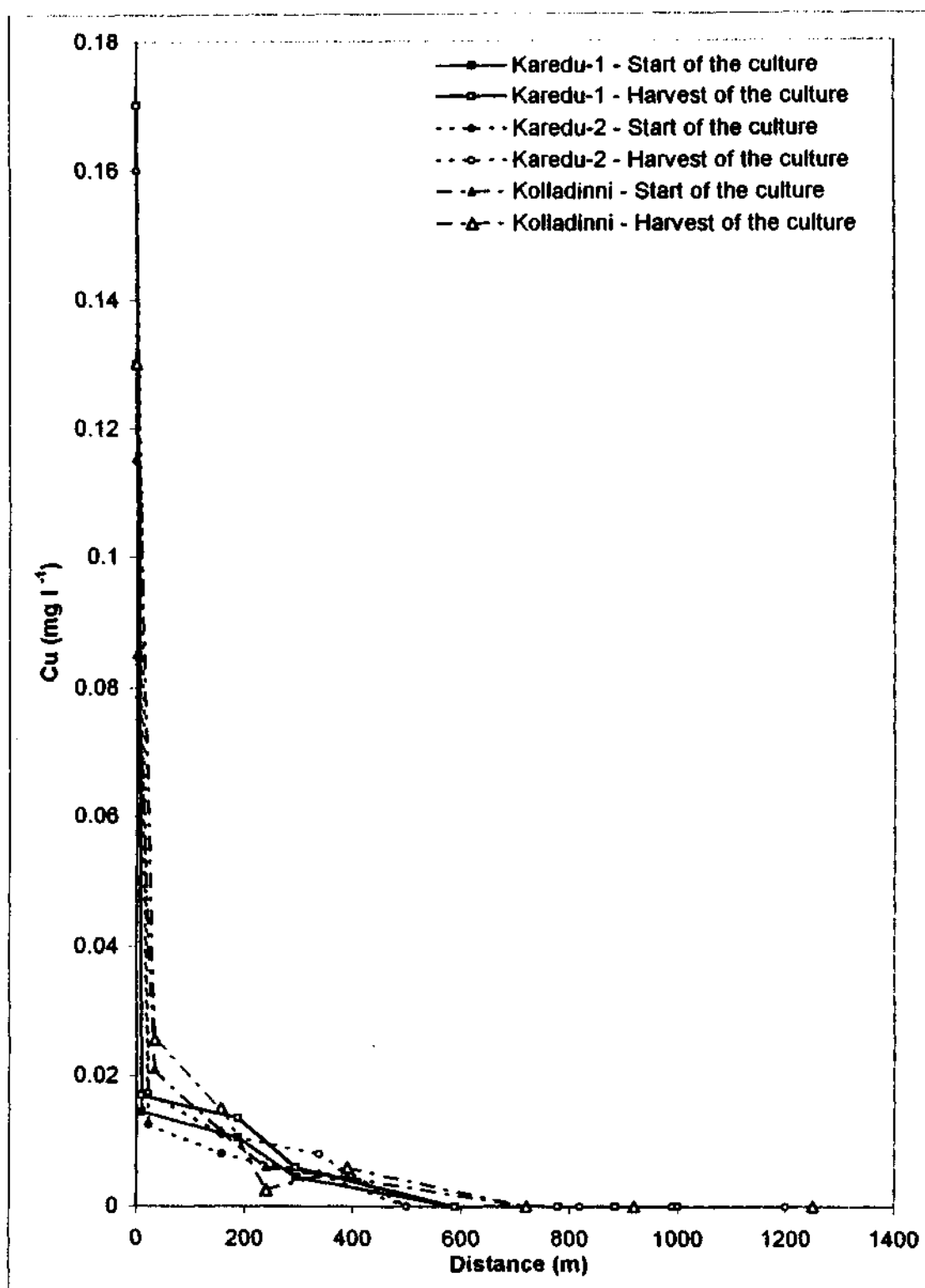


Fig. 20(d): Influence of brackish water prawn culture on Cu content of ground waters at different distances from the ponds.

Table 9 : Mean chemical composition of ground water adjoining brackish water prawn culture ponds of Karedu-I

Distance from the pond (m)	pH	EC (dSm ⁻¹)	Cations (c mol l ⁻¹)				Anions (c mol l ⁻¹)			
			Ca	Mg	Na	K	CO ₃	HCO ₃	Cl	SO ₄
Start of the culture (Mean of 1996 and 1997)										
0 (Pond water)	8.12	47.80	22.25	61.50	364.0	20.25	3.6	13.7	373.50	85.25
10	7.89	22.60	8.85	23.35	195.0	1.90	1.8	9.0	259.75	5.30
188	7.88	21.65	9.30	23.30	186.4	1.90	1.3	8.5	204.75	4.80
295	7.63	17.55	6.50	23.60	152.2	1.15	0.9	5.6	166.95	2.55
590	7.54	1.05	1.80	8.05	6.5	0.75	0.5	4.0	5.75	0.32
780	7.50	0.96	1.65	1.55	5.6	0.80	0.5	4.4	4.80	0.16
885	7.50	0.92	1.85	1.53	5.4	0.75	0.5	4.2	4.75	0.16
1000	7.50	0.99	1.85	1.55	5.6	0.80	0.5	4.2	4.90	0.15

Distance from the pond (m)	NO ₃ -N	B (mg l ⁻¹)	F	Heavy metals (mg l ⁻¹)				Micro nutrients (mg l ⁻¹)				COD (mg l ⁻¹)	
				Cr	Pb	Ni	Cd	Zn	Fe	Cu	Mn		
Start of the culture (Mean of 1996 and 1997)													
0 (Pond water)	0.700	3.45	0.63	1.310	0.950	0.480	0.185	0.060	0.420	0.130	0.130	1870.0	
10	0.353	2.40	0.54	0.280	0.140	0.085	0.007	0.033	0.120	0.015	0.026	17.0	
188	0.307	2.15	0.25	0.240	0.110	0.045	0.005	0.020	0.090	0.011	0.020	17.0	
295	0.270	1.70	0.35	0.090	0.045	0.002	0.003	0.012	0.045	0.005	0.014	15.0	
590	0.214	0.38	0.37	0.050	0.002	0.003	ND	0.009	0.021	ND	0.007	8.1	
780	0.195	0.47	0.46	0.006	0.001	0.005	ND	0.008	0.023	ND	0.008	8.9	
885	0.197	0.37	0.40	0.005	0.003	0.005	ND	0.006	0.021	ND	0.001	9.8	
1000	0.255	0.55	0.50	0.006	0.004	0.004	ND	0.006	0.020	ND	0.008	9.0	

Table 9 Contd.....

Distance from the pond (m)	pH	EC (dSm ⁻¹)	Cations (c mol l ⁻¹)				Anions (c mol l ⁻¹)			
			Ca	Mg	Na	K	CO ₃	HCO ₃	Cl	SO ₄
Harvest of the culture (Mean of 1996 and 1997)										
0 (Pond water)	8.23	49.00	22.75	56.75	371.0	22.50	4.4	14.10	381.50	89.25
10	7.93	27.00	11.25	24.65	234.0	2.45	2.3	10.75	250.25	5.65
188	7.77	24.94	10.30	24.70	217.0	2.55	2.1	10.00	232.40	5.10
295	7.61	19.41	7.58	24.00	168.4	1.55	1.5	7.90	181.55	3.30
590	7.57	1.09	1.80	8.25	7.0	0.85	0.5	4.75	5.50	0.16
780	7.45	1.03	1.80	1.65	6.0	0.95	0.5	4.20	5.50	0.15
885	7.49	1.03	1.90	1.50	5.8	0.95	0.5	4.30	5.25	0.13
1000	7.49	0.97	1.65	1.35	5.7	0.90	0.5	4.20	4.65	0.15

Distance from the pond (m)	NO ₃ -N	B (mg l ⁻¹)	F	Heavy metals (mg l ⁻¹)				Micro nutrients (mg l ⁻¹)				COD (mg l ⁻¹)
				Cr	Pb	Ni	Cd	Zn	Fe	Cu	Mn	
Harvest of the culture (Mean of 1996 and 1997)												
0 (Pond water)	0.793	3.70	0.65	1.730	1.560	0.780	0.020	0.0085	0.460	0.170	0.1700	1905.00
10	0.351	3.10	0.37	0.330	0.140	0.100	0.009	0.0385	0.145	0.170	0.0330	18.25
188	0.322	2.50	0.29	0.375	0.130	0.060	0.006	0.0250	0.105	0.014	0.0220	18.25
295	0.277	2.00	0.49	0.120	0.062	0.030	0.003	0.0145	0.055	0.006	0.0180	15.75
590	0.185	0.53	0.31	0.006	0.003	0.004	ND	0.0085	0.025	ND	0.0085	8.60
780	0.174	0.48	0.31	0.006	0.002	0.005	ND	0.0075	0.025	ND	0.0085	8.50
885	0.199	0.38	0.41	0.007	0.004	0.005	ND	0.0060	0.020	ND	0.0085	9.50
1000	0.192	0.72	0.44	0.006	0.004	0.005	ND	0.0065	0.021	ND	0.0090	9.60

Table 10 : Mean chemical composition of ground water adjoining brackish water prawn culture ponds of Karedu-2

Distance from the pond (m)	pH	EC (dSm ⁻¹)	Cations (c mol l ⁻¹)				Anions (c mol l ⁻¹)			
			Ca	Mg	Na	K	CO ₃	HCO ₃	Cl	SO ₄
Start of the culture (Mean of 1996 and 1997)										
0 (Pond water)	8.12	47.50	22.25	72.00	363.0	19.30	3.4	15.4	333.0	83.60
22	8.00	29.15	17.10	20.10	244.0	6.00	0.7	15.6	267.1	8.00
158	8.10	25.05	14.75	18.72	209.0	4.50	0.5	13.8	228.9	7.10
338	7.80	20.03	13.00	14.00	163.0	3.75	0.4	14.0	180.3	8.50
500	7.58	1.78	4.10	1.45	10.2	1.95	0.3	4.1	16.8	0.38
820	7.70	1.53	3.36	1.45	8.2	1.75	0.2	3.1	12.8	0.30
990	7.70	1.53	3.35	1.50	8.7	1.50	0.2	3.1	11.8	0.33
1200	7.75	2.05	4.20	1.55	12.0	2.05	0.3	3.7	16.2	0.38

Distance from the pond (m)	NO ₃ -N	B (mg l ⁻¹)	F	Heavy metals (mg l ⁻¹)				Micro nutrients (mg l ⁻¹)				COD (mg l ⁻¹)
				Cr	Pb	Ni	Cd	Zn	Fe	Cu	Mn	
Start of the culture (Mean of 1996 and 1997)												
0 (Pond water)	0.655	3.30	0.78	1.630	0.880	0.4800	0.2300	0.1200	0.370	0.115	0.175	2055.0
22	0.244	2.85	0.43	0.150	0.110	0.0420	0.0055	0.0285	0.110	0.013	0.023	17.8
158	0.306	2.25	0.47	0.100	0.065	0.0340	0.0035	0.0230	0.038	0.008	0.015	15.5
338	0.276	1.85	0.47	0.050	0.030	0.0200	0.0025	0.0170	0.041	0.005	0.011	12.0
500	0.214	0.45	0.38	0.040	0.003	0.0055	ND	0.0125	0.030	ND	0.009	7.0
820	0.208	0.50	0.45	0.003	0.003	0.0065	ND	0.0115	0.033	ND	0.011	7.0
990	0.138	0.45	0.40	0.004	0.004	0.0075	ND	0.0100	0.034	ND	0.012	7.0
1200	0.164	0.50	0.45	0.004	0.005	0.0060	ND	0.0011	0.034	ND	0.009	7.5

Table 10 Contd.....

Distance from the pond (m)	pH	EC (dSm ⁻¹)	Cations (c mol l ⁻¹)				Anions (c mol l ⁻¹)			
			Ca	Mg	Na	K	CO ₃	HCO ₃	Cl	SO ₄
Harvest of the culture (Mean of 1996 and 1997)										
0 (Pond water)	8.23	49.650	24.00	78.50	385.0	22.50	3.80	15.7	346.000	90.000
22	7.93	32.700	18.75	23.30	268.0	8.85	0.85	17.2	299.800	9.000
158	8.03	28.950	16.25	19.50	237.0	7.60	0.75	15.6	268.300	7.600
338	8.13	24.100	13.70	15.66	197.0	5.20	0.50	14.6	219.700	7.700
500	7.63	1.795	4.60	1.35	99.9	1.75	0.25	4.0	13.350	0.345
820	1.70	1.650	3.75	1.50	9.8	1.40	0.20	3.6	12.700	0.360
990	7.70	1.600	3.60	1.45	9.6	1.35	0.20	3.4	12.200	0.300
1200	7.65	2.000	4.25	1.40	11.8	2.00	0.30	3.8	15.500	0.435

Distance from the pond (m)	NO ₃ -N	B (mg l ⁻¹)	F	Heavy metals (mg l ⁻¹)				Micro nutrients (mg l ⁻¹)				COD (mg l ⁻¹)
				Cr	Pb	Ni	Cd	Zn	Fe	Cu	Mn	
Harvest of the culture (Mean of 1996 and 1997)												
0 (Pond water)	0.733	3.40	0.83	1.800	1.160	0.765	0.280	0.145	0.500	0.016	0.225	2176.0
22	0.390	3.15	0.50	0.180	0.130	0.047	0.008	0.037	0.125	0.018	0.029	19.0
158	0.307	2.80	0.55	0.130	0.018	0.036	0.005	0.027	0.080	0.011	0.017	16.5
338	0.294	2.35	0.47	0.060	0.050	0.023	0.004	0.021	0.052	0.008	0.013	13.0
500	0.206	1.55	0.48	0.004	0.007	0.006	ND	0.012	0.034	ND	0.010	6.5
820	0.212	0.65	0.38	0.004	0.005	0.006	ND	0.012	0.037	ND	0.012	7.3
990	0.137	0.65	0.45	0.005	0.005	0.009	ND	0.011	0.037	ND	0.013	6.3
1200	0.135	0.72	0.55	0.005	0.005	0.007	ND	0.012	0.038	ND	0.010	7.0

Table 11: Mean chemical composition of ground water adjoining brackish water prawn culture ponds of Kolladinni

Distance from the pond (m)	pH	EC (dSm ⁻¹)	Cations (c mol l ⁻¹)				Anions (c mol l ⁻¹)			
			Ca	Mg	Na	K	CO ₃	HCO ₃	Cl	SO ₄
Start of the culture (Mean of 1995-96 and 1996-97)										
0 (Pond water)	8.13	41.565	15.75	70.50	328.0	10.60	1.25	7.3	333.0	72.00
34	7.86	19.124	16.45	24.00	158.1	1.88	0.35	8.3	179.4	4.50
156	7.82	18.350	16.50	22.25	140.6	1.85	0.25	7.7	171.0	4.45
240	7.83	18.200	16.55	20.75	140.3	1.75	0.20	7.7	169.7	4.35
390	7.51	6.300	6.60	1.75	47.3	1.25	0.25	7.7	356.4	1.85
720	7.52	0.951	1.80	1.75	5.0	1.05	0.10	5.2	3.9	0.15
980	7.50	0.967	1.82	1.90	5.1	1.15	0.10	5.2	4.1	0.15
1250	7.48	0.962	1.80	1.95	5.1	1.10	0.10	5.3	4.0	0.16

Distance from the pond (m)	NO ₃ -N	B (mg l ⁻¹)	F	Heavy metals (mg l ⁻¹)				Micro nutrients (mg l ⁻¹)				COD (mg l ⁻¹)	
				Cr	Pb	Ni	Cd	Zn	Fe	Cu	Mn		
Start of the culture (Mean of 1995-96 and 1996-97)													
0 (Pond water)	0.445	2.80	0.71	1.700	0.600	0.395	0.120	0.100	0.380	0.085	0.075	1890	
34	2.250	2.80	0.71	0.500	0.230	0.110	0.009	0.510	0.210	0.021	0.033	20	
156	2.850	2.15	0.81	0.360	0.130	0.100	0.008	0.038	0.160	0.011	0.030	18	
240	2.400	1.70	0.70	0.110	0.060	0.100	0.005	0.022	0.130	0.006	0.021	17	
390	4.350	0.38	0.66	0.050	0.035	0.040	0.002	0.010	0.085	0.005	0.019	15	
720	4.600	0.47	0.53	0.002	0.006	0.007	ND	0.005	0.045	ND	0.007	8	
980	3.000	0.37	0.58	0.003	0.006	0.008	ND	0.005	0.055	ND	0.007	7	
1250	3.050	0.55	0.53	0.003	0.005	0.006	ND	0.005	0.050	ND	0.008	8	

Table 11 Contd.....

Distance from the pond (m)	pH	EC (dSm ⁻¹)	Cations (c mol l ⁻¹)				Anions (c mol l ⁻¹)			
			Ca	Mg	Na	K	CO ₃	HCO ₃	Cl	SO ₄
Harvest of the culture (Mean of 1995-96 and 1996-97)										
0 (Pond water)	8.23	43.750	18.75	69.00	340.0	12.500	1.50	10.2	346.0	77.50
34	7.98	19.960	19.35	31.00	164.0	1.975	0.30	8.5	185.5	4.75
156	7.98	19.330	18.95	28.50	148.4	2.000	0.30	8.5	180.0	4.80
240	8.00	18.610	18.35	24.50	142.0	1.900	0.25	8.1	173.1	4.45
390	7.44	6.660	6.66	1.65	148.9	1.250	0.25	8.9	64.1	2.15
720	7.46	1.045	1.28	1.45	7.5	1.125	0.10	5.5	4.7	0.16
980	7.46	1.080	1.50	1.50	6.3	1.100	0.10	5.5	5.0	0.18
1250	7.50	1.002	1.36	1.85	5.9	1.075	0.10	5.2	4.5	0.35

Distance from the pond (m)	NO ₃ -N	B	F	Heavy metals (mg l ⁻¹)				Micro nutrients (mg l ⁻¹)				COD (mg l ⁻¹)	
				Cr	Pb	Ni	Cd	Zn	Fe	Cu	Mn		
Harvest of the culture (Mean of 1995-96 and 1996-97)													
0 (Pond water)	0.49	2.9	0.73	1.7500	1.2100	0.575	0.165	0.140	0.460	0.1300	0.0950	1884.0	
34	2.55	3.1	0.68	0.6300	0.3100	0.150	0.013	0.057	0.280	0.0255	0.0390	19.5	
156	2.85	2.3	0.81	0.4500	0.1900	0.130	0.009	0.046	0.240	0.0150	0.0330	18.5	
240	2.45	2.0	0.68	0.1800	0.0850	0.130	0.007	0.028	0.160	0.0085	0.0260	16.5	
390	3.80	0.5	0.70	0.0800	0.0600	0.060	0.003	0.014	0.100	0.0060	0.0195	14.5	
720	4.20	0.5	0.50	0.0150	0.0065	0.008	ND	0.006	0.060	ND	0.0070	7.5	
980	2.75	0.4	0.53	0.0030	0.0075	0.008	ND	0.006	0.007	ND	0.0095	7.5	
1250	3.00	0.3	0.55	0.0015	0.0070	0.007	ND	0.006	0.060	ND	0.0090	7.5	

content between the start of the culture and harvest of the culture was almost identical. Higher Cu content continued upto 338 m at Karedu-2, 295 m at Karedu-1 and 390 m at Kolladinni. Beyond the above distances, the Cu was not detected during the study period.

4.2.2.10 Chemical oxygen demand (COD)

From the data presented in Tables 9 to 11 and illustrated in Fig.21 it could be noticed that the COD of ground water in general was higher in the immediate neighbourhood of pond as compared to distance far away from the pond. The COD of water was varying from 8.5 to 1905.0 mg l⁻¹ at Karedu-1, from 6.25 to 2176.0 mg l⁻¹ at Karedu-2 and from 7.0 to 1844.0 mg l⁻¹ at Kolladinni. The COD of water was higher at the harvest of the culture as compared to the start of the culture at all the three locations sampled. However, the difference in COD between the start of the culture and harvest of the culture was almost similar at all three locations studied while the higher COD continued upto 295 m in the case of Karedu-1, upto 338 m at Karedu-2 and upto 390 m at Kolladinni.

4.3 EFFECT OF AQUACULTURE ON PHYSICAL PROPERTIES OF ADJOINING SOILS

4.3.1 Fresh water fish culture

The data pertaining to physical properties of soil, viz., texture, bulk density, per cent water stable aggregates (> 0.25 mm), hydraulic conductivity and infiltration rate of soils adjoining fresh water fish culture ponds at Rebala, Kovur and Purini are presented in Tables 12 to 15 and Appendix-III.

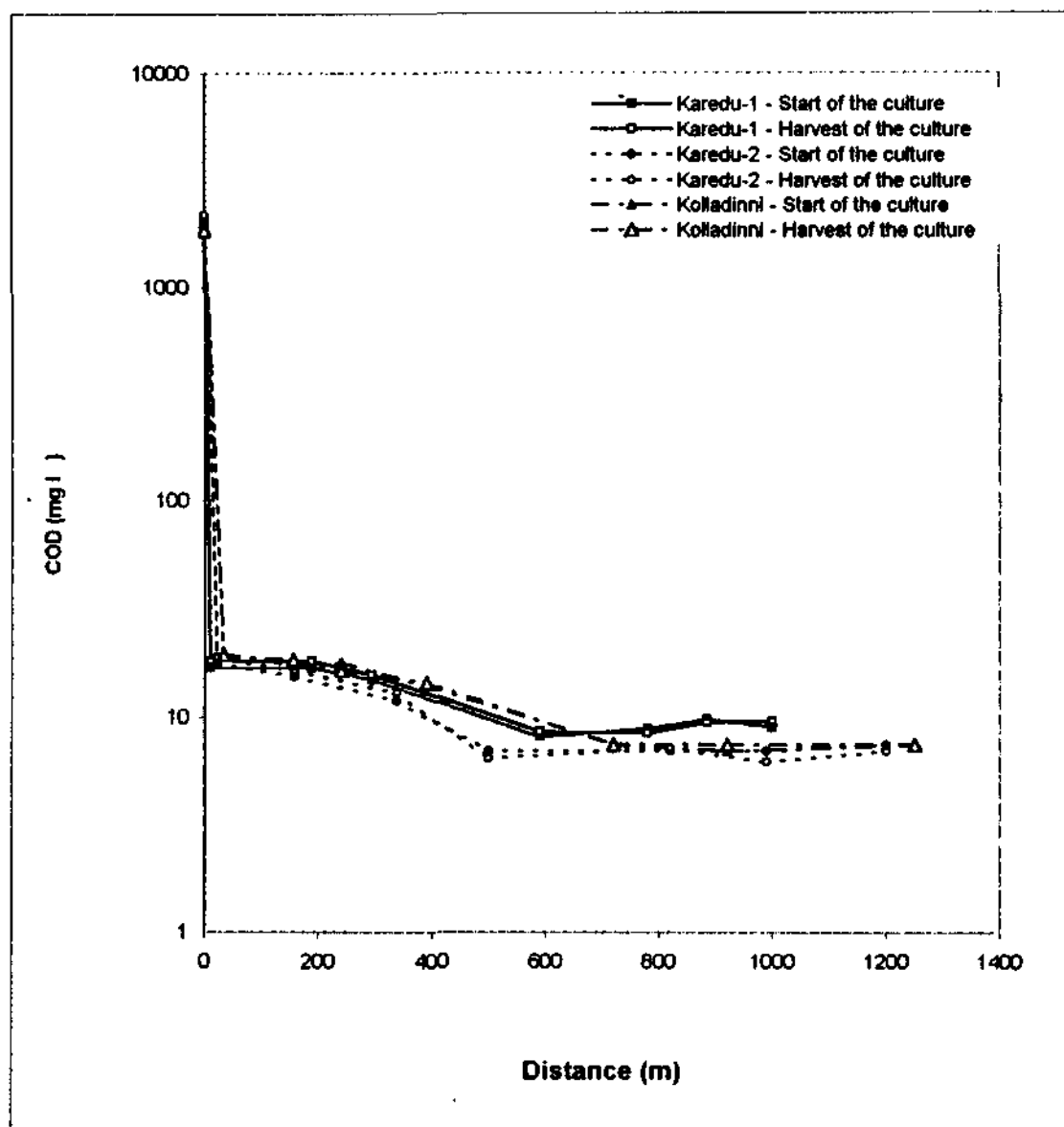


Fig. 21: Influence of brakish water prawn culture on COD of ground waters at different distances from the ponds.

4.3.1.1 Soil texture

The soils were sandy clay loam to clay loams at both Rebala and Kovur upto a lateral distance of 600 m and upto a depth of 60-90 cm (Appendix-III). At Purini, both sandy clay loam and sandy loam were observed. The soils were sandy clay loam at all the depths upto a distance of 600 m studied at Purini. Clay was varying in the profiles collected upto 600 m distance, was as follows.

Location	Depth of soil (cm)			
	0-15	15-30	30-60	60-90
Rebala	24.2 to 24.6	26.42 to 29.40	29.42 to 36.50	33.0 to 39.4
Kovur	22.82 to 27.2	26.8 to 30.8	30.4 to 34.6	37.42 to 41.50
Purini	19.2 to 22.4	26.42 to 36.4	27.62 to 37.50	29.62 to 37.4

Thus the soil profiles particularly at lower depths have considerable amount of clay and clay percentage in general was tending to increase with depth in all the profiles. There was wide variations of sand in the soils around with fresh water ponds. The sand percentage was varying between 49.2 and 72.0 at Rebala, 45.6 to 67.7 at Kovur and 47.6 to 69.3 at Purini respectively.

4.3.1.2 Bulk density (BD)

Bulk density of soil did not vary significantly with distance at all the three locations studied. However it ranged from 1.38 to 1.42, 1.39 to 1.42 and 1.41 to 1.45 Mg m^{-3} at Rebala, Kovur and Purini respectively (Table 12). It also did not vary due to the depth of soil and time of sampling at all the three locations.

Table 12 : Influence of fresh water fish culture on bulk density of soil (Mg m^{-3}) at various distances from the pond, depth of soil and sampling time.

Treatment	Village		
	Rebala	Kovur	Purini
Distance (m)			
0	1.41	1.41	1.42
25	1.40	1.42	1.45
50	1.42	1.39	1.42
100	1.38	1.41	1.43
200	1.39	1.39	1.42
400	1.38	1.40	1.41
600	1.39	1.42	1.42
CD at 5%	NS	NS	NS
Depth of soil (cm)			
0-15	1.38	1.39	1.41
15-30	1.41	1.42	1.43
CD at 5%	NS	NS	NS
Sampling time			
S ₁ Start of the culture	1.39	1.40	1.42
S ₂ Middle of the culture	1.40	1.39	1.41
S ₃ Harvest of the culture	1.41	1.41	1.42
CD at 5%	NS	NS	NS

NS: Not significant

4.3.1.3 Water stable aggregates in diameter (> 0.25 mm)

The per cent water stable aggregates of soils (> 0.25 mm) did not differ with distance from pond at all the three locations studied (Table 13). However the water stable aggregates ranged from 33.00 to 35.00, 38.65 to 40.65 and 21.45 to 24.50 per cent at Rebala, Kovur and Purini respectively. Similarly water stable aggregates did not differ due to depth of soil and sampling time also at all the three locations studied.

4.3.1.4 Hydraulic conductivity of soil (HC)

The hydraulic conductivity of soil did not vary significantly due to distance at all the three locations studied (Table 14). Nevertheless, HC was less at 0 and 25 m distance from the ponds at all the three locations. It ranged from 3.00 to 3.59, 2.00 to 2.30 and 2.89 to 3.25 cm hr^{-1} at Rebala, Kovur and Purini respectively. It also did not vary due to the depth of soil and sampling time

4.3.1.5 Infiltration rate (IR)

The infiltration rate of soils did not vary significantly with distance at all the three locations (Table 15). However, it varied from 3.7 to 4.2, 2.4 to 2.8 and 2.7 to 3.0 cm hr^{-1} at Rebala, Kovur and Purini respectively. Infiltration did not vary due to sampling time at all the three locations.

4.3.2 Brackish water prawn culture

The data relating to physical properties of soils viz., texture, bulk density, per cent water stable aggregates (> 0.25 mm), hydraulic conductivity and

Table 13 : Influence of fresh water fish culture on per cent water stable aggregate at various distances from the pond, depth of soil and sampling time.

Treatment	Village		
	Rebala	Kovur	Purini
Distance (m)			
0	34.3	40.0	21.5
25	35.4	40.1	22.5
50	33.5	39.7	23.5
100	35.0	38.7	23.5
200	34.5	40.6	24.5
400	33.0	40.4	22.5
600	34.0	40.7	22.6
CD at 5%	NS	NS	NS
Depth of soil (cm)			
0-15	33.9	40.1	23.7
15-30	34.5	39.9	22.2
CD at 5%	NS	NS	NS
Sampling time			
S ₁ Start of the culture	34.5	39.5	23.2
S ₂ Middle of the culture	34.6	40.1	23.4
S ₃ Harvest of the culture	33.5	40.4	22.8
CD at 5%	NS	NS	NS

NS: Not significant

Table 14: Influence of fresh water fish culture on Hydraulic conductivity of soil (cm hr⁻¹) at various distances from the pond, depth of soil and sampling time.

Treatment	Village		
	Rebala	Kovur	Purini
Distance (m)			
0	3.00	2.00	2.96
3.05	2.07	2.95	2.95
50	3.24	2.10	2.89
100	3.29	2.20	3.20
200	3.55	2.30	3.25
400	3.59	2.30	3.00
600	3.37	2.00	3.25
CD at 5%	NS	NS	NS
Depth of soil (cm)			
0-15	3.20	2.15	3.10
15-30	3.20	2.14	3.05
CD at 5%	NS	NS	NS
Sampling time			
S ₁ Start of the culture	3.40	2.10	3.10
S ₂ Middle of the culture	3.25	2.17	3.05
S ₃ Harvest of the culture	3.20	2.15	3.00
CD at 5%	NS	NS	NS

NS: Not significant

Table 15 : Influence of fresh water fish culture on infiltration rate of soil (cm hr^{-1}) at various distances from the pond, depth of soil and sampling time.

Treatment	Village		
	Rebala	Kovur	Purini
Distance (m)			
0	3.8	2.5	2.7
25	3.7	2.4	2.8
50	4.0	2.6	2.9
100	4.1	2.4	2.7
200	3.9	2.5	3.0
400	4.0	2.7	2.9
600	4.2	2.8	3.0
CD at 5%	NS	NS	NS
Sampling time			
S ₁ Start of the culture	4.1	2.5	2.8
S ₂ Middle of the culture	3.9	2.4	2.9
S ₃ Harvest of the culture	3.8	2.6	3.0
CD at 5%	NS	NS	NS

NS: Not significant

infiltration rate of soils adjoining brackish water prawn culture ponds at Karedu-1, Karedu-2 and Kolladinni are presented in Tables 16 to 20 and Appendix-III.

4.3.2.1 Soil texture

The soils adjoining to brackish water ponds at all the three locations were vary from loam to sandy clay loam. The clay percentage in these samples was varying as follows.

Location	Depth of Soil			
	0-15	15-30	30-60	60-90
Karedu-1	17.53 to 23.42	19.76 to 23.28	22.73 to 25.37	23.99 to 28.44
Karedu-2	14.36 to 18.74	16.36 to 19.57	19.37 to 26.72	23.72 to 29.33
Kolladinni	16.36 to 19.36	18.50 to 16.36	21.73 to 29.92	24.53 to 33.49

There was wide variations of the sand in the soils around with brackish water ponds. Sand percentage in these soils was varying between 51.1 and 59.7 at Karedu-1, 47.6 and 61.9 at Karedu-2 and from 60.7 to 81.6 at Kolladinni.

4.3.2.2 Bulk density of soil (BD)

Bulk density of soil did not vary significantly due to distance from the pond at all the three locations studied (Table 16). However, it ranged from 1.52 to 1.60, 1.56 to 1.60 and 1.55 to 1.60 Mg m⁻³ at Karedu-1, Karedu-2 and Kolladinni respectively, like distances, depth of the soil and sampling time also did not influence the bulk density at all the three locations.

Table 16 : Influence of brackish water prawn culture on bulk density of soil (Mg m^{-3}) at various distances from the pond, depth of soil and sampling time.

Treatment	Village		
	Karedu-1	Karedu-2	Kolladinni
Distance (m)			
0	1.60	1.59	1.60
25	1.52	1.56	1.55
50	1.59	1.60	1.61
100	1.56	1.58	1.56
200	1.54	1.56	1.57
400	1.59	1.60	1.60
600	1.52	1.57	1.56
CD at 5%	NS	NS	NS
Depth of soil (cm)			
0-15	1.54	1.57	1.56
15-30	1.57	1.58	1.59
CD at 5%	NS	NS	NS
Sampling time			
S ₁ Start of the culture	1.54	1.58	1.58
S ₂ Middle of the culture	1.39	1.57	1.58
S ₃ Harvest of the culture	1.57	1.58	1.58
CD at 5%	NS	NS	NS

NS: Not significant

4.3.2.3 Water stable aggregates (> 0.25 mm diameter)

The per cent water stable aggregates did not vary significantly due to sampling distance (Table 17). However, it ranged from 23.0 to 25, 25.0 to 28.0 and 21.40 to 25.50 at Karedu-1, Karedu-2 and Kolladinni respectively. The depth of soil and sampling time was also not found to have any significant effect on the water stable aggregates.

4.3.2.4 Hydraulic conductivity (HC)

Hydraulic conductivity of soil varied significantly due to distances at all the three locations (Table 18). Higher hydraulic conductivity of 5.16 cm hr^{-1} was obtained at 600 m distance, however, it was comparable with the value at 400 m distance (4.95 cm hr^{-1}) at Karedu-1. Lower value of 3.82 cm hr^{-1} was obtained adjacent the pond. The values obtained at 25 (4.43 cm hr^{-1}), 50 (4.49 cm hr^{-1}) and 100 m (4.58 cm hr^{-1}) distances were comparable and were significantly lower compared to 400 m distance. The values at 200 m distance (4.78 cm hr^{-1}) was comparable with 50 (4.49), 100 (4.58 cm hr^{-1}) and 400 m (4.95 cm hr^{-1}) distance.

At Karedu-2, highest hydraulic conductivity of 4.58 cm hr^{-1} was obtained at 600 m distance and was comparable with the value at 100 (4.19 cm hr^{-1}) and 200 (4.38 cm hr^{-1}) and 400 m (4.56 cm hr^{-1}) distances from the pond. Lowest value of 3.62 cm hr^{-1} was obtained at 0 m distance but it was at par with 25 m (3.73 cm hr^{-1}) distance.

At Kolladinni, highest value of 4.14 cm hr^{-1} was obtained at 600 m distance but it was comparable with the values at 200 (3.31 cm hr^{-1}) and 400 m

Table 17 : Influence of brackish water prawn culture on per cent water stable aggregate at various distances from the pond, depth of soil and sampling time.

Treatment	Village		
	Karedu-1	Karedu-2	Kolladinni
Distance (m)			
0	23.0	25.0	21.4
25	23.5	26.0	24.5
50	23.0	25.5	25.0
100	25.0	26.5	24.0
200	25.5	26.4	25.0
400	25.0	28.0	24.5
600	24.0	27.5	25.5
CD at 5%	NS	NS	NS
Depth of soil (cm)			
0-15	24.0	25.6	24.0
15-30	24.4	27.0	24.5
CD at 5%	NS	NS	NS
Sampling time			
S ₁ Start of the culture	24.5	25.5	24.0
S ₂ Middle of the culture	24.0	25.5	24.0
S ₃ Harvest of the culture	24.0	25.0	24.8
CD at 5%	NS	NS	NS

NS = Not significant

Table 18 : Influence of brackish water prawn culture on hydraulic conductivity of soil (cm hr^{-1}) at different distances from the pond, depth of the soil and sampling time.

Treatment	Village		
	Karedu-1	Karedu-2	Kolladinni
Distance (m)			
0	3.82	3.62	3.05
25	4.43	3.93	3.18
50	4.49	4.09	3.35
100	4.58	4.19	3.40
200	4.78	4.38	3.71
400	4.95	4.56	4.13
600	5.16	4.58	4.14
CD at 5%	0.30	0.45	0.43
Depth of soil (cm)			
0-15	4.65	4.18	3.55
15-30	4.59	4.19	3.59
CD at 5%	NS	NS	NS
Sampling time			
S ₁ Start of the culture	4.65	4.26	3.59
S ₂ Middle of the culture	4.60	4.18	3.56
S ₃ Harvest of the culture	4.55	4.12	3.55
CD at 5%	NS	NS	NS

NS: Not significant

(3.71 cm hr⁻¹). Lowest value of 3.05 cm hr⁻¹ was obtained near the pond but it was on par with those at 25 (3.18 cm hr⁻¹), 50 (3.35 cm hr⁻¹) and 100 m (3.40 cm hr⁻¹) distances from the pond.

4.3.2.5 Infiltration rate (IR)

The final infiltration rate of water into the soils varied significantly due to distances at all the three locations (Table 19). In general, it increased with increase in distance from the pond at all the three locations. At Karedu-1, the values obtained at 0 (10.8 cm hr⁻¹) and 25 m (10.7 cm hr⁻¹) were at par and both were significantly lower as compared to rest of the distances. The increase of infiltration rate was almost similar beyond 200 m distance.

At Karedu-2, lower infiltration rate values were obtained at 0 m (10.7 cm hr⁻¹) and 25 m (10.9 cm hr⁻¹) distance from the pond which were on par. Further, the values at 50 m (11.2 cm hr⁻¹), 100 m (11.3 cm hr⁻¹) and 200 m (11.2 cm hr⁻¹) distance from the pond were at par. The increase in infiltration rate was sharp beyond 200 m and significantly higher as compared to rest of the distances.

At Kolladinni, lowest infiltration rate was obtained at 0 m (6.0 cm hr⁻¹) distance. It slightly increased upto 100 m distance. From 100 m onwards, the increase in infiltration rate was abrupt (7.0 cm hr⁻¹ at 100 m and 8.2 cm hr⁻¹ at 200 m). The infiltration rate varied significantly due to sampling time at Karedu-1 and Kolladinni. Higher and lower infiltration rate was obtained at the start and harvest of the culture respectively. However, infiltration rate obtained at the harvest of the culture was comparable with the middle of the culture at Karedu-1 and Kolladinni.

Table 19 : Influence of brackish water prawn culture on the infiltration rate (cm hr^{-1}) at various distances from the pond and sampling time.

Treatment	Village		
	Karedu-1	Karedu-2	Kolladinni
Distance (m)			
0	10.8	10.7	6.0
25	10.7	10.9	6.8
50	11.1	11.2	6.9
100	11.1	11.3	7.0
200	11.3	11.2	8.2
400	12.1	12.5	8.6
600	12.1	12.7	8.5
CD at 5%	0.2	0.2	0.1
Sampling time			
S ₁ Start of the culture	11.5	11.6	7.6
S ₂ Middle of the culture	11.3	11.4	7.4
S ₃ Harvest of the culture	11.2	11.5	7.4
CD at 5%	0.1	NS	0.1

NS Not significant

Table 20: Interaction between distances and sampling times on infiltration rate (cm hr^{-1}) at Kolladinni.

Treatment	Sampling time		
	S ₁	S ₂	S ₃
Distance (m)			
0	6.2	6.1	5.8
25	7.2	7.1	6.9
50	7.2	6.7	6.9
100	7.2	6.8	6.6
200	8.3	8.1	8.2
400	8.5	8.3	8.8
600	8.4	8.3	8.6
CD at 5%		1.8	

S₁ = Start of the culture

S₂ = Middle of the culture

S₃ = Harvest of the culture

Interaction between infiltration rate and sampling time was significant at Kolladinni village only (Table 20). Lower infiltration rate was obtained near the pond at all the sampling time (6.2 cm hr^{-1} at start of the culture, 6.1 cm hr^{-1} at middle of the culture and 5.8 cm hr^{-1} at harvest of the culture). The infiltration rate of soils gradually increased with increase in distance from the pond and the maximum values were obtained at 600 m distance at all the three sampling times.

4.4 EFFECT OF AQUACULTURE ON THE SOIL CHEMICAL PROPERTIES OF ADJOINING FIELDS

4.4.1 Fresh water fish culture

The soil samples collected in the immediate vicinity and laterally above 600 meters of fresh water fish culture ponds at Rebala, Kovur and Purini, were analysed for chemical properties like pH, EC, OC, available N, P, K, DTPA extractable micronutrients viz., Zn, Fe, Mn and Cu to assess the effects of fish culture on adjoining fields. The relevant data are presented in tables from 21 to 36. A critical examination of the data revealed that there was no appreciable change in the soil reaction, but the soluble salt content was significantly higher in the immediate neighbourhood of the pond at all the three locations studied. The mean organic carbon, available N, P, K and DTPA extractable Zn, Fe, Mn, Cu were also significantly higher in the immediate vicinity of the pond at all the three places studied.

4.4.1.2 Soil reaction (pH)

From the data presented in Table 21, it ^{is} ~~could be~~ noticed that the pH of soil did not vary significantly due to sampling distance at all the three places while it was slightly higher in the immediate vicinity of the pond. However, the mean pH value ranged from 7.60 to 7.75, 7.70 to 7.85 and 7.79 to 7.88 at Rebala, Kovur and Purini respectively.

The pH of soil did not differ due to depth of soil also at all three locations studied.

Like distance and depth of soil, pH of the soil did not vary significantly due to sampling times at all the three locations studied.

4.4.1.3 Soluble salts (EC)

Soluble salts, as indicated by EC varied significantly due to sampling distance at all the three locations (Table 22). EC of the soil was higher in the immediate neighbourhood of the pond and it decreased with increase in distance from the pond at all the three locations studied.

At Rebala, EC decreased from 5.10 to 4.60 dSm^{-1} from 0 to 50 m and was significantly higher as compared to the rest of distances. Further, EC abruptly decreased beyond 50 m. The EC did not vary significantly between 100 and 600 m distance from the pond. At Kovur, EC was significantly higher at 0 m (13.86 dSm^{-1}), 25 m (13.49 dSm^{-1}) and 50 m (12.50 dSm^{-1}) distance from the pond as compared to farther distances. Beyond 50 m, the decrease in EC was sharp. At 100

Table 21 : Influence of fresh water fish culture on pH of soil at various distances from the pond, depth of soil and sampling time.

Treatment	Village		
	Rebala	Kovur	Purini
Distance (m)			
0	7.75	7.85	7.88
25	7.72	7.82	7.85
50	7.72	7.84	7.85
100	7.65	7.80	7.83
200	7.60	7.70	7.88
400	7.60	7.72	7.80
600	7.63	7.75	7.79
CD at 5%	NS	NS	NS
Depth of soil (cm)			
0-15	7.70	7.80	7.81
15-30	7.74	7.82	7.82
30-60	7.76	7.84	7.86
60-90	7.75	7.85	7.91
CD at 5%	NS	NS	NS
Sampling time			
S ₁ Start of the culture	7.72	7.80	7.80
S ₂ Middle of the culture	7.75	7.82	7.82
S ₃ Harvest of the culture	7.78	7.80	7.80
CD at 5%	NS	NS	NS

NS = Not significant

Table 22 : Influence of fresh water fish culture on EC of soil (dSm^{-1}) at various distances from the pond, depth of soil and sampling time

Treatment	Village		
	Rebala	Kovur	Purini
Distance (m)			
0	5.10	13.86	15.11
25	4.88	13.49	14.27
50	4.60	12.50	12.44
100	0.78	7.00	8.59
200	0.92	0.60	4.89
400	0.74	0.60	1.24
600	0.71	0.52	1.19
CD at 5%	0.22	0.33	0.48
Depth of soil (cm)			
0-15	2.89	7.59	9.35
15-30	2.62	6.96	8.82
30-60	2.55	6.30	7.82
60-90	2.28	6.20	7.00
CD at 5%	NS	NS	NS
Sampling time			
S ₁ Start of the culture	2.40	6.70	7.68
S ₂ Middle of the culture	2.35	6.75	8.10
S ₃ Harvest of the culture	2.90	6.73	8.96
CD at 5%	NS	NS	NS

NS = Not significant

m, the EC was 7.00 dSm^{-1} which was significantly higher as compared to 100, 200, 400, 600 m distance.

At Purini, EC decreased significantly with successive increase in distance of sampling from the pond upto 200 m (15.11 to 4.87 dSm^{-1}). After 200 m distance, the decrease in EC was sharp. EC values did not differ between 400 (1.24 dSm^{-1}) and 600 m distance (1.19 dSm^{-1}).

EC did not differ significantly with depth. However, it decreased with increase in depth of soil at all three locations. It ranged from 2.28 to 2.89, 6.20 to 7.59 and 7.00 to 9.35 dSm^{-1} at Rebala, Kovur and Purini respectively.

EC values did not vary significantly during different sampling periods at all the three locations.

4.4.1.4 Organic carbon (OC)

The organic carbon (Table 23) varied significantly due to distance of sampling at all the three locations studied and it was higher in the immediate neighbourhood of the pond. In general, organic carbon decreased with an increase in the distance from the pond. The decrease in organic carbon was sharp from 50 m onwards at Rebala, from 100 m onwards at Kovur; and at 50 m onwards at Purini. Higher OC of 0.332 per cent at Rebala and 0.196 per cent at Purini were at 0 m distance from the pond, which were significantly higher as compared to farther distance of sampling. At Kovur, organic carbon values obtained at 0 m (0.273 per cent), 25 m (0.151 per cent) and 100 m distance (0.105 per cent) were comparable and significantly higher as compared to the same at longer distances.

Table 23: Influence of fresh water fish culture on organic carbon (per cent) at various distances from the pond, depth of soil and sampling time.

Treatment	Village		
	Rebala	Kovur	Purini
Distance (m)			
0	0.332	0.273	0.196
25	0.303	0.269	0.151
50	0.272	0.260	0.105
100	0.193	0.248	0.083
200	0.152	0.161	0.093
400	0.199	0.168	0.078
600	0.155	0.175	0.071
CD at 5%	0.023	0.048	0.017
Depth of soil (cm)			
0-15	0.343	0.319	0.178
15-30	0.277	0.249	0.129
30-60	0.192	0.166	0.087
60-90	0.109	0.154	0.049
CD at 5%	0.017	0.036	0.013
Sampling time			
S ₁ Start of the culture	0.250	0.229	0.126
S ₂ Middle of the culture	0.226	0.230	0.109
S ₃ Harvest of the culture	0.214	0.207	0.078
CD at 5%	NS	NS	NS

NS = Not significant

Organic carbon was higher in surface layers as compared to deeper layers at all sampling sites. Higher organic carbon content of 0.343 per cent at Rebala, 0.319 at Kovur and 0.178 at Purini was in 0-15 cm layer. Lower OC of 0.109 per cent at Rebala, 0.154 per cent at Kovur and 0.049 per cent at Purini, was observed at a depth of 60-90 cm.

Organic carbon did not vary significantly due to sampling times at all the three locations. It ranged from 0.214 to 0.250, 0.207 to 0.230 and 0.078 to 0.126 per cent at Rebala, Kovur and Purini respectively.

4.4.1.5 Available nitrogen (N)

Available nitrogen (Table 24) varied significantly with the distances at all the three locations. It was higher nearer to the pond. In general available nitrogen decreased gradually with an increase in distance from the pond at all three locations studied. Higher available N of 211 kg ha⁻¹ at Rebala, 198 kg ha⁻¹ at Kovur and 1.55 kg ha⁻¹ at Purini was obtained in the immediate neighbourhood of the pond (0 m distance) but the same was on par with that of 25 m distance. The available N was lower at 200 m distance at Rebala (107 kg ha⁻¹), 200 m distance at Kovur (143 kg ha⁻¹) and 600 m distance at Purini (82 kg ha⁻¹) compared to the remaining distances of sampling. However, it was on par with that of 400 m distance at Kovur (147 kg ha⁻¹) and Purini (82 kg ha⁻¹).

The available nitrogen was varied significantly due to depth of soil. It was higher in the surface layers and decreased with every increase in depth of soil at all the three locations. It decreased from 219 to 96; 267 to 105, and 177 to 61 kg ha⁻¹ at Rebala, Kovur and Purini respectively.

Table 24 : Influence of fresh water fish culture on available N (kg ha^{-1}) at various distances form the pond, depth of soil and sampling time.

Treatment	Village		
	Rebala	Kovur	Purini
Distance (m)			
0	211	198	153
25	209	190	148
50	197	184	116
100	123	168	95
200	107	143	89
400	134	147	82
600	136	165	82
CD at 5%	11	13	10
Depth of soil (cm)			
0-15	219	267	177
15-30	186	177	126
30-60	138	134	74
60-90	96	105	61
CD at 5%	8	10	7
Sampling time			
S ₁ Start of the culture	158	176	118
S ₂ Middle of the culture	168	167	108
S ₃ Harvest of the culture	153	170	103
CD at 5%	NS	NS	NS

NS = Not significant

Available nitrogen did not vary significantly with the time of sampling.

4.4.1.6 Available phosphorus (P)

The available P (Table 25) in soil varied significantly due to distance of sampling at all the three locations while it was higher in the immediate vicinity of the pond. In general, it decreased with an increase in distance of sampling from the pond. At Rebala, P content at 0, 25 and 50 m distance (12 kg ha^{-1}) was more or less same, and was significantly higher as compared to the same at the remaining distances. Available P obtained at 100 m distance was higher as compared to the same at 200, 400 and 600 m distance at Rebala and Kovur. At Kovur, available P at 0 m (14.1 kg ha^{-1}), 25 m (14.0 kg ha^{-1}) distance was almost the same, but significantly higher as compared to the rest of the distances. Available P at 50 m (13.3 kg ha^{-1}) and 100 m distance (13.0 kg ha^{-1}) was comparable, but was higher than at 200, 400 and 600 m distance from the pond at Kovur. Available P at 200, 400 and 600 m distance from the pond was comparable, but relatively lower as compared to the other distances of sampling at both Rebala and Kovur. At Purini, higher available P of 11.2 kg ha^{-1} was at 0 m, but was comparable to 25 m distance (10.9 kg ha^{-1}). Available P obtained at 400 m (7.1 kg ha^{-1}) and 600 m was equal but relatively less than that of other distances of sampling.

Available P varied significantly due to depth of soil at all the three locations. It was higher in the surface layer, and decreased with successive increase in depth of soil. It ranged from 6.0 to 16.0, 6.3 to 18.2, and 5.0 to 14.5 kg ha^{-1} at Rebala, Kovur and Purini respectively.

Table 25 : Influence of fresh water fish culture on available P (kg ha^{-1}) at various distances from the pond, depth of soil and sampling time.

Treatment	Village		
	Rebala	Kovur	Purini
Distance (m)			
0	12.0	14.1	11.2
25	12.0	14.0	10.9
50	12.0	13.3	10.5
100	10.2	13.0	9.5
200	9.1	10.6	9.4
400	9.0	10.4	7.1
600	9.0	10.6	7.1
CD at 5%	1.0	0.7	0.6
Depth of soil (cm)			
0-15	16.0	18.2	14.5
15-30	13.0	16.3	11.2
30-60	7.1	8.1	6.2
60-90	6.0	6.3	5.0
CD at 5%	0.7	0.5	0.5
Sampling time			
S ₁ Start of the culture	11.5	13.3	9.6
S ₂ Middle of the culture	10.1	12.0	9.1
S ₃ Harvest of the culture	10.0	12.0	9.0
CD at 5%	NS	0.40	NS

NS = Not significant

It did not differ significantly with the time of sampling at Rebala and Purini. At Kovur, however higher P of 13.3 kg ha^{-1} was obtained at the start of the culture. The available P obtained at the middle and harvest of the culture (12.0 kg ha^{-1}) was identical.

4.4.1.7 Available potassium (K)

The available K (Table 26) varied significantly due to sampling distance at all the three locations. It was higher in the immediate neighbourhood of the pond. In general, K gradually decreased with increasing distance from the pond.

At Rebala, K estimated at 0 m (230 kg ha^{-1}), 25 m (229 kg ha^{-1}) and 50 m (226 kg ha^{-1}) distance from the pond was almost the same and significantly higher as compared to longer distances of sampling. Between 100 and 600 m distance from the pond, it was more or less the same.

At Kovur, K decreased significantly with increase in distance from the pond upto 100 m (267 to 246 kg ha^{-1}). Beyond 100 m, its decrease was sharp.

At Purini, K decreased significantly with an increase in sampling distance from the pond. At 0 m (215 kg ha^{-1}) and 25 m (211 kg ha^{-1}) distance, K values were comparable and were significantly higher as compared to the other distances of sampling. From 50 to 600 m distance, it decreased with successive increase in sampling distance from the pond.

It varied significantly due to depth of the soil at all three locations. It decreased from 311 to 153, 353 to 164 and 296 to 132 kg ha^{-1} upto 90 cm depth at Rebala, Kovur and Purini respectively. It did not vary, similarly, due to sampling

Table 26 : Influence of fresh water fish culture on available K (kg ha^{-1}) at various distances from the pond, depth of soil and sampling time.

Treatment	Village		
	Rebala	Kovur	Purini
Distance (m)			
0	230	267	215
25	229	261	211
50	226	253	203
100	190	246	197
200	189	211	185
400	182	214	163
600	186	219	152
CD at 5%	4	3	4
Depth of soil (cm)			
0-15	311	353	296
15-30	199	243	175
30-60	163	196	155
60-90	153	164	132
CD at 5%	3	3	3
Sampling time			
S ₁ Start of the culture	209	239	189
S ₂ Middle of the culture	205	237	189
S ₃ Harvest of the culture	206	240	190
CD at 5%	NS	NS	NS

NS = Not significant

time at all three locations. However, it ranged from 206 to 209, 237 to 240 and 189 to 190 kg ha⁻¹ at Rebala, Kovur and Purini respectively.

Interaction between distance of sampling from the pond and sampling time was significant at Kovur (Table 27). It decreased with an increase in distance from the pond at all three sampling times. The available K at 0, 25 and 50 m distance was almost equal and decreased sharply beyond 50 m distance at all three sampling times. The difference in available K among 100, 200, 400 and 600 m distance was very small and not significant.

These interactions at Purini were also significant (Table 28). It decreased with increase in distance from the pond at all the soil depths. The decrease was sharp beyond 100 m distance at all the depths of soil. At a given distance, the available K was higher in the surface layers (0-15 cm) and decreased with depth.

4.4.1.8 Zinc (Zn)

From the data presented in Table 29, it could be noticed that DTPA extractable Zn varied significantly due to distance at all the locations studied while it was higher in the immediate neighbourhood of the pond. It decreased as the distance increased from the pond at all three locations. At Rebala, Zn at 0 m (0.42 mg kg⁻¹) and 25 m (0.40 mg kg⁻¹) was comparable and were significantly higher as compared longer distances of sampling. Available Zn at 50 m (0.37 mg kg⁻¹) distance was higher than that at 100 (0.29 mg kg⁻¹), 200 (0.29 mg kg⁻¹), 400 (0.28 mg kg⁻¹) and 600 m (0.28 mg kg⁻¹) distance from the pond. At 100, 200, 400 and 600 m distances it was at par.

Table 27 : Interaction between distance and sampling time on available K (kg ha⁻¹) at Kovur.

Treatment	Sampling times		
	Start of the culture	Middle of the culture	Harvest of the culture
Distance (m)			
0	231	228	230
25	229	230	233
50	236	233	239
100	190	187	191
200	194	188	184
400	185	183	176
600	197	188	187
CD at 5%		6	

Table 28 : Interaction between distance and depth of soil on available K (kg ha⁻¹) at Purini

Treatment	Depth of soil (cm)			
	0-15	15-30	30-60	60-90
Distance (m)				
0	396	272	216	188
25	384	276	209	178
50	365	272	203	172
100	348	268	199	169
200	316	203	182	145
400	326	205	178	145
600	336	205	184	156
CD at 5%		7		

Table 29 : Influence of fresh water fish culture on available Zn (mg ha^{-1}) at various distances from the pond, depth of soils and sampling time.

Treatment	Village		
	Rebala	Kovur	Purini
Distance (m)			
0	0.42	0.58	0.44
25	0.40	0.53	0.42
50	0.37	0.51	0.42
100	0.29	0.43	0.42
200	0.29	0.41	0.42
400	0.28	0.37	0.29
600	0.28	0.37	0.29
CD at 5%	0.02	0.03	0.02
Depth of soil (cm)			
0-15	0.52	0.67	0.61
15-30	0.41	0.54	0.46
30-60	0.27	0.37	0.26
60-90	0.12	0.24	0.21
CD at 5%	0.02	0.02	0.01
Sampling time			
S ₁ Start of the culture	0.31	0.47	0.39
S ₂ Middle of the culture	0.34	0.46	0.39
S ₃ Harvest of the culture	0.35	0.44	0.38
CD at 5%	NS	NS	NS

NS = Not significant

At Kovur, available Zn at 0 m distance (0.58 mg kg^{-1}) was higher compared to rest of sampling distances. Zn content at 25 m (0.53 mg kg^{-1}) and 50 m (0.51 mg kg^{-1}) distance was comparable but was higher to that of 100, 200, 400 and 600 m distance from the pond.

At Purini, Zn content at 0 (0.441 mg kg^{-1}), 25 (0.421 mg kg^{-1}), 50 (0.421 mg kg^{-1}), 100 (0.421 mg kg^{-1}) and 200 m (0.42) distance was comparable but higher than at 400 and 600 m. Its content between 400 m (0.29 mg kg^{-1}) and 600 m (0.29 mg kg^{-1}) was at par. It varied significantly due to depth of soil at all the locations studied. Its content in the surface layers was higher and decreased with depth at all the three locations. It decreased from 0.52 to 0.12, 0.67 to 0.24 and 0.61 to 0.21 mg kg^{-1} at Rebala, Kovur and Purini respectively from the top to 90 cm depth. Its content, similarly, did not vary significantly due to sampling times at all the three places studied. It ranged from 0.31 to 0.35, 0.44 to 0.47 and 0.39 to 0.38 mg kg^{-1} at Rebala, Kovur and Purini respectively.

Interaction between distances and depth of soil on available Zn was significant at all three locations (Table 30). It decreased with an increase in distance in all soil depths. The decrease was sharp beyond 50 m at Rebala, 100 m at Kovur and 200 m distance at Purini.

4.4.1.9 Iron (Fe)

From the data presented in Table 31, it could be noticed that DTPA-Fe content in the soil varied significantly due to distance of sampling at all the three locations. It was higher in the immediate neighbourhood of the pond. In general, its content decreased gradually with distance from the pond.

Table 30 : Interaction between distances and depth of soil on available Zn (mg kg⁻¹)

Distance (m)	Depth of soil (cm)											
	Rebala				Kovur				Purini			
	0-15	15-30	30-60	60-90	0-15	15-30	30-60	60-90	0-15	15-30	30-60	60-90
0	0.67	0.54	0.31	0.14	0.88	0.68	0.44	0.31	0.74	0.53	0.27	0.20
25	0.59	0.53	0.29	0.18	0.77	0.64	0.43	0.26	0.67	0.52	0.29	0.19
50	0.59	0.47	0.32	0.10	0.73	0.61	0.41	0.29	0.64	0.51	0.30	0.24
100	0.47	0.34	0.23	0.11	0.66	0.51	0.32	0.25	0.64	0.50	0.29	0.26
200	0.45	0.35	0.24	0.11	0.55	0.47	0.38	0.23	0.58	0.50	0.30	0.29
400	0.45	0.34	0.24	0.11	0.55	0.43	0.31	0.18	0.48	0.31	0.20	0.15
600	0.44	0.33	0.24	0.11	0.52	0.43	0.34	0.17	0.48	0.33	0.20	0.16
CD at 5%	0.04				0.06				0.04			

Table 31: Influence of fresh water fish culture on available Fe (mg kg^{-1}) at various distances from the pond, depth of soil and sampling time.

Treatment	Village		
	Rebala	Kovur	Purini
Distance (m)			
0	21.92	15.93	40.68
25	21.43	15.50	39.34
50	20.63	14.80	38.05
100	17.18	13.91	37.80
200	16.45	12.60	36.93
400	16.14	12.47	33.76
600	16.04	11.76	33.52
CD at 5%	0.48	0.36	0.84
Depth of soil (cm)			
0-15	31.65	22.38	63.57
15-30	22.73	18.13	48.63
30-60	13.21	12.09	21.18
60-90	6.58	5.02	15.41
CD at 5%	0.37	0.24	0.64
Sampling time			
S ₁ Start of the culture	17.24	14.10	37.85
S ₂ Middle of the culture	18.33	15.63	37.08
S ₃ Harvest of the culture	18.06	13.49	36.60
CD at 5%	NS	NS	NS

NS = Not significant

At Rebala, it decreased significantly with successive increase in sampling distance from 0 to 200 m (21.92 to 16.45 mg kg⁻¹). Its difference at 200, 400 and 600 m away from the pond was not significant. At Kovur, it decreased significantly with in distance from the pond upto 600 m. However its difference between 400 (12.60 mg kg⁻¹) and 600 m (12.47 mg kg⁻¹) was not significant. At Purini, it decreased with distance from the pond upto 400 only. Its difference between 400 (33.76 mg kg⁻¹) and 600 m distance (33.82 mg kg⁻¹) was not significant.

Available Fe also varied significantly due to depth of soil at all three locations. Higher values were obtained in the surface layers, which decreased with in depth of the soil. It decreased from 31.65 to 6.58, 22.38 to 5.02 and 33.57 to 15.41 mg kg⁻¹ at Rebala, Kovur and Purini respectively as the soil depth increased upto 90 cm.

Available Fe content did not differ significantly due to sampling time at all the three locations. It ranged from 17.24 to 18.06, 13.49 to 15.63 and 36.60 to 37.85 mg kg⁻¹ at Rebala, Kovur and Purini respectively during three sampling times.

Interaction between distance of sampling and soil depth on available iron was significant at Rebala (Table 32). Its content decreased with in distance from the pond. The decrease was sharp beyond 50 m distance. At a given distance, available Fe was higher in 0-15 cm soil depth, and decreased with depth.

Table 32 : Interaction between distance and depth of soil on available Fe (mg kg^{-1}) at Rebala.

Treatment	Depth of soil (cm)			
	0-15	15-30	30-60	60-90
Distance (m)				
0	38.35	25.58	15.20	8.58
25	35.42	24.42	15.48	7.18
50	38.22	25.19	14.37	7.93
100	28.19	21.62	12.50	6.42
200	22.22	21.00	11.45	5.53
400	27.07	20.32	11.65	5.53
600	26.62	20.87	11.82	4.85
CD at 5%		0.97		

4.4.1.10 Manganese (Mn)

DTPA-Mn (Table 33) varied significantly with distance at all the three locations. It was higher in the immediate neighbourhood of the pond. Mn estimated at 0 (10.53 mg kg⁻¹), 25 (10.47 mg kg⁻¹) and 50 m (10.40 mg kg⁻¹) at Rebala, 0 m (11.74 mg kg⁻¹) and 25 m (11.76 mg kg⁻¹) at Kovur and 0 (9.22 mg kg⁻¹), 25 m (9.17 mg kg⁻¹), 50 m (9.25 mg kg⁻¹) and 100 m (9.25 mg kg⁻¹) at Purini, was comparable but significantly higher as compared to the longer distance. Beyond 50 m at Rebala, 100 m at Kovur and 100 m at Purini, Mn content decreased abruptly to mg kg⁻¹ soil.

Its content also varied significantly with depth at all three locations. It decreased significantly with depth. It decreased from 12.69 to 4.51, 12.94 to 6.76 and 11.25 to 4.64 mg kg⁻¹ at Rebala, Kovur and Purini respectively as the depth of the soil increased upto 90 cm.

Its content was also significantly higher at culture harvest in Rebala and Kovur ponds. Higher values of Mn were obtained at Rebala (9.37 mg kg⁻¹), Kovur (10.17 mg kg⁻¹) and Purini (8.57 mg kg⁻¹) at the time of culture harvest as compared to either the middle or start of the culture.

Interaction between distance from the pond and depth of soil was significant at Rebala, Kovur and Purini (Table 34). Available Mn decreased with increase in distance from the pond at all soil depths. The decrease was sharp beyond 50 m at Rebala, 100 m at Kovur and 200 m at Purini. At each distance, available Mn was higher in the surface layers of 0-15 cm and decreased gradually with depth upto 90 cm at all the three ponds studied

Table 33 : Influence of fresh water fish culture on available Mn (mg ha^{-1}) at various distances from the pond, depth of soil and sampling time.

Treatment	Village		
	Rebala	Kovur	Purini
Distance (m)			
0	10.53	11.74	9.22
25	10.47	11.76	9.17
50	10.40	11.17	9.25
100	7.88	10.38	9.25
200	7.06	7.45	7.65
400	7.13	7.70	6.43
600	7.18	7.23	6.48
CD at 5%	0.58	0.45	0.46
Depth of soil (cm)			
0-15	12.69	12.94	11.75
15-30	10.14	10.97	9.20
30-60	7.32	7.86	7.23
60-90	4.51	6.76	4.64
CD at 5%	0.44	0.34	0.35
Sampling time			
S ₁ Start of the culture	9.37	10.17	8.57
S ₂ Middle of the culture	8.59	9.72	8.16
S ₃ Harvest of the culture	8.03	9.00	7.29
CD at 5%	0.38	0.29	NS

NS = Not significant

Table 34 : Interaction between distance and depth soil on available Mn (mg kg⁻¹) at Purini

Distance (m)	Depth of soil (cm)											
	Rebala				Kovur				Purini			
	0-15	15-30	30-60	60-90	0-15	15-30	30-60	60-90	0-15	15-30	30-60	60-90
0	16.05	13.45	8.30	4.32	15.72	13.32	9.47	8.25	13.70	10.35	7.63	5.20
25	16.08	13.00	7.92	4.86	16.15	13.60	9.18	8.05	13.37	10.57	7.92	4.82
50	15.47	12.25	8.27	5.63	15.08	13.28	8.77	7.55	13.67	10.40	7.57	5.37
100	11.35	9.25	5.83	5.10	13.29	12.55	8.45	7.22	12.97	10.35	8.27	5.40
200	9.07	7.48	5.18	4.50	10.38	7.95	6.15	5.33	10.87	9.53	6.55	3.63
400	10.53	7.65	6.94	3.38	10.45	8.38	6.58	5.38	9.08	6.45	6.10	4.07
600	10.28	7.88	6.77	3.80	9.28	7.73	6.42	5.50	8.57	6.78	6.10	3.97
CD at 5%	1.16				0.90				0.91			

4.4.1.11 Copper (Cu)

Available copper content in the soils (Table 35) varied significantly due to distances at all the three places studied. Cu values remained more or less equal upto 100 m at Rebala and upto 200 m at Kovur and Purini. At 200, 400 and 600 m distance from the pond at Rebala and Purini, Cu contents were almost the same, but significantly lower as compared to the same in the soils nearer to the pond. At Kovur, its content at 400 (1.80 mg kg^{-1}) and 600 m (1.85 mg kg^{-1}) were on par and significantly lower than in the samples nearer to the pond.

Its content significantly decreased with depth upto 90 cm except in 30-60 and 60-90 cm depth at Kovur, where the trend was reversed.

The time of sampling did significantly influence the available Cu content.

Interaction between distance of sampling and depth of soil was significant at Rebala, Kovur and Purini on Cu (Table 36). It decreased sharply beyond 100 m at Rebala and Kovur, and 200 m at Purini. At each distance available Cu decreased with increase in depth of soil upto 90 cm at all three locations.

4.4.2 Brackish water prawn culture

The soil samples collected from the immediate vicinity of brackish water prawn culture ponds laterally upto about 600 m distance at Kolladinni, Karedu-1 and Karedu-2, were analysed for chemical properties like pH, EC, OC,

Table 35 : Influence of fresh water fish culture on available Cu (mg kg^{-1}) at various distances from the pond, depth of soil and sampling time.

Treatment	Village		
	Rebala	Kovur	Purini
Distance (m)			
0	3.44	2.65	2.68
25	3.26	3.30	2.80
50	3.80	3.11	3.02
100	3.58	2.56	2.79
200	2.51	2.08	2.26
400	2.17	1.80	1.50
600	2.36	1.85	1.45
CD at 5%	0.20	0.14	0.08
Depth of soil (cm)			
0-15	4.67	3.69	3.39
15-30	3.39	2.86	2.45
30-60	2.10	1.70	1.97
60-90	1.91	1.74	1.63
CD at 5%	0.15	0.10	0.06
Sampling time			
S ₁ Start of the culture	3.20	2.61	2.34
S ₂ Middle of the culture	2.98	2.43	2.36
S ₃ Harvest of the culture	3.87	2.40	2.37
CD at 5%	NS	NS	NS

NS = Not significant

Table 36 : Interaction between distance and depth of soil on available Cu (mg kg⁻¹)

Distance (m)	Depth of soil (cm)											
	Rebala				Kovur				Purini			
	0-15	15-30	30-60	60-90	0-15	15-30	30-60	60-90	0-15	15-30	30-60	60-90
0	4.80	3.78	2.73	2.43	4.45	2.72	1.82	1.63	3.77	3.10	2.12	1.75
25	5.55	3.62	2.10	1.77	5.50	4.03	1.84	1.83	4.00	2.95	2.37	1.92
50	6.37	4.48	2.32	2.05	4.63	4.05	1.71	1.85	4.07	3.10	2.82	2.08
100	5.48	4.35	2.53	1.95	3.53	2.88	1.81	2.00	4.05	2.72	2.42	1.98
200	3.98	2.83	1.73	1.50	2.70	2.87	1.43	1.52	3.68	1.93	1.95	1.48
400	3.27	2.12	1.50	1.80	2.38	1.28	1.38	1.55	2.12	1.70	1.12	1.07
600	3.22	2.53	1.82	1.88	2.28	1.77	1.56	1.78	2.07	1.63	1.00	1.07
CD at 5%	0.46				0.27				0.16			

available N, P, K and DTPA extractable micronutrients viz., Zn, Fe, Mn, Cu to assess the effects of brackish water aquaculture ponds on the adjoining fields. The data are presented in Tables from 37 to 53.

A critical examination of data revealed that the mean soil reaction and soluble salt contents were significantly higher in the immediate neighbourhood of the pond at all the three locations studied. The mean EC ranged from 10.40 to 22.95, 9.71 to 21.03 and 14.65 to 42.82 dSm^{-1} as the distance varied from 0-200, 0-200 and 0-100 m from the pond in Karedu-1, Karedu-2 and Kolladinni respectively. The mean organic carbon and available N, P, K and DTPA extractable micronutrients viz., Zn, Fe, Mn, Cu were also similarly higher. The details are presented below.

4.4.2.1 Soil reaction (pH)

From the data presented in Table 37, it could be noticed that the pH of soil in the immediate vicinity of the pond was significantly influenced sampling distance at all the three locations. It was higher in the immediate neighbourhood of the pond. In general it reduced drastically from 200 m onwards at Karedu-1 and Karedu-2, and from 100 m onwards at Kolladinni. The difference in pH between 400 and 600 m distance at Karedu-1 and Karedu-2 and between 200 and 400 m distance at Kolladinni, was not significant

pH of soil was influenced significantly at at Karedu-1 and Karedu-2 by the depth of soil. Lower pH of 7.86 at Karedu-1 and 7.69 at Karedu-2 were noticed in the surface layers 0-15 cm depth, but it was comparable with that 15-30 cm depth. Higher pH of 7.99 and 7.82 were recorded at 30-60 cm depth was at

Table 37 : Influence of brackish water prawn culture on pH of soil at various distances from the pond, depth of the soil and sampling time.

Treatment	Village		
	Karedu-1	Karedu-2	Kolladinni
Distance (m)			
0	8.01	8.14	8.38
25	8.00	7.96	8.22
50	8.00	7.94	8.20
100	7.97	7.88	8.17
200	7.95	7.80	7.50
400	7.73	7.47	7.46
600	7.70	7.47	7.50
CD at 5%	0.06	0.06	0.06
Depth of soil (cm)			
0-15	7.86	7.69	7.85
15-30	7.91	7.73	7.89
30-60	7.96	7.80	7.94
60-90	7.99	7.82	7.90
CD at 5%	0.05	0.06	NS
Sampling time			
S ₁ Start of the culture	7.96	7.79	7.94
S ₂ Middle of the culture	7.89	7.80	7.86
S ₃ Harvest of the culture	7.93	7.85	7.91
CD at 5%	NS	NS	NS

NS = Not significant

Karedu-1 and Karedu-2 respectively, but it was on par with 30-60 cm soil depth at both the places.

It was not influenced significantly by the sampling time at all the three locations. It ranged between 7.89 to 7.96, 7.79 to 7.85 and 7.86 to 7.94 at Karedu-1, Karedu-2 and Kolladinni respectively.

4.4.2.2 Soluble salts (EC)

From the data presented in Table 38, it could be noticed that the EC was significantly influenced by sampling distance at all three locations studied. It was higher in the immediate neighbourhood of the pond. It decreased with successive increase in distance from the pond at all three locations. The decrease was sharp beyond 200 m distance at Karedu-1 and Karedu-2 and beyond 100 m at Kolladinni. However the difference between 400 and 600 m at Karedu-1 and Karedu-2; and between 200, 400 and 600 m distance at Kolladinni, was not significant.

EC of the soil was also significantly influenced by the depth of soil at all three locations studied. It was higher in the surface layers and decreased with depth. Higher EC of 12.94 dSm^{-1} at Karedu-1; 12.80 dSm^{-1} at Karedu-2 and 17.78 dSm^{-1} at Kolladinni was obtained in the surface layer (0-15 cm) but it was on par with that of 15-30 cm depth at Karedu-1 and Karedu-2. The EC was low at 60-90 cm, but was comparable to that of 30-60 cm soil at Kolladinni only.

It varied significantly with the time of sampling. Higher EC was recorded at Karedu-1 (14.02 dSm^{-1}), Karedu-2 (12.46 dSm^{-1}) and at culture harvest

Table 38 : Influence of brackish water prawn culture on EC(dSm⁻¹) of soil at various distances from the pond, depth of the soil and sampling time.

Treatment	Village		
	Karedu-1	Karedu-2	Kolladinni
Distance (m)			
0	22.95	21.03	42.82
25	19.47	19.57	18.06
50	16.53	14.23	16.58
100	13.63	12.19	14.65
200	10.40	9.71	0.38
400	0.02	0.04	0.37
600	0.02	0.04	0.42
CD at 5%	0.64	0.84	1.03
Depth of soil (cm)			
0-15	12.94	12.80	17.78
15-30	12.58	12.44	13.34
30-60	11.36	10.26	11.11
60-90	10.45	9.52	11.07
CD at 5%	0.48	0.64	0.78
Sampling time			
S ₁ Start of the culture	8.40	7.74	10.83
S ₂ Middle of the culture	13.07	11.56	14.79
S ₃ Harvest of the culture	14.02	12.46	14.35
CD at 5%	0.42	0.55	0.18

NS = Not significant

as compared to start of the culture whereas at Kolladinni, the same was higher (14.89 dSm^{-1}) during the middle of the culture.

Interaction between distance and sampling time was significant and the relevant data are presented in Table 39. The EC decreased with increase in distance upto 400 m at Karedu-1 and Karedu-2 and upto 200 m at Kolladinni irrespective of sampling time. The decrease was sharp between 200 and 400 m at Karedu-1 and Karedu-2; and between 100 to 200 m at Kolladinni. The difference in EC between 400 and 600 m at Karedu-1 and Karedu-2 and between 200, 400 and 600 m at Kolladinni was not significant. It increased during the culture irrespective of sample distance from the pond.

Interaction between the distance and depth of soil was significant on the EC (Table 40). It decreased with distance from the pond upto 400 m distance at Karedu-2, and upto 100 m distance at Kolladinni at all the depths of soils studied. The decrease from 400 m onwards at Karedu-2, and at 200, 400 and 600 m distance from the pond at Kolladinni was negligible with the soil depth. EC decreased with successive increase in soil depth at all the three locations studied.

4.4.2.3 Organic carbon (OC)

The OC of the soil (Table 41) varied significantly due to sampling distance at all the three locations studied. It was higher in the immediate neighbourhood of the pond, decreased with distance from the pond. Higher OC content in the soil was obtained in the immediate vicinity of the pond (0 m) at Karedu-1 (0.130 per cent), at Karedu-2 (0.124 per cent) and at Kolladinni (0.376 per cent), but the same was on par with that of 25 m distance at Karedu-1, and at 25 and

Table 39 : Interaction between distances and sampling times on EC of soil (dSm^{-1})

Distance (m)	Sampling time								
	Karedu-1			Karedu-2			Kolladinni		
	S ₁	S ₂	S ₃	S ₁	S ₂	S ₃	S ₁	S ₂	S ₃
0	16.76	24.69	27.19	18.66	23.58	22.84	40.67	44.03	43.73
25	14.74	21.37	22.30	16.79	19.50	22.43	13.50	21.33	19.35
50	11.89	18.04	19.66	13.94	16.74	18.00	11.24	19.27	19.13
100	8.42	15.32	16.58	10.17	13.34	13.06	9.16	17.76	17.04
200	6.77	12.06	12.38	8.58	9.73	10.83	0.39	0.38	0.39
400	0.02	0.02	0.02	0.03	0.04	0.04	0.38	0.37	0.35
600	0.02	0.02	0.02	0.03	0.03	0.03	0.43	0.43	0.39
CD at 5%		0.48			1.46			1.90	

S₁ – Start of the cultureS₂ – Middle of the cultureS₃ – Harvest of the culture

Table 40 : Interaction between distance and depth of soil on EC of soil (dSm^{-1})

Distance (m)	Depth of soil (cm)							
	Karedu-2				Kolladinni			
	0-15	15-30	30-60	60-90	0-15	15-30	30-60	60-90
0	24.70	23.73	18.99	16.99	66.36	39.87	32.43	30.62
25	22.92	21.91	16.72	16.74	20.76	20.33	14.11	17.02
50	18.18	17.36	15.32	14.03	18.09	16.94	16.05	15.23
100	14.06	13.10	11.33	10.27	15.81	15.05	14.10	13.63
200	7.65	10.89	9.42	8.88	0.47	0.41	0.36	0.31
400	0.05	0.04	0.03	0.03	0.47	0.40	0.32	0.28
600	0.05	0.04	0.03	0.02	0.47	0.40	0.41	0.39
CD at 5%			1.69				1.79	

Table 41 : Influence of brackish water prawn culture on organic carbon (%) at various distances, depth of soil and sampling times.

Treatment	Village		
	Karedu-1	Karedu-2	Kolladinni
Distance (m)			
0	0.130	0.124	0.376
25	0.127	0.097	0.362
50	0.084	0.087	0.344
100	0.075	0.083	0.142
200	0.086	0.063	0.129
400	0.083	0.051	0.128
600	0.083	0.058	0.086
CD at 5%	0.008	0.037	0.042
Depth of soil (cm)			
0-15	0.137	0.108	0.334
15-30	0.094	0.148	0.295
30-60	0.079	0.059	0.171
60-90	0.074	0.048	0.075
CD at 5%	0.006	0.028	0.032
Sampling time			
S ₁ Start of the culture	0.105	0.089	0.243
S ₂ Middle of the culture	0.096	0.092	0.226
S ₃ Harvest of the culture	0.087	0.067	0.202
CD at 5%	0.005	NS	NS

NS = Not significant

50 m distance at Karedu-2 and Kolladinni. Beyond 25 m at Karedu-1, 150 m at Kolladinni, the decrease in OC was abrupt and significantly lower as compared to the remaining distances.

It also varied significantly due to depth of sampling. In general, it decreased with successive increase in soil depth. Its mean content decreased from 0.137 to 0.074, 0.108 to 0.048 and 0.334 to 0.075 per cent at Karedu-1, Karedu-2 and Kolladinni respectively as the soil depth increased upto 90 cm.

It was also noticed to vary significantly due to sampling times at Karedu-1, while such variation was not observed at Karedu-2 and Kolladinni. In general, the organic carbon decreased by the time of culture harvest.

4.4.2.4 Available Nitrogen (N)

From the data presented in Table 42, it could be noticed that the available N varied significantly due to sampling distance at all three locations. It was higher in the immediate neighbourhood of the pond and decreased with distance. Higher available N of 169 kg ha⁻¹ at Karedu-1, 148 kg ha⁻¹ at Karedu-2 and 206 kg ha⁻¹ at Kolladinni was obtained in the soil located in the immediate vicinity of pond but it was comparable with that of 25 m distance (205 kg ha⁻¹) at Kolladinni. Beyond 100 m at Karedu-1 and 50 m at Karedu-2 and Kolladinni, its decrease was sharp. Lower N content was observed at 600 m distance at Karedu-1 (113 kg ha⁻¹), Karedu-2 (106 kg ha⁻¹) and Kolladinni (86 kg ha⁻¹), but these were comparable with that of 400 m distance at Karedu-1 (114 kg ha⁻¹) and Karedu-2 (105 kg ha⁻¹)

Table 42 : Influence of brackish water prawn culture on available N (kg ha^{-1}) at various distances, depth of soil and sampling time.

Treatment	Village		
	Karedu-1	Karedu-2	Kolladinni
Distance (m)			
0	169	148	206
25	163	127	205
50	127	125	205
100	124	118	142
200	118	110	138
400	114	105	136
600	113	106	86
CD at 5%	3	5	3
Depth of soil (cm)			
0-15	197	166	258
15-30	152	136	170
30-60	105	102	117
60-90	76	77	94
CD at 5%	2	4	3
Sampling time			
S ₁ Start of the culture	139	128	163
S ₂ Middle of the culture	137	120	160
S ₃ Harvest of the culture	132	112	156
CD at 5%	2	4	2

NS = Not significant

It varied significantly with soil depth at all the three locations studied. It decreased significantly with successive increase in soil depth upto 90 cm at all the three locations.

The available N content also varied significantly with sampling time at all the three locations. Its content increased due to culture except at Karedu-1, where there was no change in its content (138 and 137 kg ha⁻¹) at the middle and start of the culture respectively.

4.4.2.5 Available Phosphorus (P)

Available P (Table 43) significantly decreased with distance at all the three locations. It was higher in the immediate neighbourhood of the pond. The decrease was sharp beyond 200 m distance at Karedu-1 and Karedu-2, and beyond 100 m distance at Kolladinni. Higher available P of 12.3 kg ha⁻¹ at Karedu-1, 12.4 kg ha⁻¹ at Karedu-2, and 16.4 kg ha⁻¹ at Kolladinni was noticed in the soil in the immediate vicinity of the pond, which was comparable with that of 25 m distance at Karedu-1. Available P at 400 and 600 m distance at Karedu-1 (7.5 and 7.8 kg ha⁻¹), Karedu-2 (7.5 and 7.8 kg ha⁻¹) and at 200 (10.3 kg ha⁻¹), 400 m (10.8 kg ha⁻¹) and 600 m (10.8 kg ha⁻¹) distance at Kolladinni were comparable but were significantly lower as compared to the soil at other distances.

It decreased with successive increase in soil depth upto 90 cm at all three locations, the decrease being from 14.4 to 6.8, 13.0 to 6.4 and 18.4 to 8.4 kg ha⁻¹ at Karedu-1, Karedu-2 and Kolladinni respectively.

Table 43 : Influence of brackish water prawn culture on available P (kg ha^{-1}) at various distances from the pond, depth of soil and sampling time.

Treatment	Village		
	Karedu-1	Karedu-2	Kolladinni
Distance (m)			
0	12.3	12.4	16.4
25	17.2	11.7	15.3
50	10.8	10.4	14.5
100	9.9	9.8	14.6
200	9.7	9.1	10.3
400	7.5	7.5	10.8
600	7.8	7.8	10.8
CD at 5%	0.4	0.4	0.5
Depth of soil (cm)			
0-15	14.4	13.0	18.4
15-30	13.3	11.8	16.0
30-60	8.4	8.2	10.1
60-90	6.8	6.9	8.4
CD at 5%	0.8	0.8	0.4
Sampling time			
S ₁ Start of the culture	10.3	10.1	13.0
S ₂ Middle of the culture	12.2	9.8	13.2
S ₃ Harvest of the culture	9.70	9.6	13.4
CD at 5%	NS	NS	NS

NS = Not significant

4.4.2.6 Available potassium (K)

From the data presented in Table 44, it could be noticed that the available K significantly decreased due to sampling distance at all the three locations. It was higher in the immediate neighbourhood of the pond. Its content decreased gradually from 0 to 200 m (176 to 160 kg ha⁻¹) 0 - 200 m (189 to 175 kg ha⁻¹) and 0-100 m (259 to 214 kg ha⁻¹) at Karedu-1, Karedu-2 and Kolladinni respectively. The decrease was very sharp beyond 200 m (134 to 129 kg ha⁻¹) at Karedu-1 and Karedu-2 (129 to 126 kg ha⁻¹); and beyond 100 m at Kolladinni (161 to 149 kg ha⁻¹).

It significantly decreased with soil depth at all three locations. While it was higher in the surface soil (0-15 cm), it decreased significantly with successive increase of soil depth.

Time of sampling did not vary the available K significantly at all the three locations. However, its mean value ranged from 156 to 159, 165 to 167 and 195 to 198 kg ha⁻¹ at Karedu-1, Karedu-2 and Kolladinni respectively.

Interaction between distance and sampling time at Karedu-1 (Table 45) revealed that the available K decreased with increase in distance from the pond but the decrease was sharp beyond 200 m distance from the pond at all three sampling times. It was lower at the start of the culture and increased by the harvest time at all distances of sampling.

Interaction between distance and soil depth was also significant at Karedu-1, Karedu-2 and Kolladinni (Table 46). It decreased with distance from the

Table 44 : Influence of brackish water prawn culture on available K (kg ha^{-1}) at various distances from the pond, depth of soil and sampling time.

Treatment	Village		
	Karedu-1	Karedu-2	Kolladinni
Distance (m)			
0	176	189	259
25	174	185	222
50	163	181	211
100	164	175	214
200	160	175	149
400	134	126	158
600	129	128	161
CD at 5%	2	2	3
Depth of soil (cm)			
0-15	226	245	307
15-30	148	165	220
30-60	134	141	134
60-90	121	111	124
CD at 5%	1	4	2
Sampling time			
S ₁ Start of the culture	156	165	195
S ₂ Middle of the culture	158	166	196
S ₃ Harvest of the culture	159	167	198
CD at 5%	NS	NS	NS

NS = Not significant

Table 45 : Interaction between distance and sampling time on available K (kg ha⁻¹) at Karedu-1.

Distance (m)	Sampling time		
	Start of the culture	Middle of the culture	Harvest of the culture
0	171	178	181
25	169	174	179
50	158	164	167
100	161	164	167
200	158	161	163
400	137	133	131
600	132	129	125
CD at 5%		3	

Table 46 : Interaction between distance and depth soil on available K (kg ha⁻¹)

Distance (m)	Depth of soil (cm)											
	Karedu-1				Karedu-2				Kolladinni			
	0-15	15-30	30-60	60-90	0-15	15-30	30-60	60-90	0-15	15-30	30-60	60-90
0	255	173	149	128	274	180	164	135	376	277	197	183
25	250	168	145	133	268	185	158	128	337	270	146	136
50	242	147	138	127	271	182	148	123	331	243	137	134
100	238	149	135	133	262	178	143	118	333	242	142	138
200	242	142	138	121	251	178	154	117	139	160	108	88
400	176	129	125	104	189	128	106	83	257	169	107	98
600	181	124	111	100	201	125	114	74	269	176	104	93
CD at 5%	3				5				6			

pond in all the soil depths. The decrease was sharp beyond 200 m onwards at Karedu-1 and Karedu-2, and beyond 100 m onwards at Kolladinni. At each distance, available K was higher in the surface layer and decreased with increase in depth of soil upto 90 cm depth.

4.4.2.7 Zinc (Zn)

The DTPA-Zn content significantly decreases with distance at all the three locations. It was higher in the immediate neighbourhood of the pond (Table 47). Its content at 0 (0.34 mg kg^{-1}), 25 (0.35 mg kg^{-1}), and at 50 m (0.33 mg kg^{-1}) distance from the pond at Karedu-1, and 0 (0.37 mg kg^{-1}) and at 25 m distance (0.38 mg kg^{-1}) at Karedu-2 did not vary significantly, but were higher as compared to the soils collected at longer distances. At Karedu-2, available Zn between 50 m (0.34 mg kg^{-1}) and 100 m (0.33 mg kg^{-1}) was comparable, and both were higher compared to that of 200, 400 and 600 m distances. At Kolladinni, highest available Zn of 0.55 mg kg^{-1} was noticed at 0 m distance, which was comparable to that of longer distances. Its content between 400 and 600 m distance at Karedu-1 and Karedu-2, and between 200 (0.35 mg kg^{-1}), 400 (0.35 mg kg^{-1}) and 600 m (0.35 mg kg^{-1}) distance at Kolladinni were comparable, and were significantly lower as compared to the samples collected at other distances.

It varied significantly with soil depth at all the three locations. Successive increase in depth of soil from 0-15 to 60-90 cm decreased the available Zn at all the three locations.

Table 47: Influence of brackish water prawn culture on available Zn (mg kg^{-1}) at various distances, depth of soil and sampling time.

Treatment	Village		
	Karedu-1	Karedu-2	Kolladinni
Distance (m)			
0	0.34	0.37	0.55
25	0.35	0.38	0.51
50	0.33	0.34	0.49
100	0.30	0.33	0.46
200	0.28	0.29	0.35
400	0.23	0.24	0.35
600	0.22	0.22	0.35
CD at 5%	0.02	0.02	0.02
Depth of soil (cm)			
0-15	0.48	0.49	0.66
15-30	0.33	0.36	0.50
30-60	0.22	0.23	0.36
60-90	0.15	0.15	0.24
CD at 5%	0.02	0.02	0.01
Sampling time			
S ₁ Start of the culture	0.31	0.31	0.44
S ₂ Middle of the culture	0.29	0.31	0.44
S ₃ Harvest of the culture	0.28	0.30	0.45
CD at 5%	NS	NS	NS

NS = Not significant

Sampling time did not influence its content. The mean zinc content varied from 0.28 to 0.31 mg kg⁻¹, 0.30 to 0.31 mg kg⁻¹ and 0.44 to 0.45 mg kg⁻¹ at Karedu-1, Karedu-2 and Kolladinni respectively.

Interaction between distances of sampling from the pond soil depth on available Zn (Table 48) revealed that it decreased with distance from the pond at all depth of soil at all the locations. The decrease was sharp beyond 200 m at Karedu-1 and Karedu-2, beyond 100 m at Kolladinni.

4.4.2.8 Iron (Fe)

Available Fe significantly decreased with distance at all the three locations studied (Table 49). It was higher in the immediate neighbourhood of the pond. It was 10.76 mg kg⁻¹ at Karedu-2 and 14.43 mg kg⁻¹ at Kolladinni in the immediate at 0 m vicinity of the pond which were on par with that of 25 m (11.08 mg kg⁻¹) and 50 m (11.04 mg kg⁻¹) distance at Karedu-2. At 400 m (8.18 mg kg⁻¹) and 600 m (8.50 mg kg⁻¹) at Karedu-2 and at 200 (10.59 mg kg⁻¹), 400 (10.19 mg kg⁻¹) and 600 m (10.28 mg kg⁻¹) at Kolladinni, it was on par, but were significantly lower as compared to the samples collected at shorter distances.

It was influenced significantly due with soil depth at all the three locations. Higher available Fe content, 15.77 mg kg⁻¹ at Karedu-1, 16.09 mg kg⁻¹ at Karedu-2 and 18.61 mg kg⁻¹ at Kolladinni was estimated in the surface layers of 0-15 cm which progressively decreased with soil depth at all the three locations.

It varied significantly due to sampling time at Karedu-2 only, where a decrease was observed with sampling time. Higher available Fe was obtained at

Table 48: Interaction between distance and depth soil on available Zn (mg kg^{-1})

Distance (m)	Depth of soil (cm)											
	Karedu-1				Karedu-2				Kolladinni			
	0-15	15-30	30-60	60-90	0-15	15-30	30-60	60-90	0-15	15-30	30-60	60-90
0	0.56	0.41	0.25	0.16	0.64	0.45	0.21	0.16	0.90	0.63	0.42	0.25
25	0.53	0.42	0.27	0.17	0.61	0.46	0.26	0.18	0.77	0.63	0.41	0.23
50	0.50	0.40	0.23	0.18	0.53	0.43	0.26	0.15	0.70	0.53	0.42	0.30
100	0.47	0.35	0.24	0.16	0.48	0.39	0.26	0.18	0.66	0.54	0.37	0.28
200	0.47	0.27	0.21	0.17	0.43	0.32	0.24	0.17	0.52	0.41	0.36	0.22
400	0.42	0.22	0.17	0.11	0.39	0.26	0.19	0.11	0.52	0.39	0.27	0.22
600	0.34	0.22	0.16	0.12	0.34	0.25	0.18	0.12	0.55	0.39	0.26	0.20
CD at 5%	0.04				0.05				0.04			

Table 49 : Influence of brackish water prawn culture on available Fe (mg ha^{-1}) at various distances from the pond, depth of soil and sampling time.

Treatment	Village		
	Karedu-1	Karedu-2	Kolladinni
Distance (m)			
0	9.55	10.76	14.43
25	11.17	11.08	14.11
50	9.59	11.04	13.23
100	9.58	10.66	13.63
200	9.63	9.94	10.59
400	8.0	8.18	10.19
600	11.35	8.50	10.28
CD at 5%	NS	0.32	0.27
Depth of soil (cm)			
0-15	15.77	16.09	18.61
15-30	11.27	10.46	16.29
30-60	7.53	8.30	8.21
60-90	4.90	5.24	6.15
CD at 5%	0.23	0.24	0.20
Sampling time			
S ₁ Start of the culture	10.99	10.63	12.27
S ₂ Middle of the culture	9.87	9.99	12.33
S ₃ Harvest of the culture	8.73	9.45	12.35
CD at 5%	NS	0.21	NS

NS = Not significant

start of the culture (10.63 mg kg^{-1}) as compared to the harvest of the culture (9.45 mg kg^{-1}).

Interaction between distance and depth of soil on available Fe was significant at Karedu-2 and Kolladinni (Table 50). In general, available Fe decreased with distance from the pond at each depth of soil and the decrease was sharp beyond 200 m distance at Karedu-2, and 100 m distance at Kolladinni.

4.4.2.9 Manganese (Mn)

Available manganese (Table 51) significantly decreased with distance at all three locations. The decrease was sharp from 100 m onwards at Karedu-1 and Kolladinni, and from 200 m at Karedu-2. Higher available Mn of 3.6 mg kg^{-1} at Karedu-1 and 4.99 mg kg^{-1} at Karedu-2 and 10.16 mg kg^{-1} at Kolladinni, were observed in the soil at the immediate vicinity of the pond and it was on par with 25 m (5.10 mg kg^{-1}) distance at Karedu-2 only.

It also varied significantly with soil depth at all three locations studied. It was higher in the surface layer of 0-15 cm depth and decreased with increase in depth of soil at all three locations.

It further varied significantly with sampling time at Karedu-2 only. Higher available Mn was recorded at the start of the culture (4.57 mg kg^{-1}) compared to the harvest of the culture (4.18 mg kg^{-1}).

Interaction between the distance and depth of soil on available Mn was significant at all the three locations (Table 52). In general, available Mn decreased with increase in distance from the pond, and the decrease was sharp

Table 50: Interaction between distance and depth soil on available Fe (mg kg⁻¹)

Distance (m)	Depth of soil (cm)							
	Karedu-2				Kolladinni			
	0-15	15-30	30-60	60-90	0-15	15-30	30-60	60-90
0	17.57	11.37	9.02	5.10	22.62	18.63	9.69	6.87
25	18.33	11.72	8.62	5.63	21.18	18.96	9.32	6.99
50	19.25	11.03	8.38	5.50	19.46	17.62	8.89	7.04
100	16.35	11.47	8.93	5.88	20.00	17.64	8.68	7.13
200	14.50	10.72	8.83	5.70	15.88	14.07	7.48	4.96
400	12.70	8.52	7.15	4.37	15.39	13.82	6.40	5.15
600	13.90	8.43	7.15	4.52	15.74	13.39	7.11	4.90
CD at 5%	0.63				0.54			

Table 51 : Influence of brackish water prawn culture on available Mn (mg kg^{-1}) at various distances from the pond, depth of soil and sampling time.

Treatment	Village		
	Karedu-1	Karedu-2	Kolladinni
Distance (m)			
0	3.60	4.99	10.16
25	2.20	5.10	9.75
50	2.08	4.51	9.94
100	2.09	4.95	9.93
200	1.40	4.40	6.38
400	1.53	3.29	6.30
600	1.34	3.43	6.54
CD at 5%	0.10	0.15	0.30
Depth of soil (cm)			
0-15	4.19	7.50	13.40
15-30	2.09	5.46	10.42
30-60	1.08	2.91	6.20
60-90	0.76	1.67	3.68
CD at 5%	0.10	0.11	0.23
Sampling time			
S ₁ Start of the culture	2.11	4.57	8.32
S ₂ Middle of the culture	2.02	4.40	8.41
S ₃ Harvest of the culture	1.97	4.18	8.55
CD at 5%	NS	0.10	NS

NS = Not significant

Table 52 : Interaction between distance and depth of soil on available Mn (mg kg⁻¹)

Distance (m)	Depth of soil (cm)											
	Karedu-1				Karedu-2				Kolladinni			
	0-15	15-30	30-60	60-90	0-15	15-30	30-60	60-90	0-15	15-30	30-60	60-90
0	6.48	4.30	2.20	1.42	8.82	6.02	3.43	1.68	15.60	13.28	7.95	8.80
25	4.60	2.28	1.13	0.83	8.78	6.48	3.32	1.85	15.18	12.2	7.67	3.93
50	4.27	2.21	1.03	0.80	8.05	5.25	3.07	1.67	15.57	13.0	7.25	3.93
100	4.50	2.12	0.93	0.82	8.43	6.18	2.95	2.23	16.10	12.1	7.13	4.40
200	3.17	1.15	0.80	0.37	7.05	5.98	3.03	1.55	9.93	7.53	4.4	3.67
400	3.75	1.27	0.67	0.45	5.62	4.0	2.13	1.42	10.18	7.27	4.52	3.15
600	2.6	1.32	0.80	0.63	5.73	4.3	2.4	1.30	11.22	9.58	4.45	2.92
CD at 5%	0.26				0.30				0.60			

beyond 100 m distance at Karedu¹ and Kolladinni, and from 200 m distance at Karedu-2.

4.4.2.10 Copper (Cu)

Available Cu (Table 53) was significantly decreased with sampling distance at all the three locations. It was higher in the immediate neighbourhood of the pond.

At Karedu-1, Cu was significantly higher at 50 m distance (1.92 mg kg^{-1}) as compared to further sampling distance. It was almost the same at 0 m (1.4 mg kg^{-1}) and 25 m distance (1.54 mg kg^{-1}); and between 100 m (1.76 mg kg^{-1}) and 200 m (1.75 mg kg^{-1}) distance.

At Karedu-2, available Cu at 0 m (1.80 mg kg^{-1}) was comparable with that of 25 m (1.83 mg kg^{-1}) and 100 m (1.80 mg kg^{-1}) and these were significantly higher as compared to the soils collected from longer distances.

At Kolladinni, higher available Cu of 2.20 mg kg^{-1} was recorded near pond. Its content at 600 m distance (1.51 mg kg^{-1}) was comparable with that of 400 m distance (1.72 mg kg^{-1}).

It varied significantly with soil depth at all three locations. It decreased with each increment in the depth of soil. It was however, not influenced with sampling time.

Table 53 : Influence of brackish water prawn culture on available Cu (mg kg^{-1}) at various distances from the pond, depth of soil and sampling time.

Treatment	Village		
	Karedu-1	Karedu-2	Kolladinni
Distance (m)			
0	1.47	1.80	2.20
25	1.54	1.83	2.16
50	1.92	1.57	2.33
100	1.76	1.80	2.15
200	1.75	1.56	1.72
400	1.12	1.33	1.52
600	0.96	1.15	1.51
CD at 5%	0.12	0.07	0.08
Depth of soil (cm)			
0-15	2.07	2.47	2.67
15-30	1.63	1.86	2.22
30-60	1.16	1.13	1.73
60-90	1.15	0.85	1.15
CD at 5%	0.09	0.06	0.06
Sampling time			
S ₁ Start of the culture	1.59	1.61	1.90
S ₂ Middle of the culture	1.49	1.57	1.95
S ₃ Harvest of the culture	1.43	1.55	1.98
CD at 5%	NS	NS	NS

NS = Not significant

4.5 INFLUENCE OF AQUA PONDS ON HEAVY METALS IN THE SOILS

The effect of ponding water on the accumulation of DTPA extractable heavy metals viz., Cr, Pb, Ni and Cd; was studied by taking the profile samples at 0, 25, 50, 100, 200, 400 and 600 m distance away from the pond at uniform depths of 0-15, 15-30, 30-60, 60-90 cm. The data are presented in Tables 54 to 59 for fresh and brackish water aqua culture.

4.5.1 Fresh water aqua culture ponds

A critical examination of the data (Tables 54 to 56) clearly showed that the heavy metals accumulated throughout the profile upto 90 cm depth at variable distances and from the pond. The extent of accumulation was also varying with the type of heavy metals. The different heavy metals were ranging as detailed below.

Place	Heavy metals (mg kg ⁻¹)			
	Cr	Pb	Ni	Cd
Rebala	0.035 to 0.274	0.013 to 0.120	0.002 to 0.095	0.002 to 0.009
Kovur	0.021 to 0.165	0.014 to 0.126	Not detected to 0.099	Not detected to 0.007
Purini	0.045 to 0.231	0.021 to 0.191	0.018 to 0.152	Not detected to 0.014

The order of heavy metals content in the samples under study was Cr > Pb > Ni > Cd. The heavy metal content was relatively higher in surface soils which steeply decreased with depth and was minimum in 60-90 cm layer. Laterally the mean accumulation as compared to that of the soil at 600 m distance, was upto 50 m distance in the case of Cr and 25 m distance in the case of Ni, upto 25 m there

Table 54. Influence of fresh water fish culture on DTPA extractable heavy metals at various distances and depth of soil at Rebala

Depth of soil (cm)	Distance from the pond (m)						
	0	25	50	100	200	400	600
Chromium (Cr) (mg kg ⁻¹)							
0-15	0.274	0.267	0.249	0.242	0.240	0.239	0.240
15-30	0.160	0.155	0.150	0.145	0.140	0.135	0.139
30-60	0.121	0.110	0.110	0.112	0.107	0.109	0.109
60-90	0.075	0.065	0.064	0.049	0.044	0.039	0.035
Mean	0.158	0.149	0.144	0.125	0.133	0.131	0.131
Lead (Pb) (mg kg ⁻¹)							
0-15	0.120	0.117	0.116	0.114	0.113	0.113	0.114
15-30	0.078	0.074	0.075	0.070	0.074	0.069	0.070
30-60	0.050	0.042	0.049	0.051	0.052	0.047	0.042
60-90	0.020	0.018	0.017	0.016	0.015	0.013	0.014
Mean	0.067	0.063	0.064	0.063	0.064	0.061	0.060
Nickel (ni) (mg kg ⁻¹)							
0-15	0.095	0.085	0.078	0.074	0.074	0.075	0.074
15-30	0.079	0.069	0.061	0.064	0.070	0.069	0.065
30-90	0.005	0.004	0.004	0.004	0.005	0.004	0.004
60-90	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Mean	0.045	0.040	0.036	0.036	0.038	0.038	0.036
Cadmium (Cd) (mg kg ⁻¹)							
0-15	0.009	0.008	0.008	0.007	0.007	0.007	0.006
15-30	0.007	0.006	0.005	0.004	0.003	0.004	0.004
30-60	0.005	0.003	0.004	0.004	0.003	0.003	0.003
60-90	0.001	0.002	0.001	0.002	0.001	0.002	0.002
Mean	0.006	0.005	0.005	0.004	0.004	0.004	0.003

Table 55: Influence of fresh water fish culture on DTPA extractable heavy metals at various distances and depth of soil at Kovur

Depth of soil (cm)	Distance from the pond (m)					
	0	25	50	100	200	400
Chromium (Cr) (mg kg⁻¹)						
0-15	0.165	0.145	0.147	0.144	0.142	0.145
15-30	0.110	0.101	0.090	0.090	0.089	0.091
30-60	0.040	0.030	0.030	0.030	0.040	0.035
60-90	0.020	0.025	0.020	0.022	0.022	0.021
Mean	0.084	0.075	0.072	0.072	0.073	0.073
Lead (Pb) (mg kg⁻¹)						
0-15	0.126	0.120	0.109	0.101	0.099	0.102
15-30	0.075	0.070	0.070	0.065	0.061	0.060
30-60	0.040	0.030	0.025	0.024	0.025	0.028
60-90	0.029	0.019	0.017	0.015	0.014	0.014
Mean	0.068	0.060	0.055	0.051	0.050	0.051
Nickel (Ni) (mg kg⁻¹)						
0-15	0.099	0.082	0.080	0.085	0.080	0.082
15-30	0.060	0.050	0.055	0.050	0.050	0.048
30-90	0.002	0.002	0.001	ND	ND	0.002
60-90	ND	ND	0.001	ND	ND	ND
Mean	0.040	0.034	0.034	0.034	0.033	0.033
Cadmium (Cd) (mg kg⁻¹)						
0-15	0.007	0.006	0.007	0.007	0.007	0.007
15-30	0.004	0.003	0.003	0.004	0.003	0.004
30-60	ND	ND	0.001	0.001	0.001	ND
60-90	ND	ND	ND	ND	ND	ND
Mean	0.003	0.002	0.003	0.003	0.003	0.003

Table 56: Influence of fresh water fish culture on DTPA extractable heavy metals at various distances and depth of soil at Punni

Depth of soil (cm)	Distance from the pond (m)						
	0	25	50	100	200	400	600
Chromium (Cr) (mg kg ⁻¹)							
0-15	0.231	0.221	0.215	0.205	0.212	0.214	0.217
15-30	0.131	0.125	0.129	0.120	0.121	0.121	0.120
30-60	0.080	0.075	0.070	0.075	0.069	0.071	0.072
60-90	0.070	0.045	0.055	0.040	0.044	0.042	0.045
Mean	0.128	0.116	0.117	0.110	0.111	0.112	0.114
Lead (Pb) (mg kg ⁻¹)							
0-15	0.191	0.181	0.174	0.169	0.172	0.170	0.167
15-30	0.101	0.101	0.115	0.111	0.102	0.112	0.108
30-60	0.070	0.071	0.065	0.062	0.062	0.062	0.065
60-90	0.045	0.044	0.045	0.031	0.025	0.021	0.021
Mean	0.102	0.099	0.099	0.093	0.090	0.091	0.090
Nickel (ni) (mg kg ⁻¹)							
0-15	0.152	0.141	0.134	0.139	0.138	0.137	0.139
15-30	0.086	0.085	0.085	0.085	0.081	0.089	0.080
30-90	0.075	0.062	0.050	0.040	0.045	0.049	0.051
60-90	0.035	0.035	0.020	0.020	0.019	0.018	0.019
Mean	0.087	0.081	0.072	0.071	0.071	0.073	0.072
Cadmium (Cd) (mg kg ⁻¹)							
0-15	0.014	0.012	0.012	0.011	0.010	0.010	0.011
15-30	0.010	0.007	0.006	0.007	0.007	0.006	0.007
30-60	ND	ND	0.001	ND	0.001	ND	ND
60-90	ND	ND	ND	ND	ND	ND	ND
Mean	0.006	0.005	0.005	0.005	0.005	0.004	0.005

was not much accumulation of Pb and Cd despite ponding water for 9 years before the period of the study at Rebala. At Kovur, slight Pb accumulation was noticed upto 25 m while there was no change in other metals as compared to that of Rebala. At Purini, the trend was more or less similar.

4.5.2 Brackish water aquaculture ponds

The heavy metal content in the soils was also affected to an extent, due to ponding with brackish water even within a span of two years of ponding as evident from the data presented in Tables 57 to 59. The mean heavy metal content at different locations in the sample studied, was in the following range:

Place	Heavy metals (mg kg ⁻¹)			
	Cr	Pb	Ni	Cd
Karedu-1	0.010 to 0.252	0.035 to 0.415	0.006 to 0.213	0.004 to 0.141
Karedu-2	0.001 to 0.195	0.014 to 0.310	0.008 to 0.231	0.008 to 0.120
Kolladinni	0.018 to 0.310	0.011 to 0.151	0.002 to 0.261	Not detected to 0.121

The order of heavy metals content was in the order of Pb > Cr > Ni > Cd. The heavy metal content decreased with an increase in soil depth at all places of sampling. No Cd could be detected at Kolladinni at 200 m in 60-90 cm soil layer. At Karedu-1, accumulation of Cr, Pb and Cd was observed upto 200 m distance from the pond while that of Ni was noticed upto 100 m only.

The trend was more or less similar at Karedu-2. At Kolladinni, the mean accumulation of Cr, Pb and Ni was observed only upto 100 m distance from the pond while that of Cd was noticed upto 50 m distance only. The heavy metal content in the soils, though higher than that of fresh water ponds, was relatively less

Table 57: Influence of brackish water prawn culture on DTPA extractable heavy metals at various distances and depth of soil at Karedu-I.

Depth of soil (cm)	Distance from the pond (m)						
	0	25	50	100	200	400	600
Chromium (Cr) (mg kg ⁻¹)							
0-15	0.252	0.242	0.235	0.212	0.125	0.115	0.118
15-30	0.141	0.131	0.120	0.110	0.075	0.060	0.065
30-60	0.090	0.080	0.065	0.040	0.027	0.020	0.020
60-90	0.050	0.040	0.030	0.020	0.015	0.010	0.010
Mean	0.133	0.123	0.113	0.096	0.061	0.051	0.053
Lead (Pb) (mg kg ⁻¹)							
0-15	0.415	0.400	0.375	0.300	0.240	0.212	0.232
15-30	0.310	0.301	0.275	0.240	0.145	0.120	0.132
30-60	0.150	0.135	0.120	0.100	0.070	0.055	0.060
60-90	0.090	0.080	0.070	0.065	0.050	0.035	0.045
Mean	0.240	0.229	0.21	0.176	0.126	0.106	0.117
Nickel (ni) (mg kg ⁻¹)							
0-15	0.213	0.205	0.190	0.165	0.130	0.125	0.118
15-30	0.110	0.100	0.085	0.065	0.060	0.055	0.050
30-90	0.060	0.050	0.040	0.025	0.016	0.012	0.012
60-90	0.012	0.011	0.010	0.010	0.007	0.006	0.007
Mean	0.099	0.092	0.081	0.066	0.053	0.050	0.047
Cadmium (Cd) (mg kg ⁻¹)							
0-15	0.141	0.140	0.132	0.125	0.110	0.095	0.101
15-30	0.112	0.108	0.095	0.065	0.055	0.035	0.038
30-60	0.055	0.040	0.032	0.027	0.020	0.011	0.014
60-90	0.020	0.018	0.015	0.011	0.008	0.004	0.004
Mean	0.082	0.077	0.069	0.057	0.048	0.036	0.039

Table 58 : Influence of brackish water prawn culture on DTPA extractable heavy metals at various distances and depth of soil at Karedu-2

Depth of soil (cm)	Distance from the pond (m)						
	0	25	50	100	200	400	600
Chromium (Cr) (mg kg ⁻¹)							
0-15	0.201	0.195	0.175	0.150	0.125	0.115	0.125
15-30	0.101	0.075	0.065	0.068	0.055	0.045	0.050
30-60	0.050	0.044	0.035	0.025	0.019	0.010	0.009
60-90	0.025	0.020	0.010	0.010	0.007	0.001	0.001
Mean	0.094	0.084	0.071	0.063	0.052	0.043	0.046
Lead (Pb) (mg kg ⁻¹)							
0-15	0.345	0.310	0.220	0.150	0.125	0.114	0.117
15-30	0.211	0.190	0.110	0.080	0.075	0.067	0.065
30-60	0.101	0.090	0.0650	0.045	0.030	0.020	0.020
60-90	0.080	0.070	0.037	0.027	0.020	0.014	0.015
Mean	0.184	0.165	0.108	0.076	0.063	0.054	0.054
Nickel (ni) (mg kg ⁻¹)							
0-15	0.245	0.231	0.205	0.185	0.165	0.139	0.135
15-30	0.121	0.115	0.105	0.090	0.082	0.072	0.070
30-90	0.075	0.069	0.059	0.045	0.032	0.024	0.029
60-90	0.040	0.030	0.024	0.020	0.015	0.008	0.009
Mean	0.040	0.030	0.024	0.085	0.015	0.008	0.009
Cadmium (Cd) (mg kg ⁻¹)							
0-15	0.121	0.120	0.110	0.099	0.090	0.085	0.080
15-30	0.101	0.096	0.082	0.071	0.059	0.055	0.052
30-60	0.075	0.050	0.040	0.035	0.025	0.021	0.017
60-90	0.017	0.015	0.012	0.011	0.008	0.008	0.009
Mean	0.079	0.070	0.061	0.054	0.046	0.042	0.040

Table 59 : Influence of brackish water prawn culture on DTPA extractable heavy metals at various distances and depth of soil at Kolladinni

Depth of soil (cm)	Distance from the pond (m)					
	0	25	50	100	200	400
Chromium (Cr) (mg kg⁻¹)						
0-15	0.310	0.301	0.255	0.205	0.145	0.155
15-30	0.210	0.201	0.170	0.130	0.101	0.100
30-60	0.095	0.085	0.075	0.060	0.045	0.050
60-90	0.075	0.065	0.045	0.030	0.019	0.020
Mean	0.173	0.163	0.136	0.106	0.078	0.081
Lead (Pb) (mg kg⁻¹)						
0-15	0.151	0.140	0.132	0.120	0.085	0.099
15-30	0.101	0.100	0.080	0.069	0.065	0.075
30-60	0.092	0.080	0.072	0.047	0.035	0.045
60-90	0.050	0.041	0.029	0.025	0.018	0.011
Mean	0.099	0.090	0.078	0.065	0.051	0.058
Nickel (ni) (mg kg⁻¹)						
0-15	0.261	0.245	0.205	0.190	0.185	0.171
15-30	0.149	0.120	0.110	0.092	0.085	0.075
30-90	0.009	0.008	0.006	0.004	0.004	0.004
60-90	0.008	0.007	0.005	0.004	0.002	0.002
Mean	0.107	0.095	0.082	0.073	0.069	0.063
Cadmium (Cd) (mg kg⁻¹)						
0-15	0.121	0.111	0.102	0.090	0.085	0.086
15-30	0.101	0.090	0.085	0.060	0.055	0.056
30-60	0.095	0.075	0.065	0.040	0.030	0.035
60-90	0.030	0.025	0.015	0.010	ND	ND
Mean	0.087	0.075	0.067	0.050	0.043	0.044

as compared to the critical levels of 5 mg kg^{-1} (Cr), 0.5 mg kg^{-1} (Cd), $2-10 \text{ mg kg}^{-1}$ (Pb) and $2-10 \text{ mg kg}^{-1}$ (Ni) as suggested by Bowen (1966) and Etherington (1982).

These trends showed that the brackish water ponds have a greater tendency for higher accumulation of heavy metals in the soils as compared to that of fresh water.

4.6 INFLUENCE OF AQUA PONDS ON WATER SOLUBLE IONS OF 1:2 SOIL WATER EXTRACT

The effect of aqua ponds on EC of water extract of profile soil (1:2, soil : water) samples collected during 1995-96 at the start of the culture and at the harvest of the culture at 25, 50, 100, 200, 400 and 600 m distance from the ponds was studied. It was observed that the lateral effect of aqua ponds varied at different locations studied. The effect was observed to be significant upto 200 m at Karedu-1 and at Karedu-2, 100 m at Kolladinni under brackish water conditions, while it was upto 50 m only at Rebala, 100 m at Kovur and 200 m at Purini in case of fresh water aqua culture ponds (Tables 22 and 38). The distribution of soluble salts in the soil profile was studied at three locations collecting profile soil samples at 25 m from the pond (nearer to the pond) and at the end of the maximum distance where the effect of the pond was observed in the earlier study (200 m at Karedu-1 and Karedu-2, 100 m at Kolladinni, 50 m at Rebala, 100 m at Kovur and 200 m at Purini) and at 400 m distance (control). Cationic and anionic concentrations of soil water extract were studied in detail. The results are presented in Tables from 60 to 65 and illustrated in Figs. from 22 to 33.

4.6.1 Effect on salt build up in the soil (EC)

From the data (Tables 60 to 65 and Figs. 22 to 33), it could be noticed that there was considerable build up of salts at all the locations studied and it was higher with brackish water as compared to that of fresh water.

4.6.1.1 Effect of fresh water fish culture pond

Against EC of 1.294 dSm^{-1} in the pond water (Table 4) and 0.80 to 1.20 dSm^{-1} in the profile at 400 m at Rebala, the EC in the profile at 25 m away from the pond even at the start of the culture in the first year ranged between 3.25 to 4.20 dSm^{-1} , and 5.00 to 6.20 dSm^{-1} in the same profile by the time of the culture harvest. The salt build up in this profile was 5 to 6 times that of the farthest point (control). The salt build up even within one year was considerable at 50 m distance from the pond. Interestingly, the EC in the profile was in the similar range (3.25 to 4.20 dSm^{-1}) as compared to the profile at 25 m distance (3.40 to 4.20 dSm^{-1}) before the start of the culture. At this distance, the EC in the profile at culture harvest ranged between 5.0 and 6.2 dSm^{-1} compared to 4.5 and 5.5 dSm^{-1} at 25 m. At 400 m also higher EC was noticed (0.80 to 1.20 dSm^{-1}) at the time of culture harvest compared to 0.70 to 0.9 dSm^{-1} at the start of the culture.

At Kovur, where the EC of pond water (1.760 dSm^{-1}) was more or less similar to that of Rebala, the salt accumulation in the profile, as compared to the same at 400 m (0.55 to 0.80 dSm^{-1}) was ranging from 10.5 to 12.0 dSm^{-1} at 25 m and from 4.10 to 5.71 dSm^{-1} at 100 m even before start of the culture, which was indicative of salt accumulation in the profile during the last 10 years of ponding. By the time of culture harvest, EC increased in the profile at Kovur also as in the case of

Rebala, which is a manifestation of seasonal effects and is also indicative of extent of salt accumulation in the profile even within one year.

At Purini, where the EC of water source is much higher (2.120 dSm^{-1}) as compared to that at Kovur and Rebala (Table 4), the salt content in the profile was 9 times more at 25 m and 4 to 5 times more at 200 m away from the pond. Thus, these data revealed considerable amount of salt accumulation in the profile even within one year.

The concentration of salts in the profile at 400 m at all the three locations is very much less than the concentration of salts in the pond water at all the three locations thereby indicating that at 400 m, the salt content in the profile is not yet fully saturated with the salts in the ponding water.

4.6.1.2 Effect of Brackish water Prawn culture ponds

The EC of the waters in the prawn ponds at the three locations was varying between 41.05 and 48.00 dSm^{-1} at the start of the culture and 43.05 to 49.80 dSm^{-1} at the time of harvest. At Karedu-1, the EC in the soil profile at 400 m away from the pond was varying from 0.012 to 0.014 dSm^{-1} at the start of the culture compared to 11.25 to 15.95 dSm^{-1} at 25 m; and 6.72 to 8.32 dSm^{-1} at 200 m away from the pond. This amount of salt build up has been attained within just 2 years of ponding, which is very considerable. Similarly at Karedu-2, the same trend was noticed with relatively higher salt accumulation varying from 12.57 to 16.37 dSm^{-1} at 25 m from the pond; and 7.35 to 10.29 dSm^{-1} at 200 m away from the pond before start of the culture. This is indicative of salt accumulation within just two years of ponding as compared to 0.025 to 0.047 dSm^{-1} in the profile at 400 m away from the

pond. Similar trend was also noticed at Kolladinni, where salt accumulation as indicated by EC was 13.29 to 16.21 dSm^{-1} at 25 m distance and 9.20 to 10.32 dSm^{-1} at 100 m distance compared to only 0.32 to 0.51 dSm^{-1} at 400 m away from the pond.

Another interesting feature that could be noted was that even within one year, there was considerable salt build up with brackish water ponds as compared to fresh water pond culture.

4.6.2 Nature of the accumulating salts in the soil

4.6.2.1 Effect of Fresh water ponds on the nature of salts in the soil

A critical examination of the data (Tables 60 to 62 and Figs.22, 24 and 26) on the cationic composition at Rebala clearly indicate the considerable build up of Na in the soil followed by that of Ca and Mg. At Kovur, the same order of relative cationic composition was reflected. At Purini, however, the accumulation of Mg in the soil profile was higher as compared to that of Ca. K accumulation was the lowest in this case also. While the Na content at harvest of the culture ranged between 5.70 to 12.00 c mol l^{-1} in the profile at 400 m away from the pond, its content was as high as 83.0 to 114.5 c mol l^{-1} at 25 m; and 27.0 to 55.0 c mol l^{-1} at 200 m away from the pond. On the other hand, Mg accumulation in the profile ranged from 22.7 to 31.4 c mol l^{-1} at 25 away from the pond, and 7.20 to 8.50 c mol l^{-1} at 200 m away from the pond as compared to only 2.9 to 3.5 c mol l^{-1} at 400 m, away from the pond. Compared to this, Ca accumulation ranged from only 10.7 to 19.5 c mol l^{-1} at 25 m away from the pond; and 4.90 to 5.90 c mol l^{-1} at 200 m from the pond compared to only 2.0 to 2.5 c mol l^{-1} in the profile at 400 m away

from the pond. K accumulation in the profile ranged from 0.20 to 0.25 c mol l⁻¹ at 25 m away from the pond and 0.06 to 0.08 c mol l⁻¹ at 200 m away from the pond compared to only 0.01 to 0.02 c mol l⁻¹ at 400 m away from the pond.

Among the anions, the accumulation of chlorides was the highest followed by sulphates and HCO₃ in that order at all the three locations of study with the fresh water ponding. The accumulation of chlorides was much higher at Purini followed by that of Kovur and Rebala as could be noticed from Fig. 23, 25 and 27. The carbonates were not detected in the soil profile and in the source water. The source water, interestingly, was dominated by HCO₃ ions at Rebala, chlorides at Kovur and HCO₃ and Cl were more or less equal at Purini. However, culturing increased chloride concentration in the soil to a higher level at all the three locations but accumulation of sulphates in the soil was more as compared to that of HCO₃.

4.6.2.2 Effect of brackish water ponds on the nature of the salts in the soil

The salt concentration in the soil profile at 400 m away from the pond at harvest of the culture was dominated by Ca (0.07 to 0.08 c mol l⁻¹) followed by Na (0.05 to 0.060 c mol l⁻¹), Mg (0.025 to 0.040 c mol l⁻¹) and K (0.012 to 0.017 c mol l⁻¹) at Karedu-1 (Table 63 and Fig.28). This trend was also similar even at Karedu-2. Compared to this at Kolladinni, the salts in the profile at 400 m away from the pond were dominated by high Na (1.40 to 2.10 c mol l⁻¹) in the profile followed by Ca (1.20 to 1.90 c mol l⁻¹) and Mg (0.50 to 0.90 c mol l⁻¹) and K (0.05 to 0.1 c mol l⁻¹) in that order. On the other hand, at 25 m away from the profile, Na content in the profile was many times more (131 to 169 c mol l⁻¹) than

Table 60 : Influence of fresh water fish culture on the composition of soil water extract (1 : 2) at various distances, depth of soil and sampling time at Rebala.

Depth of soil (cm)	EC (dSm ⁻¹)	Cations (c mol l ⁻¹)				Anions (c mol l ⁻¹)			
		Ca	Mg	Na	K	CO ₃	HCO ₃	Cl	SO ₄
25 m distance from the pond									
Start of the culture									
0-15	4.2	9.8	7.5	24.0	0.04	-	2.8	26.0	12.5
15-30	4.0	9.5	6.2	23.5	0.04	-	2.7	25.0	11.5
30-60	3.95	9.0	5.8	23.0	0.04	-	2.4	26.0	11.0
60-90	3.25	7.2	5.0	20.0	0.02	-	2.1	20.0	10.0
Harvest of the culture									
0-15	6.2	13.5	9.5	38.0	0.08	-	4.2	39.6	18.5
15-30	5.5	12.5	8.4	34.0	0.06	-	4.0	32.0	18.0
30-60	5.2	11.2	7.7	33.0	0.06	-	3.6	32.0	16.0
60-90	5.0	9.0	6.8	33.0	0.04	-	3.0	32.5	14.0
50 m distance from the pond									
Start of the culture									
0-15	4.2	9.5	7.3	25.0	0.04	-	2.5	26.5	11.9
15-30	3.9	9.3	6.0	23.1	0.04	-	2.5	25.0	11.0
30-60	3.75	9.1	5.7	22.1	0.02	-	2.3	23.5	10.8
60-90	3.40	8.8	5.5	19.0	0.02	-	2.1	21.0	10.3
Harvest of the culture									
0-15	5.5	12.3	8.2	33.7	0.05	-	4.0	32.0	18.0
15-30	5.1	11.1	7.6	32.0	0.05	-	3.5	31.1	15.8
30-60	4.6	9.9	7.8	28.0	0.04	-	2.7	30.0	12.7
60-90	4.5	9.8	7.6	27.0	0.04	-	2.7	29.8	12.5
400 m distance from the pond (control)									
Start of the culture									
0-15	0.90	3.2	1.7	4.0	0.010	-	1.2	4.1	3.3
15-30	0.90	3.2	1.7	4.0	0.010	-	1.1	4.2	3.2
30-60	0.80	2.8	1.4	3.5	0.010	-	1.0	4.4	2.6
60-90	0.70	2.4	1.2	3.2	0.010	-	0.9	4.2	1.8
Harvest of the culture									
0-15	1.20	4.1	2.0	5.8	0.015	-	1.4	6.7	3.7
15-30	1.00	3.8	1.8	4.3	0.010	-	1.2	5.5	3.2
30-60	0.80	3.0	1.7	3.2	0.010	-	1.0	4.0	2.8
60-90	0.80	2.9	1.4	3.6	0.010	-	1.0	4.1	2.8

Table 61 : Influence of fresh water fish culture on the composition of soil water extract (1 : 2) at various distances, depth of soil and sampling time at Kovur.

Depth of soil (cm)	EC (dSm ⁻¹)	Cations (c mol l ⁻¹)				Anions (c mol l ⁻¹)			
		Ca	Mg	Na	K	CO ₃	HCO ₃	Cl	SO ₄
25 m distance from the pond									
Start of the culture									
0-15	12.0	32.5	18.5	67.0	0.20	-	3.4	75.0	40.0
15-30	11.9	32.5	18.4	66.0	0.20	-	3.2	74.0	40.0
30-60	11.5	30.4	17.0	65.0	0.15	-	2.5	72.0	38.0
60-90	10.5	22.5	16.0	65.0	0.15	-	2.0	68.0	33.0
Harvest of the culture									
0-15	16.5	42.5	23.5	95.0	0.30	-	2.6	110.0	50.0
15-30	15.5	40.5	20.0	92.5	0.25	-	2.4	105.0	45.0
30-60	14.5	36.0	18.0	88.0	0.25	-	2.0	96.0	44.0
60-90	13.85	34.5	17.0	85.0	0.20	-	2.0	92.0	42.0
100 m distance from the pond									
Start of the culture									
0-15	5.71	10.5	8.1	38.0	0.10	-	1.0	40.0	15.0
15-30	4.23	7.5	6.0	28.0	0.08	-	0.7	30.0	10.0
30-60	4.10	7.5	6.0	27.0	0.08	-	0.7	30.0	10.0
60-90	4.15	7.5	6.0	27.0	0.08	-	0.7	29.0	9.5
Harvest of the culture									
0-15	10.12	21.0	10.5	67.0	0.20	-	1.5	73.0	23.0
15-30	8.77	17.5	9.0	60.0	0.15	-	1.3	65.0	20.0
30-60	7.5	14.5	7.0	50.0	0.10	-	1.2	54.0	18.0
60-90	6.2	13.0	6.0	40.0	0.10	-	1.0	43.0	16.0
400 m distance from the pond (control)									
Start of the culture									
0-15	0.8	2.5	1.1	4.00	0.05	-	0.60	3.2	4.0
15-30	0.7	2.2	0.9	3.70	0.05	-	0.50	3.0	3.5
30-60	0.7	2.2	0.9	3.70	0.05	-	0.50	3.0	3.5
60-90	0.6	2.1	0.8	2.90	0.03	-	0.30	2.6	3.0
Harvest of the culture									
0-15	0.80	2.5	1.1	4.0	0.05	-	0.60	3.2	4.1
15-30	0.75	2.4	1.0	3.90	0.05	-	0.50	3.0	4.0
30-60	0.65	2.1	0.8	2.90	0.03	-	0.40	2.8	3.3
60-90	0.55	1.9	0.7	2.80	0.03	-	0.30	2.6	2.5

Table 62 : Influence of fresh water fish culture on the composition of soil water extract (1 : 2) at various distances, depth of soil and sampling time at Purini.

Depth of soil (cm)	EC (dSm ⁻¹)	Cations (c mol l ⁻¹)				Anions (c mol l ⁻¹)			
		Ca	Mg	Na	K	CO ₃	HCO ₃	Cl	SO ₄
25 m distance from the pond									
Start of the culture									
0-15	13.5	14.5	25.00	93.0	0.24	-	2.9	80.0	51.0
15-30	13.1	13.9	24.9	90.0	0.24	-	2.2	80.0	45.0
30-60	11.5	10.5	22.5	80.0	0.20	-	1.9	70.5	41.0
60-90	9.55	6.5	14.5	73.5	0.19	-	1.1	60.0	33.0
Harvest of the culture									
0-15	16.74	19.5	31.4	114.5	0.25	-	3.9	93.0	66.0
15-30	15.64	20.8	29.7	103.0	0.25	-	3.2	93.0	59.0
30-60	13.50	14.2	25.1	94.0	0.20	-	2.5	77.0	53.0
60-90	11.74	10.7	22.7	83.0	0.20	-	1.9	72.0	42.0
200 m distance from the pond									
Start of the culture									
0-15	4.72	5.0	7.7	33.5	0.06	-	2.1	29.5	15.0
15-30	4.25	4.7	7.2	30.0	0.06	-	2.0	31.0	13.5
30-60	3.60	3.8	7.0	24.5	0.04	-	1.8	21.7	12.0
60-90	3.21	3.1	6.8	22.0	0.04	-	1.7	17.0	11.5
Harvest of the culture									
0-15	6.98	5.9	8.5	55.0	0.08	-	2.4	47.0	19.5
15-30	6.34	5.7	8.3	48.7	0.08	-	2.4	41.5	18.5
30-60	4.93	5.2	7.9	36.0	0.06	-	2.2	31.2	15.5
60-90	4.01	4.9	7.2	27.0	0.06	-	2.1	23.9	13.5
400 m distance from the pond (control)									
Start of the culture									
0-15	1.77	2.1	3.2	11.50	0.02	-	1.2	11.5	4.8
15-30	1.50	1.9	2.8	10.00	0.02	-	1.1	9.5	4.2
30-60	1.20	1.5	2.5	7.50	0.02	-	0.9	7.8	3.0
60-90	1.00	1.1	2.1	6.50	0.01	-	0.8	6.5	2.5
Harvest of the culture									
0-15	1.81	2.5	3.5	12.0	0.02	-	1.2	11.1	5.4
15-30	1.61	2.1	2.9	10.5	0.02	-	1.1	10.5	4.2
30-60	1.45	2.0	2.9	9.0	0.02	-	0.9	9.7	3.5
60-90	1.10	2.0	2.9	5.7	0.01	-	0.9	6.2	3.5

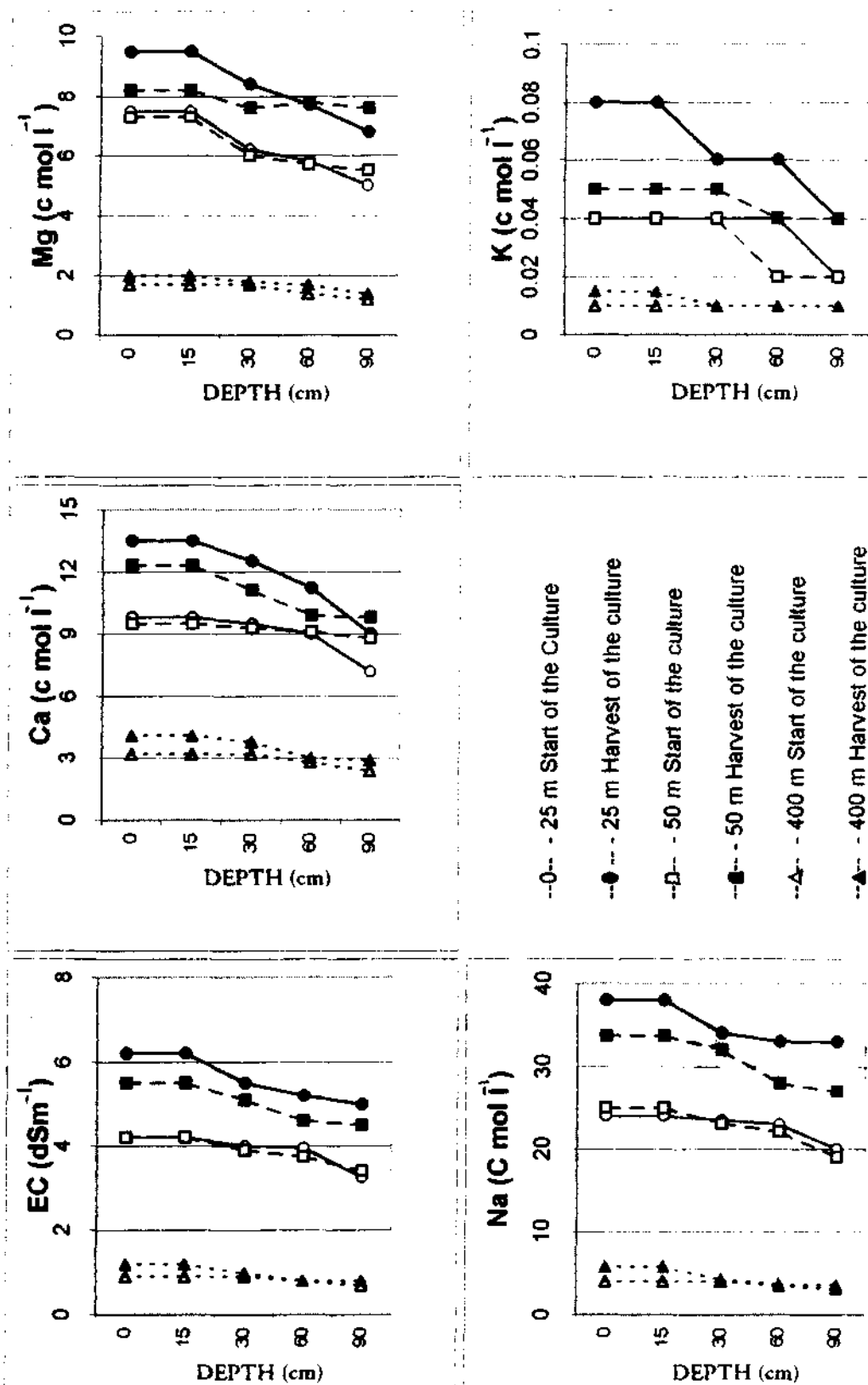


Fig. 22: Influence of fresh water fish culture on EC, Ca, Mg, Na and K of soil water extract (1:2) at various distances (m) at Rebala.

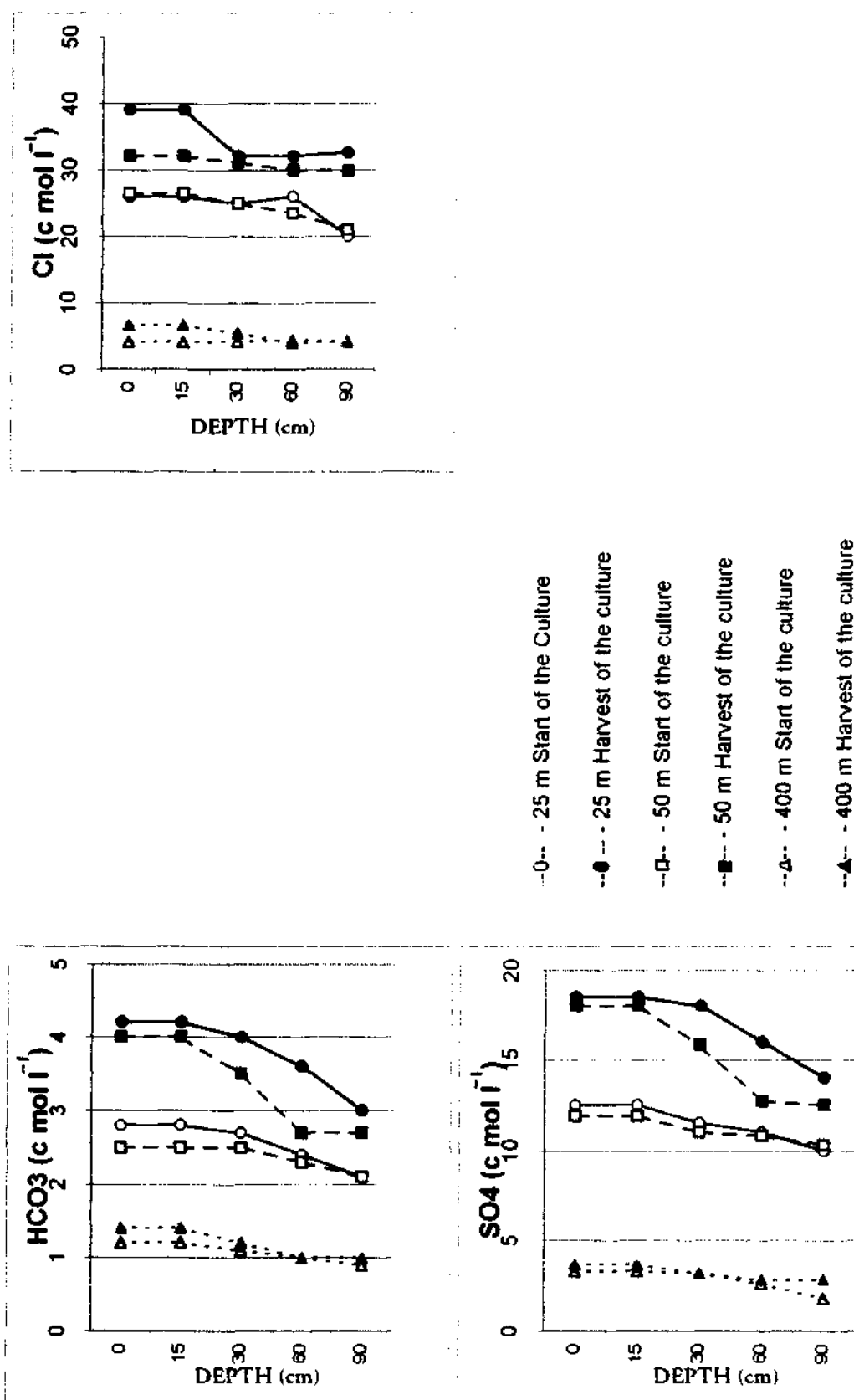


Fig. 23: Influence of fresh water fish culture on HCO_3^- , Cl^- and SO_4^{2-} of soil water extract (1:2) at various distances (m) at Rebala

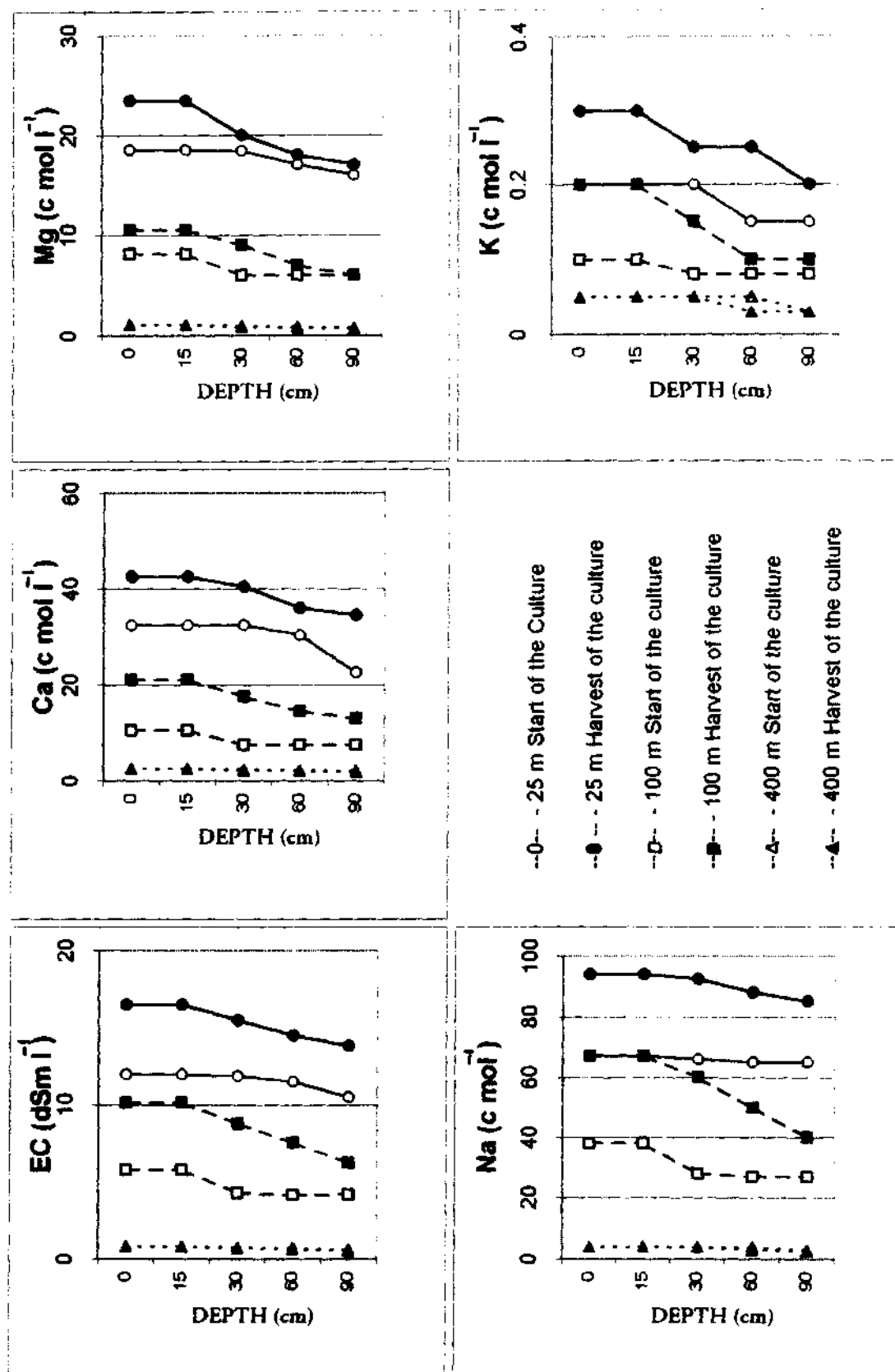


Fig. 24: Influence of fresh water fish culture on EC, Ca, Mg, Na and K of soil water extract (1:2) at various distances (m) at Kovur

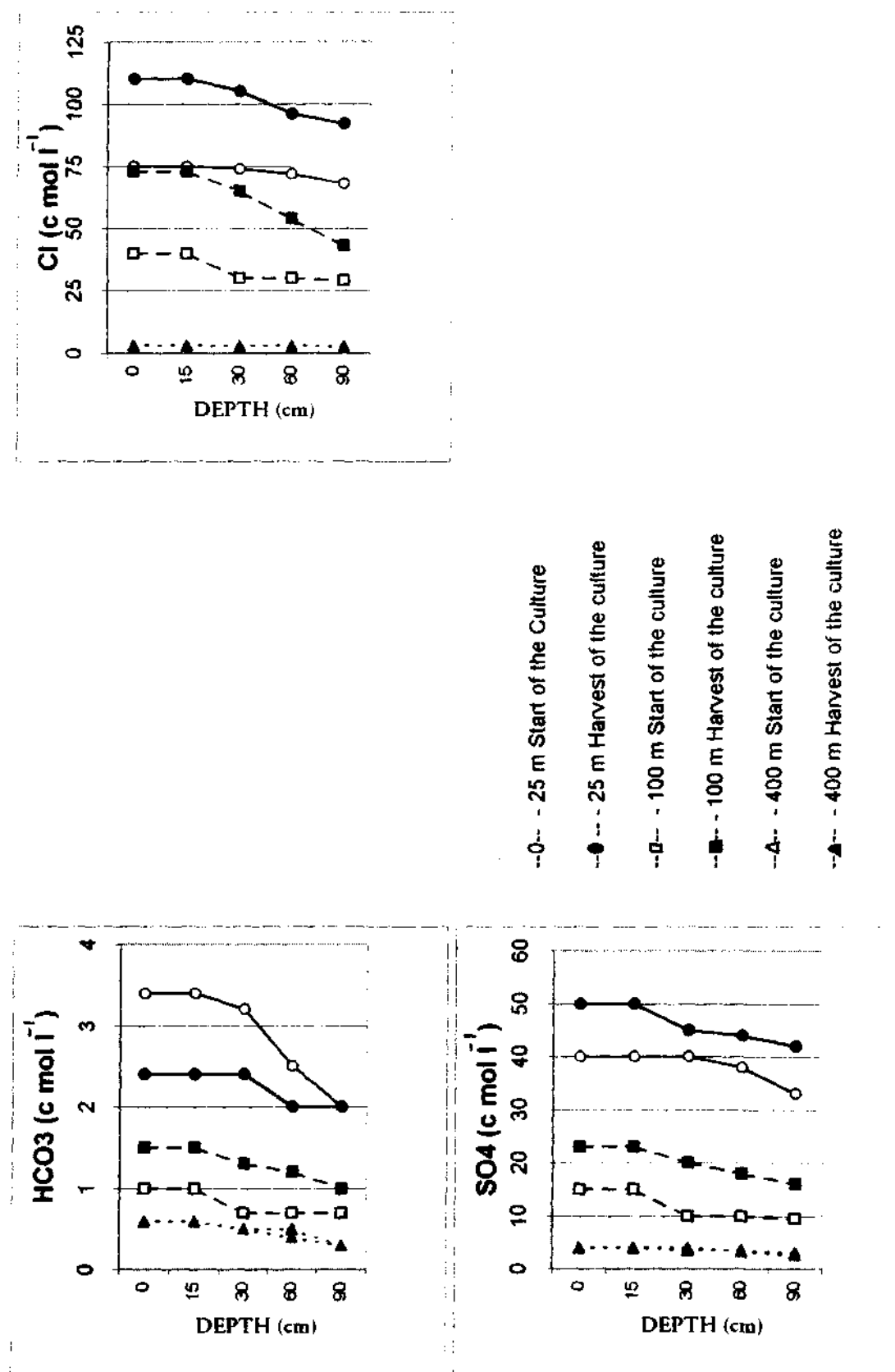


Fig. 25: Influence of fresh water fish culture on HCO_3^- , Cl and SO_4 of soil water extract (1:2) at various distances (m) at Kovur

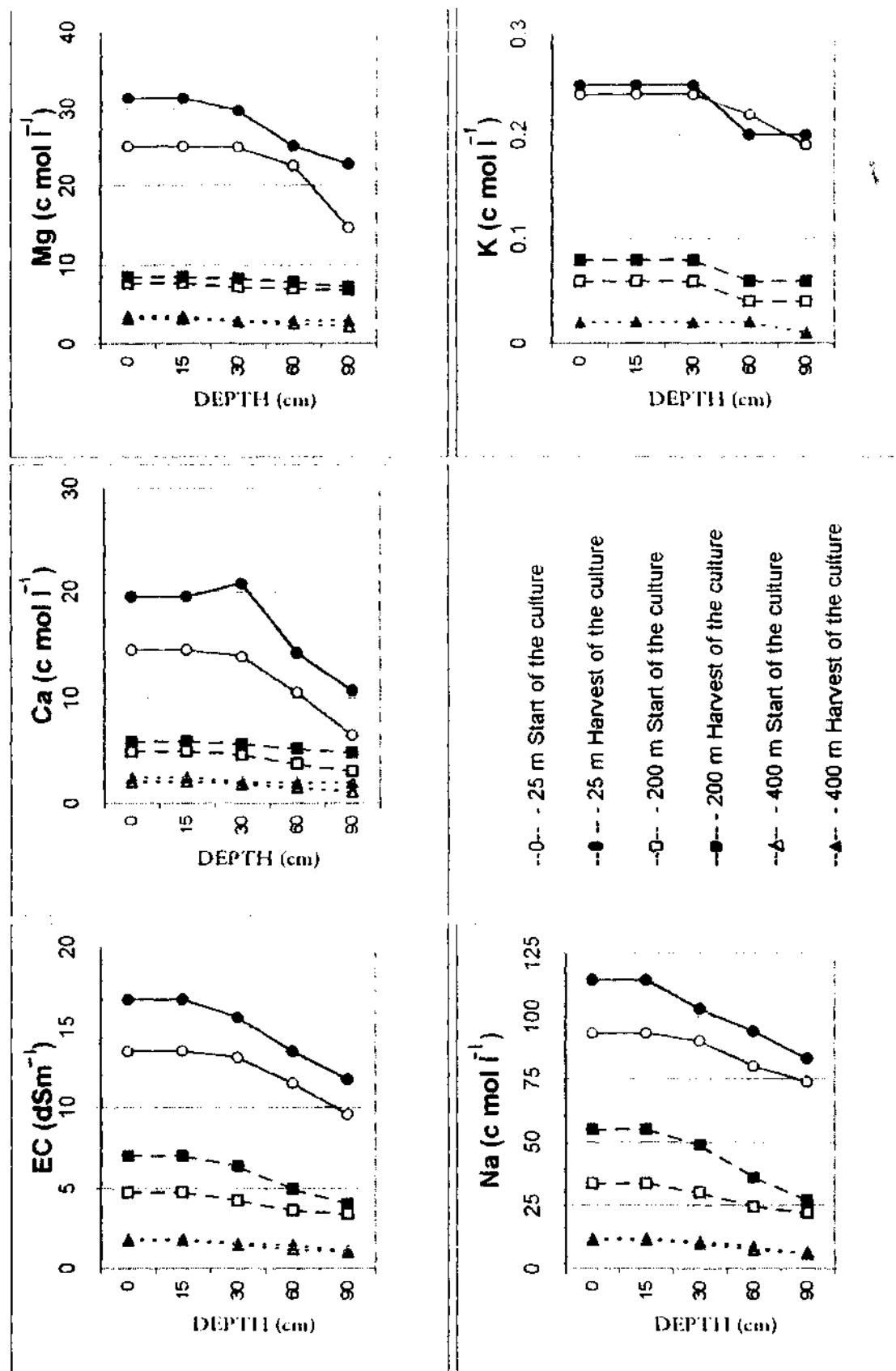


Fig. 26: Influence of fresh water fish culture on EC, Ca, Mg, Na and K of soil water extract (1:2) at various distances (m) at Purini.

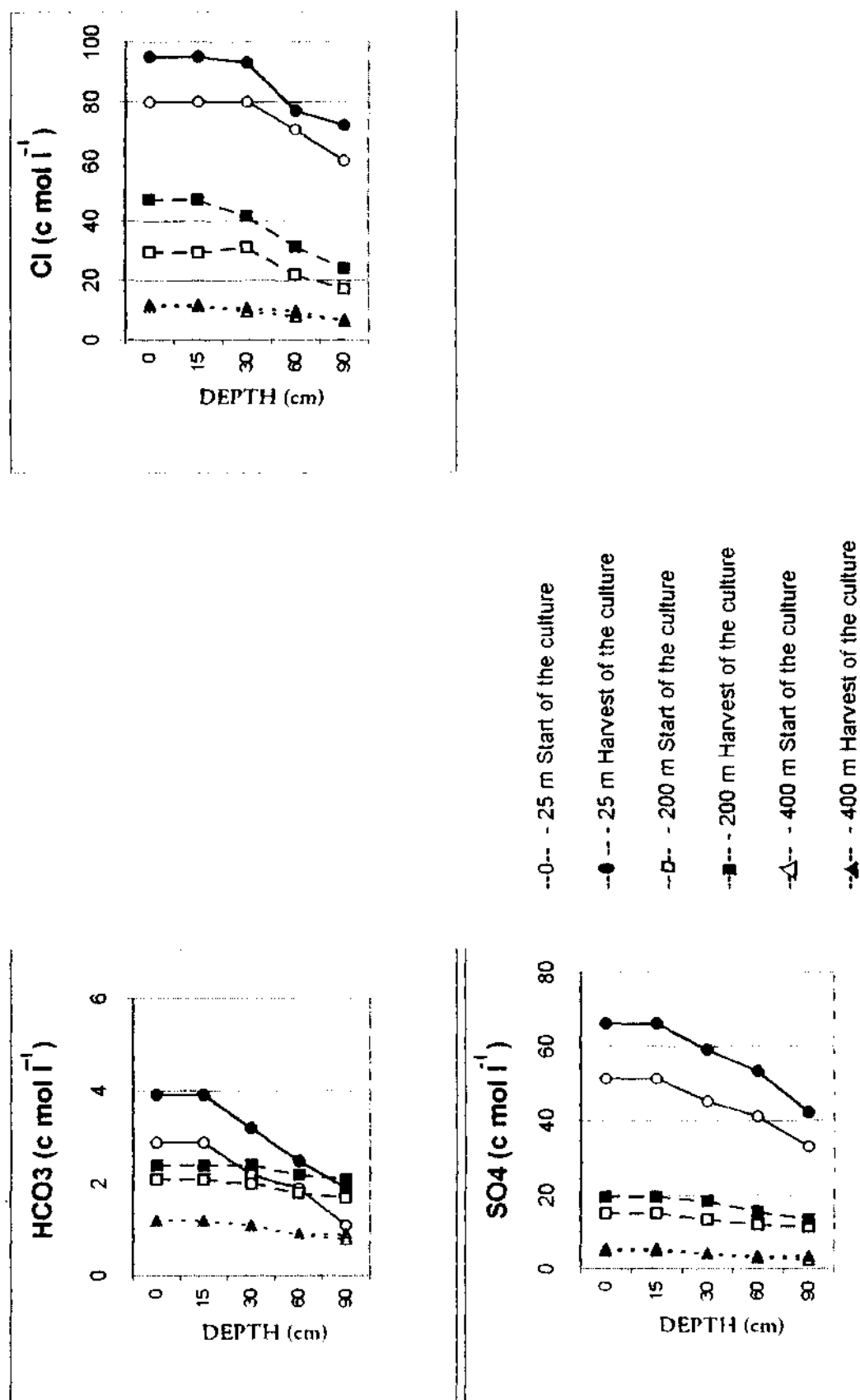


Fig. 27: Influence of fresh water fish culture on HCO₃, Cl and SO₄ of soil water extract (1:2) at various distances (m) at Purini

Table 63 : Influence of brackish water prawn culture on the composition of soil water extract (1 : 2) at various distances, depth of soil and sampling time at Karedu-I.

Depth of soil (cm)	EC (dSm ⁻¹)	Cations (c mol l ⁻¹)				Anions (c mol l ⁻¹)			
		Ca	Mg	Na	K	CO ₃	HCO ₃	Cl	SO ₄
25 m distance from the pond									
Start of the culture									
0-15	15.95	24.0	30.0	103.5	0.40	-	1.7	115.0	42.5
15-30	15.13	24.0	29.0	97.0	0.40	-	1.6	107.5	42.0
30-60	14.30	23.0	27.0	92.0	0.35	-	1.5	100.0	41.0
60-90	11.25	19.5	23.0	69.0	0.30	-	1.0	77.0	34.0
Harvest of the culture									
0-15	24.39	34.5	49.5	169.0	0.50	-	1.7	175.0	67.0
15-30	23.88	33.0	46.5	156.5	0.50	-	1.6	170.0	65.0
30-60	21.37	30.0	42.5	137.0	0.40	-	1.5	146.0	62.0
60-90	19.89	24.0	39.5	131.0	0.40	-	1.2	136.0	58.0
200 m distance from the pond									
Start of the culture									
0-15	8.32	9.0	14.5	58.0	0.20	-	0.6	59.0	22.0
15-30	8.12	8.9	14.0	56.0	0.20	-	0.6	56.5	22.0
30-60	6.75	6.0	10.0	51.0	0.15	-	0.5	48.0	19.0
60-90	6.72	6.0	9.9	50.0	0.15	-	0.5	47.5	19.0
Harvest of the culture									
0-15	14.23	22.0	27.5	91.0	0.25	-	0.9	109.5	31.5
15-30	14.32	21.5	27.5	93.0	0.25	-	0.9	110.0	32.0
30-60	12.27	19.0	24.0	79.0	0.20	-	0.8	91.0	30.0
60-90	10.39	17.5	22.0	64.0	0.20	-	0.8	73.0	30.0
400 m distance from the pond (control)									
Start of the culture									
0-15	0.014	0.06	0.03	0.04	0.025	-	0.05	0.07	0.020
15-30	0.014	0.06	0.03	0.04	0.010	-	0.05	0.07	0.020
30-60	0.013	0.05	0.03	0.04	0.010	-	0.04	0.06	0.020
60-90	0.012	0.04	0.02	0.04	0.010	-	0.04	0.06	0.015
Harvest of the culture									
0-15	0.021	0.08	0.040	0.060	0.017	-	0.06	0.10	0.045
15-30	0.019	0.08	0.030	0.060	0.015	-	0.05	0.10	0.035
30-60	0.017	0.07	0.025	0.050	0.015	-	0.04	0.085	0.035
60-90	0.017	0.07	0.025	0.050	0.012	-	0.04	0.085	0.030

Table 64 : Influence of brackish water prawn culture on the composition of soil water extract (1: 2) at various distance, depth of soil and sampling time at Karedu-2.

Depth of soil (cm)	EC (dSm ⁻¹)	Cations (c mol l ⁻¹)				Anions (c mol l ⁻¹)			
		Ca	Mg	Na	K	CO ₃	HCO ₃	Cl	SO ₄
25 m distance from the pond									
Start of the culture									
0-15	16.37	20.0	27.0	115.5	0.30	-	1.0	120.0	35.0
15-30	15.25	19.0	26.0	106.0	0.30	-	1.0	117.0	34.0
30-60	14.37	17.5	25.0	100.0	0.30	-	1.0	109.0	32.5
60-90	12.57	15.5	22.1	87.8	0.25	-	0.8	95.0	29.0
Harvest of the culture									
0-15	25.88	35.0	47.0	176.0	0.50	-	1.5	201.0	55.0
15-30	25.27	34.0	47.0	170.0	0.50	-	1.4	196.0	55.0
30-60	20.29	27.0	38.0	136.0	0.35	-	1.2	162.0	39.0
60-90	18.39	24.5	34.0	124.0	0.30	-	1.0	148.0	34.0
200 m distance from the pond									
Start of the culture									
0-15	10.29	10.5	15.0	77.0	0.20	-	0.5	78.0	25.0
15-30	10.13	10.0	15.0	75.5	0.20	-	0.5	76.0	24.0
30-60	9.47	9.0	15.0	70.0	0.20	-	0.5	70.0	24.0
60-90	7.35	7.5	13.5	52.0	0.10	-	0.4	50.0	22.5
Harvest of the culture									
0-15	12.50	13.6	19.0	91.0	0.25	-	0.50	95.0	28.5
15-30	12.20	13.2	18.7	89.0	0.25	-	0.50	91.0	28.0
30-60	10.9	10.2	18.6	79.0	0.20	-	0.4	78.0	27.0
60-90	10.0	10.0	17.0	76.0	0.20	-	0.4	74.0	26.0
400 m distance from the pond (control)									
Start of the culture									
0-15	0.047	0.2	0.1	0.12	0.04	-	0.1	0.3	0.05
15-30	0.044	0.2	0.1	0.10	0.03	-	0.1	0.3	0.02
30-60	0.035	0.2	0.1	0.10	0.02	-	0.1	0.2	0.02
60-90	0.025	0.2	0.1	0.10	0.01	-	0.1	0.1	0.02
Harvest of the culture									
0-15	0.051	0.2	0.1	0.15	0.04	-	0.1	0.4	0.02
15-30	0.044	0.2	0.1	0.10	0.02	-	0.1	0.3	0.02
30-60	0.033	0.1	0.1	0.10	0.03	-	0.1	0.2	0.03
60-90	0.033	0.1	0.1	0.10	0.01	-	0.1	0.2	0.02

Table 65: Influence of brackish water prawn culture on the composition of soil water extract (1 : 2) at various distance, depth of soil and sampling time at Kolladinni.

Depth of soil (cm)	EC (dSm ⁻¹)	Cations (c mol l ⁻¹)				Anions (c mol l ⁻¹)			
		Ca	Mg	Na	K	CO ₃	HCO ₃	Cl	SO ₄
25 m distance from the pond									
Start of the culture									
0-15	16.21	29.5	37.5	94.0	0.60	-	0.90	125.0	35.0
15-30	14.19	27.0	34.0	80.0	0.60	-	0.8	107.0	33.0
30-60	14.01	27.0	33.0	79.0	0.55	-	0.8	106.0	33.0
60-90	13.29	24.0	30.0	78.0	0.50	-	0.7	100.0	30.0
Harvest of the culture									
0-15	24.52	35.0	44.0	165.0	0.70	-	1.4	195.0	45.0
15-30	23.71	33.0	43.0	160.0	0.70	-	1.4	190.0	44.0
30-60	20.51	30.5	41.0	132.0	0.60	-	1.2	164.0	39.0
60-90	19.32	30.0	39.0	123.0	0.60	-	1.0	153.0	39.0
100 m distance from the pond									
Start of the culture									
0-15	10.32	15.5	21.5	65.0	0.40	-	0.60	79.0	23.0
15-30	10.10	15.0	21.5	63.0	0.40	-	0.50	77.0	22.0
30-60	9.38	14.0	21.0	58.0	0.40	-	0.50	72.0	20.0
60-90	9.20	14.0	21.0	56.0	0.30	-	0.50	70.0	19.0
Harvest of the culture									
0-15	18.99	32.0	38.0	117.0	0.60	-	1.0	145.0	42.0
15-30	17.39	30.0	39.0	102.0	0.60	-	1.0	130.0	41.0
30-60	16.90	29.0	37.0	100.0	0.50	-	1.0	126.0	40.0
60-90	16.80	29.0	37.0	97.0	0.50	-	1.0	124.0	40.0
400 m distance from the pond (control)									
Start of the culture									
0-15	0.51	1.9	0.9	2.1	0.10	-	0.5	3.10	1.20
15-30	0.40	1.5	0.6	1.7	0.10	-	0.3	2.70	1.00
30-60	0.37	1.4	0.5	1.6	0.10	-	0.3	2.50	0.80
60-90	0.32	1.2	0.4	1.5	0.10	-	0.2	2.30	0.60
Harvest of the culture									
0-15	0.51	1.9	0.9	2.1	0.10	-	0.6	3.0	1.1
15-30	0.39	1.4	0.7	1.5	0.08	-	0.5	2.4	1.0
30-60	0.37	1.4	0.6	1.4	0.08	-	0.4	2.2	1.0
60-90	0.32	1.2	0.5	1.4	0.05	-	0.2	1.8	1.0

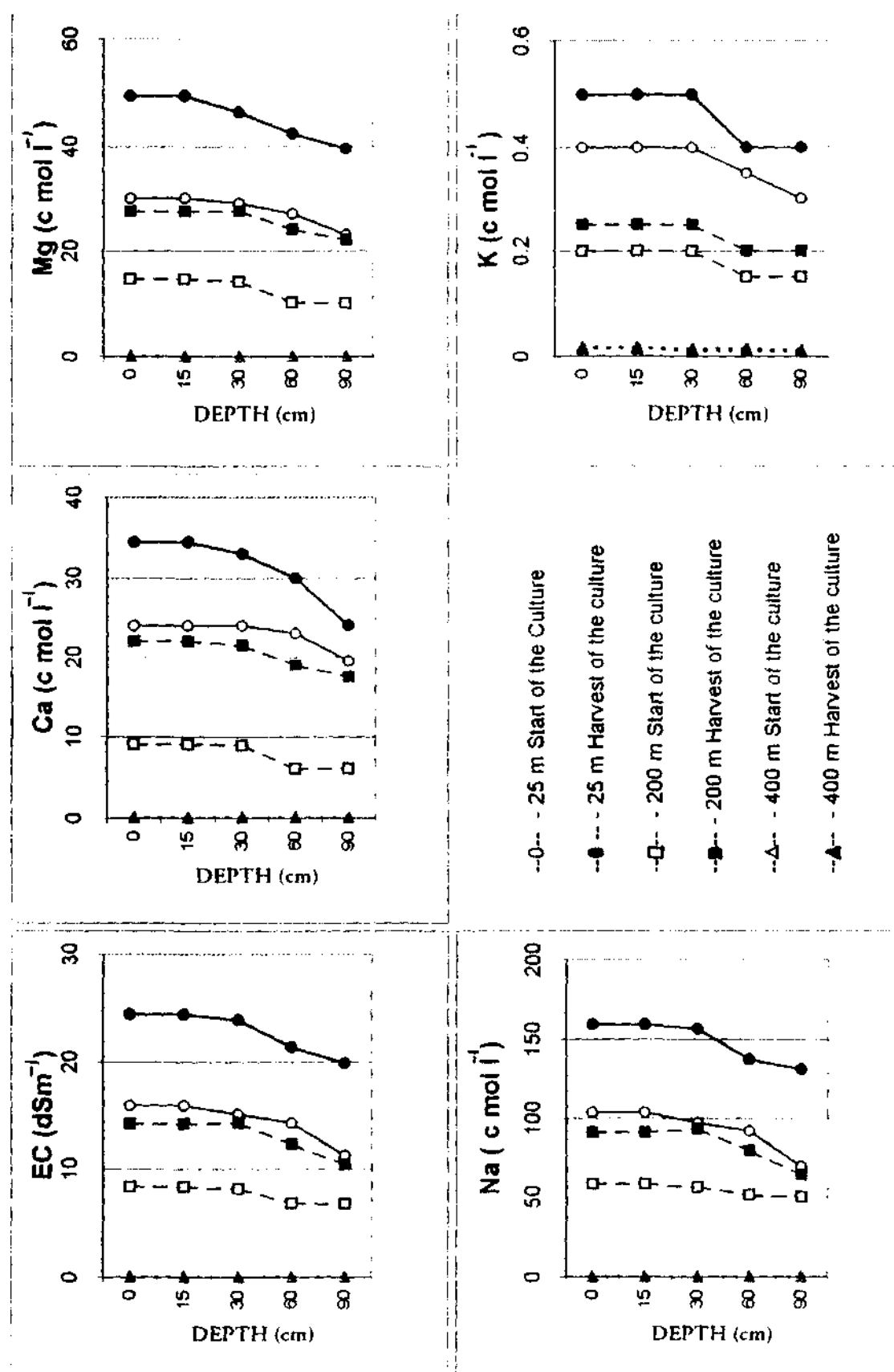


Fig. 28: Influence of brackish water prawn culture on EC, Ca, Mg, Na and K of soil water extract (1:2) at various distances (m) at Karedu-1.

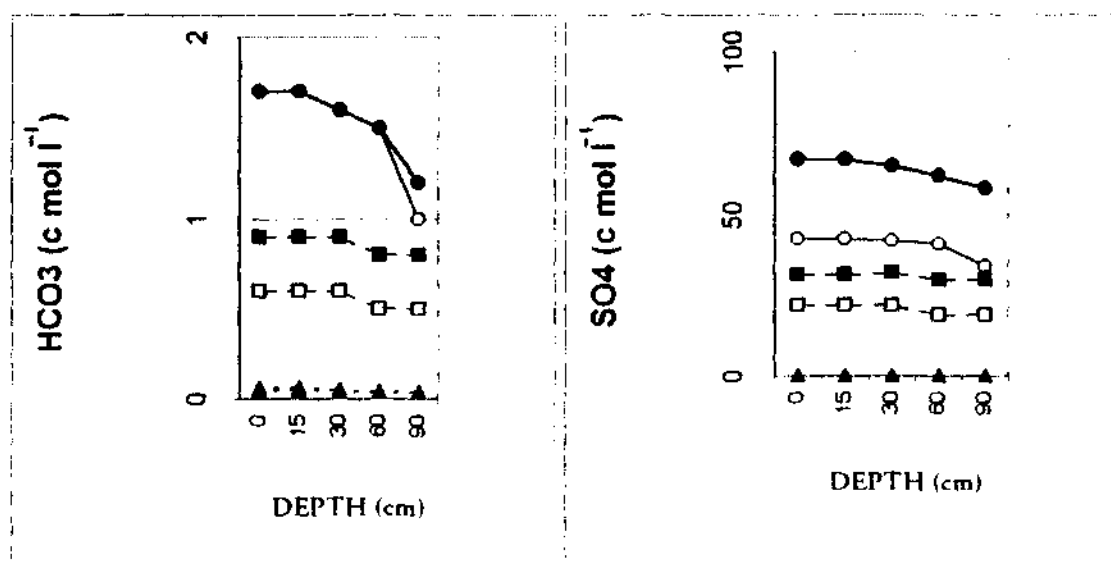


Fig. 29: Influence of brackish water prawn culture on HCO₃, Cl and SO₄ of soil water extract (1:2) at various distances (m) at Kareduf.

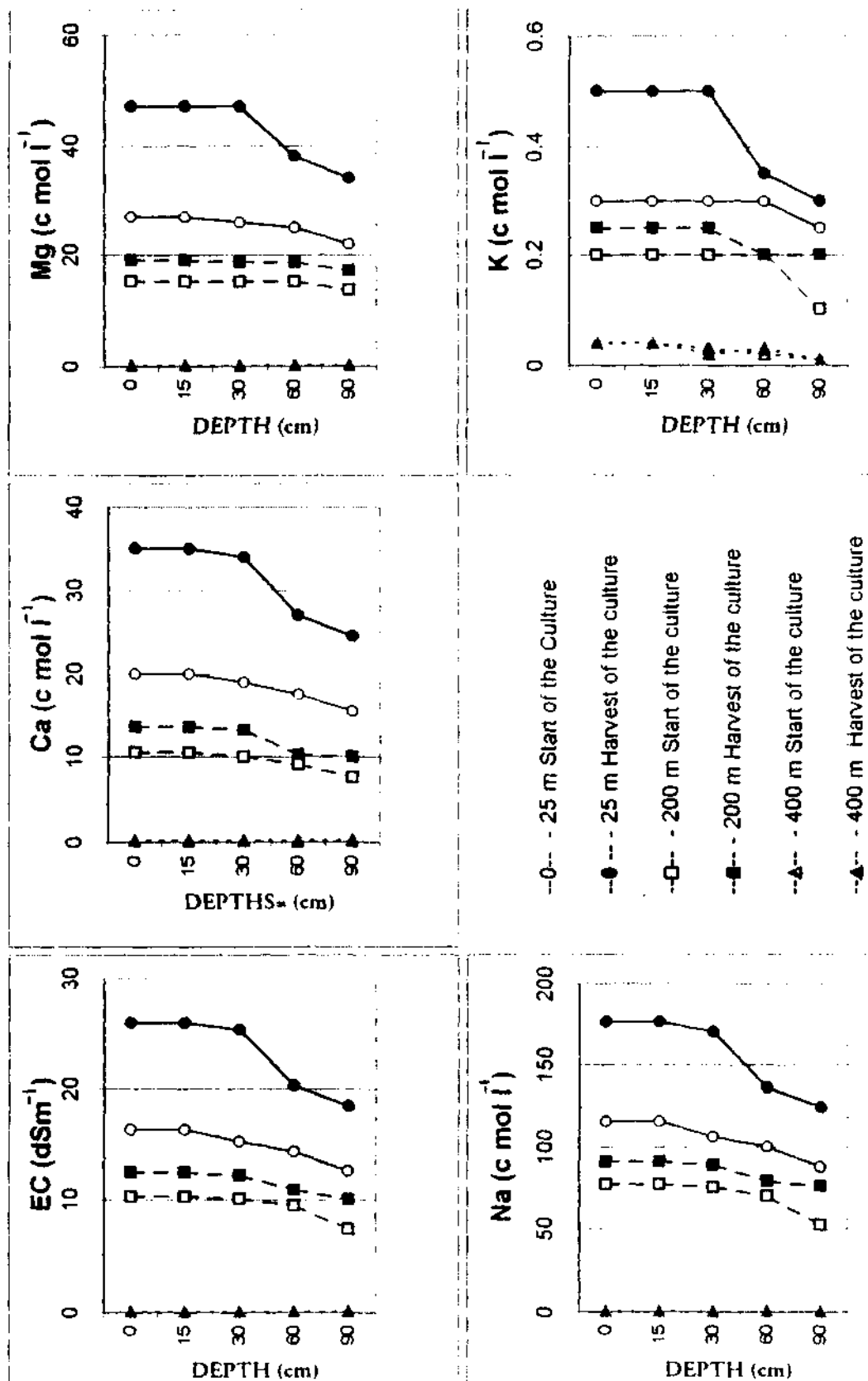


Fig. 30: Influence of brackish water prawn culture on EC, Ca, Mg, Na and K of soil water extract (1:2) at various distances (m) at Karedu-2.

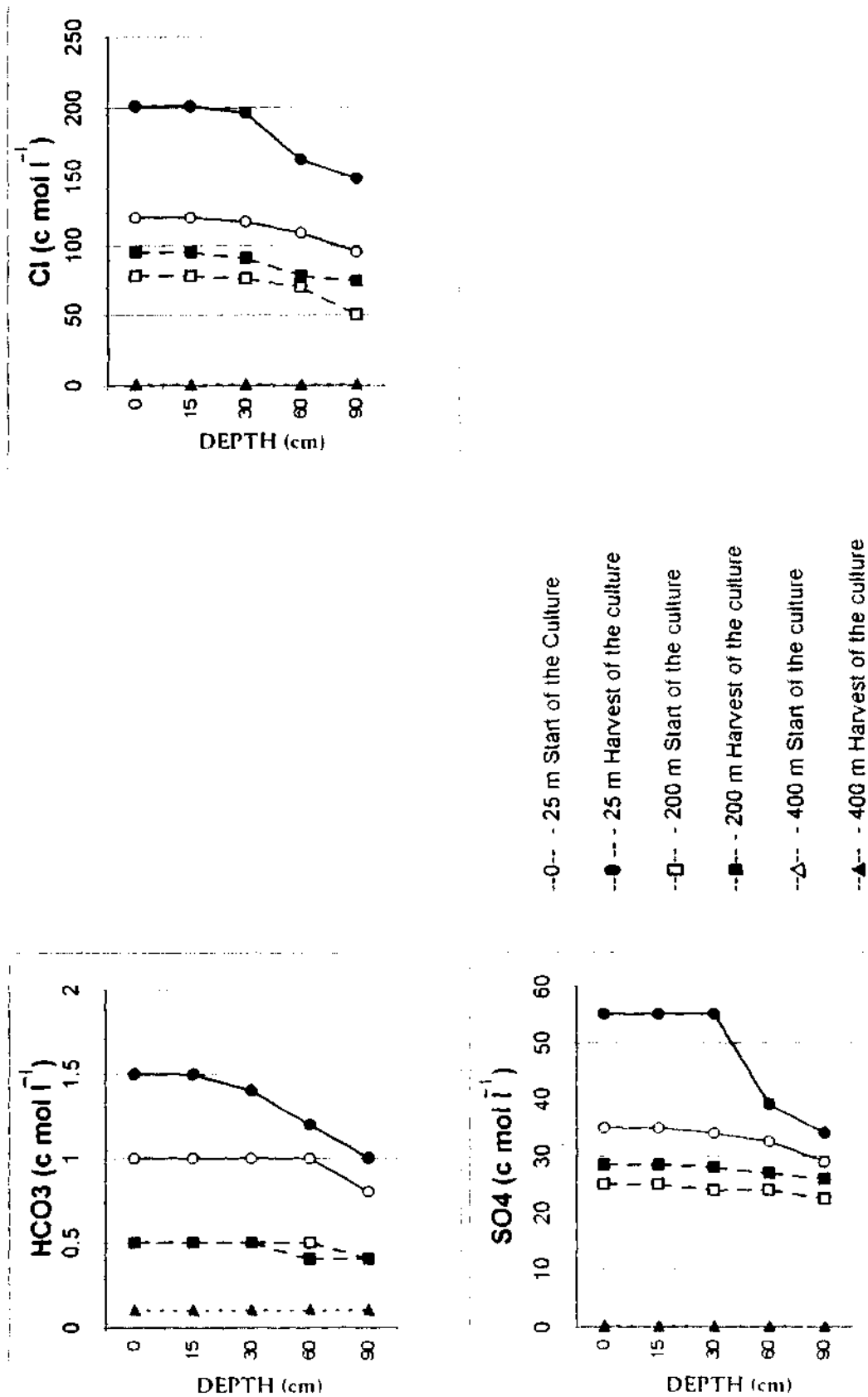


Fig. 31: Influence of brackish water prawn culture on HCO_3^- , Cl and SO_4 of soil water extract (1:2) at various distances (m) at Karedu-2.

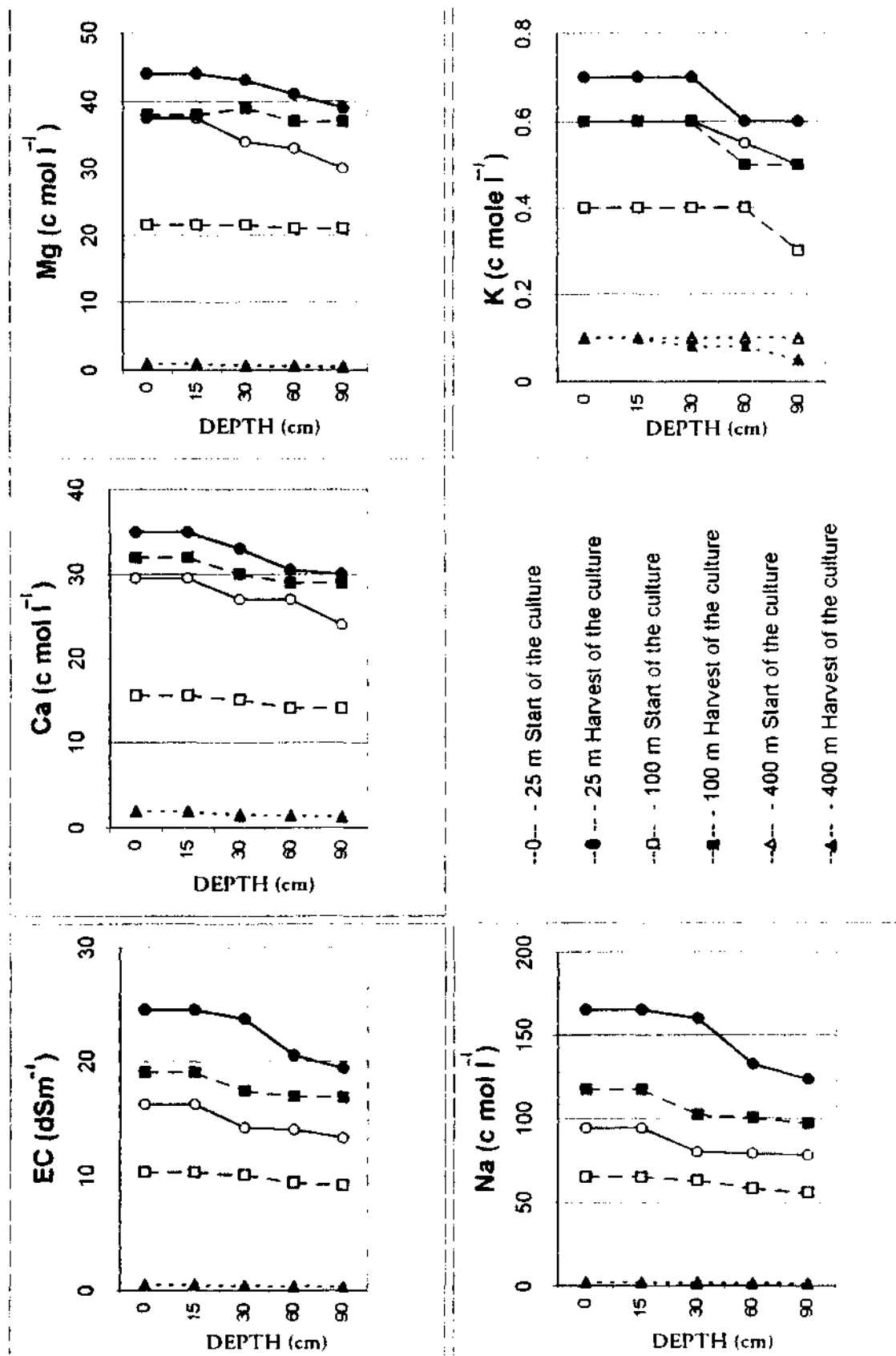
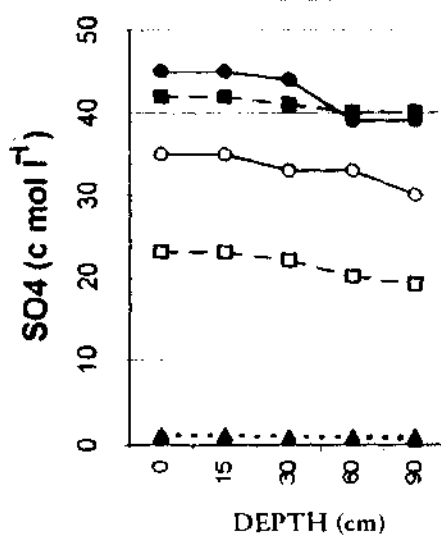
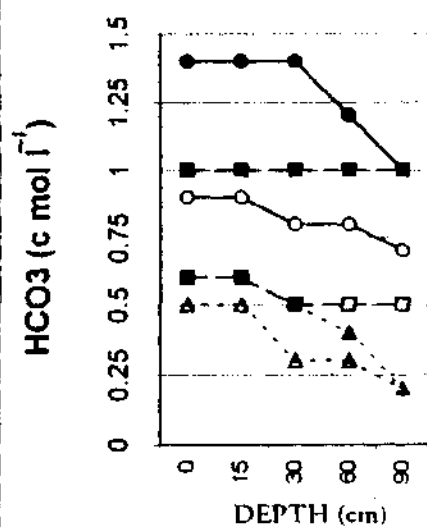
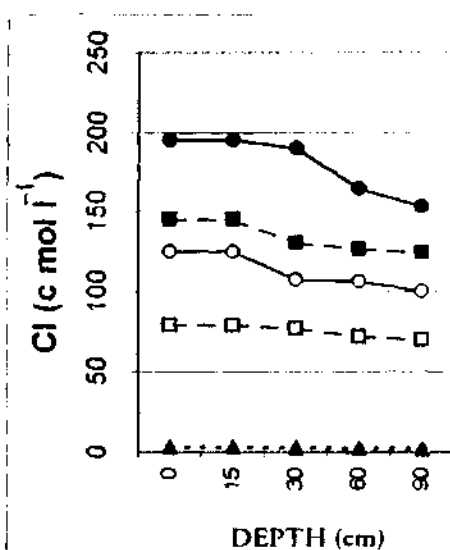


Fig. 32: Influence of brackish water prawn culture on EC, Ca, Mg, Na and K of soil water extract (1:2) at various distances (m) at Kolladinni



--○-- - 25 m Start of the culture
 --●-- - 25 m Harvest of the culture
 --□-- - 100 m Start of the culture
 --■-- - 100 m Harvest of the culture
 --△-- - 400 m Start of the culture
 --▲-- - 400 m Harvest of the culture

Fig. 33: Influence of brackish water prawn culture on HCO_3 , Cl and SO_4 of soil water extract (1:2) at various distances (m) at Kolladinni

that of the farthest point at 400 m (0.05 to 0.06 c mol l⁻¹) and at 200 m (64.0 to 91.00 c mol l⁻¹) at Karedu-1. The accumulation of Mg in the soil profile was varying from 39.5 to 49.5 c mol l⁻¹ at 25 m and 22.0 to 27.5 c mol l⁻¹ at 200 m away from the pond. The accumulation of Ca was varying from 24.0 to 34.5 c mol l⁻¹ at 25 m away from the pond, and 17.5 to 22.0 at 200 m away from the pond. The accumulation of K ranged from 0.4 to 0.5 c mol l⁻¹ at 25 m from the pond which was ranging from 0.20 to 0.25 c mol l⁻¹ at 200 m away from the pond.

Chloride was the dominating anion that accumulated in the profile, which was 2 to 3 times higher than that of the SO₄.

At Karedu-1 the accumulation of HCO₃ was minimum and ranged from 0.80 to 0.90 c mol l⁻¹ at 200 m from the pond as compared to 0.04 to 0.6 c mol l⁻¹ in the profile at 400 m away from the pond. There were no CO₃ in the soils though source water for ponding contained 1.12 to 3.5 c mol l⁻¹. Thus the data suggests the predominant influence of ponded water on the properties of soils, and on the nature of salts accumulated around the aquaculture ponds.

4.7 EFFECT OF AQUACULTURE ON THE CROP PRODUCTIVITY IN THE ADJOINING FIELDS

The fresh water fish ponds selected for the study completed 8 to 10 years of culture by the time the study was started in 1995-96. Similarly the brackish water prawn culture farms were also completed two years of culture at the time of starting the study. The effects of the aquaculture on crop productivity in the adjoining fields were studied by recording the yield data in the adjoining lands upto a distance of 600 m from the pond. Rice was generally cultivated around the ponds

in Nellore district at Rebala, Kovur and Purini (fresh water fish culture) and in Nellore district Kolladinni (Brackish water prawn culture). Around Karedu-1 brackish water prawn pond mango and around Karedu-2 pond sapota orchards (Prakasam district) were in existence. The fruit crops were in bearing state at the time of study. The data on the yield of these crops/orchards at varying lateral distances were collected as per the procedure given under materials and methods (Table 3).

Yield of rice was recorded for 2 years (1995-96 and 1996-97). Yield of mango and sapota was recorded for three years during 1995-97 (Tables 68 and 69). The mean yield data at Rebala, Kovur and Purini are presented in Appendix IV to VI and the overall mean data are presented in Table 66. The mean yield data of rice at Kolladinni are presented in Table 67.

4.7.1 Fresh water fish culture ponds

The effect of fresh water fish culture pond was reflected on severe reduction of yield of rice at all the three locations studied. Yield reduction was noticed upto 50 m at Rebala, 100 m at Kovur and 200 m at Purini. The adverse effects were not reflected on the yields at 100 m at Rebala, 200 m at Kovur and 400 m at Purini villages. The adverse effects in terms of rice crop yield reduction was more in the summer season compared to late *kharif* season. The yield reduction was 62.4% during late *kharif* and 61.5% during summer at 25 m distance and 61.0% during late *kharif* and summer seasons at 50 m distance at Rebala as compared to that of 100 m distance. At Kovur no crop was taken by the farmer at 25 m during late *kharif* and upto 50 m during summer. The reduction in yield was

Table 66 : Influence of fresh water fish culture on the mean yield of rice at various distances from the pond during 1995-97.

Distance (m)	Grain yield kg ha ⁻¹					
	Rebala		Kovur		Purini	
	Late <i>kharif</i>	Summer	Late <i>kharif</i>	Summer	Late <i>kharif</i>	Summer
25	1954 (62.4)	1674 (61.5)	-	-	-	-
50	2030 (61.0)	1690 (61.1)	608 (85.4)	-	-	-
100	5190	4343	1918 (53.9)	454 (37.7)	628 (85.8)	-
200	5185	4293	4162	3587	1429 (67.5)	799 (78.0)
400	5388	4348	4256	3446	4393	3616
600	5350	4470	4066	3509	4532	3485

Value in bracket indicates per cent yield reduction.

Table 67 : Influence of brackish water prawn culture on grain yield of rice (kg ha⁻¹) at various distances from the pond at Kolladinni.

Distance (m)	Grain yield (kg ha ⁻¹)		
	1995-96	1996-97	Mean
	<i>Rabi</i>	<i>Rabi</i>	
25	No crop	No crop	No crop
50	No crop	No crop	No crop
100	No crop	No crop	No crop
200	5685	6035	5860
400	5594	5690	5642
600	5833	6175	6004

85.4% during late *kharif* rice crop at 50 m distance. The yield reduction was 53.9% during late *kharif* and 37.7% during summer season as compared to that of 200 m distance.

At Purini village no crop could be taken at 25 and 50 m. The adverse effects were noticed at 100 and 200 m. At 100 m, the mean yield reduction was 85.8% during late *kharif* as compared to that of 400 m and no crop was taken during summer. At 200 m, the yield reduction was 67.5% during late *kharif* and 78.0% during summer season as compared to that of 400 m distance.

4.7.2 Brackish water prawn culture ponds

The adverse effects of brackish water prawn culture ponds were more severe compared to that of fresh water fish culture ponds. No crop was being taken by the farmers upto 100 m from the pond at Kolladinni. Beyond 200 m, the yield appeared to be normal. Only one crop in *rabi* is being taken up at this village under tank water.

Mango yield was also adversely effected by the brackish water ponds at Karedu-1. Mango trees nearer to the pond did not give any yield. The tops of the branches/plants were dying during period of observation. Some fruit yield obtained in the trees located at 400 m away from the pond. Average yield of mango at Karedu-1 was 63.3 kg/tree while that of same at 600 m was 67.3 kg/tree.

Similarly, in case of sapota, the existing trees were not giving any yield upto 200 m. The mean yield of trees at 400 m was 140 kg/tree and at 600 m also was almost the same.

Table 68 : Influence of brackish water prawn culture on fruit yield of Mango at various distances from the pond at Karedu-1.

Distance (m)	Fruit yield kg tree ⁻¹			
	1995	1996	1997	Mean
25	No yield	No yield	No yield	No yield
50	No yield	No yield	No yield	No yield
100	No yield	No yield	No yield	No yield
200	No yield	No yield	No yield	No yield
400	53	65	72	63.3
600	56	70	76	67.3

Table 69 : Influence of brackish water prawn culture on fruit yield of Sapota at various distances from the pond at Karedu-2.

Distance (m)	Fruit yield kg tree ⁻¹			
	1995	1996	1997	Mean
25	No yield	No yield	No yield	No yield
50	No yield	No yield	No yield	No yield
100	No yield	No yield	No yield	No yield
200	No yield	No yield	No yield	No yield
400	137	138	144	140
600	134	134	140	136

DISCUSSION

CHAPTER V

DISCUSSION

Effect of Aquaculture on Soil and Ground Water Quality in Nellore and Prakasam Districts of Andhra Pradesh was judged by studying the quality of pond water, ground water, properties of adjoining soils and yield of crops at different distances from the ponds after critically analysed are discussed in this chapter.

5.1 QUALITY OF PONDED WATER

The results obtained (Tables 4 and 5) have clearly shown that there was wide variation in the quality of waters at the start of the culture and harvest of the culture at all the locations. The quality of ponded water at the start of the culture, basically represents the quality of source water used for ponding. The quality of pond water at the time of culture harvest was also due to the resultant of the addition of feed and other products in the process of culturing. In addition, release of various metabolites by the culture organisms also influence the pond water at the time of harvest. Further, the water in the pond is not static as there is frequent water in-flow and out-flow of water during the culture period. Apart from these, seasonal effects of climate, specially the rain, which has got dilution effect on various constituents and on the process of evaporation in the absence of rain, also have to be kept in view while assessing the results regarding pond water quality.

The composition of fresh water and brackish water is quite different (Table 4 and 5). The fresh water has relatively higher pH (8.27) compared to that of

brackish water (8.04). The brackish water has high salinity (overall mean of 46.52 dSm⁻¹) compared to fresh water (average mean of 1.967 dSm⁻¹). In the fresh water, Na was the dominant cation (13.5 c mol l⁻¹) in waters followed by Ca (3.52 c mol l⁻¹), Mg (2.15 c mol l⁻¹) and K (mean of 0.21 c mol l⁻¹). On the other hand, the mean composition of brackish water was dominated by Na (358 c mol l⁻¹), followed by Mg (69.7 c mol l⁻¹), Ca (21.0 c mol l⁻¹) and K (18.0 c mol l⁻¹). Among the anions, Cl was dominant in both the waters but several times higher in case of brackish water (365 c mol l⁻¹) compared to fresh water (9.97 c mol l⁻¹). The next dominating anion was SO₄ in case of brackish water (83 c mol l⁻¹), while it was HCO₃ (9.16 c mol l⁻¹) in the fresh water. When fresh water did not contain any CO₃, the brackish water contained considerable CO₃ (3.2 c mol l⁻¹). These important differences in pond water composition also need to be kept in view, while assessing the effect of ponded water on the properties of ground water, soils and their productivity.

5.1.1 Fresh water

The composition of fresh water at the start of the culture was not the same at all the three locations. The salinity of fresh waters was varying in the order of Purini (2.280 dSm⁻¹) > Kovur (1.832 dSm⁻¹) > Rebala (1.790 dSm⁻¹). The aqua ponds at these three locations were depending on the ground water source, whose nature and composition depends upon the volume of ground water drawn and the ingression of salts through underground sea water. From the location of fresh water ponds (Fig. 1b), it could be noticed that Purini is more nearer to sea coast compared to other locations. Similarly, Rebala which has least concentration of salts, is away

from the coast and nearer to Penna river. These two factors together appeared to have lead to the ground water at Rebala to have least salt content compared to the other two locations. Kovur is in between these two locations and hence the salt content of its water is in between Purini and Rebala.

The composition of ponded water was generally lower in the first year as compared to that of second year at all the three locations (Table 4). This appears to be the resultant of the total amount of rainfall received during the respective years, which ultimately has either diluting or concentrating effect of the salts in the underground sources. The total amount of rainfall received in the area upto August (corresponding to starting of the culture) was 623 mm rainfall in the first year as compared to 367 mm in the second year (Appendix-I). Therefore, it is apparent that the dilution of underground source through rainfall has an important bearing on the quality of pond water at the start of the culture. The composition of ponded water at the start of the culture in the study area, hence, depended on the location of the pond (source of groundwater) in relation to its distance from the sea on one hand, and to the amount of rainfall received during the monsoon period till the start of the culture. Pumping of fresh water from the underground acquifer was observed to result in intrusion of underground sea water along with its dissolved salts was also observed in several countries including Bangladesh (Mahmood, 1986) and Indonesia (Cholik and Pennomo, 1987). The mean EC at different ponds was varying in the order of Purini (2.400 dSm^{-1}) > Rebala (1.790 dSm^{-1}) > Kovur (1.883 dSm^{-1}). The mean change in EC due to culturing at the start of the culture was 0.575 dSm^{-1} at Rebala followed by that of Purini (0.240 dSm^{-1}) and Kovur

(0.102 dSm⁻¹). It is possible that cultural practices also have an important bearing on the change in the EC of ponded water at these locations.

5.1.2 Brackish water

The data revealed that the EC of brackish water at Karedu-1 and Karedu-2 at the start of the culture was more or less the same (mean 47.8 and 47.5 dSm⁻¹ respectively) at these locations and even at harvest, they were similar (mean 49.0 and 49.7 dSm⁻¹ respectively). At Kolladinni, the difference in EC at start of the culture and its harvest is very small (1.95 dSm⁻¹ which is only 4.5 per cent of initial value). Thus the data showed that the brackish system is more influenced hence there is little variation in the salt content during culture period.

Though the EC was slightly higher towards harvest, the slight raise in EC towards harvest could be both due to seasonal variation and the effect of feed addition besides release of various metabolites in the pond during culture period.

Sodium was the dominating cation in both fresh and brackish water. The Na domination in fresh water (underground source) clearly establishing that the underground source at the time of study was already under the overall influence of underground sea water. The next dominating cation in the fresh water was Ca followed by Mg but the difference between Ca and Mg was relatively small compared to the amount of Na present (Table 5). Potassium was in least amounts. These data suggest that the quality of underground waters was also influenced to a certain extent, by the salts *in situ*. In the brackish waters the second dominant cation was Mg, which was much higher than that of Ca. Interestingly, the difference

between Ca and K in brackish water was not that high as compared to that of fresh water. Therefore, data suggests the dependency of brackish pond water more on the quality of brackish sea water rather than any other single factor.

The anionic composition of both fresh water and brackish water ponds prevents contrasting variation (Tables 4 and 5), while CO_3 were totally absent in the fresh water varying between 1.1 and 4.5 c mol l^{-1} in the samples studied in brackish water. Chlorides were uniformly dominant in both the waters. However, the proportion of Cl to HCO_3 ions in the fresh water ponds is not that high as compared to that of brackish waters, where Cl ions were many times more than that of HCO_3 ions. The second dominating anion in the brackish water was sulphates rather than HCO_3 contrary to that of fresh pond water. These variations are more or less similar to those of fresh water sources.

The data on anionic composition, suggested the dependency of pond water quality to the composition of sources *in situ* to a certain extent on the quality of underground waters. This kind of variation has been also reported in the literature studied.

The $\text{NO}_3\text{-N}$ content varied within a narrow range of 0.415 to 0.840 mg l^{-1} in the brackish water contrary to that of fresh water (0.045 to 4.2 mg l^{-1}). The wide variation in the fresh water, appears to be a more reflection of practices followed for the culture apart from the metabolites added by the culture organisms.

Brackish water have higher heavy metal content (Ni, Pb, Cr, Cd) compared to that of fresh water. While Pb was relatively more in fresh water, Cr

was higher in brackish water compared to other heavy metals. The variation in the heavy metal content in the pond water was reflecting more of the composition of water source rather than the influence of any other factor.

The micronutrients viz., Zn, Fe, Cu, Mn (Tables 4 and 5) varied widely in fresh water compared to that of brackish water. Iron was the dominant micronutrient present in both the waters followed by Mn in brackish water, and Cu in fresh water. Cu content was the least in fresh water while Zn and Mn were lower in the brackish water. These were reflecting more of the source variation rather than other factors.

The COD was many times higher in brackish water (1695 to 2201 mg l^{-1}) compared to that of fresh water (varying between 105 and 290 mg l^{-1}), which was again a reflection of the source composition. Culturing, in general increased the COD at all the locations, thereby showing that the culture organisms increase the COD through their activities.

5.2 EFFECT OF PONDING ON GROUNDWATER QUALITY

From the data presented in Tables 6 to 11 and illustrated in Fig. 8 to 15, it ^{was} ~~could be~~ noticed that the salt accumulation in the ground waters was much higher with the brackish water ponds as compared to that of fresh water ponds. The salt accumulation as indicated by EC varied from 30.94 dSm^{-1} to 5.618 dSm^{-1} in the brackish water over the two year cycle of aqua culture. Fresh water ponds lead to relatively lower salt accumulation in the ground waters ranging from 3.356 to 0.012 dSm^{-1} over the 10 years cycle of aquaculture. The higher salt accumulation in the

ground waters with the brackish pond waters, as compared to those of fresh water ponds, apparently was a result of very higher salt content in pond water (overall mean 46.52 dSm^{-1}) as compared to that of fresh water (overall mean of 1.967 dSm^{-1}). This is also reflected in the variation of salt accumulation in ground waters of different locations with ponding either with fresh water or brackish water. With fresh water, the salt accumulation at Purini was the highest (3.356 to 1.023 dSm^{-1}) followed by Rebala (1.780 to 0.012 dSm^{-1}) and Kovur (0.420 to 0.215 dSm^{-1}). The variability in salt accumulation was in the same order as that of EC of the water source at the start of the culture in all the three pond locations (Purini > Rebala > Kovur).

The trends of variations noticed with the brackish water in this regard were similar to those with fresh water ponds (Tables 6 to 11). These variations, thus, clearly established that the salt accumulation in the ground waters due to aquaculture basically depends on the salt content in the source water.

The salt content in ground waters at the time of harvest of culture was uniformly higher at all the locations of the study with both fresh and brackish water ponds. The higher salinity in the ground waters at the time of culture harvest as compared to that of culture starting again closely follows the variation in the EC of the pond water, which was dependent upon the rainfall received during earlier period of observations on one hand, and due to the addition of various components of feed coupled with release of various metabolites by culture organisms, as discussed under the quality of pond water.

The salt accumulation in the ground waters, due to the aqua ponds at the points chosen for sampling during the study suggests that the ground waters were getting enriched with salts. The process of salt accumulation in the ground water is much higher with the brackish water ponds as compared to that of the fresh water ponds. The soluble salt content of polluted ground water due to brackish water prawn culture ponds upto 295 m at Karedu-1, 338 m at Karedu-2 and 390 m at Kolladinni and the same due to fresh water fish culture ponds upto 10 m at Rebala, and upto 330 m at Purini was above the safe limit of 2-25 dSm⁻¹ prescribed by ISI (1983).

The data obtained (Tables 6 to 11) indicated deleterious effects of aqua culture on the quality of ground waters even with fresh water ponds. The cationic and anionic composition showed that the nature of the salts accumulated has a close linkage with the quality of the water source used for ponding. The adverse effects of aqua culture ponding on the quality of ground waters has been reported by several workers (RARS, Lam 1995; RARS, Tirupati 1997 and Raghava Reddy *et al.*, 1994). Within Andhra Pradesh itself, people living in the adjoining areas of aqua culture ponds have faced problems of deteriorated water quality for drinking and the special arrangements have to be made to ensure drinking water to the affected people, which has noticed during the field study.

The heavy metals viz., Cr, Pb, Ni and Cd in the ground waters were much higher with the brackish water ponds as compared to same with fresh water fish ponds. The Cr content of ground waters upto 295, 338 and 240 m at Karedu-1, Karedu-2 and Kolladinni respectively was above the safe limit (0.05 mg l⁻¹) as

prescribed by ISI (1983). The Pb content of ground waters upto 188 m at Karedu-1, 22 m at Karedu-2 and upto 156 m at Kolladinni was above the safe limit of 0.10 mg l⁻¹ prescribed by ISI (1983). The higher heavy metal in the ground waters with the brackish water ponds (Tables 9 to 11 and Fig.19) as compared to the fresh water ponds (Tables 6 to 8 and Fig.12), apparently was a result of very higher heavy metals in the pond water (Table 5) as compared to that of fresh water ponds (Table 4). The micronutrients viz., Zn, Fe, Cu and Mn were relatively higher in the immediate neighbourhood of the pond as compared to the same nearer to the fresh water fish culture pond. However, all the micronutrients in the ground water with brackish water ponds was below the safe limits (Zn – 5 mg l⁻¹, Fe – 0.3 mg l⁻¹, Cu – 0.05 mg l⁻¹ and Mn – 0.1 mg l⁻¹) as prescribed by ISI (1983). The data clearly indicated that the kind of property/constituent and soil properties were having significant influence on the ground water quality. Apparently, the percolating aquaculture pond water in the process of vertically down ward and lateral movement was getting reduced in different kinds of salts and ions, through a process of ion exchange between the percolating waters and soil colloids on one hand and through various kinds of chemical reactions with the other soil constituents, which were changing from location to location.

5.3 EFFECT OF AQUA CULTURE PONDS ON PROPERTIES OF ADJOINING SOILS

To find out the effect of aquaculture on the properties of adjoining soils, soil samples were collected at different distances from the ponds to an extent of 600 m. The soil analysis data on both physical and chemical properties presented in the results chapter are discussed hereunder.

5.3.1 Physical properties

Physical properties viz., soil texture, BD, % WSA, IR and HC of adjoining soils of aqua culture ponds were studied in order to assess the effect of ponding on these properties.

The data obtained on soil particle size distribution (Appendix-III) showed relatively higher clay content in the soils around fresh water ponds compared to those of brackish water ponds. Higher clay appears to have considerable effect on the properties of soils both physical and chemical. Bulk density was not significantly varied at the three locations which were ranging from 1.35 to 1.45 Mg m⁻³ but there was a wide variation in water stable aggregates. The WSA at Kovur was varying from 38.65 to 40.65 and were higher compared to that of Rebala (33.0 to 35.0%) and Purini (21.42 to 24.5%). These variations might be due to variation in clay content in soil. The variation in infiltration rate and hydraulic conductivity were not significant.

In case of brackish water ponds, the variations in these properties were significant in the adjoining soils. Those soils have relatively low clay and high salt content. Consequently the values of hydraulic conductivity and infiltration rate in general were higher in the adjoining soils at the brackish water ponds compared to those around fresh water ponds. In general, the adverse effects of aquaculture on physical properties of adjoining soils were not much prominent. This might be due to accumulation of higher quantities of organic compounds in the soil which was evident from higher organic carbon in the adjoining soils (Tables 23 and 41) which has favoured on soil physical properties. It is a known fact that soils having higher

organic matter show better soil physical conditions. Significantly lower infiltration rate and lower hydraulic conductivity near the ponds as compared to the same in the soils far away upto 600 m appeared to be the resultant of increased human activity in the immediate neighbourhood of the aqua culture ponds compared to the soils located beyond 100 m.

5.3.2 Chemical properties

5.3.2.1 Fresh water fish culture

Soil reaction (pH)

The pH of soils was not significantly (Table 21) influenced either by lateral distance, vertical depth or sampling time at all the three locations studied. This appears to have become possible due to the fact that the pH itself is related to buffering capacity of the soil and the constituents which have significant impact on the finer fraction were varying in the narrow range 7.60 to 7.65, 7.70 to 7.85 and 7.79 to 7.88 respectively at Rebala, Kovur and Purini but hence they were not significant variation. Satyanarayana *et al.* (1986) reported a similar narrow range of pH (7.5 to 7.75) of cultivated soils adjoining fish ponds within a distance of 50 m from the fish pond.

Salinity (EC)

Fish culture ponds significantly increased the soil salinity around the ponds at varying distances in all the three places (Table 22). However, there was no variation in the salt accumulation at different depths in the soil. Similarly, salinity in the soils around the ponds did not vary with sampling time also.

There was variation in the extent of influence of the fish culture on soil salinity at three places. The influence of fish culture was maximum at Purini to a lateral distance of 200 m, in case of Kovur, the effect was seen upto 100 m distance and at Rebala was upto 50 m distance from the pond. The variation in the spread of salts at the three locations may be attributed to the EC of pond water. It was highest (mean of 2.28 dSm^{-1}) in the case of Purini (Plate 3). The variations might also be due to the factors like slope of the soil, nature of the sub soil and management practices around the fish ponds. The soils at Purini were slopy and sub soil strata in general, was more saline compared to other locations. The low spread of salts in the case of Rebala might be due to the presence of deep (3 feet) drainage channel by the side of the pond which prevented the spread of salts (Plate 4). This indicates that the spread of salts around the fresh water ponds not only depends on the fish culture but also on the soil characteristics like slope and management practices. The spread can be prevented to some extent by providing deep trenches around the fish ponds. The salts accumulation was relatively uniform within the profile at a given lateral distance from the pond. Soil salinity did not change with the sampling time because there was a small variation in the pond waters (Table 4) during the study period and hence sampling time has no significant bearing on the salt accumulation in the soil. Satyanarayana *et al.* (1986) and Narasimha Rao and Narasimha Rao (1987) reported salt accumulation around fish ponds in Guntur district of Andhra Pradesh.



Plate 3: Accumulation of salts on the surface of the soils by the side of the fish pond at Purini



Plate 4: Location of the drainage channel by the side of the fish pond at Rebala

Organic carbon (OC)

Organic carbon content in the soils around fresh water pond was significantly influenced both at the lateral and vertical distances of soils from the pond (Table 23). Organic carbon was more around the ponds upto a distance of 50 m at Rebala, 100 m at Kovur and 200 m at Purini. Continuous higher moisture content around the ponds coupled with higher salt content might have significant influence on the microflora in the soils around the ponds which might have resulted in less decomposition of organic matter that lead to its accumulation. It was also possible that the finer fraction of the feed added into the ponds either in undecomposed or semidecomposed condition might have moved along with water front might have also contributed to the higher organic carbon in soils in the immediate vicinity of the pond as compared to the same at farther distance from the pond. Organic manures viz., farm yard manure @ 12 to 15 per year per acre and poultry manure @ 6 t per year per acre are recommended during culturing for getting maximum production. (APAU, 1999)

The accumulation of organic carbon was more in the top soil followed by the sub soil. This might be mainly due to the translocation of soluble organic compounds towards lateral distances and at subsequent times towards the top layer due to evaporation of water at the surface.

Available N, P and K

Soil available N, P and K were significantly influenced by fresh water fish culture at all the three places studied (Tables 24 to 26). The available N, P and K in soils increased to a lateral distance of nearly 100 to 200 m from the pond. Available N, P and K was also influenced by the depth of soil and in general it was

more in the surface soil (0-15 cm depth) followed by sub-soil layers. The increase in available N was mainly due to increase in organic matter as indicated by organic carbon content in the soil (Table 23). This might be also due to fertilizers added to the crop which were not utilized to their full extent due to failure of crops or less absorption of nutrients by the crops due to higher soluble salt content (Table 22) noticed in the earlier studies. The other reason for increased available P and K might be due to contamination of soils with effluents of ponded water which contained considerable amount of P and K. Narasimha Rao and Narasimha Rao (1987) observed increased soil available N, P and K in the immediate vicinity of the fish ponds.

Available micronutrients (Zn, Fe, Cu and Mn)

Available micronutrients were significantly influenced by the distance of sampling from the pond and depth of soil at all the three locations studied (Tables 29, 31, 33 and 35). The trends in concentrations of micronutrients in soil profiles indicated distinct effects of ponded water (Table 4). Another reason for higher concentration of micronutrients might be due to presence of higher organic carbon content in the immediate vicinity of the pond. These micronutrients were higher in the surface layers and decreased with increase in depth of the soil profile.

5.3.2.2 Brackish water prawn culture

Soil reaction (pH)

The pH of soils was significantly (Table 37) influenced by lateral distance and depth at all the three places studied. This appears to have become

possible due to the fact that soils contained less amount of clay which lead to the less buffering capacity of the soil. The pH values ranged from 7.73 to 8.01, 7.47 to 8.14 and 7.46 to 6.38 at Karedu-1, Karedu-2 and Kolladinni respectively. The pH of profile samples increased with increase in depth of soil. Similar results were also observed by the scientists of RARS, Lam (1995). The survey conducted in Prakasam district by the scientists of RARS, Tirupati (1997) revealed that the pH of affected and unaffected soils in mango orchard varied between 7.6 and 8.4 and 6.8 and 7.1 respectively.

Salinity (EC)

Salt accumulation was significantly influenced by the distance of sampling from the pond, depth of soil and sampling time (Table 38). The EC changes in the soil due to ponding was basically dependent on the soluble salt movement from pond waters into the surrounding soil.

The influence of brackish water prawn culture was maximum at Karedu-1 and Karedu-2 (Plate 5 and 6) to a lateral distance of 200 m while in the case of Kolladinni, the effect was seen upto 100 m distance. The variation in the spread of salts at the three locations might be attributed to the EC of pond waters which was highest (mean of 48-60 dSm⁻¹) in the case of Karedu-2, followed by Karedu-1 (mean of 48.00 dSm⁻¹) and Kolladinni (mean of 42.65 dSm⁻¹). It was also due to the factors like slope of the land, soil characteristics and other management practices. Salt accumulation was relatively higher in the surface layers at a given lateral distance from the pond. Salt content decreased with increase in depth of soil. The significant increase in EC from sub-surface to surface layer might be due to



Plate 5: Accumulation of salts on the surface of the soils by the side of the pond at Karedu-1



Plate 6: Accumulation of salts on the surface of soils by the side of the pond at Karedu-2

movement of salts with water to the surface layers during evaporation. Similar observations were also reported by several workers (Algarawami, 1995; RARS, Lam, 1995; Banchang, 1995; Raghava Reddy *et al.*, 1994).

Organic carbon (OC)

Variations in the organic carbon content due to brackish water prawn culture was significant both at lateral distance and vertical depths of soils from the pond (Table 41). Organic carbon was more near the ponds and it decreased sharply after 25 m from the pond at Karedu-1 and Karedu-2 and after 100 m at Kolladinni. The higher moisture content in soil near the ponds compared to farther distances has significant influence on microclimate, especially humidity which appears to have favoured more accumulation of organic carbon due to less decomposition. It is possible that the finer fraction of the feed added during aquaculture, either undecomposed or semi-decomposed moved along with water both to lateral and vertical distances might have also contributed to higher organic carbon. Organic manure viz., poultry manure @ 2.5 t ha⁻¹ was recommended during culturing for maximum production (APAU, 1995-96). The higher organic carbon content in the soils nearer to the brackish water ponds was also reported by scientists of RARS, Lam (1995).

Available major nutrients (N, P and K)

Soil available N, P and K were significantly influenced by brackish water prawn culture at all the three places studied (Tables 42 to 44). They were higher in the immediate neighbourhood of the pond and decreased with the increase

in distance from the pond. The increase in available N might be attributed to the higher organic matter content of soil near the ponds (Table 41). The increase was also might be due to application of organic and inorganic fertilizers to the crops in the earlier stages of culture period. Added nutrients and release of nutrients through mineralization process of organic matter might be one of the contributing factors for higher N, P and K in the soils in the immediate neighbourhood of the pond. The other reason for increased available N, P and K appears to be ponded water which contained considerable amounts of these nutrients. Similar results were also reported by RARS, Lam (1995).

Available micronutrients (Zn, Fe, Cu and Mn)

The available micronutrients viz., Zn, Fe, Cu and Mn were significantly higher in soils in the immediate neighbourhood of the ponds as compared to the soils away from the pond (Tables 47, 49, 51 and 53). The higher micronutrients in the neighbourhood of the pond was mainly due to the presence of considerable amounts of micronutrients in the ponded water (Table 5). Another reason for higher concentration of micronutrients was the presence of higher amount of organic carbon in the immediate neighbourhood of the pond (Table 41).

5.4 HEAVY METALS ACCUMULATION IN SOILS ADJOINING FRESH AND BRACKISH WATER AQUACULTURE PONDS

Data showed that accumulation of heavy metals viz., Cr, Pb, Ni and Cd accumulation in the soils was higher in the immediate vicinity of the pond, and gradually decreased with the distance from the pond (Tables 54 to 59). In case of soils surrounding the fresh water ponds, Cr was higher followed by Pb, Ni and Cd

in the soils at all three locations studied (Cr 0.158 to 0.131 mg kg⁻¹; Pb – 0.067 to 0.060 mg kg⁻¹; Ni 0.045 to 0.036 mg kg⁻¹ and Cd 0.00 to 0.003 mg kg⁻¹ at Rebala, Cr 0.084 to 0.073 mg kg⁻¹, Pb 0.068 to 0.052 mg kg⁻¹, Ni 0.040 to 0.031 mg kg⁻¹ and Cd 0.004 to 0.003 at Kovur and Cr 0.128 to 0.114 mg kg⁻¹, Pb 0.102 to 0.090 mg kg⁻¹, Ni 0.087 to 0.072 mg kg⁻¹ and Cd 0.006 to 0.005 mg kg⁻¹ at Purini). In the case of soils surrounding brackish water, Pb (0.240 to 0.117 mg kg⁻¹) was higher followed by Cr (0.135 to 0.053 mg kg⁻¹), Ni (0.099 to 0.047 mg kg⁻¹) and Cd (0.082 to 0.039 mg kg⁻¹) at Karedu-1, Pb (0.184 to 0.054 mg kg⁻¹) was higher followed by Ni (0.120 to 0.009 mg kg⁻¹), Cr (0.094 to 0.048 mg kg⁻¹) and Cd (0.079 to 0.040 mg kg⁻¹) at Karedu-2 and at Kolladinni, Cr was higher (0.173 to 0.080 mg kg⁻¹), followed by Ni (0.107 to 0.060 mg kg⁻¹), Pb (0.099 to 0.052 mg kg⁻¹) and Cd (0.087 to 0.044 mg kg⁻¹). The accumulation of heavy metals was relatively higher with brackish water nearer to the ponds compared to the same at 600 m away from the pond whereas in case of fresh water ponds, the accumulation of heavy metals was near the ponds was also relatively higher as compared to the same at 600 m away from the pond. The accumulation of heavy metal content was relatively higher with brackish water ponds as compared to that of fresh water ponds. The heavy metals were higher in the surface soils and decreased with increase in depth of soil profile (Tables 54 to 59) near the ponds compared to soils 600 m away from the pond at all the six locations studied. The heavy metal content in the adjoining soils of both fresh and brackish water ponds were well below the critical levels of 5 mg kg⁻¹ (Cr), 0.5 mg kg⁻¹ (Cd), 2 – 20 mg kg⁻¹ (Ni) and 2.10 mg kg⁻¹ (Pb) as suggested by Bowen (1966) and Etherington (1982). It should be kept in mind that by the time the study was started fresh water ponds were 8 to 10 years old and the brackish water ponds

were 2 years old. Despite this, the accumulation of heavy metals with brackish water was relatively higher as compared to that of fresh water.

The contributing factor besides source water for higher accumulation of heavy metals might be due to presence of higher amounts of organic matter in the immediate vicinity of the pond. Tyler (1972) reported that relationship between the organic matter content and heavy metal distribution under polluting environment. Similarly Smith (1976) and Ragaini *et al.* (1977) reported that decrease in concentration of heavy metals with increase in depth of soil profile. Chelation was ascribed as an important mechanism for the metals which form complexes with ions like Pb etc (Bergovich and Jackson, 1975).

5.5 EFFECT OF AQUA PONDS ON THE SOLUBLE SALT CONTENT IN THE ADJOINING SOILS

The effects of the aqua ponds on water the soluble salt content (Tables 60 to 65) in the adjoining soils were observed to have close relationship with composition of ponded water (Tables 4 and 5). The salt accumulation was much higher in the case of brackish water ponds which was a resultant effect of higher salt content in the respective waters for ponding. The dominant cation in the soil was sodium irrespective of whether the pond was of brackish water or fresh water (Tables 60 to 65) thereby indicating the alkali hazards with the aqua farms. The next dominating cation in the soils was Mg in case of brackish water ponds while it was more or less equal in the soils with fresh water ponds while Mg content was several times higher than that of Ca with the brackish water ponds. These variations in the soluble salt content in the soils again was manifestation of the variation in the composition of the ponded water rather than the soils at macro level.

The data showed the more dominating influence of soluble salts of Na and Mg compared to that of Ca and K.

Amount of the soluble salt content in the adjoining soils around fresh water ponds (Tables 60 to 62) was reflecting the variation of the composition of the source water for ponding conditioned by soil properties like hydraulic conductivity.

Among the anions, chlorides were dominating in the adjoining soils of aqua ponds irrespective of brackish or fresh waters. The next dominating anion in the soil was sulphates followed by bicarbonates.

5.6 EFFECT OF AQUACULTURE ON CROP PRODUCTIVITY

Data on crop yield showed more adverse effects of brackish water ponds (Tables 67 to 69) on crop yield as compared to that of fresh water ponds (Table 66).

At Kolladinni, no crop could be taken by the farmers upto 100 m distance from the brackish water pond during the observation period while rice was grown beyond 200 m. The yields were more or less similar at 200, 400 and 600 m, away from the pond (Means: 5860, 5142 and 6004 kg ha⁻¹ respectively). At Karedu-1, the existing mango trees in the orchards did not give any yield upto 200 m. The tops of the branches were drying during period of observation. The difference in the mean fruit yield between 400 and 600 m away from the pond was only 63.3 and 67.3 kg tree⁻¹. At Karedu-2, the effect of brackish water prawn culture was similar to that at Karedu-1. There was no yield of sapota upto a distance of

200 m from the pond. However from 400 m onwards the sapota fruit yield was not affected by the pond (Plate 7 and 8).

The fresh water fish culture ponds showed adverse effects on yield of rice to a distance of 200 m at Purini, upto 100 m at Kovur and upto 50 m at Rebala. The adverse effects as reflected by the reduction in the yield were more severe at Purini, followed by Kovur and Rebala (Table 66). These adverse effects reflected the variation in the quality of ground water used for ponding at these locations (Table 4). Electrical conductivity of pond water was in the order of Purini (2.28 dSm^{-1}) > Kovur (1.832 dSm^{-1}) > Rebala (1.790 dSm^{-1}). The data showed a direct reflection of the salt content in the pond waters on the intensity of adverse effects.

Based on the distance, cropped area affected around the ponds was calculated. It was about 6.5 ha at Rebala, 12.5 ha at Kovur and 29.0 ha at Purini. Similarly, the cropped area affected around brackish water prawn culture ponds was 14.5, 31.5 and 27.0 ha at Kolladinni, Karedu-1 and Karedu-2 respectively.

The results indicate that the adverse effects of brackish water ponds were severe and sharp to a longer distance from the pond compared to that of fresh water. This is because of more permeable nature of the soils around brackish water ponds as indicated by the infiltration rate and hydraulic conductivity of soils (Tables 18 and 19). This is also due to very high concentration gradient between the pond water and soil water (Tables 5 and 63 to 65). The farmers in the area have reported to the district revenue authorities seeking co-operation/help. The adverse effects of aquaculture ponds have been reported by several others in general way (Na-Sae,



Plate 7: Affected sapota plant at 150 m away from the brackish water pond at Karedu-2



Plate 8: Dried up sapota plant at 25 m away from the pond at Karedu-2

1989 and Raghava Reddy *et al.*, 1994). Quantified information on the adverse effects of these ponds is not available.

The results of the present investigation clearly indicated that there was deterioration in the soil properties and the quality of ground water adjoining fresh water and brackish water ponds. Deterioration of soil properties were noticed at a distance of about 200 m in case of fresh water fish culture ponds in a period of about 11 years and to a distance of about 200 m from the pond in case of the brackish water prawn culture in a period of about 3 years. At the same time deterioration in the ground water quality was noticed upto a distance of 330 m in case of fresh water fish culture and upto a distance of 390 m in case of brackish water prawn culture. Yield of crops both agriculture and horticulture was also affected to a distance of 200 m away from the pond due to fresh water and brackish water aquaculture in the area studied. These findings clearly bring about the need for adequate pollution control measures and effluent disposal system to reduce the adverse effects of aquaculture ponds. There is a need to take up legislation regarding location of the aquaculture ponds particularly the brackish water prawn culture, so as to maintain sufficient distance from agricultural fields and drinking/irrigation water source around human habitations.

SUMMARY

CHAPTER VI

SUMMARY

Studies on the “Effect of Aquaculture on Soil and Ground Water Quality in Nellore and Prakasam Districts of Andhra Pradesh” were conducted with the following objectives:

- 1) To study the effect of aquaculture on physical and chemical properties of adjoining soils.
- 2) To study the effect of aquaculture on quality of ground water.
- 3) To study the yield level of crops around aquaculture ponds.

Three fresh water fish culture ponds, one each at Rebala, Kovur and Purini and three brackish water prawn culture ponds one each at Karedu-1, Karedu-2 and Kolladinni were selected for the study. The quality of ponded water in the six ponds were also studied.

Ground water samples from wells/filter points/ponds/hand pumps around fresh water fish ponds were collected at 10, 58, 98, 389, 505, 600 and 1010 m from the fish pond of Rebala; 8, 88, 199, 380, 500, 700 and 930 m from pond at Kovur, and 25, 55, 100, 220, 285, 330, 825 and 940 m from fish pond at Purini at the start of the culture and at harvest of the culture during 1995-96 and 1996-97. Around brackish water prawn culture ponds, ground water samples were also collected at 10, 188, 295, 590, 780, 885 and 1000 m distance at Karedu-1, 22, 158, 338, 500, 820, 990 and 1200 m distance at Karedu-2 and 34, 156, 240, 390, 720, 920

and 1250 m away from prawn culture pond at Kolladinni at the start of the culture and at harvest of the culture in the year 1996 and 1997. Water samples from fresh water and brackish water ponds were also collected twice, i.e., at the start of the culture and at harvest during 1995-96 and 1996-97. Ground water and ponded water samples were analysed for pH, EC, Ca, Mg, Na, K, CO₃, HCO₃, Cl, SO₄, NO₃, F, B, heavy metals, viz., Cr, Pb, Ni, Cd and micronutrients viz., Zn, Fe, Mn, Cu for assessing the effect of fresh water fish culture and brackish water prawn culture on soil and ground water around the ponds.

Soil samples were collected at different lateral distances of 0, 25, 50, 100, 200, 400, and 600 m away from all the six aquaculture ponds at 0-15, 15-30, 30-60 and 60-90 cm depths. They were analysed for physical properties like soil texture, bulk density, per cent water stable aggregates, hydraulic conductivity and infiltration rate; chemical properties viz., pH, EC, OC, N, P, K, Zn, Fe, Mn, Cu, Cr, Pb, Ni, Cd, water soluble ions (1:2 soil water extract) viz., Ca, Mg, Na, K, CO₃, HCO₃, Cl and SO₄. The yield of rice crop at 25, 50, 100, 200, 400 and 600 m distance from the pond at Rebala, Kovur, Purini and Kolladinni were recorded. Fruit yield of mango and sapota grown at the same distances away from the pond at Karedu-1 and Karedu-2 were recorded.

The results obtained and conclusions drawn are summarised below.

Quality of pond water

1. The fresh waters used for fish culture has relatively higher pH (8.27) compared to that of brackish water used for prawn culture (8.04). The

brackish water has very high salinity (overall mean of 46.52 dSm^{-1}) compared to fresh water (overall mean of 1.967 dSm^{-1}).

2. Sodium was the dominating cation in both fresh ($13.5 \text{ c mol l}^{-1}$) and brackish (358 c mol l^{-1}) water. The next dominating cation in the fresh water was Ca ($3.52 \text{ c mol l}^{-1}$) followed by Mg ($2.15 \text{ c mol l}^{-1}$) and K ($0.21 \text{ c mol l}^{-1}$) whereas in case of brackish water second dominant cation was Mg ($69.7 \text{ c mol l}^{-1}$) which was much higher than that of Ca (21 c mol l^{-1}) and K (18 c mol l^{-1}).
3. Among the anions, chloride was dominating anion in both fresh ($9.97 \text{ c mol l}^{-1}$), brackish water (365 c mol l^{-1}). The next dominating anion in the fresh water was HCO_3 ($9.16 \text{ c mol l}^{-1}$) followed by SO_4 ($0.38 \text{ c mol l}^{-1}$) whereas in case of brackish water second dominant anion was SO_4 (83 c mol l^{-1}) followed HCO_3 ($12.2 \text{ c mol l}^{-1}$) and CO_3 (3.2 c mol l^{-1}).
4. Brackish water has relatively more heavy metal content as compared to fresh water. The micronutrients viz., Zn, Fe, Cu, Mn varied widely in fresh water compared to that of brackish water. Fe was the dominant micronutrient in both the waters followed by Cu in brackish water and Zn in fresh water. Cu content was the least in fresh water while Zn and Mn were in least quantities in the brackish water.
5. COD was many times higher in brackish water (1935 mg l^{-1}) compared to that of fresh water (147 mg l^{-1}).

6. Culturing generally increased the salt concentration, both cationic and anionic, heavy metals and micronutrients of fresh and brackish waters in both the years of study.

Quality of ground water around aqua ponds

7. Fresh water fish culture ponds at Purini and brackish water prawn culture ponds at Karedu-1, Karedu-2 and Kolladinni adversely affected the quality of ground waters in terms of soluble salt content (EC), COD, Na, Cl, Ca, Mg, Na, K, HCO_3 , SO_4 , B and heavy metals. The reaction of the ground waters nearer to the pond tended to be alkaline.
8. The adverse effects of the fresh water fish culture and brackish water prawn culture gradually decreased with varying lateral distances depending upon property/constituent and location of the pond, which apparently varied from location to location.
9. The ground water adjoining brackish water prawn culture was having higher soluble salt content as compared to fresh water fish culture.
10. The soluble salt content of ground water adjoining fresh water fish culture ponds was above the permissible levels at 10 m distance from the pond (range of 2.46 to 2.89 dSm^{-1}) at Rebala and at 25 m (5.09 to 5.183 dSm^{-1}), 55 m (4.49 to 4.72 dSm^{-1}), 100 (3.085 to 3.275 dSm^{-1}) and 220 m (2.88 to 3.290 dSm^{-1}), 285 m (2.475 to 2.92 dSm^{-1}), and 330 m (2.40 to 2.85 dSm^{-1}) distance from the pond at Purini.

11. The soluble salt content of ground water adjoining brackish water prawn culture was above the permissible levels for irrigation at 10 (22.60 to 27.00 dSm⁻¹), 188 (21.65 to 24.94 dSm⁻¹) and 295 m (17.55 to 19.41 dSm⁻¹) distance from the pond at Karedu⁻¹, 22 (29.15 to 32.70 dSm⁻¹), 158 (25.05 to 28.95 dSm⁻¹), and 338 m (25.05 to 28.95 dSm⁻¹) distance from the pond at Karedu-2 and 34 (19.124 to 19.96 dSm⁻¹), 156 (18.35 to 19.33 dSm⁻¹), 240 (mean of 18.20 to 18.61) and 390 m (6.33 to 6.66 dSm⁻¹) distance from the pond at Kolladinni.
12. Under the influence of ponded water, ionic constituents (heavy metals, micronutrients and other cations and anions) increased in the ground waters nearer to the ponds which gradually decreased with distance away from the pond.
13. The ground waters adjoining Karedu-1, Karedu-2 and Kolladinni ponds contained relatively higher amounts of Cr and Pb which were above the permissible levels for drinking.
14. COD of ground water nearer to the brackish water ponds was many times higher as compared to the ground water nearer to the fresh water ponds.
15. Culturing generally increased the salt concentration, cationic and anionic composition, heavy metals and micronutrients in ground water especially in the immediate vicinity of the pond in both fresh water fish culture and brackish water prawn culture.

Soil properties

16. The soil profile samples adjoining fresh water fish culture and brackish water prawn culture showed deterioration in the properties. Samples nearer to the fresh water and brackish water prawn culture pond contained higher proportion of soluble salts (EC), OC, available N, P, K, Zn, Fe, Cu, Mn, Cr, Pb, Ni, Cd which gradually decreased as the sampling distance from the pond increased. The physical properties viz., infiltration rate and hydraulic conductivity were lower in the immediate vicinity of the pond
17. The soil profile samples collected in the vicinity of the brackish water prawn ponds contained relatively higher proportion of heavy metals in the soil samples but these were below the permissible polluting levels, whereas in case of fresh water fish culture, the tendency of accumulation of heavy metals was less nearer to the ponds.
18. The adverse effects of soil salinity due to brackish water prawn culture were more severe as compared to fresh water fish culture ponds. The adverse soil salinity effects gradually decreased with increase in distance from the pond and became normal after some lateral distance from the pond. The higher soil salinity was upto 200, 200 and 100 m distance from the brackish water ponds at Karedu-1, Karedu-2 and Kolladinni respectively. Mean EC of soils adjoining brackish water prawn ponds ranged from 0.02 to 22.95, 0.04 to 21.03, and 0.42 to 42.82 dSm^{-1} at Karedu-1, Karedu-2 and Kolladinni respectively. The higher soil salinity was upto 50, 100 and 200 m from the

fresh water fish ponds at Rebala, Kovur and Purini respectively. Mean EC of soils adjoining fresh water ponds ranged from 0.71 to 5.10, 0.52 to 13.86 and 1.19 to 15.11 dSm^{-1} at Rebala, Kovur and Purini respectively.

19. The adverse effects of fresh water fish culture and brackish water prawn culture on EC of soil severe in the upper layers of soil which gradually decreased with increase in depth of sampling.
20. Among the water soluble ions, considerable build up of Na in the soil profile was noticed followed by that of Ca, Mg and K at Rebala and Kovur. At Purini, however, accumulation of Mg in soil profile was higher as compared to that of Ca. Among the anions, accumulation of chlorides was the highest followed by sulphates and HCO_3 . The build up of Na in the soil profile was highest followed by the Mg, Ca and K. Among the anions, accumulation of chlorides was the highest followed by that of sulphates and HCO_3 . Culturing generally increased concentration of water soluble ions in the immediate neighbourhood of the pond.

Crop yield

21. The adverse effects of brackish water prawn culture ponds on crop yields were more severe as compared to that of fresh water fish ponds. No crop could be taken up by the farmers upto 100 m from the pond at Kolladinni. Mango and sapota nearer to brackish water prawn ponds did not give any yield upto 200 m distance at Karedu-1 and Karedu-2 respectively.

22. The adverse effects of fresh water fish culture were reflected on the rice yields upto 50 m. at Rebala, 100 m at Kovur and 200 m at Purini villages. No crop could be taken up at 25 m, 50m at Purini and 25 m at Kovur.
23. Results in the present investigation clearly bring out the need for adequate pollution control measures and effluent disposal system to reduce the adverse effects of aquaculture ponds. There is a need to take up legislation regarding location of aquaculture ponds, particularly the brackish water prawn culture, so as to maintain sufficient distance from agricultural fields and drinking/irrigation water source around human habitations.

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APPENDICES

APPENDIX - I

Meteorological data of Nellore district during the study period (1995 -- 1997)

Month	Rainfall (mm)	Rainy days	Mean temperature (°C)		Mean Evaporation (mm day ⁻¹)
			Maximum	Minimum	
1995					
January	93.0	6.0	27.4	19.8	2.3
February	--	--	30.4	20.9	3.7
March	--	--	32.5	21.8	4.7
April	--	--	34.5	24.5	5.6
May	408.0	4	35.0	26.1	4.9
June	36.6	3	37.5	27.2	7.1
July	179.0	12	34.0	25.6	5.0
August	112.0	7	34.5	26.1	5.0
September	119.2	7	33.5	25.1	4.9
October	127.6	12	31.9	24.9	3.3
November	123.2	5	30.5	23.5	3.4
December	8.6	1	28.6	20.1	3.3
1996					
January	0.2	--	28.8	19.6	3.3
February	--	--	29.9	20.2	4.1
March	--	--	33.3	21.1	5.6
April	18.0	2	34.9	25.4	5.9
May	27.8	1	32.7	26.6	7.6
June	267.8	4	35.5	26.6	5.9
July	53.6	7	34.6	25.7	5.7
August	112.0	7	33.7	25.7	5.8
September	86.6	6	33.4	25.0	4.5
October	616.2	17	30.0	24.2	2.6
November	162.2	6	31.1	23.0	2.9
December	365.8	10	27.9	20.8	2.4
1997					
January	76.4	4	27.5	19.4	3.2
February	--	--	30.5	19.7	3.8
March	--	--	33.3	21.7	4.6
April	68.8	1	33.9	23.6	5.4
May	8.2	1	38.3	26.3	7.8
June	32.8	2	37.1	27.5	8.7
July	86.0	5	35.4	26.1	6.9
August	57.0	5	34.5	26.3	6.5
September	176.0	7	34.0	25.2	4.7
October	65.0	3	32.1	24/1	4.1
November	468.2	17	29.4	23.8	2.7
December	428.6	11	28.9	22.9	2.7

APPENDIX – II

Meteorological data of Prakasam district during the study period (1996 – 97)

Month	Rainfall (mm)	Rainy days	Mean temperature (°C)		Mean Evaporation (mm day ⁻¹)
			Maximum	Minimum	
1996					
January	--	--	28.5	19.5	4.0
February	--	--	31.5	20.2	4.5
March	--	--	34.0	21.5	5.0
April	--	--	34.0	23.7	6.0
May	36.4	1	39.5	26.5	8.0
June	110.8	3	38.5	28.5	9.0
July	44.5	6	38.2	27.5	7.5
August	49.6	4	35.5	26.5	6.9
September	109.8	9	35.5	25.9	5.5
October	515.2	15	33.5	24.9	6.0
November	217.3	5	32.5	24.9	3.0
December	167.4	6	29.5	25.1	3.2
1997					
January	44.4	2	29.0	20.5	3.9
February	--	--	30.5	21.0	4.5
March	--	--	35.5	22.0	5.9
April	69.0	4	36.0	26.4	6.2
May	53.0	1	33.0	27.0	7.9
June	9.0	2	37.0	27.0	6.5
July	73.5	6	35.5	26.2	5.9
August	24.0	4	35.0	26.0	6.2
September	211.7	10	34.0	25.9	5.5
October	111.8	7	32.0	24.5	3.5
November	420.6	18	32.0	23.5	3.9
December	318.1	10	29.0	21.2	3.5

Appendix -III contd

Village and Distance (m)	Depth of soil (cm)											
	0 - 15				15 - 30				30 - 60			
	Sand %	Silt %	Clay %	Textural class	Sand %	Silt %	Clay %	Textural class	Sand %	Silt %	Clay %	Textural class
Purini												
0	68.44	11.0	20.56	SCL	63.14	10.5	26.36	SCL	59.14	11.5	29.36	SCL
25	69.64	11.0	19.36	SL	61.64	11.0	27.36	SCL	60.14	11.5	28.36	SCL
50	65.64	12.0	22.36	SCL	60.14	12.5	27.36	SCL	59.54	12.9	27.56	SCL
100	68.14	10.5	21.36	SCL	49.64	14.0	36.36	SCL	46.50	16.0	37.50	SCL
200	68.74	11.0	20.26	SCL	59.14	13.50	27.36	SCL	58.14	12.5	29.36	SCL
400	69.34	11.5	19.16	SL	59.64	14.0	26.36	SCL	58.14	13.5	28.36	SCL
600	68.44	11.0	20.56	SCL	59.64	12.0	28.36	SCL	57.14	12.5	30.36	SCL
Karedu-I												
0	53.22	28.0	18.78	L	51.71	27.5	20.79	SL	53.90	23.32	22.78	SCL
25	56.71	24.72	18.57	SL	58.25	21.37	20.38	SCL	55.26	20.52	24.22	SCL
50	59.74	22.73	17.53	SL	59.34	20.28	20.38	SCL	56.90	20.37	22.73	SCL
100	55.64	26.0	18.36	SL	54.24	26.0	19.76	SCL	53.22	24.0	22.78	SCL
200	53.86	22.72	23.42	SCL	55.74	21.89	22.37	SCL	55.45	20.17	24.38	SCL
400	57.26	24.37	18.37	SL	53.91	22.81	23.28	SCL	50.72	23.91	25.37	SCL
600	58.91	22.57	18.52	SL	56.48	20.73	22.79	SCL	56.82	18.79	24.39	SCL
									51.66	22.97	25.37	SCL
									54.25	18.43	27.32	SCL
									58.94	17.54	23.32	SCL
									51.13	24.5	24.37	SCL
									54.25	20.37	25.38	SCL
									53.18	18.38	28.44	SCL
									58.62	17.39	23.99	SCL

Appendix - III contd....

Village and Distance (m)	Depth of soil (cm)											
	0 - 15				15 - 30				30 - 60			
	Sand %	Silt %	Clay %	Textural class	Sand %	Silt %	Clay %	Textural class	Sand %	Silt %	Clay %	Textural class
Karedu-2												
0	54.68	28.0	17.32	L	57.51	24.37	18.12	L	53.4	26.32	20.28	SCL
25	53.64	30.0	16.36	SL	57.37	23.40	19.23	SL	54.98	22.50	22.52	SCL
50	54.56	27.20	18.74	SL	57.37	23.40	19.23	SL	54.98	22.50	22.52	SCL
100	47.64	38.0	14.36	L	59.64	24.0	16.36	SL	58.63	22.0	19.37	SL
200	61.88	22.75	15.37	SL	59.5	22.12	18.38	SL	56.56	20.72	22.72	SCL
400	57.11	24.52	18.37	SL	56.46	23.97	19.57	SL	51.44	24.72	23.84	SCL
600	57.24	27.51	15.25	SL	56.12	24.51	19.37	SL	49.16	24.12	26.72	SCL
Kolladinni												
0	81.64	2.00	16.36	SL	65.64	8.0	26.36	SCL	63.27	7.20	29.53	SCL
25	80.52	2.90	16.58	SL	69.39	4.82	25.79	SCL	65.96	5.12	28.92	SCL
50	78.94	3.51	17.55	SL	73.35	4.27	22.38	SCL	65.76	4.32	29.92	SCL
100	76.13	5.29	18.58	SL	73.68	2.79	23.53	SCL	67.78	5.50	26.72	SCL
200	76.14	4.50	19.36	SL	69.57	5.2	25.23	SCL	65.58	5.50	28.92	SCL
400	78.42	5.00	16.58	SL	71.94	5.5	22.56	SCL	67.78	5.50	26.72	SCL
600	80.14	4.50	18.36	SL	75.50	4.5	20.00	SCL	74.97	3.30	21.73	SCL

L = Loam, SL = Sandy loam, SCL = Sandy clay loam, SC = Sandy clay

APPENDIX - IV

Influence of fresh water fish culture on the grain yield of rice (kg ha^{-1}) at various distances from the pond at Rebala

Distance (m)	Grain yield (kg ha^{-1})			
	1995-96		1996-97	
	Late <i>kharif</i>	Summer	Late <i>kharif</i>	Summer
25	1848 (64.0)	1605 (63.5)	2059 (60.7)	1743 (59.4)
50	1914 (62.8)	1624 (63.0)	2145 (59.1)	1755 (59.1)
100	5140	4395	5240	4290
200	5084	4395	5240	4290
400	5334	4451	5442	4244
600	5237	4517	5463	4422
CD at 5%	121	65	65	73

Value in brackets indicate that percent yield reduction.

APPENDIX - V

Influence of fresh water fish culture on the grain yield of rice (kg ha^{-1}) at various distance from the pond at Kovur.

Distance (m)	Grain yield (kg ha^{-1})			
	1995-96		1996-97	
	Late <i>kharif</i>	Summer	Late <i>kharif</i>	Summer
25	No crop	No crop	No crop	No crop
50	572 (85.2)	No crop	644 (85.6)	No crop
100	1769 (54.2)	No crop	2067 (53.6)	908 (75.4)
200	3865	3484	4458	3690
400	4014	3380	4497	3511
600	3890	3445	4242	3572
CD at 5%	107	-	59	-

Value in bracket indicate per cent yield reduction.

APPENDIX - VI

Influence of fresh water fish culture on the grain yield of rice (kg ha^{-1}) at various distance from the pond at Purini

Distance (m)	Grain yield (kg ha^{-1})			
	1995-96		1996-97	
	Late <i>kharif</i>	Summer	Late <i>kharif</i>	Summer
25	No crop	No crop	No crop	No crop
50	No crop	No crop	No crop	No crop
100	508 (88.2)	No crop	747 (83.4)	No crop
200	1267 (70.5)	771 (79.4)	1591 (64.5)	826 (76.5)
400	4299	3716	4488	3516
600	4343	3471	4720	3499

Values in brackets indicate that percent yield reduction.

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14-6-2000