INTRODUCTION
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The group of anostracan crustaceans living in salt pans and seasonal fresh water ponds in tropical, sub-tropical and arctic regions of the world continue to be of interest because of their wide distribution in terms of the geographic regions, temperature gradient to which they are exposed and finally the rigorous conditions imposed upon the organisms in salt pans and temporary pools of fresh water, which almost totally control their growth, life histories and life habits.

Edmondson (1959) in his book 'Fresh water Biology', recorded about eight species of Anostraca and two of Notostraca from Canada. Hartland Rowe (1965) published a list of Anostraca and Notostraca of Canada based on the Dexter-Linder key. Same author in 1967 recorded a new species Chirocephalus-neumanni from Israel and described another new species from North-America Eubranchipus intricatus which has a fairly wide distribution.

There is very little published information about this group of animals from India, where the temporary pond water fauna and flora are subjected to extreme conditions regarding temperature, soil, pH, salinity and duration of pond life. Gopinath (1944) recorded Streptocephalus dichotomus from Travancore, Pai (1951) some larval forms of Streptocephalus, Estheria and Triops from Panchgani, Hartland Rowe (1968) described a species from Kashmir. Sanjeeveraj (1951, 1961)
recorded the genus *Branchinella* (Sayce) and a new variety of *Branchinella kugenumaensis*. Ishikawa and described its morphology and distribution around Madurai and other parts of South India. Quadri and Baqai (1956) submitted a record of some Branchiopods of Indo-Pakistan subcontinent. Tiwari (1958, 1965) described a new species of genus *Branchinella* (Sayce) from Sambar lake and other areas of Rajasthan, Western India. Bernice (1971, 1972) mentioned the occurrence of *B. kugenumaensis* and *S. dichotomus* around Madras, India.

In the area of ecological-physiological studies, papers by Dexter (1946 and 1967) on life history of *Eubranchipus - vernalis*. Verrill and annual population changes of some Anostraca, Dexter and Kuehnle (1948). on the shrimp population of Ohio, U.S.A.; Moore (1955, 1957, 1959, 1963) and by Nourisson (1958, 1959, 1960, 1961) on *Chirocephalus stagnalis* (Prevost) and *C. diaphanus* (Prevost), Hall (1959 a, b, c) on development of the eggs of *C. diaphanus*, Baqai (1963) on *Streptocephalus seali*, Prophet (1963) on habitat ecology, Southwich et al. (1964) on survival patterns of *Eubranchipus - vernalis* in laboratory cultures, Carlisle (1968) on effects of temperature on *Triops* eggs, Gaudin (1968), on egg production of *S. seali* Ryder, Lake (1969) on effects of temperature on egg production and growth of *C. diaphanus* (Prevost), Moore (1970) on limnological studies of temporary ponds of Lousiana, North America; Rao (1972) on ecological studies of fresh water ponds of Hyderabad, South India; Bernice (1972) on ecological observations on *S. dichotomus* Baird, are some of the most important contributions, which
give us a fairly good insight about the adaptability of the fairy shrimps to various ecological conditions.

On the life history, modes of reproductions, effects of various ecological factors on the development and reproduction, very scanty information is available in some of the papers sighted above.

On neuroendocrine system, papers by Gabe (1952) on X-organs, Carlisle (1961) on decapod Crustacea _Lysmata_ sp., Miyawaki (1960) on neurosecretory cells, Menon (1962) on distribution of neurosecretory cells, Elofsson (1966) on nauplius eye and frontal organs of some non-malacostracan crustaceans, Lake (1969, 1970), on histochemical studies of neurosecretory cells and organs, are some of the significant ones that shed light on the neuroendocrine system of these animals. There is, however, no correlation established between the changes in the neurosecretory patterns and distribution of the cells and the various morphological changes in the reproductive organs consequent upon changes in their reproductive physiology.

For the present work, a common fairy shrimp _Streptocephalus dichotomus_ Baird was selected. These could be collected and cultured and were easily available in number of districts of Maharashtra, India. They were available in the last four years, in many localities in such diverse areas as (1) Panchgani and Panhala, both of which are high altitude hill-stations where the ponds last
only for three months and are directly open to the sky and rains; (ii) Nagpur, Gondia, Chandrapur, Dhulia, Amalner and Aurangabad, where they are found in small and larger ponds and stone quarries, flooded fields of jowar, where the ponds last for one month to even eight months. The ambient temperature range is quite different from those of the hill-stations; (iii) Poona, Kolhapur etc. which are comparatively colder areas and (iv) Ratnagiri which is on the west-coast of Maharashtra.

Three distinct species were found in these areas out of which _S. dichotomus_ Baird which was identified and was selected for this work. The nature of the soil, pH, temperature range, both in the water and air, salinity, altitude, shade, or absence of it are some of the factors which differ from pond to pond and area to area.

In chapter I, observations on water chemistry, effects of seasonal changes in pH, temperature, and oxygen concentration on these organisms, respiratory metabolism, in terms of oxygen consumption in relation to temperature, salinity, pH, oxygen tension, body size and ventilation frequency have been recorded, since the rate of respiration is a positive indicator in energy metabolism in animals which are normally subjected to various important limiting factors in pond life. Chapter II contains records of the breeding seasons, span of life, behaviour patterns, sex ratios and biochemical changes taking place in the body during their life history. In
addition to these observations on the growth rate, larval
development of a few significant organs in these animals
have also been recorded. The purpose of this study was to
find out any possible correlation between the life history,
development and the duration of the ponds.

It is an established fact that there are distinct
neuroendocrine organs which control various metabolic acti-
vities of the invertebrates almost as effectively as in the
vertebrates. Exhaustive studies are being made on these
neuroendocrine organs in insects, larger malacostracans,
crustaceans and molluscs. The group Branchiopoda, anostraca
a lower crustacean group, appears to be neglected in this area
of knowledge. Mention have already been made of some of the
important papers in this field, on animals of this group.
An attempt has been made to establish the possibility of
some correlation between the neurosecretory cell patterns,
their morphology and changes therein on one hand and the
state of metabolic activity and reproductive phases of the
animal in their short life span, on the other.
PLATE - 1

Streptocephalus dichotomus (Baird, 1860) - male and female
PLATE - 2

II Antenna - diagnostic feature of the species - Streptocephalus dichotomus

BS : Basal segment
DS : Distal segment
IS : Intermediate segment
SP : Spine
II ANTENNA OF MALE STREPTOCEPHALUS_DICHOTOMUS

BS

IS

DS

SP

1 mm.
PART I

ECOLOGICAL AND PHYSIOLOGICAL OBSERVATIONS

CHAPTER I

Some limnological observations on temporary fresh water ponds of Maharashtra, India.
SOME LIMNOLOGICAL OBSERVATIONS OF TEMPORARY FRESH WATER PONDS OF MAHARASHTRA, INDIA.

Most of our knowledge of temporary ponds in India has derived from the investigations made with reference to some restricted features of the ponds or with reference to the biology of some specific organisms characteristic of such habitats. Papers by Ganapati (1955) on the diurnal variations in dissolved gases, pH etc. in the temporary rock pools at Mettur Dam, Sen and Chatterjee (1960) on the pH of Gorakhpur pool, Singh (1960) on the phytoplankton ecology of some Uttar Pradesh inland water pools, Zafar (1964) on the physico-chemical complexes of some fish pond of Hyderabad, George (1966) on the comparative planktonic ecology of Delhi ponds, Sitaramiah (1966) on the ecology of fresh water pond community, Seenayya (1971) on the planktonic study of some ponds around Hyderabad with its physico-chemical complexes, Khan and Siddiqui (1971) on the water, nitrogen and phosphorus in fresh water plankton around Aligarh and Kaliyamurthy (1973) on the transparency of Pulicat lake, are some of the significant contributions. In the last few years, some exhaustive work has been published. Rao (1971, 1972) made a detailed survey of three fresh water ponds around Hyderabad with reference to the cationic and anionic contents, the free and dissolved oxygen, carbon-dioxide, ammonia and oxidizable organic matter, air and water temperature during the three seasons. Unni (1972) made a comprehensive study of a perennial lake around Raipur, Madhya Pradesh with special reference to the sodium, potassium,
calcium, magnesium contents, the pH range, specific conductivity, carbonate and bicarbonate alkalinity etc. Bernice (1972) also made a number of ecological observations on some temporary ponds around Madras. She studied the water chemistry in terms of carbonates, bicarbonates, chlorides, ammonia, nitrites, nitrates, phosphates, silicates, free and dissolved oxygen, carbon-dioxide, ammonia and seasonal ranges of air and water temperature.

There are number of publications of such comprehensive studies of temporary ponds and lakes made in western countries. Few of them are mentioned here such as, Hartland Rowe (1966) on the fauna and ecology of temporary pools in Western Canada, Sublette and Sublette (1967) on the limnology of some lakes in New Mexico and Texas, Moore and Burn (1968) on lethal oxygen, thresholds for certain temporary pond invertebrates and Moore (1970) on limnological studies of temporary pools in Louisiana, which are useful for comparative study.

Few ponds were selected for the present investigation, in Maharashtra viz., Panchgani (Dist. Satara), a hill-station; Panhala (Dist. Kolhapur), a hill-station; Amalner - East Khandesh (Dist. Jalgaon); Aurangabad and a stone quarry near Marathwada University Campus, Aurangabad for detailed study.

The term temporary pond is used in this study to mean a pond of limited duration which dries at least once a year. The dry period may extend from one month to six months even. The study of these temporary pools was started early in 1973, just prior to monsoon.
THE NATURE OF THE PONDS

(1) The ponds at Panchgani:

The Panchgani ponds under study are situated on the table land and exposed to heavy rain and wind during the period of June, July and August. There is no shade as table land is bare of trees or large shrubs. The soil is gray-white loam and contains large amount of silicate and carbonates. The associated animals along with \textit{S. dichotomus} are \textit{Triops orientalis} Tiwari, three species of \textit{Estheria}, Copepods and Dragonfly larvae in large number. The depth of the pond varies from 15 cm. to 30 cm. The maximum diameter of a larger pond is around 5 metre. Most of the ponds do not have the diameter of more than 1 metre. The ponds are filled around fifteenth June with the first monsoon showers and dry up by the end of August or late September.

(2) The ponds at Panhala:

The ponds at Panhala are situated on the table land around which there are large trees which do not shade the ponds. The ponds are directly exposed to rain and wind. The soil is oily red and contains large amount of organic matter, iron and copper. Associated animals along with \textit{S. dichotomus} include \textit{T. orientalis} Tiwari, six species of \textit{Estheria}, three species of Cladocera, Copepods and Chironomids. The smaller ponds/ditches have a depth of 15 cm. to 20 cm. and a maximum diameter of 50 cm. There is only one
large pond having the average depth of 20 cm. and a diameter of 2 metre. The ponds are filled in the last week of June with first rain and dry up by the end of September.

(3) The ponds at Amalner:

The Amalner ponds under investigation are not actually ponds, but are roadside ditches and the areas of Jowar fields by the roadside. The appearance of *S. dichotomus* in these ditches and fields is sporadic and is not a regular feature year to year. The ditches and fields where the shrimps are found, are mostly those which have large amount of organic manure. The colour of the animals varies typically according to the concentration of organic manure or heavy growth of green algae and diatoms. The animals take up bright reddish crimson colour with very bright red egg-pouch in female when the concentration of organic manure is very heavy. Alternately they take up deep bluish green colour with crimson coloured egg-pouch in the females, where the concentration of green algae and diatoms is very heavy. The animals take up these colours when they are sexually mature. In the earlier stages only the cercopods are bright red and the male antennae bright blue. These ditches are flooded in early July and dry up at the end of September. The depth is never more than 20 cm. and diameter of 100 cm.

The associated animals include Planaria, Mosquito larvae, Dragonfly larvae, Chironomus larvae, Water boatman, *Ranatra* sp., *Cyclops* sp., *Moina dubia*, *Daphnia longispina*, *Cypris* sp.,
Estheria sp. and other conchostraca, along with S. dichotomus.

(4) The ponds at Aurangabad:

The ponds at Aurangabad under investigation are situated in open areas near larger natural tanks used by the Department of Fisheries for cultivating the finger-lings of fresh water carps. Some of them are slushy and muddy while others are sandy. These ponds have a depth of around 150 cm. to 180 cm. and maximum diameter of 3 metre. They are flooded in the first week of July and dry up by the end of November. The stone quarry near the University Campus has the sandy and loam soil with a lot of organic debris. The maximum depth is 85 cm. length about 3.5 metre and breadth about 1 metre. Detailed study of these two types of ponds and the roadside ditches around Amalner has been made and the results are given in Table 1.

METHODS AND RESULTS

Meteorological data about the rainfall was collected from the available government records. The air, water and soil temperature has been recorded directly on the field at weekly intervals. Daily temperature fluctuations, both in air and water, were recorded at Panhala and at Aurangabad for some days in August, 1973 and 1974.

Since it was observed on the basis of the work of Moore, Hartland Rowe and others in western countries and Rao, Bernice etc., who have published their work on Indian fresh water pond
soils, that the occurrence, growth and development and life habits are not influenced to any appreciable extent by the major components and their variations in the soil. It was observed experimentally that black cotton soil, when provided to the experimental cultures even at the proportion of 5 gm. per litre does not favour the normal activities of these animals. In fact, it was observed that when the proportion was increased to 10 gm. per litre, the eggs do not hatch for at least a week and when they hatch, they do not survive beyond the third larval stage, unless the water is changed every fortyeight hours. When the adults were introduced in the water of black cotton soil, they were in complete distress. The observations noted earlier that the animals were found at Panchgani, Panhala, Ratnagiri, Aurangabad and Amalner where the composition of soil varied greatly, confirm the present hypothesis.

The pond water samples filtered through bolting silk were collected in the field, frozen at -5°C. and stored in that state for analysis. Laboratory analysis of water was done by using the methods described by Machereth (1957), Anderson and Foyin in 'Common methods for chemical analysis of sea water 'part II' and in Physiological Chemistry by Hawk et al. (1954). Details are given in Table 1.

It is observed that in the ponds under investigations, the following equivalent proportions of cations and anions exist which are compared with the general pattern of anions and
cations of the ponds:

Ponds under investigation: Ca > Na > Mg > K : HCO₃ > Cl > SO₄
General pattern : Ca > Mg > Na > K : HCO₃ > SO₄ > Cl

Since weekly and monthly collections of the plankton were made only for a couple of months, detailed comparative account of density of different planktonic forms in different seasons could not be worked out. However, the pond life did not show any significant variation during the period in terms of zooplankton and phytoplankton.
ASSOCIATED ZOOPLANKTON

(1) Plathyelminthes : Planaria.

(2) Annelids : Nais sp.

(3) Rotifers : Branchionus angularis, B. caudatus, B. codridentata, B. calyioflorus, Keratella tropica, K. chochleris, Filinia loagiseta, Rotaria rotelaris.

(4) Insect larvae : Mosquito, Odonata larva, Chironomus, Tendipes, Damsel fly.


(6) Other arthropods : Cyclops, Orthocyclops, Moina dubia, Daphnia longispina, Cypris, Estheria, Branchipus sp.

(7) Molluscs : Indoplanorbis sp., Melanoides sp.
### TABLE-1
**LIMNOLOGICAL OBSERVATIONS OF THREE FRESH WATER TEMPORARY PONDS**

<table>
<thead>
<tr>
<th>Factors observed</th>
<th>Stone quarry near M.U. Campus</th>
<th>Muddy pond, Delhi gate, Aurangabad</th>
<th>Littor pond, Amner</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Temperature range in °C.</strong></td>
<td>21 - 39</td>
<td>21 - 39</td>
<td>21 - 42</td>
</tr>
<tr>
<td>Air</td>
<td>21 - 30</td>
<td>20 - 29</td>
<td>18 - 28</td>
</tr>
<tr>
<td>Water</td>
<td>17 - 55</td>
<td>20 - 57</td>
<td>20 - 60</td>
</tr>
<tr>
<td><strong>Depth cm.</strong></td>
<td>55</td>
<td>183</td>
<td>72</td>
</tr>
<tr>
<td><strong>Oxygen mg./litre</strong></td>
<td>11.50</td>
<td>15.37</td>
<td>9.70</td>
</tr>
<tr>
<td><strong>Total alkalinity ppm.</strong></td>
<td>28.50</td>
<td>72.70</td>
<td>124</td>
</tr>
<tr>
<td><strong>Silicate μg/litre</strong></td>
<td>220</td>
<td>31</td>
<td>45</td>
</tr>
<tr>
<td><strong>Phosphate μg/litre</strong></td>
<td>0.0005</td>
<td>0.0020</td>
<td>0.0009</td>
</tr>
<tr>
<td><strong>Nitrate mg./litre</strong></td>
<td>0.020</td>
<td>0.040</td>
<td>0.087</td>
</tr>
<tr>
<td><strong>Ammonia μg/litre</strong></td>
<td>12.00</td>
<td>26.00</td>
<td>81.00</td>
</tr>
<tr>
<td><strong>Organic matter mg./litre</strong></td>
<td>54</td>
<td>171</td>
<td>343</td>
</tr>
<tr>
<td><strong>Iron ppm.</strong></td>
<td>0.51</td>
<td>0.65</td>
<td>0.63</td>
</tr>
<tr>
<td><strong>Carbonate ppm.</strong></td>
<td>6.125</td>
<td>16.050</td>
<td>11.700</td>
</tr>
<tr>
<td><strong>Bicarbonate ppm.</strong></td>
<td>123.00</td>
<td>170.00</td>
<td>211.00</td>
</tr>
<tr>
<td><strong>Chlorides ppm.</strong></td>
<td>45.43</td>
<td>88.70</td>
<td>56.25</td>
</tr>
<tr>
<td><strong>Free Ammonia</strong></td>
<td>6.47</td>
<td>13.90</td>
<td>29.96</td>
</tr>
<tr>
<td><strong>Calcium ppm.</strong></td>
<td>65.71</td>
<td>78.70</td>
<td>90.60</td>
</tr>
</tbody>
</table>
PLATE - 3

Stone quarry near Marathwada University Campus, Aurangabad.

PLATE - 4

Muddy pond at Aurangabad
PLATE - 5

Littor pond at Aurangabad

PLATE - 6

Collection in the sandy pond, Aurangabad.
Annual changes in temperature (in air and in water) at Aurangabad and Panhala during 1973-74.

A : Air temperature at Aurangabad
B : Water temperature at Aurangabad
C : Air temperature at Panhala
D : Water temperature at Panhala
FIGURE - 2

Daily changes in temperature in 1973 and in 1974
21-22 August at Aurangabad,
25-26 August at Panhala.

0 : Air temperature at Aurangabad
θ : Water temperature at Aurangabad
○ : Water temperature at Panhala
Anderson and Foyn: Common methods for chemical analysis of sea water Part II.


Hawk, et al. (1965): Hawk's Physiological Chemistry. (Cser, B.L. ed.) T.M.H. Publication.


