

Influence of Salinity on the Life Table Demography of a rare Cladocera *Latonopsis australis*

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Abstract

Latonopsis australis is a rare cladocera inhabiting the entire stretch of the Cochin backwaters, the largest monsoonal estuary along the west coast of India, during the Summer Monsoon, but restricted to the upper reaches during the non-monsoon periods. Here, we present the results of an experimental study, which assessed the influence of salinity on the life table demography of the species at different salinity levels. The life table demographic parameters such as net reproduction rate, generation time, intrinsic growth rate, gross reproductive rate, and survivorship of the species were measured in different salinities ranging from freshwater to mesohaline levels (salinity 14). The study showed that higher salinity had a significant negative effect on all life table demography parameters of the species, whereas freshwater to low saline conditions (salinity up to 8) favoured the survivorship, life expectancy, net production, and growth rate. It was also noticed that salinity above 8 caused a significant decrease in the survivorship, life expectancy and reproduction rate of the species, which clearly explained the seasonal distribution pattern of the species in the Cochin backwaters. The present study suggests salinity 2 to 6 as the optimum range for the large-scale production of *Latonopsis australis* for purposes like live feed in aquaculture.

Key words: cladocera, zooplankton, salinity, demography, Cochin backwaters

Introduction

Cladocerans are small crustaceans with short generation time referred to as ‘water fleas’ due to their jerky swimming movements like fleas and contribute a significant portion of the zooplankton community (more than 50%) at times when they form massive swarms. Cladocera is a good model organism in field and experimental studies due to their short generation time (Larsson and Miracle 1997; Forror et al. 2008; Suhett et al. 2015). They are generally herbivorous, but can also feed on bacteria, organic detritus and dissolved organic matter (Arnold 1971; Boersma and Vijverberg 1996; Abrantes and Gonçalves 2003) and function as prey for larger invertebrates and fishes. Cladocerans that can survive in high salinity conditions are less known and, therefore, they are collectively considered as limnophilic organisms (Frey 1993).

Earlier studies on cladocera from Indian waters include those from the freshwater systems (Fernando 1980 a, b; Michael and Sharma 1988; Murugan et al. 1998; Raghunathan and Suresh 2002; Sivakumar and Altaff 2004) and coastal/ brackish water environments (Madhupratap and Haridas 1975; Gowsami and Devassy 1991; Shrivastava et al. 1999; Acuthankutty et al. 2000). On one hand, reports from freshwater environments suggest *Latonopsis australis* as a typical freshwater species and a cladoceran of interest (Raghunathan and Suresh 2003). Remarkably, our field observations evidenced the presence of the species in the entire stretch of the Cochin backwaters/estuary during the Southwest Monsoon and in the upper reaches during other periods, indicating the ability of the species to tolerate certain level of saline conditions (Fig. 2).

Life table demography is an important tool to understand the physiological response of plankton to different environmental conditions. Parameters such as survivorship, reproductive rate and generation time provide valuable information regarding the suitability of the environmental conditions for the growth of a given species of plankton (Stearns 1976). Therefore, attempts have been made in the present study to understand the effect of different salinity ranges on the life table demography of *L. australis*. This approach is expected to generate useful information on the optimal salinity levels required by the species and thereby throw light on the observed seasonal distribution pattern of the species in the Cochin backwaters.

Materials and Methods

Study area and occurrence of *L. australis*

The Cochin backwater is an extensive and complex system of shallow estuarine network running parallel to the coastline of Kerala. The main inlet of the Cochin backwaters into the Arabian Sea is at

Fort Kochi and from there the system extends ~45km southward to reach Thannermukkom, where a barrage/barrier is situated for preventing the intrusion of salt water further southward during non-monsoon months. During the Southwest Monsoon (June to September), the barrage is open for the free flow of the flood water from further south into the Cochin backwaters and the Arabian Sea. The hydrography of the Cochin backwaters is significantly influenced by the heavy rainfall and freshwater influx during the Southwest Monsoon. During the peak Southwest Monsoon (July-August), surface salinity reaches near zero value over a major part of the Cochin backwaters. In this 'monsoonal estuary', the seasonal effect of rainfall is readily visible in the prevailing salinities, which play an important role in the ecobiology of the system (Jyothibabu et al. 2006).

L. australis mostly reproduce parthenogenetically, but during unfavourable/rare conditions they do carry out sexual reproduction. The distribution of the species in the Cochin backwaters exhibits a noticeable seasonal difference. Nonetheless, it does occur in the entire stretch of the Cochin backwaters during the Southwest Monsoon, although confined to the upper reaches by the retrieval of the monsoon. This seasonal distributional pattern of the species is a clear indication that salinity can be the most important factor controlling its distribution in the Cochin backwaters. However, no reliable and conclusive information is available so far on the influence of different salinity levels on *L. australis* in estuarine systems.

Sampling and Isolation of *L. australis*

Our zooplankton samples were collected in the morning (before 9:00 AM) from several locations (14 locations) in the Cochin backwaters during the Pre-Southwest Monsoon and the Southwest Monsoon in 2013 are presented (Fig. 1). These sampling sessions were carried out basically from the mesohaline (downstream) to the freshwater dominant upstream regions of the Cochin backwaters. A standard zooplankton net (0.22 m² mouth area and 200µm mesh size) was used to collect the zooplankton from the surface waters. The general distribution pattern of *L. australis* in the Cochin backwaters noticed during these seasonal samplings has been presented in Fig. 2, which indicates their preference for low saline to freshwater conditions.

For the present life table demography study of the species, zooplankton samples were collected from Cochin backwaters during the Southwest Monsoon of 2013. During the field sampling, *L. australis* population was found in the entire stretch of the Cochin backwaters and their contribution was found to be 5-7 % of the total zooplankton density. The samples collected were divided into two parts; one was used for species identification purposes while the other was used up for developing cultures and experimental work. For maintaining the cultures, part of the zooplankton samples were

initially stored in large containers with ~ 20 litre water, and were then sequentially filtered through meshes of varying mesh sizes, without exerting considerable stress to the organism.

Waters for developing the cultures were collected using Niskin samplers, and the salinity was measured by a Eutech multi-parameter tester (Model PCD650). The taxonomic identification of the cladocerans was carried out by an Olympus inverted microscope equipped with image analysis system (Fig. 3). The species confirmation was done in consultation with Dr. Korovschinsky, A.N. Severtsov Institute of Ecology and Evolution of the Russian Academy of Sciences, Leninsky, Moscow, Russian Federation, Russia, a world authority on the cladocera family Sididae to which *L. australis* belongs.

Culture of *L. australis*

Single parthenogenetic female was introduced into 120ml containers with GF/C filtered and autoclaved estuarine water. The organisms were fed every 24 hours with mixed algae of *Isochrysis*, *Nanochloropsis* and *Chlorella* with a concentration of 10^5 - 10^6 cells/ml. The culture medium was changed once in every two days to avoid contamination. 25 replicates were maintained for each experiment to get the first (F1) generation. Neonates from each experimental vial were removed and maintained in separate vials for the second (F2) generation. Likewise, the culture of *L. australis* was established and maintained successfully in the lab for several generations.

Maintenance of Stock Culture

The stock culture of *L. australis* was maintained in 20 litre fiberglass tank at different salinities (freshwater to 10 salinity) and these salinity levels were same as those observed in the Cochin backwaters from where the experimental animals were collected. Similarly, the temperature in the culture room was maintained at 28°C, which was comparable to the natural environment when the specimen was collected. The photoperiod was controlled at 12:12 light and dark cycles with the light intensity of ~1500 Lux. The cultured animals were fed with a diet of mixed algae at a density of 10^5 to 10^6 cells /ml. The water media in the culture tanks was changed every 6 days, and the species density was restricted to 250- 500 individuals in the stock culture to avoid the population crash due to overcrowding.

Lethal Concentration (LC 50) at Different Salinities (Halotolerance Experiment)

Prior to the life table demography experiments, basic experiments were carried out to determine the salinity tolerance limits of *L. australis*. Fifteen individuals from each stock culture (maintained at salinity levels 0, 2, 5, 8 and 10) were introduced into 150 ml vials to test against 12 different salinity

levels from freshwater (0) to 22 (0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20 and 22 salinity). Triplicates were maintained for each treatment. The desired salinity in the experiment vials was prepared by dilution of GF/C filtered and autoclaved sea water with the desired volume of distilled water. The bottles were maintained in 12h: 12h light and dark cycle for 48 - 72 hours. The vials were fed with the same mixed algae that had been used for maintaining the stock culture. The counts of mortality in each bottle during different time intervals were taken and recorded. The total survivorship was determined from the percentage mortality. Critical Salinity Maximum (CSMax), the salinity at which all individuals were died at a specific time interval, was also recorded. The 48 median lethal salinity of LC50 values were analysed using the Trimmed Spearman-Kärber Method 1.5 (Knillman et al. 2012). It shows that the LC 50 at 96 hours was at salinity 14. The CSMax was found to be salinity 20. Based on these, salinity experiments for the life table demography parameters were prepared from freshwater to salinity 14 with a difference of 2 units.

Life table demography of *L. australis* in different salinities

The effect of salinity on the life table demography of *L. australis* was studied under laboratory conditions. Prior to the experiment, 2 to 5 parthenogenetic females were picked from the stock culture and introduced into 150ml jars at different salinities in with 12:12hrs light and dark cycle and fed with mixed algae at a density of 10^3 - 10^6 cells/litre. The second or third generation neonates from the acclimated individuals were used for the life table demography experiments.

Eight different salinity treatments were used (0, 2, 4, 6, 8, 10, 12 and 14) in the experiments. In each treatment bottle, 15 individuals were inoculated and maintained under 12:12 hours dark and light cycle in room temperature. Triplicates were maintained for each salinity level. The experimental medium was renewed once in every three days from the commencement of the experiments. The experimental animals were fed with mixed algae culture with a final density of 10^5 to 10^6 cells/ml (Nandini and Sarma 2000). The mortality, fecundity and the size of the animals were recorded from the day of birth to the last day of their survival. The body length (mm) was measured daily using an eyepiece micrometer attached to a stereomicroscope. Any neonates during the study period were enumerated and then removed from the treatment and maintained in separate vials.

Population parameters considered in the present study include Age Specific Survivorship (l_x), Age Specific Fecundity (m_x), Net Reproduction Rate (R_0), Generation Time (GT), and Intrinsic Growth Rate. These parameters were estimated following (Krebs 1985) as follows:

$$\text{Gross reproductive rate} = \sum_0^{\infty} m_x$$

$$R_0 = \sum_{x=0}^N l_x \cdot m_x$$

Where x is the age class (0, 1, 2, 3.....N)

l_x is the proportions of survivorship per day

m_x is the number of offspring produced per female per day.

$$GT = \frac{\sum_{x=0}^N (l_x \cdot m_x) \cdot x}{R_0}$$

The intrinsic growth rate (r) was calculated using the Euler –Loka equation (Krebs 1985)

$$\sum_{x=0}^N e^{-rx} (l_x \cdot m_x) = 1$$

Where r is the intrinsic growth rate (day^{-1})

As r is a population parameter, the estimation of variations was generated using the Jack- Knife methods (Meyer et al. 1986).

Statistical Analysis

In order to understand the effect of salinity on the life table demographic parameters of *L. australis* under different salinity treatments, the data sets were initially tested for their normality in the distribution. Later, parametric analysis of variance (ANOVA) was carried out on normally distributed data. The Tukey's HSD post hoc test was used to compare the significance of pairwise variations obtained in parametric ANOVA. On the other hand, non-parametric ANOVA was used for non-normal data. In this case, Dunn's post hoc test was used to analyze the significance of pairwise differences. The tests of normality, parametric and non-parametric ANOVA were carried out in XL stat pro-software package. Pearson correlation analysis was performed to find the effect of salinity on the life table parameters of *L. australis*. Cluster/SIMPROF analysis was used to segregate the salinity treatments into different clusters based on their similarity to the life table demography parameters. The salinity levels within the cluster exhibited similar property on the life table

demography parameters, whereas their segregation from the other clusters showed the dissimilarity. SIMPROF analysis was performed to find the significance on the segregation of the salinity levels.

Results

Key Taxonomic Characteristics of *L. australis*

The key taxonomic characters of *L. australis* have been described by Sars(1888);Birge(1892); Richard(1895); Korovchinsky(1983and 1992). The key characteristics of the species are presented in Fig. 2based onKorovchinsky(1983and1992).

Life cycle of *L. australis*

The parthenogenetic life cycle of *L. australis* was observed to be completed in 4 - 6 days and the various stages in the life cycle have been showed in Fig. 4. Different identification features of life stages are as follows. Stage 1 - parthogenetic egg ellipsoidal in shape and covered by an elastic membrane completely filled with yolk granules. Stage 2 –the cover membrane disappeared, the second antenna started developing, and the thorax region differentiated. Stage 3 - the embryo elongated, the second antenna is fully formed, and the first antenna starts to elongate. At this stage, thoracic segments were visible and sometimes as rudiments. Stage 4-embryos were similar to the adults with thoracic appendages, carapaceand eyesfully developed. Stage 5 - developed appendages. Stage 6 - inactive digestive system and clutches of parthogenetic eggs, Stage 7 - digestive systems activated and body size increased, Stage 8 - The parthogenetic egg developed from the egg clutches.

Effect of Salinity on Life Table Demography of *L. australis*

Age-Specific Survivorship (lx)

The proportion of individuals that survived in each age group of *L. australis* maintained in different salinities showed a significant negative relationship with salinity (Table 1; ANOVA, $F = 5.2$, $P < 0.05$). Based on the influence of salinity on the age-specific survivorship pattern, the experimental salinities were grouped into two - one ranged from freshwater to 8 salinity and the other from salinity 10 to 14. The survivorship values of *L. australis* were comparable within each salinity group, whereas it was noticeably different from the other salinity ranges (Table 2). In other words, the age-specific survivorship was significantly high in low saline ranges (0 - 8 salinity) and consistently low in higher salinity ranges (12 - 14 salinity) (Fig. 5a and 5b). 100% mortality of *L. australis* was found on the 23rd day of the experiment at salinity 10, on the 17th day at salinity 12 and on the 15th day at salinity 14.

Age-Specific Fecundity (mx)

The average number of offspring produced by an individual at age x is termed as Age-Specific Fecundity. Salinity showed significant influence on the offspring production / age-specific fecundity of *L. australis* (Table 3; ANOVA, $F = 8.76$, $p < 0.05$). The population showed unimodal fecundity pattern, but Age-Specific Fecundity values significantly varied between different treatments (Fig. 6a and 6b). The life time fecundity was significantly lower in high saline ranges than in low saline ranges. In the low saline experimental conditions, three reproductive peaks were found, whereas in high saline conditions only one (12 and 14 salinity) or two (10 salinity) were found. During the later phase of the experiment, before the species attained 100 % mortality, the fecundity decreased and reached the lowest on the 25th day in salinity 10, 15th day in salinity 12 and 11th day in salinity 14.

Age-Specific Life expectancy (e^x)

Mean expectancy of life of individuals at the start of the experiment and after interval x is termed as age-specific life expectancy. Salinity showed significant influence on age-specific life expectancy values (Table 4; ANOVA, $F = 13.26$, $p < 0.01$). Age-specific life expectancy was noticeably higher in lower salinity ranges (0-8) compared to the higher salinities (10 - 14) (Fig. 7a and 7b) and followed the pattern of the age-specific survivorship pattern.

Net Reproduction Rate

Average number of offspring produced by an individual in a population during its lifetime is called as Net Reproduction Rate. The reproduction rate of *L. australis* ranged from 0.393 to 9 with the highest at salinity 2 (9) and the lowest at salinity 14 (0.393). In general, salinity showed a negative influence on the net reproduction rate of *L. australis* (Table 2). The net reproduction rate of the species decreased with increasing salinity; however, in freshwater, the net reproduction rate was lower than that in salinity 2 and 4 (Fig 8a).

Generation Time (days)

This represents the time from the laying of an egg to the time the individual reaches sexual maturity. Generation time of *L. australis* varied from 5.2 to 16.7 days and was negatively correlated with salinity (Fig. 8b). The generation time was shorter in freshwater conditions than high saline conditions. However, the generation time at salinity 2 was found to be comparatively less than that in salinity 4. However, the generation time of the species was found to be three-fold lesser in freshwater as compared to salinity 14.

Intrinsic Growth Rate (r)

The rate at which the population increases over a period of time is called intrinsic growth rate. High intrinsic growth rate in a population indicates favourable conditions. Intrinsic growth rate of *L. australis* ranged from 0.18 to 0.21 with the highest in salinity 2 followed by 4 and 6 (Fig.8c). The lowest intrinsic growth rate was at salinity 14. In general, salinity showed an inverse relationship with growth rate. Even though the growth rate of the species was slightly lower in freshwater conditions compared to salinity 2, 4 and 6, a well-marked reduction in growth rate was evident at higher salinities (10 – 14).

Gross Reproduction Rate (GRR)

The total number of offspring produced by an organism in the absence of mortality is termed as gross reproductive rate. Salinity showed significant inverse relationship with the gross reproductive rate of *L. australis* (Fig.8d). The gross reproductive rate ranged from 1 to 16.98 offspring/ female. The highest Gross Reproduction Rate was in freshwater and the lowest in high saline conditions. The Gross Reproductive Rate was more than 10-folds high at low saline conditions.

Discussion

Effective survival in saline waters demands appropriate physiological mechanisms to counterbalance the higher ionic concentrations present outside their body (Willmer et al. 2000). Without such adaptive mechanisms, organisms become osmoconformers and eventually get eliminated by external salinities beyond their tolerance level. Cladocerans are generally considered as osmoconformers, but they are capable of tolerating a certain level of salinities especially in estuarine systems (Mohammad and Agard 2007). Earlier studies in the Cochin backwaters showed that the seasonal drop in salinity caused by the monsoonal rainfall and associated runoff act as the major factors controlling the distribution and abundance of bacterioplankton, nanoplankton, and micro- and meso - zooplankton (Jyothibabu et al. 2006; Madhu et al. 2007).

In general, cladoceran family Sididae members grow slowly compared to the other related families. In higher salinities, family Sididae members show failure in the osmoregulatory mechanism that causes a significant reduction in their growth rate (Acuthankutty et al. 2000). During the present study, *L. australis* showed negative growth rates in salinities 12 and 14. Literature shows such negative growth rate of *L. australis* elsewhere where unsuitable food was present. The present observation evidenced that unsuitable salinity levels can potentially lead to a significant reduction in the growth rate as well as fecundity of *L. australis* in natural environments. In the present experimental study, it was clear that the growth rate and fecundity of *L. australis* were significantly

low in higher salinities. This is the chief cause for the disappearance of *L. australis* from the high saline regions of the Cochin backwaters during the non - monsoon periods.

It was evident that survivorship of *L. australis* was high in lower salinity as compared to higher salinity. In the present study, *L. australis* encountered 100% mortality above salinity levels of 20, within 24 hours of incubation. However, the species showed salinity tolerance and reproduction up to salinity levels of 14. The occurrence of the Sididae members have been reported in different salinity ranges (Negrea 1982). In general, the Sididae members occur in the hypohaline waters (salinity limit 13 -15). The salinity tolerance limit of *L. australis* found in the present study is in agreement with other members of Sididae. The survivorship of *L. australis* was found to be the highest in lower salinity (0- 8), and any further increase in salinity negatively impacted their survivorship.

The age-specific life expectancy depends basically on the survival rate of the organisms. The increasing salinity caused a significant reduction in the survivorship, which in turn decreased the life expectancy. Similar kinds of observation on the survivorship and life expectancy were found earlier in another cladocera member, *Branchionus variabilis* (Sarma and Nandini 2001). For *Branchionus variabilis*, the age-specific life expectancy range was from 6-8 when they were grown in favorable conditions, being considerably lower under unfavorable conditions. Similarly, in the present study, the highest life expectancy of *L. australis* was found in lower salinity ranges, and the life expectancy was less in higher salinities. The reported values of life expectancy from the present study were comparable with the values reported earlier for *Branchionus variabilis* (Sarma and Nandini 2001).

Reproduction is a major physiological activity in any organism, and is influenced by the prevailing environmental conditions (Vernberg and Vernberg 1972). Very little information is available on the reproductive characteristics of the members of the Sididae family in the tropical and temperate waters (Korovchinsky 1992). In the present study, the highest growth rate of *L. australis* was found when salinity levels were 2, 4 and 6, which was lower than that of the members of the families Daphniidae and Pontellidae (Chaparro Herrera et al. 2010). However, the ranges of net production rate reported in the present study (0.5 -9) was comparable with that of *Branchionus variabilis* (Sarma and Nandini 2001). The optimum salinity for high net reproduction rate of *L. Australis* was salinity 2 and 4, which was higher than the optimum salinity value reported for *Branchionus variabilis*.

Conclusion

This study showed that salinity has a significant negative effect on the life table demographic characteristics of *L. australis*. Experiments showed that lower salinity levels of up to 8 were favorable for the survivorship, life expectancy, net production, and growth rate of the species. Salinity above 8 was found to be unfavourable for the growth of *L. australis* and such salinity conditions caused decreased survivorship, life expectancy and reproduction. The above result clearly explains the natural distribution pattern of *L. australis* in the Cochin backwaters during the Southwest Monsoon and Non- Southwest Monsoon periods. The study also revealed that salinity level of 2 to 6 were optimum for the large-scale production of *L. australis* for applications such as live feed in aquaculture.

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Conflict of Interest:

The authors declare that they have no conflict of interest.

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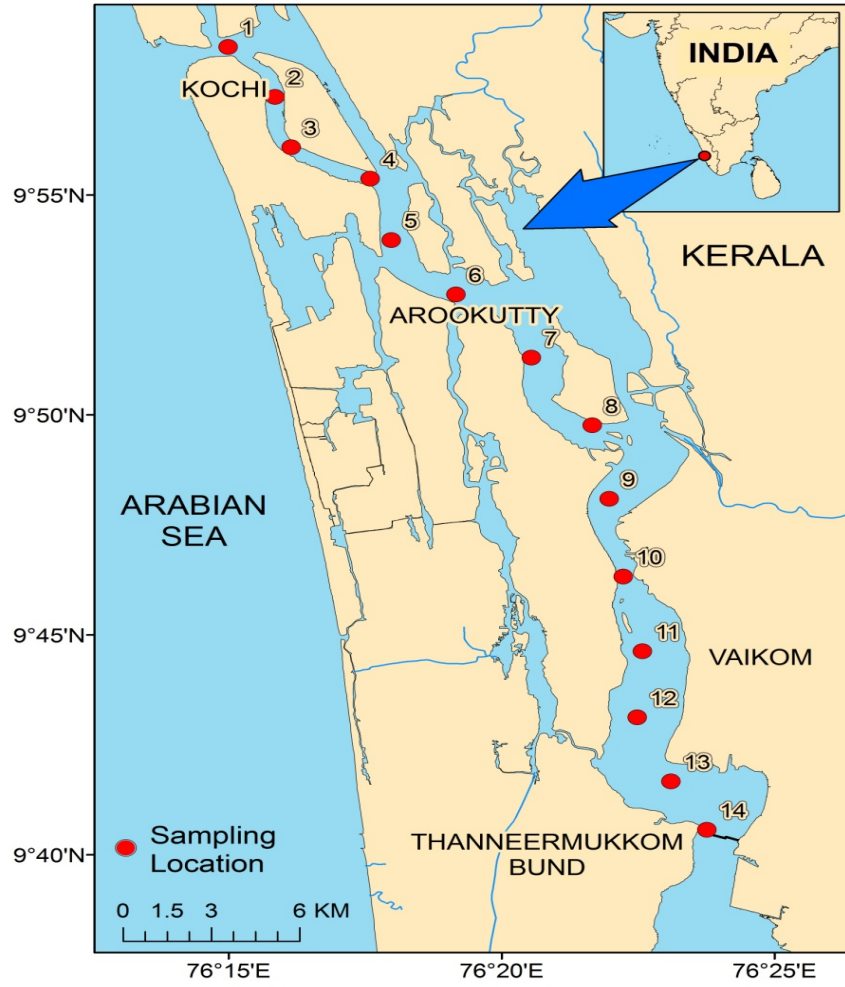


Fig. 1 Sampling locations in the Cochin backwaters

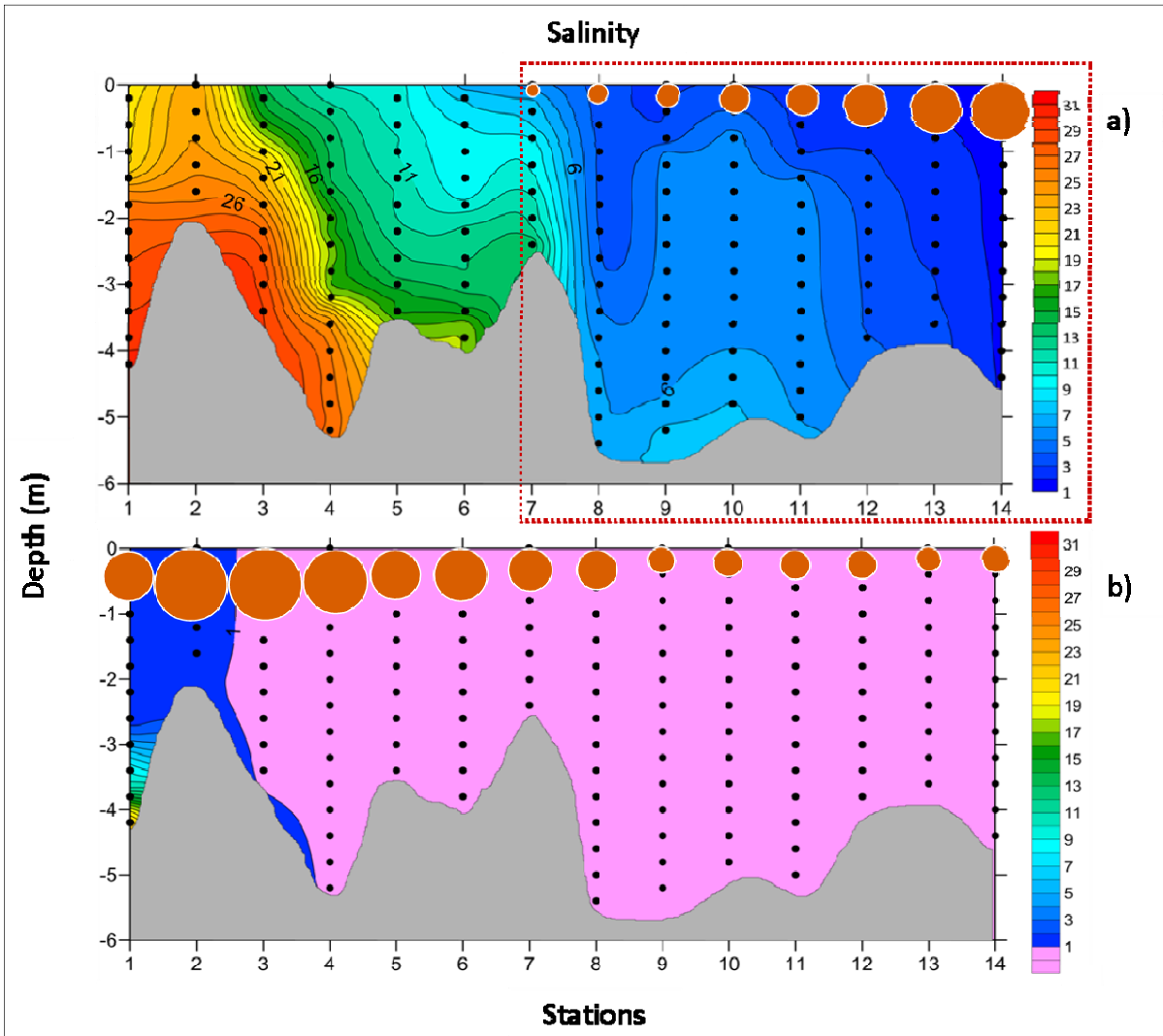


Fig. 2 Salinity vertical distributions in the Cochin backwaters during the (a) Pre- Southwest Monsoon and (b) Southwest Monsoon. The occurrence and habitat limits of *Latonopsis australis* are indicated as brown bubbles. The species was found in the low saline region of the Cochin backwaters during the Pre-Southwest Monsoon and in the entire stretch during the Southwest Monsoon. The size of the brown bubbles indicate the proportionate abundance of *Latonopsis australis* in zooplankton samples and the highest size was 110 individuals/m³ and the lowest 20 individuals/m³. Black smaller vertical dots indicate the CTD data points for salinity measurements.

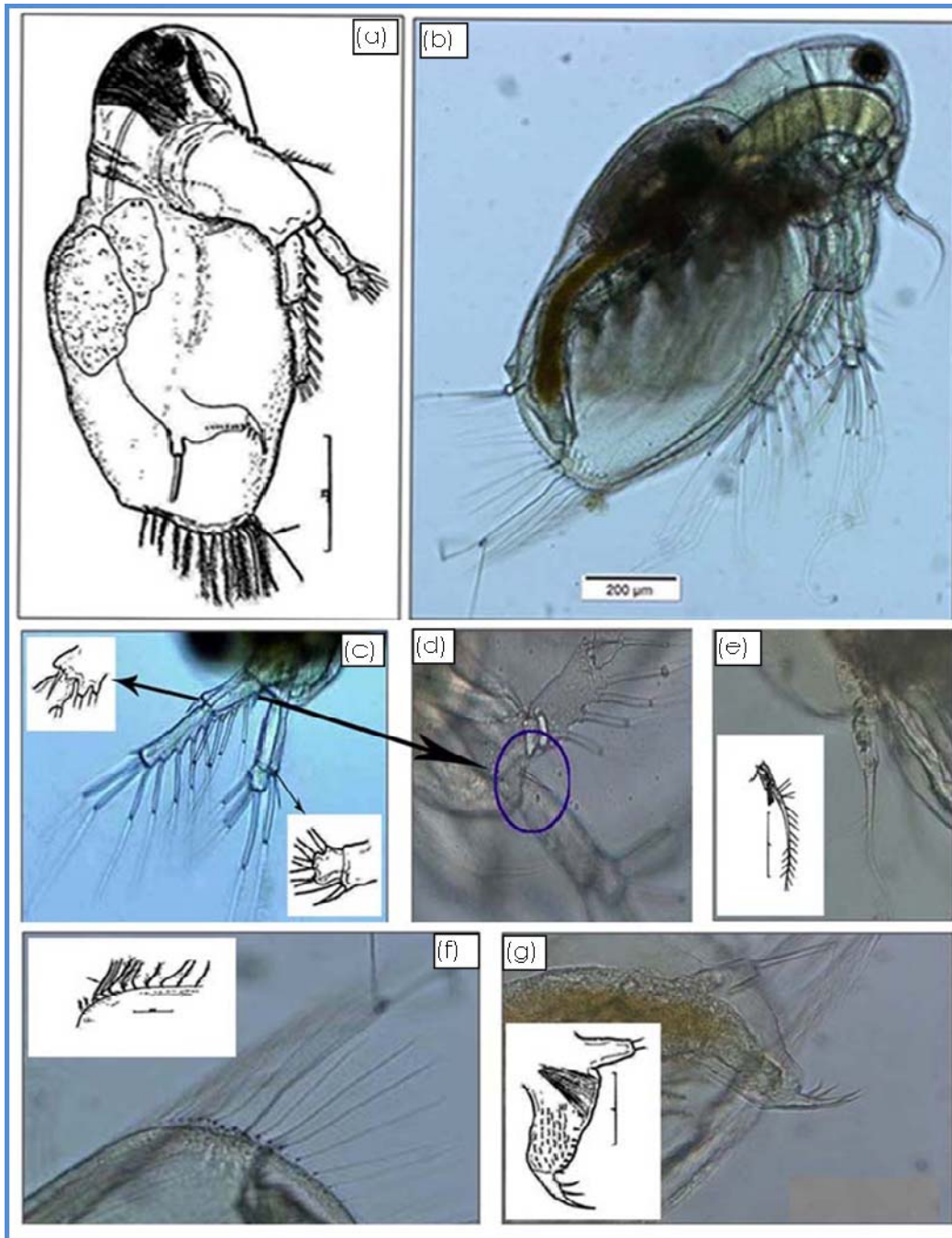


Fig. 3 Key morphological characters of *Latonopsis australis*, (a) and (b) are lateral views of whole animal, (c) and (d) are distal parts of the first segment of the upper two antennal branch; (e) antennules, (f) anterior margin of the valve and (g) enlarged view of post abdomen.

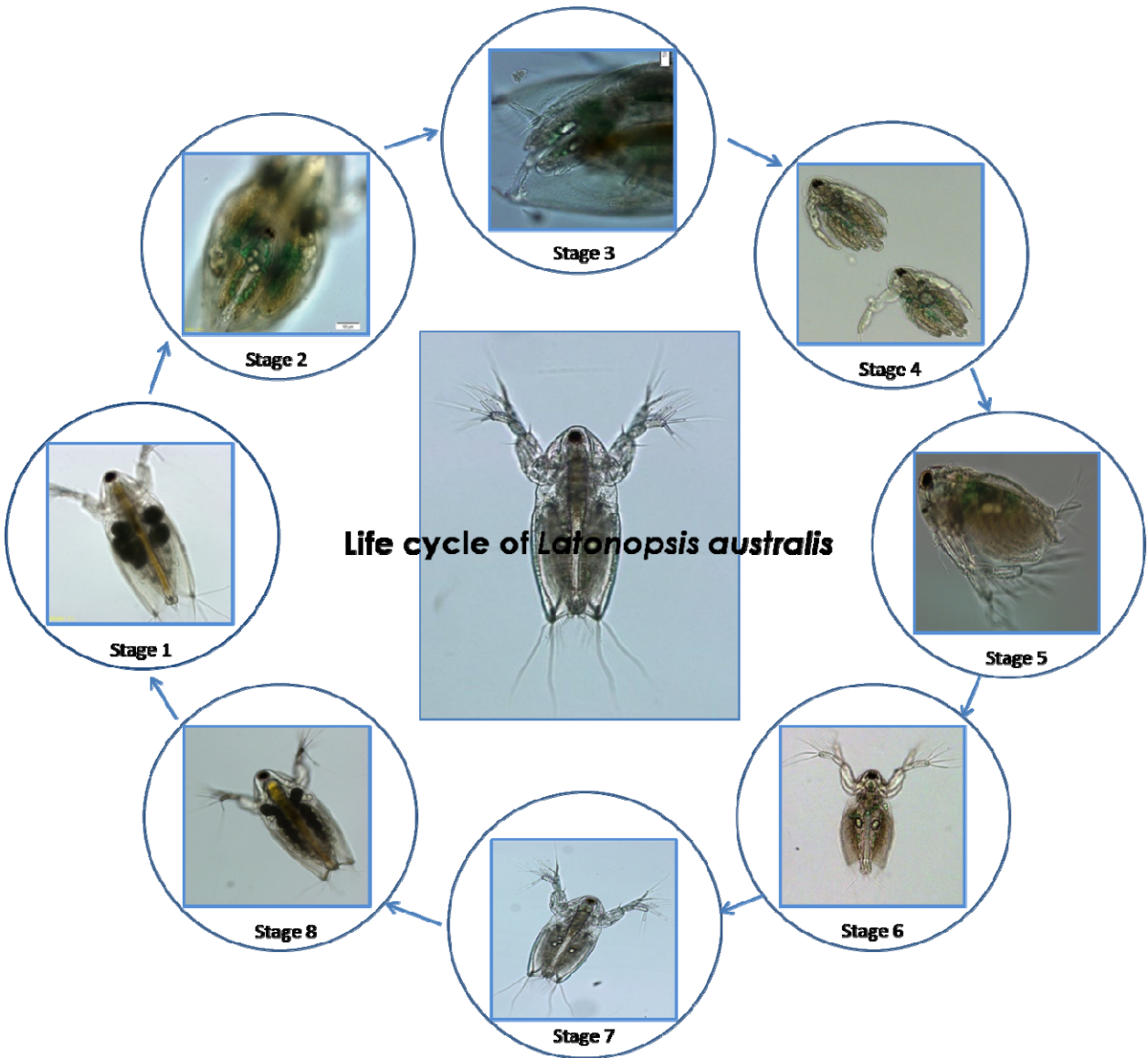


Fig. 4 The life cycle stages of *Latonopsis australis*

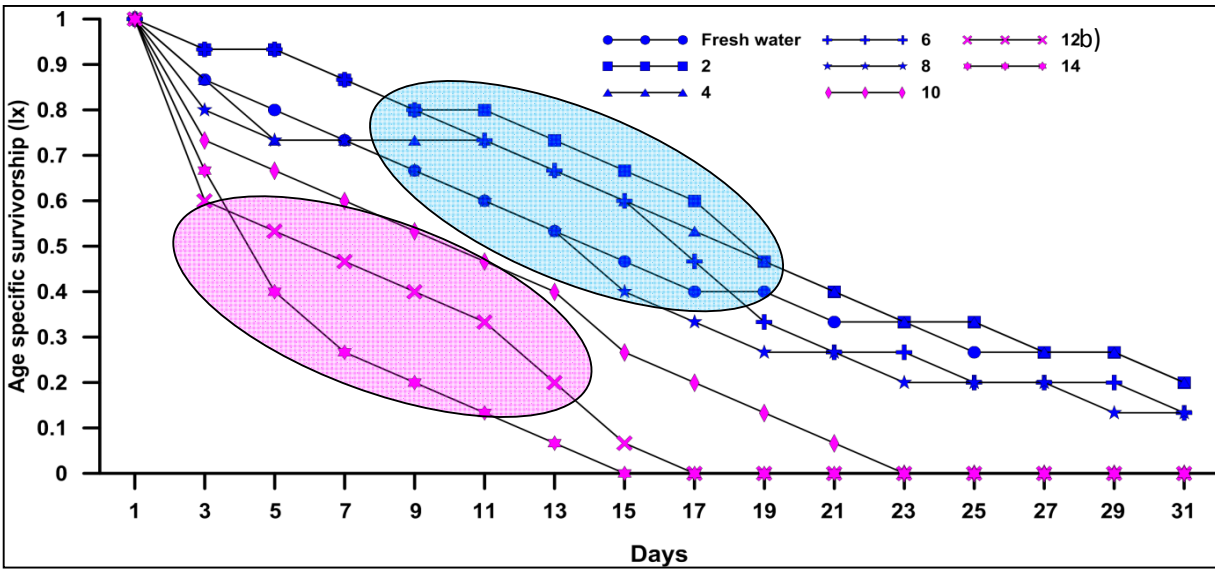
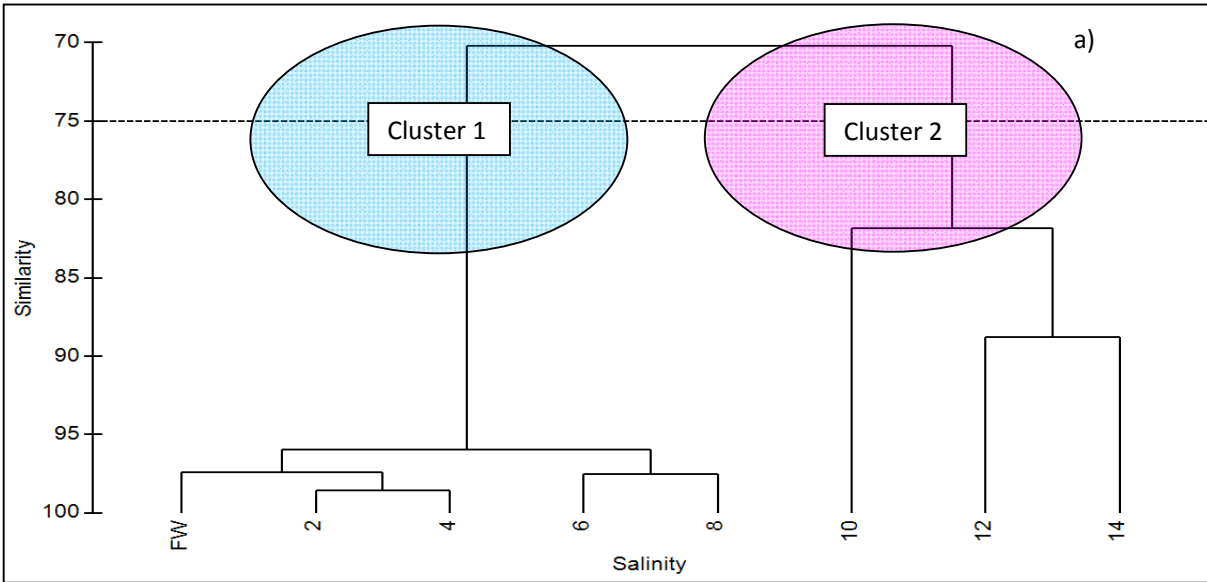


Fig. 5(a) Group average cluster dendrogram based on 31days observations of age specific survivorship of *Latonopsis australis* in different salinity treatments. Cluster analysis delineated the salinity conditions into two clusters, cluster (1) includes freshwater to 8 and cluster (2) salinity above 8. The age specific survivorship of the *Latonopsis australis* in different salinity treatments is shown as (b). Significant features are highlighted in colored oval shapes.

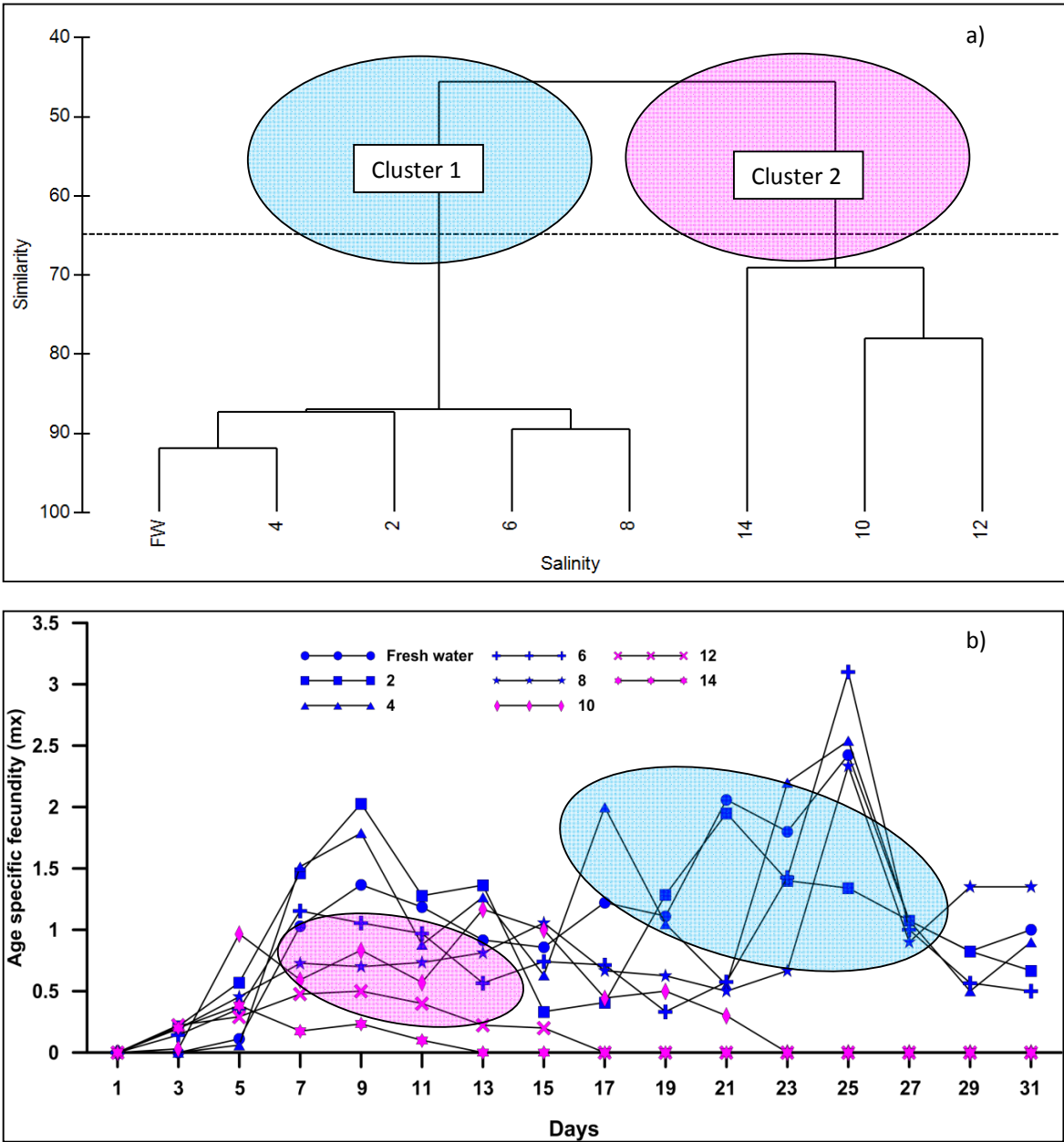


Fig. 6 (a) Group average cluster dendrogram based on 31 days observations of the age specific fecundity of *Latonopsis australis* in different salinity treatments. Cluster analysis delineated the salinity conditions into two clusters, cluster (1) includes freshwater to 8 and cluster (2) salinity above 8. b) The age specific fecundity of the *Latonopsis australis* in different salinity treatments. Significant features are highlighted in coloured oval shapes.

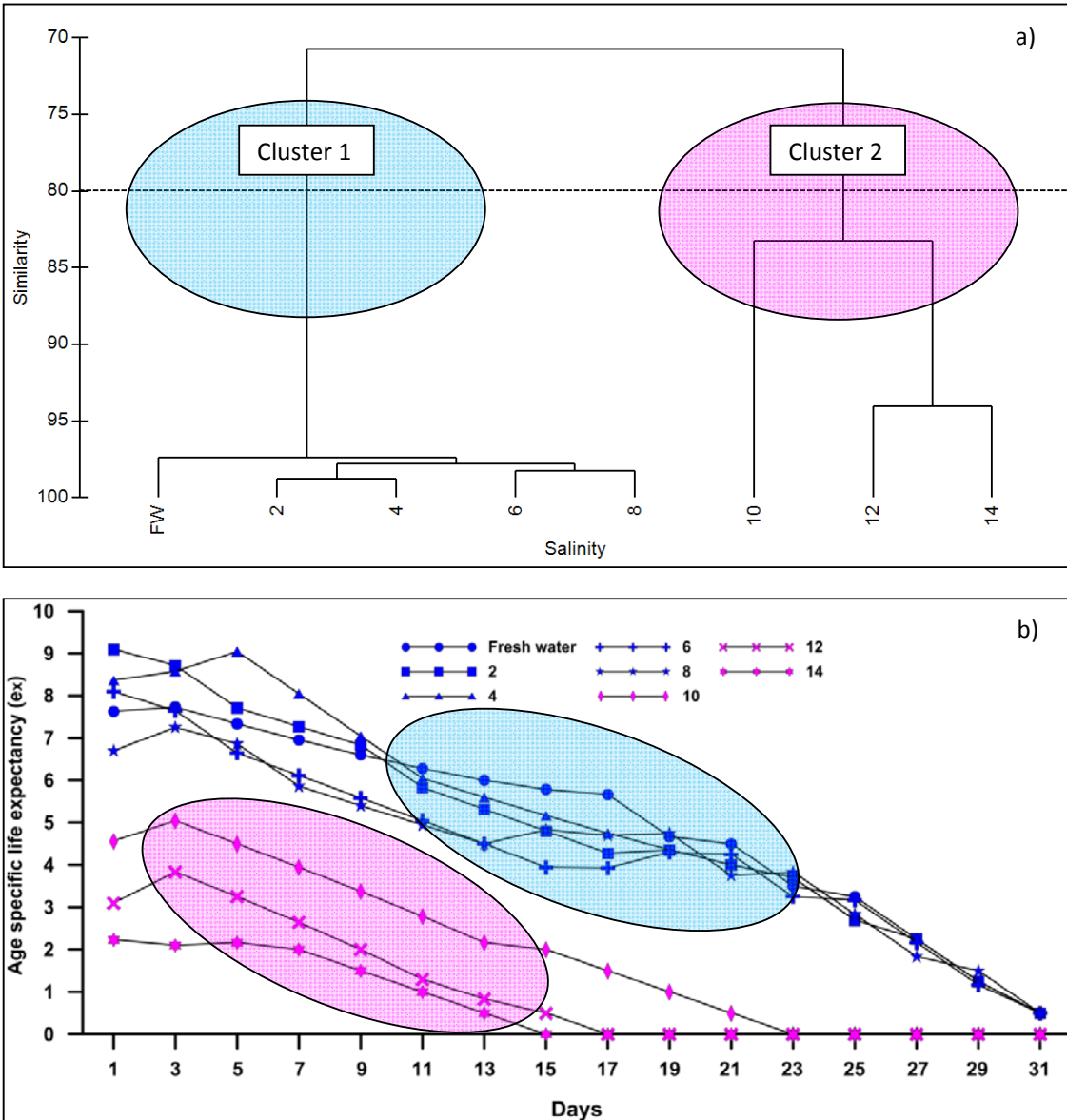


Fig. 7(a) Group average cluster dendrogram based on 31 days observations of age specific life expectancy of *Latonopsis australis* in different salinity treatments. Cluster analysis delineated the salinity conditions into two clusters, cluster (1) represents freshwater to 8 salinity and cluster (2) salinity above 8, (b) the age specific life expectancy of *Latonopsis australis* in different salinity treatments. Significant features are highlighted in coloured oval shapes.

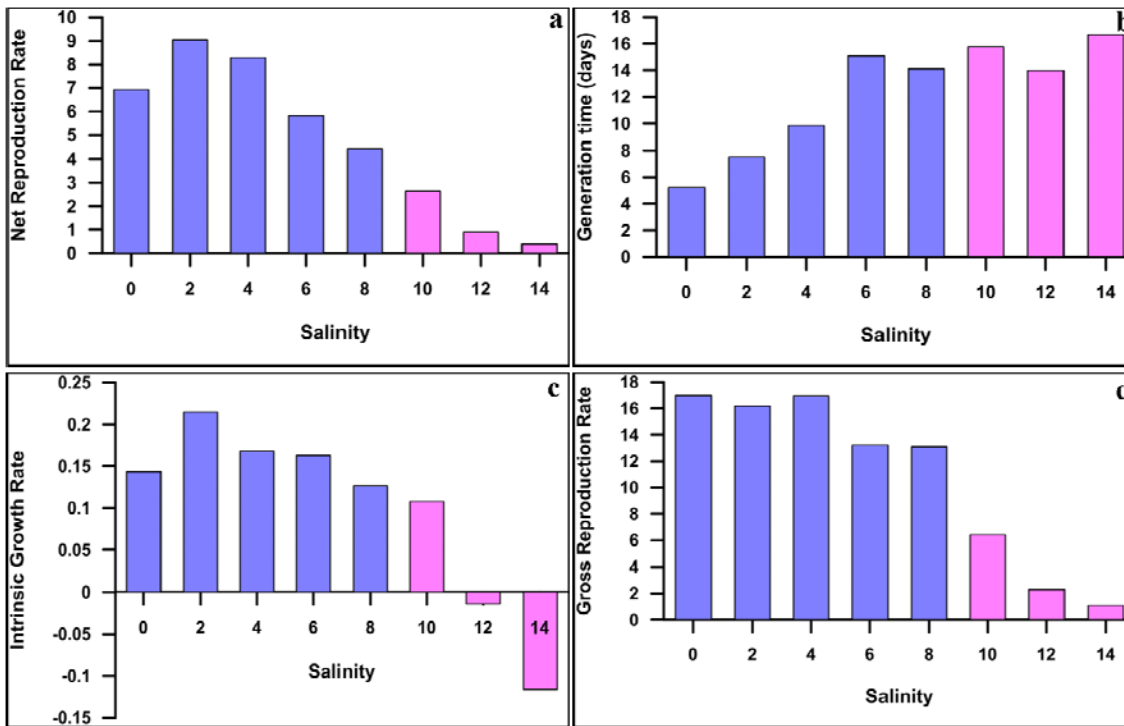


Fig. 8 (a) Net production rate, (b) Generation time, (c) Growth rates, (d) Gross reproduction rates of *Latonopsis australis* in different salinities. Blue bars represent lower salinity (< 8) and pink bars higher salinity (> 8)

Table 1 Tukeys HSD Pair wise comparison for age specific survivorship (lx) LX in different salinity treatments. Bold values indicates at significance level at $p < 0.05$.

Salinity	F. water	2	4	6	8	10	12	14
F. water	1							
2	0.984	1						
4	0.965	0.968	1					
6	0.968	0.998	0.984	1				
8	0.949	0.809	0.968	0.988	1			
10	0.046	0.099	0.037	0.048	0.049	1		
12	0.099	0.007	0.029	0.046	0.034	0.984	1	
14	0.022	0.001	0.005	0.009	0.011	0.830	0.999	1

Table 2 The interrelationship between the life table demography parameters and salinity. Pearson correlation co- efficient (r) and their significance.

Variables	Vs.	Salinity	Significance value
Net reproduction		-0.933	$p < 0.001$
Generation time		-0.896	$p < 0.001$
Intrinsic growth		-0.823	$p < 0.001$
Gross production		-0.943	$p < 0.001$

Table 3 Tukeys HSD Pair wise comparison for age specific fecundity (mx) in different salinity treatments. Bold values indicates at significance level at $p < 0.05$.

Salinity	F. water	2	4	6	8	10	12	14
F. water	1							
2	0.968	1						
4	0.967	0.947	1					
6	0.929	0.980	0.932	1				
8	0.915	0.974	0.919	0.968	1			
10	0.022	0.045	0.022	0.045	0.405	1		
12	<0.0001	0.001	0.000	0.016	0.018	0.895	1	
14	<0.0001	0.000	<0.0001	0.004	0.005	0.691	0.921	1

Table 4 Tukeys HSD Pair wise comparison for age specific life expectancy (e^x) in different salinity treatments. Bold values indicates at significance level at $p < 0.01$.

Salinity	F. water	2	4	6	8	10	12	14
F. water	1							
2	0.912	1						
4	0.897	0.810	1					
6	0.408	0.473	0.339	1				
8	0.396	0.460	0.328	0.983	1			
10	<0.0001	<0.0001	<0.0001	0.001	0.001	1		
12	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.230	1	
14	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.188	0.607	1