PLANKTON STUDIES IN A MANGROVE ENVIRONMENT. V. SALINITY TOLERANCES OF SOME PLANKTONIC CRUSTACEANS

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SYNOPSIS

The salinity tolerances of adult females of some relevant species of planktonic copepods were studies in a mangrove region of the estuarine type, at 25° south latitude. Results showed a wide range in the salinity tolerances for the adult females of all the species studied. Based on these experiments the following order of salinity tolerance can be proposed:

Pseudodiaptomus acutus > *Euterpina acutifrons* > *Acartia lilljeborgi* > *Oithona ovalis* > *Centropages furcatus* > *Temora stylifera.*

A mechanism for the maintenance of *Pseudodiaptomus acutus* at certain regions of the area studied is proposed, based on experimental and field results.

It seems probable, thus that salinity is an important factor in the distribution of some members of the zooplankton in this region.

INTRODUCTION

The studies of salinity tolerances of estuarine and coastal planktonic organisms can bring some useful information to support further investigations on their distribution, life history and responses to environmental changes.

Salinity variations are a significant factor in determining the spatial distribution and seasonal succession of estuarine plankton, and also the extent to which organisms from adjacent coastal waters can enter the estuaries (Ketchum, 1954; Jeffries, 1962 a, b; Gunter, 1961).

Investigations on the effect of changes in salinity in the survival of planktonic animals, and non planktonic free-living copepods, were carried out by some authors in temperate waters — Marshall *et al.* (1935), Barnes (1953), Ranade (1957), Barnett (1959) and Lance (1962; 1964) but little information has been provided in this respect for tropical waters. The data available are restricted to some species of marine zooplankton off the Caribbean and South Atlantic — Hopper (1960) or on distribution studies based on fixed samples and salinity determination — Vannucci (1957), Björnberg (1963), Teixeira *et al.* (1962, 1965).

The investigations reported here were carried out in a mangrove region of the estuarine type at 25° south latitude, Brazil (see sketch).

Published data and recent results demonstrated that the zooplankton was composed mainly by copepods and their larval stages — Teixeira & Kutner, (1962), Teixeira *et al.* (1965, 1967 in preparation). Also in view of the data available it was suggested that the changes and the gradient in salinity might be an important factor, affecting distribution of different planktonic species in this region. Therefore an attempt has been made to compare the extent to which some of the most important members of the zooplankton can withstand changes in salinity and how this ability checks with the distribution of some of the species studied.

MATERIAL AND METHODS

The plankton for the experimental procedure was collected with conic nets (pore size 189 to 250 μ) in the channel of the mangrove region, or in coastal waters. After the capture the animals were brought immediately to the laboratory and quickly sorted out in subdued light. Experiments commenced within approximately one hour after sampling.

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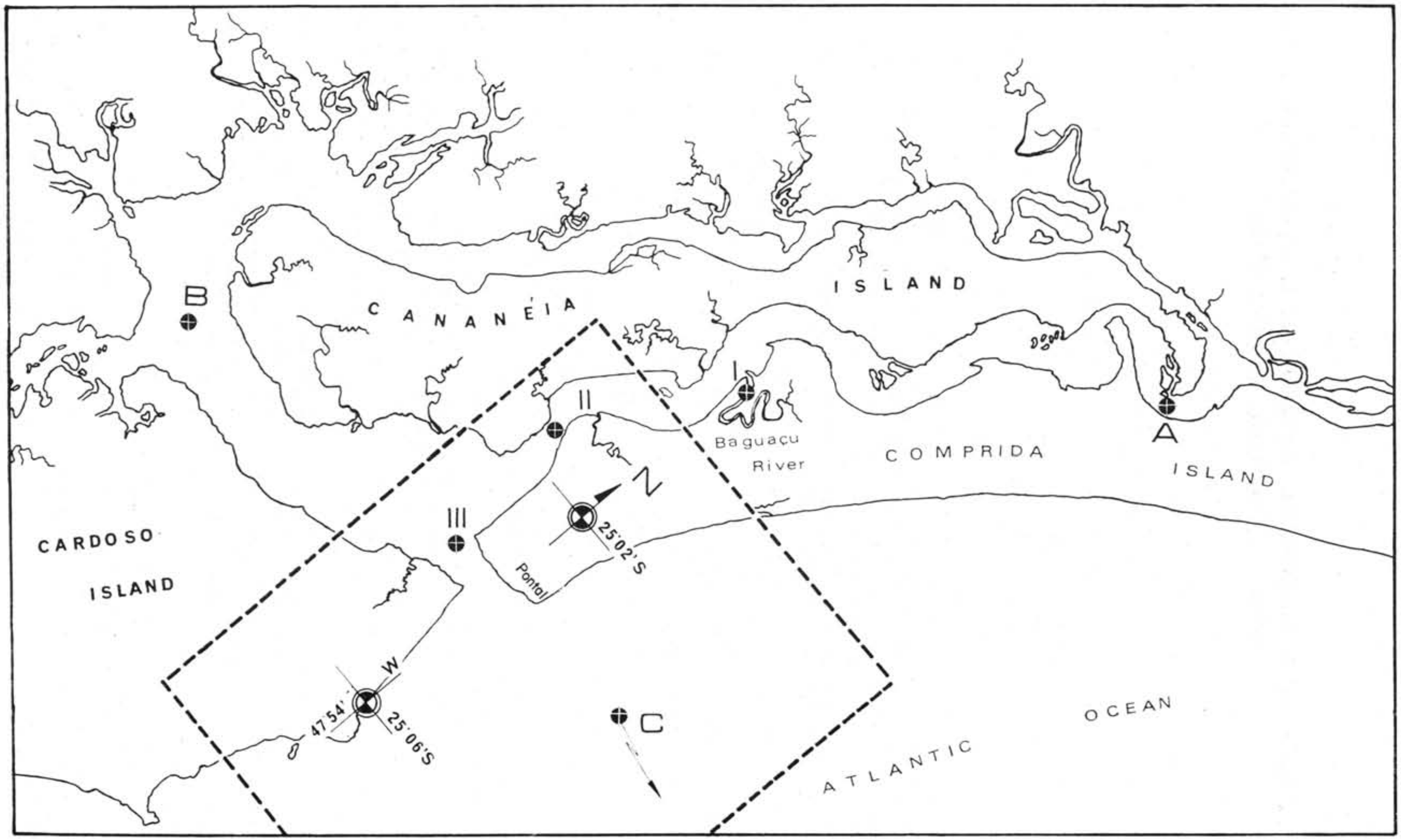

Fig. 1 — Sketch of the lagunar region at Cananéia showing: I, II, III stations where salinity variation was studied during six hours. A, B, C, and I, II, III, stations where collection for distribution studies were made. Station C, is located about 6 miles from the coast.

Previous work in coastal and shelf waters — BJÖRNBERG (1963) and in the mangrove region — TEIXEIRA *et al.* (1965) provided a background for the study on distribution. Sampling was made with an 8 litre bottle at this time in inshore waters. Since the zooplankton in these waters is composed mainly by small copepods, this method was adequated, once selectivity for these smaller forms, can be neglected (HANSEN & ANDERSON, 1962).

Species Studied

Six species of copepods were studied: *Pseudodiaptomus acutus, Euterpina acutifrons, Temora stylifera, Oithona ovalis, Centropages furcatus, Acartia lilljeborgi.* In addition a decapod larva Zoea) which occur in abundance during some times of the year was also studied.

All experiments were performed mainly with adult females of the species studied.

Experimental

1 — Water of salinity of $30^0/_{00}$ was considered as 100% sea-water. Previous results (TEIXEIRA *et al.*, 1965; KATO, 1966) demonstrated that sea-water of this salinity is more frequent in the entrance of the estuary than water of higher salinity. Therefore the extent to which this water was diluted was considered to be as the gradient that the zooplankton has to support in inshore waters. Recent surveys (TUNDISI & MATSUMURA, 1967, unpublished results) confirmed this point.

The sea water was filtered through Whatmann n.° 1 filter paper to remove larger suspended material and zooplankton.

Dilution was done by adding distilled water to this filtered sea water. Table I shows the range of dilution used, as well as the corresponding salinities. The value of 100% corresponds to the smaller dilution (i.e. sea water of $30^0/_{00}$ salinity). Thus 5% corresponds to the highest dilution (i.e. sea water + distilided water of salinity $1.6^0/_{00}$).

2 — An average of fifty animals of the same species was placed in beckers with 200 ml of the experimental water.

According to KINNE (1963) the temperature can shift, broader or narrow the tolerances to salinity. Consideration of a single factor in isolation from all others could therefore provide evidence of limited significance. Thus all the experiments were conducted in the dark, at a temperature close to that recorded in the field at the time of sampling (within ± 1°C) in a G.E. incubator. No food was added nor the experimental vessels had any supply of oxygen.

Some tests were done to check a possible influence of the use of distilled water instead of fresh water. Multiple runs with single species using distilled water and fresh water were set up and gave no significant differences. Thus only dilution with distilled water was used throughout.

Controls were set up with animals of the same species of the experiment in 200 ml of filtered water, collected at the time the tow was made. The survival of the animals in the control experiments was good. The results for the controls were compared with the results for experimental salinities, and percentage survival calculated according to LANCE (1962, 1964). The salinities which caused the death of one half of the original number were considered to be as lethal salinities (LD = 50). Results are based on duplicate experiments for all species studied. No significant differences were found in simultaneous runs.

Experiments lasted for six hours since the main purpose was to compare the survival during half a tidal cycle.

3 — *Acclimatization Experiments*

These short-term experiments were carried out with adult females of *Acartia lilljeborgi.* Since this species penetrates into inshore waters it can be useful to compare its ability to acclimatize to lower salinities during six hours. Thus the survival of animals which had been transferred directly to diluted water was compared to the survival of those gradually transferred to lower dilutions.

For each dilution the same batch of animals was left during half an hour and transferred subsequently to the lower dilution.

4 — *Salinity Variation*

The variation of salinity at three stations studied was measured every half hour at surface and at 5 m, by sampling with a Nansen bottle during six hours. All salinity determinations were carried out by titration according to the method of HARVEY (1955) with an accuracy of 0.05.

TABLE I — Salinities and correspondent dilutions used for experiments

Dilution (%)	100	90	80	70	60	50	40	30	20	10	5
Salinity (°/₀₀)	30.0	27.0	23.8	20.9	17.8	15.1	13.2	8.8	6.3	3.1	1.6

RESULTS

a — *General*

For each species studied survival in 100% sea water and in the range of dilutions imposed at 25 ± 1°C varied widely.

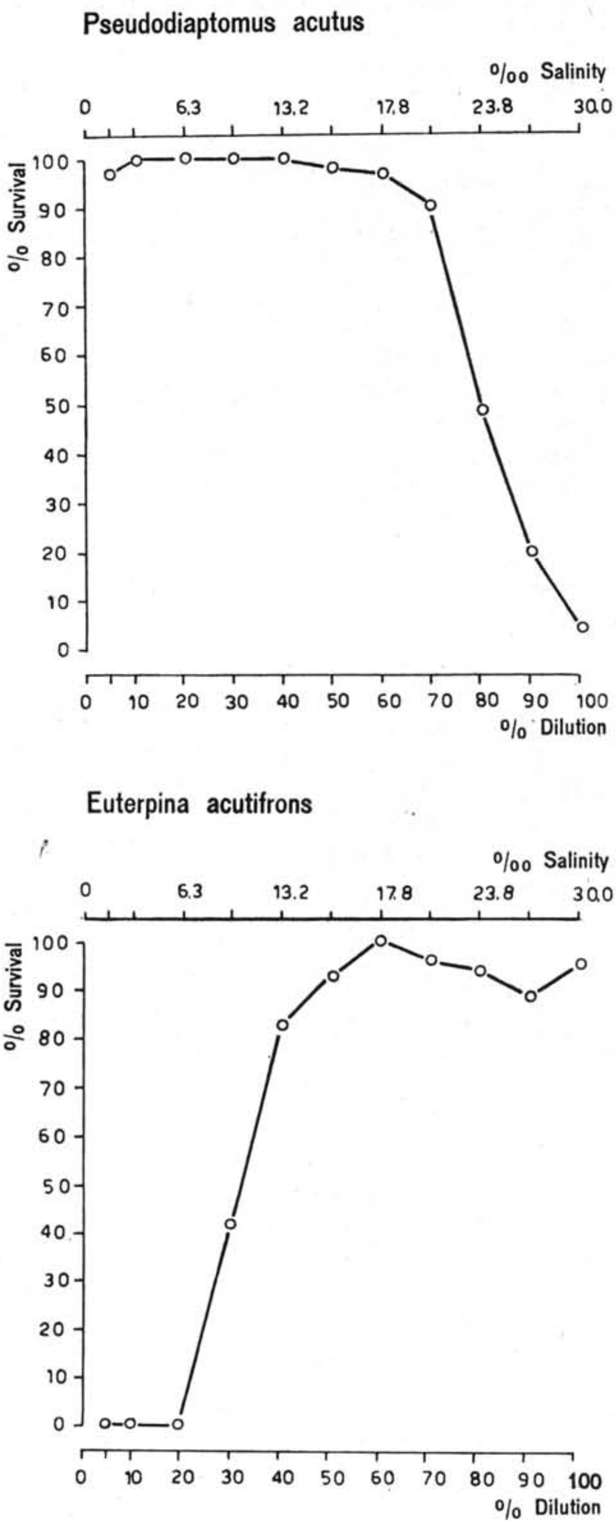

Fig. 2 — Salinity tolerances of *Pseudodiaptomus acutus* and *Euterpina acutifrons*.

Pseudodiaptomus acutus showed a high degree of tolerance to a wide range of dilutions. Only at the upper limit of the range (100 — 80% sea water) this species has its lethal salinity.

For all the other species a marked decrease in survival at salinities at the lower end of the range was observed.

Lethal salinity for *Euterpina acutifrons* was the corresponding to 30% dilution (salinity 8.8°/oo).

Oithona ovalis has its lethal salinities corresponding to 20% dilution (i.e. 6.3 salinity), and 90 — 100% (salinity 26.0°/oo — 30.0°/oo).

Acartia lilljeborgi can withstand dilutions from 100 — 40%; no mortality occurred at this corresponding salinities. Lethal salinity was the corresponding to 30% dilution.

Centropages furcatus is less tolerant to higher dilutions. For this species lethal salinity was at the corresponding to 40% dilution (i.e. salinity 13.2°/oo).

Temora stylifera has its lethal salinity at 50% dilution. However for this species mortality occurred from the dilution of 90% downwards (salinity 26.0°/oo).

These results thus show that *Acartia lilljeborgi* can withstand higher dilutions than *Centropages furcatus* and *Temora stylifera*.

Decapod larvae showed a high degree of tolerance, no mortality occurring in the whole range that it was submited.

Variation in the salinity tolerances for each species studied is demonstrated at Figures 2 to 5.

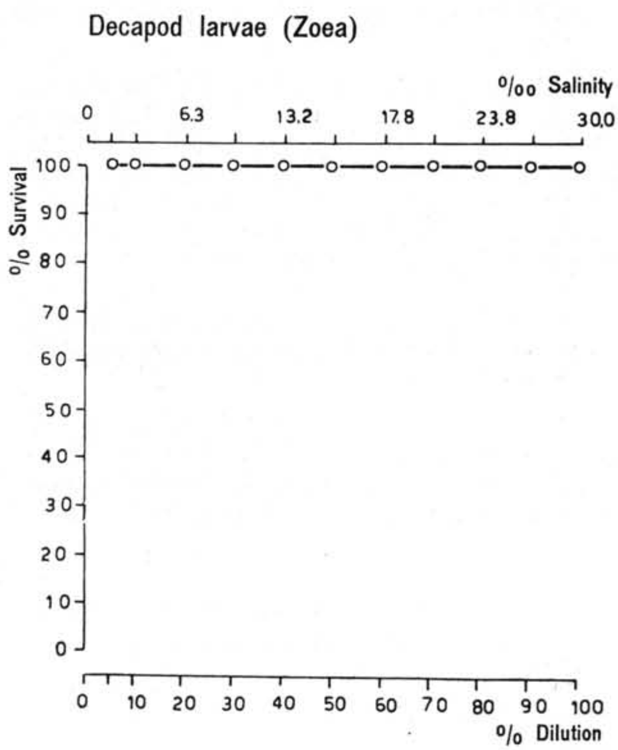

Fig. 3 — Salinity tolerance of a decapod larvae (Zoea).

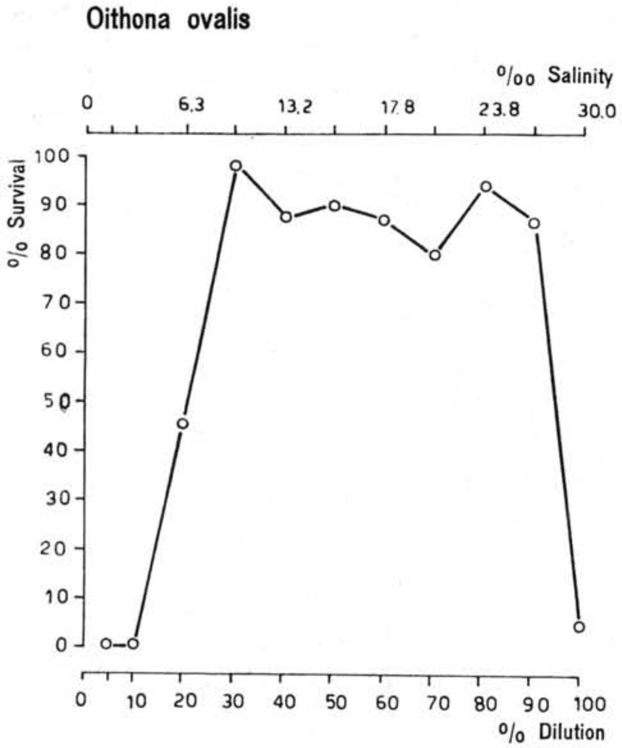

Fig. 4 — Salinity tolerance of *Oithona ovalis*.

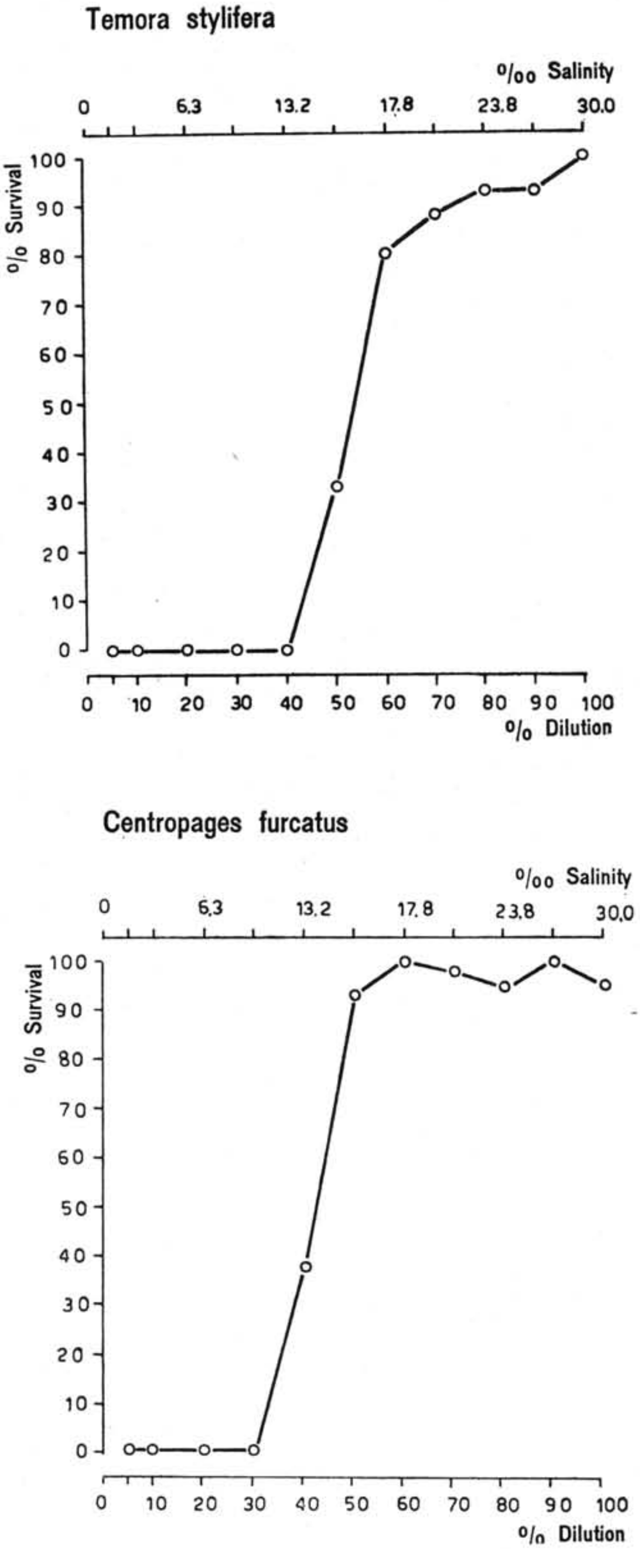

Fig. 5 — Salinity tolerances of *Temora stylifera* and *Centropages furcatus*.

b — *Salinity Acclimatization*

When *A. lilljeborgi* is acclimatized to higher dilutions the range of lethal salinities decrease from 30% — 0% dilution to 10% — 0% dilution. Figure 6 shows the differences in survival for acclimatized and non acclimatized *Acartia*.

Table II summarizes the range of lethal salinities at 25 ± 1°C for the adult females of all species studied and also for the decapod larvae.

Table III shows the range of salinity variation during six hours at the three stations studied at surface and at 5 m depth.

Based on these results and earlier data the following order of salinity tolerances can be proposed for the adults females of the species studied:

Pseudodiaptomus acutus > *Euterpina acutifrons* > > *Acartia lilljeborgi* > *Oithona ovalis* > *Centropages furcatus* > *Temora stylifera*.

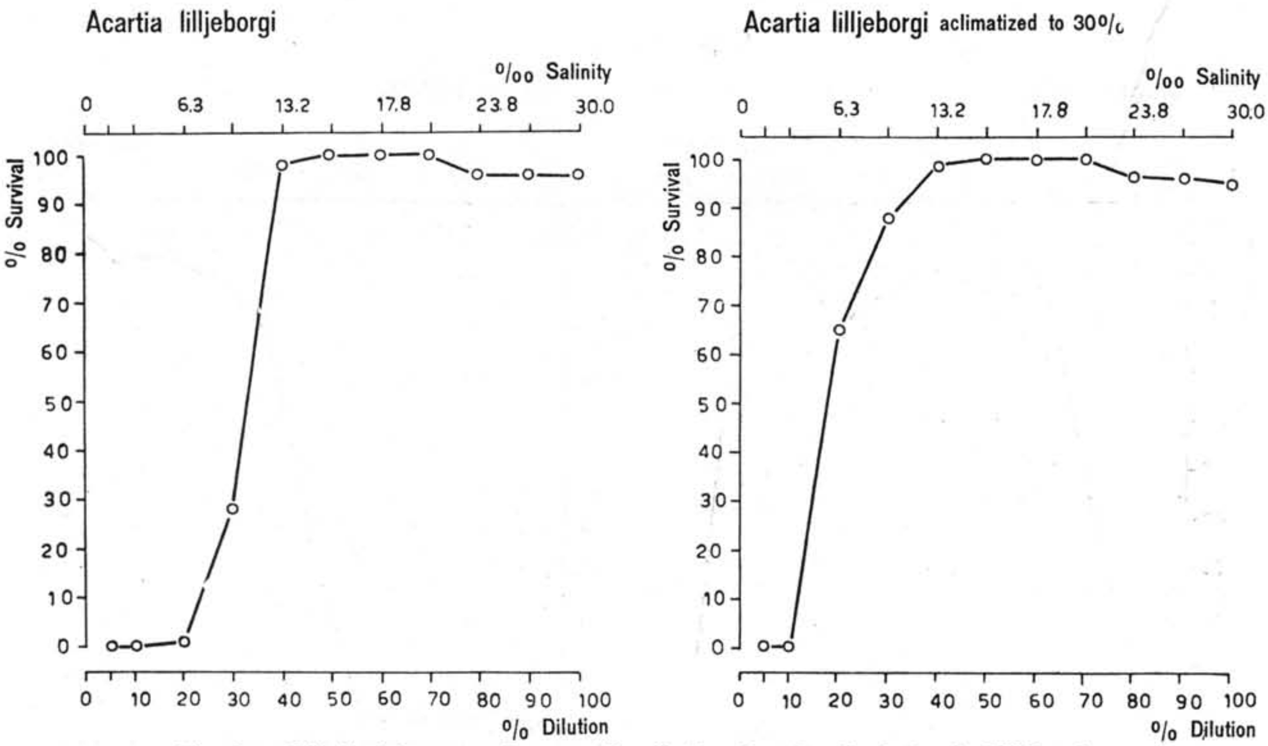

Fig. 6 — Salinity tolerances of non acclimatized and acclimatized *Acartia lilljeborgi.*

TABLE II — The lethal salinities, mortality, field and experimental temperature, for the species studied

SPECIES	STAGES	Lethal salinity (°/₀₀)	Dilution (%)	Range of salinity/dilution causing mortality		Field temperature °C (*)
Pseudodiaptomus acutus	adult females	23.8	80	20.9 — 30.0°/₀₀	70% — 100%	26.2
Temora stylifera	mainly adult females	15.1	50	1.6 — 20.9°/₀₀	5% — 70%	26.8
Centropages furcatus	adult females	13.1	40	1.6 — 13.2°/₀₀	5% — 40%	26.6
Euterpina acutifrons	adult females	8.8	30	1.6 — 13.2°/₀₀	5% — 40%	26.0
Acartia lilljeborgi	adult females	8.8	30	1.6 — 8.8°/₀₀	5% — 30%	26.4
Oithona ovalis	adult females	6.3 30	20 100	1.6 — 6.3°/₀₀ 30°/₀₀	5% — 20% 100%	26.2
Decapod Larvae	Zoea	—	—	—	—	26.2

(*) Experimental temperature: 25 ± 1°C.

TABLE III — Magnitude of salinity change, and maximum rate of salinity change per hour at three stations

STATION	DEPTH (m)	Magnitude of salinity change during 6 hours	Maximum rate of salinity change/h
I Baguassú River	0	7.43°/oo — 20.65°/oo	3.13°/oo
	5	7.97°/oo — 21.8°/oo	3.01°/oo
II Argolão	0	17.07°/oo — 28.43°/oo	2.14°/oo
	5	18.84°/oo — 31.43°/oo	6.85°/oo
III Trincheira	0	18.60°/oo — 31.85°/oo	4.71°/oo
	5	24.61°/oo — 32.23°/oo	2.30°/oo

TABLE IV — *Station I — Baguassu River* — The percentage of species, according to depth and tide, the corresponding salinities and light penetration, at station I

SPECIES	Species (%)	Depth (m)	Salinity (°/oo)	Tide	10% level light penetration
Pseudodiaptomus acutus	94.6	0	7.43	Low	0.70 m
Acartia lilljeborgi	5.4				
Oithona ovalis	—				
Pseudodiaptomus acutus	98.2	3.0	7.84		
Acartia lilljeborgi	0.9				
Oithona ovalis	0.9				
Pseudodiaptomus acutus	7.6	0	20.65	High	1.30 m
Acartia lilljeborgi	88.6				
Oithona ovalis	3.3				
Pseudodiaptomus acutus	82.2	3.0	21.81		
Acartia lilljeborgi	15.4				
Oithona ovalis	0.4				

DISCUSSION

These short-term experiments are of interest in this type of environment once short exposure to diluted of full strengh sea water (i.e. water of salinity 30°/oo in this case) are of considerable importance in the survival of the different species.

The effect of variation of salinity on the metabolism of the species studied can influence their survival as demonstrated by Lance (1964) for some species of *Acartia* and Ranade (1957) for *Tigriopus fulvus.*

Although the results for laboratory experiments cannot be compared directly with the field studies, as Bassindale (1943) pointed out, a certain indication can be given if the known distribution of the species is checked with the experimental results.

Euterpina acutifrons is found in estuaries as well as in coastal waters but its greatest numbers were found in coastal waters — Björnberg (1963), Teixeira *et al.* (1965) from 14°/oo to 35°/oo.

Oithona ovalis is characteristic of inshore waters and not found in coastal waters. It was found at

Cananéia in great numbers — TEIXEIRA *et al.* (1965) in inshore waters.

SEWELL (1934) indicates that certain species of *Acartia* can migrate into brackish or fresh water. *Acartia lilljeborgi* is found in coastal waters, where it is sometimes the dominant copepod, but penetrates successfully in estuaries. Its ability to acclimatize to lower salinities probably helps on its sucess in inshore waters.

The two marine genera *Centropages* and *Temora* have euryhaline tendencies — BAYLY, 1965; JEFFRIES (1962) recorded these two genera in Raritan Bay at salinities of 21°/₀₀. The present results on salinity tolerance agree well with the known distribution for *Centropages furcatus* and *Temora stylifera*. They are typical of coastal or shelf water, being found in inshore waters only as astray visitors.

Pseudodiaptomus acutus is abundant in estuarine waters and according to BJÖRNBERG (1963), TEIXEIRA, TUNDISI & KUTNER (1965) is eurythermic and euryhaline. This species was found in greatest numbers in the inner parts of the lagoon where the average salinity is relatively low. KATO (1966).

Some experiments with *Pseudodiaptomus acutus* demonstrated that the animals collect at the bottom of a dish, away from the light when they are subjected to diffuse or direct light from above.

Sampling made at station I (Baguassu River) simultaneously with measurements on light penetration and salinity demonstrated that as salinity increases the greatest number of animals is found at depth (Table IV). An effect of temperature seems improbable, once a difference of not more than 2°C occurs in the water column, in this station.

Thus it seems probably that as the light conditions change with the tide this species migrates vertically to the deep layers and would drift alternately upstream and downstream. Therefore the combined effect of a negative response to light, and the tolerances to a wide range of salinities, would assist in the maintenance of this species at certain positions in the inner parts of the lagoon.

This type of mechanism was demonstrated by BARLOW (1955) for *A. tonsa* copepodids.

BOUSFIELD (1955) pointed out that in the Miramichee estuary the distribution of barnacles is influenced by seaward movements of mixed and salt water and the landward counter current associated with it and CRONIN, DAIBER & HULBERT (1962) have made also the same suggestion for the maintenance of certain planktonic animals in the Delaware River.

The present results give a reasonable indication of this probability.

These data would thus suggest that salinity is a limiting factor on the distribution and succession or some planktonic species in the inshore waters and in limiting the coastal species in their penetration in these waters. However, studies on the tolerances to salinity of the different stages of life history as well as studies on growth and reproduction would have to be made to confirm this probability; frequently salinity tolerance ranges of adults of a species differ considerably from those of larvae and this may limit or not species distribution.

Other factors might be of importance in the distribution of species in this area. Recent work (TEIXEIRA *et al.*, 1967; 1967 unpublished results) on the study of the distribution of different size fractions of the phytoplankton, demonstrated that in inshore waters the fraction smaller than 65 μ was responsible for an average of 61.0% of the total C-14 uptake.

Thus food selectivity by the herbivore zooplankton might be also of importance in its distribution in inshore waters.

RESUMO

A tolerância à salinidade e temperatura de seis espécies de copépodos planctônicos (fêmeas adultas) foi estudada na região lagunar de Cananéia, a 25° latitute sul.

Os resultados demonstraram que a tolerância à salinidade das espécies estudadas, apresenta grandes variações.

Com base nesses experimentos, a seguinte ordem de tolerância à salinidade (em temperatura próxima à do campo ± 1°C) pode ser dada para as espécies estudadas:

Pseudodiaptomus acutus > *Euterpina acutifrons* > *Acartia lilljeborgi* > *Oithona ovalis* > *Centropages furcatus* > *Temora stylifera*.

Um mecanismo para a manutenção de *Pseudodiaptomus acutus* em certas regiões da área estudada é proposto, baseado nas respostas à luz e diferentes salinidades.

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