Arch. Hydrobiol.	107	4	511–519	Stuttgart, Oktober 1986

The influence of salinity on the distribution of *Egeria densa* in the Valdivia river basin, Chile

By Enrique Hauenstein and Carlos Ramirez

With 5 figures and 3 tables in the text

Abstract

A study was made regarding the influence of salinity on the distribution of *Egeria densa* in the Valdivia river basin, Chile. Measurements were taken of the biomass of this species from locations of differing salinity within the range of its distribution in the Valdivia river. In the laboratory, the growth and photosynthetic rates of shoots kept in different saline concentrations were recorded. It was found that *Egeria densa* tolerates salinities up to 5 g/l, which grow naturally in the Valdivia river. In the laboratory, by contrast, it prospers in concentrations up to around 8 g/l. In concentrations up to around 1 g/l there is a clear stimulation of shoots growth; in greater concentrations a slight inhibition of photosynthesis, growth and adventitious roots production is noted.

Introduction

Factors different from those which affect terrestrial plants influence the distribution of aquatic macrophytes. Among the important factors are the type of substrate, depth and turbulence of the water, velocity of the current, and salinity (Spence, 1966; Hutchinson, 1975). The latter is important in estuarine environments and in salt marshes and lagoons. In reference to this, Jacobs (1982) indicated that the salt tolerance of plants is affected by factors such as photosynthetic strategy, the biological cycle (perennials develop better than annuals), and morphological characteristics (for example, the presence of glands which concentrate and eliminate salt).

Regarding the particular case of submerged aquatic macrophytes, Haller et al. (1974) indicate that salinity plays an important role in distribution. Three species of these submerged hydrophytes of the Hydrocharitaceae family occur in Chile: *Egeria densa* Planch., *Elodea canadensis* Michx. and *Elodea potamogeton* (Bert.) Espinosa, according to Ramirez et al. (1981), who also determinated the geographical distribution of these taxa in Chile.

The first of the species mentioned, *Egeria densa*, was studied by Hauenstein (1981), who determined its distribution in the hydrographic system of the Valdivia River, Tenth Region of the Lakes, Chile, also providing a theoretical model of the factors which limit or control its distribution. Among these, the salinity of the water may be the most important factor in the southwest sector of the basin, due to marine influence (Fig. 1).

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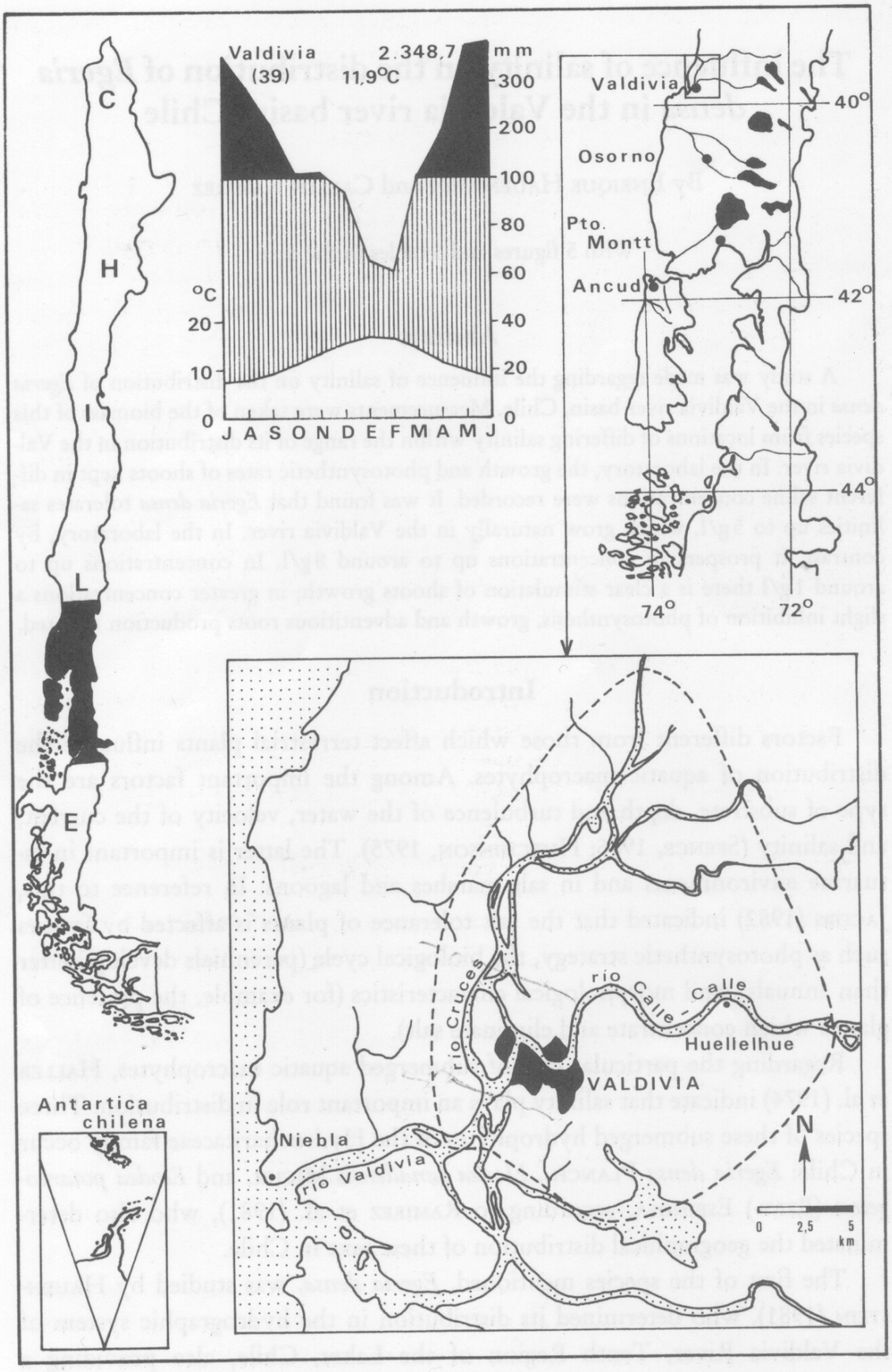

Fig. 1. Working site (Los Lagos, Xth Region, Chile); Valdivia's climatic diagram and area that occupies *Egeria densa* in the hydrographic system of Valdivia river (space circled by broken lines)..

The purpose of the present study is to determine the limits of salinity tolerated by the Valdivian populations of *Egeria densa* and the effect that this factor has on the growth and development of the plant.

Material and Methods

Measurements were taken of biomass of the plant in areas of varying salinity in the lower part of the course of the Valdivia River, Chile (33° 51′ S, 73° 15′ W). Samples were taken from each site with a can at 625 cm^2 opened on both sides which was buried in the mud, with three repetitions each. The plant material thus obtained (roots, stems and leaves), was introduced into polyethylene bags and transported to the laboratory, where it was later washed and dried in a stove at 105 °C to a constant weight. The biomass thus measured was expressed in grams of dry weight per unit surface area.

Under laboratory conditions, the growth in length of the shoots, production of roots and the photosynthetic rate in different saline concentrations were determined. For the experiments on growth, the method of Smith & Jones (1970) was used, and a culture system with 10 glass containers of 5 liters capacity, adding to each one 3 liters of seawater filtered and diluted with distilled water, according to the concentration required. The water was replaced weekly. Five previously washed and weighed pieces of *Egeria densa* were placed in each container, their apices intact. Their growth in length was measured weekly. The system was lit with 8 flourescent tubes of 40 watts, with a photoperiod of 12 : 12 hours for a six week period.

The photosynthetic rate of the shoots was determined according to the method described by Steubing & Kunze (1972), and the results were expressed in number of air bubbles produced per minute under the same light intensity but in varying saline concentrations. The salinity of the medium, both in the laboratory and in the field, was determined by use of salinometer YSI, model 33 SCT, expressed in grams per liter.

Results and Discussion

Analyzing Table 1 and Fig. 2, which show the relationship of salinity to biomass in the field, it is clear that when approaching to the sea and increasing

Table 1. Sampling sites in the hydrographical system of Valdiva river, pointing the water salinity and its distance from the sea together with the obtained biomass values.

Site	Distance from the sea (km)	Salinity (g/l)	Biomass (g/m^2)
Huellelhue	31	0.1	143
Calle-Calle bridge	19	0.2	546
Cau-Cau river	18	0.1	356
P. de Valdivia bridge	17	0.7	607
Las Mulatas	15	1.2	721
Mogol hill	12	2.5	228
Mota isle	11	5.0	15
Tres Bocas	6	11.0	0
Cutipay	5	7.2	0
Niebla	1	17.5	0

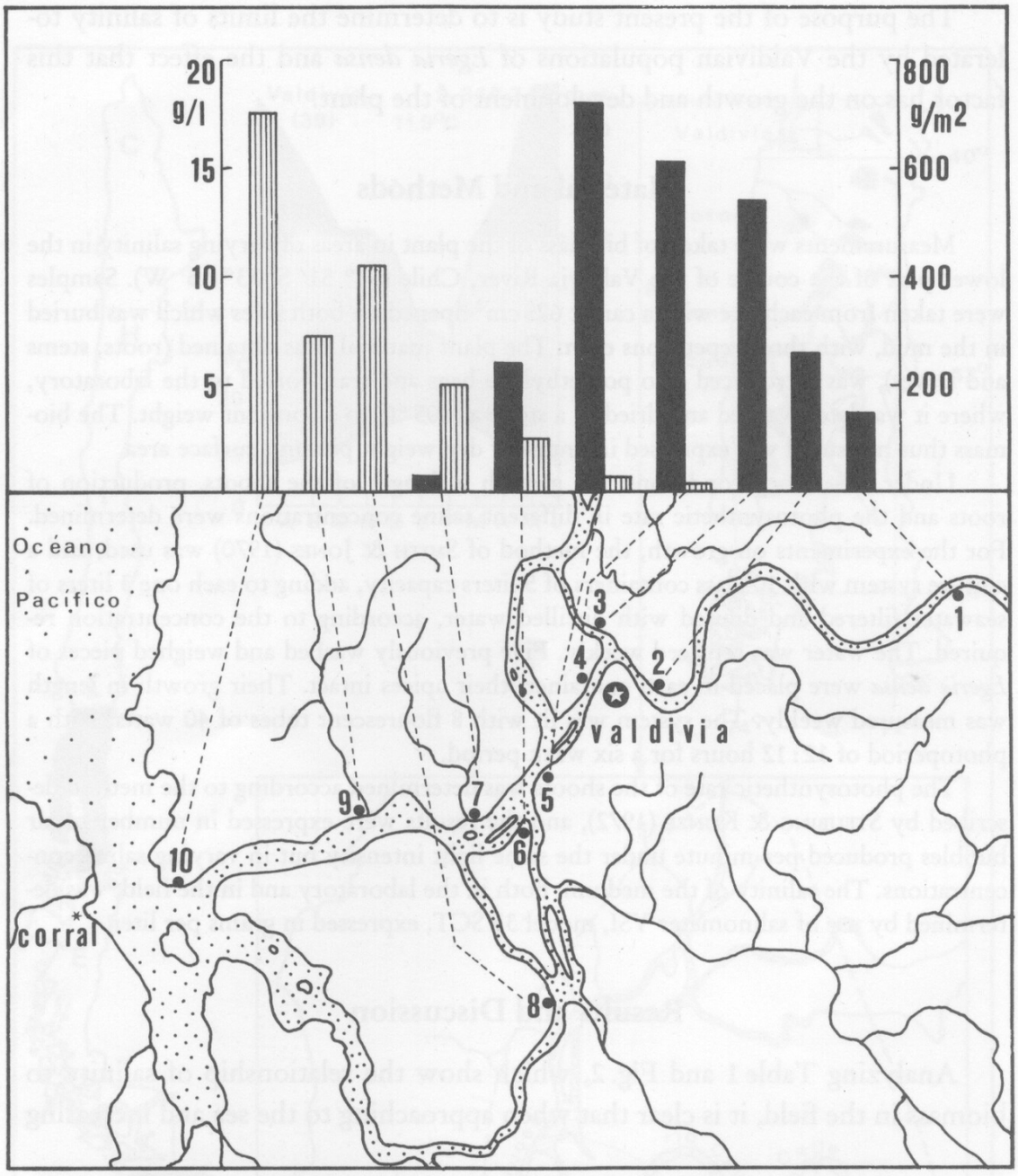

Fig. 2. Sampling sites: 1 = Huellelhue, 2 = Calle-Calle bridge, 3 = Cau-Cau river, 4 = Pedro de Valdivia bridge, 5 = Las Mulatas, 6 = Mongol Hilll, 7 = Mota isle, 8 = Tres Bocas, 9 = Cutipay, 10 = Niebla. Black bars mean biomass and stripped vertical bars indicate salinity.

the salinity, biomass also increases, up to a maximum in the Las Mulatas area which has 721 g/m² biomass and a salinity of 1.2 g/l. Further on, the biomass decreases drastically to a minimum of 15 g/m² in the Isla Mota area, where the salinity is 5 g/l. In areas closes to the ocean, with salinities over 7 g/l, *Egeria densa* does not prosper. However, its presence in the winter was reported in Niebla (Hauenstein, 1981).

The correlation index obtained between biomass and salinity of the medium was —0.67. *Egeria densa,* in natural conditions, tolerates a salinity of

up to 5 g/l, growing in limnic (<0.5 g/l) to mixo-oligohaline water (0.5 go 5 g/l), being able to tolerate greater salinity than other aquatic plants. *Callitriche palustris* L. shows positive growth in salinity up to 3 g/l (Mc Laughlin, 1974) and *Elodea canadensis* grow well in salinity up to 0.5 g/l (Hutchinson, 1975). According to Haller et al. (1974), the greatest salinity value for *Egeria densa* would be within the range of salinity considered toxic for the majority of submerged hydrophytes.

Likewise, the greatest dry weight obtained agrees with that reported by Gaudet (1974), insofar as the average biomass for the aquatic macrophytes in temperate zones is approximately 710 g/m^2. This mass is relatively low as compared with, for example, the biomass of helophytes (Ramirez & Añazco, 1982), which flourish under the same conditions.

The results of laboratory experiments agree in great measure with those found in the field, since upon analyzing Table 2 and 3 it is discovered that increasing the salinity of the medium, the plant progressively reduces its growth in length, and hence loses weight. The limit of salinity tolerated in the laboratory by the species under study was 8 g/l, under which there was practically no growth nor production of adventitious roots. In contrast, its greatest development was observed in concentrations of 2 g/l, which corresponds with

Table 2. Salinity effects upon the increase in length of *Egeria densa*. Time of the experiment: 6 weeks.

Salinity (g/l)	Growth (cm)				Weight Difference (g)
	Days: 14	28	35	42	
0	1.8	2.3	2.6	2.7	+2.6
2	4.0	4.9	5.0	5.1	+2.6
4	2.6	2.7	2.7	2.7	+1.6
6	0.8	0.9	1.0	1.0	+0.9
8	0.3	0.4	0.4	0.4	+0.8
10	–	–	–	–	–
12	–	–	–	–	–

Table 3. Salinity effects upon the increase of roots in *Egeria densa* (n=5).

Salinity (g/l)	Roots per plant ($\bar{x}$)
0	1.5
2	2.8
4	2.4
6	1.8
8	0.0
10	0.0
12	0.0

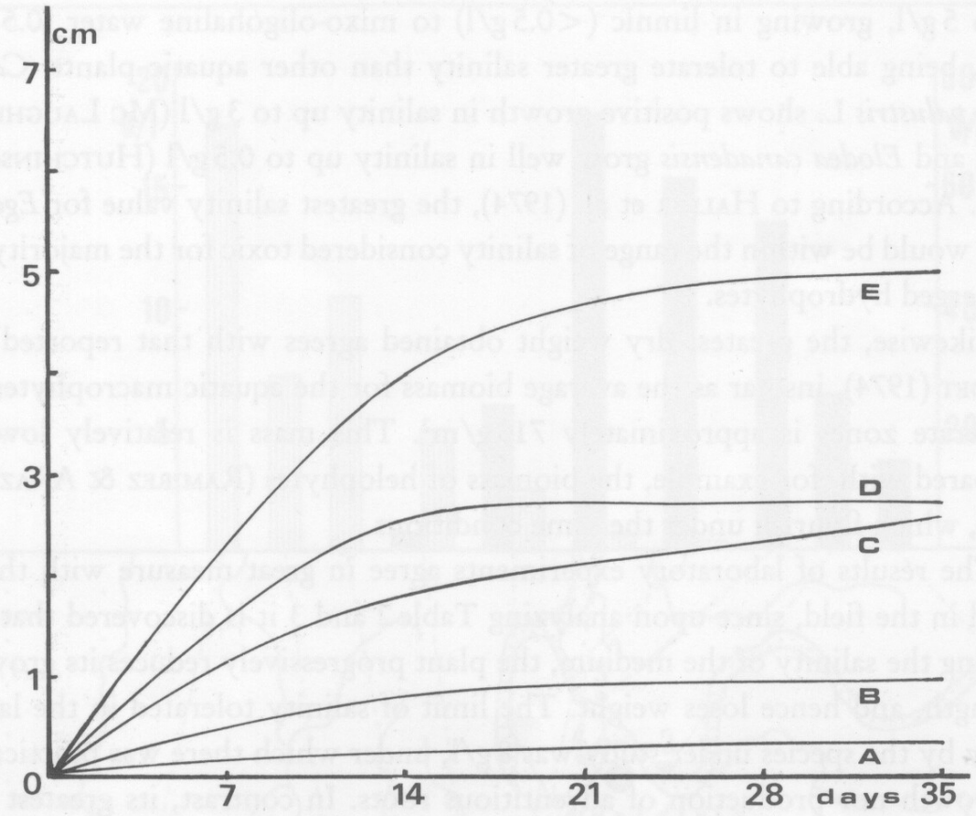

Fig. 3. Increase curves of *Egeria densa* in salinity concentrations of 8 (A), 6 (B), 4 (D), 2 g/l (E) and distilled water (C).

observations in the field, with biomass measuring 1.2 g/l. The same does not occur in concentrations greater than 2 g/l salt solution, where it is possible to infer a toxic effect inhibiting growth.

Also, Fig. 3 shows that the growth of the plant decreases with time after the second week in all concentrations tested, which may be due in part to the use of distilled water (Bastin, 1974). The coefficients of regression and correlation for salinity and growth are relatively high and negative (—0.46 and —0.72, respectively), which confirm the former (Fig. 4).

The results of the experiments on photosynthesis are shown in Fig. 5, where it is possible to observe the greater photosynthetic intensity obtained in the 4—6 g/l range, and decreasing rapidly in greater salinity. These results also fit with the limit values already mentioned.

A frequent phenomenon in plants which develop in concentrations close to the toxic salinity limit (6—10 g/l) is the appearance of a reddish color in the stem and leaves, which is due to the production by the plant of anthocyanins pigments as a response to the unfavorable environment in which it is growing, and that altes its metabolism (Nozzolillo, 1979). According to Libbert (1975), a deficiency in nitrogen is produced which diminishes the synthesis of proteins and enzymes, which translates first into chlorosis and later into the formation of nitrogenfree products such as anthocyanins.

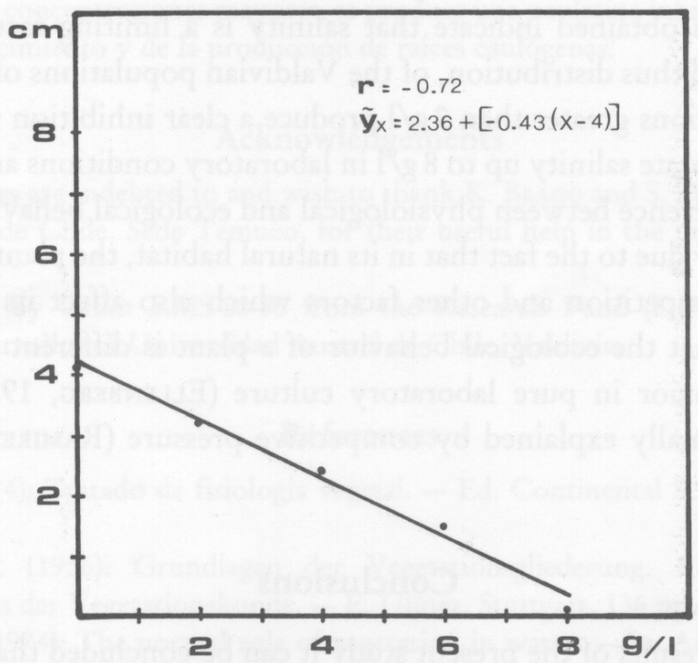

Fig. 4. Growth regression graphic of *Egeria densa* in different salinities. Time of the experiment: 6 weeks.

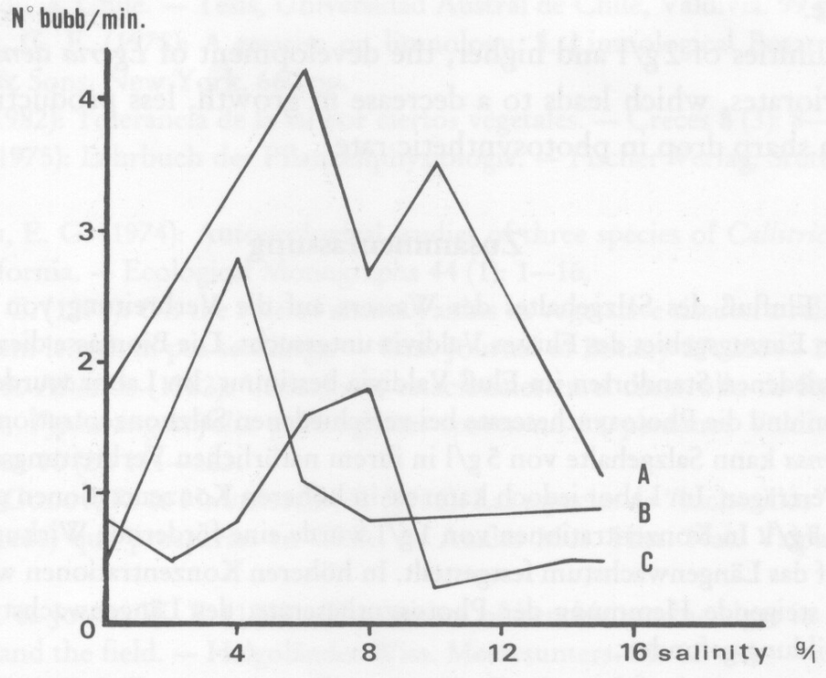

Fig. 5. Photosynthetical rate (bubbles/min) of *Egeria densa* in different salinities and dates. A = March 7th, 1981, B = May, 15th, 1980 and C = May, 16th, 1980.

The phenomenon of color change was also noted in experiments during the study. The effect of salinity on the plant then consists in the alteration of photosynthetic metabolism, which affects growth in general. According to Bastin (1974), salinity can influence photosynthesis in three ways: a) by modifying the free CO_2 value in the water, b) by the osmotic effect on the chloroplast and c) by the change in concentration of some ions involved in photosynthesis.

The results obtained indicate that salinity is a limiting factor in the development, and thus distribution, of the Valdivian populations of *Egeria densa*. Salt concentrations greater than 2 g/l produce a clear inhibition to its growth. It is able to tolerate salinity up to 8 g/l in laboratory conditions and 5 g/l in the field. This difference between physiological and ecological behavior of the species is probably due to the fact that in its natural habitat, the plant is exposed to pressure of competition and other factors which also affect its growth. It is well known that the ecological behavior of a plant is different from its physiological behavior in pure laboratory culture (Ellenberg, 1956). This difference is normally explained by competitive pressure (Ramirez & Añazco, 1982).

Conclusions

From the results of the present study it can be concluded that:

— *Egeria densa* is able to tolerate, in laboratory conditions, a salinity of up to 8 g/l, and in its habitat in the basin of the Valdivia River, 5 g/l.
— A salinity of around 1 g/l promotes growth and biomass production of the specie.
— In salinities of 2 g/l and higher, the development of *Egeria densa* gradually deteriorates, which leads to a decrease in growth, less production of roots and a sharp drop in photosynthetic rate.

Zusammenfassung

Der Einfluß des Salzgehaltes des Wassers auf die Verbreitung von *Egeria densa* wurde im Einzugsgebiet des Flusses Valdivia untersucht. Die Biomasse dieser Art wurde an verschiedenen Standorten im Fluß Valdivia bestimmt. Im Labor wurde das Längenwachstum und die Photosyntheserate bei verschiedenen Salzkonzentrationen gemessen. *Egeria densa* kann Salzgehalte von 5 g/l in ihrem natürlichen Verbreitungsareal im Fluß Valdivia ertragen. Im Labor jedoch kann sie in höheren Konzentrationen gedeihen, und zwar bis 8 g/l. In Konzentrationen von 1 g/l wurde eine fördernde Wirkung des Salzgehaltes auf das Längenwachstum festgestellt. In höheren Konzentrationen wurde eine allmählich steigende Hemmung der Photosyntheserate, des Längenwachstums und der Wurzelbildung gefunden.

Resumen

Se estudió la influencia de la salinidad sobre la distribución de *Egeria densa* en la cuenca del río Valdivia, Chile. Se realizaron mediciones de biomasa de la especie en lugares con diferente salinidad, dentro de su área de distribución en el río Valdivia. En laboratorio se controló el crecimiento y se determinó la tasa fotosintética de los vástagos mantenidos en diferentes concentraciones salinas. Se econtró que *Egeria densa* soporta salinidades de hasta 5 g/l, creciendo en forma natural en el río Valdivia. En laboratorio en cambio, puede prosperar en concentraciones superiores de hasta 8 g/l. En este caso, en concentraciones de hasta alrededor de 1 g/l hay un claro estímulo del crecimiento de

los vástagos, en concentraciones mayores, se produce una paulatina inhibición de la fotosíntesis, del crecimiento y de la producción de raíces caulógenas.

Acknowledgements

The authors are indebted to and wish to thank K. Bragg and S. Peredo of Universidad Católica de Chile, Sede Temuco, for their useful help in the preparation of the manuscript.

Supported by Grant RMS-80-30 from the Research Fund (Dirección de Investigación y Desarrollo) of Universidad Austral de Chile, Valdivia.

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Address of the authors:

M. Sc. Enrique Hauenstein B., Pontificia Universidad Católica de Chile, Sede Temuco, Temuco, Chile.

Dr. Carlos Ramirez G., Instituto de Botánica, Universidad Austral de Chile, Casilla 567, Valdivia, Chile.