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SEASONAL CHANGES IN THE CONDITION INDEX OF *DIPLODON CHILENSIS CHILENSIS* (GRAY, 1828) IN SANDY AND MUDDY SUBSTRATA. VILLARRICA LAKE. CHILE. (39° 18'S; 72° 05'W)

Cambios estacionales en el índice de condición de *Diplodon chilensis chilensis* (Gray, 1828) en sustratos arenosos y fangosos en el Lago Villarrica, Chile (39° 18'S; 72° 05'W).

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ABSTRACT

To determine the seasonal condition index of *Diplodon chilensis chilensis* (GRAY, 1828) in sandy and muddy substrates, random specimen samples were seasonally obtained at La Poza station, Lake Villarrica by scuba diving from August 1986 to April 1987. At the laboratory, the condition index was estimated for each non-reproductive individual. The results showed that the condition index of the specimens inhabiting muddy substrates was lower than that of the individuals of sandy substrates even though the observed differences were significant in spring and summer only. The observed seasonal trend of the condition index was different for each studied population. The condition index is correlated with mussel density, substrate's organic matter and organic and inorganic water-suspended particles.

KEYWORDS: Condition index. *Diplodon chilensis chilensis*. Muddy substrate. Sandy substrate. Villarrica Lake, Chile.

RESUMEN

Con el propósito de determinar estacionalmente el índice de condición de *Diplodon chilensis chilensis* (GRAY, 1828) en ambientes arenosos y fangosos del sector La Poza del Lago Villarrica, durante el período agosto 1986-abril 1987, se extrajeron muestras al azar de especimenes mediante buceo autónomo. Posteriormente en laboratorio se estimó el índice de condición para cada uno de los individuos no reproductivos. Los resultados obtenidos señalan que el estado de gordura de los individuos que habitan fango es menor que en los individuos de arena, aunque las diferencias registradas entre ambos ambientes sólo son significativas en primavera-verano. Las tendencias estacionales del índice de condición registradas en cada población son distintas. Se relaciona el estado de gordura con la densidad de almejas, materia orgánica del sustrato y con partículas orgánicas e inorgánicas en suspensión.

INTRODUCTION

The condition index, which relates the dry tissue weight to the length of the individuals permits us to evaluate indirectly the amount of food resources available in the environment for the organisms. In animal populations, this index

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can be influenced by many factors: temperature (CHIPMAN, 1947); chemical characteristics of the water and sediment (ENGLE, 1957; PEDDICORD, 1977), spawning (KORRINGA, 1952; SASTRY, 1977) and food availability (KORRINGA, 1952 op. cit., HAUKIOJA & HAKALA, 1978) among others.

Diplodon chilensis chilensis (GRAY, 1828) which is largely distributed in lakes and rivers in the south of Chile, is a hyriid bivalve characterized by its tolerance to temperature and oxygen changes, and by its great filter - effectiveness (BUSSE, 1970). It is a gonochoric, ovoviviparous species with a continuous gonadal activity and seasonal reproduction but without an external sexual dimorphism (PEREDO & PARADA 1984, 1986). Ecological studies conducted by LARA & PARADA (1988) in La Poza Station, Lake Villarrica, have indicated that in spite of inhabiting sandy and muddy substrata, *Diplodon chilensis chilensis* is more abundant in muddy water-bottoms, situation which could eventually reflect a higher availability of food resources at mud substrata and explain the animal's fat state or condition index.

The purpose of this study was to determine seasonally the condition index of *D. ch. chilensis* inhabiting different environments (sand and mud) and to relate it with the nature of the substrate, density and availability of resources.

MATERIALS AND METHODS

Through seasonal self-diving, at La Poza station in Lake Villarrica seasonally from August 1986 to April 1987, biological and abiotic samples were taken from areas with sand substrate (ruditic sand) and mud substrate (muddy sand), located at dephts which due to the lake rainfall ranged from 0,5-5,0 m and 5,0-8,5 m, respectively during the year.

During each sampling, 100 individuals from both areas were collected by hand and held in the laboratory at a temperature of 4°C. At the laboratory, all individuals were sexed through a gonadal smear and all female organisms were subjected to gill dissociation to determine the presence or absence of embryos. After having measured the anterior-posterior valve length of each individual (VL) they were processed to

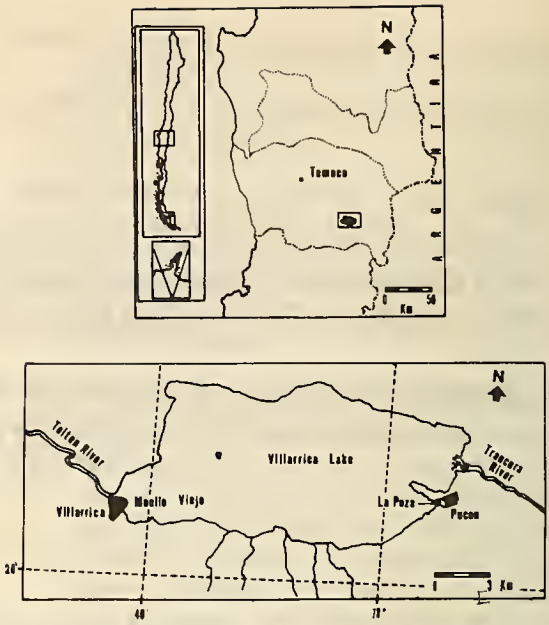

FIG. 1. Area of study in La Poza station. Lake Villarrica.

separate the valves from the soft parts. Both portions were dried out at 90°C with a dry oven to reach constant weight and then weighed with a Sartorious digital balance at 1 mg of accuracy. By means of the Statwork program of the Apple-Macintosh computer, a correlation between the valve length (VL) and the valve dry weight as well as the a and b values of the regression equation were estimated.

To clear away the problem of extra energy consumption caused by the incubation of embryos in females, in some periods of the year, RICKER'S condition index (1975) was only estimated for non-reproductive individuals (total of males and females which do not incubate). With the purpose of comparing the condition index values in periods within the same environment and between environments, the mean t test was performed 0,05 (ZAR, 1974).

By counting the number of specimens on each one of the 35 samples of 25x25x10 cm collected on both substrata, density was estimated seasonally. The mean t test (0,05) was also performed to compare both seasonal density values within the same environment, and between environments (ZAR op cit.).

The organic matter, which was taken with a core of 453,64 and 159,04 cm^3 in sand and mud areas respectively, was determined on the basis

of 5 substrata samples. The amount of organic matter contained in each sample was estimated, by weight difference, after drying in a MR 170 WC Hanau muffle at 550°C for four hours. Through the method described by ARENAS et al. (1980), suspended solid organic and inorganic particles in water were estimated as well.

RESULTS

Although recorded differences between these environments are only significant in spring and summer, the results indicate that the condition index of individuals is lower in muddy than in sandy areas (Table 1).

TABLE 1. Seasonal condition index standard deviation (mg/cc) of *Diplodon chilensis chilensis* living in sand and mud. La Poza station - Lake Villarrica. t = value observed t means test, n = non-reproductive individuals, f.d = freedom degrees, P × probability error.

Substrata	sand	mud	t(n1+n2-2)
Seasons			
Winter 1986	4,91 ± 1,06 n=76	4,76 ± 0,78 n=82	t=0,902 f.d=156 0,10<P<0,25
Spring 1986	5,29 ± 0,94 n=81	4,55 ± 0,74 n=91	t=5,744 f.d.=170 P<0,001
Summer 1987	4,38 ± 0,46 n=75	4,64 ± 0,83 n=58	t=2,282 f.d=131 0,02<P<0,05
Autumn 1987	4,20 ± 0,94 n=96	3,96 ± 0,74 n=99	t=1,851 f.d=193 0,05<P<0,10

Seasonally, the trends evidenced in every population of *Diplodon chilensis chilensis* are different. All individuals of sandy bottoms show an increment of their condition index in winter reaching their highest peak in spring, falling during the summer and reaching their lowest peak in autumn (Fig. 2a). The individuals living in mud do not show the trend described above since the condition index values, except for the fall at the beginning of autumn (April, 1987), were relatively constant for the most part of the year (Fig. 2b). The condition index in autumn is significantly lower in organisms both at sandy and muddy areas ($P < 0,001$). The valve dry weight (VDW) (relative thickness) in standard individuals of 5 cm valve-length, present no significant variation in both substrata throughout the year, whereas individuals in muddy areas always show a valve dry weight significantly lower than the weight of individuals of sandy areas ($P<0,001$) (Fig. 3, Table 2).

In connection with density, the results show

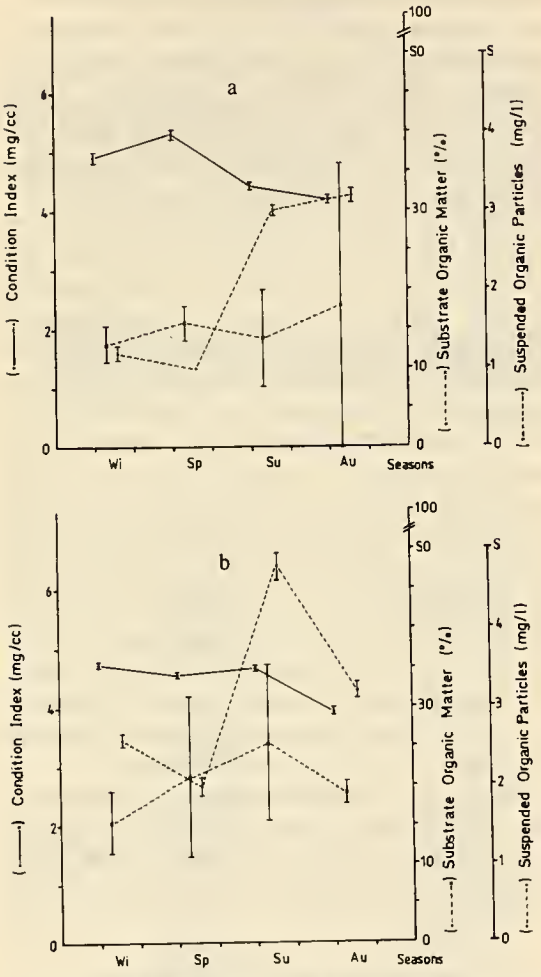

FIG. 2. Seasonal relations among *Diplodon chilensis chilensis* condition index, substrata organic matter and organic particles in suspension at sandy (a) and muddy (b) environments. (s.d.) standard deviation in horizontal segments.

that the highest values are registered in muddy areas although these values vary significantly during the year (Table 3).In sandy bottoms, on the contrary, density is relatively stable all the year round, though the values obtained are significantly lower than those obtained in muddy substrate.

The amount of organic matter attached to the substrate's particles is higher in muddy bottoms with annual variations of 15,63 and 25,69% for muddy bottoms in winter and summer, respectively and 13,37 and 18,40% for sandy substrata in the same seasons. All differences recorded are significant only during the summer (Table 4).

Water-suspended solid particles, either organic or inorganic, do not show a definite trend in both environments even though the organic·particles are always higher in muddy substrate. These differences are significant only in winter and summer (Table 5).

DISCUSSION AND CONCLUSIONS

The condition index is a parameter that has been widely used in studies of the reproductive cycles of aquatic species to show that the changes in the fat condition of individuals are due to reproductive processes. Nonetheless, few studies have related this state (condition index) to population characteristics such as density and availability of existing resources for the populations in different kinds of substrata.

TABLE 2. Seasonal regression equations between valve dry weight (VDW) and valve lenght (L) of *Diplodon chilensis chilensis* living in sandy and muddy environments. La Poza station - Lake Villarrica. (n = 100).

Seasons	Substrata	
	Sand	Mud
Winter 1986	$VDW = 0.042L^{2.99}$	$VDW = 0.011L^{3.58}$
Spring 1986	$VDW = 0.026L^{3.23}$	$VDW = 0.012L^{3.60}$
Summer 1987	$VDW = 0.080L^{2.63}$	$VDW = 0.019L^{3.22}$
Autumn 1987	$VDW = 0.035L^{3.10}$	$VDW = 0.009L^{3.72}$

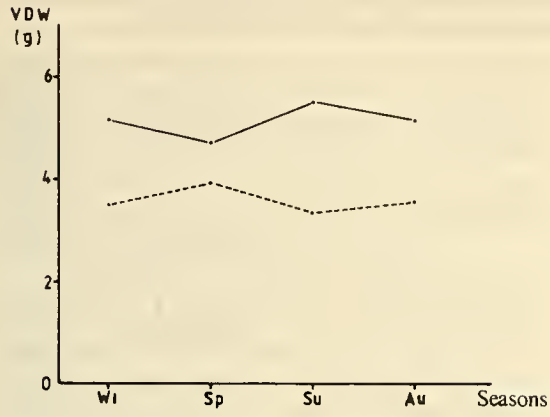

FIG. 3. Seasonal average variation of valve dry weight (VDW) in 5 cm - length standard individuals. N = 100. —·—·—·— sandy, – – –·– – –·– – – muddy.

The results of this study show that the condition index is lower in muddy than in sandy bottoms, even though in the first ones there is higher concentration of organic matter either attached to the substrate or in suspension. The greatest density of population recorded in muddy bottom could be the agent that limits food resources among individuals. Therefore, the lower condition index observed in mud populations could be attributed to the fact that in spite of the existence of a higher amount of available food in the environment —they are basically benthonic diatoms consumers— (LARA, 1988) the food has to be shared among all individuals inhabiting muddy bottoms; thus, this situation would give rise to a potential competence for the food resource, ac-

TABLA 3. Seasonal density $\pm$ standard deviation (ind/625 cm^2) of *Diplodon chilensis chilensis* living in sand and mud. La Poza station - Lake Villarrica. t = value observed t means test, n = number of samples, f.d = freedom degrees, P = probability error.

Substrata	sand	mud	t(n1 + n2-2)
Seasons			
Winter 1986	5,83 $\pm$ 3,55 n = 35	29,03 $\pm$ 11,88 n = 35	t = 10,908 f.d = 68 P<0,001
Spring 1986	5,34 $\pm$ 3,44 n = 35	22,22 $\pm$ 9,77 n = 31	t = -9,428 f.d = 64 P<0,001
Summer 1987	5,63 $\pm$ 2,99 n = 35	22,05 $\pm$ 10,29 n = 35	t = -8,932 f.d = 68 P<0,001
Autumn 1987	6,06 $\pm$ 2,89 n = 35	16,97 $\pm$ 6,75 n = 35	t = 8,649 f.d = 68 P<0,001

TABLE 4. Seasonal organic matter ± standard deviation (%) present at sandy and muddy substrata. La Poza station - Lake Villarrica. t = value observed t means test, n = number of samples, f. d = freedom degrees, P = probability error.

Substrata	sand	mud	t(n1+n2-2)
Seasons Winter 1986	13,37 ± 2,14 n=5	15,63 ± 4,10 n=5	t=-0,990 f.d=7 0,20<P<0,50
Spring 1986	15,84 ± 2,31	21,58 ± 10,26	f.d=8 0,20<P<0,50
Summer 1987	13,63 ± 5,88 n+5	25,69 ± 9,83 n+5	t=2,353 f.d=8 0.02<P<0,05
Autumn 1987	18,40 ± 17,93 n=5	18,84 ± 1,29 n=5	t=0,194 f.d=8 P<0,50

TABLE 5. Seasonal suspended solid particles ± standard deviation (mg/l) at sandy and muddy substrata. La Poza station - Lake Villarrica. t = comparison of inorganic particles with t means test, f.d = freedom degress, P = probability error.

Seasons		Winter 86	Spring 86	Summer 87	Autumn 87
Substrata	Seston				
sand	total	2,0 ± 0,0	6,8 ± 1,64	36 ± 24,69	22,8 ± 19,65
	inorganic	0,8 ± 0,44	5,8 ± 1,64	33 ± 24,46	19,6 ± 19,86
	organic	1,2± 0,44	1,0 ± 0,0	3,0 ± 0,70	3,2 ± 0,83
mud	total	3,0 ± 1,22	19,4 ± 8,56	57,2 ± 4,56	37,2 ± 12,13
	inorganic	0,4 ± 0,54	17,4 ± 8,23	52,4 ± 33,18	34,0 ± 12,18
	organic	2,6 ± 0,89	2,0 ± 1,20	4,8 ± 1,64	3,2 ± 0,44
	t	3.13	1.826	2.25	0
	f.d	8	8	8	8
	P	0.01<P<0.02	0.10<P<0.20	0.50<P<0.10	P<0.50

companied by a lower length, height, and valve thickness of the individuals. From above we can infer that the specimens of *Diplodon chilensis chilensis* in both populations (sand or mud) distribute their energy in different ways (Table 3). In muddy areas the incoming water current created by the filtrating organisms removes a large number of particles from the surface sediment, which implies that bivalves must use part of their energy in consuming and evacuating particles (PRATT & CAMPBELL, 1956). LOOSANOFF (1961) and PEDDICORD (1976, 1977) have stated that the large number of suspended inorganic particles present in the environment, would force

the organisms in muddy bottoms to waste part of their energy impeding that these particles obstruct their filtering structures. It is likely that a similar situation happens in the mud populations of lake Villarrica where the organisms limited by food resources and subdued to an imperfect choice of food, have to waste part of their energy in muscular and ciliary activities and production mucus to eliminate inorganic particles.

The seasonal variations of the condition index recorded in both environments also show that they are determined not only by the kind of substrate (particle-size and organic matter) inhabited by the organisms, but also by the annual reproductive processes, i.e., gonadal activity and larvae incubation in this species. In the present study, the use of condition index in non-reproductive individuals only, allowed us to obviate the energy wasted on the embryonic incubation in the inner demibranchs, although gonadal activity continues and seasonal spawning (PEREDO & PARADA, 1984) produces changes in the fat state of males and females. The seasonal reproductive period of *D. ch. chilensis* finishes in late summer, time of the year when the number of females incubating is considerably reduced (PEREDO & PARADA, 1986). During the autumn, the organisms begin to recover their fat state reaching their maximum during the spring-summer periods. This fact is clearly seen in sandy populations but not in muddy ones. Movements made by *D. ch. chilensis* in muddy substrate (LARA, 1988) would cause the suspension of the finest particles, which would in turn bring about an extra waste of energy for the mussels in cleaning off their filtering structures. This situation is reflected in the seasonal constancy of the condition index during the year, except for the autumn when the index falls apparently due to the termination of the breeding-period. With regard to the information discussed it seems paradoxical that in natural conditions *D. ch. chilensis* tends to settle into muddy bottoms suggesting that there are some other parameters involved, not evaluated in this study. Since it is surprising that the specimens of *D. ch. chilensis* prefer to inhabit environments that would apparently place them under major selective pressures, other field experiments need to be carried out to furnish new data on this subject.

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REFERENCES

Arenas, J. Dominguez, P. & Varela, C. 1980. Métodos químicos empleados en estudios limnológicos en Chile. Bol. Inf. Limnológico *4*:13-63.

Busse, K. 1970. Nuevo método para medir flujos de agua producidos por organismos filtradores. Medición experimental en *Diplodon chilensis* (Gray), 1854 (Mollusca, Lamellibranchiata). Not. Mens. Mus. Hist. Santiago. *172*:3-10.

Chipman, W.A. 1947. Seasonal changes in the fattening of oysters. Conv. Addr. natn. Shellfish. Ass. *38*:28-32.

Engle, J.B. 1957. The seasonal significance of total solids of oysters in commercial exploitation. Proc. Natn. Shellfish. Ass. *48*:72-78.

Haukioja, E. & Hakala, T. 1978. Life-history evolution in *Anodonte piscinalis* (Mollusca, Pelecypoda). Oecologia (Berl) *35*:253-266.

Korringa, P. 1952. Recent advances in oysters biology. Q. Rev. Biol. *27*:266-365.

Lara, G. & Parada, E. 1988. Distribución espacial y densidad de *Diplodon chilensis chilensis* (Gray, 1828) en el Lago Villarrica (39° 18'S; 72° 05'W). Bol. Soc. Biol. Concepción. *59*:105-114.

Lara, G. 1988. Ordenamiento espacial y abundancia de *Diplodon chilensis chilensis* (Gray, 1828) (Bivalvia:Hyriidae) en el Lago Panguipulli, Valdivia, Chile. Tesis Magister en Ciencias-Ecologia. Universidad Austral de Chile. 83 pp.

Loosanoff, V.L. 1961. Effects of turbidity on some larval and adult bivalves. Proc. Gulf, Caribb. Fish. Inst. *14*:80-95.

Peddicord, R.K. 1976. Effects of substratum on growth of the bivalve *Rangia cuneata* Gray, 1831. The Veliger *18*(4):398-404.

Peddicord, R.K. 1977. Salinity and substratum effects on condition index of the bivalve *Rangia cuneata*. Mar Biol. *39*:341-360.

Peredo, S. & Parada, E. 1984. Gonadal organization and gametogenesis in the fresh-water mussel *Diplodon chilensis chilensis* (Mollusca: Bivalvia). The Veliger *27*(2):126-133.

Peredo, S. Parada, E. 1986. Reproductive cycle in the fresh-water mussel *Diplodon chilensis chilensis* (Mollusca: Bivalvia). The Veliger 28(4):418-425.

Pratt, D.M. & Campbell, D.A. 1956. Environmental factors affecting growth on *Venus mercenaria*. Limnol. Oceanogr. *1*:2-17.

Ricker, W.E. 1975. Handbook of computations for Biological Statistics of Fish Populations. Fish. Res. Bd. Canadá. Bull. *191*:382 pp.

Sastry, A.M. 1977. Pelecypoda and lesser classes. In Reproduction of Marine Invertebrates. Vol V. A.C. Giese and J.S. Pearse (ed). Academic Press. New York. 113-291.

Zar, J.Z. 1974. Biostatistical analysis. Prentice-Hall Inc. 620 pp.