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Relocation of the freshwater mussel *Diplodon chilensis* (Hyriidae) as a strategy for its conservation and management

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The commonest species of freshwater mussel in Chile is *Diplodon chilensis* (Gray, 1828), with a distribution in the country extending from 34°58′S to 46°37′S in both lentic and lotic environments in a number of hydrographic basins.[1] It is also present in Argentina between 32°52′S and 45°51′S.[2] The role of this species in the ecosystem function has been amply documented. Through their filter-feeding[3] and because they are long-lived organisms,[4] they may influence the abundance of phytoplanktonic communities, water quality and the nutrient cycle.[5] In recent decades, a considerable reduction in abundance and/or disappearance of populations in lotic environments has been noted (personal observations). This decline may be attributed to degradation of water quality, destruction of habitat (damming, canalization, etc.) and probably to the introduction of fish species for tourism, or installations for industrial fish production, which have displaced the native species that are the hosts for the glochidium larvae. To date there have been no proposals in Chile for the protection of populations of hyriids in the face of anthropogenic disturbance. The aim of this study was to evaluate the effectiveness of the relocation of a population of *D. chilensis* as a strategy for its conservation and management, through the long-term evaluation of survival and recruitment.

In the summer of 1983, 400 specimens of *Diplodon chilensis* with a valve length of 1.6–6.5 cm, originating from a natural population in Villarrica Lake (VL) in the River Toltén basin, were transferred to the Gibbs Channel (GC), Temuco (Fig. 1).

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The mussels were transported in coolers filled with water taken from the lake. The area of the channel selected for the relocation is a site with muddy substrate and profuse vegetation along the banks. Sampling conducted prior to the relocation, at the relocation site as well as 3 km upstream and downstream, found macroinvertebrates and fish, but no specimens of *D. chilensis*. The features of the area indicated that this was a suitable site for relocation of *D. chilensis*. The specimens were placed at random along 6 m of the south bank of the channel, at an average density of 66 individuals/m^2. The specimens were not marked, in order to avoid stress of manipulation. However, lack of marking prohibited a true quantitative assessment of individual mussel survival, recovery and growth.

In addition, 100 individuals from the Villarrica Lake population were taken at random by hand, to measure valve length (L), valve dry weight (VDW), tissue dry weight (TDW) and gravid gill dry weight (GGDW); and to estimate the population parameters sex ratio, density of adults, percentage of gravid females, size structure, physiological state or condition index (CI), fertility, recruitment and adult mortality, in accordance with the methods developed by Parada *et al.*[6] During the summer of 1986, 100 specimens of the GC relocated population were recaptured and processed to assess and compare their biometric and population parameters.

In 2001, 18 years after the relocation, samples were taken from three sites in GC (site A corresponding to the area in which the population was relocated in 1983; site B, 3 km downstream; and site C, 4 km upstream from the relocation site) to evaluate the

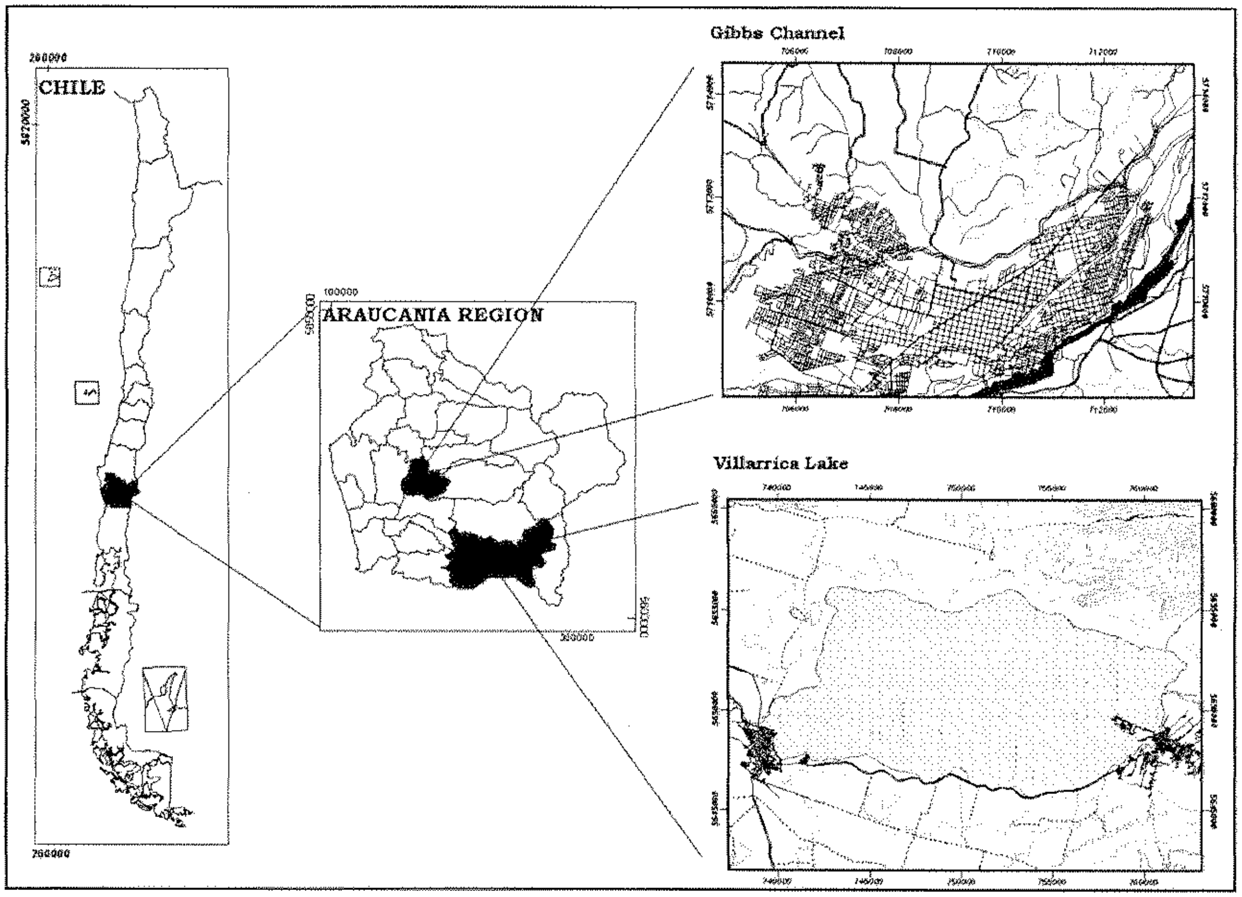

Figure 1. Location of study area on the Villarrica Lake and Gibbs Channel.

presence of *D. chilensis*, and to assess its biometric and population parameters for comparison with those recorded in 1983 and 1986. The collection of specimens of *D. chilensis* was carried out manually, at random, with all the captured individuals being collected in 2 h, which was the time required to collect 100 specimens in the natural population in VL. To estimate the capacity for sustained repopulation in the area, an examination of the three sites was carried out for the presence of juvenile and adult *D. chilensis*, benthonic macroinvertebrates (possible predators), and fishes (host species for glochidium larvae) over a 20-m stretch of the channel at each site. Each fish was examined to check for the presence of glochidial cysts in the fins and gills.

The density of the VL population in 1983 was 106 individuals/m^2, and that of the translocated population in the GC was 66 individuals/m^2 at the beginning of the study. The density of the GC population 3 years later was 50 individuals/m^2. The natural population in VL showed a sex ratio of 1:1 and so did the relocated population. The average valve length (L) for males in the VL population in 1983 was 4.01 cm ($\pm$SD 0.79) and for females 3.76 cm ($\pm$0.91); in the GC population in 1986 the average L was 4.73 ($\pm$0.78) for males and 4.91 ($\pm$0.54) for females. Histograms for each population are shown in Figure 2. The size range of adults in the GC population was 2.3–6.5 cm valve length, and in the VL population 2.2–5.1 cm; thus a larger size range was recorded in the transplanted population after 3 years than in the original population.

The biometric ratios of valve dry weight (VDW) *vs* valve length (L) and tissue dry weight (TDW) *vs* valve length (L) for both males and females are shown in Table 1. Both the VDW:L ratio and the TDW:L ratio show highly significant correlations for both males and females in each population (Table 1).

Recruitment, indicated by the presence of juveniles (individuals with a valve length of less than 1 cm), was recorded in 1983 in the VL population, with 5 ($\pm$4) individuals/m^2. Juveniles were not recorded in the GC population in 1986.

Adult mortality assessed in 1983 in the natural population (VL) and in 1986 in the translocated population (GC), by recording the number of empty valves, was low in both populations. In VL it was 10.9 ($\pm$3) individuals/m^2, whereas in GC it was 2 ($\pm$0.5) individuals/m^2. Assuming that this mortality rate is similar over time, the number of mussels left at the end of the study is feasible. The availability of food, as measured by the CI of the non-incubating individuals (males), is high: 5.22 ($\pm$0.66) in VL and 4.96 ($\pm$0.7) in GC (Table 1).

The onset of sexual maturity, or size at which the first reproduction occurs, assessed by a visual examination of the inner demibranchs of the gravid females in each population, was at 2.2 cm valve length for the VL population. In the relocated population in GC, the smallest female containing embryos was 3.8 cm in valve length.

Fertility, measured by the number of embryos contained in the inner demibranchs of females, is high, with average values in the VL population of 110,700 ($\pm$7,355) embryos in females with valve lengths between 4.8 and 5.8 cm. In the CG relocated population, this value was 45,200 ($\pm$1,757), but the length of the females was 4.4–5.2 cm. The embryos occupy the whole of both demibranchs in incubating females in both populations. The ratio gravid gill dry weight (GGDW) *vs* valve length (L) of all the

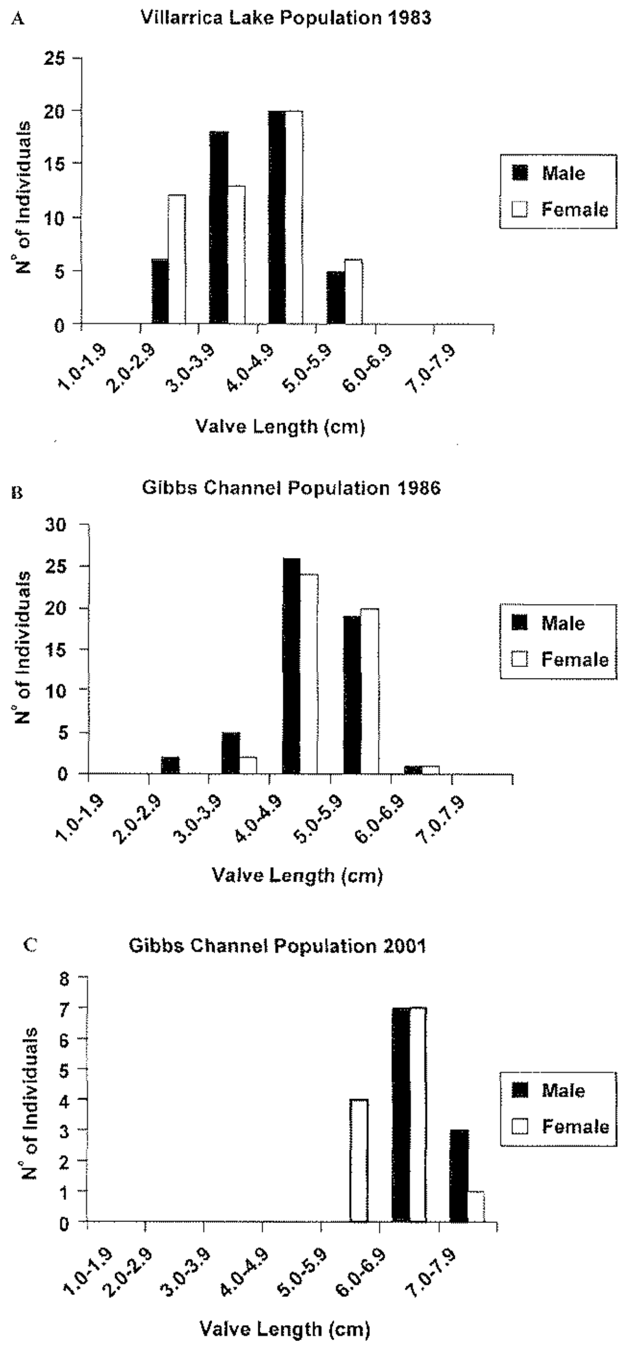

Figure 2. Size structure of Villarrica Lake 1983 (A), Gibbs Channel 1986 (B) and Gibbs Channel 2001 (C) *Diplodon chilensis* populations.

incubating females of the VL population showed a significant correlation ($y = 1.097e^{0.793x}$, $r^2 = 0.78$; $P > 0.001$). The correlation between GGDW and L for the incubating females of the GC population was not significant ($y = 9.889e^{0.354x}$, $r^2 = 0.28$; $P > 0.001$) (Table 1).

Of the three sites sampled in the Gibbs Channel in summer 2001, adult *D. chilensis* were only recorded at the relocation site (site A). Juveniles were recorded only downstream at site B, at a density of 1 (±0.5) individuals/m^2.

Twenty-two individuals from a total of 95 recovered at site A (12 females and 10 males) were sampled in 2001. The average valve length for males was 6.75 cm (±0.48 cm) and 6.19 cm (±0.45 cm) for females (Fig 2). The size range for males was 6.2–7.4 cm and for females 5.4–7.0 cm. The ratios TDW:L and VDW:L for males and females are given in Table 1. Adult mortality recorded at site A was 2 (±0.5) individuals/m^2. The average CI of males was 5.28 (±0.68). The inner demibranchs of all the females collected were full of terminal glochidium larvae, as in the females analysed in summer 1986, suggesting similar fertility. Likewise, no significant correlation between dry weight of the gravid gills and valve length was found (Table 1).

The benthonic macroinvertebrates and fishes collected at the three sites in the Gibbs Channel are shown in Table 2. Examination of the fins and gills of each of the captured fish did not show the presence of glochidial cysts.

The results of our study show that the relocation of freshwater mussels is a viable tool for the protection and/or conservation of mussel populations. The relocation of *D. chilensis* from Villarrica Lake to the Gibbs Channel was successful, as is demonstrated by the results obtained from the studies carried out 3 and 18 years after relocation.

The sex ratio of 1:1 found here is in agreement with earlier studies[6,7] for *D. chilensis* and other hyriids of South America[8,9] and Australia.[10] The size structure of the VL population agrees with that recorded elsewhere for *D. chilensis*.[6–11] However, the GC population shows a relatively lower proportion of juveniles and a higher proportion of adult individuals of larger sizes than those of the original population (Fig. 2). This may be attributable to the fact that the transplanted individuals grew to a larger size in this lotic environment, as has been found in other comparisons of *D. chilensis* in lotic and lentic environments.[4] The ratios VDW:L and TDW:L are similar in both populations, with the exception of the females in the GC population. This may be due to the energetic cost of seasonal reproduction, because incubation of embryos in lotic populations occurs mainly in spring and summer, whereas in lentic populations gravid females may be recorded almost throughout the year, albeit with greater frequency in spring and summer.[6] The non-significant correlation of GGDW with L in the GC females may be explained by the narrow range of lengths (Table 1).

With regard to recruitment, this was evident in the natural population in VL. In the GC population, no juveniles of less than 1.0 cm valve length were recorded in 1986. However, the presence of specimens of 2.0–2.9 cm, corresponding to an age of 2–3 years,[4] may indicate recruitment in the first year after relocation. They may also correspond to individuals transplanted as juveniles, whose growth was restricted due to the stress of the relocation.[4]

With respect to mortality, the values obtained for the VL population are more representative of reality, for the valves remain in place, unlike the GC population where the empty shells may be carried away by the current in the channel. From the total individuals relocated in 1983, 306 were found in 1986. The missing individuals could have been predated or their valves carried away by the current. In mark–recapture studies[4] it was possible to recover only 25% of the specimens after 1 year. In the present study, 76.5% of the individuals were recovered after 3 years.

The presence of 95 specimens (23.7%) in the relocation site after 18 years indicates that at least the adults successfully adapted to the change from a lentic to a lotic environment. The macrocrustaceans *Aegla* sp. and *Parastacus pugnax* may be the cause of the mortality recorded[12] (Table 2).

However, to achieve a successful relocation requires that the life cycle is completed and recruitment takes place. Data indicate that *D. chilensis* behaves as a generalist species with respect to fish hosts of its larvae, being able to use both native and introduced fish species.[13] Fish present in the GC in 2001 are listed in Table 2. From the data reported[14] for VL, the two bodies of water share

Table 1. Number of males and females (N), condition index (CI) and biometric relations of natural Villarrica Lake population and translocated Gibbs Channel (1983) population specimens. All relationships significant at $P > 0.001$.

Population	N°	CI	VDW *vs* L	r^2	TDW *vs* L	r^2	GBDW *vs* L	r^2
Natural VL 1983								
Males	49	5.22 (0.66)	$y = 0.088e^{0.892x}$	0.94	$y = 19.2e^{0.708x}$	0.95		
Females	51	5.12 (0.84)	$y = 0.081e^{0.901x}$	0.96	$y = 18.1e^{0.717x}$	0.90	$y = 1.09e^{0.793x}$	0.78
Translocated GC 1986								
Males	53	4.96 (0.7)	$y = 0163e^{0.718x}$	0.85	$y = 25.1e^{0.649x}$	0.90		
Females	47	4.74 (0.6)	$y = 0.148e^{0.74x}$	0.77	$y = 252e^{0.162x}$	0.01	$y = 9.889e^{0.354x}$	0.27
Translocated GC 2001								
Males	10	5.28 (0.68	$y = 0.856e^{0.437x}$	0.70	$y = 782.2e^{0.447x}$	0.70		
Females	12	6.94 (1.63)	$y = 0514e^{0.517x}$	0.58	$y = 239.9e^{0.321}$	0.37	$y = 9.2298e^{0.441}$	0.08

VDW = valve dry weight; L = valve length; TDW = tissue dry weight; GGDW = gravid gill dry weight.

Table 2. Benthic macroinvertebrates and fishes collected at the sampling sites in Gibbs Channel.

Taxa	Site A	Site B	Site C
Mollusca			
Diplodon chilensis	X (a)	X (j)	–
Musculium argentinum	X	–	X
Chilina ampullacea	–	X (j)	X
Arthropoda			
Aegla abtao	X	X	X
Parastacus pugnax	X	X	X
Vertebrata			
Geotria australis	X	X(l)	–
Galaxias maculatus	–	X	–
Percilia gillissi	X	X	X
Oncorhynchus mykiss	–	X	–

a = adults, j = juveniles, l = larvae

fish species including *Percichthys trucha*, the species which displays the greatest affinity as a host for *D. chilensis*.[13] In the present study, even though laboratory examination of the fishes captured did not reveal any glochidial cysts, nonetheless juveniles of less than 1.0 cm valve length were found at site B, downstream from the relocation site, indicating that recruitment has occurred resulting from dispersion of larvae by a host. The size of the juveniles suggests that recruitment took place in the previous reproductive season.

A comparison of the histograms (Fig. 2) indicates that there has been no recruitment at the relocation site (site A in GC) during 18 years. However, the adults have remained there, displaying an improvement in condition and growth greater than in the first years of their relocation, and indeed greater than that of the source population. We suggest that they have a functional reproductive role, and that recruitment is occurring in at least one area (site B) away from the point of relocation. One way of proving this would be to extend the sampling area during subsequent monitoring.

We conclude that relocation is a suitable tool for the conservation and management of freshwater mussel populations.

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1: Biol Trace Elem Res. 2004 Winter;102(1-3):245-63. Related Articles, Links

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Heavy metal and other trace elements in native mussel Diplodon chilensis from Northern Patagonia Lakes, Argentina.

Guevara SR, Bubach D, Vigliano P, Lippolt G, Arribere M.

Laboratorio de Analisis por Activacion Neutronica, Centro Atomico Bariloche, 8400 Bariloche, Argentina.

Native mussels, Diplodon chilensis, were sampled from four lakes in Nahuel Huapi National Park, Northern Patagonia, Argentina in order to evaluate heavy-metal distribution in the region and to assess the contribution of this compartment of the trophic web to their circulation in the food chain. The concentration of potential pollutants Ag, As, Cr, Hg, Sb, and Se, and other nine elements of interest (Ba, Br, Ca, Co, Cs, Fe, Na, Sr, and Zn) were determined in Diplodon chilensis pooled samples. Digestive glands were analyzed separately from soft tissues. Geological tracers Sc, Ta, Th, and rare earth elements were also determined in order to discriminate lithophile contributions. Elemental concentrations of Ba, Br, Fe, Sr, Se, and Zn in total soft tissues samples do not show significant differences among sampling sites. Arsenic and Cr contents in total soft tissues and digestive gland pooled samples are higher in sampling points close to zones with human settlements. Silver contents in samples collected in Lake Nahuel Huapi were higher than in the other lakes studied, and up to 50-fold higher than the sample collected in Lake Traful, considered as the reference. Mercury highest concentration values measured in total soft tissues pooled samples from lakes Nahuel Huapi and Moreno were found to be similar to those observed in other reported Hg contamination situations, and they are three to five times higher than those of the reference samples collected in Lake Traful.

PMID: 15621942 [PubMed - indexed for MEDLINE]

1: Bol Chil Parasitol. 1994 Jul-Dec;49(3-4):85-6. Related Articles, Links

[Presence of glochidia of Diplodon chilensis Hass 1931 (Mollusca, Pelecypoda) in Patagonian freshwater fishes]

[Article in Spanish]

Semenas L, Ortubay S, Ubeda C.

Centro Regiona Universitario Bariloche, Universidad Nacional del Comahue, Rio Negro, Argentina.

The presence of glochidia of Diplodon chilensis Haas 1931 (Mollusca, Pelecypoda) has been reported in gills of wild freshwater fish in the Argentinian Patagonia. Death occurrences due to glochidiasis have not been observed either in wild fish or in cultured fish. The records of Oncorhynchus mykiss, Galaxias platei, Patagonia hatcheri and Percichtys trucha extend the number of known hosts for D. chilensis and add new localities, thus extending the distributions of the mollusc.

PMID: 7654294 [PubMed - indexed for MEDLINE]