Population Dynamics of Freshwater Gastropod *Chilina fluminea* (Chilinidae) in a Temperate Climate Environment in Argentina

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Abstract. The presence and density of gastropods, and the individual growth rate of *Chilina fluminea* snails at Río de la Plata beach, Berisso, Buenos Aires province, Argentina, were analyzed to obtain population data about hosts that could be useful for control of the free-swimming larval stages (cercariae). *Chilina fluminea* has a unique annual reproductive period during winter, whereas other gastropods inhabiting the same area reproduce one to three times a year, but never in winter. Thus, autumn, the season before reproduction and oviposition, is the most adequate season for taking actions to regulate the size of *C. fluminea* populations to reduce possible cases of human schistosomic dermatitis.

INTRODUCTION

The family Chilinidae Dall, 1870 (Gastropoda: Hygrophila) is exclusive to South America, ranging from the Tropic of Capricorn to Cape Horn and the Falkland islands. The family includes the single genus *Chilina* Gray, 1828 with approximately 32 species, 17 of which have been recorded in Argentina (Castellanos and Miquel, 1980; Castellanos and Gaillard, 1981, Gutiérrez Gregoric & Rumi, 2008); the rest are distributed within Chile. From an evolutionary perspective, Chilinidae is among the most primitive of pulmonate gastropods. Dayrat et al. (2001) confirmed the monophyly of Hygrophyla, including the Chilinidae at the base of this clade.

Chilinid species have human health importance because these freshwater gastropods act as intermediate hosts of trematodes, releasing schistosomatid (Plathyhelminthes: Digenea) furcocercarias (cercariae) that usually cause human schistosomic dermatitis (Szidat, 1951; Martorelli, 1984).

Many Argentinean species of *Chilina* are endemic, and their biology and ecological strategies are largely unknown. In general, only a few such studies have been reported in this family: Miquel (1986) studied the life cycle of *Chilina fluminea* Maton (1809) and its gonad evolution; Bosnia et al. (1990) analyzed the growth of *Chilina gibbosa* G. B. Sowerby I, 1841, and its density; Estebemet et al. (2002) analyzed the natural diet for *Chilina parchappii* (d'Orbigny, 1835); Gutiérrez Gregoric et al. (2010) analyzed the growth and density of *Chilina megastoma* Hylton Scott, 1958; and Quijon & Jaramillo (1999) and Quijon et al. (2001) worked on *Chilina ovalis* (Sowerby, 1841) from southern Chile, emphasizing spatial distribution and growth.

The present work focuses on estimating population patterns, such as density, individual growth rate, and recruitment times, of a population of *C. fluminea* in a temperate climate at "La Balandra" beach, Berisso, Buenos Aires province, Argentina. The study established that recruitment times and growth rates of the host allow us to define and assess eventual actions for control of furcocercarias that usually cause human schistosomic dermatitis.

MATERIALS AND METHODS

Samples for this study were collected from the canal of La Balandra beach (34°55′S, 57°43′W). This canal arises from lowlands close to the beach and flows into the Rio de la Plata River and estuary. The sample area selected is located some 150 m from the canal mouth, and it is approximately 7 meters in length and restricted to the left margin of the canal, the only place where a population of *C. fluminea* was recorded. Bulrush (*Scirpus giganteus* Kunth) and yellow iris (*Iris pseudacorus* Linné) grow in the border of the canal.

The study included 24 samples collected between November 2000 and September 2003. Water temperature (Celsius), conductivity (microsiemens), hardness (French degrees, calculated as conductivity/20), total dissolved solids (milligrams per liter), pH, dissolved oxygen (milligrams per liter), and saturated oxygen (percentage) were measured in 23 of the 24 samples.

Gastropods were collected manually from slime soil, rocks, branches, and other objects found at the bottom of the canal bed. Squares of 0.10 m (0.01 m²) were used as a sample unit (SU). The minimum number of SUs was between 35 and 45, and they settled down with a standard error between 0.07 and 0.16. When the

number of *C. fluminea* found was low, we increased the number of SUs. From August 2001 to October 2002 (10 samples), all molluscs present in SUs also were collected. For three samples (November 2000 and January and December 2001), density could not be estimated because the high water level of the canal did not allow us to use conventional methods. This condition is generally observed when southerly winds affecting the Rio de la Plata (''sudestadas'') keep the water level high.

Samples for the study on individual growth rate were measured on site by using a 0.01-mm precision caliber. Because the apex of these gastropods is usually damaged by water streams, only the length of last whorl (LWL) was registered. Once measured, gastropods were returned to their natural environment. Data were divided according to size classes of 1-mm intervals. Polymodal size frequency distribution of each sample was carried out before the analysis of growth values. Frequency distributions corresponding to each cohort were fitted to a normal curve, whose mean and standard deviation were calculated. After cohorts were obtained, individual growth rate was analyzed according to length, following the model of von Bertalanffy (1938). This model has been widely applied for studies on planorbid (Gastropoda: Pulmonata) populations either for experimental designs on site, in the laboratory, or under natural conditions (Loreau & Baluku, 1987; Baluku & Loreau, 1989; Ituarte, 1989, 1994; Rumi et al., 2007, 2009). The model is as follows:

$$LWLt = LWLt\infty \left(1 - e^{-k(t - t_0)}\right)$$

$LWL\infty$ = maximum length of last whorl; k = growth rate constant; t = time, and t_0 = hypothetical time in which length = 0.

Time measured for each sample was divided into parts of 1 yr, following Basso & Kher (1991), Rumi et al. (2007, 2009), and Gutiérrez Gregoric et al. (2010), in the equation

$$t = [(month - 1) \times 30 + sampling\ day]/360 + A$$

A = sampling year. The year in which the study starts is considered as $A = 0$, the following year is $A = 1$, and so on. Thus, $t = 0$ corresponds to January 1, $t = 0.5$ corresponds to July 1, and $t = 1$ corresponds to approximately December 31. Maximum length of the whorl was calculated on mean values of cohorts obtained from decomposition, by using the method of Walford (1946).

For growth rate analysis, samples and cohorts with scarce individuals were not taken into account: August 2001 cohort 1 (n = 1), August 2002 (n = 3), October 2002 (n = 2), December 2002 (n = 3), February 2003 (n = 1), March 2003 (n = 1), June 2003 (n = 4), and August 2003 (n = 3). Only means from cohorts started at the time of the sampling were considered; the cohorts with higher values from November 2000 to June 2001 samples were not taken into account also (six samples). A simple regression analysis between both variables was conducted to compare the results obtained with the results expected. A gradient close to 1 and a high R^2 value (also close to 1) showed good correspondence of data.

To compare these data with data from other species or from the same species in different environments, t_0 was considered as zero and growth rate was expressed as percentage of maximum length of last whorl, as reported by Rumi et al. (2007).

RESULTS

Water temperature at the beach reveals a significant seasonal variation; a difference of almost 13°C can be observed between winter and summer average values. Winter average temperature was 11.6°C, and summer average temperature was 24.1°C. Autumn and spring showed similar average values (16.9 and 16.8°C, respectively; Table 1). Water hardness (French degrees) was 49.9 (very hard water).

Mollusc ensembles that accompanied *C. fluminea* in the canal included the gastropods *Heleobia parchappii* (d'Orbigny, 1835) (Coclhiopidae); *Uncancylus concentricus* (d'Orbigny, 1835) (Ancylidae); *Biomphalaria peregrina* (d'Orbigny, 1835; Planorbidae); *Pomacea canaliculata* (Lamarck, 1822; Ampullariidae); and *Physa acuta* Draparnaud, 1805 (Physidae) and the bivalves *Corbicula fluminea* (Müller, 1774; Corbiculidae); *Musculium argentinum* (d'Orbigny, 1835; Sphaeriidae); and *Limnoperna fortunei* (Dunker, 1857; Mytilidae). The highest density is for registered *U. concentricus* (819 individuals ind/m² in October 2002). During October 2001–May 2002, we did not observe oviposition by *C. fluminea* (Table 2). The mean density of *C. fluminea* from November 2000 to September 2003 was 111 ind/m², with a maximum value of 300 for January 2002 and a minimum of 0.25 for June 2003 (Figure 1).

Mollusc distribution in canal substrata varied for the species detected. The vertical walls of the canal were mainly colonized by the invading bivalve *L. fortunei*. The bottom of the canal was colonized by *H. parchappii* and *P. acuta*. Floating branches and other objects in the canal were colonized by *U. concentricus* and *L. fortunei*. *Musculium argentinum* and *Co. fluminea* were found in infaunal environments. *Biomphalaria peregrina* and *P. canaliculata*, both found in low numbers, could not be assigned to any particular area. *Chilina fluminea* was observed in rocky and stony substrates as well as on trunks and vertical walls of the canal. The vertical walls harbored the lowest number of individuals, most of which were found in substrates

Table 1

Mean water quality parameters at La Balandra beach.

Date	Season*	Temperature (°C)	pH	Dissolved O$_2$ (mg/L)	Saturated O$_2$ (%)	Conductivity (μS)	Total dissolved solids (mg/L)
December 2000	Su	19.10	6.48	n/d†	n/d	775	392
January 2001	Su	29.20	s/d	n/d	n/d	802	395
February 2001	Su	24.40	6.39	n/d	n/d	807	384
April 2001	A	18.50	7.14	n/d	n/d	1059	532
May 2001	A	14.33	6.52	n/d	n/d	1289	652
June 2001	W	13.66	6.60	n/d	n/d	1691	847
July 2001	W	10.25	6.49	n/d	n/d	871	411
August 2001	W	12.30	6.63	n/d	n/d	1431	736
September 2001	Sp	11.75	6.40	n/d	n/d	n/d	n/d
November 2001	Sp	22.00	6.92	n/d	n/d	n/d	n/d
January 2002	Su	24.30	6.80	1.30	14.90	732	368
April 2002	A	17.80	6.96	1.90	20.00	875	438
May 2002	A	17.30	6.98	2.71	27.90	1214	606
June 2002	W	7.70	7.04	n/d	n/d	989	497
August 2002	W	12.50	6.77	6.50	77.00	1164	552
October 2002	Sp	18.90	7.17	5.92	63.00	1729	867
November 2002	Sp	19.20	7.01	3.25	34.30	736	370
December 2002	Su	30.25	7.35	10.27	137.00	798	393
February 2003	Su	17.50	6.54	3.88	40.00	432	215
April 2003	A	16.50	7.47	9.70	98.70	377	201
June 2003	W	11.70	6.73	5.15	47.00	1194	603
August 2003	W	13.00	6.88	12.30	114.00	1114	562
September 2003	Sp	11.95	7.06	10.00	91.00	882	439

* A = autumn; Sp = spring; Su = summer; W = winter.

† n/d = no data.

that remained continuously under water even when the Río de la Plata waters receded.

Individuals of smaller size were first found in September (class 2, 1–1.99 mm; Figure 2). Samples from August 2002 and June 2003 contained young individuals, although in low numbers. These times were considered as the start of the reproductive efforts. Individuals in classes 10–12 (9–11.99 mm) were found year-round at similar numbers. From November to June–July (winter season), samples showed no young individuals, indicating the absence of new recruitment.

Polymodal size frequency distributions showed similar results, with two well-defined cohorts (Figure 3). There is only one recruitment period during the year (Figure 3). After we determined polymodal size frequency distributions, individual growth rates were analyzed. Two well-defined cohorts were observed during the sampling period: the first cohort started in 2000 and the second cohort started in 2001 (Figure 4). Cohorts of samples collected during 2002 could not be analyzed because of the low number of individuals in the samples. The start of a new cohort could be observed at the end of the sampling period (September 2003; Figures 3, 4).

Maximum length of the last whorl was estimated at 13.5mm. Thus, the 2000 cohort had a $k = 1.50$ and $t_0 =$

0.58, whereas the 2001 cohort, started during the second sampling year, had $k = 1.63$ and $t_0 = 1.62$. The regression coefficient for both cohorts was >0.9. Consequently, growth rate equations for each cohort are as follows:

$$2000 \text{ Cohort: } LWLt = 13.5 \text{ mm} \left(1 - e^{[-1.5(t-0.58)]}\right)$$

$$2001 \text{ Cohort: } LWLt = 13.5 \text{ mm} \left(1 - e^{[-1.63(t-1.62)]}\right)$$

Because both cohorts started during the same season (winter; similar t_0 values in different years), decomposition data were grouped to follow up the complete growth rate. The smallest modes were considered as year 0 and the highest mode was year 1 (Figure 5). The growth rate curve showed a high regression coefficient ($R^2 = 0.93$) and was defined as follows:

$$LWLt = 13.5 \text{ mm} \left(1 - e^{[-1.52(t-0.58)]}\right)$$

A simple regression analysis between both values was carried out to compare the values observed with the values estimated. This analysis showed a decreasing trend of 0.94 and a high R^2 value (0.97), evidencing the correspondence between observed and expected values.

Maximum length of last whorl percentage of growth

Table 2

Mollusc density (δ; ind/m^2) between July 1 and October 2, including *C. fluminea* oviposition density (ovipositions/m^2). N, total individuals; $\bar{x}$, mean calculated per SU (= 0.01 m^2). SD, standard deviation.

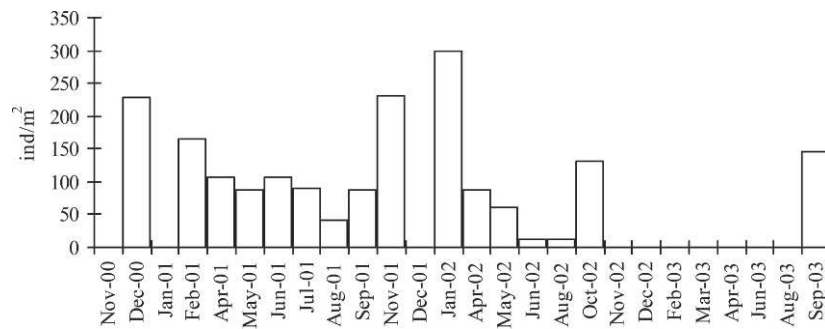| Date	N of SU	Density	*C. fluminea*	Oviposition *C. fluminea*	*H. parchappii*	*U. concentricus*	*L. fortunei*	*P. canaliculata*	*B. peregrina*	*M. argentinum*	*Co. fluminea*	*P. acuta*
August 2001	55	N	24	16	234	159	17	0	1	24	0	1
		$\bar{x}$	0.4	0.3	4.2	2.9	0.3	0	0.02	0.4	0	0.02
		SD	0.6	0.8	22.2	3.8	0.9	0	0.13	2.3	0	0.13
		δ	44	29	425	289	31	0	2	44	0	2
September 2001	63	N	55	58	123	135	174	0	1	0	2	0
		$\bar{x}$	0.9	0.9	2.0	2.1	2.8	0	0.02	0	0.03	0
		SD	0.8	1.5	5.5	2.4	6.3	0	0.13	0	0.2	0
		δ	87	92	195	214	276	0	2	0	3	0
November 2001	39	N	90	0	96	107	200	1	0	1	3	0
		$\bar{x}$	2.3	0	2.5	2.7	5.1	0.03	0	0.03	0.1	0
		SD	2.3	0	6.2	5.0	12.1	0.2	0	0.2	0.3	0
		δ	231	0	246	274	513	3	0	3	8	0
January 2002	36	N	108	0	9	65	68	1	1	0	3	0
		$\bar{x}$	3.0	0	0.3	1.8	1.9	0.03	0.03	0	0.1	0
		SD	2.5	0	0.8	3.3	6.1	0.2	0.2	0	0.4	0
		δ	300	0	25	181	189	3	3	0	8	0
April 2002	50	N	44	0	2	0	119	0	0	0	0	4
		$\bar{x}$	0.9	0	0.04	0	2.4	0	0	0	0	0.1
		SD	0.7	0	0.3	0	7.0	0	0	0	0	0.3
		δ	88	0	4	0	238	0	0	0	0	8
May 2002	67	N	40	3	5	32	276	0	0	0	0	3
		$\bar{x}$	0.6	0.04	0.1	0.5	4.1	0	0	0	0	0.04
		SD	0.7	0.2	0.4	1.0	9.9	0	0	0	0	0.2
		δ	60	4	7	48	412	0	0	0	0	4
June 2002	30	N	4	56	0	93	17	0	0	0	0	0
		$\bar{x}$	0.1	1.9	0	3.1	0.6	0	0	0	0	0
		SD	0.3	2.2	0	5.1	3.3	0	0	0	0	0
		δ	13	187	0	310	57	0	0	0	0	0
August 2002	25	N	3	32	18	82	0	0	3	2	0	58
		$\bar{x}$	0.1	1.3	0.7	3.3	0	0	0.1	0.1	0	2.3
		SD	0.2	1.8	1.2	5.5	0	0	0.2	0.3	0	4.8
		δ	12	128	72	328	0	0	12	8	0	232
October 2002	16	N	21	0	37	131	12	0	0	0	0	41
		$\bar{x}$	1.3	0	2.3	8.2	0.8	0	0	0	0	2.6
		SD	1.2	0	3.4	10.4	1.7	0	0	0	0	4.3
		δ	131	0	231	819	75	0	0	0	0	256

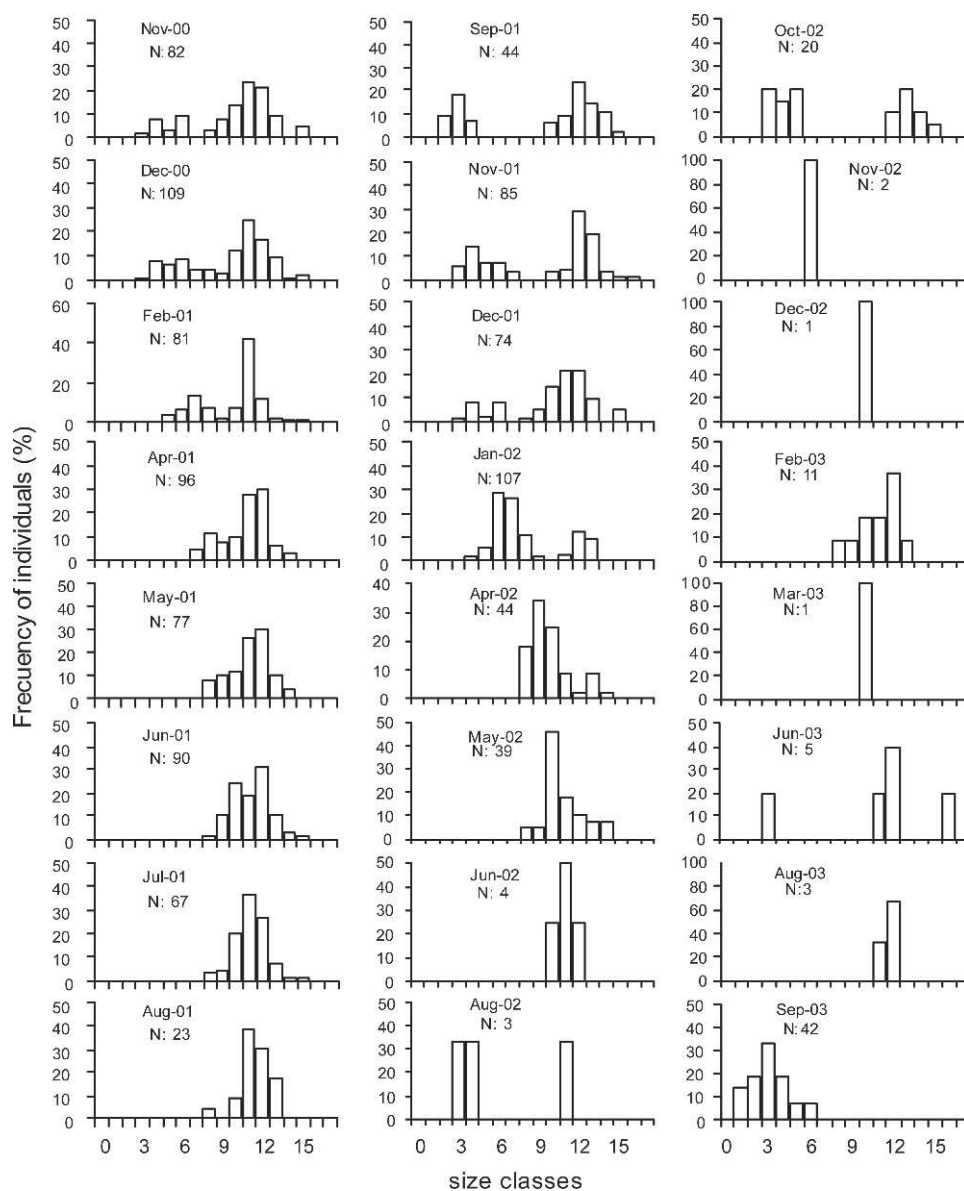Figure 1.   Density of *C. fluminea* at La Balandra beach.

Figure 2. Size–frequency distributions of *C. fluminea*, expressed as percentage of the sample total N, in intervals of 1 mm, along samples at La Balandra beach.

rate is shown in Figure 6. *Chilina fluminea* is observed to reach 78% of its maximum length during the first year of life and 95% after 2 yr. According to samples (Figure 6), life expectancy of this species was estimated as 2.5 yr.

DISCUSSION

In June 2002, the canal selected for samples in this study was dredged, thereby modifying the environment and causing a density decrease in *C. fluminea*. The main reason for this environmental change was the removal

of hard substrates (rocks and trunks) from the bottom of the canal; these substrates served not only as attachment sites for adults but also for oviposition. The removal of the brook gullies and bottom stones turned the substrate soft and the water muddy. These factors had significant influence on the stability of *C. fluminea* populations in the area. As depicted in Figure 1, the population density of this species showed a slight recovery only during the last sampling (September 2003), when young individuals could be observed. But *C. fluminea* was not the only species affected by the transformation of the canal; other
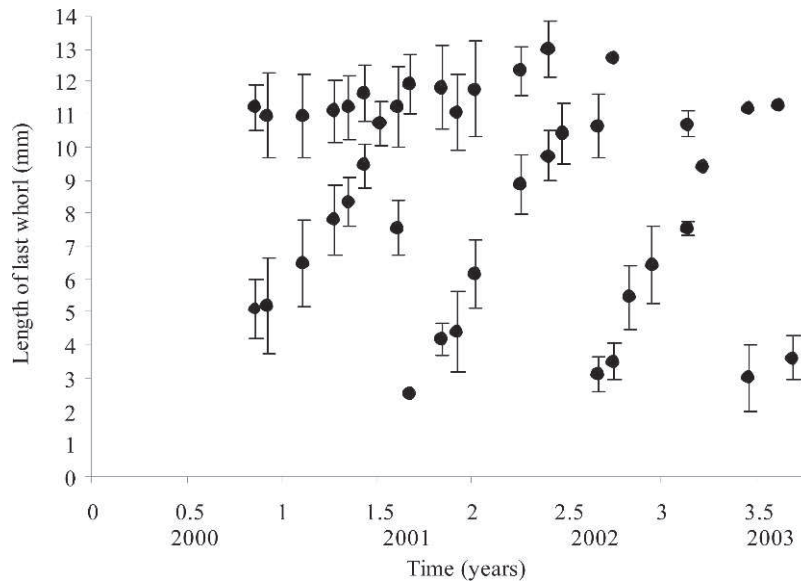
Figure 3.   Means (dots) and standard deviations (bars) of the normal curves fitted to each monthly shell-size frequency distribution.

molluscs inhabiting these hard substrates also were affected. For example, *L. fortunei*, an Asian mussel invading South American coasts (Darrigran & Pastorino, 1995), and *H. parchappii* showed significantly decreased density after these environmental changes. However, their population recovery proved to be faster than that of *C. fluminea* (Table 2). These environment disturbances allowed foreign species and those not

previously sampled to inhabit the substrate. Thus, the exotic species *P. acuta* showed highly increasing density (230 ind/m^2) and *U. concentricus* increased its average density from 250 to 850 ind/m^2.

Alternatively, the highest density for *C. fluminea* in this environment was recorded during January 2002 (300 ind/m^2) when the temperature reached 24°C. Similar findings were reported by Quijon & Jaramillo
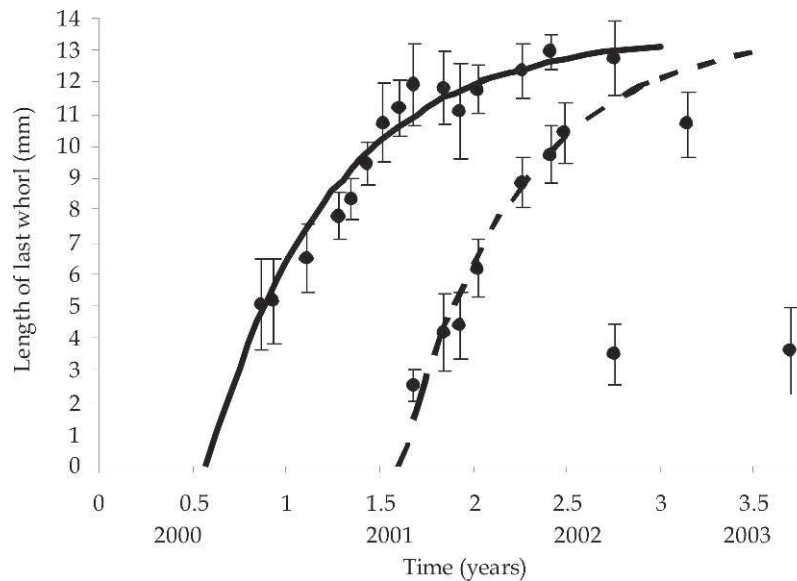

Figure 4.   Individual growth for *C. fluminea* in La Balandra beach. Dots represent means observed; bars represent standard deviations. Continuous line represents the theoretical growth curve for the 2000 cohort; broken line represents the theoretical growth curve for the 2001 cohort.
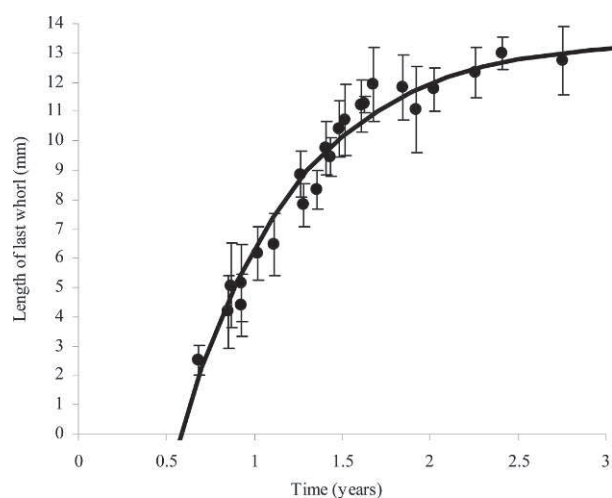
Figure 5. Growth curve for two *C. fluminea* cohorts in La Balandra beach. Dots represent means observed; bars represent standard deviations. The line represents that theoretical growth curve according to the von Bertalanffy model.

Figure 6. Growth of *C. fluminea* expressed as percentage of maximum length of the last whorl.

(1999) and Quijon et al. (2001) for southern Chile (Lingue River estuary, 39°41′S, 73°13′W), where the highest density values for *C. ovalis* were recorded during January and March, respectively (March temperature, 20°C).

The analysis of *C. fluminea* growth rate showed that the t_0 value corresponded to July. This indicates that the reproduction cycle of this species is limited to winter (June–August), when water temperature descends. These findings agree with those from other studies carried out on the same species inhabiting the same areas (Miquel, 1986).

According to Bosnia et al. (1990), *C. gibbosa*, a species found in Ramos Mexia dam (Río Negro and Neuquén provinces, southern Argentina), reproduces only once a year during the summer. They proposed a sigmoid growth formula for this species in two dam sites; in one of these sites, the cohort starts with 3.39 mm individuals, although at hatching they are usually 0.8 mm in length. In contrast, Gutiérrez Gregoric et al. (2010) concluded that *C. megastoma*, a species found in the Iguazu National Park (Misiones province, Argentina), may reproduce continually because of the low temperature variation throughout the year. However, for *C. megastoma*, its best reproductive period is when temperatures are approximately 15°C, similar to that encountered by *C. fluminea* in La Balandra beach (near 12°C).

Quijon & Jaramillo (1999) and Quijon et al. (2001) also reported a unique annual reproduction period for *C. ovalis* during spring (October, 15–18°C). It is important to emphasize that during winter (approximately 10°C), these authors did not detect any *C. ovalis*
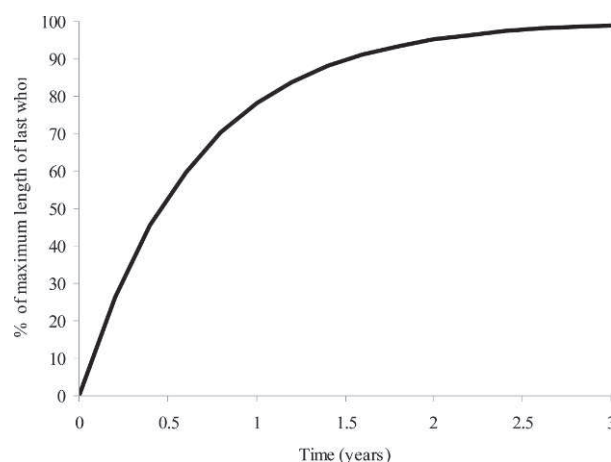
in the samples. Quijon et al. (2001) suggested a growth rate formula including a winter delay, with both cohorts first appearing in October (1996 and 1997), with similar growth rate constants, and delay values (growth stoppage) between June and July. In *C. fluminea* this delay was not observed.

Data analyses estimated life expectancy for *Chilina ovalis* in the Lingue river is approximately 3.5 yr (Quijon et al., 2001), for *C. megastoma* is approximately 2 yr (Gutiérrez Gregoric et al., 2010), and 2.5 yr for *C. fluminea* (present study). *Chilina ovalis* and *C. gibbosa* growth rates were similar and lower than those found in the present study. This could be due to the low winter temperature and to the longevity of these two species (3.5 yr); they present a maximum length substantially higher than that of *C. fluminea* (*C. ovalis*, 29 mm; *C. gibbosa*, 26.5 mm). In contrast, *C. megastoma* inhabiting subtropical climates had higher growth rates ($k = 1.46$–1.96) than *C. fluminea* and reached a higher LWL (18.47 mm).

Moreover, none of the freshwater gastropods from other families studied in Argentina reproduce during winter, regardless of the number of reproductive events of the species: *Drepanotrema kermatoides* (d'Orbigny, 1835) and *Drepanotrema cimex* (Moricand, 1839) (Planorbidae) in Isla Martín García, Río de la Plata (Rumi et al., 2007) have one reproductive event per year; *Drepanotrema lucidum* (Pfeiffer, 1839), *Drepanotrema depressisimun* (Moricand, 1839), and *Biomphalaria occidentalis* (Paraense, 1981) in the province of Corrientes (northeastern Argentina) have more than one reproductive event per year (Rumi et al., 2007, 2009); *Biomphalaria tenagophila* (d'Orbigny, 1835) and *Biomphalaria straminea* (Dunker, 1848) in Salto Grande dam (northwestern Uruguay) have two or more reproductive events per year (Ituarte, 1989, 1994); *B. tenagophila* in La Balandra beach has two or more

reproductive events per year (Rumi et al., 2009); *B. tenagophila* in Atalaya beach (Buenos Aires province) has one reproductive event per year (Rumi et al., 2009); and *B. peregrina* in Punta Lara (Buenos Aires province) has two reproductive events per year (Rumi et al., 2009). All these species inhabit lentic environments, and in very few cases they coinhabit with *C. fluminea*, one reason why it would be necessary to discard that competition exists for niches among these species, and to only be limited to a reproductive strategy.

Planorbid species usually grow faster than chilinid species because, although distributed on all of the continents, their development is significantly improved by warm water. In contrast, the highest number of well-adapted chilinid individuals can be found in the Argentinean Patagonia and southern Chile. Furthermore, average time between oviposition and hatching is shorter for Planorbidae (10 days; Rumi, 1993) than for Chilinidae (28 days; D.E.G.G., personal observations).

It is worthwhile to notice that controls for parasite infection are usually assessed during spring, before the tourist season. The appropriate time for the design of growth regulation strategies for *C. fluminea* populations is autumn (April–May), before their reproductive cycle and oviposition.

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