

DISTRIBUTION, POPULATION STRUCTURE AND CONSERVATION OF *AUSTROPOTAMOBIUS PALLIPES* IN PORTUGAL.

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ABSTRACT

Austropotamobius pallipes has suffered a considerable reduction in range and abundance over the last two decades. The main hypotheses to explain this situation are : environmental degradation, critical climatic conditions, and the crayfish plague, though the presence of *Aphanomyces astaci* as the aetiological agent is to be confirmed. White-clawed crayfish populations are now confined to a few small areas in the north-eastern part of the country and risk total extinction. Population characteristics are presented. Sex ratio is balanced and maximum size is small, very few individuals being larger than 75 mm. Four age-classes were identified through modal analysis. Females become sexually mature during the second year. Several conservation actions are proposed.

Key-words : *A. pallipes*, distribution, conservation, population structure, Portugal.

DISTRIBUTION, STRUCTURE DES POPULATIONS ET CONSERVATION D'*AUSTROPOTAMOBIUS PALLIPES* AU PORTUGAL.

RÉSUMÉ

Austropotamobius pallipes a souffert, depuis une vingtaine d'années, d'une réduction de son aire de répartition et de son effectif. Plusieurs hypothèses ont été proposées pour expliquer cette régression : dégradation des écosystèmes, conditions climatiques extrêmes et l'aphanomycose, dont la présence, cependant, n'a pas été confirmée. La population d'*Austropotamobius pallipes* est aujourd'hui limitée à quelques cours d'eau dans le nord-ouest du Portugal et risque l'extinction totale. Une brève caractérisation populationnelle est présentée. Le sexe ratio est équilibré et la taille maximum est petite, peu d'individus dépassant 75 mm. Quatre classes d'âge ont été définies par analyse modale. Les femelles deviennent adultes pendant la deuxième année. Plusieurs actions de conservation sont proposées.

Mots-clés : *A. pallipes*, distribution, conservation, structure des populations, Portugal.

INTRODUCTION

Previous distributions

Distribution in 1970's

Until mid 1970's, most of the Portuguese populations of *Austropotamobius pallipes* were confined to the north-eastern part of Portugal, Trás-os-Montes. In this area, the species was common in part of the Sabor river catchment, a tributary of the Douro river, particularly the Angueira river, where crayfish were abundant and traditionally fished by the local population. The occurrence of the species was also noticed (CORREIA, pers. comm.) in the Sever river, a tributary of the Tagus river, as a result of introduction in the late 1960's, and in Cértima stream, a small tributary of the Vouga river (Figure 1 A). Specimens were probably brought to Cértima from France (ALMAÇA, 1990).

From 1977 to 1979, some attempts were made by the Divisão de Ordenamento de Recursos Aquícolas, the National Inland Fisheries Authority, to extend the distribution by means of stocking new streams or restoring declining / extinct populations (CORREIA, 1981, and pers. comm.) :

- upper part of the Douro Portuguese catchment : the Azibo, Teja, Côa, Massueime (a tributary of the Côa) and Aguiar streams ;
- Mondego catchment : the Corvo stream ;
- Tagus catchment : the Alge stream and the Sever river.

Distribution in 1980's

The results of the stocking programme were evaluated, from 1983 to 1986, through sampling in several streams (ALMAÇA, 1990). Some of the stocking attempts succeeded but, in late 1986, most of the populations had disappeared and only two were found : in the Azibo river and in the Alge stream (Figure 1 B).

Even in the Angueira river, where a large population existed till then showing no sign of regression, the white-clawed crayfish had totally disappeared. Several causes could explain this situation : loss of habitats, water pollution, sand extraction from the river-beds, climatic constraints. But, as most north-eastern populations disappeared in a sudden way, other hypotheses should be considered. ALMAÇA (1990) refers to the possible effects of the strong summer rain, in 1986, draining significant levels of pesticides from agricultural areas into the water. Local people described a mass mortality occurring in a few weeks "as if the water had been poisoned". The description suggests the presence of the crayfish plague, caused by *Aphanomyces astaci*. CORREIA *et al.* (1996) report the observation, in the late spring of 1986, of symptoms that might be related to this disease, although no attempts to isolate the pathogen were made, and relate the disappearance of *A. pallipes* to the presence of *P. clarkii*, as the probable vector of the fungus, in the catchments.

Considering the importance of the species and as no recent data were available, the Instituto da Conservação da Natureza, the Nature Conservation Agency, decided in 1994 to promote a general survey. The purposes were (i) distribution in Portugal, (ii) main population characteristics and (iii) assessment of the conservation status.

METHODS

Several strategies were used for the detection of crayfish occurrence : electrofishing (12 V battery, 350-500 V, 10 kW/impulse, 50-80 Hz of impulse frequency), observation of crayfish remains in otter (*Lutra lutra* L.) faeces, and observation of crayfish *exuviae* and exoskeleton fragments. Field work to evaluate the current distribution took place from March 1994 to October 1995. An additional sampling in Azibo river was carried out on June 4th 1996 to evaluate the age structure.

Densities were estimated using a removal method with electrofishing. Estimates were obtained from two successive electrofishings with the same fishing effort (method by DE LURY, 1947) in isolated sections. With the first (m) and the second (n) captures, population estimate (N) is given by $N = m^2 (m-n)^{-1}$ if the capture data fit the following assumptions of the model : $m > n$ and $m^2(m-n)^2 n^2(m+n)^{-1} > 16$. Variance of the population estimate was computed as $var(N) = m^2 n^2 (m+n) (m-n)^{-4}$ (ROBSON and REGIER, 1971). Breaks between the first and the second captures lasted 30 min. All crayfish captured were measured in the field for total length to the nearest 0.1 cm, sexed and returned to the water after the end of the complete fishing operations.

Age-classes were estimated with modal analysis according to HARDING (1949) and CASSIE (1950), which is based on the analysis of polymodal frequency distributions by the probability paper method. ANAMOD software (NOGUEIRA, 1992) was used and G test was performed as a goodness of fit test (SOKAL and ROHLF, 1987).

RESULTS AND DISCUSSION

Present distribution

As the result of the national survey, populations of white-clawed crayfish were detected only in two streams, both parts of Sabor catchment : Azibo and Tortulhas (Figure 1 C). The regression observed since 1970's is therefore confirmed. *A. pallipes* populations present today a very restricted distribution.

The disappearance of *A. pallipes* in the Sever river is apparently related to the colonisation by the red swamp crayfish, *Procambarus clarkii*. Since its introduction, in late 1970's, *P. clarkii* has rapidly expanded and is now present in most inland waters of Portugal. After the invasion by this exotic species, the white-clawed crayfish, less aggressive and resistant, totally disappeared from the Sever river.

Procambarus clarkii occurs in the Douro river but in the north-eastern region (Trás-os-Montes), dams, natural accidents and, possibly, a climatic barrier contributed to control the expansion of the species. Cold winters are not suitable for *P. clarkii*, in spite of the well-known thermal tolerance of this subtropical species. Following the extinction of the native crayfish in the Angueira river, local inhabitants brought some *P. clarkii* specimens, trying to replace their lost fishery. Some crayfish survived and reproduced, but the density in Sabor and Angueira rivers is low (only 3 specimens were captured in both rivers). No individuals of this exotic species were detected in the Azibo river or in the Tortulhas stream.

Briefly, *A. pallipes* faces today a very critical situation in Portugal. Distribution is extremely restricted and, as a taxon in danger of extinction, the conservation category "endangered" should be assigned.

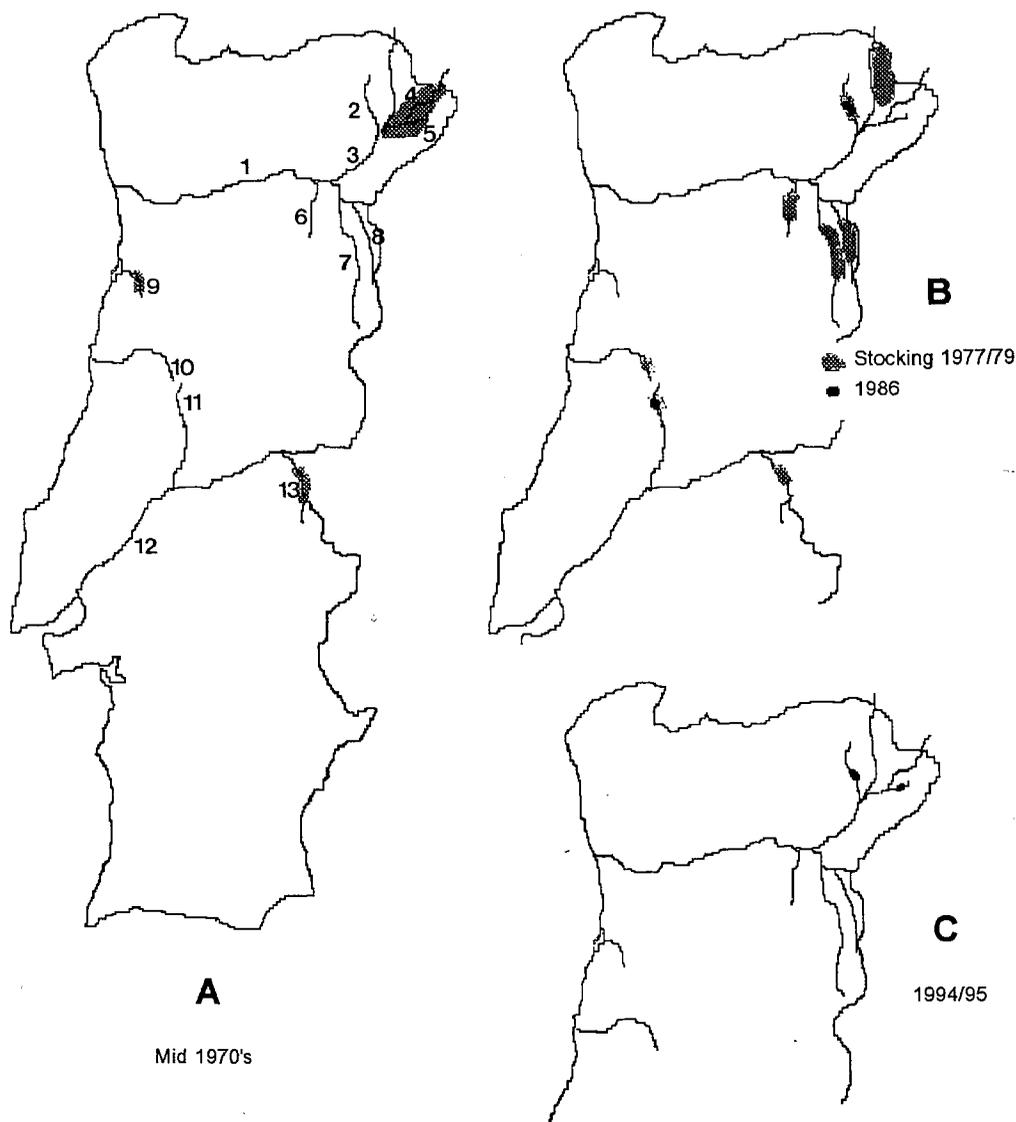


Figure 1

Changes of distribution of *Austropotamobius pallipes* : A - distribution in mid 1970's ; B - stocking areas (1977-79) and distribution in 1986 (according to observations by ALMAÇA, 1990) ; C - distribution in 1994/95. Identification of rivers : 1 - Douro, 2 - Azibo, 3 - Sabor, 4 - Angueira, 5 - Tortulhas, 6 - Teja, 7 - Côa, 8 - Aguiar, 9 - Cértima, 10 - Corvo, 11 - Alge, 12 - Tagus, 13 - Sever.

Figure 1

Evolution de la distribution d'*Austropotamobius pallipes* : A - distribution dans les années 70 ; B - aires de repeuplement (1977-79) et distribution en 1986 (d'après les observations d'ALMAÇA, 1990) ; C - distribution en 1994/95. Identification des cours d'eau : 1 - Douro, 2 - Azibo, 3 - Sabor, 4 - Angueira, 5 - Tortulhas, 6 - Teja, 7 - Côa, 8 - Aguiar, 9 - Cértima, 10 - Corvo, 11 - Alge, 12 - Tage, 13 - Sever.

General characteristics of the rivers in the segments where *A. pallipes* occurs

The Azibo river (UTM grid reference PF79) and the Tortulhas stream (UTM grid reference QF19) are both unpolluted permanent lotic systems. Average annual precipitation in this region is 750 mm and the dry period usually lasts for 4 months. Catchments have no major point source pollution and are mostly occupied by pasture, forest and some agricultural land ; population density is low.

The Azibo is a third-order river with about 7 m width and 50 cm average depth. Altitudinal distribution has a range from 290 to 360 m and mean distance from spring is 29 km. Riparian vegetation, mainly composed of alders, *Alnus glutinosa*, produces a strong shadowing effect. Conductivity ranges from 75 to 250 $\mu\text{S}/\text{cm}$.

The Tortulhas, a small tributary of the Angueira river, is a first-order stream with approximately 1.5 m width and 15 cm average depth. Crayfish location is 6 km from the spring and its altitude is about 600 m. Conductivity ranges from 95 to 160 $\mu\text{S}/\text{cm}$.

Population structure

Density estimation, sex ratio, maximum size (total length, TL) for males and for females, and percentage of females longer than 50 mm in Azibo (N^a Sra. Balsemão, near Chacim) and Tortulhas (near Fonte de Ladrão) populations are presented in Table I.

Estimated density for the small Tortulhas stream is 11.32 ind./m² and for the Azibo river is 1.68 ind./m². For the Tortulhas the evaluation was performed in October, when the young of the year were already being captured and represented the larger part of the population. The Azibo population was evaluated in March, during the reproductive period, when recruitment had not yet taken place and part of the ovigerous females might stay in refuges, thus avoiding capture. However this estimate was considered as the most reliable one, as in other periods high turbidity or current velocity significantly affected the fishing procedures. The Azibo is a much larger river and crayfish tend to prefer littoral habitats with exposed roots, which means a large part of the river-bed has a low occupation.

Average sex ratio in both populations is balanced, slightly in favour of females (Table I) but not significantly different from 1 : 1 (X^2 test, in both cases $0.5 < P < 0.9$).

Table I

Density estimation, sex ratio, maximum length and percentage of females longer than 50 mm of *A. pallipes* from Azibo river and Tortulhas stream.

Tableau I

Estimation de la densité, du sexe ratio, de la taille maximum et du pourcentage de femelles de taille supérieure à 50 mm pour les populations d'*A. pallipes* des rivières Azibo et Tortulhas.

Population characteristics	Azibo population	Tortulhas population
Population density (ind./m ²) (95% conf. limits)	1.68 ± 0.55 (March 1994)	11.32 ± 4.18 (October 1995)
Average sex ratio (M : F)	1 : 1.05	1 : 1.18
Max. total length (mm)		
Males	79	71
Females	87	68
Percentage of females with total length > 50 mm	14.8	15.6

Average size is small and most of both populations is composed of the younger cohort. Maximum crayfish size is small if compared to the Azibo population in 1986 (102 mm, ALMAÇA, 1989) or to other populations (e.g. ARRIGNON and MAGNE, 1978 ; ROQUEPLO, 1983 ; REYNOLDS and MATTHEWS, 1993). Illegal fishing is a possible explanation.

Ovigerous females were captured in February and April but not in early November nor in early June. Total length ranges from 53 to 65 mm and the number of eggs of each ovigerous female apparently shows no relation to the length : 53 mm - 22 eggs, 59 mm - 30 eggs, 59 mm - 105 eggs, 60 mm - 60 eggs, 65 mm - 15 eggs. However, the number of captured ovigerous females is very small and a larger number and a wider length range would be necessary to evaluate the relation length - number of eggs.

The proportion of females bigger than 50 mm was calculated. During the reproductive season, all the non ovigerous females were smaller than 50 mm and so all females longer than 50 mm were considered as sexually mature or pre-mature. Approximately 15 % of the total populations are composed of adult and sub-adult females. This means that, although maximum length is small (very few specimens are longer than 75 mm), these populations present actual reproductive potential.

Age structure was evaluated by modal analysis for the Azibo population. Figure 2 presents the frequency distributions and the identification of cohorts for males (G test = 17.77, df = 13, P > 0.05) and females (G test = 22.82, df = 19, P > 0.05). Total length (\pm SD) averages for male age-classes were 44.8 (\pm 5.8) mm for 1⁺ (second year of life), 62.3 (\pm 4.5) mm for 2⁺, and 74.5 (\pm 2.7) mm for 3⁺. For females, TL average for each class was 38.2 (\pm 5.1) mm, 51.3 (\pm 6.2) mm, and 70.1 (\pm 6.6) mm. The 0⁺ class is not present in the frequency distributions. Modal analysis was performed on early June data ; the recruitment took place some days or weeks before and the independent juveniles are small enough not to be captured by electrofishing. Population is composed by four age-classes and female maturity is reached during the second year.

FENOUIL and CHAIX (1992) reported a life-span of 7 years or more and ZEKHNINI and CHAISEMARTIN (1991) of 5 to 6 years. The short number of age-classes observed in the Azibo may have two possible explanations : (i) under-evaluation caused by the small number of individuals in the older groups or (ii) illegal fishing actually decreasing the maximum size and number of age-classes. The longevity is apparently short but the sexual maturation is precocious if compared to other studies, e.g. 3⁺ and 70 mm reported by FENOUIL and CHAIX (1992). This early maturation has a positive effect on the persistence of the existing populations and on the implementation of stocking actions.

Plan of action for conservation

Considering the current status of *A. pallipes* in Portugal, a plan of action is proposed :

- (re)stocking rivers where *A. pallipes* previously occurred, particularly the Angueira, and new ones, if and where environmental conditions are suitable ;
- fishing interdiction, with the agreement of the local fishing associations, and until a significant change in the conservation status is observed ;
- total interdiction of any introduction of trout, pike or other predators in the catchments with, or to be stocked with, *A. pallipes* ;
- interdiction of sand extraction from the river-bed and destruction of the riparian vegetation and no licensing of any polluting activities in the catchments with, or to be stocked with, *A. pallipes* ;

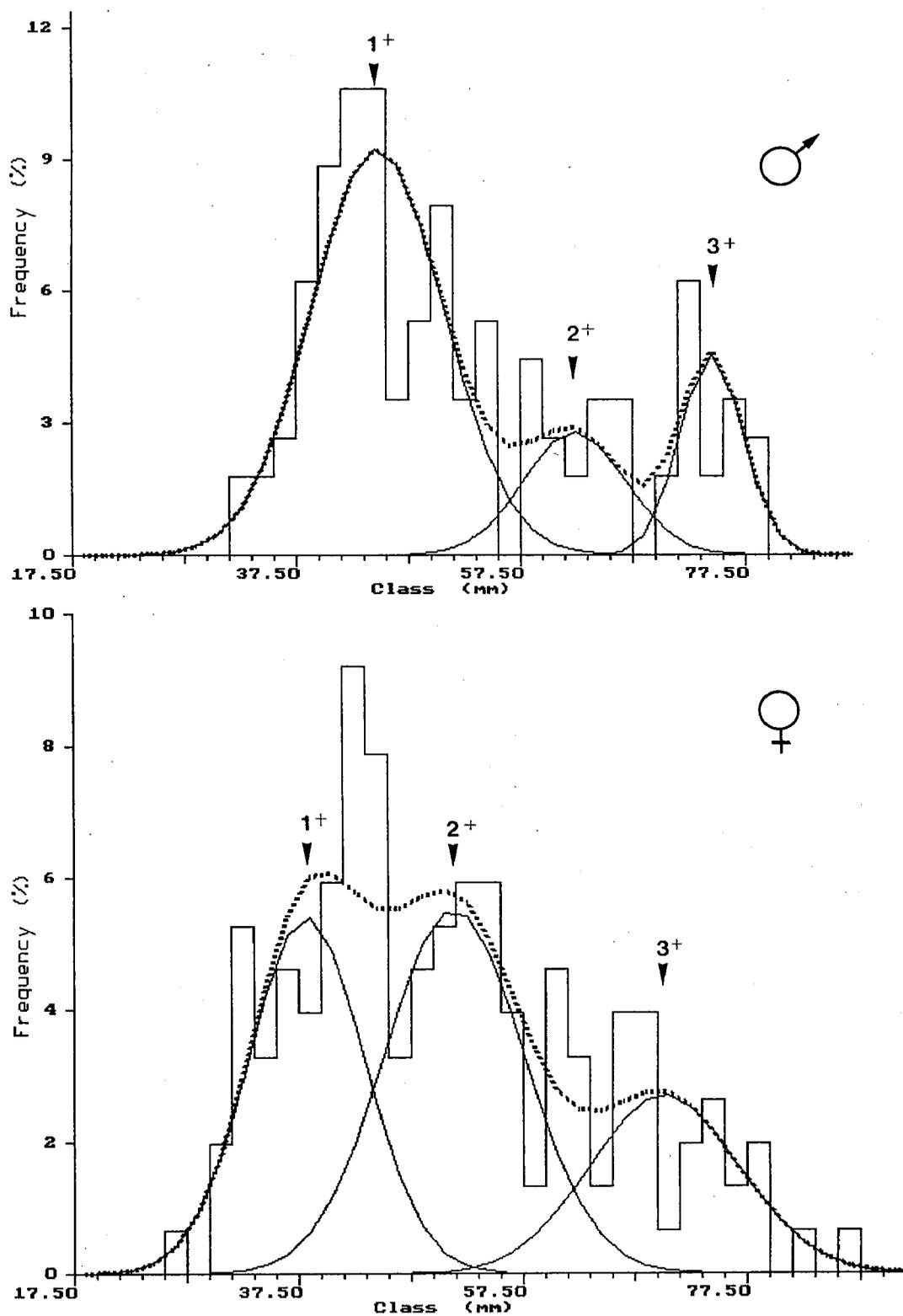


Figure 2
Frequency distribution and indication of age-classes for males and females in Azibo river on June 4th, 1996.

Figure 2
Distribution de fréquences et indication des classes d'âge pour les mâles et les femelles de la rivière Azibo, le 4 juin 1996.

- monitoring program to (i) follow the existing populations, (ii) evaluate the results of the (re)stocking actions, (iii) assess the distribution of *P. clarkii*, and (iv) detect any occurrence of the crayfish plague ;

- inclusion in NATURA 2000 proposal or assignment of Site of Special Interest to the present areas of occurrence and areas to be stocked.

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REFERENCES

- ALMAÇA C., 1989. On the biology of north-eastern Portuguese populations of *Austropotamobius pallipes* (Lereboullet, 1858). *Arquivos do Museu Bocage, Nova série 1(29)*, 419-428.
- ALMAÇA C., 1990. Recursos animais e sua conservação : as populações portuguesas do lagostim-de-rio, *Astacus pallipes* Lereboullet, 1858. Museu Nacional de História Natural, 3-22.
- ARRIGNON J., MAGNE P., 1978. Population d'écrevisses (*Atlanto-Astacus pallipes pallipes* Lereboullet) d'un ruisseau de Lozère - France. *Freshwater Crayfish*, 4, 131-140.
- CASSIE R.M., 1950. The analysis of polymodal frequency distributions by the probability paper method. *N.Z. Sci. Rev.*, 8, 89-91.
- CORREIA M.P., 1981. O lagostim de água doce na bacia hidrográfica do Rio Douro. Ciclo de palestras da Associação Portuguesa de Recursos Hídricos, 20-23.
- CORREIA M.P., BRUXELAS S., MAIA A., 1996. Contribuição para a recuperação das populações de lagostim-de-pés-brancas (*Austropotamobius pallipes* Lereboullet) na bacia hidrográfica do Sabor. Internal Report, Instituto Florestal, Lisboa, 16 p.
- DE LURY D.B., 1947. On the estimation of biological populations. *Biometrics*, 3, 145-167.
- FENOUIL E., CHAIX J.C., 1992. Mise au point d'un modèle théorique de dynamique des populations d'*Austropotamobius pallipes* après un repeuplement en eau courante. *Crustaceana*, 62, 65-70.
- HARDING J.P., 1949. The use of probability paper for the graphical analysis of polymodal frequency distributions. *J. Mar. Biol. Ass., U.K.*, 28, 141-153.
- NOGUEIRA A.J.A., 1992. ANAMOD - Extração dos componentes modais de distribuições de frequências de variáveis biométricas. Faculdade de Ciências e Tecnologia, Universidade de Coimbra, 67 p.
- REYNOLDS J.D., MATTHEWS M.A., 1993. Experimental fishing of *Austropotamobius pallipes* (Lereboullet) stocks in an Irish midlands lake. *Freshwater Crayfish*, 9, 147-153.
- ROBSON D.B., REGIER H.A., 1971. Estimation of population number and mortality rates. In RICKER W.E. (ed.), *Methods for assessment of fish production in freshwaters*, 131-165, Blackwell, Oxford.
- ROQUEPLO C., 1983. Etudes de populations naturelles d'écrevisses (*Austropotamobius pallipes* Ler.) dans le sud-ouest de la France. CEMAGREF, Bordeaux, 173 p.
- SOKAL R.R., ROHLF F.J., 1987. Introduction to biostatistics. 2nd ed. W.H. FREEMAN and Co., New York, 363 p.
- ZEKHINI A., CHAISEMARTIN C., 1991. Structure démographique et éthologie alimentaire de l'écrevisse pallipède (*Austropotamobius pallipes*) dans quatre cours d'eau. *Vie Milieu*, 41, 45-53.