A SURVEY OF THE WHITE-CLAWED CRAYFISH, *AUSTROPOTAMOBIUS PALLIPES* (LEREBOULLET), AND OF WATER QUALITY IN TWO CATCHMENTS OF EASTERN IRELAND.

A. DEMERS (1), J.D. REYNOLDS (2)

(1) Department of Zoology, Trinity College Dublin, DUBLIN 2, Ireland. E-mail : demersa@tcd.ie

(2) Department of Zoology, Trinity College Dublin, DUBLIN 2, Ireland. E-mail : jrynolds@tcd.ie

Reçu le 05 novembre 2001 *Received 05 November, 2001*
Accepté le 21 février 2002 *Accepted 21 February, 2002*

ABSTRACT

The white-clawed crayfish, *Austropotamobius pallipes* (Lereboullet), is the only crayfish species found in Ireland. Because of the prohibition on importation of exotic species of crayfish onto the island and of its relatively clean rivers up to now, Ireland has kept an abundant population of crayfish. A survey was conducted in the catchments of the Liffey and Boyne rivers, in eastern Ireland to assess water quality and to sample crayfish populations. The aim of the study was to evaluate the water quality requirements of the white-clawed crayfish in Ireland. Baited traps and nets were used to sample crayfish while water quality was measured with biological indices calculated from samples of macroinvertebrates. Distribution of this crayfish species is patchy in the Liffey catchment and seems to be related to factors such as soil types and water quality. They were not found in the downstream part of the river Liffey possibly due to poor water quality. In the Boyne catchment, no crayfish were found in most of the catchment. They were only present in the Kells Blackwater subcatchment. This may be due to an earlier outbreak of the fungal plague caused by *Aphanomyces astaci.* The disease was discovered in lakes at the top of some of the tributaries of the Boyne in 1987 and it probably spread from there through the whole catchment.

Key-words : white-clawed crayfish, *Austropotamobius pallipes*, water quality, biological indices, crayfish plague.

ÉTUDE DES POPULATIONS D'ÉCREVISSES À PATTES BLANCHES, *AUSTROPOTAMOBIUS PALLIPES* (LEREBOULLET), ET DE LA QUALITÉ DE L'EAU DANS DEUX BASSINS HYDROGRAPHIQUES DE L'EST DE L'IRLANDE.

RÉSUMÉ

L'écrevisse à pattes blanches, *Austropotamobius pallipes* (Lereboullet), est la seule espèce d'écrevisse trouvée en Irlande. Grâce à l'interdiction d'importation des espèces d'écrevisses exotiques sur l'île et grâce au maintien d'un certain niveau de qualité de l'eau dans ses rivières, l'Irlande possède une abondante population d'écrevisses à pattes

Article available at http://www.kmae-journal.org or http://dx.doi.org/10.1051/kmae:2002062

blanches. Une étude a été réalisée dans deux bassins hydrographiques de l'est de l'Irlande, ceux du fleuve Liffey et du fleuve Boyne, pour évaluer la qualité de l'eau des rivières ainsi que les populations d'écrevisses. Le but de cette étude était de déterminer les besoins en qualité d'eau d'*A. pallipes*, en Irlande. Des nasses (avec appâts) et des filets ont été utilisés pour l'échantillonnage des écrevisses. Des indices biologiques de qualité d'eau ont été calculés à partir d'échantillons d'invertébrés. La distribution géographique de la population d'écrevisses dans le bassin du fleuve Liffey est discontinue et peut s'expliquer par des facteurs environnementaux tels le type de sol drainé et la qualité de l'eau. Aucune écrevisse n'a été détectée dans la moitié aval du fleuve Liffey, probablement à cause de la mauvaise qualité de l'eau. Les écrevisses sont restées introuvables dans la majeure partie du bassin du fleuve Boyne. Elles n'ont été trouvées que dans le bassin de la rivière Blackwater (Kells), tributaire du fleuve Boyne. La peste de l'écrevisse, *Aphanomyces astaci*, pourrait être responsable de la perte des populations dans le bassin du fleuve Boyne. Cette maladie a été diagnostiquée en 1987 sur un individu trouvé dans le lac Lene, source d'un des affluents du fleuve. Il est fort possible qu'à partir de ce lac, la maladie ait contaminé presque toutes les populations du bassin.

Mots-clés : écrevisses à pattes blanches, *Austropotamobius pallipes*, qualité de l'eau, indices biologiques, peste de l'écrevisse.

INTRODUCTION

The white-clawed crayfish, *Austropotamobius pallipes* (Lereboullet), is Ireland's only species of freshwater crayfish. It is also found in Great Britain and western and southern continental Europe (HOLDICH and LOWERY, 1988; LAURENT, 1988). Irish crayfish are mostly found in the midland region where limestone soils provide good alkalinity levels for crayfish survival (LUCEY and MC GARRIGLE, 1987; REYNOLDS, 1982). They are found in streams and rivers, usually with rocky substrates; a number of lake populations also exist (*e.g.* Lough Lene, Co. Westmeath; REYNOLDS, 1988).

In most of its range, this species is in decline, threatened by diseases brought by introduced species, and by pollution (HOLDICH and LOWERY, 1988). The white-clawed crayfish is listed in Annex 2 of the EU Habitat Directive. It is protected in most European countries in which it occurs and in Ireland, it is also protected under the Irish Wildlife Act (1976). The Irish stock is still abundant and widely distributed compared to stocks in other parts of the geographical range of *A. pallipes*, mostly because American crayfish, carriers of the crayfish plague fungus *Aphanomyces astaci* (Shikora), were never introduced to the island (REYNOLDS, 1997). Although the fungal plague was introduced to Ireland in the 1980s (MATTHEWS and REYNOLDS, 1990), the Irish population remains largely untouched by the disease and can thus act as a reserve stock in terms of conservation efforts at the European level.

Ireland's rivers are still unpolluted in the majority, but repeated national surveys (for example LUCEY *et al.*, 1999) indicate that while toxic pollution is now rare, moderately polluted rivers are becoming more numerous. This degradation could be a threat to the health of the crayfish population.

During summer 2000, a survey was conducted to assess population status of the white-clawed crayfish in the Liffey and Boyne catchments, and to assess water quality. These two catchments of Eastern Ireland were known to contain crayfish (LUCEY and MC GARRIGLE, 1987). The river Liffey is approximately 130 km long and the catchment covers an area of 2 120 km^2. The river Boyne is 85 km long and the tributaries included in this project are, in total, more than 160 km long. Together they drain a catchment area of about 2 500 km^2.

MATERIAL AND METHODS

Thirty-three sites were visited in both hydrographic basins, 14 in the Liffey catchment and 19 in the Boyne catchment, from mid-June to mid-September, 2000. Each site was sampled only once.

On the first visit, a physical description of the site was made (flow, width, substrate) and chemical measurements were recorded. Conductivity, temperature and pH were measured with probes (Metler-Toledo AG Check Mate 90) and recorded. Flow was estimated by timing the passage of a neutrally buoyant marker. Width was estimated and a visual assessment of the substrate and quantity of vegetation present in the river and on the banks was performed. Depth was also measured at three different trap sites in the river. Chemical measurements, as well as flow rate, were recorded thrice at each site. Surrounding vegetation (tree roots, reeds), possible disturbance (weirs, bridges, litter, drains) or other interesting features of each site (*e.g.* otter presence, fish) were noted

Traps and nets were used to sample the crayfish population. Each technique targets a different size range; only adults are caught in traps while juveniles may be caught by net sampling.

Ten Swedish « August™ » traps were set at each site, extending over approximately 25 meters of the banks; they were usually attached in pairs to the bank. Traps were baited with liver and weighted with rocks. The traps were lifted two days later and any crayfish found was sexed, measured (carapace length in mm) and weighed. All individuals were then released. A fifteen minutes sampling was also conducted at each site using a hand net (0.06 cm^2 aperture and 1 mm mesh size), searching under stones and in vegetation. All individuals captured by net were also measured (carapace length), weighed and sexed when possible. Catch per unit effort (CPUE) was calculated for both traps and net sampling. CPUE for the traps represents the total number of crayfish caught divided by the number of traps used. For net sampling, CPUE represents the total number of individuals caught divided by the time spent sampling (which was a standard of fifteen minutes), *i.e.* crayfish per minute.

Three invertebrate samples were also taken at each site. Each sample was obtained with a ten seconds « kick » sample. Rocks and vegetation were disturbed by the feet along a one meter transect for ten seconds, and the water carrying organisms and detritus flowed through a 0.06 cm^2 net (1 mm mesh size) held downstream. Everything collected during those ten seconds was brought back to the laboratory for further identification. All invertebrates were preserved in 70% alcohol. Two biological indices and one diversity index were calculated from these invertebrate samples. The Q value is the Irish biological index used by the Irish Environmental Protection Agency (FLANAGAN and TONER, 1972; LUCEY *et al*., 1999), while the BMWP and its complement, the ASPT score, are used by the British water authorities (ARMITAGE *et al*., 1983; CHESTERS, 1980). For this study, only the ASPT score was used because it is less sensitive to sample size. The Q value is based on the tolerance of different groups of macroinvertebrates and ranges from 1 to 5, 5 indicating excellent water quality and 1 indicating bad water quality. The ASPT gives a score to invertebrate families according to their tolerance to pollution and, although there is technically no upper limit, a score above 7 indicates an excellent water quality. A score below 3.5 indicates poor water quality. We used the Simpson's index for diversity measurements (ROSENBERG and EIRESH, 1993). We measured invertebrate diversity under the assumption that sites with better quality will usually have greater biodiversity.

RESULTS

River features

Several parameters were measured to establish if each site was suitable for crayfish (Table I). All sites had a measured pH above 7 at the time they were visited. Conductivity in the Liffey is very low in the headwaters (Ballysmuttan, 41 $\mu S.cm^{-1}$) increasing gradually downstream, the lowest site in the river Liffey having a high conductivity (Lucan, 521 $\mu S.cm^{-1}$). Summer temperatures were between 10°C and 19°C in the Boyne catchment and between 13°C and 19°C in the Liffey catchment. There is variation in flow rates between sites, the highest recorded flow rates being at the headwaters of the Liffey.

Table I

Summary of chemical and physical measurements for both catchments. The table includes measurements for the Kells Blackwater subcatchment, which harboured the only population of crayfish in the Boyne catchment.

Tableau I

Résumé des mesures chimiques et physiques des sites pour les deux bassins hydrographiques. Le tableau inclut également les données pour le bassin de la rivière Blackwater (Kells), tributaire du fleuve Boyne, et contenant la seule population d'écrevisses du bassin hydrographique du fleuve Boyne.

Catchment		Conductivity	Temperature	pH	Width	Depth	Flow
		$\mu S.cm^{-1}$	°C		m	cm	ms^2
Liffey	Average	326	15.9	8.06	18	46	0.33
	Range	37-610	13.6-18.4	7.39-8.54	3-25	26-76	0.12-0.48
Boyne	Average	528	16.5	7.62	10	46	0.38
	Range	200-773	10.9-18.9	7.24-8.17	2-25	22-66	0.06-0.83
Blackwater	Average	229	16.1	7.52	10	37	0.40
	Range	200-283	15.1-17.7	7.26-8.01	2-25	22-60	0.27-0.63

The Boyne catchment has overall a high conductivity, but the Kells Blackwater subcatchment has a noticeably lower average conductivity. The pH range is shorter and lower in the Boyne catchment than that in the Liffey catchment, but is still suitable for crayfish. There is great variability in flow regimes among sites in this catchment, the highest flow rates being found in the main river Boyne.

Most sites in both catchments had a substrate of rocks and boulders, some had a mix of sand and rocks (Table II). All sites visited seemed to offer suitable shelter for crayfish.

Most Liffey sites had a riparian strip of vegetation, except for the three uppermost sites (Ballyward, Ballysmuttan, King's River). The Boyne catchment had lower tree cover along the banks, most sites being in agricultural areas and surrounded by fields. Although there was variability in aquatic vegetation between sites, most had a good degree of aquatic vegetation cover.

Crayfish capture in the Liffey (23 June 2000 to 14 September 2000)

Crayfish were found at six of the 14 sites sampled in the Liffey catchment (Figure 1). They were present in the Rye Water downstream of Maynooth and in upstream stretches of the main Liffey from the Brittas inflow, above the Pollaphuca reservoir, down to Carragh bridge. No crayfish were found in the Liffey headwaters at Ballysmuttan or in the King's

River. Crayfish were also not found at Athgarvan, between Newbridge and Kilcullen, and they were very scarce at Ballymore Eustace, just below Pollaphuca reservoir. No crayfish were caught in the downstream part of this river (about 60 km from source), from Sallins to Lucan.

Table II

Summary of substrate type and vegetation of the sites visited for both Liffey and Boyne catchments. The Kells Blackwater subcatchment is also included separately as it harbours the only crayfish population in the Boyne catchment. Percentages represent the average for all sites in each catchment.

Tableau II

Résumé du type de substrat et de la végétation des sites visités dans les bassins hydrographiques des fleuves Liffey et Boyne. Le bassin de la rivière Blackwater (Kells), tributaire du fleuve Boyne, est inclus séparément puisqu'on y trouve la seule population d'écrevisses du bassin du fleuve Boyne. Les pourcentages inscrits sont la moyenne de tous les sites de chaque bassin.

	Liffey	Boyne	Blackwater
Substrate	80% rocks 20% sand/mud/gravel	70% rocks 30% gravel/mud/sand	80% rocks 20% sand/gravel
Vegetation on bank	50-75% tree cover	25-50% tree cover	25-50% tree cover
Vegetation in river	40% cover	50% cover	60% cover

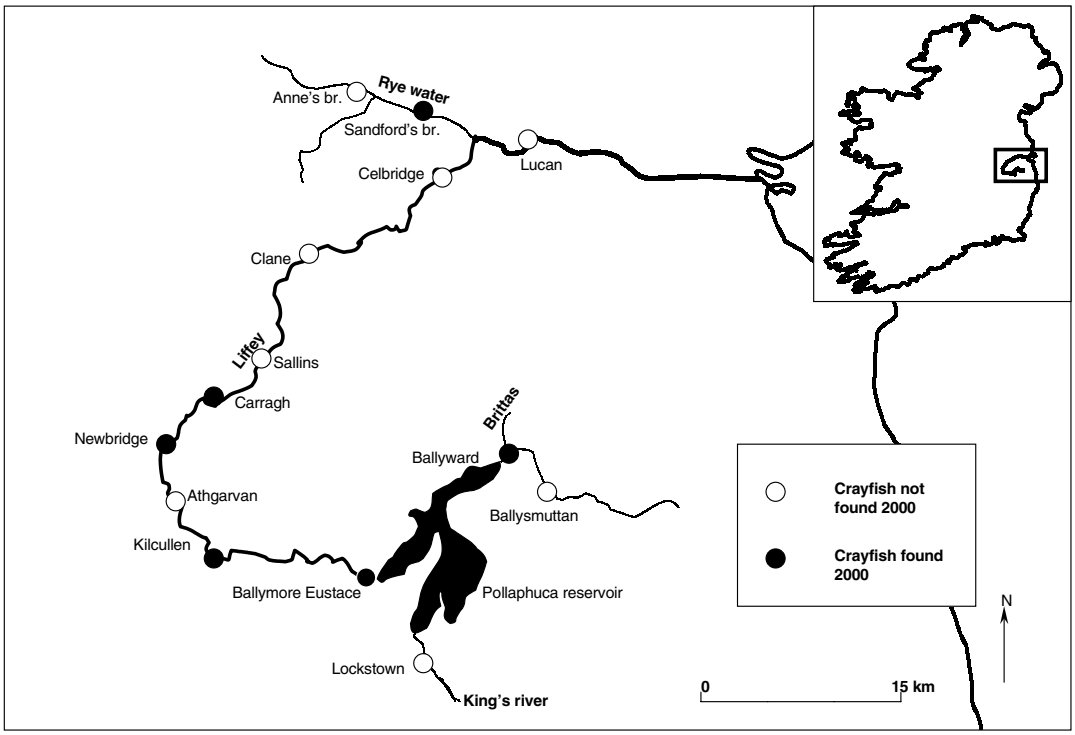

Figure 1

White-clawed crayfish distribution in the Liffey catchment, 2000.

Figure 1

Distribution de l'écrevisse à pattes blanches dans le bassin hydrographique du fleuve Liffey, 2000.

In total, 170 crayfish (87 males, 76 females and 7 unsexed juveniles) were caught during this sampling season in the Liffey using both traps and net sampling. The juveniles caught were in the 5 to 16 mm carapace length category.

Table III presents catch per unit effort (CPUE) for the six sites where crayfish were found.

Table III

Catch per unit effort of crayfish taken by two sampling methods at positive sites in the Liffey catchment. The CPUE for « all sites combined » is for all 14 sites sampled in the Liffey catchment.

Tableau III

Nombre d'écrevisses/unités (nasses ou minutes) pour les sites positifs dans le bassin du fleuve Liffey. Le nombre donné pour « tous les sites » est la moyenne pour les 14 sites visités dans le bassin.

Sites	Ballyward	B. Eustace	Kilcullen	Newbridge	Carragh	Rye Water	Average	All sites combined
Traps	3.7	0.1	1.0	2.1	1.6	1.2	1.6	0.7
Net	0.8	0.0	1.1	0.3	1.4	0.9	0.8	0.3

These numbers demonstrate the site differences in CPUE there can be between traps and net sampling. At Ballyward, for example, CPUE was very high for traps (3.7) while the net sampling CPUE is much lower (0.8). On the other hand, at Kilcullen the CPUE values for both methods are similar (1.0 and 1.1).

Figure 2 presents the size frequency distribution (in 5 mm interval) of the crayfish caught in the Liffey. Two peaks are clearly shown.

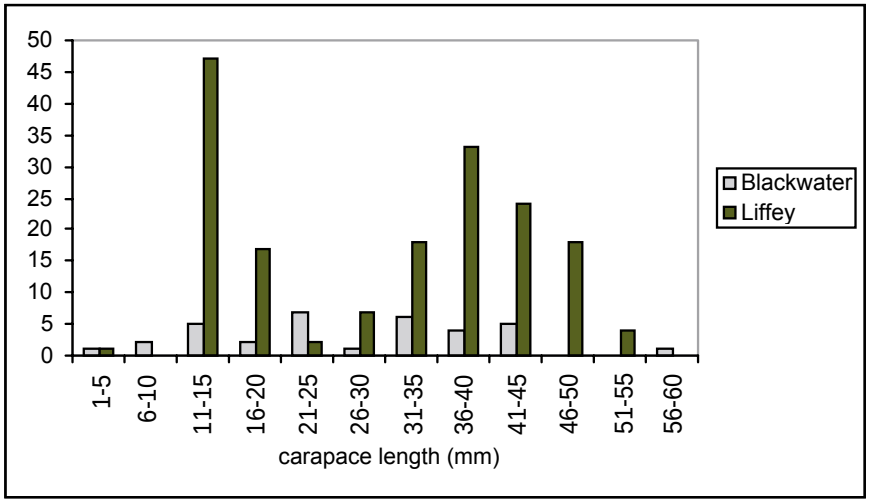

Figure 2

Carapace length distribution in the Liffey and Blackwater catchments.

Figure 2

Distribution de la longueur de la carapace dans les bassins du fleuve Liffey et de la rivière Kells Blackwater.

Crayfish capture in the Boyne catchment (22 June 2000 to 20 September 2000)

Very few crayfish were found in the Boyne catchment; they were only found in the Kells Blackwater tributary (see Figure 3). They were absent from the entire upstream region of the mainstream Boyne and its tributaries.

Only 34 crayfish were caught in the Blackwater catchment: 9 females, 21 males and 4 unsexed juveniles. Traps yielded a greater number of males than females. Low numbers in this catchment prevent a clear representation of a size frequency curve in the crayfish population (Figure 2).

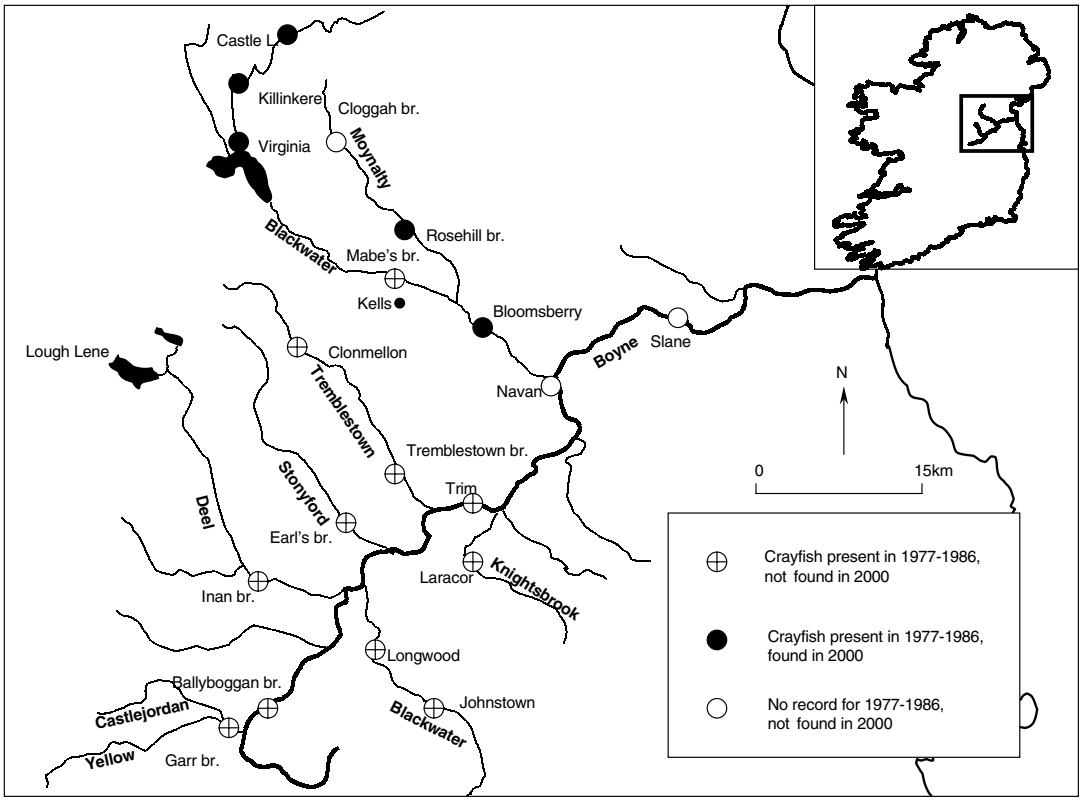

Figure 3
White-clawed crayfish distribution in the Boyne catchment, 2000.

Figure 3
Distribution de l'écrevisse à pattes blanches dans le bassin hydrographique du fleuve Boyne, 2000.

Table IV shows the catch per unit effort of the five sites that had crayfish. CPUE for all sites combined is the average for all 19 sites sampled in the Boyne catchment. The CPUE in the Blackwater is low, with no sites presenting a CPUE above 1.

Table IV

Catch per unit effort of crayfish taken by two sampling methods for positive sites in the Blackwater (Kells) catchment. CPUE for « all sites combined » is an average over the 19 sites visited in the Boyne catchment.

Tableau IV

Nombre d'écrevisses/unités (nasses ou minutes) pour les sites positifs dans le bassin de la rivière Blackwater. Le nombre donné pour « tous les sites » est la moyenne pour les 19 sites visités dans le bassin du fleuve Boyne.

Sites	Castle Lough	Killinkere	Virginia	Bloomsberry	Rosehill br.	Average	All sites combined
Traps	0.0	0.1	0.3	0.8	0.5	0.3	0.09
Net	0.4	0.1	0.2	0.3	0.1	0.2	0.06

Biological Indices

Table V shows two biological indices (Q value and ASPT score) along with Simpson's diversity index calculated from the invertebrate samples taken at each site.

Sites with crayfish and sites without crayfish exhibit a similar range of values for both the Q index and the ASPT score (Figure 4). Nevertheless the lowest values of ASPT and Q value are found for sites where no crayfish were found. There is great variation in the Simpson's index for sites with or without crayfish (Table V).

Table V

Summary of biological and diversity indices for both Liffey and Boyne catchments. Note that Simpson's index is represented here as 1-D.

Tableau V

Résumé des indices biologiques et de diversité pour les bassins des fleuves Liffey et Boyne. Notez que l'index de Simpson est écrit comme étant 1-D.

Catchment	Crayfish presence	ASPT range	ASPT average	Q range	Simpson range	Simpson average
Liffey	With crayfish	4.75-6.47	5.66	3 to 4	0.393-0.816	0.512
	Without crayfish	3.90-6.54	5.60	2 to 4	0.605-0.872	0.732
Boyne	With crayfish	4.81-6.46	5.45	3 to 3-4	0.749-0.865	0.831
	Without crayfish	3.91-5.83	5.01	2-3 to 4	0.529-0.935	0.741
Total	With crayfish	4.75-6.47	5.56	3 to 4	0.393-0.865	0.704
	Without crayfish	3.90-6.54	5.21	2 to 4	0.529-0.935	0.738

DISCUSSION

The relationship between water quality and crayfish catch per unit effort is not clearcut, indicating that the water quality values only partially explain the present distribution and abundance of *A. pallipes* in these catchments. Although it is frequently stated that this crayfish needs high water quality (for example see JAY and HOLDICH, 1981), it appears from this study that it can occur in water that is rated moderately polluted (*e.g.* Sandford Bridge in the Rye water). Habitat characteristics of the sites visited generally indicated suitability for crayfish (see for example FOSTER, 1995; NAURA and ROBINSON, 1998). Bank vegetation was variable but most sites had a rocky substrate which offered shelter; aquatic vegetation was usually also present and provided shelter for juveniles.

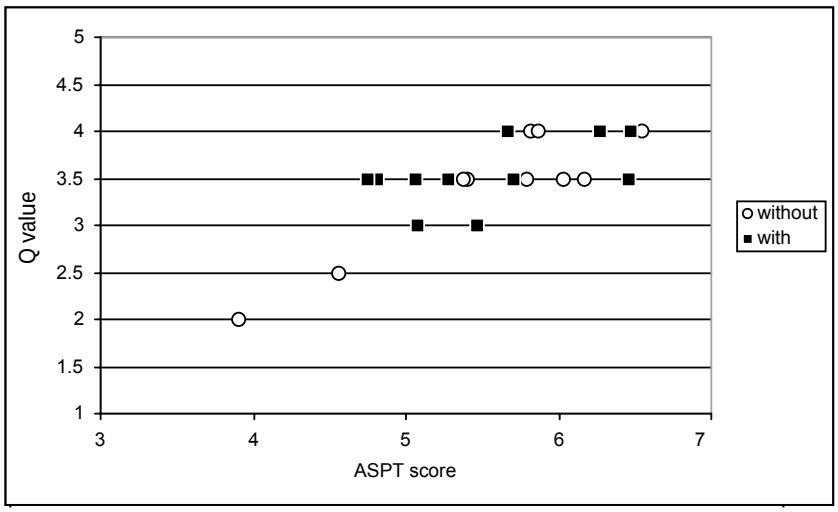

Figure 4
Q values and ASPT scores for sites with or without crayfish for the Liffey and Kells Blackwater catchment.

Figure 4
Valeurs pour l'index Q et pour l'index ASPT selon les sites possédant (with) ou non (without) des écrevisses pour les bassins hydrographiques du fleuve Liffey et de la rivière Kells Blackwater.

Distribution of the white-clawed crayfish in the Liffey catchment is patchy and sometimes difficult to explain. Crayfish were formerly recorded a few kilometres downstream of Clane (LUCEY and MC GARRIGLE, 1987), but now cannot be found downstream of Sallins (see Figure 1). The Q value and ASPT score recorded at Sallins (2 and 3.91 respectively) are very low and may reflect the presence of the sewage treatment plant located near this site. The low water quality possibly excludes crayfish from this area, whereas the population upstream is still healthy. The water quality improved at sites downstream of Sallins (Celbridge, Lucan). However, EPA surveys showed lower Q values at these sites in the recent past. BOWMAN *et al*. (1996) recorded a Q value of 3 for Celbridge in 1991 and LUCEY *et al.* (1999) recorded a Q value of 2-3 for Lucan in 1995 (these authors only recorded Q values, not ASPT scores). The low water quality at Sallins may act as a barrier to downstream movement of crayfish into their original range in the river Liffey.

Although this explanation of crayfish absence at Sallins seems plausible, the link between crayfish populations and water quality is far from universal in these two catchments. No crayfish were found at Athgarvan even though water quality was good, in summer 2000 and in the recent past (LUCEY *et al*., 1999). Other environmental factors are therefore more important than water quality in determining the distribution of crayfish. For example, *A. pallipes* was also not found in the high quality headwaters of the Liffey catchment (Ballysmuttan and King's river – see Figure 1) perhaps because of episodes of unsuitably low pH (measured pH down to 5.7 according to MC GARRIGLE *et al*., 1996, and down to 4.1 according to KELLY-QUINN, 1998). Both the Liffey and the King's river rise in peatland overlying granite soils and their water is lime deficient and has a low pH; the lower catchment (below Pollaphuca reservoir) flows over a limestone bedrock and has a high alkalinity (MORIARTY, 1998). Crayfish were numerous at Ballyward, just downstream of the Brittas inflow. This stream flows over lime-rich glacial till and has a relatively high pH (MORIARTY, 1998).

The current distribution of the white-clawed crayfish demonstrated by our sampling is not what was expected in either catchment. LUCEY and MC GARRIGLE (1987) had recorded this species in the Boyne and in most of its tributaries in the first half of the 1980s. Although complete disappearance of *A. pallipes* from most of the Boyne catchment cannot be demonstrated, the population has been reduced to the point where no crayfish were found using conventional methods (traps and nets). A possible explanation for this is the introduction of the fungus *Aphanomyces astaci* in this catchment. The plague caused by this fungus was identified in Lough Lene, in the headwaters of the river Deel, in the Boyne catchment, in 1987 (MATTHEWS and REYNOLDS, 1990). From this lake, and possibly from others, the disease could have infected individuals downstream, in the river Deel and then throughout most of the catchment, covering almost 250 km of stream length. In a case study by WESTMAN and NYLUND (1978) in Finland, the disease travelled roughly 3 km a year upriver, although it was not clear whether the spread was natural or helped by fishermen. The Boyne catchment is popular for trout and salmon angling and it is possible that spores were introduced by visiting anglers at several places in the Boyne catchment (REYNOLDS, 1988).

Pollution does not seem to be the cause of the absence of *A. pallipes* in our traps in most the Boyne catchment. Although according to our invertebrate sampling all rivers in the Boyne catchment are moderately polluted (Q values of 3 and 3-4, ASPT scores between 5 and 6), water quality should be sufficient for this species, except at Slane and in the upstream Moynalty river (with a Q value of 2-3 and a ASPT score of 4.55). Nevertheless, the degrading water quality might present an obstacle to the recolonization by crayfish of these rivers.

Arterial drainage (dredging) was practised in several rivers of the Boyne catchment, with the aim of lowering the water table and allowing more land to be cultivated. The River Boyne drainage scheme started in 1969 and continued throughout the catchment until 1985 (O'GRADY, 1998). After this date, dredging became less important but was still practised for periodic maintenance, as at Tremblestown bridge just before we visited the area. According to MC CARTHY (1977), *A. pallipes* disappears from a dredged area for several years, as does most of the invertebrate fauna. Although arterial drainage has a negative impact on the crayfish population, individuals will move back into the area after a few years (LOWERY and HOGGER, 1986). The recent work done at Tremblestown Bridge would have prevented us from catching any crayfish at this particular site, but all other sites, from our observations, had remained undredged for several years.

The only rivers of the Boyne basin where we found crayfish were the Kells Blackwater and the Moynalty (Figure 3). The population in the Kells Blackwater subcatchment possibly escaped the infection because crayfish had disappeared from the Boyne downstream of Trim (therefore upstream of the confluence with the Blackwater, see Figure 3) prior to the occurrence of the plague, thus preventing dispersion of the disease. LUCEY and MC GARRIGLE (1987) had no records of crayfish in the river Boyne, downstream of Trim, between 1977 and 1985.

In this subcatchment, crayfish numbers are low, with all CPUE values lower than 1. It is possible that the plague did infect crayfish in this river and that the low numbers represent a recovering population as not all individuals are necessarily killed by the disease (WESTMAN and NYLUND, 1978). It is also possible that predation keeps the numbers low. Crayfish remains were found in otter spraints in the Blackwater in summer 2000 (G. HAMILTON, personal communication). However, such remains were also found in the Liffey at sites where crayfish seemed numerous. Further investigations would be necessary to explain the low crayfish numbers and why they were not found at an apparently suitable site near Kells (Mabe's bridge).

A simple correlation between water quality indices and crayfish (either presence or numbers) is not sufficient; additional factors need to be taken into consideration. Furthermore, as crayfish live for many years and migrate fairly slowly (rates in summer of 4.2 $m.day^{-1}$ for males and 1.7 $m.day^{-1}$ for females, according to ROBINSON *et al.*, 2000), events that took place several years ago can influence present distribution. Water quality assessed using an ensemble of short-lived invertebrates can increase from low to moderate quality in one year, but the longer-lived crayfish will take several years to colonise a new area, depending on the length of the stretch of river concerned. Therefore, it can be useful to look back a few years in records to explain a distribution.

Tables III and IV underline the difference between the two methods of sampling used in this survey. Net sampling yields fewer and smaller crayfish and varies greatly, and independently from trap yields. Such differences probably reflect variation in the habitats present at each site. Certain sites have pockets of vegetation where juveniles congregate and can be easily captured, whereas other sites have a more even rocky substrate; juveniles are then dispersed throughout the site and are more difficult to catch. There is probably also some variation attributable to personal sampling techniques. Catch per unit effort of net sampling is therefore not a very reliable indication of abundance of crayfish in an area. Net sampling is more useful to establish that all age classes are present at a site and thus that the population is a healthy one.

CONCLUSION

The distribution of the white-clawed crayfish in the Liffey catchment was patchy and could not be firmly linked to water quality. Indeed the requirements of this species in terms of water quality cannot be clearly established from the present data.

The crayfish population in the Boyne catchment is greatly reduced, this species being now restricted to the Kells Blackwater subcatchment. It is possible that the plague fungus, *A. astaci* was responsible for the loss in crayfish stocks in this catchment.

This research underlines the need for a more extensive survey of the Irish crayfish population to see if the fungus *A. astaci* has reached other rivers and if deteriorating water quality and habitat loss are becoming a problem for the survival of the protected white-clawed crayfish.

ACKNOWLEDGEMENTS

Many thanks to Geoff Hamilton and Richard Hollinshead for their help in the field. Thanks also to Joanne Reilly, Clodagh Byrne, Andrew Chaney, and Sandra Devaney for their contribution to sampling, and to Peter Stafford and Alison Boyce for their technical assistance.

REFERENCES

ARMITAGE P.D., MOSS P., WRIGHT J.F., FURSE M.T., 1983. The performance of a new water quality score system based on macroinvertebrates over a wide range of unpolluted running-water sites. *Water Research*, *17*, 333-347.

BOWMAN J.J., CLABBY K.J., LUCEY J., MC GARRIGLE M.L., TONER P.F., 1996. Water quality in Ireland 1991-1994. EPA. Wexford.

CHESTERS K.R., 1980. Biological monitoring working party. The 1978 national testing exercise. Water data unit. Technical memorandum. No 19. pp 37.

FLANAGAN P.J., TONER P.F., 1972. The national survey of Irish rivers: a report on water quality. Water Resources Division, An Foras Forbartha. Dublin.

FOSTER J., 1995. Factors influencing the distribution and abundance of the crayfish *Austropotamobius pallipes* (Lereboullet) in Wales and the Marches, UK. *Freshwater Crayfish*, *8*, 78-93.

HOLDICH D.M., LOWERY R.S., 1988. Freshwater crayfish: biology, management and exploitation. Croom Helm. London.

JAY D., HOLDICH D.M., 1981. The distribution of the crayfish *Austropotamobius pallipes*, in British waters. *Freshwater Biology*, *11*, 121-129.

KELLY-QUINN M., 1998. The coastal streams of Dublin and Wicklow. *In* : MORIARTY C. (ed.). Studies of Irish rivers and lakes. Marine Institute, 1998, 77-98.

LAURENT P.J., 1988. *Austropotamobius pallipes* and *Austropotamobius torrentium* with observations on their interactions with other species in Europe. *In* : HOLDICH D.M., LOWERY R.S. (Eds). Freshwater crayfish biology, management and exploitation. University Press. Cambridge.

LOWERY R.S., HOGGER J.B., 1986. The effects of river engineering works and disease on a population of *Austropotamobius pallipes* in the River Lea, UK. *Freshwater Crayfish*, *6*, 94-99.

LUCEY J., BOWMAN J.J., CLABBY K.J., CUNNINGHAM P., LEHANE M., MC CARTHAIGH M., MC GARRIGLE M.L., TONER P.F., 1999. Water quality in Ireland 1995-1997. EPA. Ireland

LUCEY J., MC GARRIGLE M.L., 1987. The distribution of the crayfish *Austropotamobius pallipes* (Lereboullet) in Ireland. *Irish Fisheries Investigations*, *A29*, 1-13.

MATTHEWS M.A., REYNOLDS J.D., 1990. Laboratory investigations of the pathogenicity of *Aphanomyces astaci* for Irish freshwater crayfish. *Hydrobiologia*, *203*, 121-126.

MC CARTHY D.T., 1977. The effects of drainage on the Tremblestown river, I. Benthic invertebrates and flora. *Irish fisheries investigations*, *A16*, 1-17.

MC GARRIGLE M.L., CLABBY P.F., TONER M., NEILL J., LUCEY M., FLANAGAN M., QUINN M.B., 1996. Water quality in Ireland 1991-1994. Statistical compendium of river quality data. Wexford. EPA.

MORIARTY C., 1998. The Liffey. *In* : MORIARTY C. (ed.). Studies of Irish Rivers and lakes. Marine Institute, Dublin, 37-56.

NAURA M., ROBINSON M., 1998. Principles of using River Habitat Survey to predict the distribution of aquatic species: an example applied to the native white-clawed crayfish *Austropotamobius pallipes*. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *8*, 515-527.

O'GRADY M., 1998. The Boyne. *In* : MORIARTY C. (ed.). Studies of Irish rivers and lakes. Marine Institute, Dublin, 27-36.

REYNOLDS J.D., 1982. Notes on the Irish distribution of the freshwater crayfish. *Bulletin of the Irish Biogeography Society*, *6*, 18-24.

REYNOLDS J.D., 1988. Crayfish extinctions and crayfish plague in central Ireland. *Biological Conservation*, *45*, 279-285.

REYNOLDS J.D., 1997. The present status of freshwater crayfish in Ireland. *Bull. Fr. Pêche Piscic.*, *347*, 693-700.

ROBINSON C.A., THOM T.J., LUCAS M.C., 2000. Ranging behaviour of a large freshwater invertebrate, the white-clawed crayfish *Austropotamobius pallipes. Freshwater Biology*, *44*, 509-521.

ROSENBERG D.M., EIRESH V.H. (Eds.), 1993. Freshwater biomonitoring and benthic macroinvertebrates. Chapman and Hall. London.

WESTMAN K., NYLUND V., 1978. Crayfish plague, *Aphanomyces astaci*, observed in the European crayfish, *Astacus astacus*, in Pihlajoveski waterway in Finland. A case study on the spread of the plague fungus. *Freshwater Crayfish*, *4*, 419-426.