REINTRODUCTION OF NOBLE CRAYFISH *ASTACUS ASTACUS* AFTER CRAYFISH PLAGUE IN NORWAY

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ABSTRACT

The Glomma and Halden watercourses in Norway were hit by crayfish plague in 1987 and 1989. Reintroduction of the noble crayfish started in 1989 in the Glomma and in 1995 in the Halden watercourse. Norway has especially good conditions for reintroduction of the native crayfish after crayfish plague, as there is no alien plague-carrying crayfish species in the country.

In the Glomma watercourse, approx. 15 000 adult crayfish and 10 000 juveniles have been stocked while in the Halden watercourse the figures are 19 000 adults and 26 500 juveniles. All stocking sites were previously regarded as very good crayfish localities. Four years after stocking, natural recruitment was recorded at all adult crayfish stocking sites in the Glomma watercourse and at most sites in the Halden watercourse. Current crayfish density is, however, much lower than pre-plague densities even at the sites where population development has been in progress for more than 10 years.

Extensive post-stocking movements were recorded among adult crayfish. Some sites seemed more suitable for settling, resulting in a great variation in CPUE between the different test-fishing sites. Juveniles seem more appropriate as stocking material if the goal is to re-establish a population in a particular area, due to their stationary behaviour, which seems to remain as they grow larger.

Key-words: *Astacus astacus*, crayfish plague, stocking, reintroduction, migration.

RÉINTRODUCTION DE L'ÉCREVISSE NOBLE *ASTACUS ASTACUS* APRÈS LA PESTE DE L'ÉCREVISSE EN NORVÈGE

RÉSUMÉ

Les cours d'eau la Glomma et Halden en Norvège ont été contaminés par la peste de l'écrevisse en 1987 et 1989. La réintroduction de l'écrevisse noble a débuté en 1989 dans la Glomma et en 1995 dans l'Halden. La Norvège possède de bonnes conditions pour la réintroduction de l'écrevisse native après la peste des écrevisses parce qu'il n'y a aucune espèce non native porteuse de la peste dans le pays.

Dans la Glomma, approximativement 15 000 écrevisses adultes et 10 000 juvéniles ont été introduits tandis que dans le cours d'eau Halden sont présents 19 000 adultes et 26 500 juvéniles. Tous les sites d'introduction ont été préalablement considérés comme de très bonnes stations d'introduction. Quatre ans après le repeuplement, le recrutement

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naturel sur tous les sites d'introduction des adultes de la Glomma et sur la plupart des sites de l'Halden ont été relevés. La densité des écrevisses est cependant nettement inférieure à celle d'avant la peste et ce même aux sites où la population est en progression depuis plus de 10 ans.

De grandes migrations post-réintroduction ont été enregistrées parmi les écrevisses adultes. Certains sites semblent plus favorables à la colonisation, ayant pour résultat une grande variation de CPUE entre les différents sites tests. Les juvéniles semblent plus appropriés en tant que matériel d'introduction si le but est le rétablissement d'une population dans un secteur particulier, ce qui est dû à leur comportement stationnaire qui semble demeurer avec leur croissance.

Mots-clés : *Astacus astacus*, peste de l'écrevisse, stockage, réintroduction, migration.

INTRODUCTION

Crayfish plague (*Aphanomyces astaci*) and plague-carrying, alien crayfish species are the most severe threats to the native European crayfish species (TAUGBØL and SKURDAL 1999; VOGT, 1999; EVANS and EDGERTON, 2002). In general when struck by crayfish plague, populations of native crayfish suffer total mortality. *A. astaci* is a parasitic fungus and depends on live crayfish as a host. The American crayfish species are plague tolerant and act as permanent hosts and carriers of the disease. Thus, if American crayfish are present in a plague-affected waterbody, the disease will be permanently established. If the waterbody contains European crayfish only, the population will most likely be wiped out, and through lack of hosts the fungus itself will also die out. After the plague has disappeared, it is possible to reintroduce the native crayfish.

In restoration ecology (cf. JORDAN *et al.*, 1987), reintroduction in general suffers from a discrepancy between practical actions, published as grey literature if at all, and projects with a scientific approach. A main reason is that reintroductions often are initiated by voluntary organisations, private persons and/or the environmental authorities with no link to research institutes. The projects are aimed at practical works and rarely have resources available for scientifically valid pre- and post-stocking investigations and ecological modelling (SARRAZIN and BARBAULT, 1996). Crayfish reintroductions fit well into this pattern. There are few well-documented cases of reintroduction of native European crayfish after crayfish plague (FISKERIVERKET, 1993; SCHULZ *et al.*, 2002).

Restocking efforts have very often met limited success due to new outbreaks of crayfish plague, particularly in areas where plague-carrying American crayfish species are established (FISKERIVERKET and NATURVÅRDSVERKET, 1998). In Ireland, Norway, United Kingdom, Russia and Sweden there are a few examples of successful reintroductions (FISKERIVERKET, 1993; REYNOLDS, 1997; REYNOLDS and MATTHEWS, 1997; TAUGBØL, 2001; SCHULZ *et al.*, 2002). In Ireland and Norway a native crayfish is the only species and thus the possibilities for successful reintroductions after crayfish plague are greatly enhanced. In this paper, I will first briefly describe the crayfish plague situation in Norway and then focus on the ongoing efforts to reintroduce the noble crayfish in two of the affected watercourses. Results from the crayfish population development in different parts of the watercourse after restocking are presented.

CRAYFISH PLAGUE IN NORWAY

The noble crayfish is the only freshwater crayfish species in Norway. The distribution is mainly restricted to the southeastern part of the country with a few populations in the middle and western part (Figure 1). Most waters in Norway are privately owned and the right to catch crayfish and fish belongs to the landowners.

Four watercourses in Norway have been affected by the crayfish plague (TAUGBØL *et al.*, 1993). The first outbreak was reported in 1971-74 in the Veksa/Vrangselva watercourse (HÅSTEIN and UNESTAM, 1972; HÅSTEIN and LUND, 1978). In 1987, the plague appeared in River Glomma and in 1989 the disease also struck in the Store Le and Halden watercourses (Figure 1). In the Veksa/Vrangselva case, the introduction of the disease into Norway could be followed by the observations of crayfish mortality moving upstream from Sweden. A concrete weir about 20 km from the Swedish border became the final stop for the spread in that case. How the plague reached the Glomma watercourse in 1987 is unknown. The plague could have been transmitted from a Swedish lake, previously hit by the disease the same year and located within a driving distance of less than two hours from R. Glomma. The outbreak in Store Le in 1989 was probably due to an illegal stocking of signal crayfish as this species was detected on the Swedish side of Store Le in 2002. It is likely that this occurrence may result from an illegal stocking back in 1989. From Store Le to the Halden watercourse in 1989 the disease was most likely spread by tourists/fishermen. There was/is a large transfer of boats, canoes, fishing equipment etc. between the waterbodies, and a crossing distance of just a few hundred metres leads to a high risk of spread. Just a few days after the plague was diagnosed in Store Le in July 1989, the first observations of crayfish mortality was reported from the Halden watercourse, at a site very close to Store Le.

Based on diving investigations, reports of crayfish mortalities, cage experiments and knowledge of previous crayfish distribution, plague affected areas were defined in the Glomma- and Halden watercourses (TAUGBØL *et al.*, 1993). In Glomma the crayfish disappeared in the main river downstream of the village of Kirkenær and in the connected lakes Vingersjøen and Storsjøen. Upstream of Kirkenær previous crayfish occurrence was only sporadic. In the Halden watercourse all crayfish were killed in the main course from Bjørkelangen downstream (Figure 1). The last plague-suspected mortality occurred in R. Glomma at Skarnes in 1990, and in the Halden watercourse close to Bjørkelangen in 1993 (TAUGBØL, 1994) (Figure 1).

REINTRODUCTION

To reduce the motivation for illegal stocking of signal crayfish the environmental authorities aimed at a fast reintroduction of the noble crayfish and, in collaboration with the landowners, played an active role in this process. Both state and private money were used for buying stocking material. Restocking in the Glomma watercourse started in 1989 and in the Halden watercourse in 1995 following caging of live crayfish to test survival. Reintroduction in Store Le was not desired by the authorities, because if this lake stayed empty of crayfish it would act as a barrier for a new possible transfer of the disease from Sweden. In the Veksa/Vrangselva watercourse the noble crayfish population was re-established in parts of the watercourse around 1975-1985, most likely due to restocking by local fishermen. However, the crayfish density is very low compared to the pre-plague situation, probably because of inferior water quality due to eutrophication and other pollution. Eutrophication has also led to increased mud accumulation and a bottom substrate more unsuitable for crayfish (TAUGBØL *et al.*, 1993)

Stocking material and monitoring methods

In the Glomma watercourse a total of 3 580 juveniles (10-12 mm, stage 4) and 13 832 adult crayfish were stocked between Skarnes and Gjølstadfossen, including L. Vingersjøen, in the period 1989-1998. In addition, 6 314 juveniles and 1 280 adults were stocked in the southern part of L. Øyeren (Figure 1). The number of crayfish stocked at different sites in the Glomma watercourse is given in more detail below. In the Halden watercourse a total of 26 404 juveniles and 18 916 adult crayfish have been stocked in the period 1995-2001 (Figure 1 and 2).

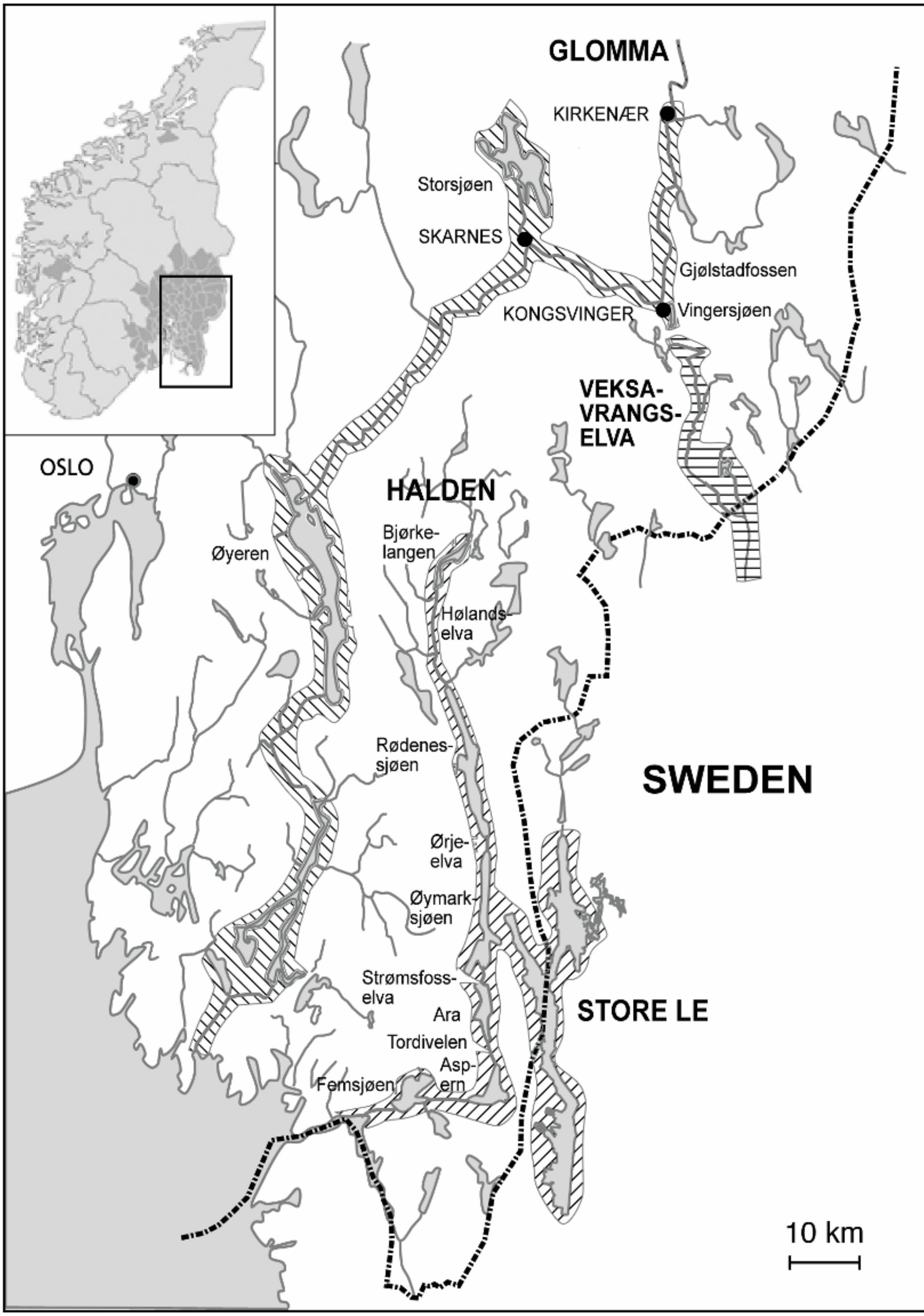


Figure 1

Map showing the four crayfish plague-affected watercourses in Norway. The shaded area on the small inset map shows crayfish distribution in Norway.

Figure 1

Carte des quatre cours d'eau norvégiens infectés par la peste des écrevisses. La zone ombragée sur la carte en insert montre la distribution des écrevisses en Norvège.

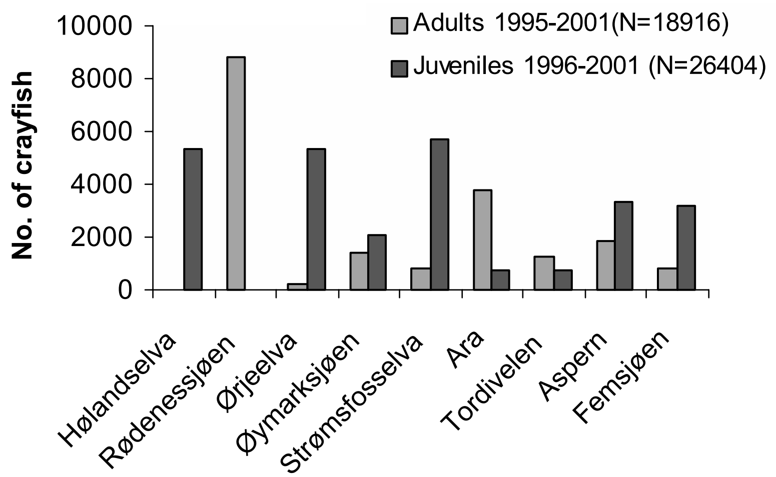


Figure 2
Number of crayfish stocked at different sites in the Halden watercourse.

Figure 2
Nombre d'écrevisses introduites en différents sites sur le cours d'eau Halden.

The adult crayfish used as stocking material originated from other lakes within the catchment (L. Einavann in the Glomma and L. Øgderen in the Halden catchment). Crayfish above the legal minimum size of 95 mm total length were bought from local fishermen during the catching season. The juveniles were bought from two private hatcheries with parental crayfish originating from lakes in the Halden catchment. All stocking sites were regarded as very good crayfish localities before the plague struck.

Population development after stocking was monitored by SCUBA-diving and test fishing with baited traps (cylindrical, two entrances, 12 mm mesh size) at the different stocking sites. When diving, a relative abundance (catch per unit effort, CPUE) of crayfish was estimated as number of crayfish caught per hour diving. When trapping, the CPUE was estimated as number of crayfish per trap and night. Normally, the annual survey of a site included an effort of 25 or 50 traps during one night in late August-early September. Natural recruitment of crayfish was proved when crayfish smaller than stocking size were detected in the catches.

RESULTS AND DISCUSSION

Population development at different stocking sites

The speed at which crayfish populations developed at the different stocking sites varied markedly, probably reflecting the migration ability of adult crayfish and their desire to migrate when stocked into a new environment (SKURDAL and TAUGBØL 1995). Habitat characteristics at the different sites probably also play a role, making some sites more favourable for settling. At all investigated sites current crayfish density is much lower than pre-plague densities even in cases with more than 10 years of development. This slow population development is in accordance with other observations from Norway of crayfish being introduced to new waterbodies. In L. Einavann for instance, it took approximately 25-30 years from the introduction of crayfish till the population reached a density worthwhile catching.

The Glomma watercourse

At Gjølstadfossen in R. Glomma, 3 843 adult crayfish were stocked in 1989-1991. Natural recruitment was proved in 1993 (TAUGBØL 2001), but further development of the population has proceeded surprisingly slowly. CPUE has never exceeded one crayfish per trap night and also the diving catch has been quite modest (Figure 3).

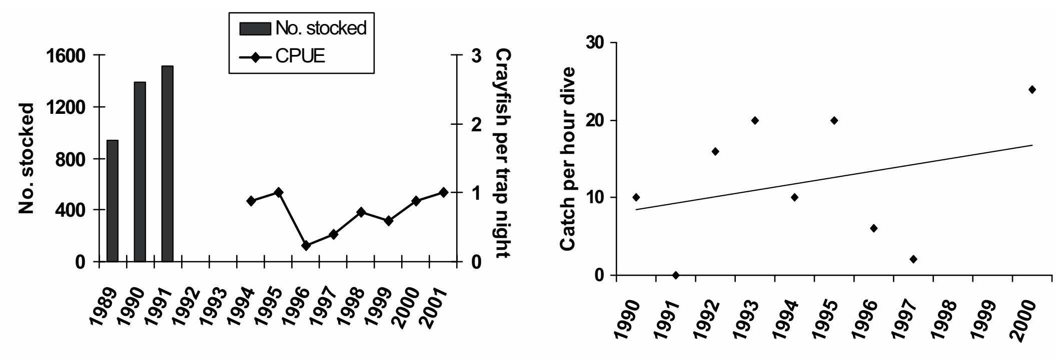


Figure 3
Number of crayfish stocked and test-fishing CPUE (trapping & diving) in R. Glomma at Gjølstadfossen.

Figure 3
Nombre d'écrevisses introduites et essais de pêche CPUE (par piégeage & par plongée) dans la Glomma à Gjølstadfossen.

The stocking sites R. Glomma at Kongsvinger, R. Vingersnoret and L. Vingersjøen are closely situated (Figure 4). Most crayfish were stocked in L. Vingersjøen (2 319 adults in 1992-1994) and fewest (926 adults in 1995 and 1997) in the R. Vingersnoret, which connects the L. Vingersjøen to the R. Glomma at Kongsvinger. In the R. Glomma at Kongsvinger a total number of 2 475 adult crayfish were stocked in 1994-1997 (Figure 5). In L. Vingersjøen and R. Glomma at Kongsvinger the population development resembles that at Gjølstadfossen; only one crayfish per trap night or less are caught 7-9 years after the first stocking effort. At the R. Vingersnoret site, however, the population has developed much faster even though the number of stocked crayfish was much lower compared to the other sites. More than 3 crayfish per trap night were caught in 2000, 5 years after the first stocking (Figure 5). The high catch is probably due to settling of crayfish that migrated out of L. Vingersjøen after originally being stocked there.

In the R. Glomma at Skarnes, the crayfish population also seemed to develop very slowly in spite of quite a large number of crayfish stocked. Almost no crayfish were caught by trapping (Figure 6). However, diving investigations were also carried out, and demonstrated a well-known weakness in monitoring surveys using trap catching only (PEAY and HIRST 2003). In 2000 and 2001, quite a large number of crayfish of all size classes were caught by SCUBA-diving at the same site as the trapping was done, and gave a totally different view of the crayfish abundance, compared to the trapping results (Figure 6). At the other sites, however, trapping and diving catches were more consistent, although a general trend was that diving results indicated a higher density of crayfish compared to the trapping results (cf. Figure 9, the Halden watercourse).

Figure 4
Detailed map of the stocking and test fishing sites Gjølstadfossen, Leirud, Kongsvinger, Vingersnoret and Vingersjøen in the Glomma watercourse.

Figure 4
Carte détaillée des sites de réintroductions et d'essais de pêche Gjølstadfossen, Leirud, Kongsvinger, Vingersnoret et Vingersjøen sur la Glomma.

There were marked differences in the mean size of crayfish in the trap catches at the different sites (Figure 7). At stocking, the adult crayfish were approximately of the same size (the stocking material was divided arbitrarily between the different sites) and post-stocking differences are probably mainly due to habitat preferences or survival rates of different size groups. For instance Gjølstadfossen in the R. Glomma seems to be a site that smaller crayfish find less attractive (or suffer higher mortality) (Figure 7).

The Halden watercourse

Two sites in the Halden watercourse, Strømsfoss and Tordivelen, have been systematically test-fished since 1996, and the crayfish population development has shown diametrically different trends (Figure 8). From the same starting point in 1996 with approx. one crayfish per trap night, crayfish abundance at Tordivelen decreased to less than 0,1 crayfish per trap night in 2001. At Strømsfoss, CPUE increased to 3.6 crayfish per

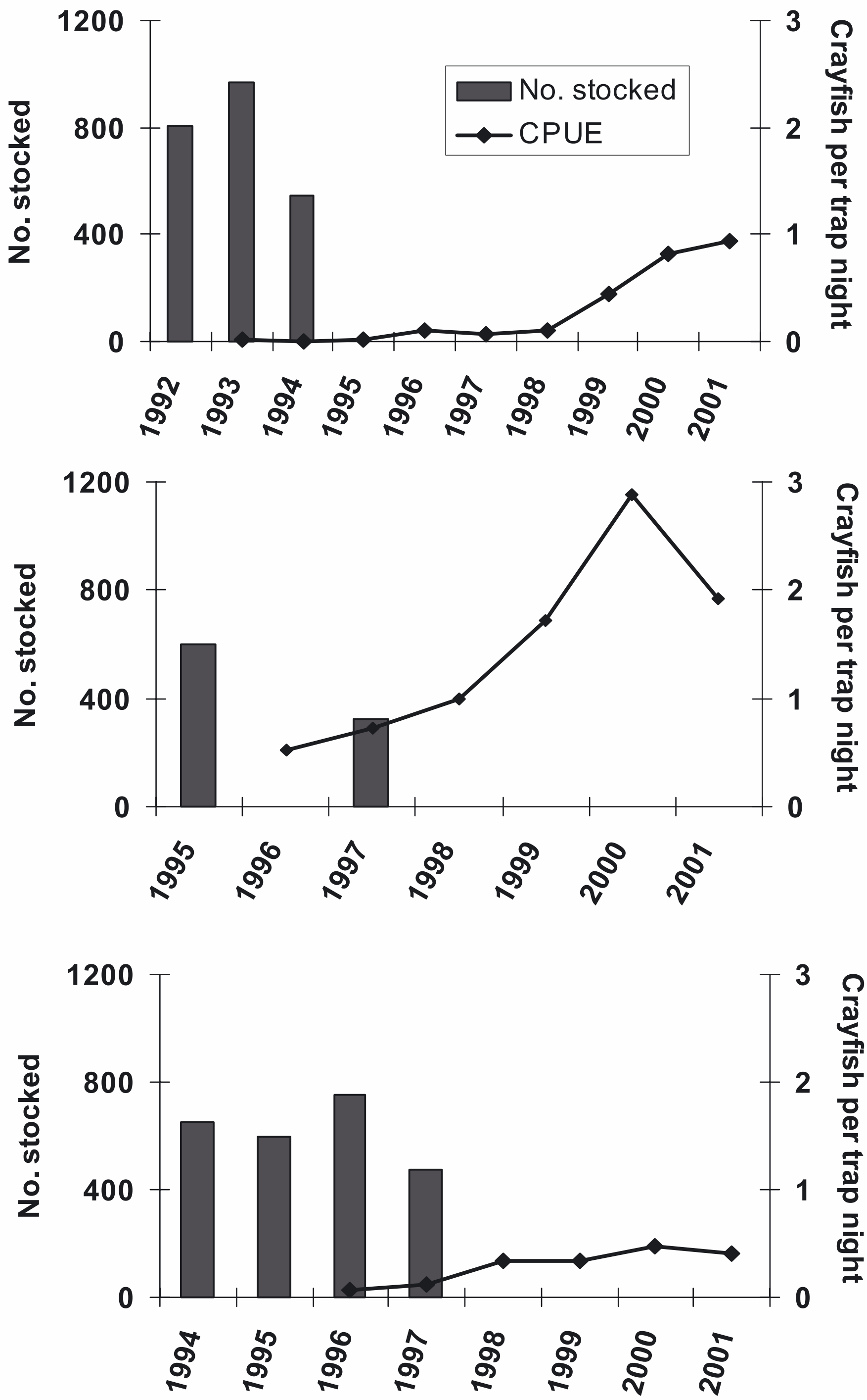


Figure 5

Number of crayfish stocked and test-fishing CPUE (trapping) in L. Vingersjøen, R. Vingersnoret and R. Glomma at Kongsvinger.

Figure 5

Nombre d'écrevisses introduites et essais de pêche CPUE (par piégeage) dans L. Vingersjøen, R. Vingersnoret et R. Glomma à Kongsvinger.

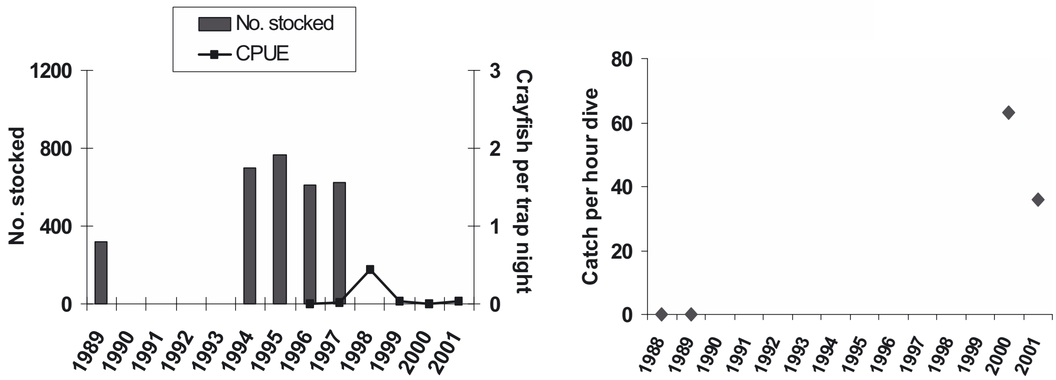


Figure 6
Number of crayfish stocked and test-fishing CPUE (trapping & diving) in R. Glomma at Skarnes.

Figure 6
Nombre d'écrevisses introduites et essais de pêche CPUE (par piégeage et par plongée) dans la Glomma à Skarnes.

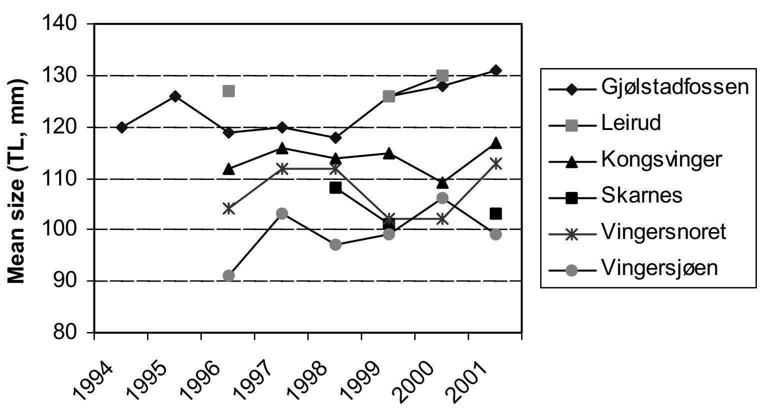
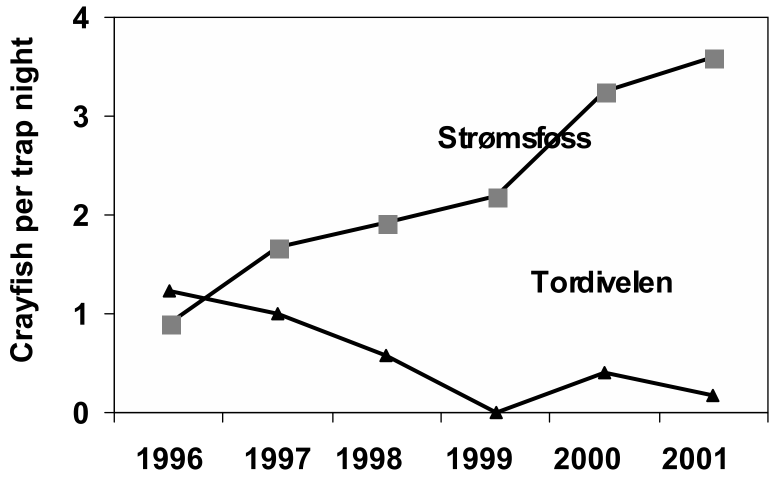


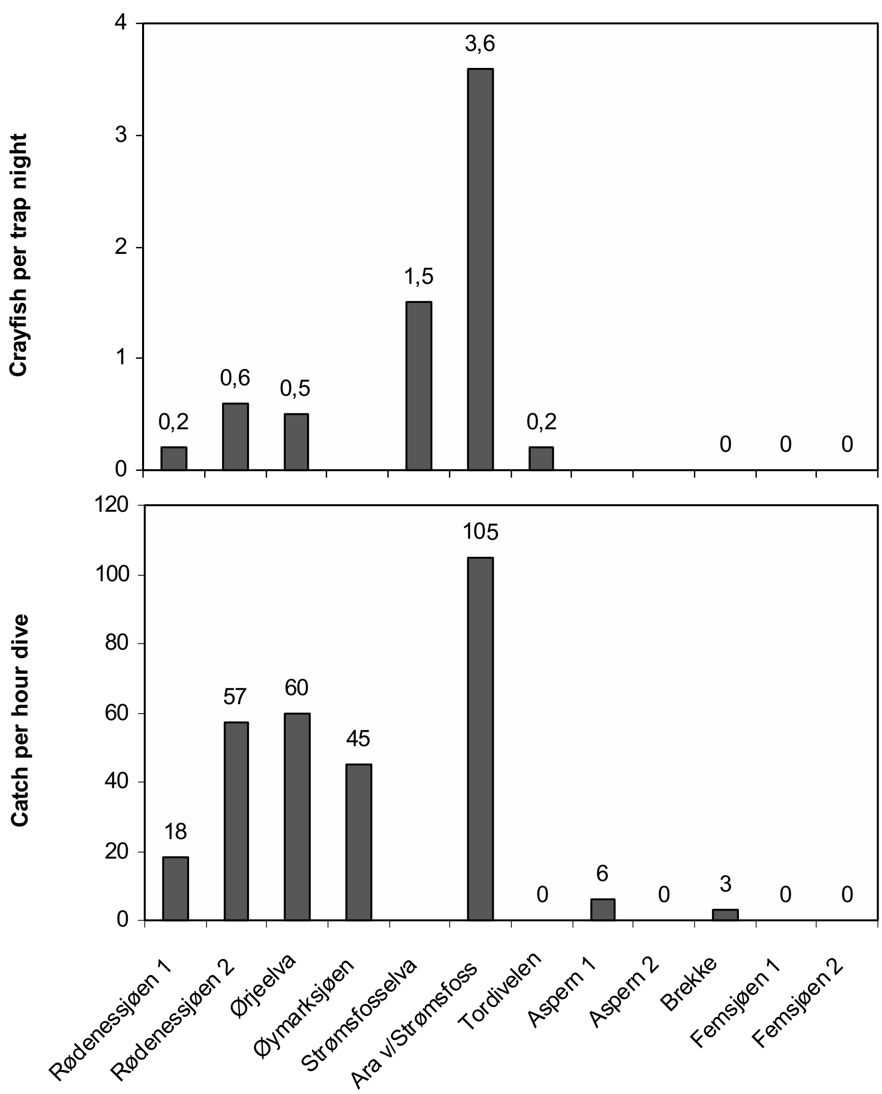
Figure 7
Mean size of crayfish in trap catches at adult crayfish stocking sites.

Figure 7
Taille moyenne des écrevisses dans les pièges aux sites de réintroduction des écrevisses adultes.

trap night over the same period. This is the fastest population development recorded with trapping at any of the test-sites in the two watercourses.

In 2001, different sites in the Halden watercourse were investigated by SCUBA-diving and trapping (Figure 9). The diving catches varied from zero to more than hundred individuals caught per diving hour, which may be categorized as a very good crayfish population. Trap catches varied from zero to 3.6 crayfish per trap night. In general the catches were better in the northern part of the watercourse (Rødenessjøen – Ara) reflecting a higher number a crayfish stocked in this part (Figure 2).


Crayfish per trap night
Strømsfoss
Tordivelen
0
1
2
3
4
1996
1997
1998
1999
2000
2001


Crayfish per trap night
Catch per hour dive
0,2
0,6
0,5
1,5
3,6
0,2
0
0
0
18
57
60
45
105
0
6
0
3
0
0
Rødenessjøen 1
Rødenessjøen 2
Ørjeelva
Øymarksjøen
Strømsfosselva
Ara v/Strømsfoss
Tordivelen
Aspern 1
Aspern 2
Brekke
Femsjøen 1
Femsjøen 2

Post-stocking movements in adult crayfish

In previous restocking experiments with adult crayfish we have experienced extensive post-stocking migrations (SKURDAL & TAUGBØL, 1995; TAUGBØL, 1996). SCHÜTZE *et al.* (1999) report similar behaviour in a telemetry experiment in a German river. Most of the adult noble crayfish in this case showed large-scale post-stocking migrations. Movements of some hundred meters per night, upstream as well as downstream, were observed. In the present reintroduction project, long post-stocking migrations were documented from the R. Glomma. At Leirud, situated approx. 5 km from the nearest stocking site (Figure 4), crayfish were caught for the first time in 1998 (Figure 10). Although the number is low, it clearly demonstrates the presence of crayfish, and these individuals must have migrated to this area from one of the stocking sites upstream or downstream. Also the fast population development in the R. Vingersnoret mentioned above, is most likely due to migration of crayfish from L. Vingersjøen.

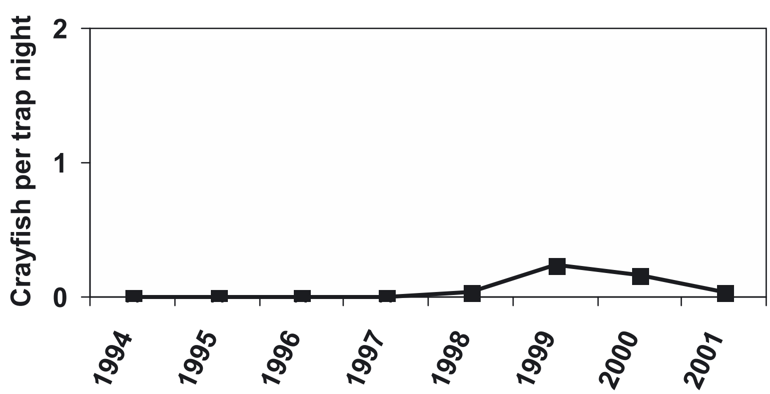


Figure 10
CPUE (crayfish per trap night) in R. Glomma at Leirud.

Figure 10
CPUE (écrevisse capturée de nuit) dans R. Glomma à Leirud.

Stocking with juveniles

Juveniles are much more stationary, obviously due to their small size and limited migration ability, but they seem to remain stationary also when they have grown larger. In the R. Ørjeelva in the Halden watercourse only a few adult crayfish (256) were stocked in

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▼ **Figure 8**
Development of post-stocking CPUE (crayfish per trap night) at Ara/Strømsfoss and Tordivelen in the Halden watercourse.

Figure 8
Développement du CPUE post-introduction (écrevisses capturées par nuit de piégeage) à Ara/Strømsfoss et Tordivelen dans le cours d'eau Halden.

◀ **Figure 9**
CPUE (trapping & diving) at different sites in the Halden watercourse in 2001.

Figure 9
CPUE (capture & plongée) à différents sites dans le cours d'eau Halden en 2001.

1995, the main stocking consisted of 5320 juveniles in 1998-1999. Diving investigations in 2000-2001, only two years after the first stocking, revealed a high abundance of crayfish, approximately at the same level as before the plague outbreak (Figure 11). The trap catch was still relatively low (Figure 9) most likely because a large proportion of the stocked juveniles had still a size not easily caught by traps (i.e. smaller than 70-75 mm).

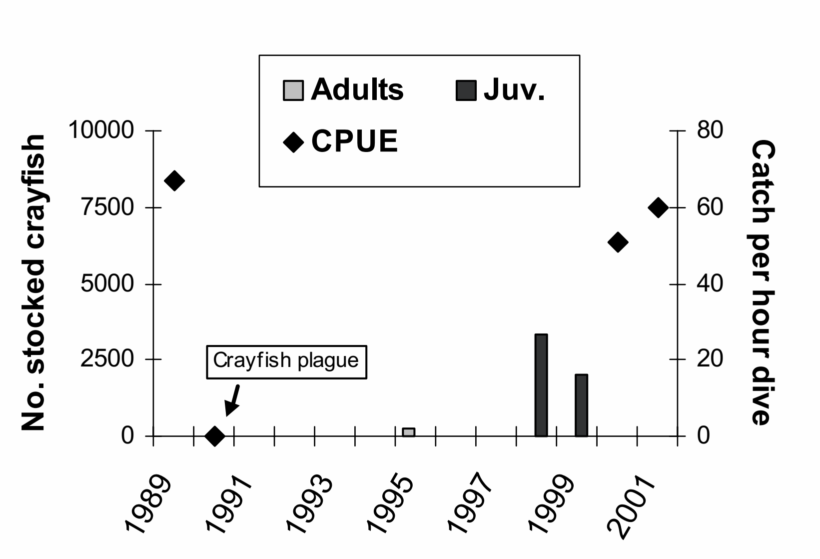

Figure 11
Number of crayfish stocked and CPUE (catch per hour dive) in R. Ørjelva in the Halden watercourse.

Figure 11
Nombre d'écrevisses introduites et CPUE (capture par heure) dans R. Ørjelva dans le cours d'eau Halden.

CONCLUSIONS

Reintroductions of native crayfish after crayfish plague are more likely to be successful in countries where there are no plague-carrying American crayfish species. There are, however, few documented examples of successful reintroductions lasting over a long period (i.e. more than 20 years).

Four years after stocking, natural recruitment was recorded at all adult crayfish stocking sites in the Glomma watercourse and at most sites in the Halden watercourse.

Current crayfish density estimated by trapping is, however, much lower than pre-plague densities even at sites where the population development has been in progress for more than 10 years.

Extensive post-stocking movements were recorded among adult crayfish. Juveniles seem more appropriate as stocking material if the goal is to re-establish a population in a particular area, due to their stationary habit, which seems to remain even when they have grown larger.

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