Freshwater Crayfish 17:77–83, 2010

ISSN:2076-4324 (Print), 2076-4332 (Online)
ISBN: 978-951-27-1322-6 (Print) / 978-951-27-1343-1 (Online PDF)

Evaluation of Crayfish Stocking Success in Finland

Esa Erkamo,[1,†] Timo Ruokonen,[2] Tarja Alapassi,[3] Janne Ruokolainen,[4] Teuvo Järvenpää,[3] Jouni Tulonen [1] and Jorma Kirjavainen [5]

[1] Finnish Game and Fisheries Research Institute, Fin-16970 Evo, Finland
[†] Corresponding Author — *esa.erkamo@rktl.fi*
jouni.tulonen@rktl.fi
[2] Department of Biological and Environmental Science, University of Jyväskylä, Survontie 9, Fin-40014 PL 35 Jyväskylä, Finland
timo.ruokonen@jyu.fi
[3] Finnish Game and Fisheries Research Institute, Viikinkaari 4, PL 2, Fin-00790 Helsinki, Finland
tarja.alapassi@rktl.fi; teuvo.jarvenpaa@rktl.fi
[4] Fisheries Advisory Centre Häme, Mariankatu 8A, Fin-15110 Lahti, Finland
janne.ruokolainen@proagria.fi
[5] Employment and Economic Development Centre for Häme, Fishery sector, Raatihuoneenkatu 11, Fin-13100 Hämeenlinna, Finland
jorma.kirjavainen@te-keskus.fi

Abstract.— The last two decades of the 20th century saw more crayfish stockings than any other 20 year period in Finland. During the 1990s alone, 1.5 million noble crayfish (*Astacus astacus*) were restocked and 1.6 million signal crayfish (*Pacifastacus leniusculus*) were stocked into Finnish lakes and rivers. The Finnish Game and Fisheries Research Institute (FGFRI) and its partners monitored the success of the stockings by test trappings during the years 1974 – 2005. The FGFRI collected and analysed follow-up information on 174 noble crayfish and 98 signal crayfish stockings in this survey. In about half of the cases, it could not be concluded whether the stocking was successful. In the cases where the success of stocking could be evaluated, about a third of noble crayfish stockings proved successful, a third failed completely and the rest produced weak and very slow growing populations. About 80% of the signal crayfish stockings were successful and the rest either failed completely or produced sparse, unproductive populations. In the most successful stockings, it took on average 5 years for signal crayfish and 8 years for noble crayfish to reach a CPUE > 1, a threshold for a commercially exploitable population. Better stocking outcomes for signal crayfish were supposedly a consequence of beneficial species specific characteristics and more favorable stocking sites. At least 30 stocked noble crayfish populations suffered mass mortality during the monitoring period, and in 25 cases, the only obvious explanation was crayfish plague (*Aphanomyces astaci*) infection. [*Keywords*.— *Astacus astacus*; noble crayfish; *Pacifastacus leniusculus*; signal crayfish; stocking success].

INTRODUCTION

Since 1893, crayfish plague (*Aphanomyces astaci* Schikora), has devastated Finland's most productive noble crayfish, *Astacus astacus* (Linnaeus), populations, causing great losses to once very valuable crayfish fisheries and exports (Järvi 1910, in ref. Westman 1991). Efforts to halt the spread of crayfish plague failed, so it was decided in the late 1960s to try to revive crayfish production and fisheries by introducing signal crayfish, *Pacifastacus leniusculus* (Dana), into Finnish waters (Westman 1973a, 1991, 2000). The first signal crayfish were imported from California during 1967 – 1969 and were stocked in 12 small lakes located in Southern and Central Finland and the Ahvenanmaa Islands (Westman 2000). Due to the fear of importing fish or crayfish diseases with the stock, the importation of wild-caught signal crayfish was halted and experimental stocking continued with farmed 2nd stage juvenile signal crayfish imported from Sweden (Westman 1991, 2000). During 1970 – 1974, about 35,500 2nd stage juveniles from Sweden were released into 45 separate waterbodies in Finland (Westman 1991, 2000). Järvenpää and Kirjavainen (1992) estimated that < 10 populations from that time frame are derived from these initial stockings.

At the same time as the experimental stockings, the Finnish Game and Fisheries Research Institute (FGFRI) developed culture methods for juvenile crayfish, and in the late 1980s, the commercial production of one-summer-old (and older) juvenile signal crayfish and noble crayfish for stocking purposes was started by several part-time crayfish farmers (Westman 1973b; Pursiainen et al. 1983, 1989; Järvenpää and Kirjavainen 1992). In 1989, a national

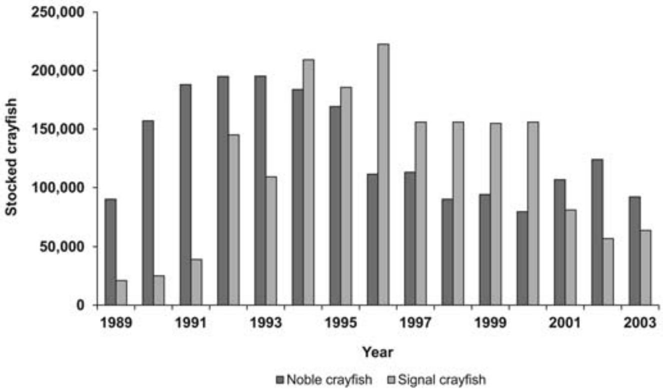

Figure 1. The number of stocked crayfish in Finland during 1989 – 2003.

crayfish strategy was developed and implemented by the Finnish fisheries authorities (Järvenpää and Kirjavainen 1992; Mannonen and Westman 1998). This strategy defined the preconditions and geographical limits for stocking signal crayfish into Finnish lakes and rivers, and large scale stockings of signal crayfish commenced. At the same time, stocking of noble crayfish also increased to a level higher than ever before (Figure 1).

According to the Finnish stocking registry (1989 – 2004), during 1989 – 2004, signal crayfish and noble crayfish were stocked into 352 and 1066 water bodies, respectively. In order to provide the necessary guidelines for stocking, the FGFRI implemented a monitoring and research programme in 1989 to examine reasons behind differing success of crayfish stockings. Some of the stocking results have been published earlier (e.g., Järvenpää and Kirjavainen 1992; Erkamo et al. 1998), and this paper gives a synopsis of the data collected since 1974. Results of the earlier signal crayfish introductions during 1967 – 1974 (Westman 1991) are also briefly re-examined for comparison.

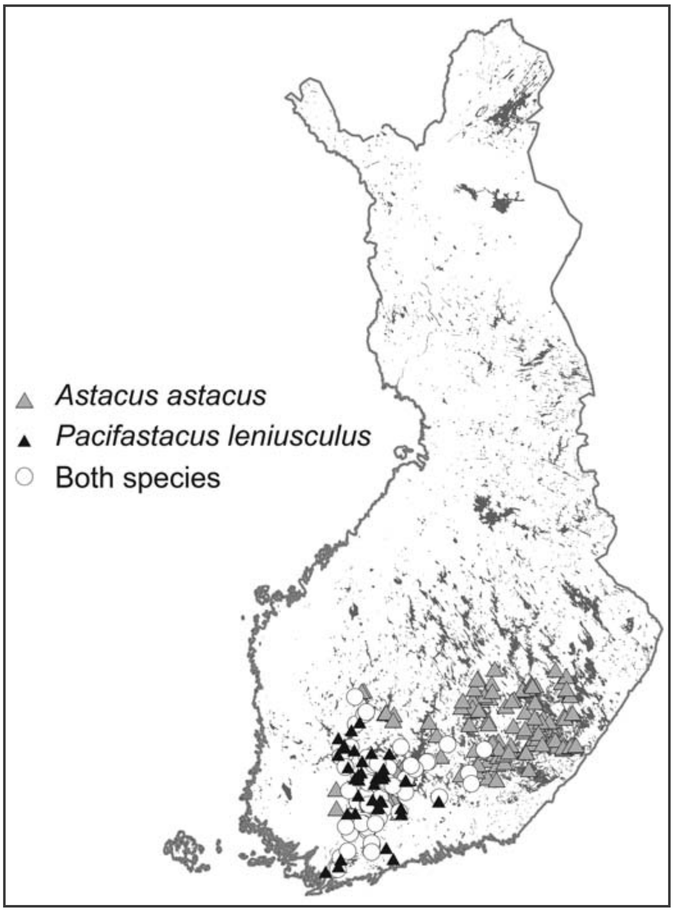

Figure 2. Location of monitoring sites stocked with noble crayfish (*Astacus astacus*) and signal crayfish (*Pacifastacus leniusculus*) in Southern Finland.

MATERIALS AND METHODS

Studies on Stocking Success of Noble Crayfish (1975 – 2003) and Signal Crayfish (1982 – 2002)

Stocking sites and stocklings

The studied stocking sites were located in southcentral Finland (Figure 2). The data from 174 waterbodies stocked with noble crayfish and 98 waterbodies stocked with signal crayfish were based on test-trapping. The stocking at the sites in question took place during 1975 – 2003 for noble crayfish and 1982 – 2002 for signal crayfish.

At most of the sites monitored, crayfish had been stocked repeatedly over the course of several years. In 58% of the cases, sites were stocked with signal crayfish that contained several age groups. The most common signal crayfish stocked were the cultured one-summer-old juveniles, which were the only type released at 28% of the sites. In comparison, mature wild-caught individuals predominated the noble crayfish stockings, and in 67% of the cases, they were the only type stocked. The mean stocking density in the cases monitored, calculated for whole waterbody, was 7 and 10 crayfish ha^{-1} for noble crayfish and signal crayfish, respectively.

The stocked signal crayfish were cultured in a presumably crayfish plague-free environment (Järvenpää and Kirjavainen 1992) or were caught from wild sympatric populations of noble crayfish and signal crayfish which had coexisted for several years. The mean number of stocked crayfish per case was 7700 for signal crayfish and 2250 for noble crayfish.

The test trappings

The test trappings were carried out by the FGFRI, the Fisheries Advisory Centres for Häme, Pirkanmaa and Etelä-Savo, the Employment and Economic Development Centres for Häme and Etelä-Savo, local fisheries management associations and other stakeholders. The trap model used in most cases was the Evo trap (Westman et al. 1979). Other cylindrical plastic (August™ or Rapu-Rosvo™, www.rapurosvo.fi) traps were used in some of the test-trappings. The traps were baited with fresh roach and were attached at 5 m intervals to a line that ran parallel to the shoreline in the vicinity of the stocking sites. In a few cases, traps were placed at irregular intervals along the shoreline. The trapping depth was normally between 0.5 and 3 m. For noble crayfish, test-trapping was carried out during 1975 – 2004, while signal crayfish were trapped during 1984 – 2005. There were, in general, between 1 and 4 trapping nights per test trapping site each year, and the number of follow-up years was between 1 and 15. About 80% of the test trappings took place within 12 yrs of the first stocking (Figure 3).

In about 80 to 90% of the monitored sites there were between 1 and 5 follow-up years of trapping. The mean number of follow-up years for noble crayfish was 3 yrs, while for signal crayfish it was 4 yrs. The total follow-up trapping effort was 1247 nights and 56,898 trap-nights (number of traps * number of nights) for noble crayfish and 809 nights and 50,925 trap-nights for signal crayfish. Only in years where the trapping effort at a study site was higher than 20 trap nights were included in CPUE calculations. The average effort was 235 trap-nights site^{-1} yr^{-1} for signal crayfish and 117 trap-nights site^{-1} yr^{-1} for noble crayfish. The sites monitored covered 16% of all noble crayfish and 28% of all signal crayfish sites stocked during 1989 – 2004, and in the study area, the proportion monitored was 42% of all signal crayfish and 34% of all noble crayfish stocked sites.

The stocking results were classified on the basis of three questions, as follows: 1.) had a new reproductive population been established; 2.) were the catches increasing over time (years); and 3.) how high were CPUEs at the end of the monitoring period. Four categories were formed according to answers to these questions (Table 1). In addition, we used a fifth category, "could not be judged", for the cases were success could not be determined, mostly because of insufficient data (i.e., whether the population was reproducing or not).

Stocking success

The success of a crayfish stocking was defined on the basis of the stocking history, CPUE values and on the crayfish size (length) distribution in the catches. In cases where one age group of crayfish was stocked only once, the age at the onset of maturity in females could be estimated from the size distributions of the catches. In these cases, female signal crayfish seemed to reach maturity at ages 2+ or 3+ while estimates suggested female noble crayfish reached maturity at 3+ or 4+. These estimates were generalized to all stocked sites when determining if the crayfish captured in traps were original stocked crayfish or their offspring (which would suggest a reproducing population).

In 40% of signal crayfish sites and 33% of noble crayfish sites no offspring were caught, even though the sites were stocked a few years earlier. At 19% of signal crayfish and 7% of nobel crayfish sites, repeated and intensive stocking over many years made it impossible to judge if the crayfish trapped were from the original stocking effort or the progeny from a breeding population in the lake or river in question. Both these groups were included in the category "could not be judged" and were excluded from the final analysis. On average, at least 7 years from the first stocking was required to make conclusions on the success of the stocking efforts in > 50% of the studied sites (Figure 4).

Analysis of Signal Crayfish Stocked During 1967 – 1974

Sites and stocking density

The geographical range of the earliest stocked sites (Westman 1991), was wider than in the main data analyzed here, with about 60% of the sites being located in the Häme, Pirkanmaa and Uusimaa provinces. River and lake size classes were similar to the main data, with the smallest lakes (< 50 ha) being the most common size class (47%), and larger lakes (> 500 ha) being the least common (11%).

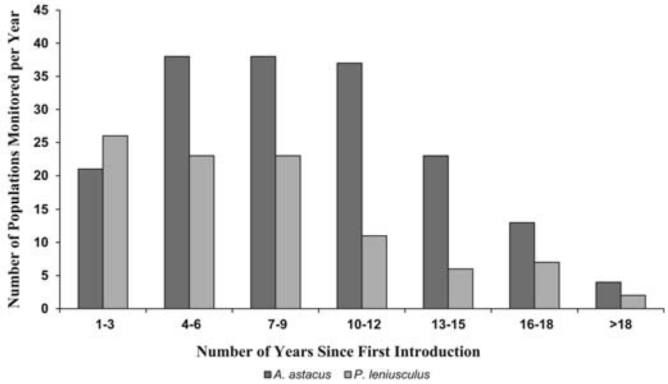

Figure 3. Mean number of noble crayfish and signal crayfish sites monitored per year, in 3 year periods from the first introduction.

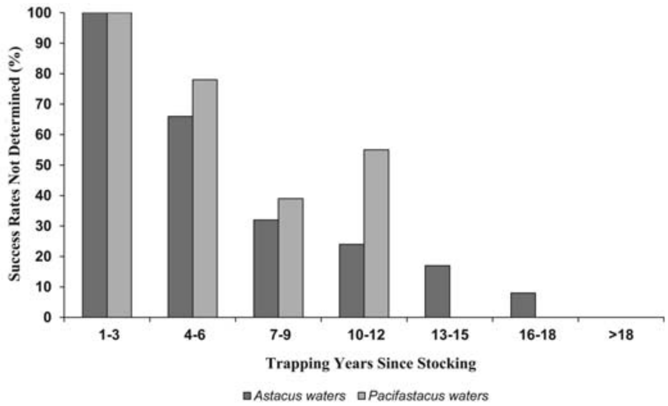

Figure 4. Length of the time crayfish stocks were monitored in relation to the ability to evaluate the success of stocking. Results were based on test-trappings during 1975 – 2005.

Among the follow-up cases were 7 sites stocked with mature signal crayfish of Californian origin, 23 introduced with 2nd stage juveniles from Sweden and 4 introduced with older juveniles cultured in Finland from Swedish 2nd stage juveniles. The mean number of crayfish stocked was 740 site^{-1} for 2nd stage juveniles, 180 site^{-1} for cultured juveniles and 420 site^{-1} for mature crayfish, with the mean stocking density for the whole waterbody at 29 crayfish ha^{-1} for 2nd stage juveniles and 69 crayfish ha^{-1} for mature crayfish.

Test trappings

The first experimental introductions of signal crayfish during 1967 – 1974 (Westman 1991) were test-trapped by FGFRI during 1969 – 1978. A total of 34 out of the initial 53 original introductions were test-trapped at least once. The total trapping effort was more than 10,000 trap nights. About 90% of test trappings were carried out within 5 yrs after introduction. The mean number of trapping years was 4 and the mean trapping effort was 84 trap nights site^{-1} yr^{-1}. Stocking was repeated at only 1 of the 34 sites.

Table 1. The categories of stocking success and their definitions.

Category	Description
No new population	No catch or only stocked individuals were caught. At least two consecutive years with this outcome were required.
A weak population	At least two generations of offspring were caught, but the CPUE remained low, < 0.2.
A growing population	The CPUE increased over time but remained < 1.
An exploitable population	Similar to previous category but the CPUE > 1, and offspring dominated the catch.
Could not be judged	Could not decide whether catches consisted of only stocked crayfish, or if offspring were also present.

Data processing

For comparison, we re-examined the results of these older trappings with the same methods as in our main data. The data was processed separately from the main analyses because a different trapping methods that had been applied (traps were examined several times each night) along with different preconditions for stocking success (i.e., low number of stocked crayfish).

RESULTS

Analysis of Stocked Noble Crayfish (1975 – 2003) and Signal Crayfish (1982 – 2004)

Monitored waterbodies

The type of waterbody and size distribution of noble crayfish sites corresponded quite closely to all those stocked Finnish during 1989 – 2004. In contrast, among signal crayfish sites, the proportion of smaller lakes was lower while the proportion of large lakes was higher in our data than among all waterbodies stocked with signal crayfish. The most common water system type in our data were medium-sized lakes. On average, lakes and rivers stocked with noble crayfish were smaller than those for signal crayfish (Table 2). Separate open lake areas of larger waterbodies were considered as individual lakes.

Stocking success

At 59% of signal crayfish sites it could not be concluded if a reproductive signal crayfish population had developed (Figure 4). However, by excluding the sites where success could not be determined by test trappings, we concluded that 95% of the introductions of signal crayfish we studied resulted in a reproductive populations and most of those had already developed into exploitable populations (Table 3). The mean time for CPUE to reach a value ≥ 1 at sites stocked with signal crayfish (= an exploitable population) was on average 5 yrs (range 2 – 11) .

Table 2. Type, size and number of waterbodies stocked with noble and signal crayfish in this study.

Type and size of waterbody	Noble crayfish (n)	Signal crayfish (n)	Noble crayfish (%)	Signal crayfish (%)
Lake < 50 ha	55	10	32	10
Lake 51 – 500 ha	68	36	39	36
Lake > 500 ha	25	39	14	40
River	26	13	15	13
Total	174	98	100	100

At 40% of monitored noble crayfish sites, the stocking success could not be judged. Most of the uncertain cases were recently stocked sites with a follow-up of only a few years. After excluding the uncertain sites, we concluded that 64% of noble crayfish stockings resulted in a reproductive population (Table 3). Furthermore, the sites stocked with noble crayfish resulted in growing or exploitable populations in 33% of the cases. For noble crayfish sites, the mean timespan for the CPUE to reach a value ≥ 1 was 8 yrs (range 4 – 12).

In many of the monitored noble crayfish, and most of the signal crayfish, sites there were low numbers of noble crayfish at the time of first stocking. This did not affect the success of signal crayfish introductions, but seemed to have some positive effect on the stocking success of noble crayfish (Table 4).

For river sites, there were only 4 sites stocked with signal crayfish and 14 sites stocked with noble crayfish where the success could be judged. On average, when noble crayfish were stocked into lakes they were more successful than when stocked into rivers. For example, nine of 14 (64%) river sites stocked with noble crayfish were unsuccessful.

In waterbodies stocked with noble crayfish, the proportion of clearly successful stockings (i.e., sites resulting in a growing or exploitable population), was highest (43%) among medium-sized lakes (50 to 500 ha), and lowest in small lakes (22%) and rivers (21%). In waterbodies stocked with signal crayfish, the success was highest (91%) among large lakes (> 500 ha).

At least 30 of the 174 noble crayfish populations that were stocked suffered mass mortality during the follow-up period. In 25 cases, there were no obvious explanations for the population collapse other than crayfish plague infection. Among these sites, crayfish plague infection was observed on average 9 yrs after they were first stocked. Water quality analyses and local observations indicated that the remaining 5 population collapses were probably caused by oxygen depletion. Sudden mass mortality of fish or fatally low oxygen content in water samples was observed in these 5 cases only.

Analysis of Signal Crayfish Stocked From 1967–1974

At 20 of the 34 sites where test trapping occurred, the trapping efforts were intensive enough to estimate whether the introduced population was successful. In 4 out of 8 (50%) of the sites stocked with mature signal crayfish, or older juveniles, and at 3 of 12 (25%) stocked with 2nd stage juveniles, introductions resulted in a reproductive population.

DISCUSSION

According to our data, signal crayfish stockings carried out during 1982 – 2002, in most cases, resulted in a productive population in Southern Finland. Noble crayfish stockings were less successful, but still showed reasonable results. One of the main reasons for the observed success of the signal crayfish stockings was probably the quality of waterways that were stocked. According to the owners of these waterbodies and local fishery advisors, nearly all of the sites had featured highly productive noble crayfish populations in the past (Water Owners and Local Fishery Advisors 1989-2009). In fact, the most productive noble crayfish populations inhabited these watercourses before the crayfish plague was first introduced into Finland (Järvi 1910; in Westman 1991).

Another important finding was the observed rate of population development. Signal crayfish had a faster growth rate, higher fecundity and earlier maturation (Abrahamson 1971; Westman 2000) and therefore, on average, have a faster population development rate than noble crayfish. A reason for the low CPUE observed in noble crayfish populations stocked into large lakes could be a much lower stocking density than that used for signal crayfish in lakes of the same size-class. Furthermore, in some of these large lakes, the state of the noble crayfish populations might have been misinterpreted as a weak population instead of a growing population. In a sparse population resulting from a relatively low stocking density, the population growth may be directed into dispersing into the new habitat for several years, rather than immediately increasing of the population density. In addition, the monitoring period could have been too short in many cases, to draw definite conclusions about the stocking success of the noble crayfish.

Most of the rivers in southern and central Finland have been affected by forestry, agriculture, hydroelectric power plants, the peat industry and transportation infrastructure (Eloranta 2004). This and other means of water usage, such as building of dams and channels, dredging, draining, ditching and water level regulation, has caused harmful effects to our aquatic ecosystems (Eloranta 2004; Tulonen et al. 2009, 2010). The high proportion of unsuccessful crayfish introductions in rivers may reflect the sensitive nature of these crayfish (Pursiainen and Westman 1984; Westman 1991) to man-made environmental changes.

The proportion of clearly successful stockings was lowest in small lakes. Due to the low levels of littoral wave erosion in small lakes, soft bottoms rich in organic material were more common and hiding places more infrequent in small as opposed to large lakes (Hellsten and Juntura 2000). Both noble crayfish and signal crayfish favour rigid bottoms with large numbers of stones or other hiding places (Goldman 1973; Goldman and Rundquist 1977; Westman and Pursiainen 1979, 1982). Relatively low pH values and calcium content of water, both suboptimal (e.g., Appelberg 1992) for crayfish, were also more common in smaller lakes (Erkamo, unpublished data). The unfavourable bed structure and water quality were probably the main reasons for the rather poor stocking results found in small lakes.

Table 3. Success of signal crayfish and noble crayfish stockings made during 1975 – 2003 (58 signal crayfish sites and 70 noble crayfish sites with insufficient data have been excluded).

Stocking result	Signal crayfish (n)	Noble crayfish (n)	Signal crayfish (%)	Noble crayfish (%)
No new population	2	37	5.0	35.6
Weak population	5	33	12.5	31.7
Growing population	12	23	30.0	22.1
Exploitable population	21	11	52.5	10.6
Number of sites	40	104	100.0	100.0

Table 4. Summary of results for noble crayfish versus differing CPUEs at time of stocking.

	CPUE before stocking			
	0	< 0.1	0.1 – 1	all
No new population	39%	33%	27%	36%
Weak population	35%	30%	27%	32%
Growing population	20%	23%	27%	22%
Exploitable population	6%	13%	18%	10%
Totals	100%	100%	100%	100%

The success of the early signal crayfish stockings during 1967 – 1974 was clearly lower than that of later introductions during 1982 – 2002. There were at least 3 differences evident between these two stocking periods: the quality of stocked crayfish, the number of stocked crayfish per site and the mean size of the waterbodies that were stocked. According to Westman (1991), the main reasons for their poor results were probably low numbers of crayfish stocked into the wrong habitat types, and poor water quality in some of the lakes, as previously speculated by Erkamo et al. (1998). Furthermore, Fürst (1977) and Fjälling and Fürst (1988) estimated that 90 – 95% of 2nd stage juveniles will die before reaching maturity, thus adding to the poor outcome of stocking efforts. Early June stockings, using artificially incubated 2nd stage juveniles, have resulted in better outcomes (Erkamo et al. 1998).

During the average follow-up period of 9 yrs in this study, about 14% of the noble crayfish stockings that were monitored failed due to crayfish plague infections. This percentage is not high, but it should be taken into account that the majority of noble crayfish populations were too sparse for commercial trapping and our observation is that the probability of crayfish plague infection increases once commercial crayfish trapping begins (Erkamo, *unpublished data*).

The overall success of signal crayfish stocked in Sweden and Finland seems comparable. The total investment in the first 20 yrs of introductions of signal crayfish and the highest historical total catches of noble crayfish have also been about the same for both countries (Fjälling and Fürst 1988; Westman 1991; Finnish stocking registry 1989 – 2004). However, large-scale stocking of signal crayfish in Finland commenced 20 yrs later than in Sweden, and annual catches in Finland are still far below those in Sweden

(Fjälling and Fürst 1988; Westman 1991; FGFRI 2008; Gren et al. 2007).

For the current study, and that from Sweden (Fjälling and Fürst 1988), about 42% of the sites stocked with signal crayfish had a mean CPUE value > 1 from 6 to 11 yrs after the first stocking. This level of CPUE (i.e., > 1) can be considered the minimum threshold for profitable commercial crayfish trapping. In the Swedish study, about 10% of the sites yielded no catches and about 5% had a CPUE ≥ 10, while our data included only one site where the CPUE was as high as 10 during a follow-up period of 11 yrs. The annual mean CPUE for sites initially stocked 10 – 15 yrs previously were also found to be higher in the Swedish study (CPUE 2.5 – 4) when compared to our findings (CPUE 1 – 2.5). However, the proportion of failed signal crayfish stockings was similar in both studies. When generalizing our results, it should be remembered that the mean stocking densities of the monitored sites were appreciably higher (7 crayfish ha^{-1} for noble crayfish and 10 crayfish ha^{-1} for signal crayfish), than the average stocking densities for all Finnish waterways stocked between 1989 – 2004, 1 and 3 crayfish ha^{-1} for noble crayfish and signal crayfish, respectively, according to the Finnish stocking registry database from 1989 – 2004.

Smietana et al. (2004) studied stocking success of *A. astacus* and *Astacus leptodactylus* (Eschscholtz) in 54 waterbodies in Poland. According to their results, restocking was successful in at least 61% of sites. However, the sites were only monitored for 2 yrs in their study, and their definition for successful stocking differed from the one used in the current paper.

Albeit preliminary, our results show that it is possible to restore at least some proportion of the noble crayfish populations devastated by the crayfish plague. Also, the adaptation of signal crayfish to the environmental conditions in southern Finland is obvious based on our results. A further goal for research could be a detailed analysis of the environmental factors leading to differential stocking success. Especially urgent are studies concerned with the effect of the crayfish plague on the rate of success in restocking European crayfish species in different situations and environments.

ACKNOWLEDGMENTS

The authors wish to thank all their partners, especially Dr. Lasse Hyytinen from the Employment and Economic Development Centre for Etelä-Savo and Mr. Petri Mäkinen, Ms. Päivi Pyyvaara, Mr. Ismo Kolari and Mr. Harri Liikanen from the Pro Agria Advisory Centres for Häme, Pirkanmaa and Etelä-Savo and Dr. Kai Westman (retired from FGFRI) for providing their trapping data. The FGFRI and its Crayfish Research Program were responsible for funding this study. Special thanks to Dr. Japo Jussila (Crayfish Innovation Center, Finland) for his uncharacteristic patience. We thank our two anonomous reviewers for helpful comments and suggestions.

LITERATURE CITED

Abrahamsson SA (1971). Population ecology and relation to environmental factors of *Astacus astacus* (L.) and *Pacifastacus leniusculus* (Dana). PhD Thesis, Lund University, Sweden.

Appelberg M (1992). Liming as a measure to restore crayfish populations in acidified lakes. *Finnish Fisheries Research* 14:93–105.

Eloranta A (2004). River restoration. Pp. 105–115. *In*: Inland and Coastal Waters of Finland. Eloranta P, (ed.). Palmenia Publishing, University of Helsinki, Finland.

Erkamo E, Järvenpää T, Kirjavainen J and Tulonen J (1998). The influence of the size of noble crayfish and signal crayfish on stocking results in southern Finland. *ØF-Rapport*. 26/1998:149–159.

FGFRI (2008). Crayfish Review 2007. Publ. Internet. http://www.rktl.fi/en/julkaisut/j/416_.html [accessed 28 Oct 2009].

Finnish Stocking Registry (1989-2004). Unpublished official register maintained by Finnish fisheries authorities.

Fjälling A and Fürst M (1988). The development of a fishery for the crayfish *Pacifastacus leniusculus* in Sweden 1960-86. *Freshwater Crayfish* 7:223–230.

Fürst M (1977). Introduction of *Pacifastacus leniusculus* (Dana) into Sweden. Methods, results and management. *Freshwater Crayfish* 3:229–247.

Goldman C (1973). Ecology and physiology of the California crayfish *Pacifastacus leniusculus* (Dana) in relation to its suitability for introduction into European waters. *Freshwater Crayfish* 1:106–120.

Goldman CR and Rundquist J (1977). A comparative ecological study of the California crayfish *Pacifastacus leniusculus* from two subalpine lakes (Lake Tahoe and Lake Donner). *Freshwater Crayfish* 3:51–80.

Gren I-M, Campos M, Bohman P and Edsman L (2007). Ideologies and regulation of invasive species: an application to signal crayfish in Sweden. Publ. Internet.*www2.ekon.slu.se/seminar*/070216.pdf [accessed 28-Oct-2009]

Hellsten S and Juntura E (2000). Effects of the wave induced shoreline erosion on the littoral zone: Case studies in northern Europe. Pp. 302–312. *In:* Workshop on hydrologic and environmental modelling in Mekong basin, Phnom Penh, Cambodia 11 – 12 September 2000. Mekong River Commission.

Järvenpää T and Kirjavainen J (1992). Crayfish stockings in Finland. EIFAC workshop on Crayfish Management and Stocking, 22 – 23 August 1991, Kuopio, Finland. *Finnish Fisheries Research* 14:69–75.

Järvi TH (1910). Über den Krebs *Astacus fluviatilis* (Rond.) und die Krebsepidemieen in Finnland. *Acta Societatis pro Fauna et Flora Fennica* 33(3):1–41. (Ref. Westman 1991).

Mannonen A and Westman K (1998). Crayfish situation in Finland. *ØF-Rapport*. 26/1998:29–38.

Pursiainen M, Järvenpää T and Westman K (1983). A comparative study on the production of crayfish *Astacus astacus* (L.) juveniles in natural food ponds and by feeding in plastic basins. *Freshwater Crayfish* 5:393–402.

PURSIAINEN M AND WESTMAN K (1984). The restoration of the crayfish *Astacus astacus* in river Siikajoki, Finland. FAO, Rome. *EIFAC Technical papers* 42(2):412–421.

PURSIAINEN M, JÄRVENPÄÄ T, TULONEN J AND WESTMAN K (1989). Crayfish culture in Finland. Pp. 69–78. *In:* Crayfish Culture in Europe. Skurdal J, Westman K and Bergan PI (eds.). Report from the workshop on crayfish culture 16 – 19 November 1987. Directorate for Nature Management, Trondheim, Norway.

SMIETANA P, KRZYWOSZ T AND STRUZYNSKI W (2004). Review of the national restocking programme: Active protection of native crayfish in Poland 1999-2001. *Bulletin Français de la Pêche et de la Pisciculture* 372-373:289–299.

TULONEN J, ERKAMO E, JUSSILA J AND MANNONEN A (2009). Shelter and depth use of adult noble crayfish *Astacus astacus* and signal crayfish *Pacifastacus leniusculus* in the presence of a predator. *Freshwater Crayfish* 16:93–96.

TULONEN J, ERKAMO E, MANNONEN A AND JUSSILA J (2010). The mortality of juveline noble crayfish (*Astacus astacus*) under conditions of water level regulation and predator pressure. *Freshwater Crayfish* 17:135–139.

WATER OWNERS AND LOCAL FISHERY ADVISORS (1989-2009). Queries and *Personal communication* with most of the water owner's representatives of studied waters and local fishery advisors during the study period.

WESTMAN K (1973a). The population of crayfish *Astacus astacus* (L.) in Finland and the introduction of the American crayfish *Pacifastacus leniusculus* (Dana). *Freshwater Crayfish* 1:41–55.

WESTMAN K (1973b). Cultivation of the American crayfish *Pacifastacus leniusculus* (Dana). *Freshwater Crayfish* 1:211–220.

WESTMAN K (1991). The crayfish fishery in Finland – its past, present and future. *Finnish Fisheries Research* 12:187–216.

WESTMAN K (2000). Comparison of the crayfish *Pacifastacus leniusculus* (Dana), a species introduced into Finland, with the native species, *Astacus astacus* (L.), in allopatry and sympatry. PhD Dissertation. University of Helsinki, Finland.

WESTMAN K, PURSIAINEN M AND VILKMAN R (1979). A new folding trap model which prevents crayfish from escaping. *Freshwater Crayfish* 4:235–242.

WESTMAN K AND PURSIAINEN M (1979). Development of the European crayfish *Astacus astacus* (L.) and the American crayfish *Pacifastacus leniusculus* (Dana) populations in a small lake. *Freshwater Crayfish* 4:243–250.

WESTMAN K AND PURSIAINEN M (1982). Size and structure of crayfish *Astacus astacus* populations on different habitats in Finland. *Hydrobiologia* 86(1-2):67–72.