ØF-Rapport nr. 26/1998

Nordic-Baltic Workshop on Freshwater Crayfish Research and Management

May 23-26, 1998, Sagadi Training Centre, Estonia

Trond Taugbøl (ed.)

Eastern Norway Research Foundation

Estonian Ministry of Environment, Department of Fishery

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Referat:	A Nordic-Baltic workshop on freshwater crayfish research and management was held at Sagadi Training Centre, Estonia, May 23-26 1998. The workshop gathered 37 participants from 9 different countries. In total 21 oral and 8 poster presentations were given, and there was also group work. The purpose of the workshop was to exchange information and knowledge based on current research and mangement experiences, and discuss future research needs. The Nordic and Baltic countries have many of the management problems and challenges in common. Good communication, co-operation and co-ordination between researchers and managers in the different countries are of great importance in order to enhance crayfish management and research. This report presents submitted manuscripts of the oral/poster presentations and conclusions and recommendations from the workshop, based on group work, country presentations, and plenary discussions.

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Foreword

Since 1978 there has been quite many meetings between Nordic crayfish researchers. The first Nordic meeting was arranged at Erken, Sweden, in 1977 and was attended by researchers and managers from Norway, Sweden and Finland. The second Nordic meeting was held in Lammi, Finland, in 1979. Two EIFAC (European Inland Fisheries Advisory Committee) crayfish meetings, focusing on aquaculture and management and stocking respectively, were held in Trondheim, Norway, and Kuopio, Finland, in 1987 and 1991. Preceeding the EIFAC meeting in 1991 was a NorFA research course on crayfish management and culture. A NorFA workshop was held in Älvkarleby, Sweden, in 1993 focusing on crayfish population ecology, and a NorFA research course on crayfish pathogen methodology was held in Jyväskylä, Finland, in 1995. The last two meetings also gathered participants from Lithuania and Estonia, and subsequently the Nordic-Baltic cooperation and mutual visits further increased. That encouraged us to arrange the first crayfish workshop with participants from all Baltic and Nordic countries, in Estonia, May 23-26, 1998. The aim of this workshop is further outlined in the "Introduction" section of this report.

The workshop gathered 37 participants from 9 different countries (Appendix 1). In total 21 oral and 8 poster presentations were given (Appendix 2) and there were group discussions on different subjects related to management of crayfish. (Workshop program in Appendix 3). This report presents the submitted manuscripts of the oral/poster presentations, arranged in two different parts. Part 1 gives the crayfish status situation by country, and part 2 contains the other contributions on different aspects of crayfish biology and ecology. With the exception of minor, editorial corrections, the papers are presented as received by the editor, i.e. there has been no reviewing process. Part 3 of the report presents in short, conclusions and recommendations from the workshop, based on the group and plenary discussions. The workshop has mainly been financed by NorFA (Nordic Academy for Advanced Study). Also the International Association of Astacology (IAA), the Estonian Fisheries Capital Fund, the Norwegian Ministry of Environment, and Eastern Norway Research Institute have granted economical support. On behalf of all the participants, thanks to the supporters who made this workshop possible. As organizers, we would also like to thank all the participants for making the workshop to a successful event. The professional outcome was good, but not less important was the warm and friendly atmosphere in which new friendship and contcts were formed.

Lillehammer/Sagadi, January 1999

Trond Taugbøl

Jaanus Tuusti
(sign.)

Contents

Introduction

Freshwater crayfish are a major component of the freshwater systems in large parts of the Nordic and Baltic countries. There are two European (*Astacus astacus* and *A. leptodactylus*) and two North American (*Pacifastacus leniusculus* and *Orconectes limosus*) species in the region. Freshwater crayfish are subject to great concern due to a large decline of the native populations. The native crayfish species of Europe are considered as vulnerable and special care is recommended in the management (exploitation and conservation) of these species (cf. the Bern convention and the EC`s Habitat Directive). In addition, crayfish have a high economical, as well as recreational and ecological value, and there is a considerable interest to increase harvest from wild and cultured stocks.

The Nordic and Baltic countries have many of the management problems and challenges in common. Good communication, co-operation and co-ordination between researchers and managers in the different countries are of great importance in order to enhance crayfish management and research. The purpose of the workshop was to exchange information and knowledge based on current research and mangement experiences, and discuss future research needs. Manuscripts from most of the oral and poster presentations are published in the present report.

Aim of the workshop

- Review current status (distribution, development trends and threats), ongoing research projects and managment of freshwater crayfish in the Nordic and Baltic countries, including both native and introduced species.
- Identify and discuss important crayfish management problems and actions, based on current research/knowledge and mangement experience.
- Identify future research needs in order to improve the management (exploitation and conservation) of the crayfish stocks.
- Enhance Nordic/Baltic co-operation on crayfish research and management, and strengthen the network of Nordic/Baltic crayfish researchers.
- Enhance interest for crayfish research and mangement by including research students/young researchers in the more established group of Nordic/Baltic crayfish researchers.

Part 1

Crayfish situation by country

Freshwater crayfish in Denmark; species, diseases, legislation and management

Bjarne Styrishave[1], Soren Berg[2] and Berit Bojsen[1]
[1]Department of Life Sciences & Chemistry, Roskilde University,
P.O. Box 260, 4000 Roskilde, Denmark
[2]Danish Institute for Fisheries Research, Dept. of Inland Fisheries,
Vejlsøvej 39, DK-8600 Silkeborg, Denmark

1 Introduction

During the last 10 - 15 years the interest in several aspects of freshwater crayfish has increased in Denmark. Before this period very few individuals and no regional or national authorities payed much attention to the existence of freshwater crayfish. The issue of freshwater crayfish was more or less positioned in a vacuum between low fisheries interest (both commercial and recreational), low aquaculture interest and low protection (or conservation) interests and, probably as a consequence of these, low scientific interest as well. Freshwater crayfish research performed in Denmark during the last 10 - 15 years is limited to ca. 10 M. Sc. - thesis. No graduate researchers have been engaged in any research of their own. In this respect Denmark is very different from it's neighbouring countries, e.g. Sweden, which has an old and very strong tradition in both production and consumption of crayfish and crayfish research.

The foundation of two crayfish farmer associations around 1988 one of which still exists, indicates an increasing interest in crayfish farming at that time. Several new laws with more or less direct relevance to freshwater crayfish were adopted during the early 1990's, indicating more focus on crayfish from the authorities. But knowledge and information on distribution of species and status of single populations is still very poor, mainly due to the lack of national or regional monitoring programmes. In spite of these difficulties this paper will describe the present situation for freshwater crayfish in Denmark, by summarizing official and unofficial knowledge.

2 Distribution and status of freshwater crayfish species in Denmark

2.1 Native crayfish

Noble crayfish, Astacus astacus

Denmark has only one native species of crayfish, the noble crayfish (*Astacus astacus*). Thus, the noble crayfish is an integral part of Danish freshwater systems. Within the last century, however, stocks have declined primarily due to eutrophication and drainage of lakes and regulation of rivers for agricultural purposes. However, stocks are still found in many major river systems and in all parts of the country. Denmark is administratiwely separated into 31 regions with respect to river systems. The noble crayfish is found in all 31 regions. On the Jutland peninsula, the largest stocks are found in Skals river, Simested River and in the Gudenå River system. On the island of Funen, the largest stocks are associated with the Odense river system, and on the island of Zealand, major stocks are found in the Lindved, Tude, and Suså river systems (Larsen 1990). Noble crayfish farming is on a small scale and the annual yield is assumed to be less than 5 tonnes.

In recent years, efforts have been made to restore lakes and rivers throughout the country. The noble crayfish is assumed to benefit from these restorations. Yet, the noble crayfish has only little commercial value in Denmark and a limited amount of data are available on noble crayfish distribution and exploitation. Therefore, the importance of nature restoration on noble crayfish populations are unknown. In recent years, the noble crayfish have been threatened by the introduction of alien crayfish species, primarily the narrow-clawed crayfish, *Astacus leptodactylus* and the signal crayfish *Pacifastacus leniusculus*, which carries the crayfish plague, *Aphanomyces astaci*.

2.2 Introduced crayfish

Signal crayfish, Pacifastacus leniusculus

In the early 1970's, the signal crayfish were introduced to Denmark (Bruun 1992). Signal crayfish were introduced partly to replace the noble crayfish in small scale crayfish farming and partly, because signal crayfish with its higher reproductive potential and faster growth is assumed to have a greater potential than noble crayfish for large scale commercial production. However, several noble crayfish farmers pointed out, that signal crayfish could potentially threaten the remaining stocks of noble crayfish due to the spread of crayfish plague and in 1992 new laws made it illegal to release alien crayfish including signal crayfish into Danish natural waters. At that time, however, several signal crayfish farms were established and are still found in all parts of the country. No registration of signal crayfish implants in natural waters has been made prior to 1992, and therefore a map on the distribution of signal crayfish implants in Denmark is not currently available. Signal crayfish are now found in the wild but no effort has been made to map the distribution. Consequently, little is known about signal crayfish in the wild.

On the Jutland peninsula signal crayfish have been found in the Ribe river system. No further information is available on this population. On the island of Zealand, signal crayfish have been found in the Tude river system. Specimens from this river was found to carry the crayfish plague, *Aphanomyces astaci*. In Skovse stream, a tributary of Tude river, females with hatchlings have been caught. This is the only clear evidence for signal crayfish reproducing in the wild in Denmark. The population size is not known, however.

Narrow-clawed crayfish, Astacus leptodactylus

The narrow-clawed crayfish, was introduced to Denmark primarily from Poland and Turkey in the early 1970's for use in crayfish farming. As a result stocks are found in most parts of the country (especially on the Jutland peninsula and on the Island of Zealand) in privately owned, isolated lakes and ponds. The distribution of narrow-clawed crayfish in Denmark in the wild has never been investigated and as a result is not known. However, the Danish Crayfish Farmers Association has two records on the occurrence of wild populations of narrow-clawed crayfish in Denmark, both in the Southern part of the Jutland peninsula where it has been found in a pond associated with the Ribe river system, and in Ferup Lake close to the City of Vejle. How and when these stocks were introduced is unknown as are the population sizes. Also, it is not known whether these populations reproduce in the wild and can expand to other areas. The narrow-clawed crayfish is found in all 7 districts associated with Zealand and surrounding islands in isolated ponds and lakes (National Forest and Nature Agency 1997) but has not yet been reported in the wild.

The narrow-clawed crayfish is considered to be a potential threat to the noble crayfish due to its higher fertility, higher growth rate and better utilisation of food supply (Holdich and Lowery 1988). However, since both species are sensitive to the crayfish plague, the signal crayfish is concidered a threat to both species.

Red swamp crayfish, Procambarus clarkii

The red swamp crayfish has recently been introduced to Denmark in low quantities for use in domestic aquarias. The species has not been recorded in the wild. It is presently unknown, if this species can survive during the Danish winter or reproduce in the wild.

3 Crayfish diseases

Crayfish plague, Aphanomyces astaci

No crayfish plague outbreak has yet been reported in Denmark. However, a large stock of noble crayfish disappeared suddenly from Bonderup Bog in 1992. Signal crayfish were caught in the nearby Tude River, and was found to carry the crayfish plague. This suggests, that this stock of noble crayfish may have disappeared as a result of crayfish plague, but this is highly speculative.

Porcelain disease, Thelohania conjeteani

Essentially no information are available, but the disease has been observed in several stocks throughout the country. It appears to infect less than 5-10% of a population.

Burn spot disease, Ramularia astaci

The burn spot disease is not very common, yet the disease is frequently observed. With few exceptions, the disease appears to have little effect on populations.

Psorospermium haeckelii

Psorospermium haeckelii is frequently observed and is probably very common. It has been observed in othervise healthy individuals of noble crayfish, and the effects on noble crayfish populations are presently unknown.

4 Legislation related to the protection of native crayfish

Four Danish laws have relations to the protection of the native noble crayfish. Two laws have specific goals of protecting habitats and their quality and two laws have sections more or less directly aiming at freshwater crayfish.

Habitat protection

The environment protection act serves the general purpose of preventing pollution of air water and soil, and to provide the basis for planning actions against pollution. This law is very important for the well being of all aquatic habitats in Denmark. The discharge of pollutants and sewage from towns, factories and agriculture during this century is considered one of the main reasons for the reduction in number and density of noble crayfish populations.

The stream act has the general purpose to ensure that streams can be used to drain off surface waters, but all actions must be taken under consideration of environmental demands, especially the physical quality of stream habitats. This is done via maintenance schemes for each river system in Denmark, stating how maintenance must be performed to ensure the draining capacity of the stream without reducing the quality of the river as a habitat for aquatic organisms. I 1997 a new section was added to the stream act. It is now forbidden for farmers to plough fields closer than two metres from the top of stream banks. This rule is expected to reduces the erosion of stream banks significantly.

Both laws are important for preventing the deterioration of aquatic habitats in general. As a result, all aquatic species, including the noble crayfish, is assumed to benefit from the adoption of these two laws.

Noble crayfish species protection

The nature protection act has the general purpose to protect animals and plants native to Denmark and to improve or re-establish habitats. An important section makes it forbidden to impose physical changes to all lakes larger than 100 m^2 and selected rivers of high nature value without prior permission. The law also contains a ban against putting alien species of plants and animals out into the Danish nature without prior permission. It is also possible to put special restrictions on the use of landscapes, rivers etc. by naming them nature reserves or "special protected areas", but this can only be done by compensating the landowners for economical losses resulting from the restrictions.

The inland fisheries act of 1992 is the only law directly naming crayfish. The noble crayfish has a minimum legal size of 90 mm and a closed season for males from October 1st to March 31st and for females from October 1st to July 31st. There is no legal size and closed season for alien species.

A governmental order of 1994 under the inland fisheries act has made it illegal to stock alien species of freshwater crayfish in any kind of freshwater in Denmark, including closed lakes and ponds (e.g. garden ponds). At the same time the order imposed strong restrictions on farming with already introduced alien crayfish.

The inland fisheries act also has general rules on size and type of gears allowed as well as a ban against fishing with explosives, poison, light, by draining ponds or by chasing fish into gears. All these rules put restrictions on the effectiveness of fishing thereby protecting crayfish populations from overfishing.

Red list status of the noble crayfish

In Denmark, the National Forest and Nature Agency is responsible for the development and updating of the List of Endangered Species, the so called Red List. An appendix to this list is also being published, called the Yellow List. This list covers species that are not presently threatened with extinction and therefore do not fit into the categories of the Red List, yet to some extend demands attention because they could be further threatened in the near future. A new Red List will be published in 1998, and for the first time the noble crayfish will appear, but only in the Yellow List appendix.

The fact that the noble crayfish will appear in the Danish Red List appendix demonstrates that the National Forest and Nature Agency are more concerned with the noble crayfish now than when the latest issue of the Red List was published in 1990.

Other regulations important to freshwater crayfish

According to the rules of the inner market in the European Union, freshwater crayfish can be imported live, but according to the Danish rules they can only be imported for consumption and must not be used for stocking. Live crayfish imported from outside the European Union must be killed before distribution within the country. The fact that it is allowed to import alien species of crayfish live must, however, be considered a major risk to the native noble crayfish, as it is very easy to use live crayfish bought for consumption for illegal stocking purposes.

5 Management of noble crayfish stocking

Since 1993, the Danish Fisheries Management Funds (the Danish anglers or rod license) have supported stocking of noble crayfish financially paying 50% of the expenditures to establish self-reproducing populations of noble crayfish in lakes and ponds. The support is limited to the price of stocking max 15 0+ noble crayfish per metre shore line, distributed over 1, 2 or 3 years. Fishing on the noble crayfish populations established with support must obey the rules of the inland fisheries act and feeding the crayfish is not allowed. In this way the financial support aims at creating new populations of noble crayfish in natural balance rather than supporting the establishing of crayfish farms.

So far, 40 land owners have benefitted from this arrangement, stocking a total of 106.700 noble crayfish (0+ or older) during the period 1993 - 1997.The interest from the applicants to receive support was highest during the first two years and has declined steadily since then. The reason for this is not known.

6 Conclusions

Positive and negative aspects in the present situation in Denmark from a noble crayfish protection point of view:

Advantages

Noble crayfish are still found in all parts of Denmark and lakes and ponds are being repopulated with noble crayfish. As far as anyone knows introduced crayfish are still rare in the wild, and they can only be imported for consumption. For these reasons, the noble crayfish is not considered to be neither endangered, threatened, vulnerable, or rare, but the fact that the noble crayfish will appear in the Danish Red List appendix and that the Danish Fisheries Management Funds actively supports the stocking of noble crayfish indicate that the Danish authorities are now becoming increasingly aware of the crayfish problem. The noble crayfish and it's habitats is also considered to be well protected by legislation.

The crayfish populations are often located on different islands and thereby separated from one another by marine barriers. The natural spread of introduced crayfish is therefore likely to be slow and some noble crayfish populations may be completely isolated and protected from the invasion of alien crayfish.

Disadvantages

It is now established, that populations of signal crayfish live, grow and reproduce in the wild. It is also known that these signal crayfish carries the crayfish plague. The major problem concerning signal crayfish is, that no records on signal crayfish implants exists. It is therefore extremely difficult to map the distribution of signal crayfish, and the authorities do not know where to look for signal crayfish in the wild. Another problem is that live crayfish can be imported to Denmark from other member states of the European Union. Live signal crayfish are frequently being imported from England and Ireland for consumption, but the Danish authorities have no means to ensure that the crayfish are actually being consumed and not released into freshwater habitats. This is also the case when signal crayfish are being sold for consumption from already existing signal crayfish farms. Crayfish imported from countries outside the European Union must be killed before distribution within the country. This law can legally be bypassed, however, if crayfish from outside the EU are exported to another EU member state where the species already exists before being exported to Denmark. In Denmark, crayfish plague outbreaks have not yet been reported with certainty. Therefore, the Danish authorities have no experience in diagnosing the disease, and no precautions are taken to counteract a crayfish plague outbreak. In Denmark, crayfish farming is on a small scale. As a result, most crayfish production, sale, and distribution are essentially out of the authorities control. Presently, about 15 noble crayfish farms are registered and frequently controlled by the Danish Veterinary and Food Service. These farms only represents a fraction of the total crayfish production.

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Crayfish situation in Estonia

Jaanus Tuusti
Sagadi Training Centre
EE-2123 Sagadi, Estonia

Noble crayfish *Astacus astacus* L. probably migrated into Estonian lakes and rivers concurrently with the end of the last glaciation and the elevation of the land. At the wave of crayfish plague struck turn of the 19th century Estonian lakes and rivers were very rich of crayfishes. First in Estonia in 1896-1903 in watersheds of lakes of Peipsi and Võrtsjärv. During the following 40 years the plague wiped out nearly all crayfish stocks on mainland. Last plague similar outbreak was registered in 1985-86, when crayfishes disappeared in 8 good crayfish waterbodies. Only islands of Saaremaa, Hiiumaa and Muhu have not been affected. Thus one of the main threats to our crayfish stocks are still plague – similar deaths.

Geographical position of Estonia provides very good natural barriers against the immigration of alien species. Migration from the eastern direction by natural watercourses is difficult due to lake of Peipsi. This border waterbody has average depth of 7 meters and length more than 150 km. Migration of alien crayfish species, i.e. narrow clawed crayfish and signal crayfish (introduced into 2 lakes of Latvia close to Estonian border) using natural watersheds might be more successful from south-east of Russia and north Latvia. Hence the immigration or introduction of alien crayfish species is the second threats to the noble crayfish stocks.

Crayfish distribution pattern is more or less connected with the habitat conditions. It is better on the islands, where there are small rivers and streams with high Ca content due to limestone rocks and in south of Estonia in the biggest lake areas (Fig. 1). In central and western parts, there are slowflowing lowland rivers, which middle and downstreams are often polluted and therefore not suitable for crayfish. In north of Estonia there are biggest salmon rivers, but only few of them provide good habitat condition for crayfish due to the high pollution load from industry. In the period of 1950-1980 almost all rivers and streams lost their natural streambed. Dredging was one part of collectivisation program to provide new fields for agriculture. Thus pollution and dredging have also contributed to the decline in large scale in crayfish abundance.

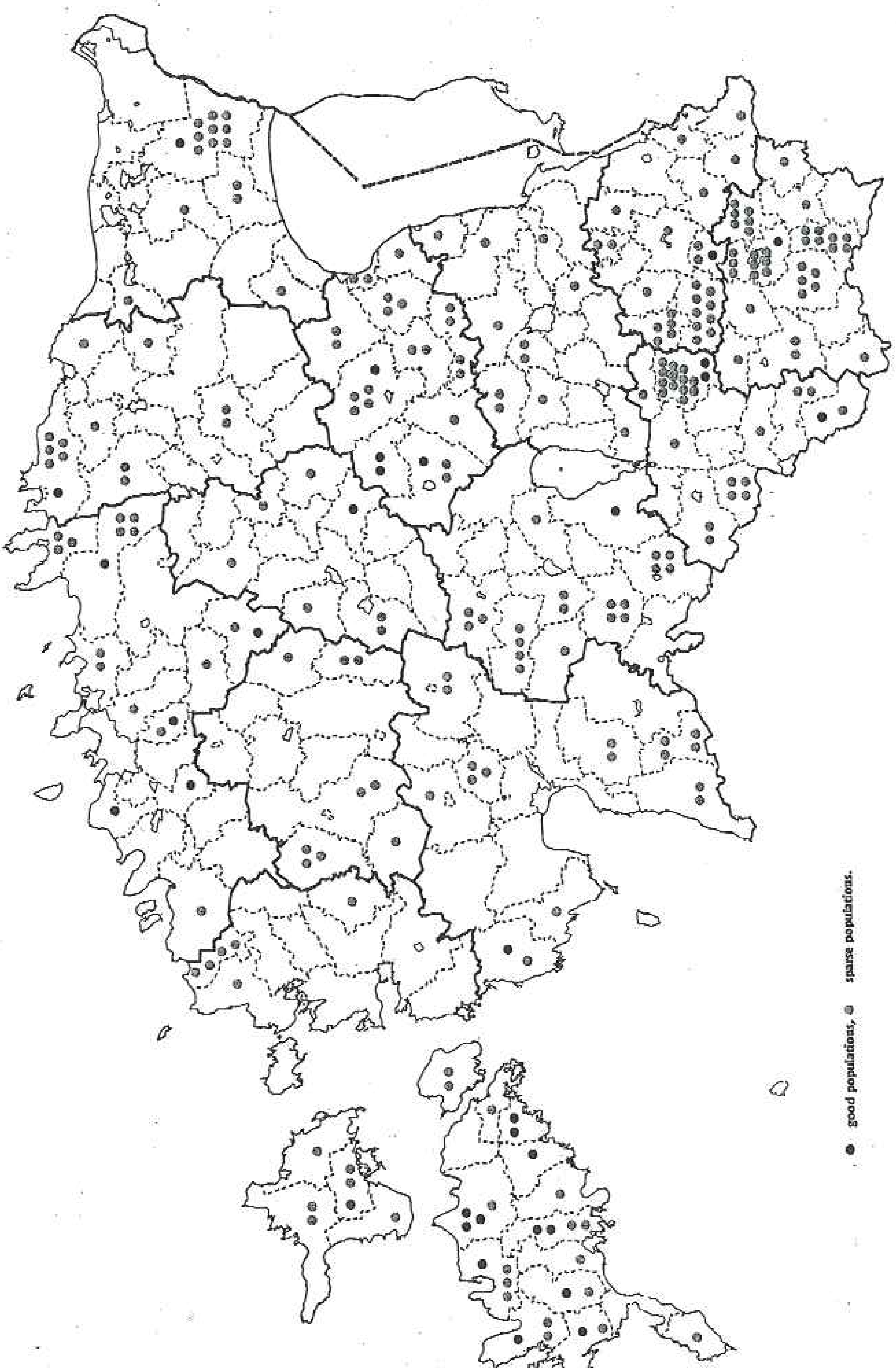

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Fig. 1 *Crayfish situation in Estonia*

Commercial harvest has been in Estonia up to 31 tonnes in 1929. Since 1940 the catch have declined. The biology, distribution and stocks of noble crayfish have been studied in detail in 1952-56 by A. Järvekülg. Later information on crayfish catching and yield has mainly obtained from annual catching reports based on the licences, which were given out by the local authorities to the fisherman.

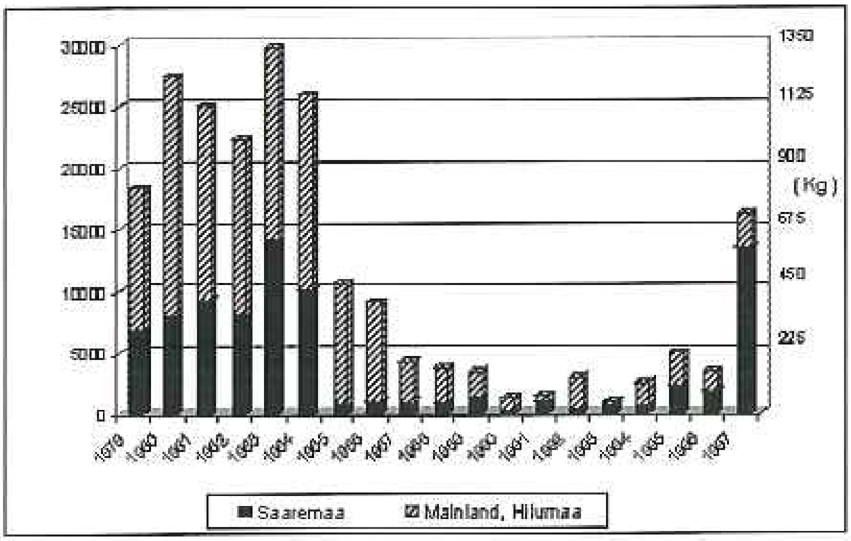

Fig. 2 *The number of sized noble crayfish caught with licences in 1974 - 1987.*

After crayfish season the licences will be collected and analysed. Official figures are shown on Fig. 2. There are annual reports available since 1971. As it is shown, the official numbers are very small and one can ask, if it is reasonable at all catch crayfish or to protect crayfish resources, is it better to put a ban to the fishing? Reality seems to be a little different. To make speculations, a real annual catch might be from 1,5 to 2 tons and proportion between Saaremaa and mainland is the same (see Fig. 2). A heavy poaching level will be explained as follows (especially year 1997): presently crayfish are valuable on the market and it is easy to get during short time a good income. Hence, the next problem for crayfish stocks is poaching.

During recent years there has been an increasing focus on the restoration of crayfish lakes and rivers. Matured crayfish have been collected mainly from the island of Saaremaa and transplanted to the mainland. Since 1970 more than 200 000 specimens have been transferred from good and strong populations to the old and new crayfish waterbodies. First experiments to develop crayfish aquaculture in Estonia were carried through in the seventies. Then, after a short break in 1989 in total 8000 juveniles were hatched in indoor conditions in the Fishfarm of Saare, which were released to the natural waterbodies. Next year the experiment was continued in indoor conditions in a small brook. In total 3500 juv. were hatched and released to the same stream. At the same time experiments have been done in a smaller scale at Äksi hatchery and in 1996 Härjanurme Fishfarm started crayfish aquaculture in the reconstructed carp ponds. An estimated one summer old juveniles production was over 10 000. In 1997 the outcome was up to 20 000 juveniles. The hatching of crayfish can be considered as a beginning of crayfish farming in Estonia.

Data about the diets of otter *Lutra lutra* and mink *Mustela vison* have been collected since 1967 by Nikolai Laanetu. The diet of otter and mink is reflecting in a quite good way the changes of species composition in the waterbody ecosystem. At present there are in total 1300 otters inhabiting in mainland and 5000 minks on all over Estonia. Hence there will be a heavy pressure to the small and scattered crayfish populations. The composition of droppings of otter and mink, the crayfish remains are giving us essential information about crayfish distribution especially in the riversystems.

Distribution and number of water mammals' otter and mink is one of the main threats to the small and scattered crayfish populations in little brooks and rivers.

Thus the main threats in Estonia are:
1. Crayfish plague
2. Introduction or immigration of alien species
3. Pollution and dredging
4. Poaching
5. Distribution of otter and mink

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Crayfish situation in Estonia: Legislation

Leelo Kukk
Ministry of Environment, Dept. of Fishery
Kopli 76, Tallinn, EE0004, Estonia

Crayfish catching, stocking and farming in Estonia is regulated by two main Acts:

- Estonian Fisheries Law and Estonian Fisheries Rules which is laying down the main principles of catching of crayfish and stocking of fish, including crayfish;
- Water Act which is regulating the aquaculture in Estonia, including crayfish farming.

1 Licensing of crayfish catch in Estonia

According to the Fisheries Rules in Estonia it is allowed to catch crayfish from the 25th of July up to 25th of September.

It is in the competence of Minister of Environment to change these dates temporarily if the nature conditions are not favourable and catch period can endanger the crayfish stock (for example cold and long spring).

In private waterbodies amount of catch is regulated by the owner.

For crayfish catch in state and municipality owned waterbodies every person must have a crayfish license, which is issued by the local County Government.
In this license is laid down:

- the waterbody and area of the waterbody (in the case of the river) where the owner of license can catch crayfish
- the number and type of fishing gears allowed to use
- the period during which the catch is allowed (see enclosed form of the license).

After the license has lost its validation it should be returned to the county government with catch data. In addition to above mentioned licences, Ministry of Environment is issuing also licenses for scientific research (testfishing). Data of these two type of catches are basis for the price fixed for using certain type of gear during 24 hours and it is enforced according to Estonian Fisheries Law by the Minister of Environment.

Usually the price has quite big variation dependent on the situation of crayfish stock in the different waterbodies. In some counties the catch of crayfish is not allowed at all due to the poor stock size. For crayfish catch it is allowed to use crayfish lift net and crayfish fyke net.Legal size of crayfish is 10 cm. Fine for illegal catches is 50 EEK (1 DEM=8 EEK) per individual

2 Stocking

According to the Act of Protection of Nature Objects in Estonia, it is forbidden to introduce foreign species to natural waters. Thus it is prohibited to stock any other crayfish species than *Astacus astacus.*

For stocking of local species it is obligatory to get permission from local County government, and a commission with at least one representative from County Government has to observe the stocking and fill the act of stocking.

3 Licensing of aquaculture

Licensing of aquaculture does not make any difference between crayfish or fish farming. Licenses have the same requirements. For fishfarming the company has to get the permission for water use if they give supplementary food and if the increase of fish weight in their fish farm is more than 2 tonnes per year. For fishfarms the permission for water use is free of charge. The permissions are issued by local County Governments.

With the permission for taking the water for aquaculture is fixed:

- the maximum amount of the food;
- the maximum amount of the water;
- demands for the environmental observation (frequency of taking the samples of P, N, BOD, from water).

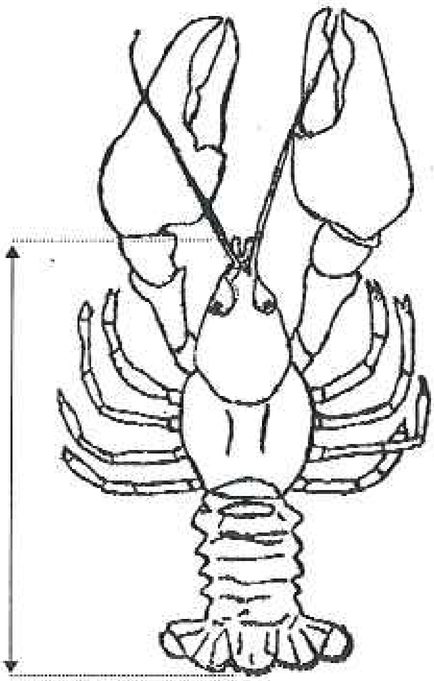
Up to now fishfarms also do not have to pay destruction fee as the procedure of calculating their pollution amount is in elaboration. Up to now Estonia has only one fishfarm who is dealing with crayfish farming. Its capacity is up to 30 000 one-summer old crayfish and this production is used for stocking.

VÄHIPÜÜGILUBA nr ______

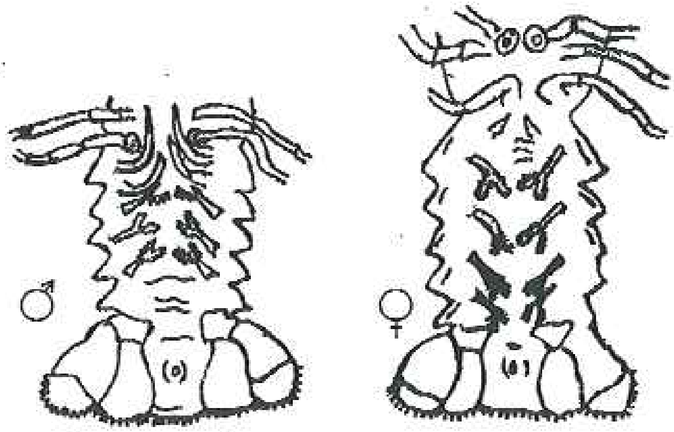
Crayfish licence

<table>
<tr><td colspan="4">Name of the licence owner</td></tr>
<tr><td colspan="4">Waterbody and area</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="2">Fishing gears</td><td>Number</td><td rowspan="3">Number of crayfish allowed to catch</td></tr>
<tr><td colspan="2"></td><td></td></tr>
<tr><td colspan="2"></td><td></td></tr>
<tr><td>Date of issuing the license</td><td colspan="2">Validation of licence (hours, date)</td><td>cost of the licence</td></tr>
<tr><td colspan="4">Organization by whome the license is issued</td></tr>
<tr><td colspan="3">Name of person by whom the license is issued</td><td>Signature Stamp</td></tr>
<tr><td colspan="4">Remarks</td></tr>
</table>

Crayfish license is valid only with the identification document



Jõevähi pikkuse mõõtmine



Isase (♂) ja emase (♀) jõevähi välismorfoloogilised erinevused

Püügipäevik:

Date	time				gears				Weather	
	beginning		end		name		No			

No of specimens	Length(cm)									
	-5	6	7	8	9	10	11	12	13	14+
female										
incl. diseased										
male										
incl. diseased										
total										

Signature of the license owner

Crayfish situation in Finland

Ari Mannonen[1] *& Kai Westman*[2]
[1]Evo Fisheries Research and Aquaculture,
SF-16970 Evo, Finland
[2]Finnish Game and Fisheries Research Institute,
P.O. Box 6, SF-00721 Helsinki, Finland

1 Crayfish species and their distribution in Finland

At present there are three freshwater crayfish species in Finland, two native and one introduced. Noble crayfish (*Astacus astacus*) and narrow-clawed crayfish (*A. leptodactylus*) are considered as native species, while signal crayfish (*Pacifastacus leniusculus*) is introduced.

The first consistent data on the distribution of *A. astacus* in Finland was published by Nylander in 1859 (Fig. 1). At that time, *A. astacus* had spread to about 62 °N. From this and other data (Westman 1973, 1991) we can deduce that the natural distribution of A. astacus in Finland has not extended beyond about 62 °N. Noble crayfish has - thanks to intensive stockings - spread to all the major watercourses up to the Arctic Circle, its distribution extending further into north in western parts of the country than in the eastern parts. At present the continuous area of distribution of *A. astacus* appears to extend to about 65 °N in Eastern Finland and to about 67 °N in northern Finland, i.e. north of the Arctic Circle (Fig. 1). There are also some isolated populations at Kittilä and Salla and even in the northern part of Enontekiö where the world's northernmost known *A. astacus* populations are found in Lake Leppäjärvi 68 30′ °N and Njurgalahti of River Lemmenjoki 68 45′ °N (Westman 1991, Tast 1993).

A. leptodactylus is an Eastern species which is encountered only occasionally in a few southeastern border waters. The small numbers observed indicate that this species has established no permanent populations in Finland. *P. leniusculus* was introduced into Finland for the first time in 1967. To this date it has been stocked into almost 300 water bodies, mainly lakes located in Southern Finland, within the natural range of the noble crayfish, i.e. below 62°N. The stocking waters are former crayfish waters devastated by the plague. Only a few experimental stockings have been made in more northerly waters of which Lake Kermajärvi (66°N) represents the world's northernmost locality.

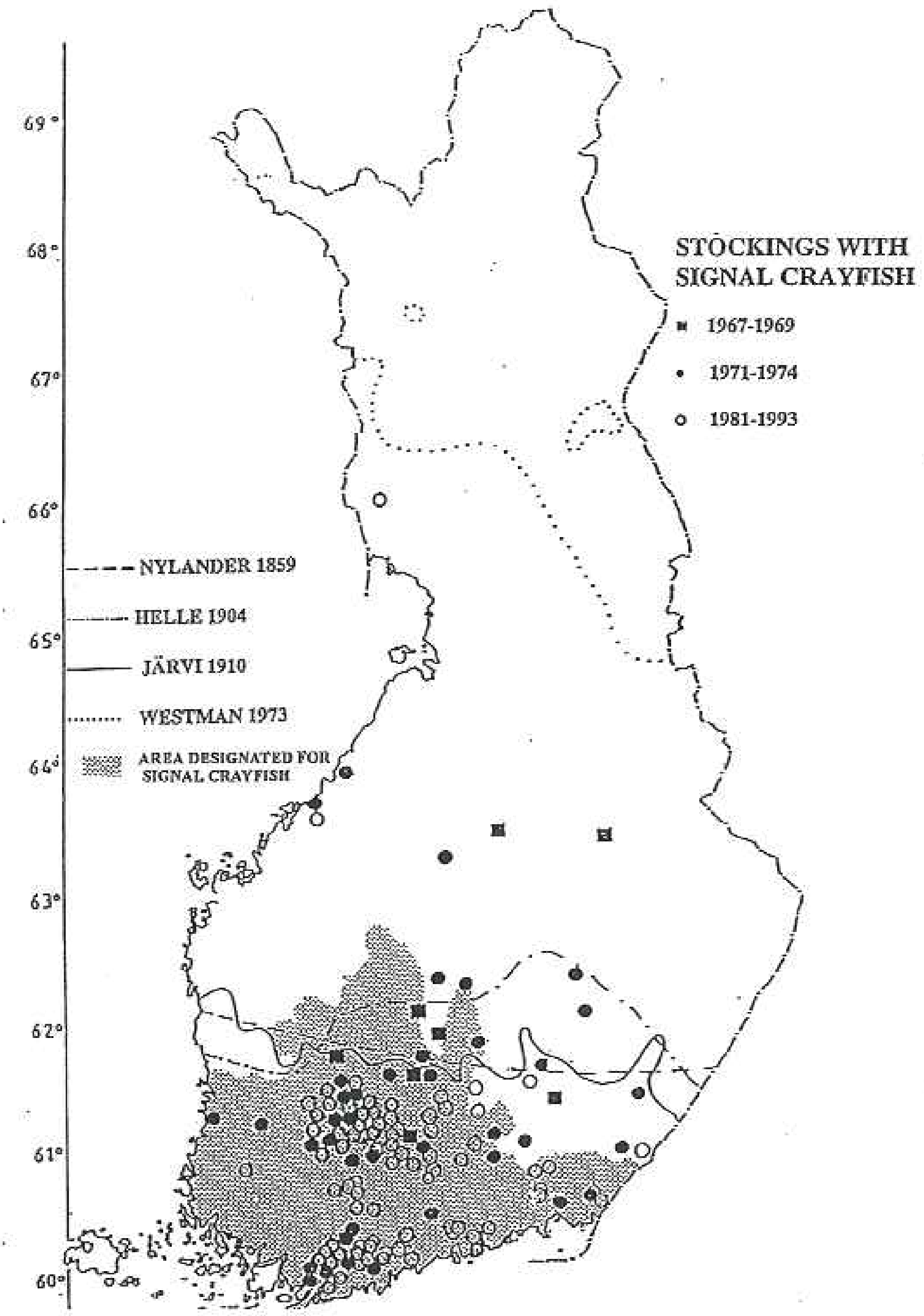


Fig. 1 *The historical distribution of noble crayfish in Finland. The stockings with signal crayfish in 1967 – 1993 and the geographical area designated for signal crayfish in Finland.*

2 The annual catch of crayfish in Finland

Current annual catch of crayfish in Finland and its economic value is difficult to estimate, since there is no systematically compiled data available on either the fees paid to the trappers or retail prices. In recent years the total catch of crayfish has generally been estimated to 2.5 - 4.8 million individuals per year (e.g. Leinonen 1993, Anonymous 1995), out of which 2 - 3 % has been signal crayfish. The signal crayfish has been observed to reproduce roughly in about 100 lakes and it is estimated that in 1998 signal crayfish are recreationally or commercially trapped in 15 - 20 lakes. The number of lakes opened for licensed trapping is now estimated to rise rapidly.

Despite constant rises in the price of crayfish the decline in *A. astacus* stocks has decreased the numbers of professional crayfish trappers. By contrast the number of recreational trappers has increased and is estimated to be about 100 000. The catch of the recreational trapping in 1996 was estimated to be 3.0 million crayfish, the value of which equals to about FIM 28 million (Anonymous 1998).

3 Factors endangering crayfish stocks

Crayfish plague (*Aphanomyces astaci*) has caused by far the greatest losses to noble crayfish stocks in Finland. Crayfish plague has undoubtedly occurred in most of Finland's crayfish waters, often several times during the past hundred years. Of the 74 major watercourses in Finland, excluding the seven flowing to the north in which A. astacus have never lived, less than 20 remain uninfected (e.g. Westman 1973, Westman et al. 1973, Nylund and Westman 1992). In total the noble crayfish has vanished from thousands of waters and due to the plague its distribution is not anymore continuous but is split up to innumerable separate areas of mainly small extent, often in the upper parts of watercourses.

Despite intensive stocking attempts during the last hundred years only few catchable noble crayfish stocks have redeveloped in most plague stricken waters, particularly in large lakes. With the decline of noble crayfish stocks, the present occurrence of the plague is confined to relatively few areas. Fresh outbreaks of plague have been recorded at the rate of about ten a year in plague-free waters as well as in revived populations (Westman 1991). Because of inherent problems in plague diacnostics the actual number of outbreaks may be considerably greater. It has also been reported that for diagnostics of the disease, sample crayfish are sent in only one third of the cases of suspected plague outbreaks. Also signal crayfish may in some instances be susceptible to the crayfish plague. In 1996 a plague outbreak caused an estimated mortality of 50 - 70 % in a signal crayfish population in Lake Puujärvi. The coexistence of a noble crayfish population, which vanished from the lake due to the plague, may have contributed to the high mortality. Since the high initial mortality the *Pacifastacus* population has recovered fast, but remains infected with plague.

Burn spot disease (*Ramularia astaci*) is rare and white tail *disease (Thelohania contejeani*) occurs in most noble crayfish populations, but is rare (Westman 1991, Nylund and Westman 1992). So these diseases are hardly expected to have any impact on noble crayfish stocks. *Psorospermium haeckeli* occurs in most screened noble crayfish populations (Nylund and Westman 1992, Henttonen 1996). In some lakes with high infection rate there has been a noticeable decline in noble crayfish catches, but so far it has not been possible to link this weakening of stocks to the parasite. In signal crayfish, *Psorospermium* has in Finland been discovered only in one individual on a crayfish farm.

The crayfish plague is considered responsible for most of the decline in crayfish catches, but, at the same time, considerable changes have taken place in Finnish waters in the past decades. This degradation of environment has caused considerable damage to noble crayfish populations. The clearing and dredging of rivers and brooks was performed for log floating from forestry or as a measure against flooding (e.g. Westman 1985).

In a study that covered 300 streams in central Finland, a stretch of stream longer than one kilometer that had not been cleared could not be found (Horppila 1993). Approximately 20% of the total land area in Finland, mostly forested peatlands, has been ditched and drained (Ahtiainen 1990). Peat mining has also had a major impact on many Finnish streams and lakes. It has also been estimated that about 6-7 % of Finnish waters are vulnerable to acidification and about 5 000 lakes are slightly acidified. On the other hand acidification is mostly limited to small watercourses, which have never been important for crayfish production.

These and other radical changes in the natural state of Finland's inland waters in recent decades have led to considerable damage to *Astacus* stocks and continue to pose a serious threat to populations. The effects of these habitat modifications are varied and include increased mortality, emigration, reduction in growth rate and production, and problems in reproduction.

4 Crayfish culture in Finland

Crayfish cultivation in Finland consists mainly of raising 1-summer old noble and signal crayfish juveniles for stocking. The interest in crayfish culture, especially in signal crayfish culture, is rapidly increasing and directed more and more towards the production of marked-sized crayfish for consumption.

A total of around 21 000 (about 30 000 in 1997) noble crayfish juveniles were produced for stocking and about 4 000 for further rearing in 1996 (none in 1997). Total number of noble crayfish in crayfish farms at the end of 1996 was about 78 000 specimens. Corresponding figures for signal crayfish: about 227 000 (same in 1997) juveniles produced for stocking and about 6 000 (about 10 000 in 1997) for further rearing. At the end of 1996 the total number of individuals in farms was about 66 000 specimens.

Currently there are 140 registered crayfish farmers in Finland. Registration is required by law but yet not all farmers are registered and this applies especially to small scale pond rearing. Of the registered farmers about 70 have sold crayfish in the past few years. According to an enquiry, 40 of the registered farms will sell crayfish in the year 1998. There is 18 farmers of noble crayfish and 26 of signal crayfish. 10 noble crayfish and 24 signal crayfish farmers produce juveniles and for consumption noble crayfish is produced by 12 and signal crayfish by 11 farmers.

5 Regulations

Most crayfish waters in Finland are under private ownership. The owner of a particular water area has the right to catch crayfish and to make decisions on it. Under the terms of the 1983 Fishing Act the owner is also obliged to manage and enhance the crayfish population to ensure maximal sustainable utilisation.

- In Finland the crayfish season starts 21 July at 12 o'clock and lasts until 31st October for both noble and signal crayfish
- Since 1993 there has been no minimum legal catch size either for noble or signal crayfish.
- The Fishing Act does not regulate crayfish traps, the mesh size or quality of netting used.
- The catch size or "bag" is not restricted by law.
- It is prohibited to use explosives, firearms, anaesthetics, toxic or polluting substances or an electric current when catching crayfish.

- The water owners can - and in practice generally do - lay down their own rules regarding crayfish fishing in their waters.

There are no regulations in Finland at present to make the disinfecting of traps and other gear compulsory. However the authorities do strongly recommend that gear and traps should always be disinfected if they are to be moved from one water body to another, or to be used in running water upstream of previous trapping place. Certain disinfection methods are also recommended (see Nylund and Westman 1992). Currently the only known way of protecting noble crayfish from the crayfish plague is to prevent the disease from spreading from infected waters. It is immaterial whether these are "ordinary" plague waters populated by noble crayfish, or are signal crayfish waters.

By law crayfish may only be stored alive in the same water body from which they were caught, dead and diseased crayfish must be destroyed and live crayfish transported only in new boxes. For transfer stockings only crayfish, which can definitely be shown to have been caught in plague-free waters, may be used.

6 Management

Most common method of managing crayfish populations is stocking (Järvenpää and Kirjavainen 1992). Noble crayfish is stocked in suitable waters where the species has never occurred or in water bodies where the population has vanished, due to crayfish plague or some other reason. In 1996 some 21 000 juveniles and 98 000 adults were stocked. Stockings with signal crayfish have been directed to chronically affected plague waters where stocking efforts with noble crayfish have failed. In 1996 some 227 000 juveniles were stocked. The introductions have been concentrated on the southernmost part of the country.

The introduction of both noble and signal crayfish into waters where they have not previously existed needs permission from local fishery districts. Introductions of signal crayfish into waters with a noble crayfish stock are not permitted. Stocking with plague infected juveniles is currently allowed only into waters with a infected signal crayfish population.

Habitat improvement is becoming more and more important management method. In Finland there are tens of thousands of small water bodies, which hold potential for the crayfish fishery, but which owing to their barrenness, low calcium content, and high acidity are unsuitable for crayfish. Consequently, it can be expected that the liming of crayfish waters will increase as a consequence of the lakes becoming increasing prone to acidification. So far only a few water bodies have been limed. Also some trials have been made to improve the environment for crayfish by supplying shelters composed of stones, drainage piping and perforated bricks.

The restoration and management of crayfish stocks in habitats modified e.g. by hydroengineering activities has in practice proven to be a very difficult problem (e.g. Pursiainen and Westman 1992, Tulonen et al. 1998). As no effective means of mitigation against many adverse effects are as yet known, the habitats of valuable and productive crayfish stocks should be kept intact in their natural state.

6.1 Guiding the stocking of signal crayfish

Interest in stocking lakes with signal crayfish has increased dramatically, so that in 1993 alone they were stocked in at least 41 new waters. Finnish Game and Fisheries Research Institute has been monitoring the development of signal crayfish around 30 water bodies after initial stocking. Presently *Pacifastacus* is known to reproduce in roughly 100 waters in Finland. Three decades of studies clearly indicate that signal crayfish can become a renewable, permanent resource in waters, especially, affected by crayfish plague and where it has appeared impossible to re-establish noble crayfish populations. Catches of *Pacifastacus* appear to become larger than before, due to the more rapid growth rate and vigorous reproduction. Signal crayfish also stands up to utilisation well and to this date the populations have not appeared to suffer from stunting in Finland (e.g. Westman 1995).

By rigidly confining signal crayfish stockings to chronical plague-infected water bodies and using only cultured, plague-free juveniles for stocking, the number of incidences of the plague will not be directly increased. However, the greatest risk of increased stockings of signal crayfish is that the species may spread crayfish plague and thus contribute to the vanishing of the native noble crayfish. Also there is a possibility of signal crayfish establishing e.g. in barren waters sparse, non-exploitable populations with chronical plague infection. Such populations would still pose a risk of infection and thus prevent noble crayfish populations to be established in the area. This is used as one of the arguments for not to extend the geographical distribution of signal crayfish from the present. In 1989 fisheries authorities agreed on a signal crayfish stocking strategy in which the stockings of signal crayfish would be confined according to the watersheds to southern and south-western parts of the country - roughly the same as the original distribution of noble crayfish in Finland (Fig. 1). This agreement is not binding, but it has been well adhered to.

In Finland the introductions of noble crayfish into totally new areas and environments - in Finland alone in thousands of lakes - is not questioned, but the restoration of former noble crayfish waters with another crayfish species has evoked lot of discussion. At any rate, there is great need for the adoption of procedures to reduce the adverse effects arising from the introduction of an alien species.

6.2 Conservation and restoration of the native *Astacus*

The fact is, whether we like it or not, that the signal crayfish is in Finland and it's doing well. A clear distinction between conservation and fisheries aspects must be made. Native noble crayfish must be protected, but from fisheries aspects this should not prevent repopulating the chronic plague-waters with signal crayfish or the farming of these. This distinction is very important e.g. for water owners, trappers, farmers, dealers and others with commercial aspects to crayfish - many of them are not willing just to conserve native species - they want to make profit. But at the same time one has to keep in mind that the conservation of noble crayfish is not just conserving the biodiversity, but also conserving a valuable crayfish fishery.

As it has proved very difficult and often impossible to restore a noble crayfish stock in modified habitats, the environments of good noble crayfish populations should be restored to or rather yet, preserved in their natural state. Protected areas for conservation of noble crayfish should be established. These areas should be large enough to form meaningful entities and to contain buffer zones. The areas with active plague infection and waters with infected signal crayfish populations should be mapped and uncontrolled transport of crayfish, traps etc. should be prevented. Stockings of signal crayfish should rigidly be confined to chronical plague-infected water bodies. Only healthy noble crayfish and signal crayfish juveniles should be used for stockings. Signal crayfish shouldn't be stocked into noble crayfish waters, as plague free signal crayfish will before long outcompete noble crayfish. Diagnostic methods for crayfish plague fungus should be improved and developed also for other diseases in order to be for example able to diagnose plague from signal crayfish displaying no outward signs of the disease. Cheap, efficient and easily usable disinfection methods for traps and other equipment in field conditions should be developed. Also the life cycle, method of infection, and significance of *Psorospermium haeckeli* on noble crayfish should be further studied. Crayfish disease legislation should be developed to effectively stop the spreading of crayfish plague. Existing and potential legislative mechanisms for the protection of noble crayfish and the control of signal crayfish should be reviewed.

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Crayfish situation in Latvia and the Latvian crayfish program

Augusts Arens
Latvian Biotechnology
Pilsetas Lauk 3, Kuldiga , LV-3300, Latvia

1 Introduction

The natural crayfish population is near the biological allowable limit to ensure existence, and because of that factor, relying on nature to regenerate the population would be a lengthy process, not even to think about some kind of commercial use.

Some of the negative aspects of relying on natural crayfish population growth in natural waterways are:

- The low survival percentage (2-5%) of the fertilized eggs
- A large number of natural predators ranging from fish to four legged and to the birds.

Left alone the population growth is subject to cyclical ups and downs. Taking this into consideration, it is hard to project that crayfish farming can become a financially viable branch of aquaculture in Latvia.

What led to the decline of the crayfish population which seemed to reach its peak in Latvia in the 1920's?

- First there was the crayfish epidemic of the 1920's that started in Europe and affected also Latvia.
- Environmental pollution due to pesticide usage in agriculture and uncontrolled waste disposal from factories.
- The increased sensitivity of the noble crayfish to ever changing environmental factors.

In the past few decades, especially the use of pesticides in agriculture has seriously damaged the natural crayfish population in Latvia. However, in recent years pesticide use has declined and become more controlled, which has permitted crayfish stocks to recover and remain stable. This also suggests that water quality for crayfish farming would be acceptable. Today there are 3 species of crayfish in our waters, the *Astacus astacus* (the most common and highly valued crayfish species), *Astacus leptodactylus* and the *Pacifastacus leniusculus*. The later being found in only one lake which was stocked with them in 1983.

In lakes where the population is very small or not at all, it was found that unsanctioned stocking of crayfish is taking place. Fishermen are taking crayfish from one lake to another not taking into consideration the species type. For this reason you might find a mixture of the *Astacus* species in some lakes.

The farmed production of crayfish in Latvia is considered by the consultants to be entirely feasible by transferring existing methods of pond culture to the Latvian situation. The unused man-made ponds in redundant carp farms could easily be used for crayfish culture, with relatively low financial input. A remarkable potential exists, both in production for restocking and for the market. However, achieving this potential requires the introduction of production systems on a proper scientific basis, for both hatchery and grow-out operations. The crayfish resource today is so small that it can not be used as a commercial consumer product. Since there is no national program developed to regenerate the crayfish population, it is up to the private sector to initiate and realize this.

2 Crayfish catch licensing

The stabilization of the crayfish population in Latvia is also due to the ban of commercial fishing and regulated crayfish yields for sport usage. This is the only apparent legislation concerning crayfish.

This means that a person wishing to catch crayfish must first buy a license at a cost of 5 lats (about 7.67 ECU). This allows him for a one time harvest of 50 crayfish with a minimum size of 10 cm. The area in which he is allowed to do this is specified on the license. Only few of the lakes contain populations large enough to allow licensed capture of them. There is however an abnormal amount of illegal harvesting going on which is hard to control. This product, though illegal, is still being sold in the market. There are not enough enforcement agents to cover the vast amount of lakes, nor is there any money allocated to the fisheries budget to improve the situation.

3 Population statistics

Little research has been done on local crayfish populations and there are no statistics available concerning yield other than scattered data such as;

- In the 1920's, in just one region (Latgale) of Latvia, 20 tonnes of crayfish were supplied for the consumer market a year.
- In the 1950's, the total yield for *all of Latvia* averaged 14 tonnes per year.

Special study of crayfish population was done in the 1960's when the Biotechnical Institute conducted research on 80 lakes and talked with local inhabitants and other institutes. From all resulted material gained, it was concluded that crayfish are found to inhabit most of Latvia's territory, but the *Astacus leptodactylus* specifically is found in the southern region.

The Inland Water Laboratory in early 1990 conducted control capture in 67 lakes and found crayfish in 58 (67%) of them. In recent years the National Board of Fisheries and Inland Water Laboratory using control catches and input from local municipalities found that, in 792 lakes whose area is more than 10 ha, crayfish inhabited approximately 575 of them, a total of 68,155 ha. It is very important to note here that the remaining population is just enough to survive in the natural environment but is not big enough to be able to increase without help. This means that we should start a semi-intensive breeding program.

4 Crayfish program

In the early 1980's an intensive effort to save the crayfish population was started by:

- Selective cross-breeding
- Planning and introduction of spawning methods in natural environment

The result of these efforts was the stabilization of the crayfish population in the natural waterways. Unfortunately the program stopped, as all efforts in the socialist period did, and nothing was done to help regenerate the population.

To offset this situation and realizing the vast commercial potential of crayfish, in 1994 the private crayfish farm 'OZOLINI' started a breeding program, the only of its kind in Latvia. This encompasses selective breeding, egg incubation, water temperature control and early intensive feeding using biotechnology principles, brood stock and commercial stock segregation. Though at an early stage of development, the crayfish farm still is a model for the rest of the country.

'OZOLINI' in the near future plans to establish a breeding center with modern technology by a 30 ha lake.

A stimulus to crayfish farming in an organized manor was given by a study conducted by PHARE program MEGAPESKA which evaluated the aquaculture situation in Latvia. The main conclusion was that the use of modern technology, investment and semi-intensive growing methods, the farming of crayfish in man-made ponds is a financially viable aquaculture industry. This study also maintains that using all the untapped resources, the potential can reach 200 tonnes per year.

Based on this, in 1997 with an initiative started by the Kurzeme Regional and Business Development Center 'KURZEME' and with intensive consulting and research together with the Fisheries Research Institute, Latvia Biotechnology Ltd., the Danish Crayfishbreeders Association, Finland's consulting company KALAVESI Ky and the Norwegian Aquaculture Research Center S/A/ AKVAFORSK, crayfish farming was organized as a branch of the fisheries industry.

The basic concept is:

- On the groundwork that the OZOLINI farm has set, an educational and demonstration center will be formed. Its function is to become the scientific technical information and crayfish development center. Here it will be possible to learn the technologies and methods used to grow crayfish, acquire females with eggs and fry for their own ponds.
- Within 2 years the program foresees to establish 5-6 crayfish fry hatcheries in the following areas; Ventspils, Dobeles, Limbazu, Madonas, Sarkanu and Algonas regions

With these program, it is projected that within 3-5 years we should be able to harvest approximately 8 tonnes a year.

The concepts of the Crayfish Center is :

- Devolop crayfish population monitoring program
- To provide education and information concerning crayfish cultivation
- Crayfish selective breeding
- Introduce new technology
- Semi-intensive fry breeding
- Crayfish population regeneration
- Crayfish marketing
- Provide environmental control of water quality
- Analyze and recommend new sites for farming
- Develop legislation and principles of crayfish farming and harvesting
- Develop structure to encompass tourism in aquaculture leisure

To realize this intensive program the following is necessary:

⇒ The formation of the educational and demonstration center. This is currently in the beginning phase with the help of Norwegian, Finnish and Danish consultants.

⇒ Scientific technical information in the designated rural areas

⇒ Thorough marketing studies

⇒ Of course, as always, the most important - the necessary investment, ~ 600,000 - 750,000 ECU

5 Conclusion

The basic conception is to stimulate an *alternative agricultural program* to enhance the growth and population of the native noble crayfish (*Astacus astacus*) by using modern scientific and biological methods proven in the Nordic countries. The use of highly toxic pesticides in agriculture has seriously damaged the natural crayfish population in Latvia. However, this practice has declined and allowed water quality to recover enough so to be able to sustain crayfish farming operations. The farmed production of crayfish in Latvia, which is non-existent today, is considered by consultants to be entirely feasible by transferring existing methods of pond culture to the Latvian situation. A significant portion of carp ponds have ceased operation (because of low market value), so there are nearly 5,000 suitable ponds of untapped resource available which could be refurbished and put to crayfish production quite cheaply. Studies have shown that semi-intensive pond culture of the noble crayfish is the most promising possibility for aquaculture development from the point of view of investment, technology and markets. Productivity could be considerably improved by making use of technology, planned breeding programs and organizing the private sector. And this is our goal.

Crayfish situation in Lithuania

Aloyzas Burba
Institute of Ecology,
Akademijos 2, LT-2600 Vilnius, Lithuania

Abstract

There are 4443 lakes in Lithuania with a total surface area of 950 km^2 and 29900 rivers with a total length 63700 km. Noble crayfish *Astacus astacus* is the only native crayfish species in Lithuania. In 1578 the Livonian Chronicle stated that there was a lot of crayfish in Lithuania. About 250 tonnes of noble crayfish was caught and exported annually in 1890-1914. Lithuania was one of the most important crayfish export centres in Europe. The large abundance of crayfish stimulated also to research activities. 10 lakes were investigated in 1883 (Girdwoyn 1883). Girdwoyn transferred crayfish to lakes with poor crayfish populations, and calculated the number of crayfish needed for stocking. The most comprehensive investigations on crayfish populations were made in the period from 1960 until 1969 (Sestokas 1969, Cukerzis 1970). Astacologists investigated 117 waterbodies inhabited by crayfish and collected information on crayfish distribution from 287 waterbodies. In 1972 the Laboratory of Carcinology headed by J. Cukerzis was established, but put down in 1984. Since 1993 we have formed the data base on crayfish. More than 1000 waterbodies were included in data base and until 1997 we have investigated about 70 waterbodies inhabited by crayfish (Burba 1997a, 1997b, Burba et al. 1997). The main part of this work was done according to joint project "Crayfish management in Lithuania" between the Institute of Ecology, Lithuania and the Eastern Norway Research Institute, Norway. Investigations were also supported by Environmental Protection Ministry and Fisheries Department of the Ministry of Agriculture and Forestry of Lithuania.

1 Crayfish species in Lithuania

1.1 Native crayfish species

Noble crayfish *Astacus astacus* is the only native crayfish species in Lithuania. In the end of the 19th century noble crayfish were distributed in the large majority of lakes and rivers. Some populations of noble crayfish in the lakes were very abundant.

1.2 Introduced crayfish species

Narrow-clawed crayfish *Astacus leptodactylus* began their spontaneous spreading and were transferred to Lithuanian waters from Belarus and Latvia in the end of the 19th and the beginning of the 20th centuries (Sestokas 1969). Some local people believe that this species of crayfish is resistant to crayfish plague. Part of lakes were private at that period, and owners transferred exotic for them narrow-clawed crayfish into their lakes situated in different parts of the country. Spreading of narrow-clawed crayfish was spontaneous only in the north-east of Lithuania. This species was transferred into separate lakes of other parts of the country. Spontaneous spreading of this southern crayfish species in Lithuania was not intensive. In case of transferring them to separate waterbodies, narrow-clawed crayfish did not spread to neighbouring waterbodies. In 1963-1969 narrow-clawed crayfish were distributed only in 8.5% of waterbodies inhabited by crayfish (Sestokas 1969).

Signal crayfish *Pacifastacus leniusculus* was introduced to Lithuania in 1972. Scientists-astacologists initiated the introduction of this alien crayfish species. The scientists were able to investigate the biology of this species and its harvesting possibilities. Scientists headed by J. Cukerzis hoped to increase crayfish stocks by stocking signal crayfish to Lithuanian waterbodies. A number of experimental works on signal crayfish population growth and physiology have been done, but this species is not used for harvest. 500 adult and 1000 juvenile signal crayfish were bought from Sweden. 260 adult signal crayfish (85 males and 175 females) were stocked to Lake Berziukas (1.2 ha) and 92 crayfish (32 males and 60 females) to Lake Nevardas (2.8 ha). In 1976 in Lake Berziukas was caught only one signal crayfish, in Lake Nevardas 149 crayfish. Later, scientists stocked signal crayfish from Lake Nevardas to 5 lakes. In the 1980's the situation went out of control.

Spiny-check crayfish *Orconectes limosus* (=*Cambarus affinis*) was found for the first time accidentally in a small isolated lake situated in the north-west of Lithuania. We have no idea how crayfish of this species appeared in this part of Lithuania. It was known that spiny-check crayfish are distributed in the Russian enclave of Kaliningrad and in Poland situated to the south-west from Lithuania. In 1995 the spreading of spiny-check crayfish was determined in interrelated lakes and rivers situated in the mid south of Lithuania. All waterbodies abundant in spiny-check crayfish are situated in the basin of the River Nemunas. The Nemunas flows from Belarus, and there a large tributary flows into the Nemunas from Poland. In 1996 spiny-check crayfish was found in River Sesupe, which flows from Poland in the west of the country.

2 Distribution of different crayfish species

According to Sestokas (1969) and Cukerzis (1970) the main crayfish distribution areas were the north-east, south-east and south-west of Lithuania. On the basis of our investigations and interrogations we prepared a map of crayfish distribution in 44 administrative regions of Lithuania (Fig. 1).

Fig. 1 *A region-based distribution map of crayfish (all 4 species) in Lithuania. Darker shading indicate more crayfish localities.*

We established the crayfish factor (CF) to estimate crayfish abundance in every region and in all territory of Lithuania. The CF shows the relation of crayfish lake area with the area of all lakes. On the basis of interviews and original investigations we found CF to be 20.6% (Table 1). The CF increased twofold since 1993. The growth of crayfish abundance is due to re-establishing the noble crayfish stocks and not to alien crayfish introductions.

Table 1 *Crayfish abundance (CF expressed in %) in Lithuania*

Year	CF	References
1963-1968	40.2	Sestokas 1969, Cukerzis 1970
1993	10.7	Report of EPM
1994-1997	20.6	Original data

CF for every Lithuanian region was calculated on the base of our investigations and interrogations (Fig. 2).

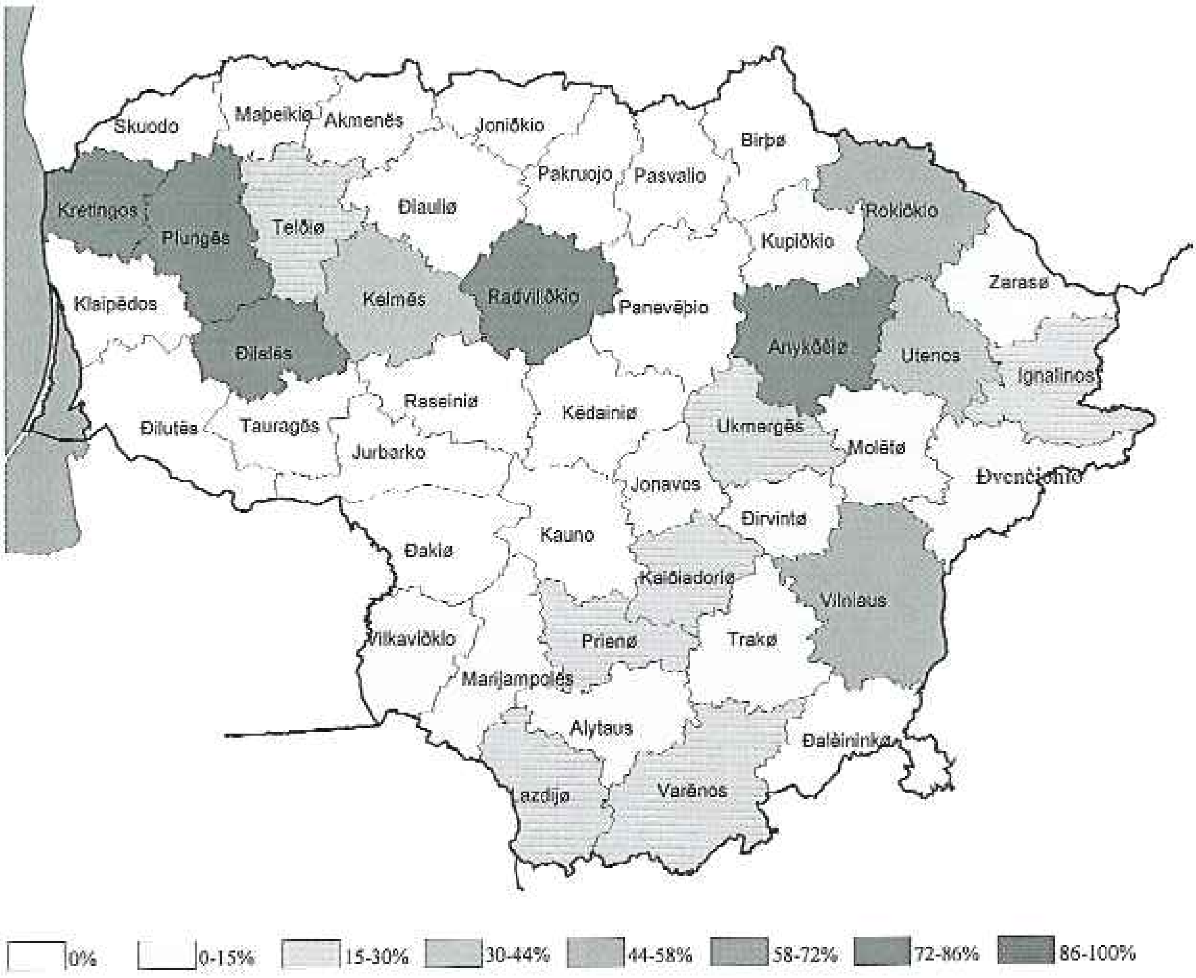

Fig. 2 *A region based CF of crayfish in Lithuania in 1996*

3 Yield

As mentioned above the catch of noble crayfish in Lithuania was very large previously. Official statistics of the annual commercial catch of noble crayfish from 1890 onwards, show that the catches normally exceeded 100 tonnes before 1940 (Fig. 3). Also in the 1950's the catches were significant (20-30 tonnes). Since then, however, the commercial catches have been less than 7 tonnes and insignificant since 1989.

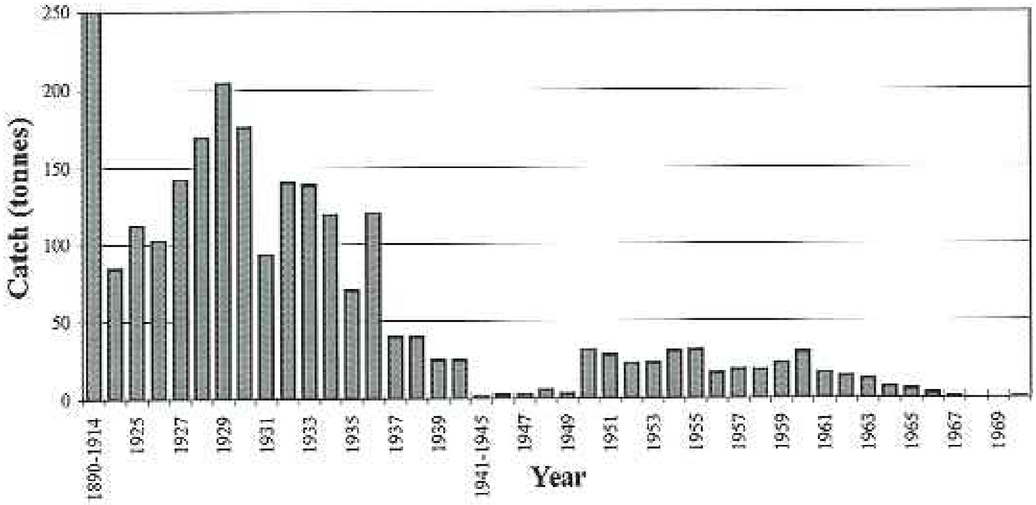

Fig. 3 *Commercial catch of noble crayfish in Lithuania*

All commercial catches in the period 1970-1995 consist of narrow-clawed crayfish, caught in single lake, shallow L. Apvardai (550 ha, max. depth 5 m, mean depth 2.6 m) situated in the north-east of Lithuania on the border to Belarus (Figure 4).

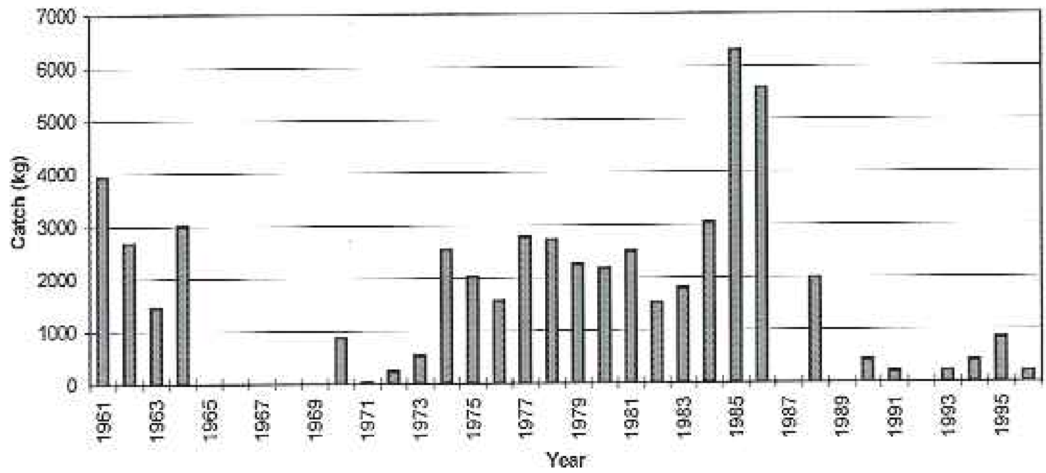

Fig. 4 *Commercial catch of narrow-clawed crayfish in Lithuania.*

In 1960-1969 noble crayfish were found in 387 waterbodies from 404 in which crayfish *A. astacus* and *A. leptodactylus* had been distributed (Sestokas 1969, Cukerzis 1970). Abundance of noble crayfish we expressed in catch per unit effort (CPUE). CPUE of noble crayfish from 96 waterbodies in earlier investigations of these authors was 3.3 individuals (Table 2).

According to our investigations (1994-1997), CPUE of 3.1 individuals was established in 48 waterbodies inhabited by noble crayfish. Individuals of 90-100 mm TL predominate in experimental catches in the lakes with abundant noble crayfish populations. According to interrogations and questionnaires, stocks of noble crayfish over the recent years have increased: crayfish appear in waterbodies in which they lived earlier and are found in new water systems (ponds, irrigation systems).

Table 2 *Noble crayfish population abundance (CPUE) in Lithuanian lakes and rivers*

Year	Mean CPUE	CPUE range	n	References
1963-1968	3.3	0.004-21.8	96	Sestokas 1969 Cukerzis 1970
1994-1997	3.1	0.02-15.5	48	Burba et al. 1997 Original data from 1996-1997

4 Catching activity, export and import

In 1996, Environmental Protection Ministry with our assistance issued first licences for commercial noble crayfish catching in two lakes. In 1997, 2 licences for commercial narrow-clawed crayfish catching was issued. In 1998, 2 licences for commercial catching was issued, one for noble crayfish and one for narrow-clawed crayfish. All these 6 lakes are situated in north-east of Lithuania.

Official statistic shows export and import of frozen crayfish to Lithuanian market and from Lithuania (Table 3).

Table 3 *Export and import of frozen crayfish in Lithuania*

Year	Export		Import	
	Country	Amount in kg	Country	Amount in kg
1995	Finland	till 50	Denmark	1500
	Georgia	till 50		
	Russia	200		
1996	Russia	200	Switzerland	till 50
			Denmark	800
1997	Russia	200	Denmark	600

All noble crayfish caught by commercial way in 1890-1940 were exported from Lithuania. In the period from 1957 to 1965 only part of noble crayfish catches was exported. In the period from 1961 to 1964 narrow-clawed crayfish were exported too (1449-3935 kg annually). Some endeavours of the export of live crayfish took place in 1995-1996 (Table 4). Official statistic did not show catches of 200 kg crayfish in 1995.

Table 4 *Export of live crayfish from Lithuania*

Year	Country	Amount in kg
1995	Finland	200
	France	till 50
1996	France	till 50

5 Crayfish harvest regulations

Crayfish harvest regulations for the last time were changed in June 1995 (Table 5). Legislation parameters such as season, minimum size, fines were changed. Crayfish catching season before 1995 lasted from 15 July to 1 November, minimum size was 110 mm, and fine for illegally caught signal crayfish was higher than for catching noble crayfish. In the 1990's a large part of lakes became rented, and a special regulation was issued to get license for commercial fishing. Earlier commercial fishing and crayfish catching had been performed only by state farms.

Table 5 *Regulations of crayfish catching in Lithuania (from June, 1995)*

Legislation parameter	Crayfish species	Meaning of parameter
Catching season	Crayfish	15 July - 15 October
Minimum size	*A. astacus*	100 mm
	A. leptodactylus	100 mm
Amateur fishing	Crayfish	5 trap per person, bag limit - no more then 50 crayfish per twenty-four hours
Commercial fishing	The same way like for fish	Test fishing - establishing stocks in waterbody and calculating the catching limit (individuals/season) Issue license on the basis of limit (individuals/season)
Fine for one illegally caught crayfish	*A. astacus*	2 Lt (equivalent of 0.5 USD)
	A. leptodactylus	2 Lt (equivalent of 0.5 USD)
	P. leniusculus	2 Lt (equivalent of 0.5 USD)
It is not allowed to pick crayfish by using light		

6 Conservation and stocking

The main part of lakes in Lithuania now is rented by private persons or enterprises. Some valuable lakes and the most number of small rivers are state waterbodies. We have historical data about distribution of noble crayfish in these lakes and rivers which now are state waterbodies (Table 6). In various period amateurish and commercial crayfish catching was protected in some of these lakes and rivers.

Table 6 *State water bodies crayfish catching in which was protected*

Data about crayfish water bodies		Lakes	Rivers
Historical data		35	28
Commercial catching		11	1
Amateurish and	1978-1982	12	18
Commercial fishing	1983-1987	12	13
was protected	1988-1992	8	19

Crayfish stocking activity in the period 1952-1964 was very high (Table 7).

Table 7 *Crayfish stocking activity in Lithuanian waterbodies*

In the period 1952-1964 were stocked about 1500000 specimen of *Astacus astacus* and 7900 specimen of *A. Leptodactylus*	
1991	2750 adult specimen of *Astacus astacus*
1992	7178 adult specimen of *Astacus astacus*
1993	4429 adult specimen of *Astacus astacus*
1994	2762 adult specimen of *Astacus astacus*
1995	4488 adult specimen of *Astacus astacus*
1996	4750 *A. Astacus* + 20000 adult *A. Leptodactylus*
1997	3000 *A. Astacus* + *A. Leptodactylus*

7 Culture

In 1993 a project on noble crayfish aquaculture was initiated. The main objective is to develop a method for juvenile production. The experiments are carried out by scientists of Institute of Ecology in the Fishery Farm (Mackeviciene et al. 1996).

In 1994 were produced 17000 of noble crayfish juveniles in this farm. 4000 of juveniles were stocked to state lakes.

In 1996 were produced 18000 of noble crayfish juveniles of 2-3 stage.

In 1997 were produced 71200 of noble crayfish juveniles of 2 stage.

The only private crayfish aquaculture enterprise that officially exists, is a signal crayfish farm on lake Nevardas (Westman & Manninen 1996). No information exists on the breeding stock, production, or how a possible production is used (stocking or consumption).

8 Management

In 1995-1997 joint project between Institute of Ecology, Lithuania and Eastern Norway Research Institute, Norway was executed. The result of this project is Report "Freshwater Crayfish in Lithuania. I: Action plan for crayfish management, II: Crayfish status report". Report was delivered to Institute of Ecology, Environmental Protection Ministry and Ministry of Agriculture and Forestry Fisheries Department. Executors of this project (T. Taugbol, J. Skurdal and A. Burba) hope Lithuanian environmental authorities will find the management useful in the future management of the valuable crayfish resource and that recommended actions will be appraised, adopted and implemented.

Future

The main tasks for our future investigations are:

- Investigation of the dynamic of native crayfish *Astacus astacus* distribution and populations parameters.
- Investigation of alien crayfish *Orconectes limosus* spreading dynamics and impact on native crayfish species
- Investigation of the relationship between different crayfish species and their habitat.
- Investigation of the relationship between habitat parameters changes and changes in crayfish distribution and abundant.

9 Discussion

Noble crayfish *Astacus astacus* is the only native from the four crayfish species inhabiting Lithuanian waters. The first introduced crayfish species *Astacus leptodactylus* began to spread spontaneously and was transferred to the north-east of the country from Belarus and Latvia in the end of the last century. In 1972 signal crayfish *Pacifastacus leniusculus* was introduced in two isolated lakes in the mid east of the country. In 1995 the spontaneous spreading of spiny-check crayfish *Orconectes limosus* was stated in the south-west of Lithuania. The supposition of Lithuanian physiologist G. Mackeviciene (1997) that *A. leptodactylus* is native for Lithuania is not correct, because only historical knowledge and investigations of crayfish distribution and not physiological research can serve as a basis for establishing crayfish status.

We established the crayfish factor (CF) to estimate crayfish abundance in every region and in all territory of Lithuania. The CF shows the relation of crayfish lake area with the area of all lakes. On the basis of interviews and original investigations we found CF to be

20.6%. The CF increased twofold since 1993. The growth of crayfish abundance is due to re-establishing the noble crayfish stocks and not to alien crayfish introductions. The effect of narrow-clawed crayfish *A. leptodactylus* introduction we estimated as neutral, that of signal crayfish *P. leniusculus* as negative and as a wrong path, introduction of spiny-check crayfish *O. limosus* as negative. It is necessary to continue investigations on crayfish in Lithuania.

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Crayfish situation in Norway

Trond Taugbøl & Jostein Skurdal
Eastern Norway Research Foundation,
P. B. 1066, 2601 Lillehammer, Norway

1 Crayfish species and distribution in Norway

Norway has only one species of crayfish, the native noble crayfish *Astacus astacus*, which has been part of the Norwegian fauna for at least 250 years. It is distributed in the south-eastern part of Norway with a few populations in the west and in mid-Norway (Fig. 1).

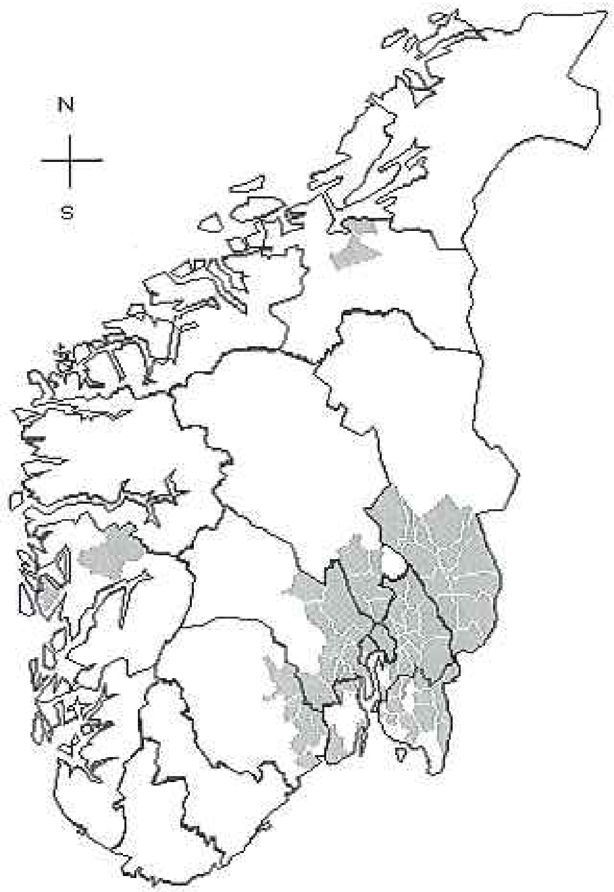

Fig. 1 *Map of southern Norway. Shaded area shows noble crayfish distribution.*

Most Norwegian crayfish populations have been stocked, only those close to the Swedish border probably being natural immigrants. Temperature (Abrahamsson 1972, Pursiainen & Erkamo 1991) is a main factor limiting crayfish distribution in Norway, along with migration barriers making it difficult to invade new areas. Low calcium content of the waters (France 1987) and predation by eel, *Anguilla anguilla*, (Svärdson 1972) also make large areas uninhabitable for the crayfish. There are many waterbodies outside the present distribution area which are suitable for crayfish production, but crayfish has never been stocked.

Information on all known crayfish localities in Norway are registered in a database, hosted and continuously up-dated by the Eastern Norway Research Institute. In total, there are information on 577 localities, and crayfish are confirmed to exist in 368 (Taugbøl & Skurdal 1996). The other crayfish localities are "empty" because the crayfish populations have been exterminated for different reasons and/or because stocking attempts have failed.

2 Main threats to Norwegian crayfish populations

The crayfish populations in Norway have been dramatically reduced during the last 25-30 years. As crayfish catching has been very popular throughout this century, the harvest reflects very well crayfish abundance. In the peak year 1966, crayfish harvest was approx. 40 tonnes, whilst in the 1990's the harvest is reduced to some 10-12 tonnes (Taugbøl & Skurdal 1993).

The main threat to the native crayfish in Norway, like elsewhere in Europe, is the spread of non-native North American crayfish species (Taugbøl & Skurdal, in press). These species are all resistant carriers of the crayfish plague which kills the European species (Dieguez-Uribeondo & Söderhäll 1993). Possible disease-free American species may also otherwise out-compete the European species (Holdich & Domaniewski 1995, Söderbäck 1995). So far, no foreign species has been registered in Norwegian waters, but the signal crayfish, *Pacifastacus leniusculus*, have been stocked and established in more than 2600 Swedish localities (Fiskeriverket/Naturvårdsverket 1998), some of them pretty close to the Norwegian border. A main objective for Norwegian authorities is thus to prevent introduction of signal crayfish from Sweden.

Although no foreign crayfish species has been found in Norway, it has still been problems with crayfish plague. The disease first appeared in Norway in 1971-73 in a small watershed on the border with Sweden. In 1987-1989, crayfish plague reappeared in the Glomma, Store Le and Halden watersheds. Glomma and Halden were among the best crayfish loclaities in Norway. The last crayfish mass mortality most probably caused by the plague was been reported in 1991 (Taugbøl et al. 1993). However, in test cages in two different watersheds, repeated mass mortality of crayfish occured in 1995 and 1998. It is quite clear that the mortality was caused by an aggressive pathogen, but crayfish plague could not be detected in spite of help from the best international experts. Not surprisingly, other aggressive pathogens than crayfish plague can cause mass mortality in wild crayfish populations, and these two examples document the great lack of knowledge on other harmful crayfish diseases.

Habitat alterations and pollution are considered to be a major reason for the decline in crayfish populations in many areas (Westman 1985). In Norway, the 75% reduction in crayfish yield during the last 25-30 years are mostly due to these factors (Taugbøl & Skurdal 1993). The habitat alterations in streams are mainly caused by encroachments like canalization, dredging and embanking. In many lakes and slow flowing rivers, mud accumulation due to erosion from agriculture areas have turned previously good crayfish bottoms into unfavourable habitats (Waters 1995). Important hiding places, especially for juveniles, have disappeared. Pollution from agriculture and other domestic and industrial sources may act directly on crayfish survival (toxic effects) or more indirectly through mud accumulation, oxygen depletion, and a change in flora and fauna composition (e.g. the effects of eutrophication). Also acidification has wiped out many crayfish populations in Norway. Overexploitation and predation by mink are also considered as threats to the crayfish, but these factors are probably of minor importance with a possible exception in small rivers and streams.

3 Crayfish catching and culture

The interest for catching crayfish in Norway emerged in the beginning of this century in step with the inceasing demand in Sweden. In Sweden, a strong interest in crayfish as food ("crayfish parties") developed among ordinary people during the last century. When the crayfish plague wiped out many of the good Swedish crayfish populations in the beginning of this century, it caused a great lack of crayfish on the Swedish market. Most of the Norwegian crayfish catch has been exported to Sweden. In 1908-1940, statistics show that 5-18 tonnes of crayfish was exported. From 1950 on, it gradually increased and the peak was reached in 1966 with more than 30 tonnes exported. Total harvest this year was approximately 40 tonnes. During the last decades the interest for "crayfish parties" has increased also in Norway. The harvest has declined since the peak year of 1966 and today it is some 10-12 tonnes (Taugbøl & Skurdal 1993). Most of it is used domestically; by the fisherman himself or directly from the fisherman to the consumer (black market).

Number of persons involved in crayfish catching in Norway are relatively few, probably not more than 1500-2000. However, taken into account the limited distribution and number of good crayfish localities and the short catching season, it means that crayfish, where it exists, are of significant recreational and economical importance.

Crayfish culture is of minor importance in Norway. Following the fast development of aquaculture in Norway in the 1980's, some interest in intensive crayfish culture emerged. In November 1987, 25 permissions for crayfish culture were issued or for consideration (Taugbøl 1989). All but one related to intensive, indoor culture. A few pioneers invested a lot of money in this business, but no one succeeded. Many of those who got a permission never started, mainly due to bad experiences made by others, and the license was withdrawn. In the 1990's the interest for crayfish culture has turned more towards outdoor, extensive (pond-culture) or semi-intensive (juvenile production indoors) methods (Taugbøl et al. 1989, Taugbøl & Skurdal 1996). In 1996, there was only 11 licenses for crayfish culture in Norway, mostly related to extensive/semi-intensive methods. Annual culture production of consumption crayfish is still negligible; less than 500 kg up to date. Annual juvenile (stage 4) production for stocking purposes has varied between 5000-15000 individuals in recent years.

As long as indoor, intensive culture methods do not seem to be profitable, crayfish culture will remain a very limited activity in Norway. In most parts of Norway, climatic conditions are unfavourable for crayfish. To succeed with pond culture of crayfish, the conditions should be optimal regarding temperature and water quality. Within the original, narrow crayfish distribution area in Norway (Fig. 1), probably only a few areas have such good conditions.

4 Legislation and regulations

In Norway, most of the lakes and rivers are private, and the right to catch crayfish (and fish) belongs to the landowners. In some lakes and rivers landowner's or fishermen's associations sell licences for catching crayfish, but most crayfish-catching areas are not organized. Crayfish are defined as fish with respect to management and legislation.

Present crayfish management and disease control are regulated by the Salmonid and Inland Fish Act of 15 May 1992 and the Fish and Aquatic Organisms Diseases Act of 13 June 1997. In addition, crayfish culture requires permission based on the Aquaculture Act of 14 June 1985.

Current national crayfish fishery regulations based on the Inland Fishery Act include:

(1) a legal catching season from 18.00 hours on 6 August to 15 September.

(2) a minimum mesh size of 21 mm (stretched mesh) in traps or other gear with mesh applied for catching crayfish.
(3) a ban against SCUBA diving for the captive of crayfish.
(4) a minimum legal size of 95 mm total length.
(5) a general ban against stocking of crayfish (permission is needed).

The fishery authorities at the county level can establish more strictly regulations if necessary. For instance in Lake Steinsfjorden a local regulation sets the legal catching season to only ten days (August 6 - 16) compared to almost six weeks in the national regulation.

The regulations in force, based on the Fish and Aquatic Organisms Diseases Act, include the following:
(1) a ban against import of live, or dead, unboiled, freshwater crayfish into Norway. This ban also includes crayfish for aquarium purposes.
(2) a ban against releasing, or keeping crayfish in cages outside the locality where they were caught. Diseased or dead crayfish must not be thrown into waterways.
(3) equipment involved in catching and keeping crayfish must be disinfected between seasons and before use in another watershed. Crayfish catching gear used abroad are not allowed into Norway.
(4) boats, angling equipment and other gear must be completely dry or disinfected before used in other watersheds or allowed into the Norway. Water-containers must not be emptied directly into another watershed.

5 Management efforts

The Norwegian Directorate for Nature Management recognize a special responsibility for the noble crayfish. A proposal to a national management plan, listing managment objectives and actions, has been worked out (Taugbøl & Skurdal 1998), and will hopefully be formally adopted in near future.

5.1 Prevent spread of crayfish plague and stop introduction of non-native crayfish species

Legislation

Good legislation is a necessary basis in order to prevent spread of diseases and stop introduction of non-native species. The Norwegian legislation is currently considered very good regarding this matter. The forthcoming harmonizing with EU trade legislations is, however, of great concern. It is doubtful if Norway will still be allowed a total ban against import of live crayfish which also include consumption and pet shop crayfish.

Public information, control and enforcement

Good legislation alone do not solve any problem. Information is necessary to get people to respect the regulations, and to behave properly in order to prevent spread of diseases. Information brochures/leaflets on this matter are produced in large numbers in Norway and distributed to regional and local authorities and fishermen. In the period 1988-1997, there was a general ban against crayfish catching in Norway due to serious plague outbreaks in main watercourses. Permissions could be obtained outside the plague-infected areas, and all those granted a permission were given information on the crayfish plague and how to prevent further spread. Newspapers are also provided with information each year before the catching season starts. Control and enforcement are mainly carried out by the landowners or fishermen associations who have the right to catch crayfish

Co-ordination between authorities

In Norway, regulations to prevent spreading of diseases are under the jurisdication of the Ministry of Agriculture and associated authorities whilst regulations for catching, exploitation and stocking belong to the Ministry of Environment. In a protection context, all these matters must be considered as a whole and actions co-ordinated. Some cases are treated at a local authority level, others at a regional or national level. In Norway, an advisory 'crayfish plague committee' was established after the plague outbreak in 1987 (Taugbøl et al. 1993) and lasted up to and including 1998. The committee had representatives from different authorities at national and regional levels and from a research institute. The aim of the 'crayfish plague committee' was to discuss and recommend actions to prevent spread of the crayfish plague and non-native species and to secure a co-ordinated effort from the different authorities. Furthermore, a major aim was to re-establish native populations eradicated by the plague. The 'crayfish plague committee' also acted as a catalyst with respect to information exchange and meetings between Norwegian and Swedish authorities. Norway and Sweden have several watersheds in common. In Sweden, signal crayfish are stocked in a great number of waterbodies, but so far not in waters with an easy access into Norway. In Norway, only the native noble crayfish exist. To maintain this situation it is imperative that Swedish authorities ban signal stocking in the border area and promote the interest for the native noble crayfish. Regular meetings between the two countries are necesssary for a good co-ordinated effort.

The "crayfish plague committee" do not exist any more as a formal committee. The intention is, however, to continue the good cooperation between the different authorities and experts, based on ten year of experience from the committee.

5.2 Re-establish noble crayfish populations

In plague-struck localities

Noble crayfish are re-established in plague-struck localities. In the watercourse hit by the plague in 1971, crayfish were taken from neighbouring waters and stocked by local fishermen in the late 1970's. Harvestable populations have developed since then. In the watercourses hit after 1987, the environmental authorities have initiated restocking programs, in co-operation with landowners. So far, the restockings have been successful. Recruitment is registered, populations are developing, and no new plague outbreaks have occured.

Restocking has been done with both adult and juvenile crayfish. It is obvious that adult crayfish migrates to a very large extent, and makes it difficult to establish a population at a desired location. Juvenile crayfish are more stationary and seems to be very well suited for restocking purposes (see also Erkamo et al., this report).

In acidified and previously polluted localities

Reintroduction of crayfish are encouraged in all previous crayfish localities if conditions again are favourable. Many crayfish populations have been eradicated or reduced due to acidification, and most of these localities are limed. Pollution from domestic and industrial sources have in many cases been eliminated or greatly reduced during the last 15-20 years, and thus, crayfish may again find viable conditions. Municipality authorities and landowner/fishermen associations can apply for state money for reintroduction of noble crayfish.

Introduction in new localities

Most, if not all, of the crayfish populations in Norway are a result of stocking. In a great number of localities there have been unsuccessful stockings. There are also many suitable localities where crayfish has never been stocked. The attitude of the authorities towards stocking in crayfish-empty localities have changed during the last years. It is known that crayfish has a key role in the bentic community and strongly influence other flora and fauna.

From a biological diversity point of view it is not recommended to spread species to new localities (see also Nystrøm, this report). Thus, Norwegian authorities are restricitive against stocking of crayfish in new localities, but encourage such activity in localities previously occupied by crayfish.

5.3 Sustainable exploitation and local involvement

A sustainable exploitation of the noble crayfish populations are encouraged because the recreational and economical value of crayfish is a benefit to man and crayfish harvest may represent important additional income. Further, exploitation and protection are in fact closely linked. Those who exploit are also concerned about the exploited resource. If local people are allowed to catch the crayfish, if children grow up with the magic of catching crayfish, they will also be interested in the protection of the crayfish populations. In Norway, many local landowner or fishermen associations are involved in fishery management today. The local concern and awareness are stimulated because the local participants are given responsibility and authority.

5.4 Mapping and monitoring

Effective management of crayfish, i.e. adopting suitable regulations, restoration, enhancement and exploitation, rely on updated information on the distribution and abundance of the crayfish populations and the development in annual crayfish harvest. Also data on characteristics of the individual populations of crayfish are valuable. Eastern Norway Research Institute, on behalf of the Directorate for Nature Management, has established a database with historic and present data on crayfish distribution and abundance in Norway. The database is continuously maintained, improved and up-dated.

Monitoring programs for single localities are going on, and provide those who regulates the fishery with very valuable information as a basis for management decisions (see Taugbøl & Skurdal, this report).

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Crayfish situation in the North-West of Russia

Valeri P. Fedotov, Svetlana A. Bykadorova & Sergei V. Kholodkevich
St.Petersburg Scientific Research Center for Ecological Safety
18 Korpusnaya str, 197114 St.Petersburg, Russia.

Abstract

The region of the North-West of Russia is 357300 km² sq.km by area. Administrative structure is presented by five districts. This whole territory of the North-West region is included in one Baltic province of zoo-geographical crayfish inhabitant area. In the lakes of this province of the N-W of Russia two aboriginal dominating crayfish species can be found: *Astacus astacus* L. and *Astacus leptodactylus*. In this paper physical-geographical conditions of the region, data on internal waterbodies pollution of each administrative district, and characteristics of water resources and situation with crayfish in each are presented. We tried to range districts by density of crayfish waterbodies from the highest to the lowest. Unfortunately, aboriginal crayfish trapping is performed by trade teams using old technology. It is not profitable due to the low crayfish density. In order to increase crayfish density it is necessary to have crayfish artificial introduction. At the present moment a project on establishing a base station for noble crayfish restoration in the region is prepared and realized by St. Petersburg Scientific Research Center for Ecological Safety in collaboration with St. Petersburg State University. Project includes work on noble crayfish populations monitoring, dissemination of knowledge on crayfish breeding among local people, and carrying out economically effective technology of juvenile crayfish production. Project is supported by regional Committee on Nature Protection and Ministry of Ecology of the Russian Federation as well. The 15th issue of crayfish news (in Russian) has been prepared and published.

1 Common characteristics of the North-West region of Russia

In 1993 a scheme of systematic-geographic region of internal waterbodies of North Euro-Asia was published (Kruglov & Starobogatov 1993). The similar scheme was proposed to range provinces of crayfish dissemination by Starobogatov (1995). On the base of data for the North-West the whole region is included in one Baltic province of zoo-geographical crayfish inhabitant area (Fig. 1). The Baltic province includes basins of rivers of the Baltic, White (western part), Barents, Norwegian and North seas, the European coast of the Atlantic Ocean, and north of the Bay of Biscay. Besides, the province includes the Alpine upper parts of South European rivers, the upper flows of the Volga - above Galich-Chukhloma Hills; and the Dneper - north of Smolensk-Moscow Hills (Starobogatov 1995).

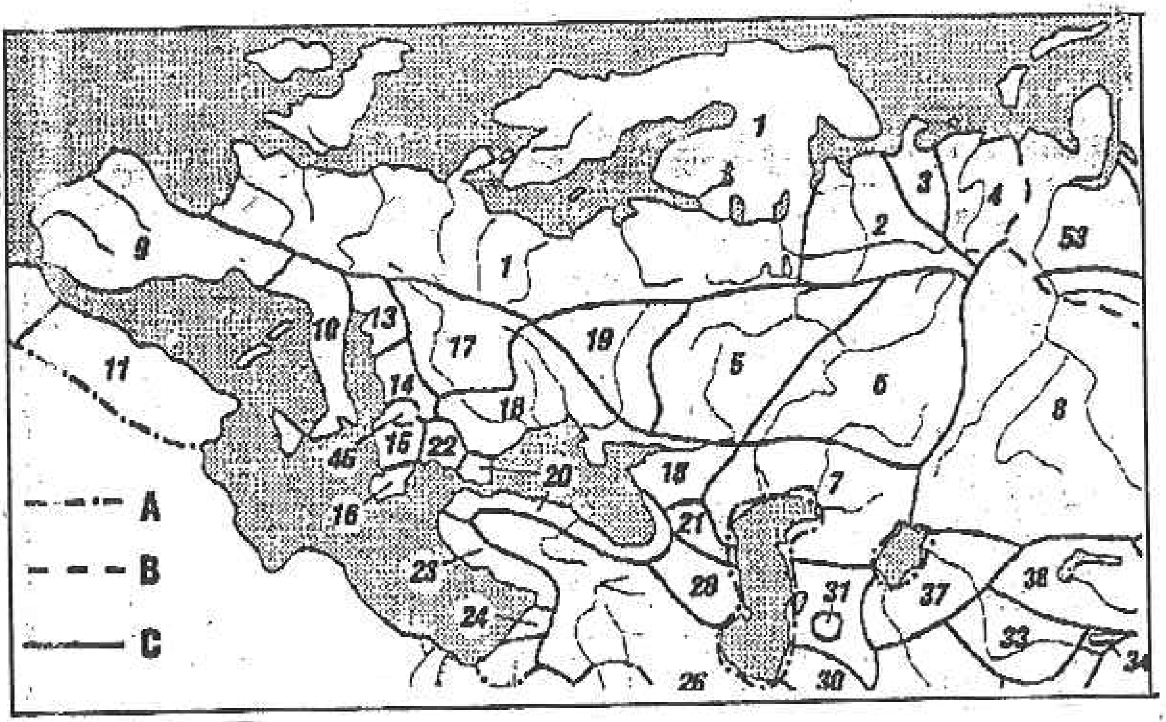

Fig. 1 *A systematic-zoogeographical division of inland waterbodies of northern Euroasia (Starobogatov 1995). Provinces devoid of crayfish are not mentioned. Ademarcation of region; B-subregion; C-province. Palearctic Region, European-Asiatic Subregion, North European Superprovince, provinces: 1-Baltian.*

The North-West region of Russia is a part of this province and it is 357300 km² sq.km. Administrative structure is presented by five districts: Vologda, Novgorod, Pskov, Leningrad, Kaliningrad, (Fig. 2). In the lakes and rivers of this province two aboriginal crayfish species can be found: *Astacus astacus* L. and *Astacus leptodactylus* bororientalisa (Starobogatov 1995). In a whole, North-West of Russia gives 10% of fish from the stock of all freshwater waterbodies of Russia. But the advantage is that exactly this territory is included in the natural noble crayfish inhabitancy area and from here Russia supply European market with more than 50 tonnes crayfish.

1.1 Physical-geographical conditions of the North-West region of Russia

Basic area of the region is a plane timed to Russian platform. Baltic shield is situated in the North and West of the Russian platform. It was formed by frizzing, hollows of which were filled by lakes. The foundation of crystal is situated to the East and South from Russian platform and by lower sediment plates from Paleozoic and Mesozoic. There are ridges Onega-Valdayskaya, Belozerskaya, Kirilowskaya, Koloshsko-Nandomskaya Hills. Large river systems have been formed on this plane. The most of them inflow to the Arctic Ocean. However, rivers of South-West part of the region belong to the basin of Atlantic Ocean and small part of the river basin belongs to the Caspian sea. By water level and water-flow big rivers are less only than Volga. The most big rivers are: Pechora, Severnaja Dvina, Vichegda, Mezen, Neva, etc. There are many other smaller rivers and lakes, especially in the N-W and Western parts. The most big lakes are: Ladozhskoe, Onezhskoe, Chudskoe. Information on crayfish inhabitancy in these lakes is available, but there is no catch there.

Climate of the region is excessfully wet, continental, with often cyclones, non-stable weather and abundant precipitation. Mean temperature in July is +18°, in January -3° Celsius. By geo-climatic zones from North to South territory of the region is occupied by middle taiga and south taiga.

Table 1 *Characteristics of North-West regions by area, population and pollution of water resources (data of 1995).*

North-West regions	Area thousand km²	Population thousand for 1993	Population density men/km²	Total outlet of harmful substances in 1992, thousand tonnes	Mean pressure of total outlet of harmful substances tonnes/km²	Volume of sewage waters in 1991 millions m³
St. Petersburg and Leningrad region	85,9	6626,5	77,14	585	7	490,6
Novgorod	55,3	751,5	13,59	77,2	1,3	154
Pskov	55,3	839,9	15,19	166,1		115,8
Vologda	145,7	1362,4	9,35	820	8,8	
Kaliningrad	15,1	906,1	60	168,9	11	

Table 1 presents data on internal waterbodies pollution of each administrative district of the North-West region (according to the data by Frolov (1995). Although, this is difficult to evaluate without taking into consideration self-settling of waterbodies. From Table 1 it can be seen, that by area the largest district is Vologda, by population density is Leningrad, by purity Novgorod and Pskov.

2 Characteristics of water resources and crayfish situation in districts of the North-West of Russia

2.1 Situation in Vologda district

The Vologda district is situated in the North-East of the region (Fig. 2). The area is about 146000 km^2. Fish-farming organizations rent here about 30 000 hectares of internal waterbodies, but only 10% of them are assimilated. In waterbodies of Vologda district following fish species are caught: *Osmerus eperlanus, O.e. spirinchus, Abramis ballerus, Stizostedion lucioperca, Esox lucius, Leuciscus idus, Rutilus rutilus, Perca fluviatilis, Acerina cernua, Pelecus cultratus, Lota lota*, etc.

Fig. 2 *The administrative structure of the North-West region of Russia.*

There are lakes and rivers with a market stock of narrow-clawed crayfish (*A. Leptodactylus*) in the district. There is no data on noble crayfish (*A. Astacus*). Mr. Zujanov, the head of Fishery Administration, on our inquiry on crayfish breeding in the district replies that there is no special monitoring of crayfish waterbodies due to the lack of money. However, there are crayfish in most of lakes and river while they can be found in by-catch of fishermen. The license for crayfish catch is about 3.5 US$ for a month. But none of them have been sold to local population over the last two years. In addition there were no protocols on illegal crayfish catch fixed over this time. There is no enterprises for crayfish catch or breeding. Demand of crayfish for internal market is minimal.

In 1987 about 500 kg of crayfish were supplied to Sweden through Leningrad district. Here an interesting population of narrow-clawed crayfish with bright red antennas can be found.

2.2 Situation in Novgorod district

Novgorod district is 55300 km^2 and is situated in the South of the North-West region. It has on its territory 503 rivers, with the length 15026 km and 799 lakes, 1730 km^2 area. 28 rivers and 603 lakes trade weigh. Populations of noble and narrow-clawed crayfish inhabit in this waterbodies. The largest stock of noble crayfish is in Hvoininsky province of the district. In 1995 member of Novgorod headquarters of GOSNIORH (State Scientific Research Institute of Rivers and Lakes Fishery), O.Yu. Asanov and O.V. Anisimova presented successful works on juvenile production of noble crayfish in one of Fishery farms of the district.

2.3 Situation in Kaliningrad district

Kaliningrad district is the smallest by area in the region; only 15100 km^2. But there is high population density (Table 1). Rivers are badly polluted. The most big rivers are Pregola and Neman, but there is no fish catch there. In small lakes and water reservoirs there are four crayfish species, from which two are introduces *(Orconectes limosus, Pacifastacus leniusculus*). Mr. V.Osadchi, the head of Fishery Inspection on our inquiry on crayfish breeding in the district replies the following: crayfish *Orconectes limosus* was broadly spread on internal waterbodies of the district. The crayfish was penetrated in the district through the water systems of Mazurskaya river and they inhabitant in almost all rivers and lakes of the district. There is no special monitoring of crayfish waterbodies. The stocks of aboriginal crayfish (*Astacus astacus* and *Astacus leptodactylus*) are almost absent in the waterbodies of the district. *Pacifastacus leniusculus* from Lithuanian lake Shkiletas were introduced here in order to restore the crayfish stock. Acclimatization was successful. In present, these already adult crayfish have acclimatized in some of the waterbodies of the district (Fedotov et al. 1997). Crayfish investigations are performed by a small group of scientists from Kaliningrad State University, headed by Prof. S.M. Nikitina (Nikitina 1982, Nikitina & Chibisova 1996).

2.4 Situation in Pskov district

Pskov district is situated in the South-West of the North-West region. Lakes and rivers of Pskov district occupies 6% of its territory. There are 213 rivers with total length 10862 km. The majority of lakes before 1976 were inhabitant area of noble crayfish. Water in Pskov lakes and rivers are highly mineralized. There is a lot of lime and this support crayfish growth. Based on the data by Perminov (1995) modern state of crayfish in the region allows to establish annual catch of 10980 kg. There are more than three firm in the district which supply crayfish for market, but they are working seasonally. More serious plans has society organization "Astacus 97" which from 1997 is creating crayfish farm in Gdov province of the Pskov district. The organization is oriented on establishing of the base for live crayfish stock in bags and its supply for market by small parts during the year. In addition they plan to create low-cost technology of crayfish breeding using artificial juveniles production. Some results of their work in this sphere are presented in papers (Fedotov et al. 1993, Fedotov et al. 1997).

2.5 Situation in Leningrad district

Leningrad district is situated in the North of North-West region of Russia. There is highest population density (Table 1). Before 1970 crayfish caught by districts of the North-West region in lakes is presented in Table 2. From these data it can be seen that the highest crayfish supply was from Leningrad district.

Table 2 *The yields of noble crayfish (tonnes) in period 1963-1970 in waterbodies of North-West of Russia by districts.*

District	Years							
	1963	1964	1965	1966	1967	1968	1969	1970
Leningrad	19,6	11,7	16,4	14,8	18,6	14,8	8,6	1,5
Novgorod	9,3	5,0	2,6	3,2	4,2	4,0	2,1	-
Pskov	16,4	10,2	8,1	4,8	7,5	3,6	3,1	-
Vologda	0,1	0,3	-	-	2,5	-	-	-

In 1987 there was a questionnaire performed on presence and distribution of crayfish waterbodies in Leningrad district. Data analysis showed available crayfish waterbodies in 8 provinces of the district. In 1986 a pilot project has been started in the district. It is aimed on creating full-system crayfish farm with financial support from AGROPROM (Ministry of Agriculture). An experimental department for crayfish juvenile production was created on the territory of Vyborgsky collective farm. There was created a fish-pond base for crayfish accumulation and preparation of live animals for transportation. Afterwards, based on the commitment with Swedish company Thomesto-Smidt on the territory of the collective farm there was established the first Russian factory for crayfish processing on the base of Swedish technology. During the two years work, the services for forage production and teams for crayfish catch and crayfish stock intelligence were created, there were established links for crayfish supply from other regions (Astrahan, Dnepropetrovsk, Volgograd, Karelia, etc.) of Russia. Over five years about 50 tonnes of narrow-clawed and noble crayfish were supplied to Sweden. Noble crayfish were about 10% of this amount. The main steps of the juveniles crayfish production under intensive technology were set up. Some results of this work were published (Fedotov et al. 1993). This work in Leningrad district has a high response in other regions. In 1992 guided by A. I. Pahomov firm "Apex" the work was performed on juvenile noble crayfish production at the one fish breeding factory. There were obtained around 300000 of crayfish specimens. Unfortunately, the results of this work were never published and it is not clear what were the outcome of crayfish introduction.

Likhareva & Moiseeva (1988) published data for several crayfish waterbodies in Leningrad district. Preliminary evolution shows that there is crayfish stock about 10 tonnes of noble crayfish. However, its catch using old technology, i.e. by trade teams, is not profitable due to the low crayfish density. The most worth while is to organize the network of crayfish farms at the rented waterbodies based on Finnish or Swedish experiences (Pursiainen et al. 1987, Ackefors 1997). In order to increase crayfish density it is necessary to have crayfish for introduction. Unfortunately, market of juveniles is not organized yet and expenditures on its creation are considered to be a risk for business and farmers (Alexandrova 1997).

3 Conclusions

We can range districts by density of crayfish waterbodies. From the highest to the lowest this will be Pskov, Novgorod, Leningrad, Vologda and Kaliningrad districts. From aboriginal species *Astacus astacus* and *Astacus leptodactylus* are dominating in the region. Except Vologda, in all other districts aboriginal species *Astacus astacus* are dominating in the region. Saying in a whole, crayfish farms in this region is not developed yet. The almost catch is performed mainly by amateurs and is not fixed. Mr. V. K. Evdokimov, the head of Basin administration on internal waterbodies preservation, on our inquiry on crayfish catch and crayfish breeding in the region replies that there is no licenses sold for crayfish catch in internal waterbodies during 1995-1997. The permissions for crayfish catch were given only to 8 organizations during1995-1997. In crayfish waterbodies were revealed only 7 violations in this time. There is no special actions for conservation and crayfish breeding due to the lack of money. In the present catching regulations start of crayfish season is 15 July and ban catch of crayfish during of mass molts. There are no special regulations for crayfish *Astacus astacus* and *Astacus leptodactylus* and other species of crayfish.

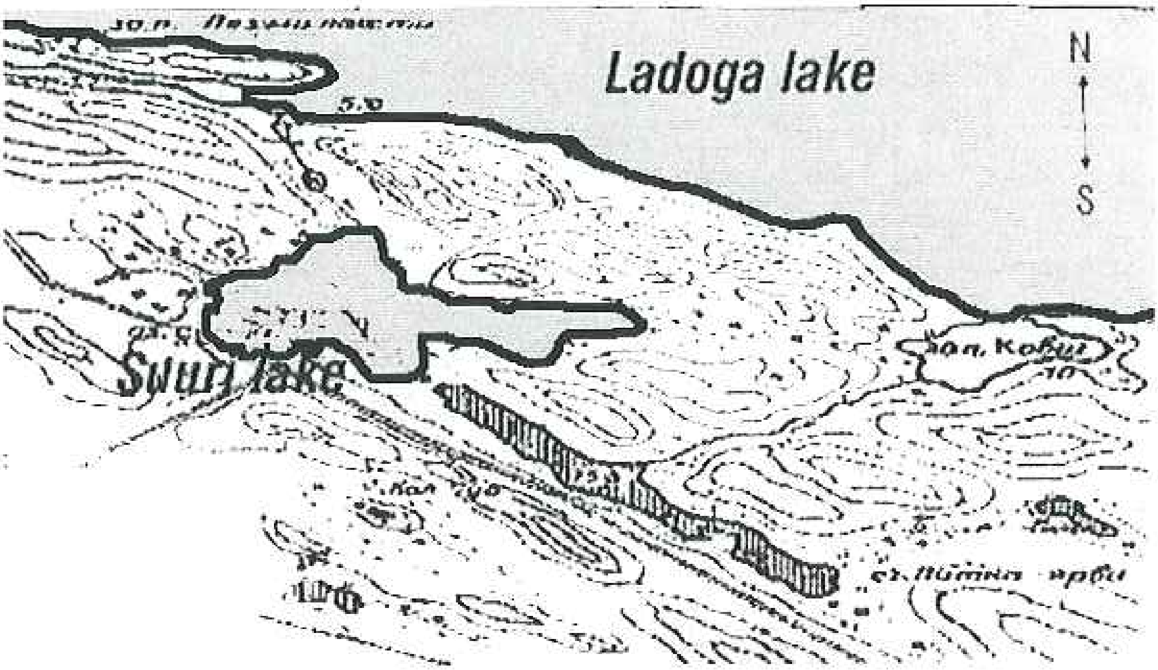

Fig. 3 *Map showing location of the lake Suuri in the Leningrad district of the Priozersk province.*

Minimum size is 100 mm for all crayfish species (from pick of rostrum to edge of telson). For amateurs, permission catch is 20 crayfish per trap per person with mesh size not less than 20mm. For trade crayfish catch it is permitted to use 20 traps with minimal mesh size. Fine for illegally caught crayfish is 2000 rubles per crayfish (about 3,5 US$). It is also banned to transport traps and other nets from waterbodies with indus of infection without preliminary disinfecting.

At the present moment a project on establishing base station for noble crayfish restoration in the Leningrad district is prepared and is realizing at St. Petersburg Scientific Research Institute Center of Ecological Safety. Station is planned to be at the Suury lake, Priozersk province (Fig. 3). Project includes three years work on noble crayfish population monitoring, carrying out on economically effective technology of juvenile crayfish production with development scheme construction of crayfish farms for local population of the North-West region and dissemination of knowledge on crayfish and crayfish breeding among local people in order to attract investments in crayfish farms development. There is already prepared a biological approving for crayfish in lakes Berezno, Orlovo (Pskov district). The 15th issue of "Crayfish news" in Russian has been prepared and published.

Although the price for crayfish at the internal market (for example in St.Petersburg) gets up to 17 US$ per kilogram for live crayfish during the winter, this stimulates only amateur hunting. But amateurs catch of crayfish is not totally fixed in the region. In 1995 there was developed a State program on protection and reproduction of crayfish populations and development of crayfish farming in the Russian Federation but it has not been signed yet in the Ministry of Agriculture and there is no financing for this program. This was the main reason why we prepared a project which has been submitted to Life-Third Countries program with European Union. Its realization enables civilized protection and exploitation of crayfish populations in the region. Project was supported by regional Committee on Nature protection and Ministry of Ecology of the Russian Federation as well.

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Crayfish Situation in Sweden

Lennart Edsman
Institute of Freshwater Research, National Swedish Board of Fisheries,
SE-178 93 Drottningholm, Sweden

Crayfish has a long and strong tradition in Sweden, its utilisation being documented back to the 16th century. The crayfish fishery within the country today thus constitutes a substantial social, cultural and economic value. The economic value of the annual catch has been conservatively estimated to approximately 80 000 000 SEK (10 000 000 US$). The native noble crayfish, *Astacus astacus*, is today threatened by diseases, pollution, acidification and competition from the introduced signal crayfish.

1 Species distribution

The indigenous noble crayfish, *A. astacus* had its original distribution in Sweden limited to the southern parts of the country, with the northern border of occurrence stretching from the middle of the county of Värmland, through the south east part of the county Dalarna, to the south parts of the county Hälsingland. Even within this original range the occurrence was sparse, especially in water sheds that drains directly into the Baltic or into the sea on the west coast. Through extensive stocking during the last 500 years, the range has been extended northward to also include mainly running waters and mainly waters along the east coast, all the way up to the Finnish border. Since the plague came to Sweden the annual catch, that was estimated to be 600-1000 tons at the turn of the century, has been reduced with more than 95%. The main reason for the decline is probably the arrival of the crayfish plague, but acidification of the water, water pollution, changes and fluctuations in the water regime in connection to power plants, and the introduction of the signal crayfish which has worked as a vector for the spread of the plague are all factors that have caused the decline. In the last 25 years the most severe threat for the noble crayfish has probably been the spread of signal crayfish into areas where they do not yet exist, with the consequence that crayfish plague has become permanent. In a survey conducted in 1996, noble crayfish was reported from 1596 localities of which 943 were lakes, 356 were running waters and 297 were ponds (Fiskeriverket & Naturvårdsverket 1998; Fig.1). However, still in 1995, 90 new plague outbreaks in noble crayfish populations were reported.

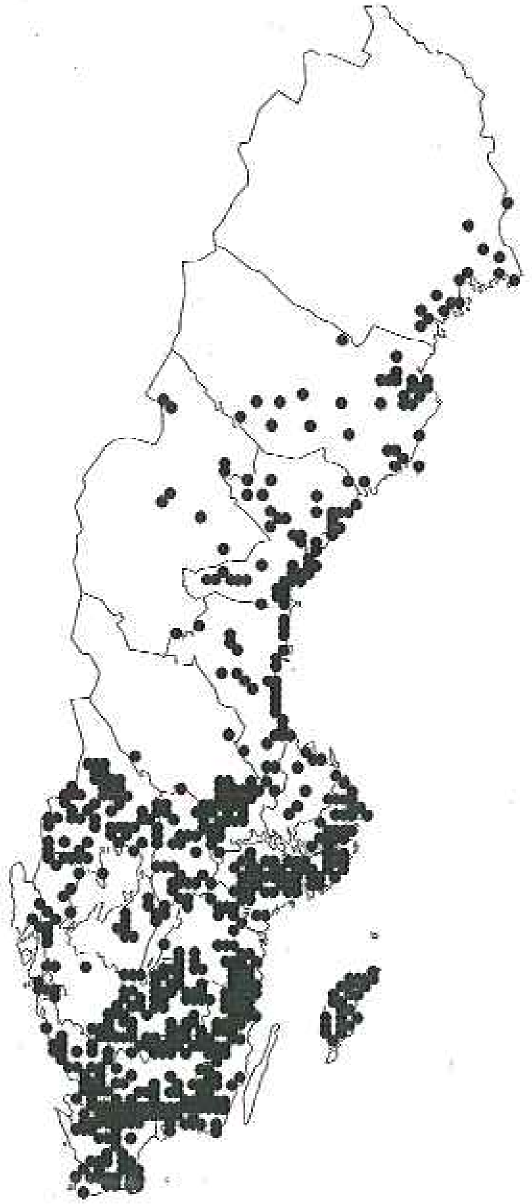

Fig. 1 *The distribution of Noble crayfish in Sweden 1996.*

Signal crayfish, *P. leniusculus*, was introduced into lakes in Sweden as a replacement for the noble crayfish, lost mainly due to plague outbreaks. After a trial period in a few lakes in the 1960ies, a more extensive stocking program was started 1969, both with imported adult animals and with fry produced by a hatchery in Simonstorp, southern Sweden. The stocking of signal crayfish into lakes continued to be extensive for the next 20 years. This was partly due to that it was more or less the rule to stock signal crayfish into all new waters that had been struck by the plague. In a survey conducted in 1996, signal crayfish was reported from 2697 localities of which 1042 were lakes, 319 were running waters and 1336 were ponds (Fiskeriverket & Naturvårdsverket 1998; Fig. 2).

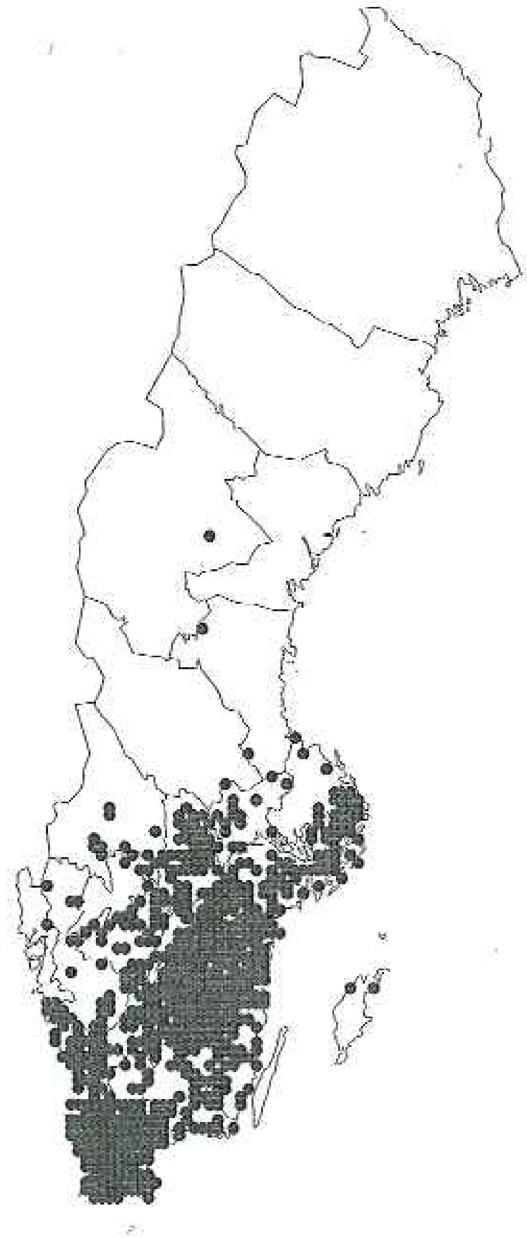

Fig. 2 *The distribution of Signal crayfish in Sweden 1996.*

2 Crayfish plague

The crayfish plague, *A. astaci*, came to Sweden in the beginning of the summer in 1907. It arrived with a shipment of crayfish from Finland to Stockholm, and noble crayfish in the lake Mälaren drainage area were all crayfish were killed that summer. The quite extensive trading with crayfish and the increased mobility of people and modern transportation unfortunately facilitated the spread of the plague. In the end of the 1920ies and during the 1930ies, many water sheds in southern Sweden were struck by the plague, and since then periods with a high frequency of outbreaks have been alternated with periods with few outbreaks. Today, crayfish plague has been reported from all drainage areas up to the river Dalälven, and there are a few reported outbreaks also north of this border. From the islands of Öland and Gotland plague has not been reported. During 1995 new outbreaks of plague were reported from approximately 90 localities with noble crayfish representing 19 different drainage areas (Fiskeriverket & Naturvårdsverket 1998; Fig. 3).

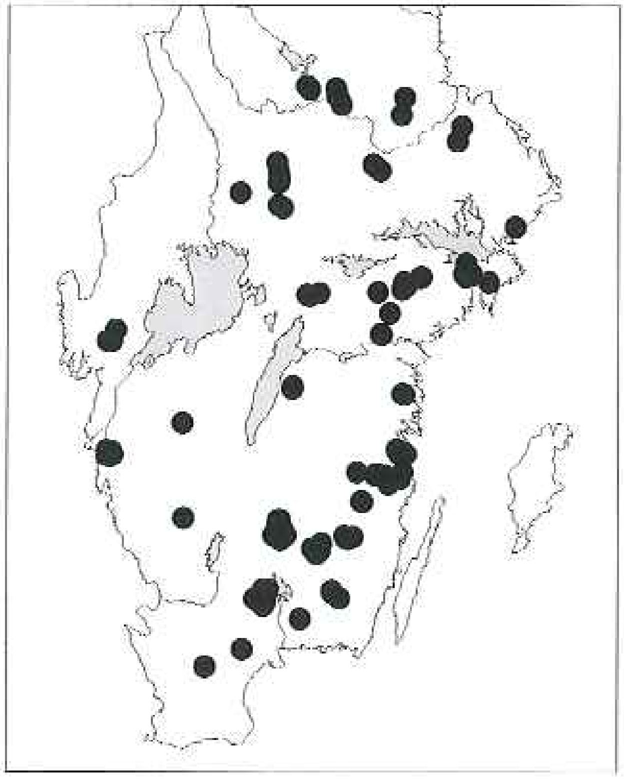

Fig. 3 *Crayfish plague outbreaks in 1995.*

3 Crayfish management

Before 1994 catching crayfish was only allowed from the beginning of august to the end of the year. There was also a minimum catchable size of 9 cm carapace length. From 1994 all rules are taken away and today there are no regulations for catching crayfish. Many local fisheries management associations have however voluntarily kept more or less the same rules as before and there is also often a limit to the number of traps used.

Even though permits were always needed to release crayfish, and the regulations have always aimed at protecting the remaining populations of noble crayfish, the practical policy was to give permits rather liberally during the 1970ies and 1980ies. The stricter regulations for stocking that have been effective since 1994 means that permits to stock signal crayfish should only be granted in water sheds that already contain signal crayfish and where noble crayfish restoration is not a possible alternative. Thus, permits to stock signal crayfish should not be given on the islands Öland and Gotland and north of the river Dalälven, for water sheds that extends into Norway, in connection to areas with acute plague, in connection to areas with noble crayfish populations that should be protected, where the signal crayfish is not present today or where noble crayfish restoration is considered to be a possible alternative.

4 Import legislation

Until 1997 all import of live crayfish for food required a special permit from the agricultural board. Only noble crayfish could be brought into the country without this special permit. The live trade for all crayfish species was connected to it being compulsory to report the arrival of all shipments to the customs in advance and the obligation to have a veterinarian accompanying the shipment all the way from the border to the approved place for cooking the crayfish. The veterinarian also supervised the cooking and checked that the packing material and the cooking water was taken care of properly, in order to minimise the spreading of diseases. These import regulations, when applied, should have stopped foreign crayfish species and diseases from entering Sweden. However in practice it proved almost impossible to check that the regulations were always followed, one reason being that the personal at the customs were not trained and the identification of species requires special training. As a result it happened that narrow-clawed crayfish and other species were sold as noble crayfish in the fish market. When live crayfish are imported for consumption there is also no guarantee that they do not escape. Therefore any import of live crayfish poses a threat to the noble crayfish. On several occasions exotic species like Procambarus clarkii, were sold in pet shops as native noble crayfish. Procambarus clarkii has also obviously been released into waters in Sweden, since actual populations have been found in ponds in southern Sweden. As far as we know they have not reproduced in nature but it may be possible, taking into consideration the climatic conditions of the southern parts of the country.

In September 1997 the situation got worse, since the former veterinary control was abolished and no permit was needed any more to import live crayfish for food consumption. This change in legislation was a response to question by the European commission about how Sweden was following the free trade policy, in connection to a crayfish farmer not being given a permit to export live crayfish into Sweden. This "open border" actually applies to not only the European Community, but also to crayfish from other parts of the world. The only restriction is that the crayfish has to come from an approved producer that fulfils the hygienic requirements for food production and that the producer is listed by the National Food Administration. By this Sweden at the moment has the weakest control of the trade with live crayfish at the same time as other European community are imposing stricter legislation (i.e. England, Scotland and Spain).This change in the regulations has resulted in that in 1998, live imported crayfish is being sold in shops over Sweden for the first time in nearly 20 years. Pressure is now being put on the authorities, however, on having stricter regulations for the import, in order to avoid getting new species and diseases into the country.

5 Protection and restoration

The interest in the noble crayfish has increased lately and as a result a project for the restoration of noble crayfish was started in 1996, and an action plan for the restoration was presented in the summer 1998 (Fiskeriverket & Naturvårdsverket 1998). The main suggestions in the action plan are: Protection of noble crayfish should be given higher priority at the environmental units in the regional administration. Areas with good possibilities for protection of the noble crayfish should be identified and efforts to protect the noble crayfish should be concentrated to these protected areas. Total stop of the import of live crayfish. Information material, aimed at the general public, about the crayfish situation, the value of the noble crayfish and the threats it faces, the consequences of illegally spreading crayfish and about how to protect the species, should be produced and distributed. Whenever possible, noble crayfish populations hit by the plague should be restored with noble crayfish again. As a practical result of suggestions from the restoration project, several reintroductions of noble crayfish into lakes hit by the plague have been conducted, where the development and eventual success of the reintroduction is followed closely.

6 Production and yield

The official statistics concerning crayfish harvest only reports a total catch of 16 metric tonnes of crayfish in Sweden for 1997, and this is only a fraction of what is actually known to be caught. In two other publications (Anon. 1993, Ackefors 1997) the yield is estimated based on questionnaires to fish farmers, fisheries right owners and local authorities. These figures are presented in Table 1 and gives a totally different picture, even if they also are likely to underestimate the actual catch, e.g. by not including the fishery for household requirements. Thus a conservative estimate of the total yield in Sweden is 400 tonnes a year.

Table 1 *Approximate yield of crayfish from culture and wild harvest in metric tonnes.*

	Noble crayfish	Signal crayfish
Wild harvest	50	300
Culture	12	42
Total	62	342

7 Future

The crayfish situation in Sweden today has probably arrived at the cross-roads. Either the actions in the restoration plan are carried through, meaning that import of live crayfish is stopped, areas suitable for protection of noble crayfish are identified and efforts are concentrated to these protected areas, information to the general public and the local authorities about the crayfish situation and the actions needed are produced and distributed, lakes hit by plague are restored with noble crayfish and noble crayfish lakes are given high priority in liming projects. The aim of the action plan is to have conservation and exploitation to go hand in hand, and to maintain a sustainable fishery on viable noble crayfish populations. If this is successful it should be possible for people in Sweden to continue to catch crayfish, both signal crayfish *but* also in some parts noble crayfish and to have crayfish parties in August with Swedish crayfish.

If the necessary actions are not carried through, however, I am afraid that the native noble crayfish will soon be confined to a few unique localities. Thus it would not be part of the natural Swedish fauna any more, but it would be more like a object displayed on an exhibition. Lets hope that the first option comes through.

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Part 2

Other oral and poster presentations

Ecological effects of crayfish on littoral communities

Per Nyström
Limnology, Department of Ecology, University of Lund, Ecology Building,
S-223 62 Lund, Sweden

1 Background

In order to meet the high demand of crayfish for human consumption in Europe, both the stocking of exotic and native crayfish is expected to increase (Pérez et al. 1997). In Sweden for example, the signal crayfish (*Pacifastacus leniusculus*) has been successfully introduced in many waters where the native noble crayfish (*Astacus astacus*) populations have been eliminated by the plague (*Aphanomyces astaci*). However, the signal crayfish has also been stocked in many ponds, where crayfish have not been present. Moreover, many farmers in Sweden have created new ponds optimised for signal crayfish culture. Today, ponds are also stocked with noble crayfish because of its high commercial value as well as the increasing interest among farmers to conserve the native species (Ackefors 1998). Crayfish are omnivores and feed on a wide range of food items including detritus, macrophytes, algae, invertebrates but may also consume vertebrates such as the eggs and larval stages of fish and amphibians. If the habitat is favourable, crayfish can reach very high densities and thus, dominate the macro-invertebrate biomass in lakes, ponds and rivers. Recently, Momot (1995) concluded that in these waters, crayfish often act as keystone predators and through their foraging activity, reduce or even eliminate other plants and animals from the ecosystem. Maintaining a high diversity in freshwater communities is an important goal in ecology, and thus for crayfish farming to be ecologically sustainable, we must consider the ecological effects of crayfish introductions. Here, I give a short summary of the current knowledge of crayfish effects on macrophytes, invertebrates and amphibians. The aim is to answer the following questions: Will a crayfish introduction have negative (positive) effects on biodiversity? Crayfish are omnivores, but do they impact all tropic levels? Do introduced crayfish species (i.e., the signal crayfish) have the same impact as native crayfish (i.e., the noble crayfish)? Many amphibians are threatened, but do crayfish have any negative impact on amphibians during the aquatic stage?

2 Effects on macrophytes

Macrophytes often play a key role in freshwater ecosystems by influencing water chemistry and the interactions between organisms within the ecosystem. Macrophyte rich communities are therefore often more diverse (e.g. Carpenter and Lodge 1986).

- Crayfish affect macrophytes by directly consuming plants and their seeds, but may also affect macrophyte biomass through their non-consumptive destruction (e.g. Lodge et al. 1994).
- Crayfish are selective in their choice of macrophytes. Submerged species (easy to handle) are preferred to robust emergent species (e.g. Nyström and Strand 1996).
- The submerged stages of emergent species are however grazed by crayfish, and thus crayfish may affect the establishment of these species. If a crayfish population becomes established before the emergent macrophytes do (as often is the case in new ponds), then, no macrophytes may become established in the ponds.
- The macro-algae *Chara* are particularly consumed, and impacted in lakes and ponds by many crayfish species. Moreover, this genus contains many threatened species.
- Fast-growing macrophytes that are able to establish from fragments (such as *Elodea canadensis*) are less impacted from crayfish.
- Introduced and native crayfish species have similar preferences for macrophytes Olsen et al. 1991, Nyström and Strand 1996).
- The signal crayfish has a greater consumption rate of macrophytes over a wide range of temperatures than the noble crayfish.
- The signal crayfish has a more rapid population development than the noble crayfish and may therefor have a stronger impact on the establishment of macrophytes.

3 Effects on invertebrates

Correlative studies suggest that crayfish-rich environments have a low biodiversity of invertebrates (e.g. Nyström et al. 1996), but some invertebrates are more reduced in terms of biomass than others:

- Slowly moving taxa, such as thin-shelled snails, are strongly impacted by crayfish predation.
- The signal crayfish has a stronger direct effect on snail biomass than the noble crayfish.
- Active swimmers such as bugs and beetles, or sediment burrowing taxa, are less affected by crayfish predation.

- The reductions of macrophyte biomass and species richness by crayfish indirectly affect associated invertebrates.

4 Effects on amphibians

Do crayfish have any negative impact on amphibians at the population level? This is a very debated question in Sweden because many species of amphibians breed in permanent ponds without fish, where crayfish introductions often occur. Several experiments suggest that crayfish consume embryos and amphibian larvae (e.g. Axelsson et al. 1997). Numerous factors affect predation effects of crayfish on embryos (i) and larvae (ii):

i)

- *Temperature*: some amphibians spawn when the water temperature is low and when crayfish consumption rate is reduced.
- *Location of egg clusters*: some species lay their eggs on the water surface or attach them to macrophytes (e.g. Stebbins and Cohen 1995), which make the eggs out of reach for crayfish.
- *Protecting jelly layers*: most frog species have eggs surrounded by gelatinous, transparent jelly layers, which may reduce crayfish predation.
- *Unpalatability*: predators, due to the presence of toxins (e.g. Henrikson 1990) less consume embryos of bufonids. However, in laboratory experiments, both the signal crayfish and noble crayfish consume embryos of the common toad (*Bufo bufo*) (Axelsson et al. 1997).

ii)

- *Swimming performance*: the swimming ability and behaviour differ between amphibian species, and thus also the encounter rates with crayfish. Larvae of the common toad are often swimming in the water column, whereas larvae of many frog species are found near the sediment surface. The ability of a crayfish species to catch larvae may differ. For example, in a laboratory experiment, the noble crayfish caught more larvae than the signal crayfish (Axelsson et al. 1997).
- *Unpalatability*: bufonid larvae are generally considered as unpalatable to predators with chewing mouth parts, and also to signal and noble crayfish (Axelsson et al. 1997). However, the palatability of bufonid larvae varies with the developmental stage (e.g. Brodie and Formanowicz 1987), and recent experiments suggest that the intermediate larval stages of the common toad can be greatly reduced by signal crayfish (Nyström, unpublished data).

- *Injuries*: crayfish may cause non-lethal injuries to larvae, which makes the larvae more susceptible to crayfish predation (Figiel and Semlitsch 1991).

A crayfish population may also affect amphibians by the elimination of oviposition sites through the reduction of macrophytes. Moreover, adult amphibians avoid crayfish-rich streams because of great risk of injuries (Gamradt et al. 1997). Directly, crayfish affect food availability for the larval stages by consuming detritus and algae, but also indirectly by reducing the biomass of other grazers. Since froglets are less mobile than the larval stages, crayfish predation on froglets may be strong (Nyström, unpublished data). It appears that crayfish may have a negative impact on some amphibian species, but field studies are needed to determine the effects of crayfish on amphibians at the population level.

5 Conclusion

1. A successful crayfish introduction may have strong effects on the overall community structure.
2. The signal crayfish and the noble crayfish have similar food preferences, but the introduced species have a stronger impact on lower tropic levels (macrophytes and invertebrate grazers).
3. The introduction of crayfish into small ponds that have been devoid of crayfish for many years, may give little money back, and may result in a great loss of other species.
4. Hence, from an ecological point of view, it is best to encourage the creation of new ponds in agricultural areas and to stock these with a native crayfish species.

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Astacus astacus stock in a catchment in south west England. A lacustrine *Procambarus clarkii* population has survived for several years in London (Holdich, Rogers & Reynolds 1998).

P.clarkii, O.limosus and the Australian crayfish *Cherax tenuimanus* and *Cherax destructor* were imported for the aquarium trade in the early 1990s although this is now illegal. *Cherax quadricarinatus* may be legally kept by aquarists (Holdich, Rogers & Reynolds 1998).

Officially there are no native crayfish stocks in Scotland although there has been a recorded population of *A.pallipes* ('native' to England & Wales) at one site since the 1940s (Thomas 1992). There were ten unconfirmed records of *P.leniusculus* in Scottish rivers to 1987 (Holdich & Reeve 1987) and there is at least one established population of *P.leniusculus* in south west Scotland giving rise to concerns about the impact of the species on Scottish salmon rivers (Maitland 1996).

Orconectes limosus, the North American spiny cheek crayfish, was introduced to the River Oder in mainland Europe in 1890 and then successfully to the River Loire, France, in 1911-13. In 1987 Holdich & Reeve commented that:
Considering the lack of import control it is surprising that Great Britain does not have more species of naturalised crayfish, e.g. Orconectes limosus. Now, one hundred and eight years later, *O.limosus* has crossed the English Channel. In 1994 live *O.limosus* were reported for sale in England for the first time (Foster 1995a). In 1998 two lacustrine populations of *Orconectes limosus* have been recorded in England (Holdich, Rogers & Reynolds 1998).

2 Legislation

In Great Britain legislation has been driven by the decline of the native and the spread of alien species of crayfish. The legislation is now among the most stringent in Europe. The native crayfish of Great Britain, *Austropotambius pallipes* (Lereboullet) is listed in Appendix III of the Convention on the Conservation of European Wildlife and Natural Heritage 1979 (Bern Convention). The 'Bern' Convention on the Conservation of European Wildlife and Natural Habitats encourages in particular the promotion of co-operation between countries in their conservation efforts. The United Kingdom is a part to this convention, having ratified its provisions in 1982 (Stroud et al. 1990). *A.pallipes* is listed in Appendix II of the European Union Habitats and Species Directive (1992) which requires Special Areas of Conservation to be set up to protect it.

Consequently, the Government Body, the Joint Nature Conservation Committee (JNCC) has drawn up an action plan that includes the designation and management of protected areas (Palmer 1994) which have now been set up in law by the statutory body the Ministry of Agriculture, Fisheries and Food (MAFF).

On Schedule 5 of the Wildlife & Countryside Act, 1981 since 1986; it is illegal to take *A.pallipes* from the wild (without a licence) or sell it. Schedule 9 of Wildlife & Countryside Act 1991 can class alien fauna as 'pests'. *A.astacus*, *A.leptodactylus* and *P.leniusculus* are listed in this way. Under Section 14 of the Wildlife & Countryside Act 1981 it is illegal to release alien crayfish into the wild without a licence or to allow alien crayfish to escape from holding facilities.

Under the 1985 Order of the Diseases of Fish Act people producing crayfish for transfer or sale are required to register with MAFF. MAFF, the Welsh Office and the Scottish Office have introduced further measures to protect *A.pallipes* by 'The Prohibition of Keeping of Live Fish (Crayfish) Order 1996' by

- designating 'No-Go' areas for crayfish farming for most of England & Wales and all of Scotland.
- banning the unlicensed keeping of *P.leniusculus* in 'No-Go' areas.
- banning the unlicensed keeping of all other alien crayfish species throughout Great Britain (apart from the tropical Australian crayfish *Cherax quadricarinatus* which may be kept in closed, heated aquaria).

3 Reasons for monitoring crayfish

Crayfish stocks are monitored because of well documented problems associated with:

1. Demise of native crayfish *A.pallipes* due to decimation by crayfish plague, carried by the North American alien crayfish species and actual or potential competitive exclusion by three expanding North American and two European alien crayfish species (Holdich, Rogers & Reynolds 1998).
2. Concerns about the alien crayfish species affecting freshwater & even estuarine ecology by detrimental effects due to predation on aquatic macro invertebrates affecting the aquatic invertebrate community structure (J. Bywater [Environment Agency Biologist], pers. comm.) and predation on benthic fish eliminating some benthic fish species (Guan & Wiles 1997). There may be effects on aquatic macrophytes involving destruction of weed cover (although alien crayfish have been used in enclosed waters with too much weed to keep water bodies open).

3. Restocking and stocking for commercial or conservational purposes. The efficacy of such operations needs to be assessed by monitoring. For example, plague threatened *A.pallipes* have been stocked in a river in West Wales in the 1980s for restocking if the original substantial River Wye stocks in East Wales were decimated by crayfish plague (Foster 1989, 1996). Restocking of *A.pallipes* in waters previously affected by crayfish plague has been successfully carried out in the Bristol Avon catchment, England (M. Frayling, pers. comm., 1998). *A.pallipes* is being cultivated using local stock to restock the River Itchen, southern England, where *A.pallipes* may have been decimated by crayfish plague in the 1980s (Hutchings 1997).
4. Effects of natural or anthropogenic catastrophic events on crayfish populations including natural drought or overabstraction drying out watercourses such as the River Darent in Kent, England (Ingle & Thomas 1978, Environment Agency 1998).
5. Concerns about alien crayfish affecting recreational fisheries. Anglers do not like crayfish interfering with their bait while sport fishing may be rendered impracticable in some areas due to the destruction of weed cover and fish spawning sites (Goddard, pers. comm. to Holdich & Reeve 1987).

There is also a need to monitor crayfish in eradication programmes to ensure that eradication is successful.

4 Who monitors the crayfish populations?

Only a few academic & commercial bodies were interested in crayfish in Great Britain in the 1970s but now many organisations have statutory, conservational, academic or commercial interests. The government bodies **The Environment Agency of England & Wales, English Nature, the Countryside Commission for Wales,** the **Scottish Environment Protection Agency (SEPA)** and **Scottish National Heritage** have statutory interests in the conservation of native crayfish, detrimental impacts of alien crayfish on native flora and fauna and commercial exploitation of alien crayfish in England & Wales and in Scotland respectively (Environment Agency 1997).

In response to the United Nations Convention on Biological Diversity (Palmer 1994), English Nature proposes to implement the Joint Nature Conservation Council's action plan for the conservation of *A.pallipes* at suitable and strategic sites while the Environment Agency is undertaking R&D on native crayfish conservation. All river catchments in England and Wales have recently been categorised on the basis of their crayfish status by the Environment Agency (Holdich & Rogers 1997).

The **Institute of Terrestrial Ecology Biological Records Centre** at Monkswood, England, maintains a freshwater crayfish distribution data-base which is regularly updated and is available to interested parties (Holdich & Rogers 1997).

MAFF, the **Welsh Office** and the **Scottish Office** have responsibilities for registering and regulating (commercial) crayfish farms in England & Wales and have introduced 'No-Go' areas and other legislative measures to protect native crayfish.

CEFAS, the **Centre for Environment, Fisheries and Aquaculture Science** (formerly part of MAFF) has responsibilities for monitoring and controlling fish and crustacean diseases in England & Wales, notably 'crayfish plague', *Aphanomyces astaci* (Alderman, 1993). British Universities with interests in monitoring crayfish stocks include the **University of Nottingham** which has played a leading role in crayfish research in Great Britain over many years (Holdich & Rogers 1998) and the **University of Wales College Cardiff** which has been concerned with the conservation of native crayfish in Wales & the Welsh/ English border country (Foster 1995).

Many national and local conservation bodies have interests in crayfish conservation. The **Worldwide Fund for Nature** has sponsored work on native crayfish conservation in Wales & the English/Welsh border country (Foster 1989). The **Game Conservancy Trust** has sponsored distribution and habitat work on the River Piddle in the south of England (Summers & Stubbing 1996). More recently, The **Fish Conservation Centre** has taken an interest in crayfish in Scotland (Maitland 1996). **County Nature Trusts** and **local naturalist societies** have contributed significantly to local knowledge of stocks (Baker 1983; Thomas & Ingle 1971; Thomas 1992).

Commercial Water Companies (such as **Yorkshire Water Company**) have interests in crayfish due to the potential spread of crayfish plague and alien crayfish via water transfer schemes and the control of such spread by current legislation. There are also concerns relating to overabstraction of waters from rivers detrimentally affecting native crayfish stocks.

Environmental consultants are often hired to do basic survey work on freshwater crayfish stocks by interested parties. Representatives of commercial exploiters of crayfish such as the **British Crayfish Marketing Association** may also have interests in monitoring crayfish stocks.

However, many commercial exploiters of wild stocks of alien crayfish may effectively monitor crayfish stocks but they may not wish to inform others of catch results for reasons of commercial confidentiality. The interests of most of these groups requires monitoring of crayfish stocks.

5 Monitoring Methods

Monitoring should include descriptions of the catch method, study population, type & incidences of disease or parasites, other species, habitat, water quality and history of aquatic pollution at the site .

Kick-sampling (Foster 1995), stone-turning & hand capture (Thomas & Ingle 1971) and capture with a light at night are particularly useful in upland spate or fast flowing rivers where *A.pallipes* are often the crayfish species present; such methods are often used for conservation purposes. Swedish design crayfish traps are vulnerable to spates in such rivers and have had zero catches in areas of high *A.pallipes* density in upland British rivers (Table 1, Foster 1996).

Swedish design crayfish traps, fyke nets, seine nets and hand-capture during scuba-diving (often at night) are useful in lakes and slow flowing rivers where alien *P.leniusculus* or *A.leptodactylus* are often the dominant crayfish species. Consequently, such methods may be used for commercial exploitation of alien crayfish species.

Electrofishing can be useful in fast or slow flowing rivers or lakes (Westman, Sumari & Pursianinen 1978) although crayfish are generally taken only from rivers and small enclosed water bodies in Great Britain due to a paucity of large lakes holding crayfish.

Kick-sampling is selective towards juvenile crayfish while stone-turning and electrofishing are selective towards larger, more mature crayfish (refer to Table 1.). Kick-sampling, electrofishing, stone-turning and hand-capture generally are inapplicable at depths greater than about one metre, unlike nets, traps and capture while scuba-diving. It is well documented that Swedish design crayfish traps are selective to large, mature crayfish, particularly mature males, for example, about 50 mm mean carapace length for trap catches of *P.leniusculus* in the Thames area.

Draw-down of water in the inhabited site followed by collection of crayfish revealed after draining (Brewis & Bowler 1983; Foster 1996) is probably the most accurate method for population estimation and for minimising selectivity and will achieve maximum exploitation.

However, it is feasible at few sites and it may have catastrophic effects on the local aquatic environment and on exploitation in subsequent years.

Examination of otter *Lutra lutra* spraints and food remains for crayfish can reveal crayfish presence when their population densities are low, can infer the spread of crayfish plague along a river system and can be a useful technique when rivers are in spate and cannot be sampled by other means (Slater, Davies & Foster 1995). Observation while scuba-diving is particularly useful for behavioural studies under natural conditions (Thomas & Ingle 1971; Ingle 1979).

Table 1 *Catch per unit effort, mean carapace length and size range of* A. pallipes *captured by three methods from Dulas Brook, an Upland Welsh River in Spring.*

Catch method (Man-hrs)	N	CPUE	Carapace length (mm)	+/- 95% CL	Range Min. (mm)	Max. (mm)
Baited Swedish Design Traps	0	0	*	*	*	*
Kick-sampling	137	27.7	16.73	14.15	6.8	40.1
Stone-turning	35	17.5	20.34	15.34	7.1	30.3
Electrofishing	149	18.75	21.04	13.62	7.05	37.1

CPUE and the sex ratio of a catch of the native crayfish, *A.pallipes* is affected by seasonality. The catch of *A.pallipes* caught by stone-turning and electrofishing, in a Welsh upland river, the Dulas (Table 1) almost doubled in one week in late March, due to Spring warming leading to increased river temperature and hence more active and catchable crayfish. CPUE in the Summer and Autumn was two to three times higher than that typical of late March (i.e. four to six times higher than early March). CPUE fell back to March levels in early October when ambient temperatures declined and stayed at this relatively low level through the Winter (Foster 1996). Females dominated the catch in Spring while males dominated the catch in Summer and early Autumn, the predominance of males decreasing moving into the Winter. This may be related to seasonal behavioural differences between the sexes, notably territorial, sexual and brooding behaviour (Foster 1996).

6 Monitoring and habitat preferences

For native crayfish to be successfully reintroduced there is a need to establish the habitat preferences of the species. Such information would aid development of more effective management plans for Special Areas of Conservation (SACs) and Sites of Special Scientific Interest (SSSIs) containing native crayfish and could also be used as a management tool for sympathetic river engineering or other river management work, e.g.

seasonal weed cutting, bank enhancement schemes nominally for fin fish fisheries etc.

Analysis of variance and multiple regression models have been used to indicate environmental factors explaining up to 65% variance in *A.pallipes* abundance in rivers in Wales and the English/Welsh border country (Foster 1995). Highlighted factors were associated with:

A) the river margin, i.e., deciduous trees, tree roots, canopy higher than 0.5m, grass, beach, sloping bank and, usually, maximum depth;
B) refuge, i.e. tree roots, boulders, presence of deep water;
C) a lack of refuge (negative), i.e., sloping bank, bedrock, gravel, beach
D) Bankside deciduous trees, i.e., deciduous trees, tree roots, canopy higher than 0.5m.

Models based on logistic regressions were developed to predict presence or absence of *A.pallipes* in rivers in England and Wales using the Environment Agency River Habitat Survey data-base (Naura and Robinson 1998). Variables identified as having a positive impact on *A.pallipes* presence were overhanging boughs, the presence of boulders, the amount of tree shading and the number of riffles. Variables with a negative impact were exposed tree roots, eroding cliffs, the amount of poached or reinforced banks, gravel/pebble/sand banks and cobble substrate. *A.pallipes* presence or absence could be predicted with a high degree of success from both field data and map-derived information. Although preliminary work has been done on *A.pallipes*'s habitat preferences there is still a need for more research and development on 'HABSCORE' techniques for different crayfish species to use in applied fisheries & conservation work.

7 GIS & MAPINFO

Records of crayfish distribution collated by the **Institute of Terrestial Ecology Biological Records Centre** can be plotted on geographic information systems such as 'MAPINFO' at any desired level. This is a very useful management tool. Crayfish distribution at national, regional and local levels are illustrated in Fig. 1-3 (Environment Agency, 1998). River catchments in England and Wales have been categorised on the basis of their crayfish status where:

DISTRIBUTION OF CRAYFISH IN ENGLAND AND WALES

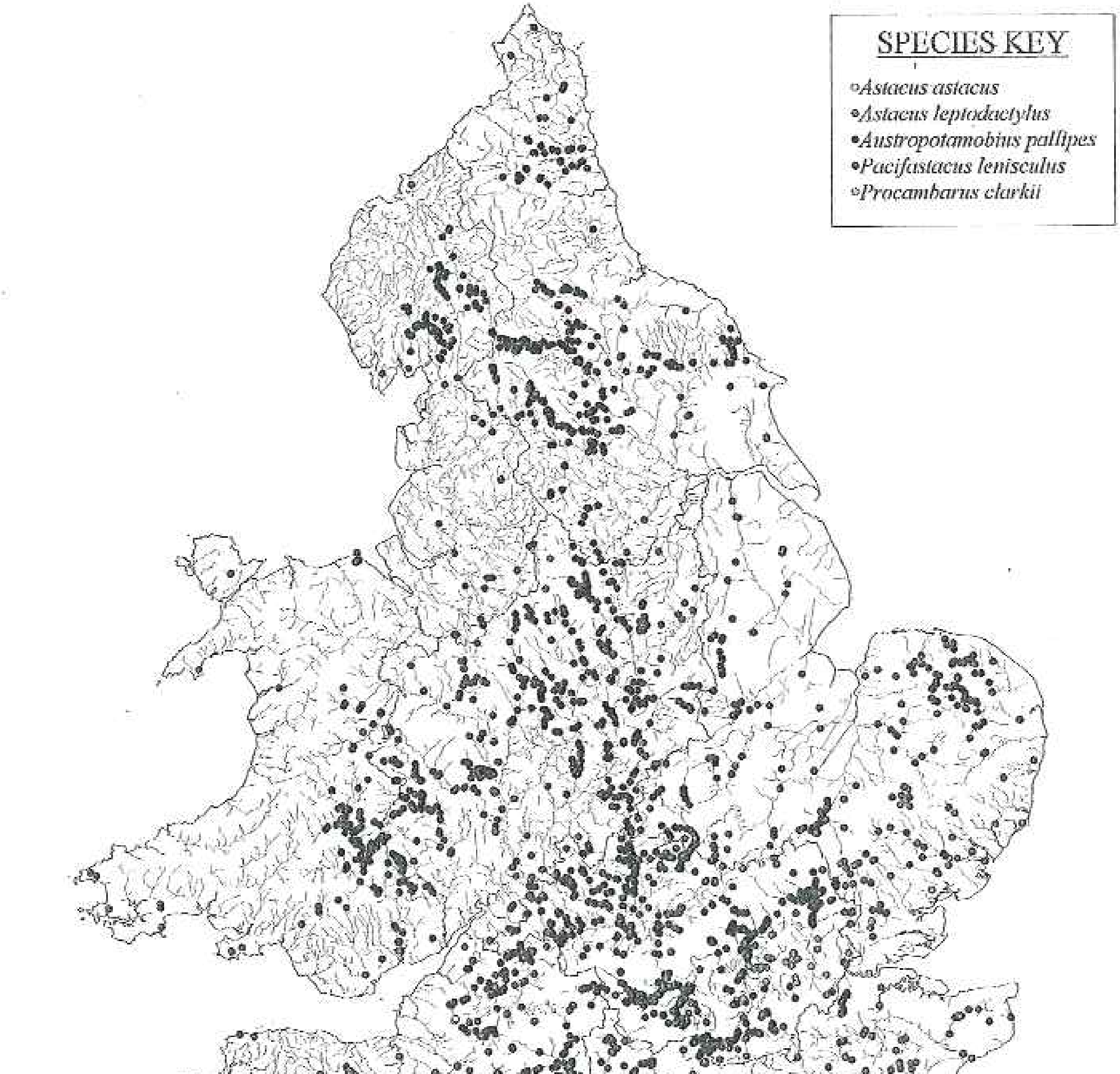


Fig. 1 *Distribution of crayfish in England and Wales.*

Fig. 2 *Crayfish records for environment agency southern region.*

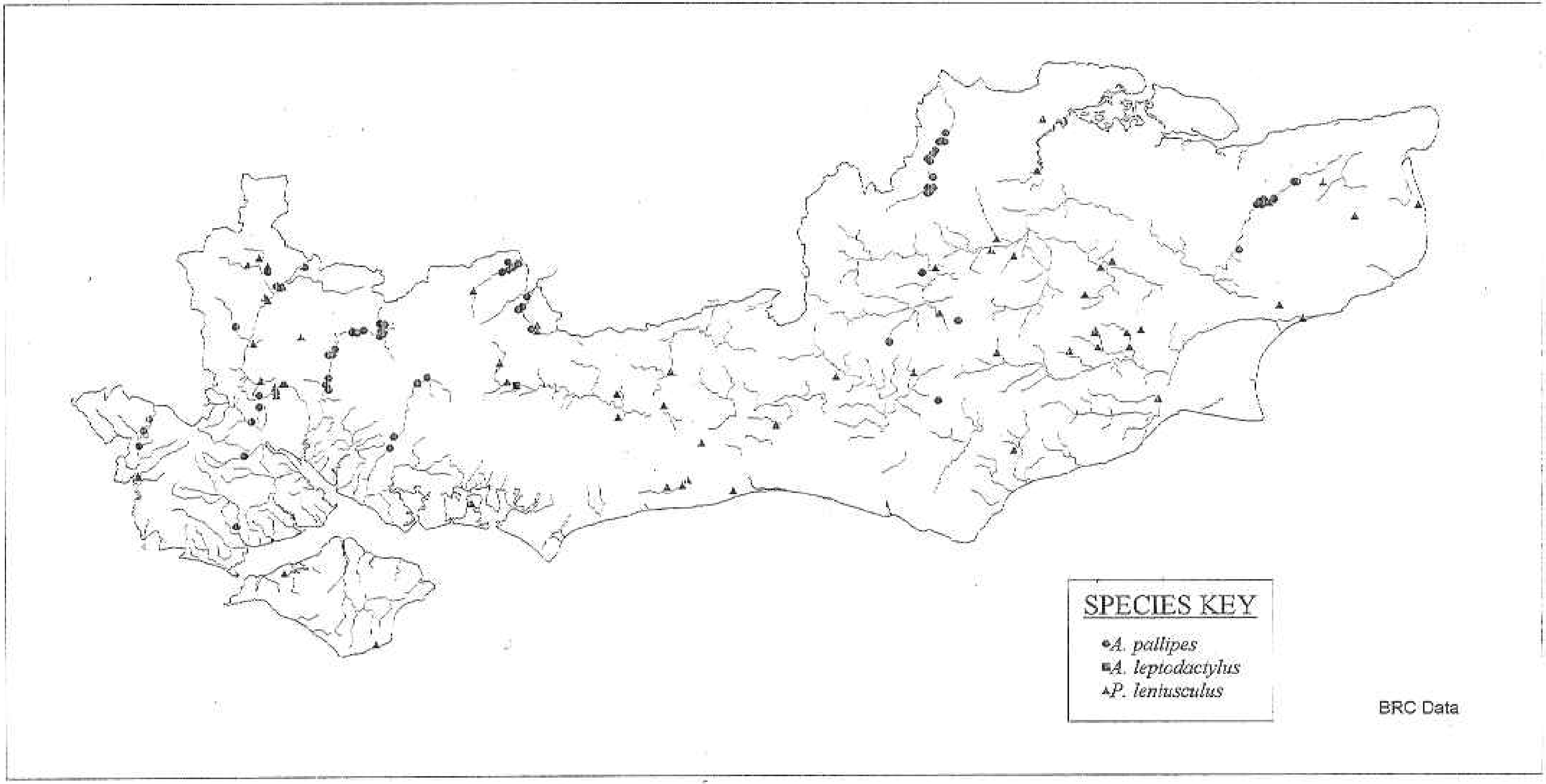
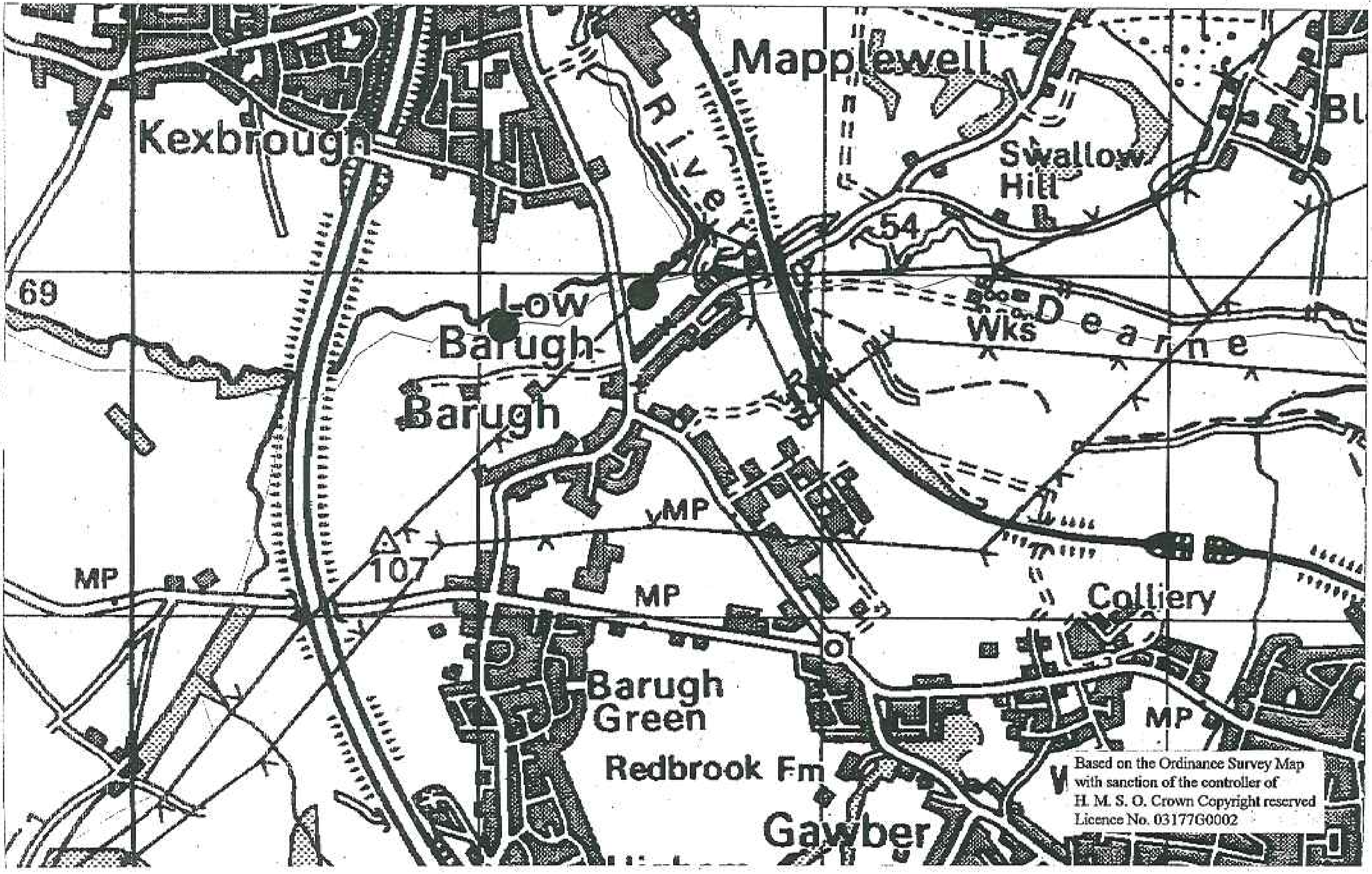


Fig. 3 *A. Pallipes records in the low Barugh area*



'A' are catchments with no alien crayfish present. Native crayfish should be protected.

'B' are catchments with a limited spread of alien crayfish. Such populations should be contained or eradicated. Native crayfish should be protected.

'C' are catchments with a widespread occurrence of alien crayfish. The spread of such alien populations should be prevented and native crayfish should be protected.

'D' are catchments with no native crayfish records. Alien crayfish in the catchment should be prevented from spreading further.

'E' are catchments with no known crayfish records
(Holdich & Rogers, 1997b).

This information should assist managers in deciding what further measures are needed to conserve *A.pallipes* locally within Environment Agency Local Environment Agency Plans, LEAPS, and nature conservation bodies' Biodiversity Action Plans, BAPS and which catchments in the country merit resources (Holdich & Rogers, 1997b). However, knowledge of the crayfish *'status'* of a catchment is susceptible to quite *rapid* change, ie, from **'A'** to **'B'** or from **'D'** to **'C'** in the above classification on the basis of only one new crayfish record so that there is a requirement for ongoing monitoring.

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Preliminary results of monitoring of crayfish population distribution in Leningrad District.

Svetlana A. Bykadorova & Valeri P. Fedotov.
St.Petersburg Scientific Research Center for Ecological Safety
18 Korpusnaya str, 197114 St. Petersburg, Russia

Abstract

This work is devoted to the detecting of crayfish population distribution in the North-West region of Russia. The main chosen monitoring method was questionnaires, prepared for Local Committees for Nature Conservation and Fish Inspections. Questions included waited to clear situation with total waterbodies (lakes and rivers) area, percent of crayfish waterbodies area, crayfish species inhabit in the region and reasons for common crayfish extinction in different years. Questionnaires were distributed in April 1998. In this paper preliminary results obtained before end of May 1998 are presented. Data on five administrative sub-districts of Leningrad District show that almost 34% of lakes and 12% of rivers have crayfish. The work is planning to be continued further. This will give an opportunity to perform monitoring of crayfish waterbodies in the region and give recommendations on conservation and exploitation. The second problem discussed is legislation problems. Difficulties in implementation of adopted Regional Crayfish Conservation and Exploitation Program are presented. In this paper some recommendation are given to improve existing legislative system in order to perform the best monitoring and management of crayfish stock in the region.

1 Crayfish waterbodies in Leningrad district

In April 1998 a survey has been started to find out crayfish waterbodies distribution in the North-West of Russia. A questionnaire was prepared and sent to Local Committees for Nature Conservation (18) and district Fish Inspections (10). Total amount of questionnaires was 28.

Questionnaire included several questions different for district Fish Inspections and Local Committees for Nature Conservation. Total survey intended to find out.

- total area of waterbodies in the district (lakes in hectares of area and rivers in km of length);
- approximate area of crayfish waterbodies and their amount in the district before 1995 and in 1997;
- crayfish species inhabit in the district waterbodies (which one are dominant);
- area of waterbodies for rent (percent of crayfish among those);
- reasons for crayfish extinction in the district, if so;
- which organizations and when for the last time performed hydro-biological and hydro-chemical waterbodies characteristics' evaluation;
- is there any data on crayfish diseases and crayfish disappearance due to the diseases, in which waterbodies and when;
- is there any crayfish introduction from one waterbody to the other, who, which organization is responsible for such activity;
- are there a necessity for lecturing and literature dissemination in the district. Questionnaires for district Fish Inspections in addition tried to get data on some other aspects of monitoring activity, in particular
- is there any local people willing to have crayfish farms and perform crayfish breeding;
- is there any crayfish waterbodies in the district with the market stock of crayfish;
- is there a necessity in crayfish juvenile production and additional crayfish introduction in order to reach market stock of crayfish.

By present time five districts already replied questionnaires. We have got them from Priozerskii, Lodeinoplskii, Podporozhskii, Vyborgskii, Volosovskii districts and ZAPBALTRYBSTROI (West-Baltic Fishing Building Committee). This allows to discuss a picture for a part of Leningrad region (Table 1).

Table 1 *Crayfish distribution in the waterbodies of Leningrad district by sub-districts.*

Sub-district	Total waterbodies area		Crayfish waterbodies area		Percent of Crayfish waterbodies (%)		Crayfish species	Reasons of crayfish extinction
	lakes (ha)	rivers (km)	lakes(ha)	rivers (km)	Lakes	Rivers		
Priozerskii,	36929	285	10572	37	28.6	12.9	A.a.; A.l.	pollution; plague (1987)
Lodeinoplskii	6700	1500	60	-	0.9	0	A.a.	pollution
Podporozhskii	18800	1900	1820	285	9.7	15	A.a.	plague (1996)
Vyborgskii	35000	946	21000	130	60	13.7	A.a.; A.l.	pollution
Volosovskii	109.6	333	-	153	0	45.9	no data	
Total	97538.6	4964	33452	605	34.3	12.2		

* A.a. - Astacus astacus;
A.l. - Astacus leptodactylus.

Survey data also show that no one district perform activity on crayfish farming at present time. Only few are interested in literature on crayfish breeding and Vyborgskii Fish Inspection is willing to support crayfish juvenile production in order to introduce crayfish in the waterbodies of the district. Pollution appears to be one of the reasons of crayfish extinction. Main source of pollution is agricultural activity and washing of fertilizers from ground to lakes and rivers. Additional pollution comes with domestic sewage waters. Vyborgskii district has experience on crayfish introduction. Based on survey data, in the 1960s there was crayfish introduction from Sweden to lake Pionerskoe. Latter it was totally caught by local population. Data on which organizations and when for the last time performed hydro-biological and hydro-chemical waterbodies characteristics evaluation are mainly absent. No one is doing such investigations, except GosNIORH (State Scientific Institute of Lake and River Fishery) in early 1980s. Data on crayfish stock in the waterbodies of Leningrad District are unavailable. There were no regional epidemiological control for a long time, but survey showed that not all populations are healthy. The main source of infection is in Priozerskii sub-district. Based on the data by Water Research Laboratory mass crayfish extinction was detected in 1987 caused by plague.

2 Legislation: problems and future development

Although the amount of stock in the waterbodies of Leningrad District is not detected, SevZapRybVod (North-West Water and Fish Administration) provide licenses for 1-3 tonnes' crayfish trapping in the Eastern parts. At the same time, commercial exploitation of crayfish is forbidden over all North-West region due to the low density of populations. The fishery rules active now are old, signed in 1988. They are used only in several districts and sub-districts. Regulations of amateur trapping are not based on crayfish species peculiarities. Only on the amount of crayfish in sub-district/district. The prices for private license are also different. So, for Leningrad district this is 4,5 rubles (0,75 US$) per one crayfish, whereas in Pskov sub-district this is only 0,3 rubles (0,05 US$) per unit. The main way of crayfish trapping is amateurs, which is not registered. Fine for illegal trapping is 80-800 rubles (13-133 US$).

Regarding regional rules, there are restrictions for crayfish catch by size (minimal size 9 sm), and by time (15 July - 1 October). The numbers of crayfish traps are restricted for up to three per man without right to sell them.

3 Conclusions

Preliminary results are the base for further work on monitoring and data base creation on crayfish waterbodies. This will include physiological state of crayfish populations, epidemiological control and investigation, and hydrochemical and hydrobiological evaluation of waterbodies. In the first place this is planned to perform in Priozersk sub-region for two reasons: as a boundary one with Finland and detected plague at the recent time.

Existing rules and regulations are necessary to be improved as for now there is almost no management and control over waterbodies and crayfish populations themselves. Information on crayfish distribution should be made available to the local population. As there is no one equal fishing policy for the region and each district has its own rules, a set of rules and regulations should be prepared or existing Regional Fishery Program should be implemented using one establishing mecanism.

Monitoring of crayfish populations

Trond Taugbøl & Jostein Skurdal
Eastern Norway Research Foundation
P. B. 1066, 2601 Lillehammer, Norway

1 Why monitor crayfish populations?

Few long term monitoring series of crayfish populations exist. Such monitoring series are valuable for several reasons:

a) study of crayfish population dynamics
b) evaluate effects of or response to exploitation, catching regulations or environmental changes
c) a basis for management decisions (knowledge-based, adptive management)

Before any monitoring programme is established it is imperative to define the objective of the program.

2 Monitoring methods and parameters

First of all, it is important to emphasize that monitoring design must be adapted to the objective of the programme and to available resources.

Methods can include test fishing following a specified test-fishing procedure, collecting of catch & effort data from local fishermen, and a combination of these methods. Baited traps are most often used in test-fishing, but also SCUBA-diving/snorkelling can be applied. Often a combination is recommended because the two methods complement one another. When using baited traps little information are obtained on smaller crayfish (< 70-75 mm) because small crayfish are very reluctant to enter the trap. Further, the crayfish catchability in the traps are much influenced by different factors, especially molting and temperature (Taugbøl et al. 1997). When diving, it is more easy to catch smaller crayfish, and the larger seems to be underrepresented, especially during daytime seeking. Diving is also more labour-intensive, and normally rather few persons are trained and available for this activity.

Parameters registered are normally catch (number of crayfish) and effort (number of traps, diving time, etc.) (which gives catch per unit effort, CPUE) and for the individual crayfish: size, sex, maturity and possible diseases/parasites.

3 Special challenge for long term monitoring

A long term monitoring programme needs a careful design and depends upon several factors:

- equipment, sampling and analyses should be cost and labour reasonable
- one should stick to the sampling strategy and equipment once chosen
- there must be a clear interest and responsibility for maintaining the programme, including practical work, data analyses, maintenance and updating of the database, and, not at least, the preparation for and use of the results in practical management.

4 Monitoring examples from Norway

4.1 Monitoring in Lake Steinsfjorden

Lake Steinsfjorden (area 13.9 km^2) is the best crayfish locality in Norway, supporting an annual yield of 1.1-6.5 tonnes of noble crayfish since 1910. Unlike most water bodies in Norway, in which the right to catch crayfish belongs to the landowners, L. Steinsfjorden is public water, i.e. everybody is allowed to catch crayfish during the catching season. Increasing exploitation and the invasion by Canadian waterweed (*Elodea canadensis*) in the 1970's made local fishermen and the environmental authorities concerned about the future of the crayfish population, and a monitoring programme was established in 1979.

The objective of the programme was to monitor the crayfish population in order to document possible population changes in relation to exploitation, changes in harvest regulations and *Elodea*-invasion. It should supply the environmental authorities with necessary knowledge for adaptive management. Little money was available for the monitoring programme, especially when taking into account that it should run for several years ahead. Thus, the programme had to be relatively small and cheap. It consists of pre- and post-season test-fishings with baited traps (50 traps on a permanent test station), registration of total trap effort in the lake (counting by boat several times during the catching season which is possible because the traps are kept in the lake also during daytime as long as the catching season lasts), and recording of catch statistics (CPUE)

from local fishermen. Based on these, information on structure and size of the catchable population, total catch effort and total crayfish harvest are obtained.
Test-fishing CPUE and total crayfish harvest and catch effort for the period 1979-1996 are shown in figures 1 and 2. Results and management recommendations based on this monitoring programme have been presented in several papers and reports (e.g. Skurdal et al. 1993, 1995a, b, 1997, Skurdal & Taugbøl 1994, Skurdal & Garnås 1997). More details on the monitoring methods and parameters recorded can also be found here.

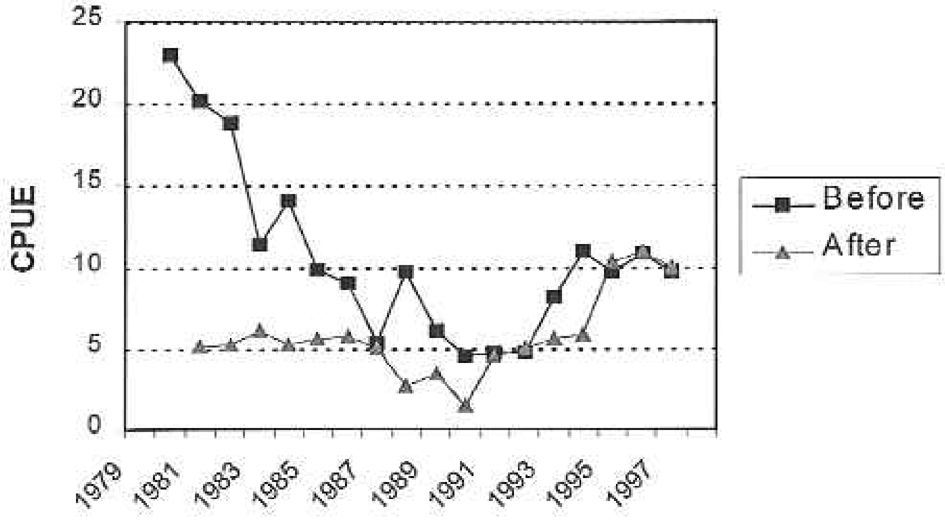

Fig. 1 *CPUE (no. of crayfish per trap night) in test-fishing before and after the crayfish catching season in L. Steinsfjorden in the period 1979-1997.*

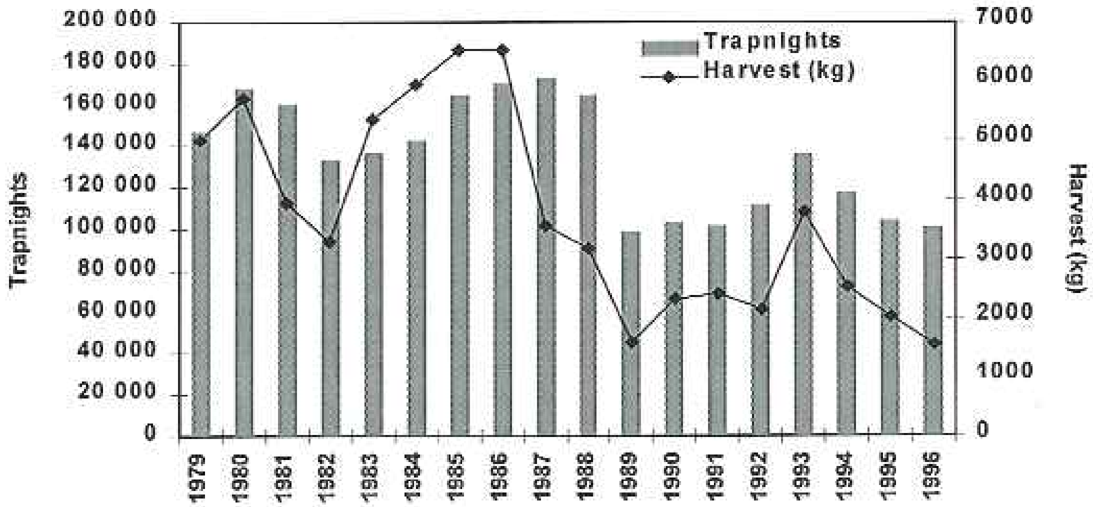

Fig. 2 *Total catching effort (trapnights) and harvest of crayfish in L. Steinsfjorden in the period 1979-1996.*

The County Environmental Administration is responsible for the management of the crayfish in L. Steinsfjorden and has the authority to establish catching regulations for fish and crayfish within the national framework (may adopt further restrictions). In L. Steinsfjorden there are several hundreds of fishermen catching crayfish and many different opinions on how the catching regulations should be, based on individual experience. Pressure from fishermen with different opinions, the free access to crayfish catching leading to a very high exploitation, and the *Elodea*-invasion complicates the management decisions. According to the County Fishery Officer, the crayfish monitoring programme has been of invaluable help in this connection. The management decisions made have been based on real knowledge about the development of the crayfish population, and in general, seems to be very much accepted and respected by the fishermen.

4.2 Monitoring in Lake Harasjøen

Lake Harasjøen (area 1.9 km^2) is also a good crayfish locality supporting an annual yield of 300-400 kg of noble crayfish. The landowner association which controls the lake, sell licenses for crayfish catching. In 1994, following an increase in licenses sold, many local fishermen and landowners were concerned about the crayfish population. It was claimed that the exploitation was too high and that the number of crayfish catching licenses should be limited. Instead of an immediate restriction of the catching activity, which was a great pleasure to many people, it was decided to get more information on the crayfish situation, based on professional investigations and advice.

Thus, a monitoring programme was established in 1995 aimed at documenting a possible negative development of the crayfish population due to overexploitation (Taugbøl 1997). Since little money (as usual!) was available for the monitoring activity, the programme had to be cheap and simple. It was based on test-fishing (at a fixed station) before and after the legal catching season and collecting of catch data (total effort and catch) from the fishermen. The fishermen had to fill out and return the fishing license with catch data. This was a prerequisite in order to achieve a new license next year. Based on these data, relative population density (CPUE), population structure, total catch effort and total harvest can be calculated.

Table 1 summarize data on crayfish catching and yield from the first three years since the programme started. As mentioned, already in 1995 it was a concern that the exploitation had been too high and that the crayfish population was endangered. During the monitoring period the number of catching licenses increased by more than 60%, the total catch effort increased, and also the total crayfish catch (Table 1). This could of course be due to an increased fraction of small-sized crayfish in the catch, i.e. that the negative effect was not yet discovered. However (and here comes the benefit from the test-fishing data), if we look at the size structure of the crayfish in the test-fishings, the proportion of large crayfish (i.e. larger than the minimum size of 95 mm) has also increased (Table 2). The last year (1997) it was 73 % in the pre-season and 56% in the post-season catch, which means that a lot of large crayfish remains in the lake after the catching season. If there had been an overexploitation (or the population had become stunted), this proportion would be low (at least less than 20% in the pre-season catch). The much lower CPUE in the post-season catch are of course due to the fact that much crayfish has already been caught, but are also due to lower temperature and thus lower catchability in baited traps.

Table 1. *Crayfish catching and yield in L. Harasjøen in 1995-1997, based on data from the monitoring programme*

	1995	1996	1997
Catching licenses sold	52	68	85
Total number of trap nights	4408	3978	4845
Total crayfish catch (in kg)	303	389	405
Yield (kg per ha.)	1,6	2,1	2,2

Table 2. *Key figures from the pre-(August) and post (Sept.-Oct.)-season test-fishing in L. Harasjøen. CPUE = no. of crayfish per trap night*

Year	Catch date	No. of traps	No. of crayfish caught	CPUE	Mean-length (mm)	Proportion ≥ 95 mm (%)	Proportion males (%)
1995	05.08	30	170	5,7	92,8	36	37
	17.09	20	32	1,6	90,6	37	44
1996	03.08	27	230	8,5	96,1	57	54
	09.10	27	7	0,3	90,7	29	57
1997	02.08	30	217	7,2	99,0	73	47
	14.09	24	50	2,1	94,7	56	44

5 Conclusions and recommendations

Based on 15-20 years experience from investigations of crayfish ecology, crayfish monitoring programmes and the use of results from research and monitoring in practical crayfish management, we would like to put forward the following recommendations and conclusions:

1) Define the objective of the monitoring (always ask: Why monitor?) and then adapt suitable methods and parameters. It is very important to consider economy which often is a major constraint, especially if the monitoring programme is supposed to run for several years. If possible, use local fishermen and their data. Local people and fishermens/landowners associations can often contribute significantly with practical work.

2) Long term monitoring may contribute significantly in knowledge-based, adaptive management of the crayfish population and also in the understanding of crayfish population dynamics.

3) Crayfish sampling is influenced by many factors. It may be difficult to obtain representative/comparable samples and data needs qualified/experienced interpretation.

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Interaction between Canadian waterweed (*Elodea canadensis*) and crayfish (*Astacus astacus*) in Lake Steinsfjorden.

Jan Erlend Bråthen
Institute of Biology, University of Oslo
0316 Blindern, Oslo, Norway

1 Area description

Lake Steinsfjorden is located in Buskerud in southeastern Norway. The lake has an area of 13.9 km^2 an average depth of 10.2 m and a maximum depth of 24 m. It is connected with the much larger lake Tyrifjorden, through a shallow and narrow strait. The lake is ice free from late April to late December, which has a great impact on the oxygen content, as in most lakes of this kind, with the oxygen dropping over the summer in the deeper layers, and rising in the autumn with the turnover. Followed by a smaller decline in the spring. Because of the calciferous content of the bedrock the lake has a high pH of about 7.0-9.0 in the open waters (Skurdal et al. 1991). In addition to the pH, the large content of rocks on the shores of the lake makes it very suitable for crayfish production.

2 Canadian waterweed (*Elodea canadensis*)

The Canadian waterweed (*Elodea canadensis*) came to the lake probably around 1976-1977, according to local observations and knowledge of the plant growth (Rørslett et al. 1984). The first secure observations are from 1979. Since then it has spread to most of the area between 0-5m (Johansen 1987). The area covered by the waterweed has been closer investigated in 1979-1982 and in 1996 (Fig.1).

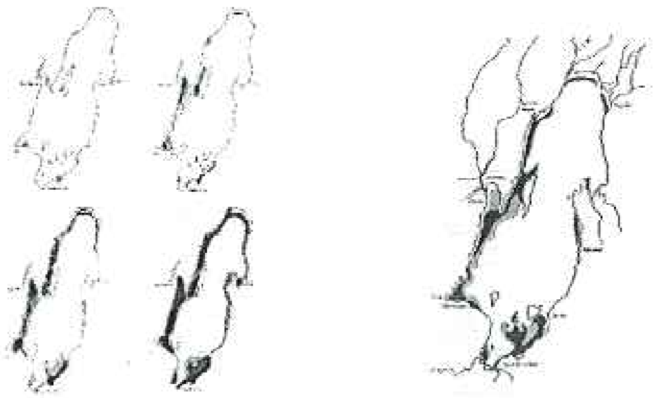

Fig. 1 *To the lef: Area coverage of waterveed from 1979-1982. To the right: Area coverage of waterveed in 1996. Dark regions: Mass densities; brighter regions: Low densities.*

In 1983 the waterweed had the largest registrated coverage of the total area (Table 1). In 1996 the total coverage went down to 54%. This is due to reduction in the population in several shallow areas. Maybe because of special conditions in the water level the same year (Johansen 1997).

Table 1 *Area coverage of waterweed 1979-83 and 1996 (Johansen 1996)*

Year	Total coverage% of lake area	Total coverage% of 0-6m
1979	.72	2
1980	9.57	28
1981	18.6	54
1982	26.2	76
1983	26.4	76
1996	18.3	54

The goal of this work was to find out if there is a relationship between waterweed production and crayfish production in Steinsfjorden.

Hypothesis 1: There is a relationship between the placement of the crayfish and the placement of the weed.

Hypothesis 2: There is a relationship between the amount of weed and the crayfish production.

3 Materials and methods

I measured the pH changes in the waterweed over a greater part of the year. These measurements took place two times a day in summer and three times a day during autumn and winter. The measurements were taken at the surface, 2m depth and inside the waterweed population just above the bottom. This was done because of a suspicion that it could have been due to the pH changes inside the waterweed that the crayfish abandoned these places.

I also looked at the placement of the crayfish compared to the waterweed. This was done by collecting catch data from the local fishermen which showed where the catching effort took place. This was also compared to a test fishing were the fishermen said no crayfish had been caught lately, and an other one were the catches were normal. These data were also used to compute total crayfish number, with Leslie's method. (Ricker 1975)

4 Results

The result of the testfishing was highly significant. Only one crayfish was caught where the *Elodea* was abundant and 734 at the other locations. I also tried SCUBA diving in a highly invaded place and a place without *Elodea*. With the same effort the result was 72 and 3, with and without weed, respectively. According to the fishermen both locations had been good crayfish spots previous to the waterweed invasion.

The total crayfish number showed to be rising prior to 1987, and then falling from over 250000 to below 100000 in 1988. This cannot be related to the waterweed since it had already been in the lake for 10 years (Fig. 2). Without being for certain, this decline is probably due to overfishing (Skurdal et al. 1991).

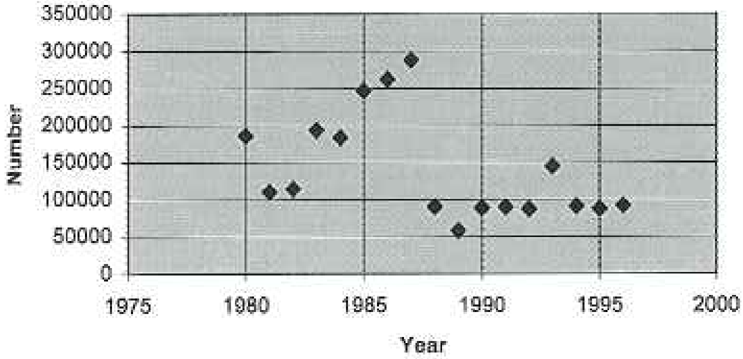

Fig. 2 *Total number of crayfish in Steinsfjorden from1980-1996.*

There is an obvious trend towards a greater proportion of the catching effort being made at the waterweed free spots (Fig. 3).

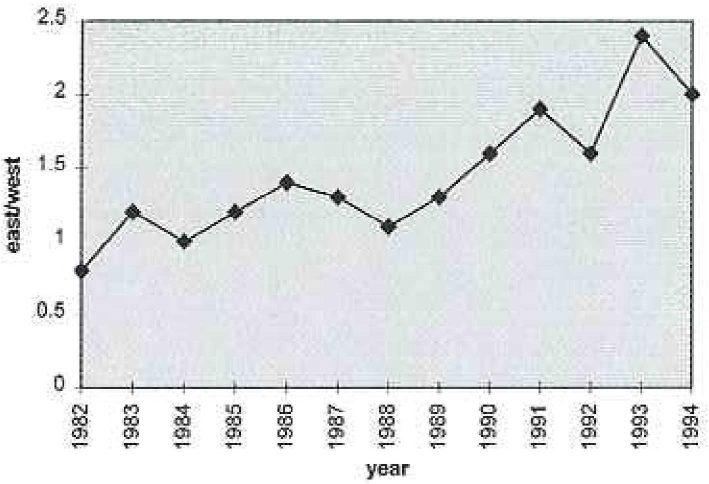

Fig. 3 *The relationship between the catching effort on the eastside of L. Steinsfjorden and the westside in 1982-1994.*

The differences in pH were small in the open waters during the 24 hours, but large inside the weed population.

The levels I have found is not sufficient to explain why the crayfish disappears from these places. With a high amount of calsium the crayfish can overcome a pH at least down to 4.5-5.0. (Malley 1980, Appelberg & Odelstrøm 1990). The measurements outside the waterweed and during day or evening showed no major differences. The fall before the circulation occurs have previous been found to have the largest difference inside the waterweed compared to outside concerning pH (Johansen 1987).

5 Conclusion

There has been a significant change in the places where the catching effort takes place and the placement of the waterweed if you compare the years 1982-1985 with 1991-1994. This is when the difference is at the largest. The results of the testfishing and diving were also significant.

It is not possible to relate the total number of catchable crayfish to the weed population, with a rise in the population from about 100000 in 1981-1982 to over 250000 in 1985-1987. After this top the population seems to have been fairly stable around 100000. On the other hand, the testfishing in the weed belt, the SCUBA diving, and the catching effort all showed highly significantly that the crayfish has abondoned the invaded areas.

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The organisation of associations outside the authorities (NGO) - and their role in crayfish management in Sweden

Björn Tengelin
The Swedish Fishing Water Owners Society
P.O.B 275, S-58102 Lindköping, Sweden

The Swedish Fishing Water Owners Society organises the fishing water owners through regional organisations. The regional organisations consist of different types of members. It can be private fishing water owners, that is private persons, farms or forest owners. It can also be owners in the form of communities or companies owning land with adjoining fishing water. The third category is associations of owners. That means groups of fishing water owners, which together own the fishing grounds in one or more lakes or streams.

The Swedish Fishing Water Owners Society organises about 110 000 fishing water owners throughout Sweden.

The national and regional Fishing Water Owners Societies just have a handful of persons employed. My colleagues and I are employed at Hushållningssällskapen: The Rural Economy and Agricultural Societies.

Associations of fishing water owners have been more or less voluntarily formed around all fishing waters of any importance in Sweden. They have been formed by a special law because the fishing-grounds are owned in an old and complicated way. In Sweden all inland fishing-grounds are owned by the adjoining landowners individually or through their villages (example shown in figure 1).

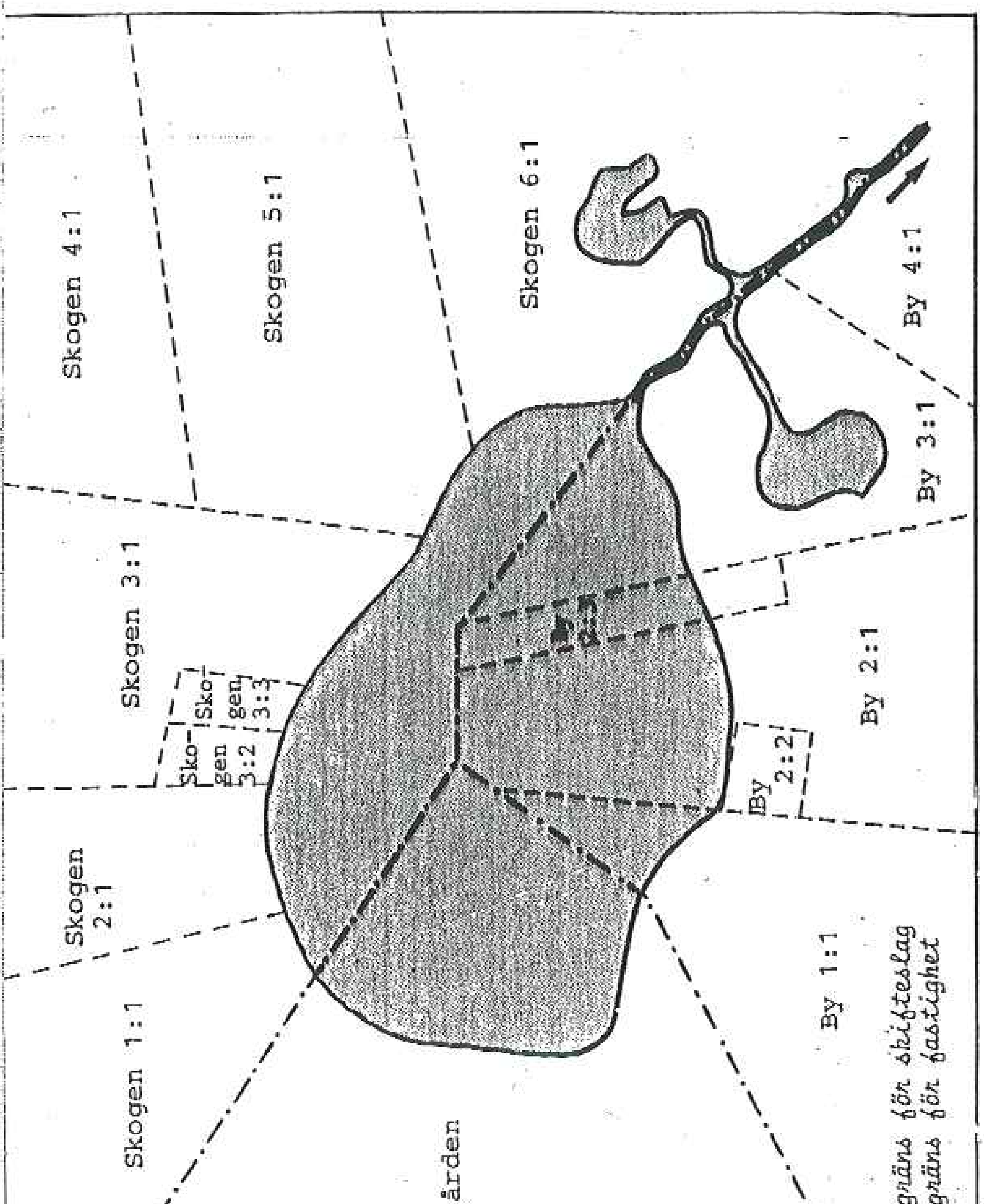

Fig. 1 *The different ways private fishing water can be owned in Sweden: Left: Property "Storgården" owns all land and fishing water within its boarders. Top: Village "Skogen": All properties, along shore and inside shore, own a specified part of the village fishing right within village boarders. Each property owns specified part but it is not defined where each part is situated. They can all fish on all the water belonging to entire village. Bottom: Village "Byn": Each property own a specified part of the village fishing right. The location of fishing right is specified. Each property fish on ones own part.*

In Sweden we do not have any regulations around crayfish management on private waters. In 1994 we skipped central regulations about size and time to fish. If wished, this can be handled by each association of fishing water owners.

Most lakes in the southern half of Sweden have crayfish, either our old noble crayfish (*Astacus astacus)*, but mostly nowadays the signal crayfish (*Pasifastacus leniusculus*). Our lakes generate around 600 - 1000 tonnes of crayfish annually. Intensive crayfish farming only generates some odd percentage.

A good crayfish water can be used either by being commercially fished or by being rented for leisure fishing. The leisure fishing is expanding fast. It is very popular for families or groups to rent a good fishing ground just for a night, one year or on a more permanent basis. For the owner it is sometimes better paid to let other people pay for doing the fishing, rather than doing the fishing and selling the crayfish himself.

The crayfish is highly valued. The fisherman or owner is paid between 120-200 SEK per kg the last couple of years. The costs around the fishing is very low. A fishing water for crayfish, a natural lake or stream, gives if it is worth fishing at least 5 kg per hectare. 10 kg is good, but much higher volumes occur. Two clever fishermen with one boat can on a good fishing-ground with 100 cages and by working about 6 hours a day per man, catch 50-100 kg of crayfish.

The national and regional Fishing Water Owners Societies did organise a couple of regional crayfish handling organisations about 8 years ago. The purpose was to help smaller and medium sized producers to sell their catches together to wholesale dealers where the crayfish were distributed for consumption. This did not turn out as good as expected. The members did deliver only little of their catches to their own organisation. Most crayfish were, and still are, sold on the black, or informal, market.

It meant that the producers just wanted their handling organisation as a security if they did not manage to make a deal themselves. And they expected the handling organisation to sell their crayfish legal for a higher price when in the meantime the very majority of the crayfish were sold the informal way to a lower price.

The problem where also the very short and intensive season for fishing. On less than two months everything happened. During this period when the handling organisations acted, the price of crayfish was very high but the handling marginal was very low. It meant, that despite a lot of money was handled, it was difficult to cover the costs of the organisation.

The organisation was also very vulnerable. If just a few kilos of crayfish died or one buyer did not pay, all economic marginals were wiped out. To further develop the private crayfish waters we help to split up fishing waters that are owned as a community by a village. By this it will become much easier for the separate owners to use their crayfish fishing in an optimal way. We mean, that what one owner does or does not with his crayfish water, will not inflict on his neighbours rights.

We have also together with the Swedish Board of Fisheries developed a method for test-fishing crayfishwaters. By this we can on a biological and economical ground judge the value of particular crayfish water, and how to prize it for the market or how to further develop it. Together with the test fishing we can also provide help with contracts and how to judge a specific fishing ground.

The future concerning crayfish is to make owners of crayfish grounds aware of the possibilities with their waters and to optimise management, that is about the law, the biology and the economy around crayfish. If we are successful in this we have made a big step concerning rural development, giving the people living and owning the grounds outside the more densely populated areas a better possibility to make an income.

Good crayfish water can today generate the highest net income per area annually compared with all other sorts of farming or forestry.

Prevalence of crayfish (*Astacus astacus*) in Estonia on the basis of nutritional analysis of otter (*Lutra lutra*) and mink (*Mustela vison*)

Nikolai Laanetu
University of Tartu, Institute of Hydrobiology
Vanemuise 46, EE2400 Tartu, Estonia.

1 Introduction

Crayfish has been one of the most essential links of the ecosystems of the waters. It is the processor of one part of detritus and bioproduction, being at the same time a nutrition object for many beasts and fish of prey: including weasel, otter, and mink who has widely spread in Estonian bodies of water during the latest decades. Prevalence and numerousness of crayfish are some of the most important indicators of the "healthy" condition of a body of water. Prevalence of crayfish in the ecosystem of a body of water is the presupposition of its normal functioning, preservation of the diversity of species and high productivity.

Changes in the population of crayfish characterise the changes in the water and its catchment basin, thus, in the environment as a whole. That is why it is very important to know the general condition of the crayfish population and the changes taking place in it. Following changes in the crayfish population is presuming following certain population parameters, of which the most important are prevalence and density of population, supplemented by fecundity, death rate, average lifetime, etc. The aim of the present paper is to find out the prevalence of crayfish and its relative density of population in Estonia with the help of nutrition analysis of otter and mink, complemented by special test catches and observations.

2 Material and methodology

There are over one thousand lakes (1114) in Estonia, with total area of 211.500 hectares (Kask 1964) and 7308 fluvial bodies with total length of 31.019 kilometres (Loopman 1979), where crayfish can live. The scope of Estonian water network is so wide that traditional methods (catching with a weel and crayfish net) in determining the prevalence of crayfish with limited number of labour is inconceivable. One of the disadvantages of these methods is the fact that the animals come to the traps only during the periods of active feeding. It is not always possible for us to detect the prevalence of crayfish in the waters by this method. Therefore, the results of the faeces analyses of otter and mink were additionally started to use in addition to the above-mentioned method to determine the prevalence of crayfish in various bodies of water (foremost fluvial bodies). Remnants of crayfish in nutrition samples are a sure evidence of the prevalence of this species in the given region.

Taking into account the territoriality and twenty-four-hour mobility of otter and mink (Erling 1967, 1968, Laanetu & Veenpere 1971, Všivtšev 1972, Rosendal & Sjolin 1989), the faeces generally should not locate farther than 2-3 kilometres from the place of nutrition.

Data about the nutrition of otter have been collected from Estonian bodies of water since 1967, about which the respective overviews have been published (Laanetu & Veenpere, 1971, Laanetu 1973, 1974, 1986, 1989). Several authors have studied the nutrition of otter and mink (Erlinge 1967, 1969, 1972, Všivtšev 1972, Brzezinski, Jedrzejewski & Jedrzejewska 1993, etc.). The data they have presented are also reflecting the prevalence of crayfish in the ration of food of these species and, thus, the prevalence of crayfish in the waters populated by otter.

The ration of food of otter and mink is foremost consisting of the species living in the bodies of water and the shoreline of the latter. The main food in summer period is fish, frogs, crayfish as well as smaller mammals, water birds and their young birds. Other kinds of food occur less frequently (Laanetu 1989). It is an interesting peculiarity that almost in all waters populated by crayfish, the latter can be found in the nutrition of otter and mink both in summer as well as winter, i.e. all seasons (Fig. 1).

The given peculiarity is the methodological basis for the present work. The decades-long research work has certified the fact that in the waters populated by crayfish one can find it also in the food and faeces of otter and mink. This methodology cannot be used only in the case there are no otter or mink in the studied waters.

Detection of the remnants of crayfish in the faeces of otter, weasel and mink is relatively easy as the cortices of crayfish passing the digestive track become brownish-yellow or bluish-yellow and are therefore easily distinguishable from the other kinds of food in the faeces.

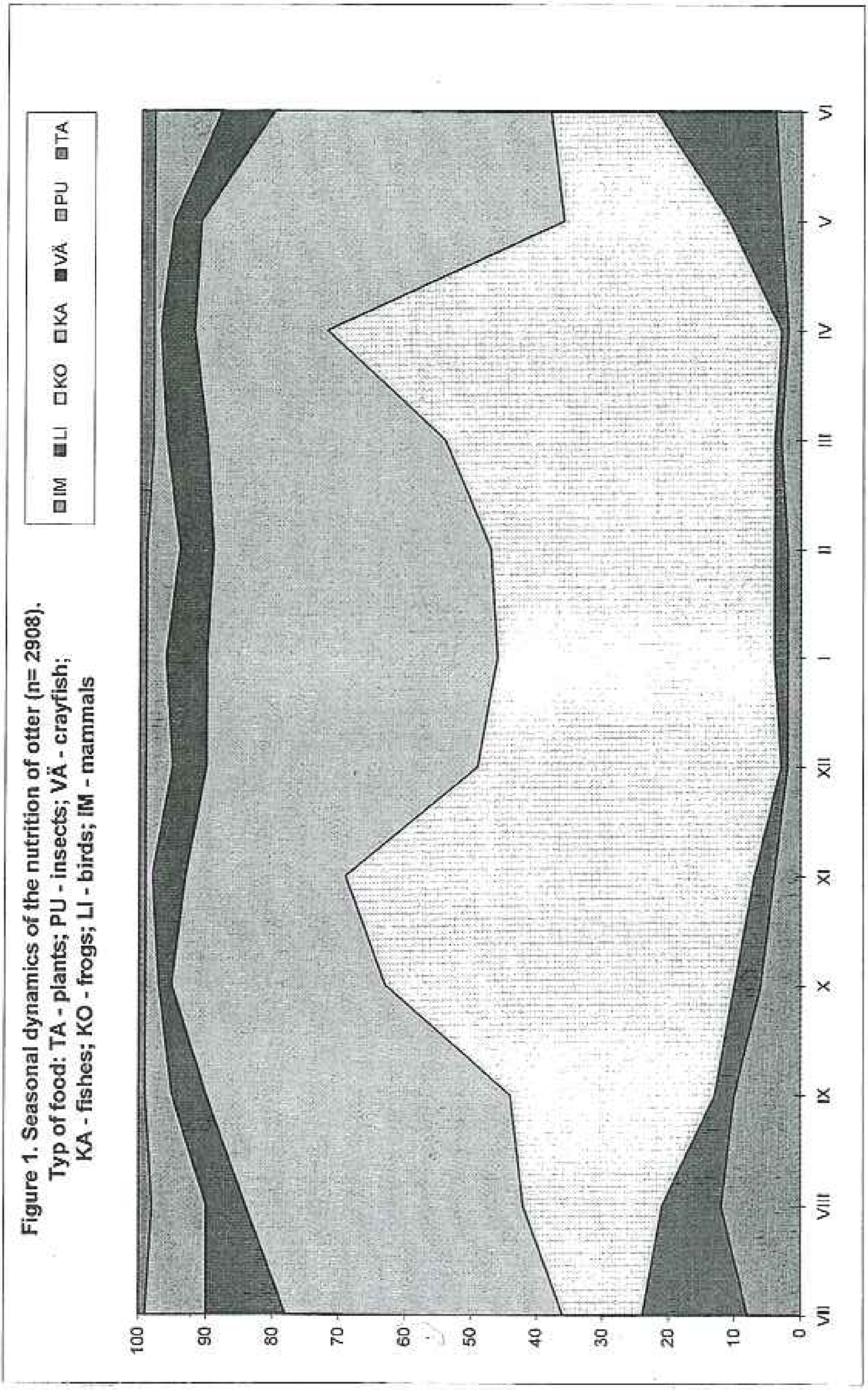

Fig. 16.1 *Seasonal dynamics of the nutrition of otter (n=2908).*

In the sections of bodies of water where remnants of crayfish were found in the food of otter, the occurrence of crayfish was mostly checked in the places more suitable for crayfish to live in. In shallow water, crayfish holes were checked by hand feeling. In clear waters, the occurrence and number of populated holes were determined in the region of the hole orifice by the existence of fresh ground. The given method was also used in the study of the waters of Saaremaa, Hiiumaa and some other West-Estonian bodies of water where there was no otter and mink. In several rivers, the occurrence of eelpout under the stones turned out to be disturbing, as they leave the same kind of image on the bottom of the body of water while moving. Usually, the bodies of water were shallow and one could perform additional checking by hand of the holes under the stones.

For general characterisation of crayfish population in the earlier periods, the results of faeces analyses collected during the years 1968-1970 (n=406) and 1980-1985 (n=2908) have been used in the present paper.

The material characterising the prevalence of crayfish has been collected during the years 1992-1997 in the course of observations of otter, mink, weasel and beaver. During this period, 6796 faeces of otter and 3800 faeces of mink, totally 10.776 samples have been studied. Data have been collected from bodies of water suitable for crayfish to live in at 2344 test spots (Figure 2). The material has been collected from the shoreline in such a way as to have at least one test spot in every five kilometres along the river. Prevalence of otter and mink was foremost determined by faeces and occurrence of footprints. On smaller streams and ditches, data have been collected from the region of bridges and drains. An overview of the prevalence of otter and mink, number and location of test spots and prevalence of crayfish are presented on UTM (size of the network 10x10km) maps (Figures 2, 3, 4, 5).

3 Results

3.1 Prevalence of otter and mink in Estonia

Otter has spread all over the mainland of Estonia. The number of this species was high around 1960. Then, around 2000 otters were counted. The number of the species was at a deep low level during the years 1970-1985 when the number decreased to 300-350 individuals. The number of otters started slowly to grow at the beginning of the eighties again, having grown to 500 individuals by 1985. In 1988, 750-800 otters were counted in Estonia (Laanetu 1989).

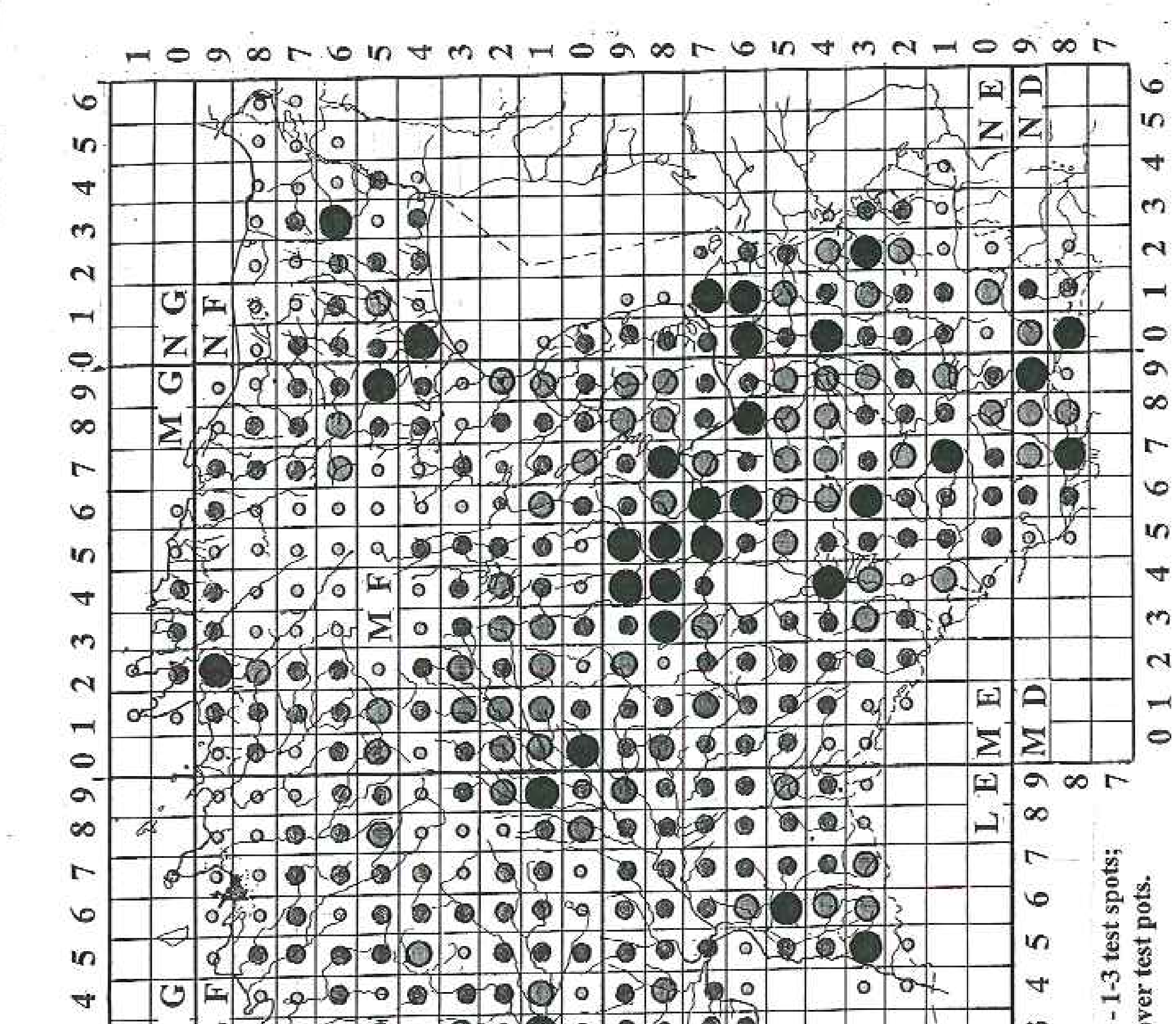

Fig. 2 *Spots of collecting material.*

The data collected during 1992-1993 and 1994-1995 showed that otter was populating almost every suitable body of water in the mainland of Estonia. Comparison of the data collected during the two close periods showed that the area of prevalence of otter had more or less remained the same, some changes had taken place only in the local numerousness of the species (Figure 3).

In 1992-1993, the number of otters was estimated to be 1400-1600 (1500) in Estonia, by 1994-1995, it had somewhat decreased, being 1400-1500 (1450) (Laanetu 1998). By now, the number has decreased even further.

Mink is a small beast of North-American origin, which had initially been brought over to Europe as a farm animal. Animals who have escaped from farms have formed numerous natural colonies. The first natural colony of mink in Estonia was formed in the region of Matsalu Bay at the beginning of 1960s (Paakspuu & Meriste 1981, 1982).

At the beginning of 1980s, the rapid expansion of the distribution of mink started. By 1985, the species was already relatively numerous at Kasari and Pärnu catchment basin and in some rivers in the north-western part of Estonia (Maran 1988). Around 1980s, mink appeared in the catchment basin of Lake Peipsi-Pskov.

The high number of muskrats during that period facilitated the increase of the numerousness of mink in every way. The hole systems dug by muskrat provided a good hiding place for mink, and muskrat itself was a prey for mink. Mink has been found on the shoreline of Lake Peipsi in almost every suitable dwelling place since 1985, while the highest density of population has been noted in 1989-1995.

The number of minks underwent a similar increase and some decrease on the river Suur-Emajõgi and Lake Võrtsjärv. The numerousness of mink increased abruptly at Lake Võrtsjärv in 1986-1987, causing the rapid decrease in the number of muskrats up to almost total disappearance of the species.

Mink has considerable influence on the aborigine fauna of the shoreline, causing general decrease in the number of water birds and several species of mammals, including polecat, and disappearance of weasel. On waters rich in crayfish, mink has specialised in eating crayfish.

At the present moment, the species can be found in relatively high number almost on the whole mainland of Estonia and on most of the islands (Figure 4).

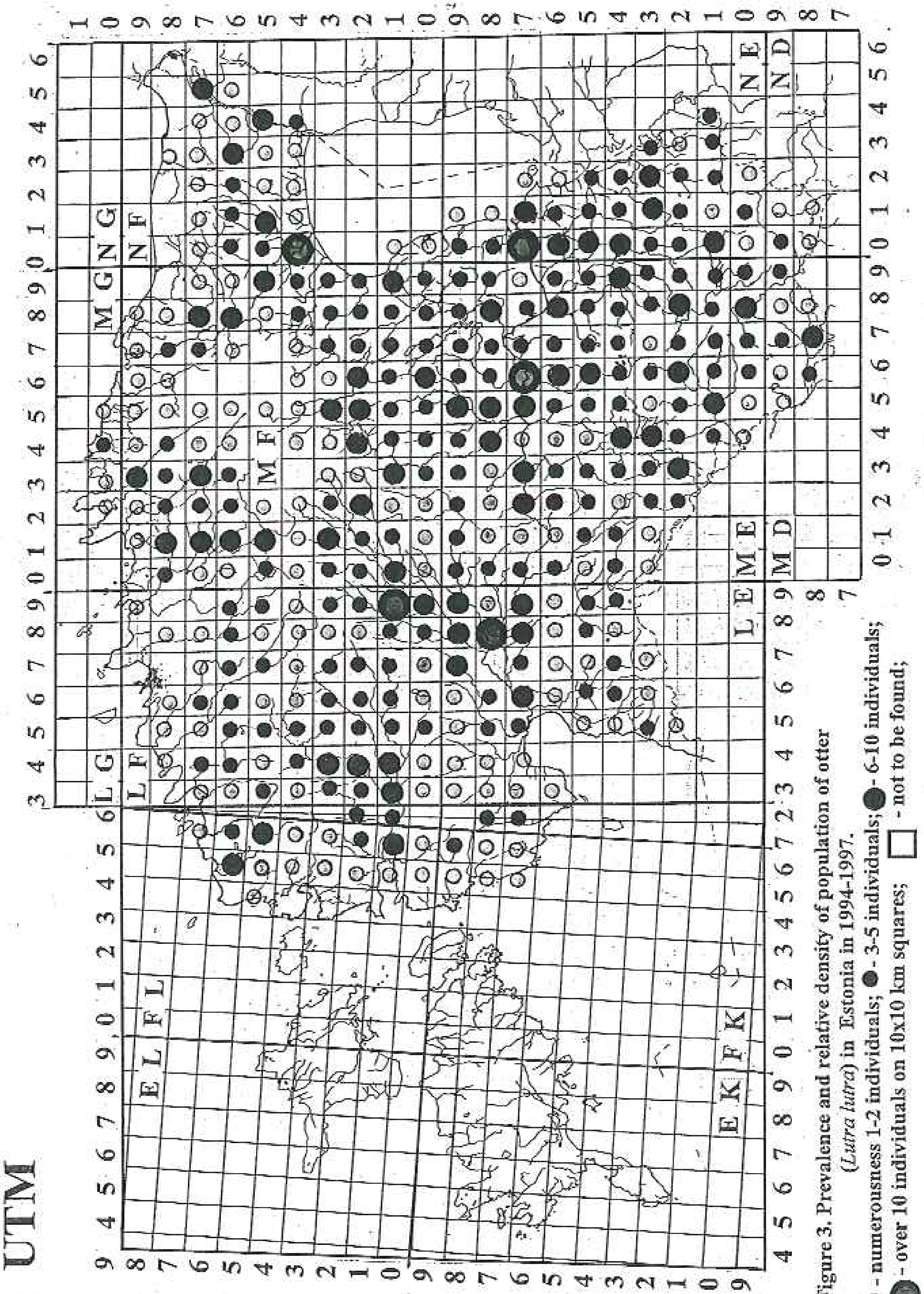

Fig. 3 *Prevalence and relative density of population of otter* (Lutra lutra) *in Estonia in 1994-1997.*

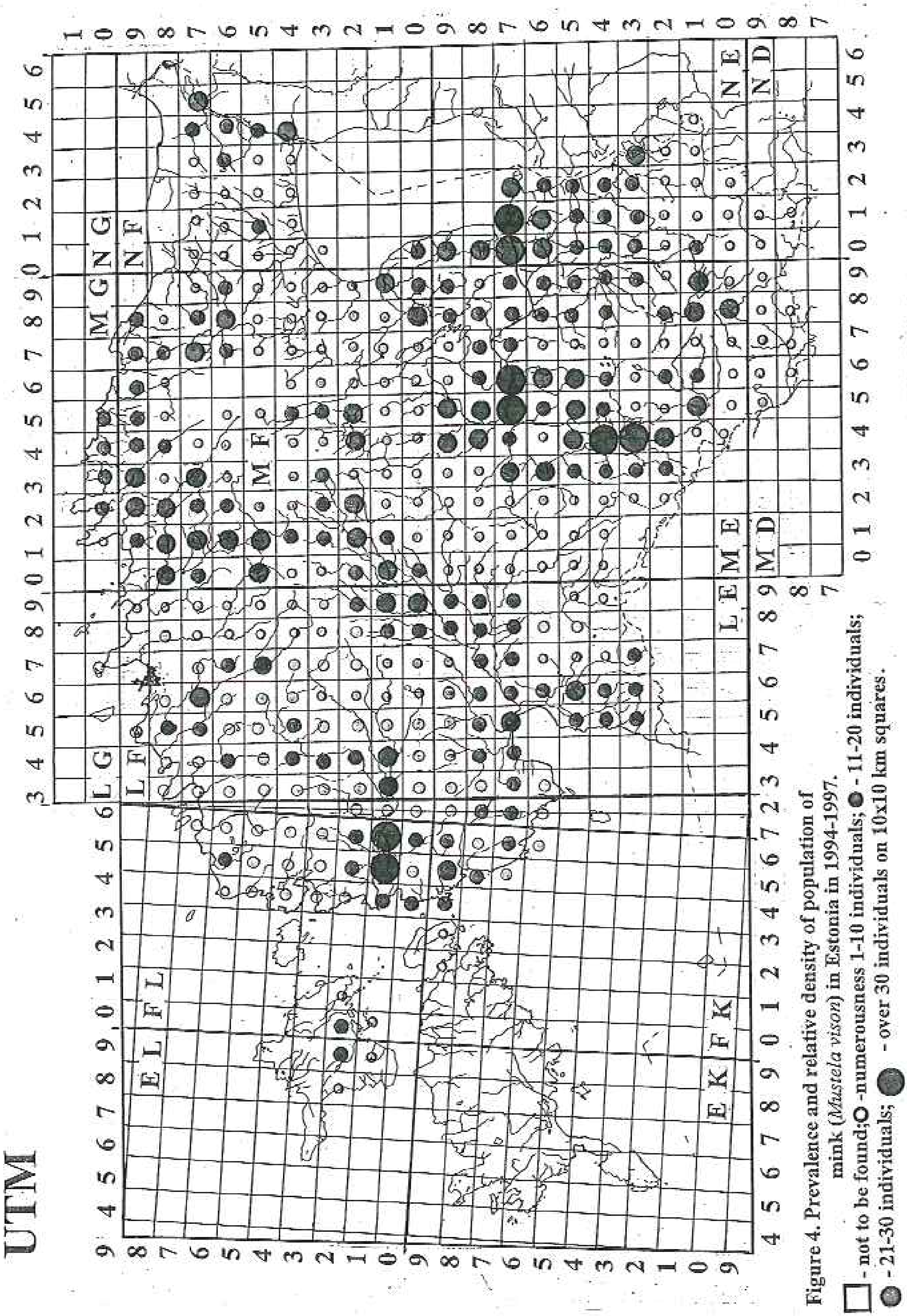

Fig. 4 *Prevalence and relative density of population of mink (Mustela vison) in Estonia in 1994-1997.*

3.2 Prevalence of crayfish in Estonian waters on the basis of faeces analyses of otter and mink, and results of special observations

Crayfish could be found in almost every Estonian body of water in the previous century and even at the beginning of the present century (Järvekülg 1958). It had a very important part in self-regulation of the ecosystem of bodies of water, and was a nutritional object for many water animals and half-water mammals as well as people.

Extensive and rapid spread of crayfish plague in Europe arrived in the territory of Estonia by the turn of the century and was disastrous to the rich crayfish supplies here (Reinwaldt 1936, Järvekülg 1958). Apparently, as a result of extensive cumulative influence of crayfish plague and human activity, the crayfish disappeared from many bodies of water, and for the time being there have remained only a couple of hundred rivers and lakes populated by crayfish (Tuusti 1991).

The area of population of crayfish has remarkably decreased in Estonia. Unfortunately, we do not have a satisfactory overview of these changes. Decrease in the number and area of distribution of crayfish has brought along decrease in their share in the ration of food of species eating crayfish.

Crayfish was, and is up to now, one of the most important nutritional elements in the ration of food of otter. It had essentially important role earlier when crayfish was numerously occupying most of the waters in Estonia. It is still an essential component of food for otter in winter when waters freeze and the availability of fish is remarkably decreasing. During this period, the crayfish and frogs living in the region of rapids and springy streams form a big part in the ration of food of otter (Laanetu 1989).

The food of otter is relatively precisely reflecting the wildlife and composition of species of a body of water and the changes taking place in it. When we have collected enough material during a longer period about the studied bodies of water, we can also asses the changes taking place in the wildlife of the body of water. The wildlife of water in natural conditions is very stable. Extensive changes can be brought along only by changes in climate or activity of people.

Studies of the nutrition of otter in 1969-1970 (n=406) showed that the frequency of occurrence of crayfish in the food of otter was 10% (Laanetu 1971). In the samples collected in 1980-1985 (n=2908), the frequency of occurrence of crayfish was 5.5% (Laanetu 1989). In the faeces of otter collected and studied in 1992-1995 (n=4962), the frequency of occurrence of the remnants of crayfish was 7.8%. In the faeces of mink collected during the same period (n=2934), the remnants of crayfish were found in 6% of the samples. In the faeces of otter (n=1834) and mink (n=866) collected in 1996-1997, the frequency of occurrence of crayfish was 6.1% and 5.4% respectively (Table 1).

Table 1 *The frequency of occurrence of crayfish in the nutrition of otter and mink in Estonia during different periods of study.*

Studied species	Period of collecting material	Number of samples (n)	Frequency of crayfish in the samples	
			Occurrence No.	Occurrence %
Lutra lutra	1969-1970	406	41	10.0
Lutra lutra	1980-1985	2908	160	5.5
Lutra lutra	1991-1995	4962	432	8.7
Mustela vison	1991-1995	2934	79	6.1
Lutra lutra	1996-1998	1834	112	6.1
Mustela vison	1995-1998	866	47	5.4

The frequency of occurrence of crayfish in the ration of food of otter should characterise the changes that have taken place in the population of crayfish in Estonia rather objectively. An apparent low level has been during the years 1980-1990, followed by a certain improvement at the first half of the nineties. The studies of the recent years have again indicated the decrease in the share of crayfish in the nutrition of otter (Figure 6).

Special observations of the bodies of water in various counties are ascertaining the described tendency. In 1995-1997, crayfish disappeared from several bodies of water and sections of waters in the county of Järvamaa (the Prandi, the Saarjõgi, the Lintsi), the county of Tartumaa (the upper course of the Suur-Emaõgi, the Elva river, and also partly from several sections of the rivers of Põltsamaa and Pedja) as well as from many other places. One of the major causes for the death of crayfish was an abrupt sinking of the water level in the winter of 1995-1996, as a result of which a great part of crayfish holes remained dry, froze and the crayfish died. Low water level and total or partial drying of smaller streams in the summers of 1996-1997 had a remarkable effect on the crayfish population on the islands and the bodies of water in the western part of Estonia.

The present Estonian crayfish population is in a bad condition. Regardless of the relatively wide prevalence of crayfish in several Estonian rivers (Figure 5), the population density is low. Many bodies of water possessing hydrological conditions suitable for crayfish are empty and their re-population with crayfish would be highly recommendable. Many bodies of water have considerably changed in the course of a melioration works. Therefore, it is necessary to carry out respective hydrological studies before bringing crayfish in.

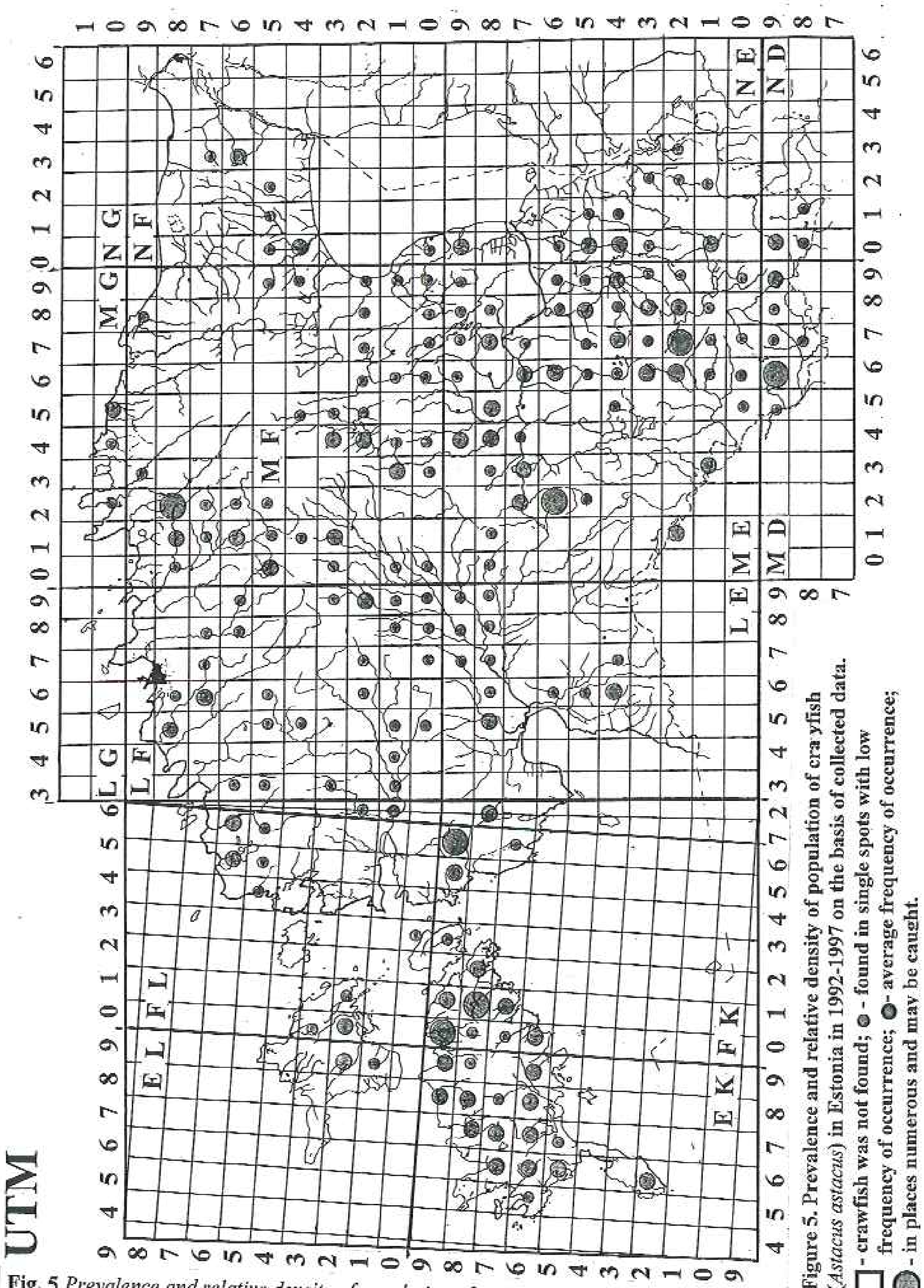

Fig. 5 *Prevalence and relative density of population of crayfish (Astacus astacus) in Estonia in 1992-1997 on the basis of collected data.*

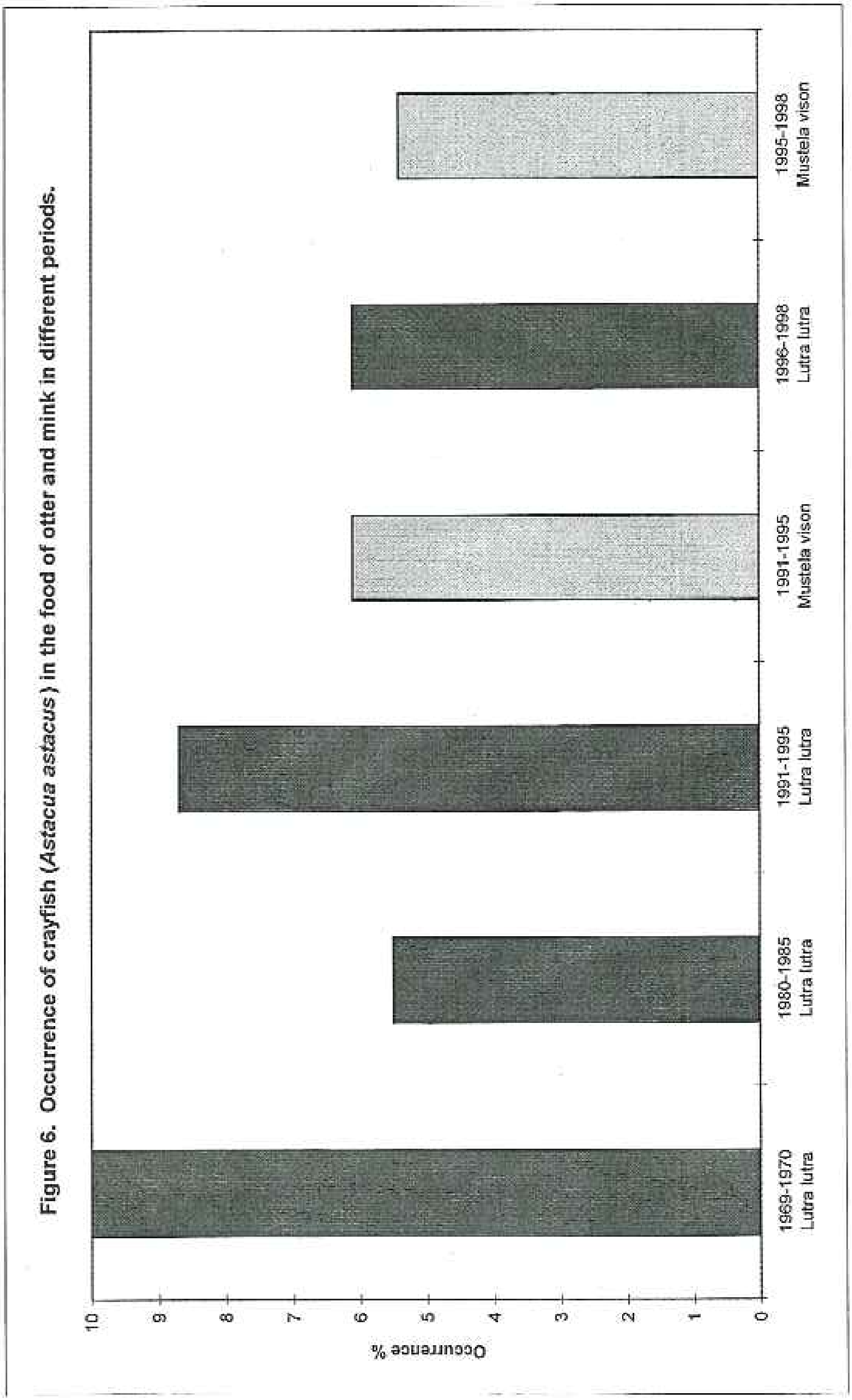

Fig. 6 *Occurrence of crayfish (Astacus astacus) in the food of otter and mink in different periods.*

Preservation and restoration of crayfish supplies is one part of the employment and management programme of our inland waters wildlife, helping to mitigate (decrease) the negative consequences of human activity in the ecosystems of waters.

4 Summary

Crayfish (*Astacus astacus*) is an inseparable part of the ecosystems of Estonian inland waters. As a result of human activity, a sundance of crayfish has considerably decreased. We have relatively few data about the changes in the crayfish populations. It is caused by the lack of required observation system, and big scope and number of bodies of water. The study of the prevalence of crayfish by traditional methods is expensive and labour consuming. Therefore, the results of faeces analyses of otter and mink have been started to use in addition to catch data.

In 1992-1997, in the course of observation of half-water mammals, material was also collected about the prevalence of crayfish as well as the nutrition of otter and mink. An overview of the prevalence of crayfish has been obtained on the basis of faeces analyses and special observations, reflecting the present prevalence of the given species (Figure 5).

A prerequisite for the use of the method of nutrition analysis of otter and mink is the prevalence of these species in the observed bodies of water. Good results can be obtained by this method in the case the number of test spots and nutrition samples is big, enabling relatively precise description of the general prevalence of crayfish in Estonia. The discussed method is worth greater attention and further improvement.

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State of noble crayfish stocks in Võru, Valga and Põlva counties in Southern Estonia in period 1993-1997

Margo Hurt[1], *Mati Kivistik*[2] & *Tiit Paaver*[3]
[1]Võru County Government,
Environment Dept., Karja 17a, Võru, Estonia
[2]Haanja Nature Park,
Valgjärve 6-4, Kose, Võrumaa, Estonia
[3]Dept. Fish Farming,
Estonian Agricultural University, Kreutzwaldi 1, Tartu, Estonia

Abstract

Noble crayfish stocks of 55 lakes of Southern Estonia were studied in period 1993-1997. Crayfish was present in 67 % of the investigated lakes, in 7 lakes CPUE was over 2 crayfish per trap night. There was evident decline in crayfish stock of Southern Estonia - several lakes have lost the crayfish population, in the others CPUE has decreased. Among of the reasons of decline of crayfish stock the harsh winters when oxygen deficiency occurs in the eutrophic lakes must be considered. Burn spot disease, porcelain disease and *Psorospermium haeckeli* occurred in a few lakes. Classification of abundance of crayfish and potential yield in the lakes on the basis of trapping efficiency must be developed.

1 Introduction

Southern Estonia is rich in small lakes. Most of these lakes have had good crayfish stocks in the turn of the century. There is only one species of crayfish in Estonia: noble crayfish *Astacus astacus*. In the second half of the 20th century the crayfish stocks decreased due to crayfish plague, habitat destruction, declining water quality, predation by mink and eel and poaching (Tuusti et al. 1993). Nowadays in Southern Estonia there are only few water bodies, which have crayfish stock big enough to be exploited.

The goal of this study was to estimate the status of crayfish populations of Southern Estonia and to determine how many stocks possess potential for recreational crayfishing. Estimation of situation of crayfish stocks in South Estonian lakes is based on the results of testfishings carried out in 1993-1997 by M. Hurt and M. Kivistik. In the years 1996-1997 testfishing was partly financed from the Norwegian-Estonian research project

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2 Material and methods

The studied area covered three Southern Estonian counties: Valga, Võru and western part of Põlva county. During years 1993-1997, 105 crayfish testfishings were carried out in 55 lakes with surface area 1-230 ha. Those lakes were chosen from the list of Estonian crayfish water bodies compiled by J. Tuusti on the basis of official records about sales of licences of recreational crayfishing and his own results of testfishing carried out by means of dipnets in 1980s and beginning of 1990s. Some lakes were included as they were recommended by staff of County Government Environment Departments.
For testfishing were used traps with 2-entrances and 15 mm mesh size (knot to knot). Test area which was expected to be suitable for crayfish was selected in each lake after screening of longer stretches of shoreline. The repeated crayfish trappings took place in the same area. 10-40 traps were used in each lake. The distance between traps was 10 m. Baited traps were held in the lakes overnight. Mainly fresh fish (roach, bream) was used as bait. The minimum size (total length) of crayfish caught by traps was usually 75 mm. As the relative measures of fishing efficiency (CPUE), number of crayfish and number of legal sized crayfish (total length over 10 cm) per trap night were calculated. To characterise the populations, the crayfish were measured individually, the number of females and males was counted and infestibility by parasites was fixed.

3 Results

3.1 Catch efficiency

According to results of testfishings the noble crayfish was present in 67 % of the investigated lakes (37 lakes, Table 1). In 44 % of lakes CPUE was below 1 crayfish per trap night. In five lakes (9 %) the catch per trap night was between 1 and 2 and at the same time CPUE of legal sized crayfish was around 1. Testfishings in four lakes (7 %) gave some better results: 2-3 crayfish per trap night. In three lakes CPUE was over 7 crayfish per trap night. The highest number of legal sized crayfish per trap night was caught in L. Aheru. Changes of the state of the crayfish populations could be followed in 10 lakes where testfishings were carried out repeatedly at least in three years. A general decline could be revealed as the CPUE decreased in 7 lakes. In the lakes with scarce populations (CPUE below 1) there were no significant fluctuations in the testfishing efficiency between the years.

Table 1 *State of the crayfish populations of Southern Estonia by the results of testfishing*

Lake	Surface area, ha	Enrichment by crayfish stocking material	Last test-fishing year	CPUE (crayfish per trap night)	CPUE (legal sized crayfish per trap night)
AHERU	234		1997	9,4	3,2
PÜLME	6,4		1996	7,9	1,7
LAMBAHANNA	3,5		1997	6,7	2,1
KUBIJA	13,6		1997	3,0	1,3
UDSU	6,2		1996	2,9	1,4
VOKI	16,9		1997	2,9	0,5
HURMI	5,8		1997	2,1	1,5
PÄIDLA MÕISAJÄRV	13,8		1997	1,6	1,4
TÜNDRE	72,9		1997	1,5	0,7
ERASTVERE	16,3		1997	1,4	1,2
KARSNA	16,3	in 1996 715 juveniles	1997	1,3	0,9
MÄHKLI	8,1		1997	1,1	0,9
PILLEJÄRV	7,2		1995	0,8	0,5
KARULA PIKKJÄRV	34,9		1997	0,8	0,5
KURGJÄRV	10,5		1997	0,8	0,3
KANEPI VÄHKJÄRV	8,7		1997	0,7	0,6
LASVA KALIJÄRV	10,5		1997	0,7	0,5
VIDRIKE	14,3		1997	0,6	0,3
PAPPJÄRV	4,8	in 1992 46 adults, in 1997 210 juveniles	1997	0,4	0,4
JÕKSI	64,9		1997	0,4	0,2
JAANUSJÄRV	9,4		1996	0,4	0,1
KOORKÜLA VALGJÄRV	44,1		1993	0,4	0,1
VIHTLA	5,9	in 1991 100 adults, in 1996 615 juveniles	1997	0,4	0,3
PINDI KÄRNJÄRV	8,3		1997	0,4	0,1
KAASJÄRV	2,9	in 1991 100 adults, in 1996 470 juveniles	1997	0,3	0,2
KÕLLI	3,2		1997	0,3	0,1
TILSI KÕRBJÄRV	13		1997	0,2	0,2
LÕVASKI	1,1	in 1994 40 adults, in 1995 163 adults	1996	0,2	0,2
KAVADI	27,4	in 1991 100 adults, in 1995 782 adults, in 1996 1040 juveniles	1997	0,1	0,1
ÄHIJÄRV	176		1997	0,1	0,1
ANDSU PERAJÄRV	1,4		1996	0,1	0,1
MURATI	66,6		1997	0,1	0,1
KAARNA	23,6		1996	0,1	0,0
VASKNA	23,6		1995	0,1	0
KURITSE	11,9		1997	0,1	0

Lake	Surface area, ha	Enrichment by crayfish stocking material	Last test-fishing year	CPUE (crayfish per trap night)	CPUE (legal sized crayfish per trap night)
PLAANI KÜLAJÄRV	16,1	in 1991 100 adults, in 1996 1360 juveniles	1996	0,1	0
KISEJÄRV	48,9	in 1997 2000 juveniles /1994	1997	0	0
LASVA	10,9	/1988	1997	0	0
LÕÕDLA	76,7		1996	0	0
NOODASJÄRV	25,6	/1990	1995	0	0
PALOJÜRI	6,9		1997	0	0
RÄPO	1,2	/1995	1997	0	0
SUUR MÄESTJÄRV	3,1	/1992	1996	0	0
TAMULA	231	/1996, 1997	1996	0	0
TSOLGO MUSTJÄRV	6	/1983	1995	0	0
UHTJÄRV	43,5		1997	0	0
VIITINA	6,4	/1989	1997	0	0
MÖRTSUKA	19,7	/1976	1996	0	0
PIKRE	12,5		1993	0	0
TORNI	13,3		1996	0	0
INNI	24,5		1997	0	0
ALOPI	7		1997	0	0
PÕLDEALUSE	5	in 1995 218 adults	1996	0	0
PIIGANDI	43,4		1997	0	0

3.2 Population structure and disease situation

In the better crayfish lakes (CPUE over 2) the average total length of caught crayfish varied from 90,1 mm in L. Voki to 104,8 mm in L. Hurmi (Fig. 1). The biggest crayfish were caught from L. Aheru - a 145 mm male in 1993 and also a 145 mm female in 1997. Generally males were bigger than females. The proportion of males and females probably reflected more the fishing conditons than real number of specimens of different sex in the lake.The burn-spot disease was detected in four investigated lakes (Pülme, Udsu, Koorküla Valgjärv, Karsna). The proportion of infected individuals was the highest in L. Pülme (5.8%), which is not very high for Estonia. The porcelain disease was found in six lakes (Kubija, Kaasjärv, Lõvaski, Andsu Perajärv, Räpo, Vidrike), where 1-5 % of crayfish were infected. Infestibility by *Psorospermium haeckeli* was estimated in 1993 and 1997 in 22 lakes. 3-5 crayfishes from each lake were analyzed. *Psorospermium* was found in 12 lakes. In all studied lakes the parasites of family *Branchiobdellidae* were common. In almost all crayfish lakes individuals with missing and regenerative claws were found. That can indicate abundance of enemies of crayfish or high density and small number of hiding places in these lakes.

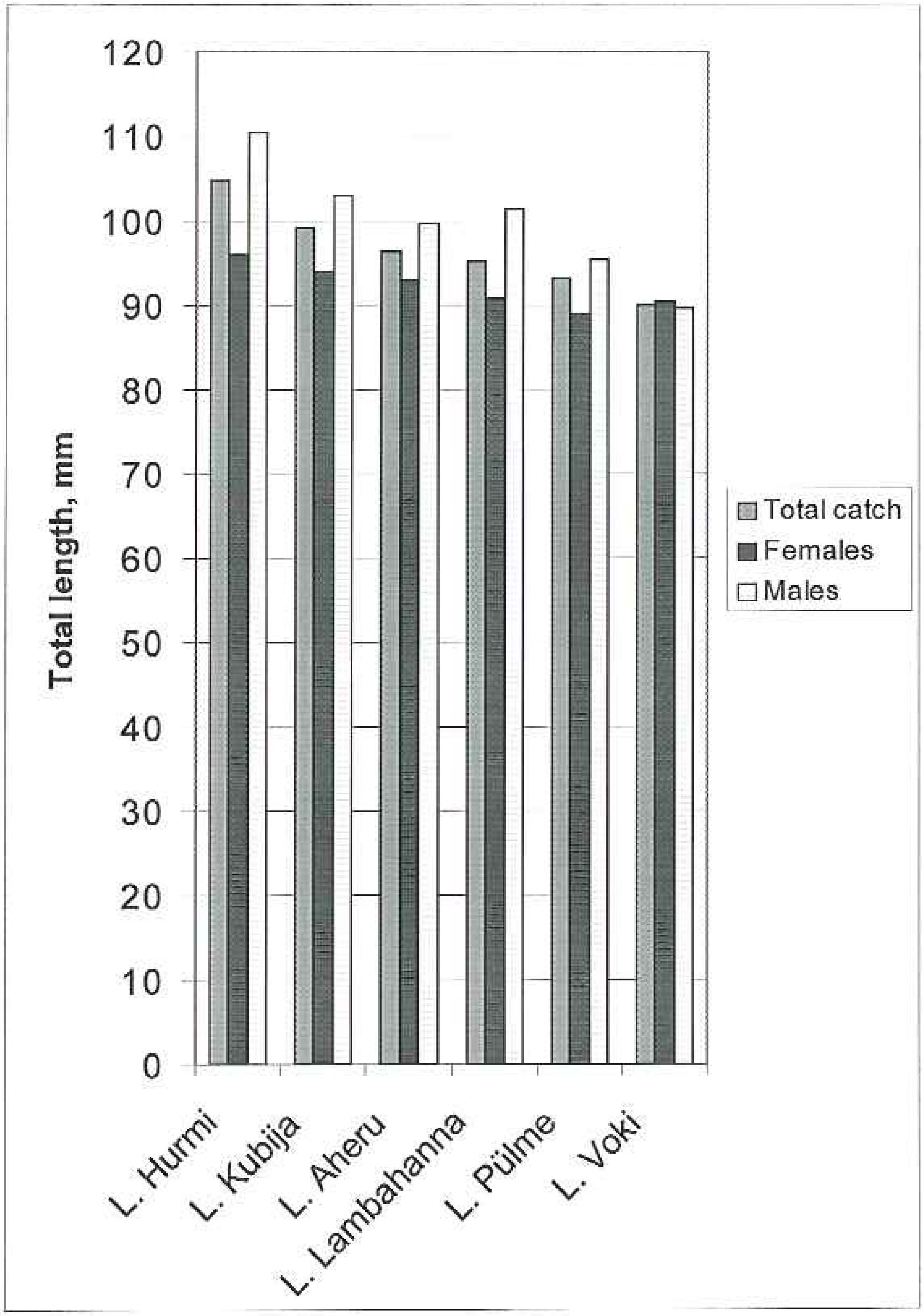

Fig. 1 *The average total length of noble crayfish in better lakes*

4 Discussion

The results of trap fishing are a good relative measure which can be used to reveal trends in density of a population. But it is difficult to use them for estimation of exploitable size of stock and potential yield. For this the area inhabited by crayfish must be determined, density of crayfish measured and also recruitment estimated by collecting younger year classes. Thus, we cannot now predict the allowable or potential catch in the investigated lakes. In earlier times even small lakes of this region have sustained catch over 50 kg/ha (Järvekülg 1958). Nowadays 2-5 kg/ha and CPUE 1-4 legal sized crayfish per trap night is considered big enogh to develop recreational crayfish fishery (Skurdal et al.1993). Evidently there is need to fix some classification of state of the crayfish populations according to trapping efficiency.

Results of testfishings carried out in 1993-1997 demonstrate that in many former good crayfish lakes the stocks were declining or had disappeared. Some of them, e.g. relatively large Lake Tamula may still retain a scarce population, which was not detected during testfishing. In lakes Aheru, Pülme and Lambahanna the crayfish population was in relatively good condition. L. Aheru is no doubt the best crayfish lake in Southern Estonia. It is relatively large (234 ha) and has viable crayfish population. L. Aheru certainly needs deeper investigations to find out what is the potential of it as a source of adult stocking material and how to regulate the recreational crayfish fishing. The problem of another good crayfish lake, L. Pülme, is high rate of infestation by burn-spot disease that makes impossible to use this lake as a donor source for crayfish stocking material.

The reasons of recent decline of crayfish stock are difficult to determine. There have been no proved outbreaks of Aphanomycosis. Overfishing (poaching) can be one of the reasons, but it is impossible to estimate its amount and influence. Besides these factors the harsh winters, when the crayfish die due to oxygen deficiency must be taken into account. Lake Räpo and some others have evidently lost their crayfish population for this reason. After such winters the fish community of the lakes has also changed significantly.
The lakes of Southern Estonia have been stocked with adult or juvenile noble crayfish brought from other regions of Estonia since the beginning of century. In some cases it has kept crayfish population alive or even restored a lost population. However, the efficiency of stocking and rate of recovery has not been estimated yet.

5 Conclusions

1.The crayfish stock of Southern Estonia is generally in poor state. There are only 7 good crayfish lakes, where the CPUE of testfishings was over 2 crayfish per trap night. 34 % of lakes have lost the crayfish population.

2. Burn spot disease, porcelain disease and *Psorospermium hackeli* are present in Estonian crayfish populations, but do not have high rate of infestation, they are present in a few investigated lakes.

3. Among the other commonly known reasons of vanishing of crayfish population harsh winter conditions must be considered.

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The influence of the size of noble crayfish and signal crayfish stocklings on stocking results in southern Finland

Esa Erkamo[1], Teuvo Järvenpää[2], Jorma Kirjavainen[3] and Jouni Tulonen[1]
[1]Finnish Game and Fisheries Research Institute,
Evo Fisheries Research and Aquaculture,
FIN-16970 Evo, Finland
[2]Finnish Game and Fisheries Research Institute,
PO Box 6, FIN-00721 Helsinki, Finland
[3]Employment and Economic Development Centre for Häme, Fisheries Section,
PO Box 20, Hämeenlinna, Finland.

Abstract

The stocking of noble crayfish *Astacus astacus* and signal crayfish *Pacifastacus leniusculus* increased rapidly in the 1980s in Finland. The main reasons were the progress made in cultivation methods for producing crayfish juveniles for stocking and the new regional plans for crayfish fishery.

Earlier, the stocked crayfish were adult individuals transferred from the wild or newly hatched juveniles. Since 1980, one-summer-old juveniles that were produced by a new cultivation method have predominated signal crayfish introductions. Also, more than 600,000 one-summer-old noble crayfish have been stocked in Finland since 1980, although adult individuals have predominated in most of the years.

The results of signal crayfish stocking have been monitored by test-fishing since the 1970s and for noble crayfish since 1989. The results of stocking with different types of stocking material are compared, the advantages and disadvantages of different stocking material are assessed and recommendations are given for different stocking situations

1 Introduction

The restoration of crayfish populations in Finland has traditionally been conducted with young noble crayfish trapped in wild populations (60-100 mm in total length). The introduction of signal crayfish in the 1960s was made with mature individuals brought from USA. However, the risk of introducing alien fish diseases with crayfish stopped the import in 1968. Therefore, the only way to get signal crayfish for stocking was to start their cultivation. In the 1970s, signal crayfish stocking was carried out with only newly hatched, so called second stage juveniles (Järvenpää & Kirjavainen 1992), as was in Sweden at that time (Fjälling & Fürst 1988). The Finnish Game and Fisheries Research Institute (FGFRI) developed an economical method of raising bigger, one-summer-old juveniles in small ponds using natural food in the late 1970s (Pursiainen *et al.*1983). Also, a method for the artificial incubation of crayfish eggs was developed in early 1980s that produced plague free juveniles from infected individuals. In this method the embryonal development was, in most cases, accelerated by heating the water to make juveniles hatch in late May, one month earlier than normal, thus getting a longer first growing season. After the first summer the early hatched juveniles of signal crayfish were 3-6.5 centimetres long. Since 1980, nearly all stocked signal crayfish in Finland have been produced by this method. In the 1990s, cultured 1-3 year old and 5-10 centimetre long signal crayfish and adult individuals from growing wild populations have also been released in great numbers into Finnish waters.

The majority of the releases of noble crayfish in Finland have been for 7-10 cm long adult individuals. However, between 1980 and 1994 more than 600,000 one-summer-old 1.5-3.5 cm long individuals were also released. Only a small number of these young noble crayfish were produced with warm water egg incubation. In the 1990s, small numbers of 1-year-old juveniles have been stocked.

Precise numbers of stocked crayfish in Finland cannot be given before 1989, when the national register of stockings was established. The estimated numbers in the early 1980s were fewer than 10,000 individuals per year for noble crayfish, and 500-3,000 individuals per year for signal crayfish. In 1989, the numbers stocked were 90,000 for noble crayfish and 21,000 for signal crayfish. In the 1990s, the stocking activity of noble crayfish has almost doubled and the number of stocked signal crayfish has risen tenfold since 1989 (see Tables 1 and 2).

Many of the first water bodies to be introduced with signal crayfish were chosen from isolated ponds and small lakes without any outlet. Not all the chosen water bodies were suitable for crayfish, or the number of newly hatched juveniles used for stocking were too small. Only about 15% of these stockings were successful (Järvenpää & Kirjavainen 1992). After 1988, when the national strategy for signal crayfish stocking was published the introductions were expanded to larger water bodies.

Table 1 *Introductions of noble crayfish since 1989 when the national register of stockings was established. The yearly numbers of individuals representing different types of stocking material are given.*

Year	2nd stage young	1-summer-old juveniles	1-3-year old subadults	Adults	All together
1989	4,000	47,000	0	39,000	90,000
1990	0	61,000	21,000	75,000	157,000
1991	0	72,000	2000	114,000	188,000
1992	10,000	59,000	7,000	119,000	195,000
1993	0	37,027	91	158,116	195,234
1994	0	14,677	2684	166,457	183,818
1995	0	5,391	14273	149,576	169,240
1996	4,450	500	8907	97,546	111,403
1989-1996	18,450	296,595	55,955	918,695	1,289,695

Table 2 *Introductions of signal crayfish since 1989 when the national register on stockings was established. The yearly numbers of individuals representing different types of stocking material are given.*

Year	2nd stage young	1-summer-old juveniles	1-3-year-old subadults	Adults	All together
1989	4,000	15,000	1,000	1,000	21,000
1990	0	18,000	3,000	4,000	25,000
1991	0	33,000	3,000	3,000	39,000
1992	55,000	77,000	7,000	6,000	145,000
1993	9,000	56,948	17,325	25,851	109,124
1994	45,200	120,694	28,157	15,225	209,276
1995	10,133	124,782	32,759	18,037	185,711
1996	36,114	148,164	21,786	16,521	222,585
1989-1996	159,447	593,588	114,027	89,634	956,696

Most stocking is financed by fishing-rights owners but the FGFRI has also carried out wide crayfish stocking activities of its own. Between 1980-1997, the FGFRI stocked 35 lakes and 8 rivers with 84,000 signal crayfish. From 1975 to 1997, 127,000 noble crayfish were also introduced by FGFRI into 23 lakes and 15 rivers, all which were test-fished before stocking. Almost all signal crayfish introductions have been successful, because larger lakes with a known history as crayfish producing lakes were chosen and the numbers of stocked crayfish was high enough. However, the stocking of noble crayfish has been clearly successful in only seven out of 38 water bodies. The most obvious explanation for the poor results with noble crayfish is that many of the waters were slightly acidified and therefore not ideally suited.

2 Materials and methods

The stocking results have been monitored yearly, or at a minimum of every second year in most water bodies stocked by the FGFRI. The successfully stocked lakes and rivers have been trapped regularly and the unsuccessful ones reasonably frequently, just to ascertain the failure. Active monitoring of signal crayfish stocking started in the late 1970s, and about 10 years later for noble crayfish. An extensive test trapping programme was organised in the 1990s in co-operation with the fisheries' authorities, regional fisheries' advisors and local fisheries' management societies. The purpose was to obtain more data on the results of signal and noble crayfish stockings made by private water owners.

The test-fishing data on signal crayfish stocking is rather extensive, and only a few more years are required to conclude the results. With noble crayfish, sufficient data is collected only from stocked one-summer-old juveniles produced by the natural cycle of the species, without warm water egg incubation. About 5-10 years are still needed for a more final summary of the results.

Test-fishing in stocked waters is generally carried out or supervised by the FGFRI. The traps and the fishing methods have been standardised as much as possible. The trap models used were the ones presented by Westman et al. in 1978 (the Evo-trap) or Swedish August-trap, both of which were baited with roach. The traps were connected five metres distant from each other in a line. The catch was started in the evenings and the traps were emptied in the morning. The entire shore line of the stocked area was fished, not only the best spots. The most obvious weakness in the data relates to the variable stocking and test-fishing practices used by some of the co-operators. This mainly concerns adult noble crayfish stockings. A sparse population of noble crayfish may also have been present in some of the waters before stocking. In many cases, there was no information about the stocking density, but in most cases the recommendations (1-5 adults, 5-10 raised juveniles or 10-20 newly hatched fry per metre of shoreline) were probably followed.

Each place stocked was counted as one individual case if it was clear the crayfish that originated from different stocking places could not mix, otherwise both stockings were excluded from the data. Data on the catch per unit effort from stockings with different types of stocking material was collected from nearly 200 crayfish stockings using this method - although in many cases the data covered only one or two years of test-fishing. Because the catch per unit effort data was not always available for all waters and for all years, it is presented as a three-year mean: for noble crayfish the years 6th to 8th following stocking and for signal crayfish the years 4th to 6th after stocking. These years were the first period when almost all caught crayfish were born in the stocked place and the values of catch per unit effort clearly reflected the abundance of the growing population. The longer time for noble crayfish was needed because of its slower growth, when compared with signal crayfish (Kirjavainen & Westman 1992).

Since so many of the stockings were still fresh, setting the criteria for successful introductions was difficult. In many cases, the stock development seemed to need much time, but catch per unit effort increased from year to year. Our choice (catch per unit effort > 0.15, 6-8 years after stocking for noble crayfish and 4-6 years after stocking for signal crayfish) was rather arbitrarily based on the observation that there was a wide gap in the data below that level. So, this seemed to be a natural distinction level in our data.

In some of the lakes stocked by the FGFRI, several sizes and age groups were released into different but comparable stocking sites within the same lake. The environmental variables are minimised in these stoking experiments. The number of crayfish in each experimental group was balanced to the same economic value in many of these lakes, so that the relative profitability of different stocking material could directly be compared with the base of catch per unit effort-data. These cases are, however, so few and so fresh that separate analysis for this publication served no purpose.

3 Stocking results

The preliminary results of stocking are quite clear. Noble crayfish smaller than 2.5 cm have given poor stocking results. Only 22% of the releases were successful. The stocking of bigger juveniles and mature crayfish succeeded in about 60% of the cases (see Table 3). The adult individuals had a quicker average stock development than the others, although the difference between the stocking materials is probably smaller than can be seen in Table 18.3 (causes for bias in "materials and methods").

All stocking sizes have given good results for signal crayfish. Stocking for mature individuals has given a slightly faster population growth on average than smaller crayfish (Fig.1) but also a higher variation in results (Table 4). One summer-old and one-year-old juveniles instead have given a little slower but more certain stock development than mature crayfish on average. Also, the latest stockings with newly hatched signal crayfish juveniles have given quite good results.

Table 3 *Results of the test-trapping in noble crayfish populations originating from stocking in the years 1986-1996.*

Type of released crayfish	Number of released groups*	Mean number of crayfish in stocked group	Successful** releases	Mean catch/unit effort 6-8 years after the stocking***	S.D.of the mean cpue
16-24 mm	41	1690	9/41 = 22%	0.20	0.14
25-36 mm juveniles	12	1455	7/12 = 58%	0.20	0.11
Adult 7-10 cm	39	952	23/39 = 59%	0.70	0.63
Total	92	1347	39/92 = 42%		

* Number of stocking sites test-trapped.

** Classified as succesful if mean catch per unit effort after 6-8 years from release was more than 0.15 crayfish (or >0.1 crayfish in years 1-5 if not trapped in years 6-8).

*** Mean catch per unit effort in years 6-8 for succeeded releases. The catch per unit effort for adult crayfish is

Table 4 *Results of the test-trapping in signal crayfish populations originating from the stockings in the years 1980-1996.*

Type of released crayfish	Number of released groups*	Mean number of crayfish in stocked group	Succesful** releases	Mean catch/unit effort 4-6 years after the stocking***	S.Dev.of the mean c/ue
Newly hatched	5	2300	3/5 = 60%	1.0	0.9
1-summer old	25	948	21/25 = 84%	1.2	1.0
1-s.old, repeated	10	2409	8/10 = 80%	1.3	1.0
1-year old	10	432	9/10 = 90%	1.3	1.0
Adult, 7-12 cm	24	299	17/24 = 70%	1.5	1.6
Several types, rep.	21	2253	15/21 = 71%	1.0	0.8
Total number	95	118,099	73/95 = 77%		

* Number of stocking sites test trapped with standard method.

** Classified as succesful if mean catch per unit effort after 4-6 years from release is more than 0.15 crayfish (or >0.1 in years 1-3 if not trapped in years 4-6).

*** Mean catch per unit effort in years 4-6 for succeeded releases. The best lake excluded (see fig.1).

The development speed of the stocked signal crayfish populations was strongly dependent on environmental factors. The best result in Finland was achieved in a middle-sized lake (600 hectares) where the number of stocked crayfish was quite low but both newly hatched and one-summer-old juveniles resulted in quick exponential population development. The difference between this lake and others with much slower and fluctuating development was really astonishing (Fig. 2).

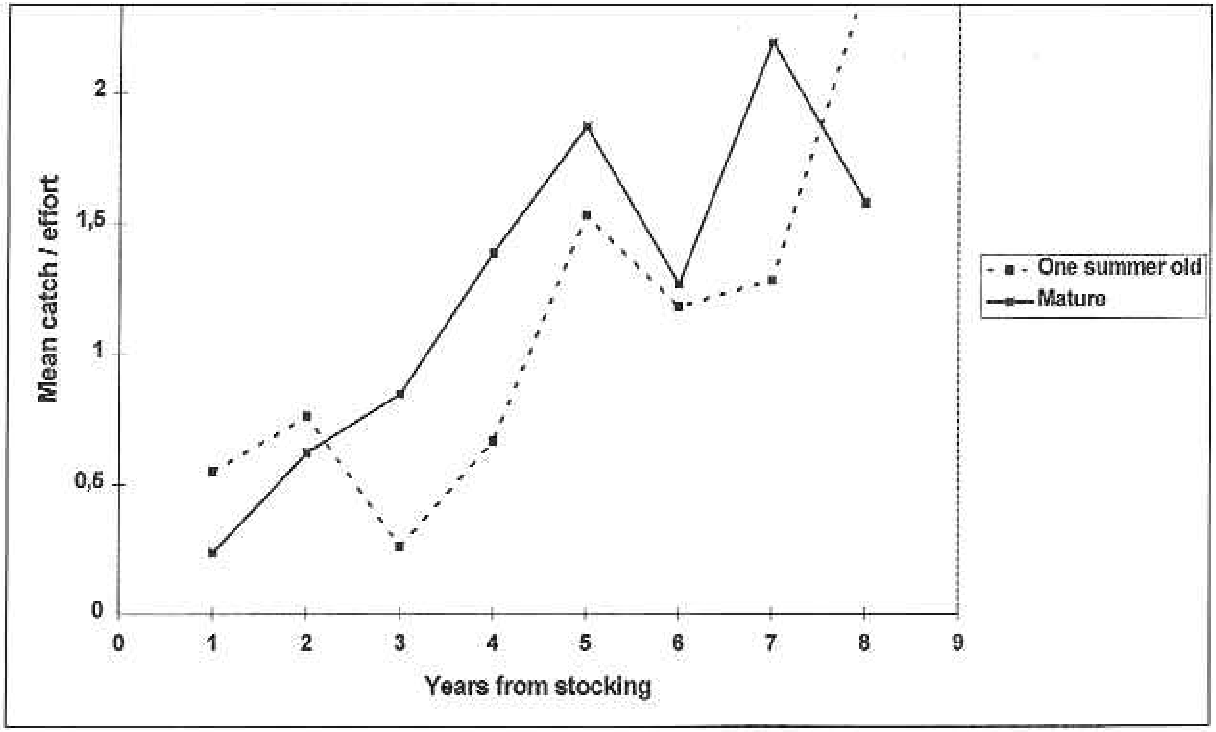

Fig. 1 *Mean stock development as catch per unit effort (and/trap/night) in stockings of one-summer-old juvenile and mature (trapable, 60-100 mm TL) signal crayfish.*

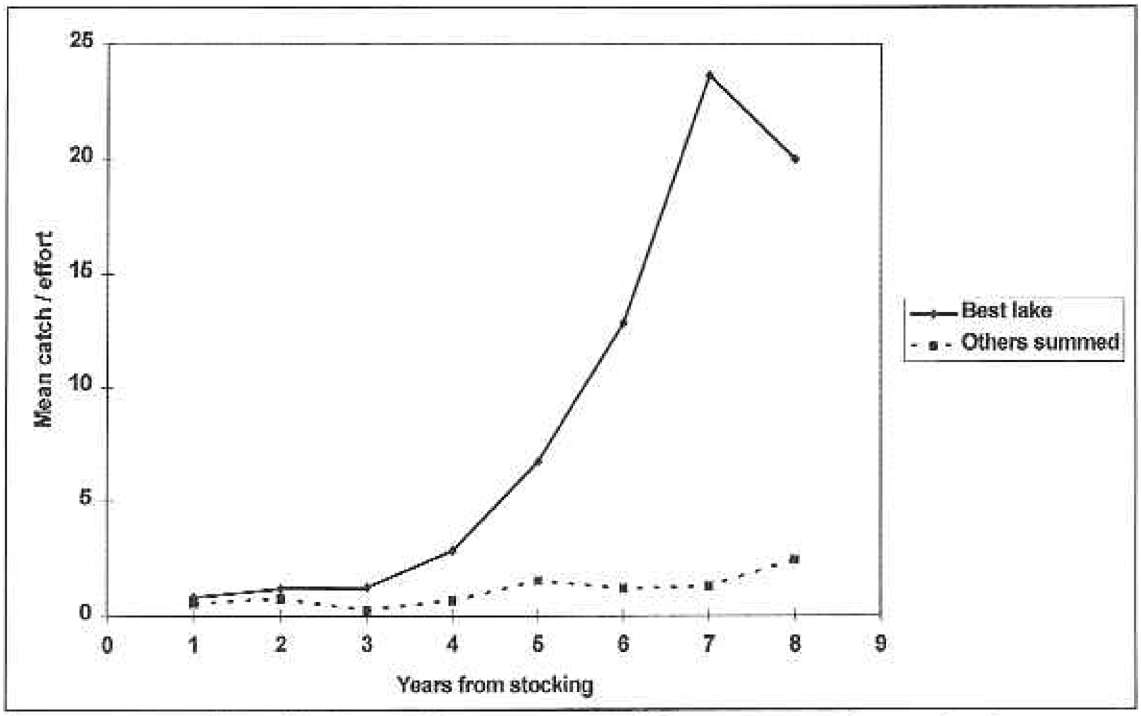

Figure 2 *The effect of lake specific environmental factors on population development after stockings of one-summer-old juvenile signal crayfish*

4 Discussion and conclusions

According to Swedish researchers, it became obvious during the late 1970s and in the 1980s that it was more economical to stock mature individuals of signal crayfish than newly hatched juveniles, because 90-95% of juveniles seemed to die before they reached maturity (Fürst 1977, Fjälling & Fürst 1988). Our results were parallel but not so obvious. The newly hatched juveniles stocked in 1980s and 1990s in Finland had been incubated in heated water and hatched in late May about a month before the natural time. They were stocked in early June when there was a lot of food but not so many predators and competitors as there were later in summer. This action may be the reason these stockings seemed to have given much better results than earlier stockings with second stage juveniles in Finland. Finnish prices are also more favourable for newly hatched juveniles than the Swedish ones. The relative prices for newly hatched, one-summer-old and adult individuals in Finland are around 1:5:15.

Järvenpää & Kirjavainen (1992) presented a list of advantages for one-summer-old signal crayfish: low mortality, fast stock development, remaining where they were introduced and a low risk of transmitting infectious diseases or parasites. All these benefits have yet to be confirmed. The benefits gained in introducing subadults and adult individuals are in their reproduction beginning earlier and their lower vulnerability than juveniles to fish predation. On the other hand, they could be more vulnerable to mammal predators, especially in running waters. Also, their tendency to emigrate in running waters and large and shallow lake areas with a firm bottom, is a problem.

According to our results, no one type of stocking material was clearly more cost-effective than another in establishing new populations of signal crayfish. The adult individuals gave on average one-year quicker population development than one-summer or one-year-old juveniles but their assurance in establishing a new population was lower, probably due to high emigration. However, the risk of the introduction failing seemed to be highest for newly hatched juveniles, probably because of their low capability to withstand unfavourable environmental conditions. On the other hand, we had some cases where early hatched second stage fry were exceptionally cost-effective stocking material. The probable higher "disease risk" with transferred adult individuals was considered and it seemed that reared juveniles were the most certain choice. Adult individuals and newly hatched fry were a "gambler's" choice or an expert's choices in a suitable environment.

The average speed of population development for signal crayfish was about the level figured by Fjälling and Fürst (1988) in Sweden. They did not report the stocking densities nor the average stocking numbers. It seemed that weather and geographical distribution did not affect the population development, or Swedish stocking numbers, stocking densities or stocking material quality were lower than in Finland.

The clearly better results with signal crayfish than with noble crayfish, were probably due to both environmental and species related qualities. Almost all waters stocked with signal crayfish formerly had productive noble crayfish populations devastated by crayfish plague. There were no problems with water quality as there were in many of the lakes and rivers stocked with juvenile noble crayfish (state owned lakes near the Evo research station). The smaller stocking size of the raised juveniles was also an important cause for the weaker results with noble crayfish. Besides the higher predation pressure on small crayfish, we have noticed that most of the small (<2.5 cm) crayfish die during the winter in culture conditions, at least in some years. It appears that their energy reserves are too small. Their fasting endurance is, at least, poor (Erkamo et al. unpublished data). In some lakes, crayfish plague might also have destroyed the developing noble crayfish population soon after stocking.

5 Recommendation

Our results should be considered as preliminary. Most of the studied populations are still below the minimum level for reasonable fishing (<1 crayfish per unit effort) and some conclusions may change in the future. However, one conclusion can be stated quite firmly. At far as signal crayfish are concerned, the environmental factors for the stocking site and the water body have a much greater crucial effect (as seen in Fig. 1) on stock development than the type of stocking material or amount used.

A further important conclusion is that the number of stocked crayfish and stocking density should be high enough. According to our analysis, it seems that low number and density were one of the main factors for failing to establish noble crayfish populations. Therefore, we recommend slightly higher stocking numbers (see Table 5) and densities (2-5 adults, 5-10 one year old, 10-20 one-summer-old or 50-100 newly hatched juveniles per metre of shoreline) than earlier. Only half the recommended number of crayfish will be enough in most cases but to be sure, and to accelerate stock development (especially with noble crayfish) the numbers should be at the level of the recommendations. Considering stocking results, an extra investment for crayfish stocking is always profitable as long as the waters are chosen with care.

Also recommendations about which stocking material should be used in different environments are given in Table 5. These recommendations are mainly based on what has already been said in this discussion. The leading principles are to avoid risks caused by predators and the emigration of stocked crayfish. The higher figures for noble crayfish are due to a lower natural population development speed. Since there are not enough noble crayfish waters left in Europe for transfers nowadays, more emphasis should be laid on the cultivation of stocking material. Juvenile noble crayfish should be produced by the warm water incubation method to ensure adequate stocking size in northern Europe.

Table 5 *The recommended stocking numbers for different types of stocking material. The types of water bodies where each stocking material has special advantages are also mentioned.*

Age	Signal crayfish	Noble crayfish
Newly hatched	Early hatched, In favourable environment, running waters >5000	Early hatched, In favourable environment, running waters >10000
One summer	running waters, big lakes >1000	Early hatched, running waters, big lakes >3000
1-2 year	open and shallow lakes >600	open and shallow lakes >1200
> 2+ (mature)	small and middle size lakes, >400	small and middle size lakes, >800

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Heavy metals in crayfish (*Astacus astacus* L.) - preliminary results

Timo Halonen[1], *Marjatta Kantola*[2], *Kirsti Loukola-Ruskeeniemi*[3] & *Paula Henttonen*[1]
[1] Department of Applied Zoology and Veterinary Medicine, University of Kuopio,
P.O. Box 1627, 70211 Kuopio, Finland
[2] Department of Chemistry, University of Kuopio,
P.O. Box 1627, 70211 Kuopio, Finland
[3] Geological Survey of Finland,
P.O.Box 96, 02151 Espoo, Finland

Abstract

Heavy metal concentrations in the abdominal muscles and hepatopancreas of crayfish (*Astacus astacus* L.) were measured in five different water systems in eastern and central Finland. One of the lakes studied, Lake Mäntyjärvi, is located in a black shale area. The bedrock of such areas contains more arsenic, copper, mercury, nickel, selenium and zinc than do other rock types in Finland. We found a clear difference in the mercury content of muscles between Lake Mäntyjärvi and the control lakes. In Lake Mäntyjärvi, the mean mercury concentration in crayfish muscles was 0.26±0.08 μg/g (wet weight), whereas in control areas the mean values varied between 0.15 and 0.18 μg/g. We also found a statistical difference between the sexes, with mercury contents in the muscles of females being higher than those in the muscles of males (0.22±0.08 μg/g vs. 0.15±0.05 μg/g). The mercury content of the hepatopancreas varied greatly and there were no differences between lakes and sexes. Mercury concentrations in muscles and hepatopancreases do not exceed the values recommended by the Finnish National Board of Health, according to which the highest mercury content allowed in crustaceans is 0.5 μg/g (wet weight). The contents of other elements were analysed only in the muscles of females trapped from Lake Mäntyjärvi and a control lake. The preliminary data show that arsenic, cadmium, copper and selenium concentrations are statistically higher in Lake Mäntyjärvi than in the control lake.

1 Introduction

The introduction of potentially toxic metals into the food chain is a major problem. Metals such as lead, mercury and cadmium are ubiquitous and are cumulative poisons in both aquatic and terrestrial ecosystems. Also concerning is the possibility that continuous both aquatic and terrestrial ecosystems. Also concerning is the possibility that continuous exposure to low concentrations may result in bioaccumulation and become a health hazard to man. Intake and bioaccumulation of elements and tissue concentrations of pollutants form the basis of biomonitoring. In many studies, crayfish have been used as an indicator for metal pollution in the aquatic environment (e.g. Alikhan *et al.* 1990 and Stephen *et al.* 1991).

The aim of the present study was to find out, if crayfish could be used to monitor the concentrations of metals in freshwater ecosystem. Main objective was to demostrate how a special bedrock type, black shale, affects the metal concentrations of crayfish tissues. This rock type, metamorphosed black shale, is approx. 2 million years old and contains more arsenic, copper, mercury, nickel, selenium and zinc than any other rock type found in the country (Loukola-Ruskeeniemi & Heino 1996). Previous studies have shown that black shales affect at least lake sediments and water metal content (Loukola-Ruskeeniemi *et al.* 1996). Impact on aquatic animals and man is still uncertain.

In Finland, annual catch of crayfish is about 3-5 million individuals. In Finland has been investgated crayfish which live in waters mixed with the warm waste waters of steel industry and found that cadmium concentrations in hepatopancreas exceed the values recommended by Ministry of Trade and Industry (Wiikinkoski 1997). Natural metal concentrations of crayfish has not been studied in Finland. Because of that, another aim was to determine these concentrations in crayfish (*Astacus astacus*).

2 Materials and methods

Twenty mature crayfish (10 male and 10 female) were trapped from each five water systems (Figure 1) in early autumn of 1997. One of the lakes studied, Lake Mäntyjärvi, is located in a black shale area. Three lakes and one river were chosen as control areas. All the animals were weighed and measured. The abdominal muscle and the hepatopancreas were removed and frozen at -20 °C. The samples were homogenised in an aquate vessel and digested with nitric acid in a microwave oven. To avoid contaminations, only special glass instruments, polyethene gloves and plastic labware were used in preparing the tissue samples. All glass and plastic ware were acid washed. Total mercury determinations were made in the Department of Chemistry, University of Kuopio, using an FIA-Atomic Absorbtion Spectrophotometer (FIA-AAS). The analysis of the other elements is still going on at the Geological Survey of Finland (Espoo), using an Inductively Coupled Plasma Emission Spectroscopy (ICP-MS). So far, muscles of the female crayfish taken from Lake Mäntyjärvi and the control lake, Lake Kotajärvi, have been analysed.

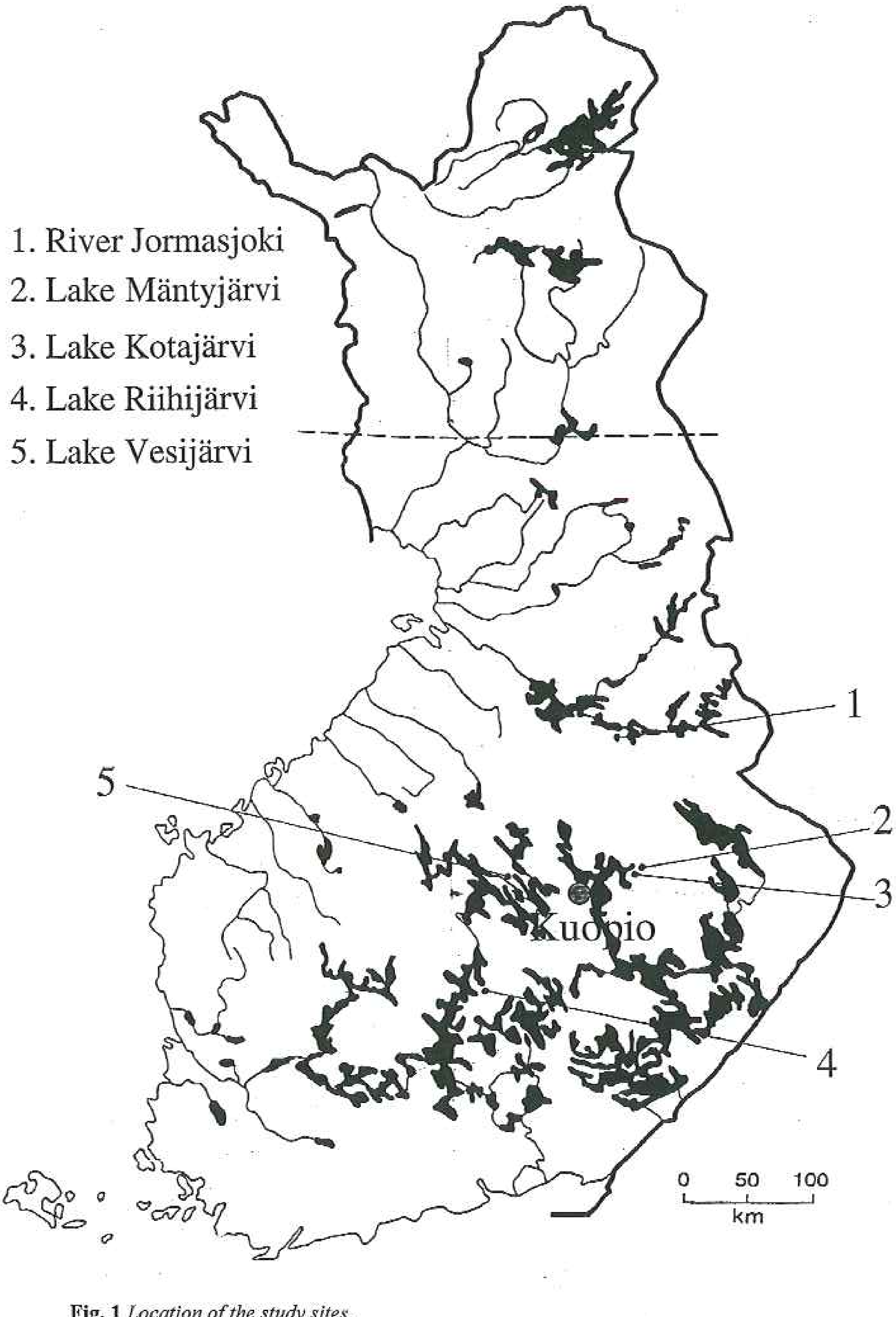

Fig. 1 *Location of the study sites.*

SPSS-statistical software was used for all statistical work. The means between sexes and water systems were compared using Nonparametric Wilcoxon rank sum test, analysis of variance, and Scheffe's multiple range tests. Pearson's correlation coefficient were used in correlation analyses.

3 Results

Mercury concentrations in muscles and hepatopancreases of crayfish are shown in Figures 2 and 3. Tissue mercury concentrations are represented as means (wet weight) with standard deviations. There were no differences in lengths between the sexes, but the lengths did vary between lakes. Crayfish from River Jormasjoki were the longest (9.9 ± 0.7 cm) and those from Lake Riihijärvi the shortest (8.7 ± 0.3 cm) ($p<0.05$). Both water systems are situated in control areas.

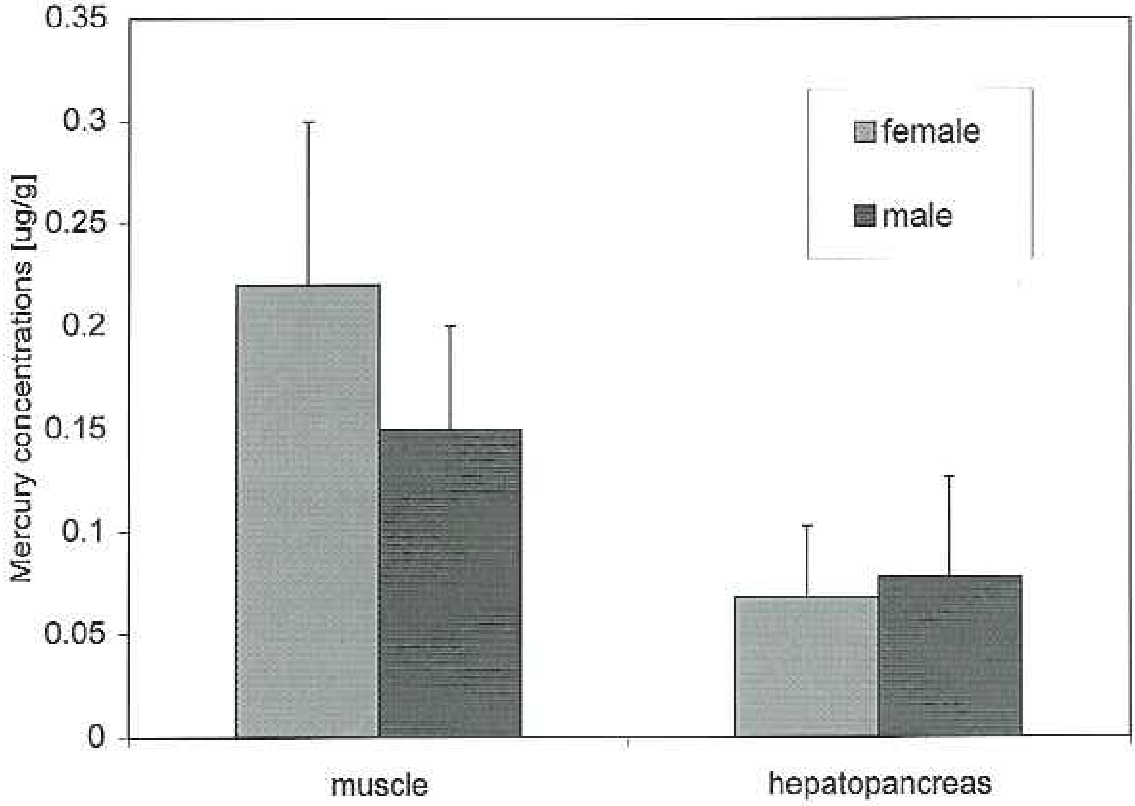

Fig. 2 *Mean mercury concentrations in the hepatopancreases and the muscles by sexes.*

Mercury concentrations in the hepatopancreas varied greatly and the mean values were lower than those in the abdominal muscle (Fig 2 and 3). Mercury concentrations in females' muscles were 0.22 ± 0.08 µg/g, compared to 0.15 ± 0.05 µg/g in males (Fig 2). Differences between the sexes were statistically significant ($p<0.01$). The highest mean mercury content was found in muscles of crayfish trapped in Lake Mäntyjärvi, a black shale area lake (Fig 3). The differences between lakes were also significant ($p<0.05$).

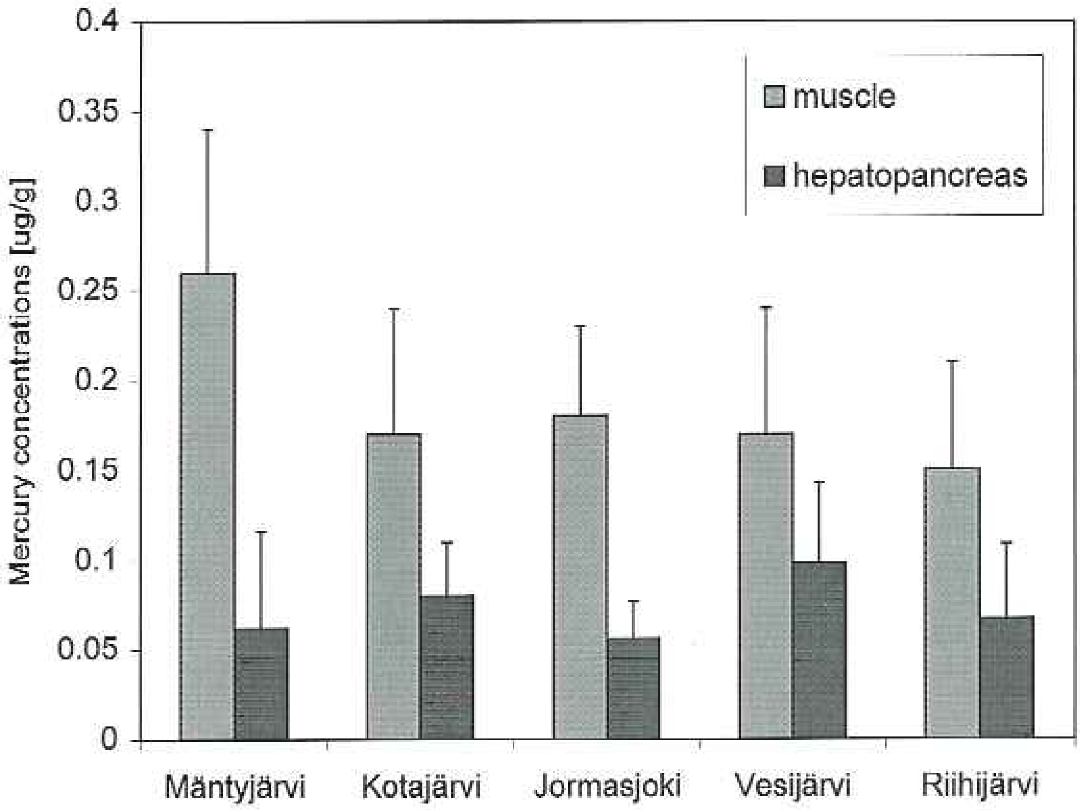

Fig. 3 *Mean mercury concentrations in the muscles and the hepatopancreases by water systems.*

Large deviations in the mercury concentrations of muscles (fig 3) are caused by mixing the sexes, with female's having the higher mercury concentrations than those in male's. No statistically signifigant correlations were found between mercury concentrations and the size of crayfish.

Arsenic, cadmium, calcium, copper and selenium concentrations in muscles were statistically higher in crayfish trapped in Lake Mäntyjärvi than those in Lake Kotajärvi. No signifigant differences was found in zinc and lead concentrations in muscles of crayfish trapped in these two lakes.

Table 1 *Mean element levels (µg/g (dry weight)) and statistical signifigance between the means, found in the abdominal muscle of the female crayfish.*

Element	Lake Mäntyjärvi	Lake Kotajärvi	Statistical signifigance
Arsenic	0.55 ± 0.11	0.35 ± 0.05	0.002 (**)
Cadmium	0.03 ± 0.01	0.02 ± 0.00	0.000 (***)
Calcium	0.78 ± 0.17	0.99 ± 0.18	0.002 (**)
Copper	16.81 ± 3.69	10.86 ± 2.59	0.003 (**)
Lead	0.08 ± 0.02	0.09 ± 0.01	0.280
Nickel	0.20 ± 0.05	0.18 ± 0.06	0.267
Selenium	0.785 ± 0.18	0.64 ± 0.09	0.022 (*)
Zinc	75.42 ± 9.29	86.41 ± 17.23	0.086

* $p<0.05$)

** $p<0.01$)

*** $p<0.001$)

4 Discussion

The mercury concentrations of hepatopancreas varied greatly. This might be due to the chemical composition of the crayfishs' food, since one of the hepatopancreas' functions is that of a digestive gland. Surprisingly, mercury concentrations of hepatopancreas were lower than those in the muscles. According to Wright & Welbourne (1993) exposure test, mercury tends to accumulate espesially in the hepatopancreas of crayfish (*Orconectes propinquus*). They also point out, that levels of mercury remain high after the exposure because of the metal binding proteins in the hepatopancreas.

Other elements found in the hepatopancreas are still undergoing analysis. However, many studies suggest that the hepatopancreas is the organ, which tends to accumulate the greatest concentrations of elements from the environment (e.g. Stephen *et al.* 1991 Jorhem *et al.* 1994 and Wiikinkoski 1997).

There was a clear difference in the amounts of mercury in the tail muscles of the two sexes, with females generally accumulating almost twice the amount of mercury than males do. It is well-known that mercury tends to accumulate in organs of high fat content. Airaksinen *et al.* (1977) has shown that total lipid contents in females are higher than in males. Rincón *et al.* (1987) studied mercury concentrations of crayfish (*Procambarus clarkii*) in Spain and found no statistically signifigant differences between the sexes. However, Heit and Fingerman (1977) investigated influences of size, sex and temperature on the toxicity of mercury to crayfish (*Procambarus clarkii*) and found that female crayfish were much more tolerant to the effects of mercury. They also noticed that the ability to cope with mercury depends on the size of the crayfish and most importantly the external temperature.

The highest concentration of mercury was observed in the tail muscle. However, even these concentrations did not exceed the values recommended by the Finnish National Board of Health, according to which the highest mercury content allowed in crustaceans is 0.5 μg/g (wet weight). Mercury levels in other studies are more or less the same as were our results. Rincón *et al.* (1987) found value 0.1 ± 0.029 μg/g to be the mean concentration in whole *Procambarus clarkii* in Spain. They also found no correlations between the size and the mercury concentrations of crayfish. Sheffy (1978) obtained a mercury concentration ranging from 0.07 to 0.56 μg/g.

Mercury may affect the life of crayfish by several ways. Wright and Welbourn (1993) found that mercury has an influence on calcium regulations in *Orconectes propinquus* and could have an impact on crayfish' molt cycle. We found that calcium levels were lower in the muscles of female crayfish taken from Lake Mäntyjärvi, where the mercury concentrations were highest. Reddy *et al.* (1997) have investigated effects of cadmium and mercury on ovarion maturation in the red swamp crayfish, *Procamparus clarkii*. According to them, mercury significantly inhibited ovarion maturation in the red swamp crayfish. Also it has been speculated, that Hg-mercury inhibits active transport from hemolymph to exoskeleton, or that it promotes or mimics molt-promoting hormone (Bjerregaard and Vislie 1985, according to Wright and Welbourn 1993)

The amounts of toxic metals such as cadmium and lead in muscles were fairly low. Jorhem *et al.* (1994) have analysed different metal concentrations in four crayfish species from five countries. According to them, cadmium concentrations of muscle varied from 0.004 to 0.006 μg/g (wet weight) and lead concentrations of muscle from 0.0022 to 0.061 μg/g. Our values are represented according to dry weights and are therefore a bit higher than those of Jorhem *et al.* (1994).

The present study shows that arsenic, copper, mercury and selenium concentrations in crayfish trapped in Lake Mäntyjärvi, a black shale area, are relatively higher than those from control water systems. This may be a reflection of the concentration of these metals in the sediments and the water of these lakes.

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Gastroliths formation and reabsorption in noble crayfish (*Astacus astacus*) and signal crayfish (*Pacifastacus leniusculus*) juveniles

Tero Ahvenharju
Department of Biology, University of Joensuu
PL 111, 80101 Joensuu, Finland.

Abstract

When proceeding the moulting, many crustaceans store the calcium compounds in certain parts of their bodies for the material to harden some parts of their new soft exoskeletons. Only in crayfish these compounds are stored as two gastric stones. In this X-ray study it was investigated how long period before ecdysis gastroliths started to deposite in two months old noble crayfish (*Astacus astacus*) and signal crayfish (*Pacifastacus leniusculus*) juveniles. Gastroliths growth during the premoult have been monitored and also the decomposition of these stones. 32.7% of the signal crayfish juveniles and 46.4% of the noble crayfish juveniles moulted during the experiment (almost two months), 15.5% and 29.9% of the juveniles were without gastroliths. On average gastroliths were visible 12.3 days in *A. astacus* and 11.3 days in *P. leniusculus* juveniles before ecdysis. The rate of reabsorption was high and usually complete within 1 to 2 days.

1 Introduction

Most crustaceans store a proportion of the calcium carbonate withdrawn from the old exoskeleton before ecdysis. The amount resorbed and stored is highly variable even between closely related taxa, ranging from 3.9 % in *Gammarus pulex* to 74.6 % in *Ligia exotica* (Greenaway 1985). The storage site too is variable (e.g. gastroliths, midgut gland, haemocoel) and is generally but not always related to taxon.

The purpose of the present X-ray study is to report the findings of the gastrolith formation and reabsorption in noble crayfish and signal crayfish juveniles. I was also interested in how often these juveniles moult during the experiment period, differences between individuals and species and how long it take gastroliths to dissolve in hemolymph. Travis (1960) presented a detailed morphological description of the paired gastrolith discs; they are composed of the cuticular lining of the stomach, the thickened gastric epidermis and the underlying connective tissue. They are located in the anterior lateral walls of the cardiac stomach. Their function is to collect calcium from the hemolymph and this activity culminates at the end of the premolt in the formation of hard calcified, disc-shaped gastroliths. The paired and rounded mineralised gastroliths lie in the sac or pouch between the epidermis and cuticular lining of the stomach.

According to Travis (1963), the development of the mineralised gastroliths occurs simultaneously with premolt breakdown and resorption of the exoskeleton and may be interpreted as representing an evolutionary attempt of the animal to conserve mineral.

At ecdysis the fully formed gastroliths are shed with the old stomach lining in the lumen of the stomach where they are converted to ionic calcium for use in postmoult mineralisation (Aiken & Waddy 1992). The role of gastroliths as a calcium storage in crustacea have been discussed by Greenaway (1985), who presented that they occur as paired discs in the Macrura, notably the astacid and parastacid crayfish and lobsters, e.g. *Homarus americanus* and as four more irregularly shaped concretions in gecarcinid landcrabs, e.g. *Gecarcinus lateralis*. They are also reported in *Sesarma haematocheir* but are not common in aquatic crabs.

Calcium stored in the gastroliths is small in comparison with total body content, amounting to ca. 10 % of the content at previous intermoult stage in adult crayfish and only 4-7 % of its requirement at the next intermoult (Greenaway 1985). According to Lahti (1988), an adult *A. astacus* individual needs approx. 4-5 g of calcium for a new exoskeleton. The total weight of the gastroliths of that size of crayfish is approx. 200 mg and their calcium content is approx. 70 mg (35 %).

2 Materials and Methods

The newly hatched (stage 2) signal crayfish (*Pacifastacus leniusculus*) and noble crayfish (*Astacus astacus*) juveniles were maintained in individual plastic cages (40 mm x 40 mm x 70 mm) which were situated in two watertanks (2m x 2m x 0.5m), both species have their own tank. The total number of crayfish were 110 individuals of both species. Mean carapace lengths (from the tip of the rostrum to the end of the carapace) were 9.0 mm (SD=1.0) in *P. leniusculus* and 8.6 mm (SD=1.0) in *A. astacus*. Crayfish were held outdoors in constantly running water at the Evo Research Station. The water source was River Majajoki. Water in that river is dark in colour (100-150 mg Pt / l) and pH could be as low as 5.5 in autumns and springs (Kirjavainen et al. 1992). The outdoors period started in the second week of June and continued to the September 10 in 1997. Range of temperature recorded outdoors was from 12.9 °C to 21.0 °C. After this all animals were removed to indoors and were housed in the same cages as earlier in constantly running and partly circulated tap water. In indoor system temperature was continuously stable (approx. 6°C). The experiment ended September 25.

Crayfish were fed at the end of the outdoors period and whole indoor period with fish and sprouts of the peas. To record gastrolith growth with X-ray radiography a Philips XG 2000 X-ray unit operated at a tube current of 25-45 kV for 0.3-0.4 sec was used in conjunction with Kodak Min-R-E mammography X-ray film. The first X-ray images were taken in August 8. During August and September there were 15 exposures for noble crayfish and 14 for signal crayfish (August 8, 18, 19, 20, 26, 27, 28, 29 and September 1, 3, 4, 8, 9, 10 and 25).

Length, width, area and roundness of gastroliths were measured from X-ray images with Leica Quantimet 500+ image analysis system (those results not included in this paper).

3 Results

During the experiment noble crayfish juveniles molted more than signal crayfish juveniles (Table 1) Total number of moulted animals were 87 (39.5 %). Almost all moults occurred during the outdoor period. Maximum increase in carapace length per moult was 2.0 mm in signal crayfish and only 0.1 mm less in noble crayfish (Table 1).

Table 1 *Crayfish used in this experiment, SD of the average of carapace length = 1.0 for both species. Data on moulting, gastroliths and growth/moult, SD of the average = 0.5 for both species.*

Species	number of crayfish	carapace length mm	crayfish moulted	N	Average	Min	Max	crayfish without gastroliths
P. leniusculus	110	9.0	36 (32.7%)	24	0.8	0.1	2	17 (15.5%)
A. astacus	110	8.6	51 (46.4%)	41	0.9	0.1	1.9	23 (20.9%)

Calcium deposition in the epithelial pockets of the cardiac stomach initiated approx. two weeks before moulting (Fig. 1). For some individuals in both species this process progressed very fast and took only 6-8 days. The rate of reabsorption was high and usually complete with in 1 to 2 days (Fig. 2).

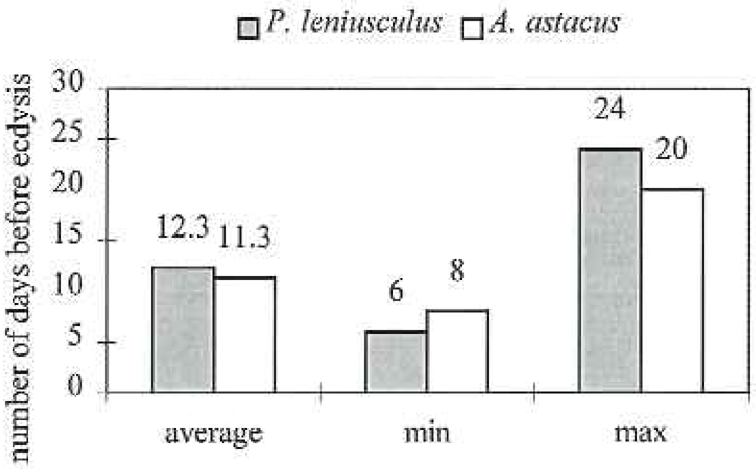

Fig. 1 *Gastroliths formation before ecdysis in P. leniusculus (N = 20, SD of the average = 4.1) and A. astacus (N = 22, SD = 3.3).*

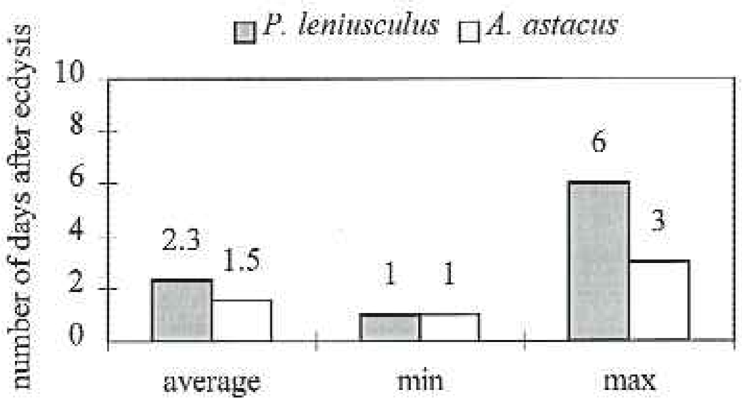

Fig. 2 *Gastroliths reabsorption after ecdysis in P. leniusculus (N = 13, SD of the average = 1.4) and A. astacus (N = 19, SD = 0.7).*

Gastroliths exist continuously for three weeks in some animals (Fig. 3). Completely without gastroliths were 40 individuals (18.2 %), animals of both species were among this group (Table 1).

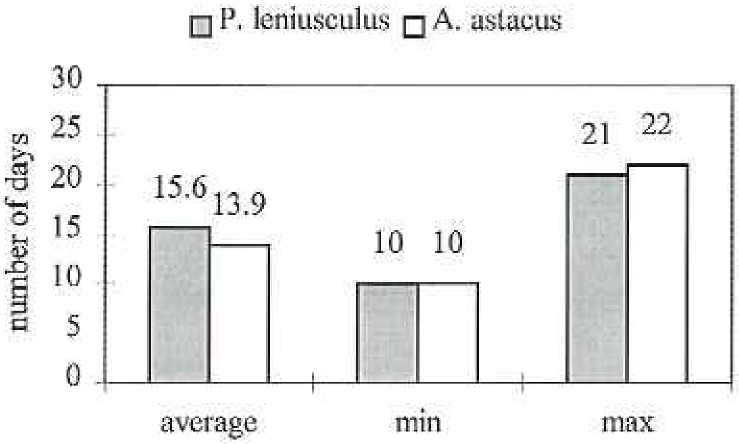

Fig. 3 *Duration of the period (number of days) from gastroliths appearance to their reabsorption in P. leniusculus (N = 11, SD of the average = 3.0) and A. astacus (N = 19, SD = 3.5).*

Mortality of noble crayfish juveniles was much higher than signal crayfish juveniles (Table 2), especially when removed from outdoors to indoors. Nine *P. leniusculus* juveniles died during outdoor period and only four when housed in indoor system. For *A. astacus* juveniles the numbers were 25 and 49, respectively.

Table 2 *Crayfish mortality during the experiment. Range of temperature recorded outdoors was from 12.9 C to 21.0 °C. Indoor temperature was continuously stable (approx. 16 °C).*

Species	Crayfish mortality in outdoors Aug. 8 - Sep. 10	Crayfish mortality after removal from outdoors to indoors Sep. 11 - 25	Crayfish mortality during the whole experiment
P. leniusculus	9 (8.2 %)	4 (4.0 %)	13 (11.8 %)
A. astacus	25 (22.7 %) +	49 (57.6 %) =	74 (67.3 %)
Total	34 (15.5 %) +	53 (28.5 %) =	87 (39.5 %)

4 Discussion and conclusions

By use of X-ray visualisation of calcium deposition it is possible to follow individual animals through the premoult period by non-sacrifice means. Gastroliths were visible even 20-21 days before ecdysis in two months old signal crayfish and noble crayfish

Freshwater crayfish virus research in Finland: state of the art

Pieturi Paasonen[1], Brett Edgerton[2], Hannele Tapiovaara[3], Timo Halonen[1] & Paula Henttonen[1]
[1] Department of Applied Zoology and Veterinary Medicine, University of Kuopio,
P.O. Box 1627, 70211 Kuopio, Finland
[2]Oonoonba Veterinary Laboratory, Queensland Department of Primary Industries,
P.O. Box 1085, Townsville, Queensland 4810, Australia
[3]Department of Virology, National Veterinary and Food Research Institute,
P.O. Box 00231, Helsinki, Finland

Abstract

Some new prevalence and preliminary *in vitro* cell culture studies were carried out for the detection and isolation of a recently found freshwater crayfish virus, *Astacus astacus* Bacilliform Virus (AaBV) in Finland. Histopathologically, the lesions characteristics of AaBV were observed in all five surveyed native *Astacus astacus* populations. Prevalence rates varied from 5.0 % to 100.0 %. The intensivity of infection was very high in some populations. AaBV caused no cytopathic effect (CPE) in five established fish cell lines BF-2, FHM, CHSE, RTG and EPC or in an insect cell line Sf 9. In an effort to produce primary cell cultures, some amebocyte-like cells of putative haemopoietic tissue attached to the surface of the culture flask, aggregated and emitted pseudopod-like structures to form larger cell aggregations. Of four different growth media tested, Leibowitz (L-15) in double concentration was the best growth medium for *A. astacus* cells. This is the first report of an attempt to culture a freshwater crayfish virus in a cell culture.

1 Introduction

In Finland, the disease research and diagnostics of the freshwater crayfish, *Astacus astacus*, are mainly focused on crayfish plague caused by fungus, *Aphanomyces astaci*, white-tail disease caused by sporozoan, *Thelohania contejeani*, and the parasite *Psorospermium haeckeli*. Viral infections of freshwater decapod crustacean have remained unknown until the initial discovery of a virus infection in the red claw crayfish, *Cherax quadricarinatus*, in the tropical Australia. The virus was named *Cherax* baculovirus (CBV) as described in the other paper (Anderson & Prior 1992). According to Edgerton et al. (1994), Hedrick et al. (1995), Edgerton et al. (1996), Edgerton (1996) and Edgerton et al. (1997), five other freshwater crayfish viruses have now been described.

In the summer, 1995, the very first virus was found in the European freshwater crayfish. This virus, named *Astacus astacus* bacilliform virus (AaBV), was discovered during a brief histopathological survey in Finland. According to Edgerton et al. (1996), AaBV is an intranuclear bacilliform virus and it infects the hepatopancreas, the midgut, midgut caecum and tegmental glands at the junction of hindgut of *A. astacus*. However, no clinical symptoms of an illness caused by this virus have been detected. By light microscopy, the lesions are easily seen as eosinophilic inclusions and chromatin margination in the infected nuclei. Depending on the intensity of the infection, 1-4 eosinophilic inclusion bodies are seen in the nucleoplasm. AaBV shares many morphological characteristics with other freshwater crayfish and shrimp bacilliform viruses. The nucleocapsid of the virion is rod-shaped and a true cylinder, and is covered by trilaminar envelope. Like many other crustacean gut-infecting bacilliform viruses the virion contains an apical cap, tail-like structure and subapical unilateral envelope expansion as described in the other paper (Johnson & Lightner 1988). The virus does not form occlusion bodies.

Currently, freshwater crayfish virus research has to rely on histopathology and electron microscopy. The lack of simple *in vitro* techniques such as an established cell line or reliable primary cell culture methods prevent succesfull virus isolation and characterisation. Thus, there is no information of gene sequences of these viruses. The taxonomic position and relatedness to insect baculoviruses remain also unresolved until the genomic construction is clarified. The purification of the virus from the fresh tissue is time-consuming and a great number of heavily infected animals are needed for this purpose. Fortunately, the European AaBV is the best candidate from all freshwater crayfish viruses for the purification because some heavily infected populations exist in Finland as described in other paper (Edgerton et al. 1996) (see also this report).

This paper describes the prevalence of *Astacus astacus* bacilliform virus in some native *A. astacus* populations in Finland. Some preliminary *in vitro* infectivity studies in established fish cell lines and a primary cell culture effort are also reported and discussed here.

2 Materials and methods

2.1 Prevalence study

To elucidate the distribution of AaBV in native *A. astacus* populations in Finland, five populations were surveyed during the years 1995-1998. The collection sites and years, together with numbers of examined animals are summarized in Table 1. Collection sites are also shown in map (Fig. 1). All examined crayfish were adults. Males and females were chosen randomly. Briefly, all crayfish were either sacrificed immediately after trapping or reared in tanks in a flow-through water system at Kuopio University Fish Research Unit for several days. When reared in tanks, frozen roach (*Rutilus rutilus*), carrots and leaves of alder (*Alnus glutinosa*) were offered daily to the crayfish. For the histopathological survey, the crayfish were sacrificed by severing the cephalothorax from the tail. The cephalothoraxes were preserved in Davidson's solution. After fixation for 1-7 days, hepatopancreata were removed and tissue samples were processed in a grading series of ethanols and xylene and embedded in paraffin. 4 µm slices were cut using Reichert - Jung Mod. Hn 40 microtome. All samples were stained conventionally, using Mayer's Haematoxylin and Young's Eosin. Sections were observed using Nikon Labopohot - 2 and Leitz Dialux 22 - light microscopes at magnifications of 250 x and 400 x. The prevalence of the virus was reported according to Margolis et al. (1982).

2.2 The preliminary infectivity study of AaBV in established cell lines

Five established fish cell lines and one insect cell line were used to study the growth of AaBV in cell culture. Fish cell lines were chosen to study the possibility that the fish might be vectors of the crayfish virus in aquatic environment and therefore, can be infected by this virus. An insect cell line was used because some insect baculoviruses can be cultured in this cell line. Cell lines included: RTG (rainbow trout gonads), BF-2 (bluegill fry, caudal trunk), CHSE (chinese salmon embryo), FHM (fathead minnow), EPC (epithelioma papulosum cyprini) and an insect cell line Sf 9 (*Spodoptera frugiperda* ovaries). The growth medium used in fish cell lines was Eagle's MEM (Gibco® BRL, Life Technologies) supplemented with 10 % fetal bovine serum (FBS), 2mM L-glutamine, 1 % non-essential amino-acids (neaa), 2 00 IU/ml penicillin and 4 mg/ml streptomycin. Express Five SFM (Gibco®) based growth medium was used in insect cells. Supplements were the same as in fish cell line growth medium with the addition of 0.5 µm/ml Fungizone.

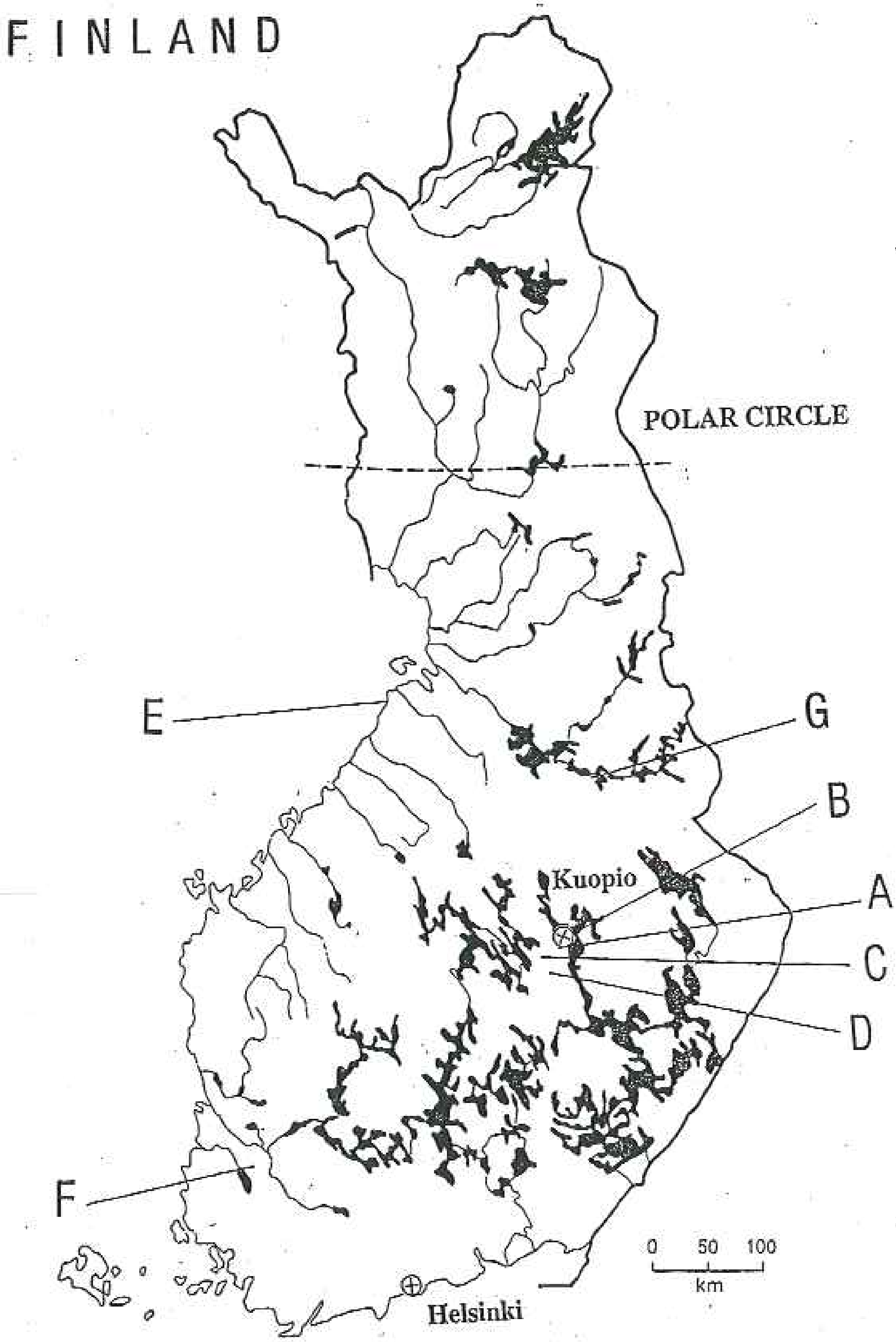

Fig. 1 *Map shows the sampling sites, where the crayfish have been collected for determing the distribution of* Astacus astacus *Bacilliform Virus in native* Astacus astacus *populations in Finland. A = Pond North Valkealmpi, B = Pond Valkeinen, C = Lake Suurlauas, D = River Kutunjoki, E = Reservoir Kuljunlahti, F = River Köyliönjoki, G = River Jormasjoki.*

Infective suspension was made using heavily infective animals from the Pond Valkealampi population. The infectivity was examined by histopathology as described above. The hepatopancreata of highly infective animals were removed and the virus was isolated from tissue homogenate of infected crayfish diluted 1:10 in fish cell culture medium. Infective suspension was supplemented with additional antibiotics (2 000 IU/ml penicillin, 4 mg/ml streptomycin and 20 IU/ml nystatin). To ensure that suspension contains virions, a drop of viral suspension was pipetted in a formvar-coated carbon-stabilized copper grid, incubated 20 s, dried with filter paper and stained with 2 % phosphowolframacid for 20 s and stored in – 4 ° C. Negatively stained virions were identified using JEOL JEM 100S transmission electron microscopy (TEM). Viral suspension was inoculated to one-day old subconfluent or confluent cell cultures in two dilutions (10^{-1} and 10^{-2}). Culturing of crayfish virus was attempted in fish cell lines with CO_2 for three passages at + 16 ° C and three passages at + 27 ° C (without CO_2) in an insect cell line. The growth pattern was observed daily using an OLYMPUS CK – 2 light microscopy.

To study if AaBV is capable of infecting insect cells without causing any kind of cytopathic effect (CPE), some of the infected Sf 9 cells were stained with H & E. Infected cell cultures were grown in 24 multi-well dishes (Nunclon™). The growth medium was then removed and the cells were washed with sterile NaCl. Cells were fixed with methanol and incubated at the room temperature (+ 23 ° C) for 10 min. After the incubation, methanol was removed, cells were dried (- 4 ° C) for 24 hours and stained with H & E.

2.3 Primary cell culture

Approximately four months old *A. astacus* juveniles (mean total length 2.5 cm) were used in primary cell culture. The crayfish were obtained from the Finnish Game and Fisheries Research Institute (FGFRI) at the Evo Research Station, where the crayfish had been cultured in earthern ponds (density ≈ 15 crayfish/m^2). Crayfish were surface-sterilized by dipping them in 70 % denaturated ethanol tincture containing 2 % iodine according to Ke et al. (1990). Tincture was then washed off by dipping crayfish in phosphate buffered saline (PBS), supplemented with 2 00 IU/ml penicillin and 4 mg/ml streptomycin.

Tissues (haemopoietic tissue, hepatopancreas, gills and eyes) were removed with sterile techniques using sterile scissors and forceps. Tissues were placed in PBS with the antibiotics. To obtain isolated cells from the tissue, hepatopancreata were minced by pipetting the tissue fragments up and down in growth medium. Fragments were in 1 mm^3

in size. Gills were dissociated either mechanically or enzymatically using trypsin. Eyes were dissociated mechanically using a sterile syringe plunger. Primary cell cultures were initiated in 25 cm^2 culture flasks. Cells were cultured at + 23 ° C without CO_2.

In this study, four different Gibco's growth media were used in primary cell cultures. Basal growth media used were: Schneider's Drosophila Medium with L-glutamine, Express Five SFM without L-glutamine, Leibowitz-15 (L-15) with L-glutamine (in double concentration) and Dulbecco's Modified Eagle Medium (high glucose) with L-glutamine and D-glucose (4 500 mg/ml) and without sodium pyruvate. All culture media were supplemented with 20 % FBS, 2 00 IU/ml penicillin, 4 mg/ml streptomycin, 1 % neaa, 2 mM L-glutamine and 0.5 µg/ml Fungizone. Fresh culture medium was added weekly to the cells. Some of the culture flasks were treated with collagenase (type I). All media and supplements used in this study were sterile. FBS was heat-inactivated before use. The vitality of cells were observed using Trypan Blue staining.

3 Results

3.1 Prevalence study

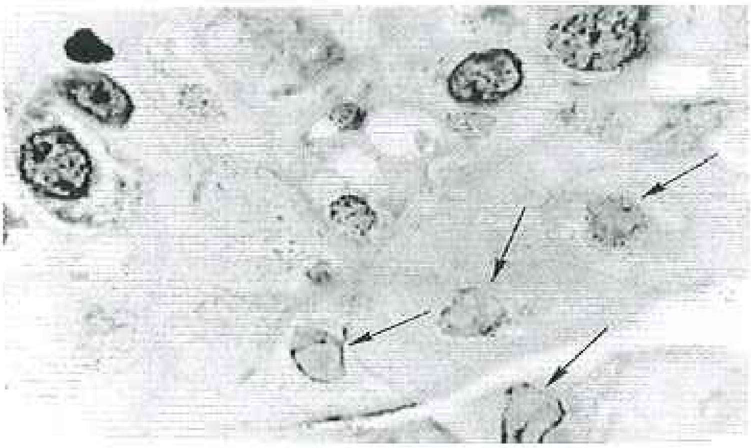

Fig. 2 *Histopathology of the hepatopancreas of* Astacus astacus. *Note that infetced nuclei (arrows are irregularly shaped and there is marginated chromatin and eosinophilic inclusions in the nucleoplasm. H & E. 800 x.*

AaBV was present in all surveyed populations. The prevalence was highest in River Jormasjoki (100.0 %) and in Pond North Valkealampi populations (93.8 %). In these populations, the intensivities of the infections were often high. In Reservoir Kuljunlahti, the intensivity was also very high, although prevalence was less at 64.0 %. In two other populations (Pond Valkeinen, River Köyliönjoki), intensivity was low, only few cells being infected by AaBV (Table 1). An example of AaBV infection is presented in Fig. 2.

3.2 The preliminary infectivity study of AaBV in established cell lines

No cytopathic effect was observed in established cell lines. Toxic effect caused by autolytic enzymes originated from minced hepatopancreata of *A. astacus* was common in the first passage but this pattern disappeared in the next two passages. No inclusion bodies were observed in H & E-stained *S. frugiperda* ovarian cells.

3.3 Primary cell culture

Cells originated from the putative haemopoietic tissue attached to the vessel surface and started to grow within two days after the initiation of primary cell culture. Cells were amebocyte-like having length of 3-6 µm. Cells aggregated within three days and emitted pseudopod-like structures to form larger aggregations (Fig. 3). Some of these aggregations of amebocyte-like cells detached from the bottom of the culture flask, floated off and reattached to the other areas of the container. Some of the cells remained vital for three weeks. Despite the growth, a confluent monolayer was never obtained.

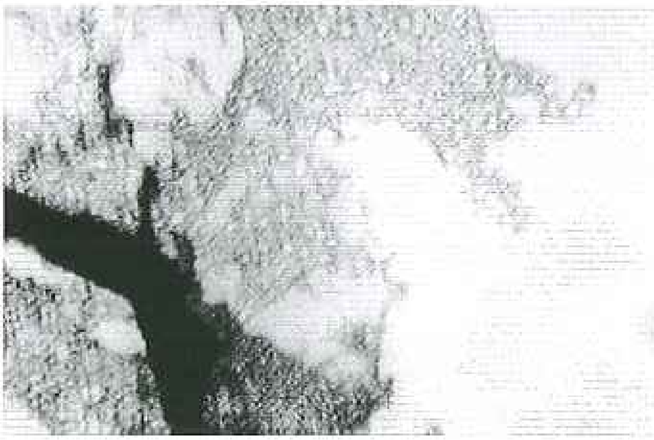

Fig. 3 *The aggregation of amebocyte-like cells of putative haemopoietic tissue of Astacus astacus 530 x.*

Few cells from the hepatopancreas attached to the flask surface within two days from the initiation of cell culture. More cells and tissue fragments attached within six days. Some of the cells showed mitotic activity. Some hepatopancreatic tubuli were also attached to the surface. Single cells remained vital for two weeks. When half of the growth medium was eighth days after initiation some of the non-attached cells in old growth medium attached to the surface of a new culture flask, showing that cells were vital.

Cells originating from gills and eyes showed minimal growth pattern. Only few cells from eyes attached to the flask surface.

The maximum growth in primary cell cultures was obtained in 2 x L-15-based growth medium. There was no difference in terms of cell growth between uncoated and collagenase-coated culture flasks.

Table 1 *The Prevalence of Astacus astacus bacilliform virus (AaBV) in some native* Astacus astacus *population in Finland. Table contains also the prevalence rates of AaBV from the previous survey as described in the other paper (Edgerton et al. 1996). The collection sites included in this paper are referred as a bold text.*

Collection Site (and Code)	Collection Year(s)	Number of animals examined (n)	Prevalence
Pond North Valkealampi (A)	1995, **1997**	15, **48**	100.0%, **93.8%**
Pond Valkeinen (B)	1995, **1997**	15, **14**	53.3%, **71.4%**
Lake Suurlauas (C)	1995	15	100.0%
River Kutunjoki, upstream (D)	1995	15	100.0%
River Kuntunjoki, downstream (D)	1995	15	100.0%
Reservoir Kuljunlahti (E)	**1995**	**50**	**64.0%**
River Köyliönjoki (F)	**1998**	**20**	**5.0%**
River Jormasjoki (G)	**1997**	**15**	**100.0%**

4 Discussion

As described here and in the other paper (Edgerton et al. 1996), the prevalence of AaBV is often very high in native *A. astacus* populations in Finland. However, the prevalence of AaBV was only 5.0 % in River Köyliönjoki population. This is the first report of such a low prevalence rate of AaBV. Low prevalence rate in this population might be due to different zooplankton and benthos fauna to other surveyed populations. Zooplankton may act as carriers of this freshwater crayfish virus as it is in the case with the penaeid virus, *Baculovirus penaei* (BP), as described in the other paper (Overstreet et al. 1988). According to Anderson & Prior (1992), Groff et al. (1993), Edgerton et al. (1995) and Edgerton (1996), the prevalence of other freshwater crayfish bacilliform viruses have never exceeded the prevalence of *Astacus astacus* bacilliform virus. According to Groff et al. (1993), the prevalence of *Cherax quadricarinatus* bacilliform virus (CqBV) was 92.0 % in the USA. However, the number of infected cells never exceeded 10 % of the cells constituting the hepatopancreatic tubular epithelium. As described in other papers (Anderson & Prior 1992, Edgerton et al. 1995), the prevalence of CqBV has been 52.0 % and 59.1 % in farmed red claw crayfish, *C. quadricarinatus*, in the tropical Australia. According to Edgerton (1996), 33.3 % prevalence of *Cherax destructor* bacilliform virus (CqBV) has been reported in farmed *C. destructor* in Australia. There are no prevalence data for *Pacifastacus leniusculus* bacilliform virus (PlBV). According to Hedrick et al. (1995) PlBV infects the signal crayfish, *P. leniusculus* in the USA.

Based on our *in vitro* studies, the replication mechanism of AaBV is different from that of some insect baculoviruses. This freshwater crayfish bacilliform virus can not be cultured in Sf 9 cell line. Our preliminary infectivity studies in established fish cell lines show that AaBV does not infect fish cell lines routinely used in laboratories all over the world for the detection of fish viruses. This finding confirms that this bacilliform virus is very likely an invertebrate virus.

The cells of putative haemopoietic tissue showed the best mitotic activity and attachment in attempts to produce a primary cell culture. However, these cell cultures can not be used for the isolation of crayfish viruses due the absence of confluent monolayer cell sheets. From four different growth medium tested, Leibowitz (L-15) in double concentration was found to be the best basal growth medium for *A. astacus* cells. This finding is in agreement with some shrimp primary cell culture studies as described in the other papers (Chen et al. 1986, Nadala et al. 1993, Hsu et al. 1995). Our cell culture studies provide a valuable starting point for the development of reliable *in vitro* cell culture methods for the isolation of freshwater crayfish bacilliform viruses. The lack of reliable *in vitro* techniques causes several problems in freshwater crayfish virology. The taxonomic position of freshwater bacilliform crayfish viruses is unknown because no means of *in vitro* amplification exist. The four crayfish bacilliform viruses resemble the former subgroup C, non-occluded baculoviruses of the family *Baculoviridae* as described in the other paper (Francki et al.1991).

According to Murphy et al. (1995), this subgroup was dropped in the most recent meeting of the International Committee on taxonomy of Viruses and the taxonomic position and relatedness to nucleopolyhedrosis and granulosis baculoviruses remains unclear. The lack of *in vitro* isolation techniques to allow the detection of latent infections from the infected crayfish. By histopathology, only advanced viral lesions can be detected.

In addition, studies on the replication mechanism and kinetics of AaBV is hampered due to absence of the virus culture methods. Future work should concentrate on developing a crustacean cell line. Until then, the state of the crayfish virology remains somewhat primitive.

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Fecundity of Lithuanian crayfish *Astacus astacus* and *Orconectes limosus* in various natural habitats

Lina Vozgirdaitė
Vilnius University, Ciurlionio 21/27
LT - 2600 Vilnius, Lithuania

Abstract

Fecundity of *Astacus astacus* populations was examined in twelve water bodies, fecundity of *Orconectes limosus* population was examined in one water body. Relationship between crayfish females body length and number of oocytes was investigated. Relationship between crayfish females fecundity and water body parameters was determinated. According to our results the fecundity of alien species *Orconectes limosus* is significantly higher than native crayfish species *Astacus astacus* fecundity.

1 Introduction

Reproducing of each animal species is the main species existence condition. Process of species reproducing is the main and the most responsible life stage. All other animal species life stages serve to succesful realization of reproducing process. If we know about crayfish reproducing process in some more details, we could establish crayfish protection parameters which the most important aim is to protect crayfish during their reproducing period. Only precise knowledge about crayfish reproducing time can help us to establish crayfish protection parameters when the capturing of these animals would be limited.

According to various data of crayfish researchers, noble crayfish mature three – four years old. In very good living conditions noble crayfish mature with 80 mm body length, in good living conditions noble crayfish mature with 70-80 mm body length and in bad conditions they mature with 67-70 mm body length (Smolian 1928). According to another authors data (Arnolds 1929) there were 2.8% of mature noble crayfish females in 65-79 mm length group, 11% in 80-84 mm length group, 22% in 85 mm length group, 34.7% in 90 mm length group, 59% in 95 mm length group, 80% in 100 mm length group and 95% in 100-104 mm length group. In Estonian water bodies noble crayfish males mature two years old with 60-80 mm body length and females mature three years old with 80-89 mm body length (Jarvekulg 1958). In Lithuanian water bodies noble crayfish females mature three years old with 80 mm body length and males mature two years old with 70 mm body length (Cukerzis 1970).

The aim of this work was to examine fecundity of different crayfish species found in Lithuania and its relationship with habitat parameters.

To accomplish this aim some tasks were raised:

- To examine fecundity of different crayfish species: *Astacus astacus* and *Orconectes limosus.*
- To examine relationship of different crayfish species fecundity with habitat parameters.
- To examine dynamics of different crayfish species fecundity in their distribution area ranges.
- To examine importance of alien crayfish species fecundity to their distribution in Lithuanian water bodies.

2 Methods

Fecundity of two crayfish species found in Lithuania were examined: *Astacus astacus* in twelve water bodies and *Orconectes limosus* in one water body. In autumn (september – october) five crayfish females were chosen of each length group in every water body. Crayfish females were cooked, their ovaries were taken out and ovarian eggs were calculated. In spring and early summer pleopod eggs of egg carrying females were stripped from the pleopods, they were counted and weighed, their diameter was measured. Amending the collected material with regression analysis methods relationship between ovarian egg number and body length was examined and egg number was calculated in 90 mm length and habitat parameters was calculated, area and depth of water body and parameters of water quality.

3 Results and Discussion

Investigation results showed that ovarian egg number increased with *Astacus astacus* crayfish female body length. The ovarian egg number ranged from 102.5 to 208.4 in 90 mm length group, the mean number was 150.4. The mean ovarian egg number of

Orconectes limosus population was 490.7 in 90 mm length group (Table 1).

Table 1 *Fecundity (number of oocytes) of crayfish Astacus astacus and Orconectes limosus relationship with females body lenght*

No	Water body	Regresion equation	N	r^2	p	syx	Number of oocytes in 90mm lenght group
			Astacus astacus populations				
1	Ragaþius	y=2x + 28.4	6	0.40	0.1600	27.00	208.4
2	Berþinis	y=5x - 274.7	17	0.50	0.0120	39.40	175.3
3	Vygrio	y=5x - 270.4	16	0.90	0.0001	22.90	179.6
4	Trikojis	y=2.9x - 89.14	16	0.74	0.0001	18.60	171.8
5	Gailintas	y=2.3 - 100.49	66	0.48	0.0001	20.95	106.5
6	Verniejus	y=2.26x - 99.7	31	0.50	0.0001	18.54	103.7
7	Vidinkstas	y=3.27x - 191.78	19	0.57	0.0002	24.74	102.5
8	Liedis	y=5.08x-319.52	40	0.75	0.0010	21.35	137.8
9	Ðamukas	y=4.40x-256.30	45	0.46	0.0010	36.76	139.4
10	R. Ðirvinta	y=3.6x - 186.1	9	0.35	0.1000	31.30	137.9
11	R. Musë	y=4.8x - 234.5	5	0.70	0.0800	28.10	197.5
			Orconectes limosus population				
1	Pastovys	y=0.11x+480.85	5	0.01	0.9872	116.1	490.7

Correlation was determined between crayfish fecundity and hydrological and hydrochemical parameters of water body, precisely between fecundity and area of water body, area of sandy bottom of water body, acidity (pH), alkalinity, permanganate oxidation of water body. Relationship between alkalinity, acidity, area of sandy bottom and crayfish population fecundity was direct. If these mentioned hydrological and hydrochemical water body parameters increased, crayfish fecundity increased too. Relationship between area of water body, permanganate oxidation and crayfish fecundity was inverse (Table 2).

Table 2 *Relationship between noble crayfish Astacus astacus fecundity (number of oocytes) and habitat parameters*

No	Parameter	N	r^2	p	Regression equation
1	Area, ha	7	0.773	0.009	y= -0.9x - 202.6
2	Sand, ha	4	0.623	0.211	y= 4.5x + 193.6
3	Water pH	7	0.640	0.030	y= 69.3x - 397.6
4	Oxygen, mg/l	7	0.640	0.030	y= - 15.3x + 255.8
5	Alkalinity, mg/l	7	0.800	0.007	y= 2..5x - 205.6

4 Conclusions

1. Fecundity of crayfish females in 90 mm length group:

    Astacus astacus - 150.4

    Orconectes limosus - 490.7

2. Correlation was found between *Astacus astacus* fecundity and:

    (-)Area of the lake

    Area of sandy bottom

    pH

    Alkalinity

    (-)Permanganate oxidation

3. *Astacus astacus* is the only native crayfish species in Lithuania and Lithuania is a center of the areal of its distribution..

4.The fecundity of *Orconectes limosus* is significantly higher than fecundity of native crayfish *A. astacus*. It may cause intensive and aggressive spreading of this crayfish species in Lithuanian water bodies.

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Relationship between Lithuanian crayfish of different spieces: distribution, population parameters and habitats

Tadas Karaliunas
Vilnius University, Ciurlionio 21/27,
LT - 2600 Vilnius, Lithuania

Abstract

Three crayfish species *Astacus astacus, Astacus leptodactylus* and *Orconectes limosus* were investigated. *Astacus astacus* populations were investigated in 13 lakes, *Astacus leptodactylus* populations in 2, and *Orconectes limosus* populations were investigated in 2 lakes. Crayfish were collected using standard traps for crayfish, after that CPUE (catch per unit effort) were calculated. Results showed that the most dense populations in Lithuania were of noble crayfish. Trying to examine relationship between parameters of water body and CPUE, correlations were calculated. Our data showed that there are no correlation betweeen total area of water body and CPUE. Investigations of coexisting *A. astacus* and *A. leptodactylus* in Lake Liedaitis have showed, that *A. leptodactylus* outcompetes *A. astacus.*

1 Introduction

Four crayfish species are found in Lithuania: noble crayfish (*Astacus astacus* L.), narrow-clawed crayfish (*Astacus leptodactylus* Esh.), signal crayfish (*Pacifastacus leniusculus* Dana) and spiny-cheek crayfish (*Orconectes limosus* Raf.). Only noble crayfish is native.

There are information on 616 noble crayfish localities, but 50% information about noble crayfish localities are of old standing and crayfish probably no longer exist in these localities. There are information on 48 localities with *A. leptodactylus*. The information is of old standing and crayfish probably no longer exist in 21 localities (Taugbøl et al. 1998). *Pacifastacus leniusculus* was introduced into water bodies of Lithuania in 1972. *O limosus* population was found in Lake Ruskis in 1994.

The *Astacus astacus* area center is in the Baltic countries (Cukerzis 1970). The *Astacus leptodactylus* area edge is in north-western part of Lithuania. One of the reasons of its appearing in Lithuanian water bodies was an intentional introduction to interior water bodies when natural resources of *Astacus astacus* decreased significantly.

The investigations of *Astacus astacus* natural habitat, its relation with other crayfish species, determination of its perspectives in interior water bodies are extremely urgent because *Astacus astacus* is the most valuable and wide spread species in Lithuania. Every species has it's zone of the ecological optimum (ZEO), e.c. in definite geographical latitude and longitude, individuals and populations use the least amount of energy for their adaptation therefore they are most vital and appreciated in genetics field (Volskis 1997). Because crayfish are freshwater animals, their populations should be influenced by the same habitat factors (parameters) as freshwater fish, e.c. maximum and minimum depth of water body, area of water body, overgrowing, acidity (pH), the oxygen amount in water body and so on. The specific characteristic of crayfish water bodies is useful area for crayfish of water body. Specific parameter only for noble crayfish is the amount of hiding-places or the amount of potentially suitable places for their building (Kossakowskii 1966, Cukerzis 1970). Cukerzis have determinated optimal for noble crayfish lake parameters (Table 1). According to his classification crayfish abundance in optimal for noble crayfish lakes should be a CPUE of 8-9 individuals.

Astacus leptodactylus, as all Ponto-Caspian basin species, is eurobiotic (Brodski 1983), and natural hiding places are unevenness of bottom, submerged stones, logs, stumps, thickets of underwater plants, different objects lying on the bottom (Kossakowski 1966), that means that it can occupy bottom areas and water bodies unsuitable for *A. Astacus*.

Orconectes limosus, are even less fastidious, as regards hiding-places. They usually dwell on shallows, both in submerged meadows and on sandy bottoms, on stony bottoms or along embankments of canals in harbours, etc (Kossakowski 1966).

Astacus leptodactylus is found for one hundred years in Lithuania but it's distribution area does not reach further than north-western part of Lithuania.

Orconectes limosus spreads from Poland and Kaliningrad (Burba 1994), but its further perspectives is not clear in Lithuanian water bodies. *O.limosus* was found in two thirds of thePoland territory passing after its introduction (Kossakowskii 1966).

Table 1 *Typology of water bodies suitable for Astacus astacus (Cukerzis, 1988)*

Environmental conditions	Optimal	Medium	Possible
Area (ha)	Less than 50	Less than 100	More than 100
Average depth (m)	5-15	10-20	More than 20
Maximum depth (m)	10-20	20-30	More than 30
Bank line	Well developed	Average	Weak
Character of bottom	Compact, limey	Varied	Varied
Silt	Compact, detrital	Varied	Thin
Transparency (m)	1-2	About 1	Below 1
Oxygenation (mgO_2/l)	9-12	7-9	Below 7
PH	7-8	6-8	6-8
Ca''(mg eq/l)	About 3	About 2	About 1
Summer temperature (°C)	18-22	16-24	14-26
Aquatic vegetation width of the zone (m)	10-20	5-10	Less than 5
Bottom vegetation (percentage of total area)	50-80	30-50	Less than 30
Plankton (mg/m^3)	45-55	35-45	Less than 30
Benthos (mg/m^2)	More than 150	More than 100	Less than 100
Useful space (percentage of total area)	More than 25	10-25	Less than 10
Crayfish catches (specimen/trap/night)	8-9	4-5	1-2
Crayfish productivity (kg/ha)	More than 50 (excellent)	10-50 (moderate)	Less than 10

2 Materials and methods

Astacus astacus was investigated in thirteen lakes. Lakes were investigated which had 8.5-110 ha area; 6.1-50 m maximum and 2.9-12.5 average depth (Table 2). *Astacus leptodactylus* was investigated in two lakes with total areas 550 ha and 49.3 ha (Table 2).

Orconectes limosus was investigated in two lakes either which differed significantly in their area (4.4 and 252.1) (Table 2).

The investigations of water bodies inhabited by crayfish and crayfish populations were carried out as follows:
Before sunset (at 7-9 p.m.) ~50 (no less than 30) crayfish two-funnel traps (420 mm length and 240 mm diameter, mesh size 14 mm) baited with bream or roach were attached in the lake or river not far from the shore at 5-7 m intervals and set in the depth 1-3 m. Traps were lifted at sunrise and the number of crayfish in every trap and the parameters of catch area were registered. The analysis of caught crayfish was carried out as follows: all crayfish were weighted to the nearest gram and measured to the nearest mm TL, the sex of animals registered. The number of crayfish infected with visually seen diseases were registered. Animals infected with *Branchiobdella* sp.

were registered. Crayfish molting phases were registered. Crayfish cheliped loss was registered. Color variations of animals were registered. In autumn the number of mature females was registered.

Table 2 *Parameters of examined crayfish water bodies*

N	Lake	Total area(ha)	Maximum epth(m)	Average epth(m)
Astacus astacus				
1.	Atesys	110	13.9	6.8
2.	Verniejus	107.2	50	12.5
3.	Alnis	104.4	-	-
4.	Antakmeniu	85.6	-	-
5.	Vazajis	77.7	-	-
6.	Sariai	75.4	-	-
7.	Gailintas	66	32.5	9.2
8.	Liedis	65.5	6.1	2.9
9.	Vabaliu	59	20.6	4.4
10.	Liskiavis	58.5	21.1	7.2
11.	Ragazius	30.7	9	4.6
12.	Gilse	10.6	-	-
13.	Samukas	8.5	-	-
Astacus leptodactylus				
1.	Apvardai	550	4.9	2.6
2.	Juzintai	49.3	9.4	4.5
Orconectes limosus				
1.	Ruskis	4.4	-	-
2.	Seiros-Ancios basin	252.1	-	-

3 Results and discussion

Astacus astacus

Carried out investigations have showed that CPUE in thirteen lakes ranged from 0.3 to 13.6 (Table 3)

Table 3 *Predominate crayfish length groups and cpue in examined water bodies*

	Lake	Predominate length group (mm)			CPUE
		Average male length	Average female length	Mean total length	
Astacus astacus					
1.	Atesys	120	95	120	0.6
2.	Verniejus	95	90	90	6.5
3.	Alnis	-	-	100	0.6
4.	Antakmeniu	-	-	100	2.5
5.	Vazajis	-	-	95	0.3
6.	Sariai	95	90	90	13.6
7.	Gailintas	100	90	90	7.4
8.	Liedis	100	95	100	3.1
9.	Vabaliu	120	105	110	2.4
10.	Liskiavis	95	85	85	4.3
11.	Ragazius	115	95	100	0.3
12.	Gilse	-	-	100	5.0
13.	Samukas	100	90	100	2.4
Astacus leptodactylus					
1.	Apvardai	105	95	105	2.1
2.	Juzintai	110	100	105	1.8
Orconectes limosus					
1.	Ruskis	95	105	85	1.0
2.	Seiros-Ancios basin	-	-	90	0.4

Trying to examine relation between parameters of water body and population abundance correlation's were counted (*Astacus astacus* only).

Correlation between CPUE and total area.

	Value	**Asymp. std.error**	**Approx. T.**	**Approx. sig.**
Pearson's R	0.026	0.311	0.086	0.933
Spearman correlation	0.22	0.274	0.073	0.943

Correlation between CPUE and average depth.

	Value	**Asymp. std.error**	**Approx. T.**	**Approx. sig.**
Pearson's R	0.445	0.226	1.142	0.305
Spearman correlation	0.464	0.350	1.172	0.294

Only lake Sariai CPUE (13.6) corresponds optimal crayfish lake parameters. The second biggest CPUE was found in Lake Verniejus, but its maximum depth (50 m) and total area (107.2 ha) belong to the available category.

Astacus leptodactylus

Investigation results have showed that CPUE is high 1.8 and 2.1. 105 mm crayfish length group predominates in both lakes. As we can see just both lakes differ significantly in their area and depth, crayfish abundance is not high enough as it could be in *Astacus astacus* species. *A. leptodactylus* does not spread mass in

Lithuanian lakes just one hundred years passed after it is introduction. If *A. leptodactylus* is found together with *A. astacus* in water body, *A. leptodactylus* outcompetes *A. astacus* (Cukerzis, 1970).

The Lake Liedaitis was investigated with coexisted *A. astacus* and *A. leptodactylus* populations (Table 4). Earlier only *A. astacus* was found in this lake. No data have been found how and when *A. leptodactylus* occupied this lake. About 80-90% of bottom is covered with thin silt.

Table 4 *Predominate crayfish lenght group and CPUE of Astacus astacus and Astacus leptodactylus in theLake Liedaitis*

Species	Average male length (mm)	Average female length (mm)	Mean total length (mm)	CPUE
A. astacus	100*	90	-	0.06
A. leptodactylus	125	130	125	0.4

* only one male of *Astacus astacus* was caught

A. astacus CPUE is approximately 7 time smaller than *A. leptodactylus*. *A. astacus* individuals are smaller too. We might draw a conclusion that *A. leptodactylus* outcompetes *A. astacus* population.

Orconectes limosus

O. limosus spreads in very different water bodies from hypertrophic Lake Ruskis to mesotrophic basin. CPUE is low high in both water bodies. *O. limosus* was found in Lithuanian river Ancia too.

4 Conclusions

According to our data *Astacus astacus* populations are most abundant. We might draw a conclusion that conditions of water bodies of Lithuania are suitable for them or entirely correspond to their ZEO.

Astacus leptodactylus did not spread widely in one hundred years just its toleration to habitat parameters allowed to do that.

O. limosus spreads in water bodies of vary environmental conditions. We think that such aggressive spreading in the future will allow for wide distribution in Lithuania.

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Study of some signal crayfish (*Pacifastacus leniusculus* Dana) populations in Vilnius region

Tomas Kolesinskas[1], Guoda Mackeviciene[2], Anatolij Terentjev[1] & Vytautas Mazeika[3]
[1]Vilnius University, Ciurlionio 21/27, 2001 Vilnius, Lithuania
[2]Institute of Ecology, Akademijos 2, 2600 Vilnius, Lithuania
[3]Nevardas Crayfish Station, Vilnius region, Visalauke

Abstract

Investigations into acclimatized signal crayfish (*Pacifastacus leniusculus* Dana) population density, their age and sex structure were carried out in the two lakes: Aukstutinis (A) Nevardas and Zemutinis (Z) Nevardas located in the first site of the introduction of signal crayfish from Sweden in 1972 (Vilnius region, Lithuania). According to the results of population study in 1995, after 23 years since the introduction, the abundance of signal crayfish population in A. Nevardas was 12,700 and the density was 3.6 ind./m^2. At the same time the population in Z. Nevardas was 14,200 (2.1 ind./m^2) - 16 years ago from introduction. The following age groups predominated in Lake A. Nevardas: 3+ (35%), 4+ (33%) and 2+ (17%), while crayfish in Z. Nevardas consisted of 2+ (24%), 3+ (22%) and 4+ (20%). The ecological study carried out in both lakes in 1997, showed a significant decrease in the signal crayfish population influenced by cold winter in 1996/97. Besides, a short cycle of the signal crayfish life (about 10 years) could have influenced the population abundance.

1 Introduction

According to Holdich (1998), it is essential to know the current distribution of native and alien species of crayfish - regionally, nationally and Europe-wide. There is a need for a European databank. The message is that as Europeans we need a much more unified effort to protect native crayfish and manage alien crayfish population (Holdich 1998).

Resources of native crayfish decreased in Lithuanian lakes and rivers because of the repeated outbreaks of crayfish plague which dates back to 1886 (Cukerzis 1989). Its last signs were observed in 1967 (Mazylis & Grigelis 1979). In order to restore crayfish stocks, Lithuania as other European countries (Finland, Poland, Germany, France), in 1972 imported legally 500 adult and 1,000 juveniles of signal crayfish (*Pacifastacus* *leniusculus* Dana) from Sweden. North-American crayfish species from California was found to be highly reproductive, rapidly growing and resistant to crayfish plague (Abrahamsson & Goldman 1970).

Mature signal crayfish were introduced into two isolated lakes with noble crayfish populations of high density. 92 crayfish with sex ratio 1:1.9 male:female were released into Lake Aukstutinis (A) Nevardas (Vilnius region) and 270 crayfish, male:female ratio 1:1.8 were stocked into Lake Berziukas (Trakai region) by Laboratory of Carcinology, headed by Professor Jakov Cukerzis, institute of Zoology and Parasitology (at present Ecology), the Lithuanian Academy of Sciences.

The results of acclimatization studies carried out in 1976 revealed that introduction and acclimatization of signal crayfish in Lake A. Nevardas were successful. In 1977 the crayfish population was 2,200 (density 0.78 ind./m^2). The results of introduction in Lake Berziukas were adverse. Death of native noble crayfish in both lakes after the introduction of signal crayfish was determined in October of the same year (Cukerzis & Sestokas 1977). Signal crayfish, as more adaptable and resistant species, proved to be a vector of crayfish plague, very dangerous disease of crayfish native populations (Cukerzis 1976, 1989, Alderman & Polglase).

In 1979, 600 mature males and females were transferred from Lake A. Nevardas to Lake Z. Nevardas, located close to A. Nevardas. The population study showed later that in 1983 the abundance of signal crayfish population in Z. Nevardas was 10,000.

Plague-free juveniles of signal crayfish were obtained in 1978 using the method of artificial egg incubation at Juodis Field station (Sukackas & Mazylis 1981) and introduced into some lakes in Trakai region (Skilictai I, Skilictai II and Juodis) with population of noble crayfish at low density. Ecological investigations of interspecific competition between noble and signal crayfish showed that, when they live together (Lakes Skilictai & Leikstekis) *P. leniusculus* as more aggressive and adaptable species of crayfish, having higher growth rate and fecundity, force out native noble crayfish from their habitats (Sukackas & Mazylis 1981, Mackeviciene & Terentjev 1993).

2 Material and methods

To determine the stocks of the acclimatized signal crayfish in Lakes A. Nevardas and Z. Nevardas, investigation into crayfish population, their age and sex structure was carried out during 1995-1997.

Crayfish were caught by standard cylindrical traps (mesh size 14 mm) which were 70 cm long and 30 cm in diameter with two tapered entrances in the end. Frozen fish (roach and redeye) was used as bait. The traps were placed at the littoral zone of the lake at about 8 p.m. They were checked 12 hours later at sunrise. The distance between the traps was 7-10 m and that from the bank was 2-3 m, the depth was 1.5-4.5 m.

The number of crayfish in each trap and their sex were determined. The crayfish were weighed and the total length of each was measured. The crayfish without claws were registered. The trapped crayfish were marked and released at the same place.

The method of repeated catches was used to determine the number of the crayfish population. The abundance of the population was calculated by the following formula (Cukerzis 1989):

$$N = \frac{mc}{r},$$

where: m - total number of marked crayfish,

c - the number of the trapped crayfish,

r - the number of marked crayfish.

3 Results and discussion

During 1995-1997 population studies of signal crayfish were carried out in Lake Aukstutinis Nevardas, with a surface area of 2.8 ha, 9 m average depth (max 14 m), and in Zemutinis Nevardas (5.5 ha, 2.5 m average depth, max depth 21 m). Mean water temperature in A. Nevardas varied in summer between 16-21°C, in Z. Nevardas 19-24°C. The bottoms of both lakes are covered with sludge, small places with gravel bottom are found in Z. Nevardas. Before the introduction of signal crayfish, artificial shelters were made in the littoral zone of the lakes. Hydrochemical parameters determined (O_2 8.8 mg/l, pH 7.85, hardness 3.8 meqv./l, Ca^{2+}46 mg/l, mineralization level 289.9 mg/l) corresponded well with requirements made to water quality for crayfish harvest (Rognerud et al. 1989).

According to Grigelis (1980, unpublished data) in 0.3-1.2 m depth of the littoral zone of Lake A. Nevardas *Chironomidae* larvae predominated, the abundance of macrozoobenthos was 120-480 ind/m^2, biomass 1.04-1.34 g/m^2. In a turphy soft bottom of the lake, at a depth of 8 m, the biomass of benthic fauna was 0.92 g/m^2, *Corethra* larvae (240 ind./m^2) predominated. Roach, pike, tench, rudd and perch dominated in the both lakes. Mink and beaver are living in the littoral zone of the lakes.

The data of 8 catches in 1995 showed that crayfish abundance (CPUE) was 0.55 in A. Nevardas. The useful area in this lake is only 0.13 % of the total area. Crayfish abundance was 12,700 specimens in 1995 (Fig. 1), density 3.6 ind./m^2. At the same time in Lake Z, Nevardas a useful area for crayfish consisted 12.5% , crayfish population density was 2.1 ind,/m^2, CPUE - 0.63, the total abundance was 14,200 individuals (Fig. 2). The data showed that the density of the signal crayfish population in A. Nevardas increased slowly, while that in Z. Nevardas increased more rapidly (Fig. 1, 2). It can be associated with a greater number of crayfish introduced into Lake Z. Nevardas.

It is supposed that in 1997 the population of signal crayfish decreased significantly in Lake A. Nevardas (Fig. 1), because no crayfish were caught. This sudden decrease of the population was caused by the very cold winter in 1996/97 and thick layers of ice and snow on the lakes, which caused a lack of O_2 in the water. In spring of 1997 (April) a large amount of dead fish was determined. The investigations carried out in Z. Nevardas in 1997 also showed a marked decrease (69%) in the abundance of signal crayfish population (CPUE - 0.74 ind.), density 1.4 ind./m^2, abundance 9,800 specimens (Fig. 24.2). Besides, a relatively short cycle (5-8 years) of North-American crayfish species life (r-strategy), according to Lindqvist (1997), could have influenced the decrease.

In 1995 the crayfish populations consisted of six age groups. Three age groups predominated in A. Nevardas: 3+ (35%), 4+ (33%), 2+ (17%) (Fig. 3), while in Lake Z. Nevardas the following age groups predominated: 2+ (24%), 3+ (20%), 4+ (20%) (Fig. 4). In 1997 the age ratio changed, after the cold winter in 1996 the number of age group 2+ decreased in Z. Nevardas (Fig. 5).

According to Keller (1995), the natural sex ratio in crayfish population is male:female 1:1. Our investigations showed that a male:female ratio in 1995 in Lake A. Nevardas was 1:1.7 and in Z. Nevardas 1: 1.4 (Fig. 6). In 1997 sex ratio in Z. Nevardas changed significantly, and it was 1.5:0.5 male:female (Fig.6). The amount of females in catches decreased about three times, which influences the reproductiveness of crayfish population.

At present time, populations of signal crayfish in Lakes A. Nevardas and Z. Nevardas are needed for the actions of stocks restoration, using methods of natural and artificial breeding.

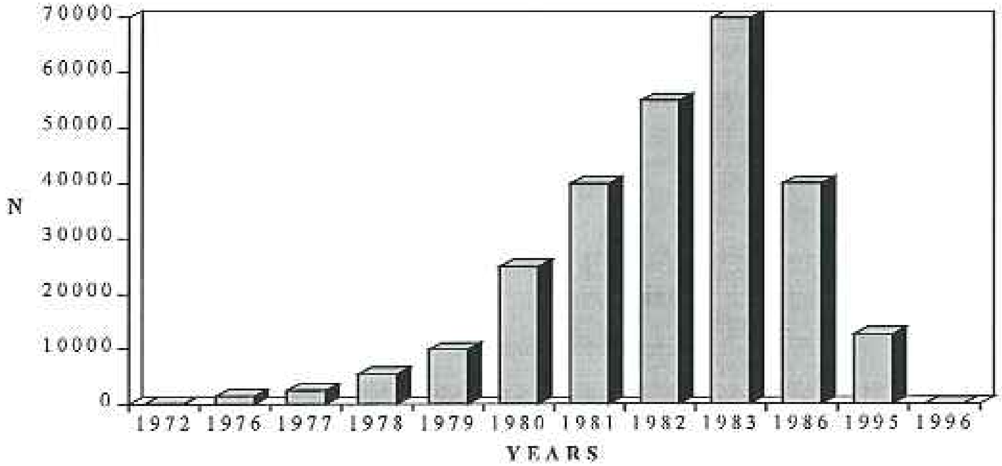

Fig. 1 *The abundance (N) of signal crayfish* Pacifastacus leniusculus *Dana population in Lake Aukstutinis Nevardas (Vilnius region) during 1972-1996.*

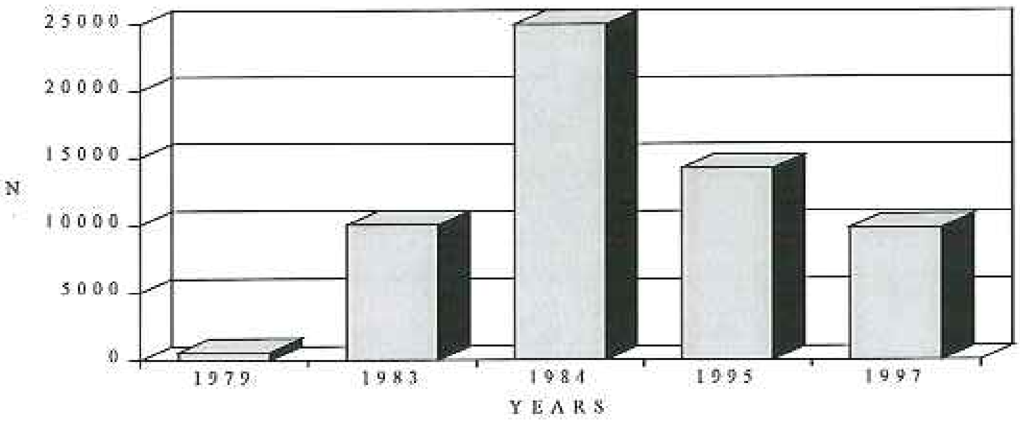

Fig. 2 *The abundance (N) of signal crayfish Pacifastacus leniusculus Dana population in Lake Zemutinis Nevardas (Vilnius region) during 1979-1997.*

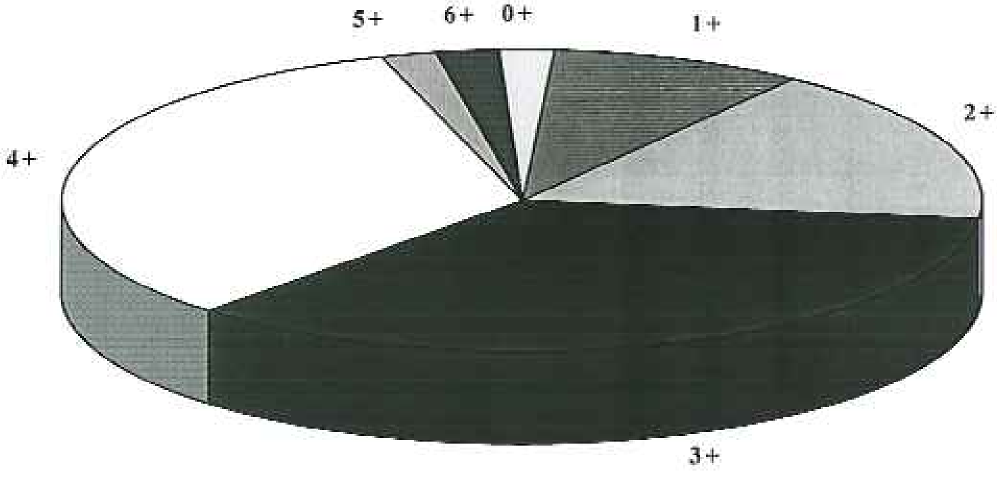

Fig. 3 *Age structure of the population of signal crayfish Pacifastacus leniusculus in Lake Aukstutinis Nevardas in 1995.*

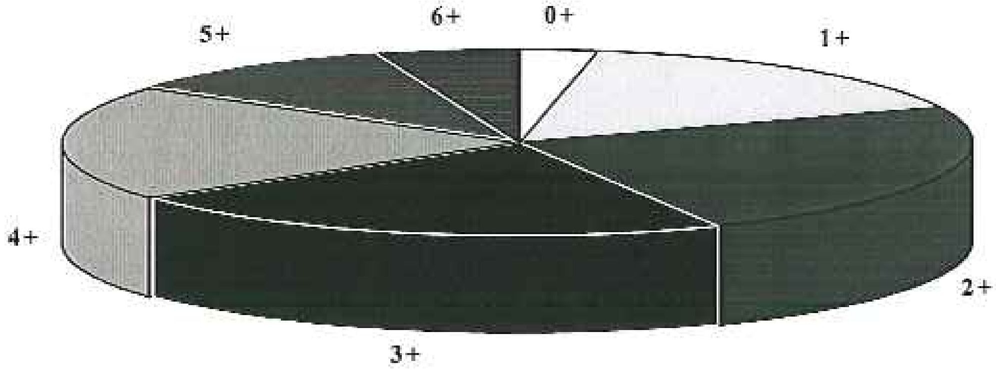

Fig. 4 *Age structure of the population of signal crayfish Pacifastacus leniusculus in Lake Zemutinis Nevardas in 1995.*

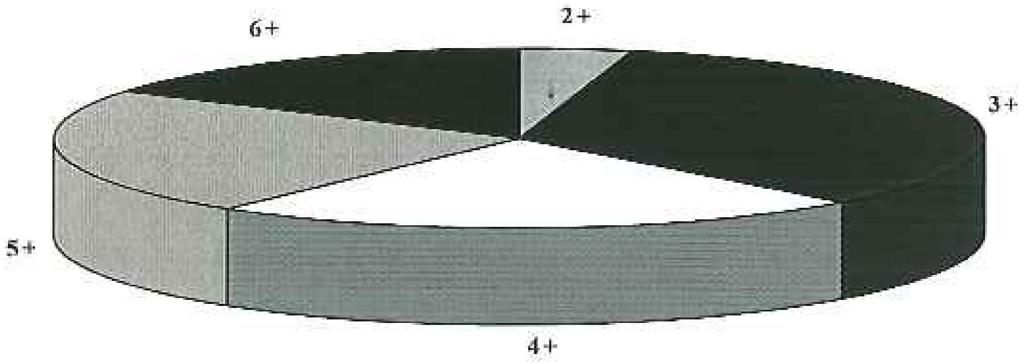

Fig. 5 *Age structure of the population of signal crayfish Pacifastacus leniusculus in Lake Zemutinis Nevardas (Vilnius region) in 1997.*

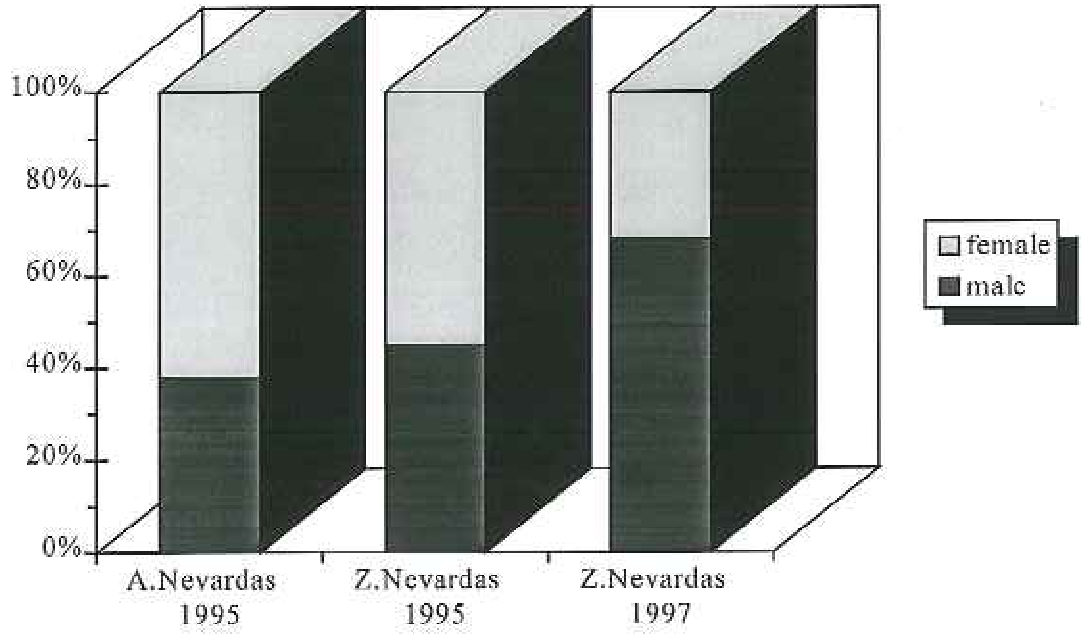

Fig. 6 *Sex ratio of signal crayfish populations in Lakes Aukstutinis Nevardas ir Zemutinis Nevardas (Vilnius region) during 1995-1997.*

4 Conclusions

Signal crayfish population density in Lake A. Nevardas in 1995, twenty-three years after the first introduction of the North-American crayfish species, was 3.6 ind./m^2. Crayfish population consisted of three predominating age groups: 3+, 4+, 2+. A male: female ratio was 1:1.7. Crayfish abundance decreased significantly in 1997 after cold winter in 1996/1997.

Crayfish density in Lake Z. Nevardas, situated close to A. Nevardas, was 2.1 ind./m^2 after sixteen years of introduction. A marked decrease (69%) in crayfish abundance also was determined in 1997 (population density - 1.4 ind./m^2).

In 1995, the following age groups dominated in crayfish population of Lake Z. Nevardas: 2+, 3+, 4+, sex ratio 1:1.4, male:female, which also changed in 1997 - older crayfish predominated in age groups: 3+, 4+, 5+, male:female ratio was 1.5:0.5.

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Microflora of the digestive tract of signal crayfish *Pacifastacus leniusculus* Dana

Liongina Mickėnienė
Institute of Ecology, Akademijos 2,
2600 Vilnius, Lithuania

1 Introduction

It has been recognised that intestinal microflora of homeothermal animals play important roles in nutrition, carcinogenesis and self-defence of the host (Hungate 1975, Savage 1977, Cheng et al. 1981, Mitsuoka 1983). A large number of microorganisms are known to colonise the surface layer of host animals, and also the gastrointestinal tract of terrestrial mammals (Cheng et al. 1981). In the cases of the marine wood-boring isopod (Boyle and Mitchell 1978) and oyster (Garland et al., 1982), a surface associated microflora could not be demonstrated in the alimentary tracts by using scanning electron microscopy. Consequently, the microflora occurring in the digestive tract of aquatic animals must be considered as a resident flora rather than an autochthonous one, in reference to the concept of surface colonisation (Sakata & Koreeda 1986). No aquatic animal has ever developed a rumen or caecum similar to the one found in certain mammals, in which food materials are left to microbial degradation. Although the intestinal tracts of omnivorous or herbivorous fish are comparatively long and have several bends, it is generally supposed that the digestive tract of most aquatic animals are undeveloped straight tube. However, the intestinal microflora of aquatic animals has been reported to contribute to the nutrition and physiological processes of host animals, producing vitamins, digestive enzymes and metabolites similar to that of mammals. Furthermore, normal flora of aquatic animals occupy habitats on the body surfaces and the digestive tract of the host animals usually preventing pathogenic organisms from growing there (Horsley 1977, Moriarty 1990, Sugita et al. 1985, 1988, 1989, 1993). In spite of these findings, the ecological and physiological significance of normal microflora for aquatic animals requires fundamental clarification with further studies.

Water pollution and outbreaks of crayfish plague have caused great losses to the crayfish stocks in Lithuanian waterbodies. A danger of losing all the crayfish populations promoted detailed studies on crayfish biology and required urgent measures to restore crayfish stocks. For restoration purposes signal crayfish *Pacifastacus leniusculus* Dana have been introduced and the method for artificial breeding and rearing of crayfish has been worked out. In order to regulate metabolic processes in the organism of the introduced crayfish it is necessary to investigate their growth, reproduction, feeding and the interrelation between a new species and its habitat in a new biotope. Studies on normal microflora of their digestive tract and its functioning are indispensable as well, since all these factors are stable and interrelated.

Under aquacultural conditions the contact between the breeding object and natural environment is restricted and habitat and feeding conditions are changed to a great extent. This often brings about pathological changes in the organism limiting growth ability in hydrobionts. The efficiency of crayfish reproduction, growth and yield should be raised by improving crayfish diets. Thus, studies on normal microflora in the digestive tract of crayfish become necessary for solving problems related to crayfish cultivation. There are some published data on microflora of the digestive tract of crustacean (Colorni 1985, Hug et al. 1986, Sugita et al. 1987, Dempsey et al. 1989, Harris 1993) while knowledge on the crayfish microflora is absent. According to Colorni (1985), *Aeromonas* and *Vibrio* were the most common bacteria isolated from prawn *Macrobrachium rosenbergii* larvae intestine, but were absent in brine shrimp nauplii the food of prawn. The early establishment of an autochthonous, homeostatic bacterial flora in the prawn larvae digestive tract is indicated. The changes of aerobic bacterial flora in the digestive tract of euryhaline freshwater shrimp with its gradual acclimation to sea water were investigated (Sugita et al. 1987a). In the rearing water with tap to 50% sea water, microflora in the digestive tract of shrimp was varied and *Pseudomonas, Aeromonas, Acinetobacter, Moraxella* and *Enterobacteriaceae* dominated. In 100% sea water, however *Enterobacteriaceae* dominated in the digestive contents. As described in other paper (Dempsey et al. 1989) bacterial densities in the digestive tract of shrimps *Penaeus aztecus* and *Penaeus setiferus* vary greatly, while they seem not to be influenced dramatically by shrimp species, size, location of capture. Data here suggest that bacterial diversity in the digestive tract of shrimp is greatly reduced from their environment. Direct observation by scanning electron microscopy indicates that the presence of bacteria in the hindguts of *Crustacea* is widespread, occurring across taxa, feeding types habitats and continents (Harris 1993). According to author, crustaceans hindguts clearly represents suitable environments for colonisation by microorganisms, despite the lack of specialised structures or modifications of the gut to facilitate this. Mats of closely packed epimural rods and scattered epimural rods were the most common types of bacteria observed in the guts of the *Crustacea* examined. Abundance of hindgut microflora was unrelated to the host's taxon, habitat or geographical locality, but appeared to be affected by the feeding habitats of the animal.

In the present paper the author describe the results of qualitative and quantitative investigations on the heterotrophic bacteria in the digestive tract of signal crayfish (*Pacifastacus leniusculus* Dana) at different habitats and feeding conditions.

2 Material and methods

Adult males of crayfish *Pacifastacus leniusculus* Dana were trapped in Lake Škeletas (Trakai district, Lithuania) and Lake Nevardas (Vilnius district, Lithuania). The animals were transported on ice to the laboratory. Only live crayfish of similar weight and body length were used. Some animals were analysed immediately, while others were maintained in aquarium equipped with water recirculating systems and starved for 10 days, then fed on fish and *Chara rudis* Br. for three summer months. Water temperature ranged from 18°C to 24°C. The ventral surface of the crayfish was thoroughly scrubbed with a 70% ethanol solution.The gastrointestinal tracts were removed and the contents were immediately squeezed out of the gut with sterile pincette. The contents were then weighed, placed in a test tube and a suitable amount of diluent was added to receive a tenfold dilution, vigorously vibrated, diluted serially and plated on to different media. Beef extract agar, beef extract agar + 0,5% of glucose, starch agar, milk agar, potato agar, mineral agar + casein hydrolisate, Hatchinson's medium and Omeliansky's medium were used (Rodina 1965, Duda 1979, Segi 1983, Romanenko 1985, Kuznetsov & Dubinina 1989). Inoculated beef extract agar, starch agar, milk agar and Hatchinson's medium were incubated at 20°C for 3 to 5 days under aerobic conditions, while the remainder were incubated at 20°C for 5 to 7 days under anaerobic conditions. After incubation colonies that appeared on each plate were counted and viable count (i.e. colony forming unit) per g was obtained. Colonies were then divided into similar types according to colonial characteristics. Three representatives of each colony type were plated on the same media and purified. Identification of aerobes and facultative anaerobes was facilitated by examination of morphology and pigmentation of the colony as well as by examination of the staining characteristics and motility of the cells. In addition, the ability of the isolates to produce oxidase and catalase, metabolise glucose fermentatively or oxidatively was tested. A total of 230 strains of aerobic and facultative anaerobic bacteria were isolated and identified by the scheme of Shewan et al. (1960) and Bergey's manual (1984). The obligate and facultative anaerobes isolated under anaerobic conditions were classified on the basis of Gram reaction, cellular morphology, spore formation, and ability to grow under aerobic condition. The studies of obligate anaerobic bacteria in the intestinal contents of signal crayfish were performed together with scientists of Institute of Microbiology of the Academy of Sciences of Russia.

3 Results and discussion

Shewan and Hobbs (1967) suggested that the bacterial flora of hydrobionts reflect the aquatic environment. However, other investigators (Sugita et al. 1985) showed that faecal pellets of hydrobionts significantly influenced the microflora of the rearing water. Therefore, the microflora in rearing water may be affected by that of hydrobionts and account for the resemblance. Others (Sugita et al. 1993) found that microflora of hydrobiont's intestines and environmental water influences each other. It is possible that the favoured environment for many aquatic bacteria is the digestive tract of hydrobionts rather than the water. However, natural selection takes place in the digestive tract of hdrobionts; those species of microorganisms survive only if such conditions are favourable. The counts of aerobic heterotrophs in the digestive tract of signal crayfish are shown in Fig. 1.

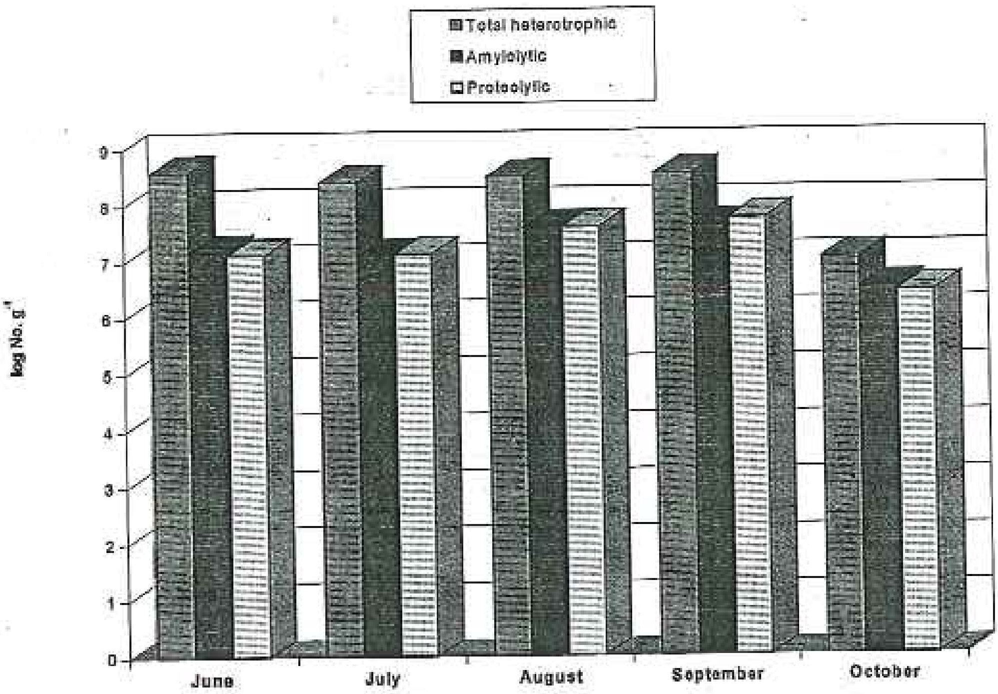

Fig. 1 *Viable conts(log No g-1) of the bacteria in the contents of intestines of crayfish Pacifastacus leniusculus from the Lake Skeletas.*

Bacteria are found in great abundance in the contents of the digestive tract of the signal crayfish in the course of the whole season. Bacteria isolated from the contents of the digestive tract of crayfish were: total heterotrophic, amylolytic, proteolytic, while no cellulose-degrading bacteria, yeasts and mold fungi were detected. Digestion of cellulose and other cellular tissue components is an important biochemical function of microflora in the digestive tract of ruminants, some fishes and insects (Savage 1977). The fact that cellulose-degrading microflora has not been detected in the contents of the digestive tract of crayfish suggests that either cellulose from plant food is digested with the aid of enzymes produced in the gland of the macroorganism, or crayfish assimilate plant material with difficulty. According to the data obtained by some researchers (Gomez et al. 1989), high contents of cellulose in the diets of the giant prawn *Macrobrachium rosenbergii* caused a delay in growth rates, as well as a reduction in locomotion activity. It is important to take this into account when composing optimal artificial diets for crayfish under aquaculture conditions.

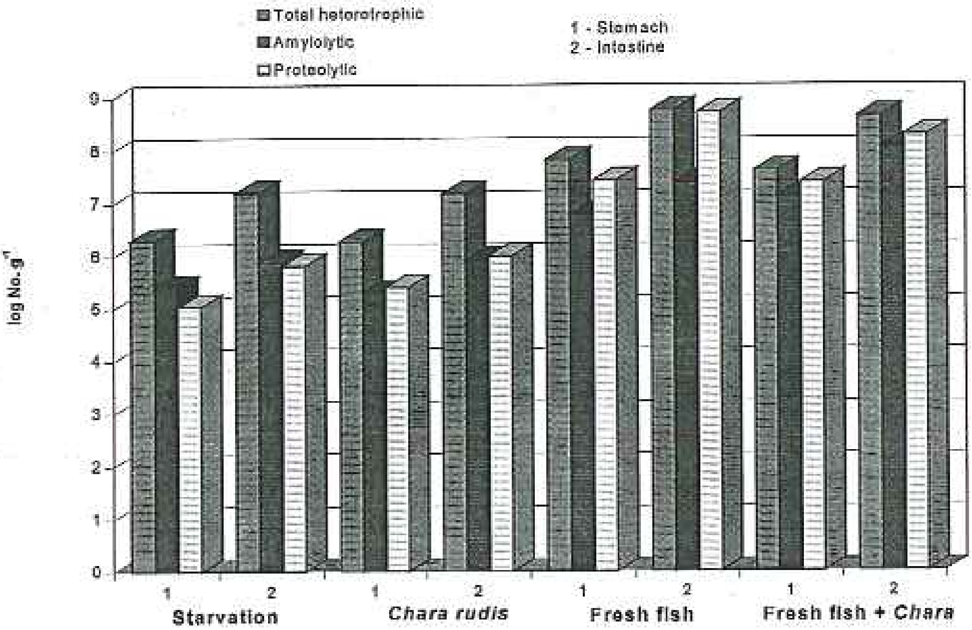

Fig. 2 *Viable counts (log No g^{-1}) of bacteria in the contents of the digestive tract of crayfish Pacifastacus leniusculus depending on their diet.*

A marked seasonal variation of viable counts of bacteria in the contents of the digestive tract of signal crayfish was observed. The data obtained have shown that the viable counts of bacteria in the contents of the digestive tract depend on the characteristics of feeding intensity of the crayfish under study. Low environmental temperatures (below 10°C in October) are associated with a decrease in the viable counts of bacteria (Fig. 1). A fall in water temperature causes a delay in crayfish feeding intensity, thus the amount of energetic material for growth and biochemical activity of microorganisms decreases. The greatest numbers of bacteria of different groups were detected in summer and early autumn (beginning of September). This result agrees with the data on crayfish feeding intensity (Hessen et al. 1988; Cukerzis 1989).

Experimental studies prove that starvation of crayfish leads to the decrease of the viable counts of bacteria in the contents of the digestive tract (Fig. 2). It is evident that feeding increases the number of bacteria, but in starving animals this flora is always high, which suggests the existence of a permanent population (up to 10^5).

Heterotrophic bacteria constituted 86% of the total counts of the bacteria of the studied group. The group composition of the microflora and viable counts of bacteria from the contents of the digestive tract of the tested crayfish depended on the diets. When crayfish are fed on *Chara*, the viable counts and group composition of bacteria are similar to these of starving crayfish. It is known that *Chara* contains much carbonate - more than 50% of the total amount of mineral balance, ash content is 45-50%. It is likely that the bacteria living in the digestive tract of crayfish are not able to assimilate this alga. *Chara* intensifies calcium metabolism in crayfish (Cukerzis 1976). According to the data obtained by Khmeliova et al. (1984), the caloricity of crayfish exoskeletons is low. Crayfish consume cast exoskeletons as *Chara* does too not to satisfy their energy demands, but for mineral salts, necessary for their new exoskeletons to become hard.

The greatest viable counts of bacteria were obtained in animals fed on mixed diets, containing fish, which is rich in protein. The results of this study support the contention that a dense bacterial population occurs in the digestive tract of signal crayfish, with numbers of bacteria much higher than those obtained in surrounding water. A comparative study was conducted on the bacterial flora associated with digestive tract of signal crayfish taken at two different lakes. Bacteria belonging to the genera *Pseudomonas, Aeromonas, Acinetobacter, Flavobacterium,* the family *Enterobacteriaceae* and gram-positive cocci and bacteria were isolated from the digestive tract of signal crayfish from Lake Nevardas and Lake Škeletas (Fig. 3).

Among them *Pseudomonas, Aeromonas* and *Enterobcteriaceae* were distributed predominantly in the intestinal tract of crayfish with occurrence ranging from 79 to 87%. These bacteria were isolated from the contents of the digestive tract of signal crayfish regularly and in great numbers in two habitat conditions. Gram-positive cocci and bacteria were isolated in small amounts and irregularly from the contents of digestive tract of signal crayfish from Lake Nevardas. These bacteria were not detected in digestive tract of crayfish from Lake Škeletas. Some differences were evident in the group of dominating bacteria from the digestive tract of signal crayfish: whilst *Aeromonas,* *Enterobacteriaceae* and *Pseudomonas* (in decreasing order) predominated in the digestive tract of crayfish from Lake Nevardas; *Enterobacteriaceae, Aeromonas* and *Pseudomonas* were prevalent in Lake Škeletas.

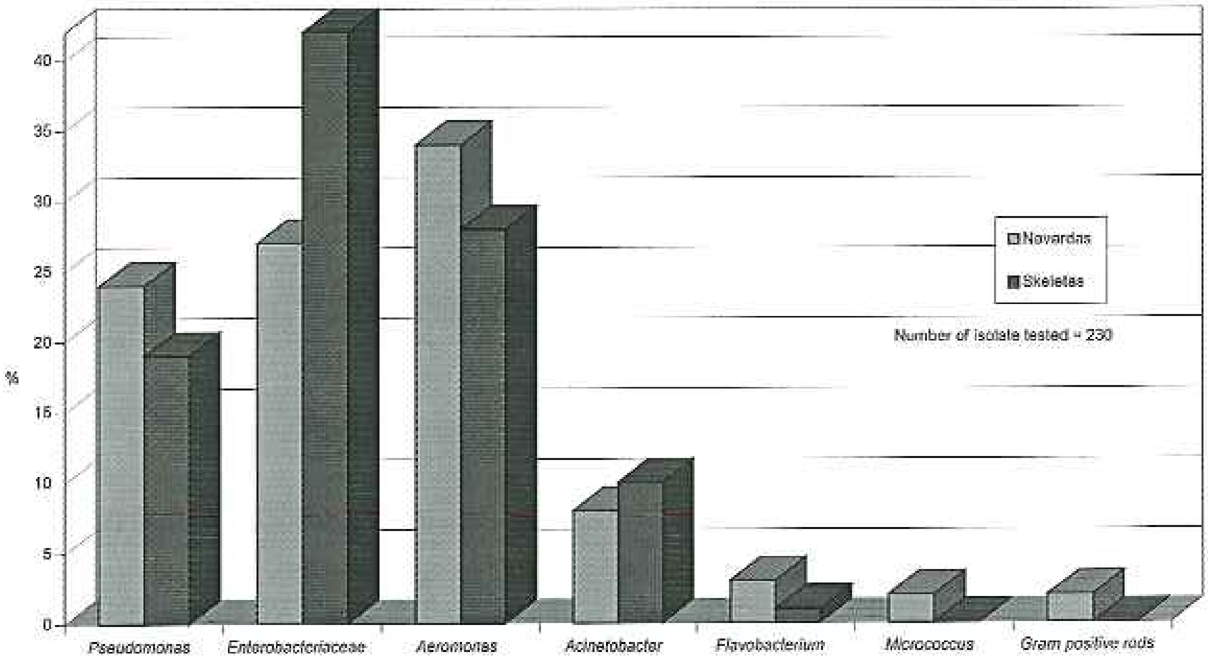

Fig. 3 *Comparative distribution of different groups of bacteria isolated from the contents of the digestive tract of signal crayfish Pacifastacus leunusculus from two lakes.*

Sugita et al. (1987) and Dempsey et al. (1989) analysed the gastrointestinal microflora of different species of *Crustaceae* and, similarly to our findings, reported that the major groups of bacteria present in the gastrointestinal tracts belonged to the genera: *Pseudomonas, Vibrio-Aeromonas, Acinetobacter* and the family *Enterobacteriaceae,* which were uniformly distributed throughout the entire alimentary canal. Fig. 4 shows the number of viable bacteria grown on different agars under aerobic and anaerobic conditions.

The data obtained have shown that the viable counts of bacteria in the contents of the digestive tract of signal crayfish were higher under anaerobic condition of growth. We isolated gram negative and gram positive anaerobic bacteria. Gram negative bacteria predominate and viable count of these bacteria ranged from $1.1x10^6$ to $3.1x10^7$ CFU/g. The obligate anaerobes consisted of *Bacteroidaceae* and *Clostridium.* From the digestive tract of signal crayfish we isolated a new bacteria in all taxonomy of bacteria. This is sporeforming bacteria *Bacillus vesiculiliferous* sp. nov., which forms extracellular gas balloons on her cells. This is the first case of isolation of obligate anaerobes in the digestive tract of crayfish.

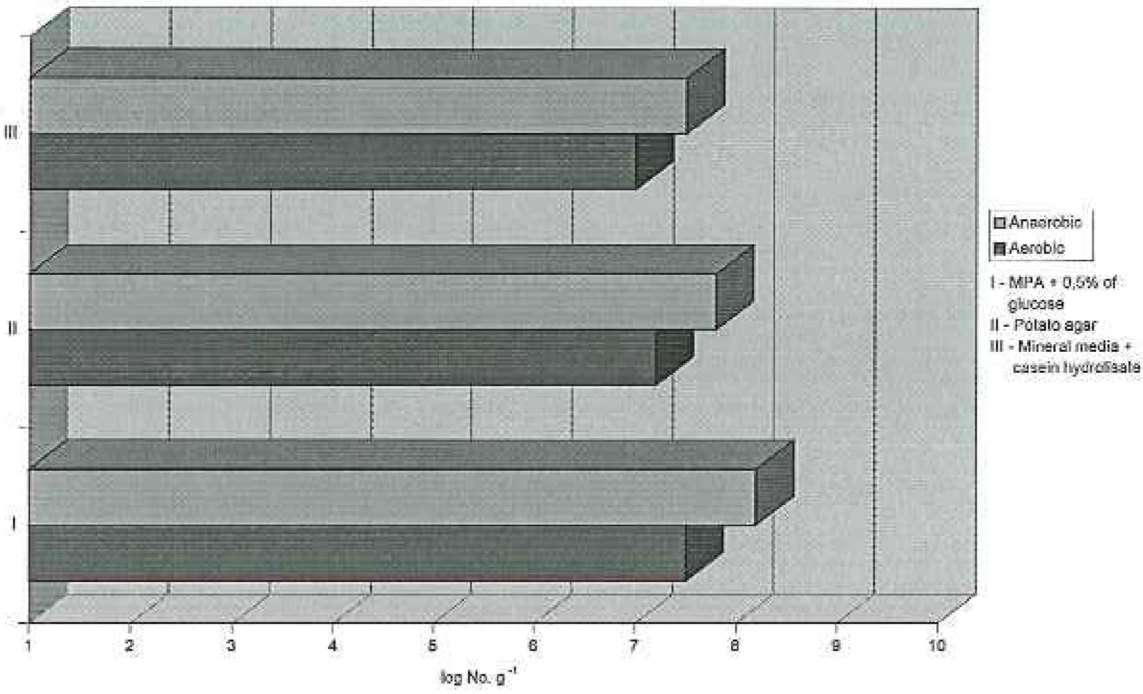

Fig. 4 *Comparison between total aerobic and anaerobic counts of bacteria in the digestive tract of crayfish Pacifastacus leniusculus recovered on various media.*

In the gastrointestinal tracts of homeothermic animals, strictly anaerobic bacteria outnumber facultative anaerobes and play important roles in the nutrition and physiological process of the host (Savage, 1977). However, obligately anaerobic bacteria occur commonly in the intestinal tracts of freshwater fish (Sakata et al. 1980). Later investigates found obligately anaerobic bacteria in the digestive tract of marine crustaceans (Sugita et al. 1987).

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Some characteristics of metabolism of signal crayfish *Pacifastacus leniusculus* Dana acclimatized in Lithuania

Guoda Mackeviciene
Institute of Ecology,
Akademijos 2, 2600 Vilnius, Lithuania

Abstract

The study of physiological and biochemical characteristics of signal crayfish *Pacifastacus leniusculus* Dana, acclimatized in Lake Aukstutinis (A.) Nevardas, Vilnius region, provides the possibility to interpret the extent of crayfish metabolic adaptations to its new ecological niche. Investigations of the bioenergetic parameters of crayfish showed that oxygen consumption rates increased according to temperature of the waterbody. The Q_{10} values for temperature ranges of 6°C was 2.6. Oxygen uptake rates were maximum at the stages during molt (D_4, A_1) and decreased about 59% during the intermolt period. Respiration rates were found to be directly proportional to body mass, when expressed per individual. Energy requirement for respiration increased during ontogenesis of signal crayfish from a minimum value at the embryo stage before hatching to highest in adult crayfish age 4+. The general relationship between the signal crayfish tissues (digestive gland, muscles, exoskeleton) and trace metals concentration was: zinc>copper>nickel>chromium. The greatest bioconcentration of zinc was found in the digestive gland, while signal crayfish exoskeleton accumulates the relatively highest amount of chromium, copper and nickel. Studies on crayfish behaviour of feeding and digestion physiology have proved a rhythmic secretion of digestive enzymes in the digestive system. After feeding proteolytic activity decreases in the stomach and digestive gland and recovers in the digestive gland during the hydrolysis of food substance in the course of 24 hours. Comparatively high levels of proteolytic activity and protein concentration have been observed when young-of-the-year (0+) of signal crayfish reared in natural conditions fed on animal food (fish) and detritus. The concentration of glucocorticoids and sex hormones (hydrocortisone, corticosterone, estradiol and testosterone) varied significantly in different organs and tissues of signal crayfish (heart, eyestalk, nerve cord, green glands, digestive gland, muscles and exoskeleton). The changes of amount level of steroid hormones at stages of the intermolt cycle suggested that these hormones can be involved in the regulation of metabolic processes, ensuring crayfish molt.

1 Introduction

Crayfish, being the largest macroinvertebrates in fresh waters, play a central role in aquatic ecosystems by functioning on several trophic levels and being capable of structuring their biotope (Gydemo 1998). Crayfish also often dominate the biomass of the benthic fauna of many waterbodies and can dominate the energy flow within the hydroecosystem (Momot 1987, Crandall 1997).

The European continent has been successfully invaded by deliberate introductions of several North American crayfish species: *Orconectes limosus, Pacifastacus leniusculus* and *Procambarus clarkii.* They are typically r-selected crayfish species with short life cycle, faster growing and higher fecundity (Huner & Lindqvist 1991). The following biological characteristics of signal crayfish: resistance to crayfish plague disease and adaptability to environmental stress, great fecundity, high growth rate, were the reasons of introduction of this crayfish species to Lithuanian waterbodies (Goldman 1973, Cukerzis 1978).

Studies on acclimatization of signal crayfish populations have revealed that this species can readily adapt to a range of aquatic environments (Terentjev 1979, Cukerzis 1989, Lewis & Horton 1997). Population characteristics of *P. leniusculus* can vary between environments (Westman et al. 1983). Ecological study showed that the growth rate of crayfish in Lake A. Nevardas (Lithuania) and in Lake Billy Chinook (Oregon) was greater than in native populations in Lake Tahoe (California) (Terentjev 1979, Lewis & Horton 1997). Juveniles of *P. leniusculus* hatch earlier, grow faster and are more aggressive than native noble crayfish *Astacus astacus*. *P. leniusculus* reach a large size and mature earlier (Lewis & Horton 1997)

Where introduced, *P. leniusculus* has apparently eliminated populations of native species of crayfish. Population studies in Lake Leikstekis (Svencionys region) and in Lakes Juodis and Skilictai (Trakai region) have shown that *P. leniusculus* has the competitive advantage, increase in density and prevalence over a 2-3 year period and will normally be a dominant species (Mazylis 1984, unpublished data, Cukerzis 1989, Mackeviciene & Terentjev 1993). To properly manage crayfish, knowledge about biology, population size and structure, habitat requirements, and ecological niche are needed (Hoggen 1988).

A greater adaptability of the acclimatized signal crayfish is determined by the characteristics of metabolism of its organism. To determine physiological and biochemical characteristics of a new species, investigations of behavioural responses of signal crayfish and the following indices of metabolic rate have been carried out during 1980-1998: respiration rate of crayfish under natural and laboratory conditions; bioconcentration of trace metals in organism; feeding behaviour and activity of digestive enzymes; concentrations of steroid hormones, non-ecdysone character (types). The studies of ecological and physiological properties of alien species make it possible to reveal characteristic features of population, due to which they retain species-specificity.

2 Material and methods

Investigations of ecological, physiological and biochemical indices of signal crayfish were started in 1980 at Lake Nevardas Field Station (Vilnius region) of Laboratory of Carcinology (now Freshwater Ecology), institute of Ecology. The trapped mature signal crayfish were maintained in cases and were adapted before the experiment in the aquaria of the Lake Field Station.

In each experimental group about 7 animals of the same body weight and stage of the intermolt cycle were used. Stages of the intermolt cycle were determined using a modification of the Drach classification (Passano 1960).

2350 crayfish of different age were used for studies on oxygen uptake rate during 1983-1995. Oxygen consumption rate of embryos, juveniles and adult signal crayfish was determined at normoxic environmental oxygen tension at O_2 8-10 mg/l in the littoral zone of Lake A. Nevardas and at natural temperatures.

The crayfish were not fed 24 hours prior to measurements. Oxygen consumption rates for individual crayfish were determined using a closed chamber. Before the introduction of the individual crayfish, the respirometer was filled with filtered water. The mean oxygen consumption rate was established according to measurements of 7-10 specimens. Oxygen concentrations were estimated by modification of Winkler's method (Stroganov 1962) and by oxymeter. Oxygen uptake rate was calculated as R, mg O_2 h^{-1} individual^{-1}. Indirect calorimetry was used to calculate energy requirements for respiration (E, J, day^{-1} individual^{-1}), according to Gnaiger (1983).

Concentrations of three metals in crayfish tissues were determined by electrothermal atomic absorption spectrometry with spectrophotometers AAS-30 and AA-25 Plus Varian with graphite furnace in the trace level (Analytical Methods for Graphite Tube Atomisers, 1988). Amount level of heavy metals was calculated in mg/kg wet weight.

The structure of the feeding behaviour of adult signal crayfish was investigated under natural (at Lake A. Nevardas) and laboratory conditions. Observations of the feeding behaviour of crayfish were conducted at 6 p.m., each animal was given food (a piece of fresh fish) only once. Behavioural studies were carried out by the method of protocoling, recording the work of separate organs: antennules, antennae, chelae and walking legs in sequence (Dorosenko 1984).

The study of the activity of protein hydrolysing enzymes in the digestive system of crayfish was carried out under the following aspects of feeding behaviour: I - active search for food (crayfish captured by traps with an isolated bait); II - food intake (crayfish were analyzed for 2 hours after food intake); III - after food intake for 24 hours; IV - at state of "relative dormancy" (crayfish which did not manifest food-capturing activity for 3-4 hours after introducing the feeding stimulus).

The influence of different diets on the activity of digestive enzymes was established in juveniles of signal crayfish age 0+, reared in aquarium at Lake Nevardas Field Station. The juveniles were divided into several experimental groups, crayfish of each group (n=300) were fed on different plant and animal food (fresh fish, *Chara*).

The activity of proteinase was determined in the samples of the diluted gastric juice (1:200 by physiological solution) and in the supernatants of the homogenates of the digestive gland and digestive tract. Caseine proteinase activity - proteolytic activity (PA) was determined by a modification of the method of Anson (Kunitz 1947) at 25°C on the phosphate- citrate buffer at pH=6. Optic density was determined by the spectrophotometer at 280 mm. The proteolytic activity in unit for 1g of wet weight of the digestive gland (u/g) and for 1 ml of non-diluted gastric juice (u/ml) was calculated according to Kaverzneva (1971). The content of protein in the digestive system of crayfish was established by Lowry et al. (1951).

Separation and purification of sex hormones were performed by thin-layer chromatography using different systems of solvents. The quantity of sex hormones was determined by radioimmunologic analysis. Quantitative assay of glucocorticoids was made by fluorimetric techniques, using a Hitachi spectrofluorimeter.

Numerical data were processed by standard statistical methods, applying Student's t-test. Only reliable ($p<0.05$-0.01) changes of indices are presented.

3 Results and discussion

In the colonization of most types of fresh water environments crayfish show exceptional powers of physiological adaptation. Mechanisms of physiological compensation are set in the genotype to allow an animal to compete successfully within certain environmental limits (McMahon 1986). Some degree of communication with the environment, and most regulatory processes, occur at the gill surface, making the gills organs of fundamental importance of physiological adaptation. Crayfish gills are involved in exchange of the respiratory gases O_2 and CO_2, the oxygen sensitive receptors are found on the branchial apparatus either in the gill tissue or blood system (McMahon 1986). Such receptors can rapidly inform the central nervous system that hypoxic water has entered the branchial cavity. The response is a very rapid increase in the frequency of scaphognathite pumping, which increases ventilatory water flow over the gills. These responses are of neural origin and may also be influenced by release of hormones and neuropeptides.

According to Powel et al, (1997) and Goldman (1973), crayfish species of North American origin: *Procambarus clarkii, Procambarus zonangulus* and *Pacifastacus leniusculus*, are able to maintain near constant oxygen consumption rates. All these species regulated oxygen consumption rates to low oxygen levels. This ability and tolerance to low oxygen levels in crayfish may be a key factor in determining species distribution in the new area (Powel et al. 1997). Oxygen consumption rate has been widely studied in crayfish and has been shown to be affected by environmental factors, such as temperature, light, salinity, oxygen concentration and pollutants (Ivleva 1981, Foncesa et al. 1997). The main abiotic factor, regulating the respiration rate in poikilothermal animals, is water temperature. According to Ivleva (1981), the level of respiration rate changes in abiokinetic zone according to Van't-Haff-Arrhenius law. The functions of oxygen consumption rate in stage 4 juveniles under the influence of a natural thermogradient 17.8-24.0°C have been determined in Lake A. Nevardas thermal regime. During the experiment at Nevardas Field Station water temperature in the littoral zone decreased by 6 degrees in the course of 6 days. Significant differences were obtained when comparing the oxygen uptake rates in juveniles of the same mass (Fig. 1). At lower temperatures a decrease in the values of metabolic rates has been noticed. In signal crayfish the temperature optimum was recorded as between 18-20°C.

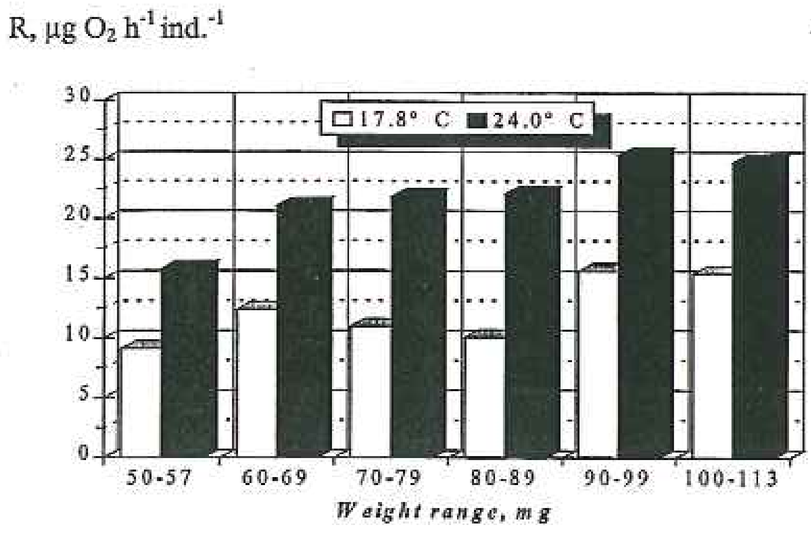


Fig. 1 *Oxygen uptake rates of the juvenile stage 4 of signal crayfish Pacifastacus leniusculus Dana under simulated natural thermogradient*

Oxygen consumption rate is closely connected with molt, which induces significant changes in metabolic reactions of crayfish. The rate of oxygen uptake during the molt period (stages D_4 and A_1 of intermolt cycle) in juveniles of various body mass was on average 1.5 times higher than at stages of the intermolt period (D_1-D_2, A_2-B, C_1-C_4) (Fig. 2).

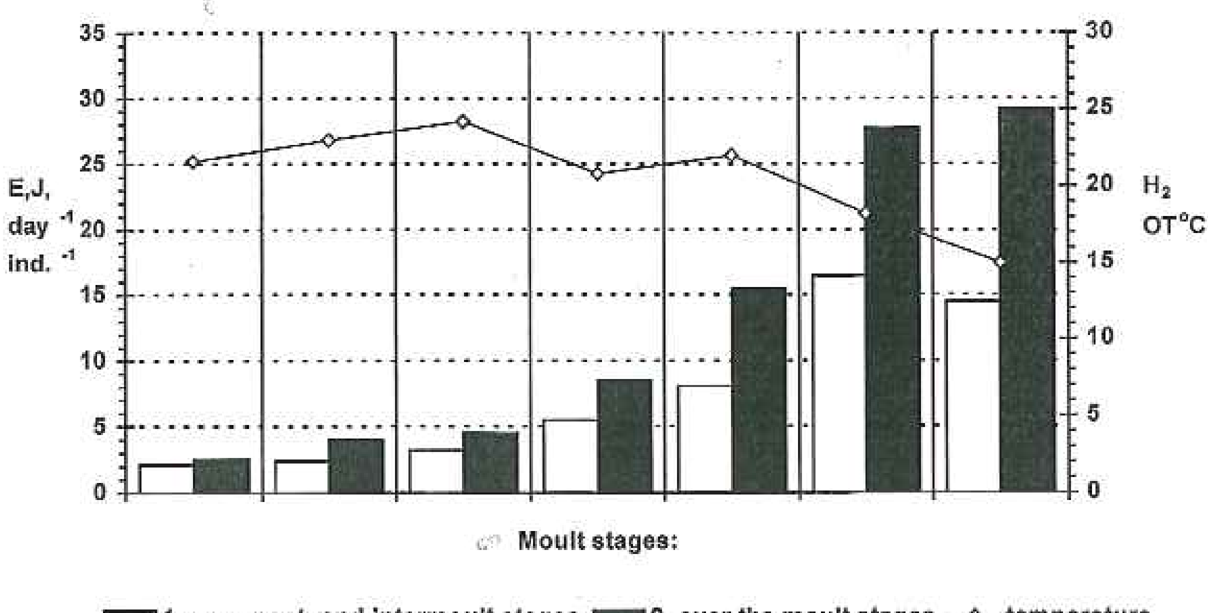


Fig. 2 *Influence of moulting on oxygen uptake rates of the signal crayfish* Pacifastacus leniusculus *Dana. (1. - pre- (D_1 - D_2); post- (A_2-B); intermoult (C_1-C_4) stages. 2. - over the moult (stages D_4-A_1))*

The trends of the variation of oxygen uptake rates during separate periods of signal crayfish life cycle are similar to those described for other species of decapods (Suscenia 1972). Oxygen consumption was found to be directly proportional to body mass when expressed per individual (Fig. 3).

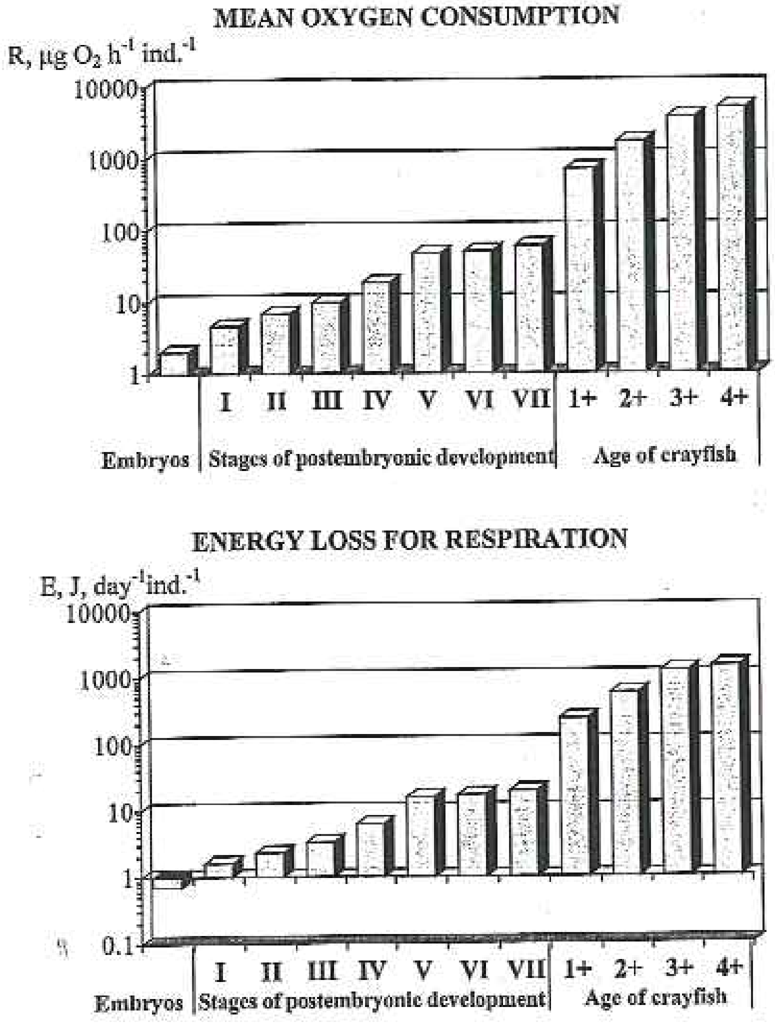


Figure 3 *Bioenergetic parameters of signal crayfish Pacifastacus leniusculus at the different periods of life cycle*

After hatching the rate of oxygen uptake in the juvenile stage 1 increased by 133-186% in comparison with the level of oxygen consumption in embryos at stage "heart beat". It can be concluded that oxygen consumption rate and energy requirement for respiration respectively increases from a minimum value (1.55 J, day^{-1} $ind.^{-1}$) at stage 1 to maximum (1421.3 J, day^{-1} $ind.^{-1}$) during later life periods of signal crayfish (age 4+).

To generalize our results regression from oxygen uptake rates and wet weight was calculated for each life period of signal crayfish. The relationship between respiration and body mass at a given temperature follows an equation $R = aW^b$, where R = oxygen consumed per time unit, W = wet weight, a = intercept, theoretical metabolic rate of animal with W = 1 mg, b = the slope. For poikilothermal animals the value of b is considered to vary between 0.7 and 0.8 (Suscenia 1972). According to our respiration data for signal crayfish, recalculated at temperature 20°C, the following regression equation, similar to the equation for *Crustacea*, was obtained:

$R = O.138 \pm 0.065 W^{0.78 \pm 0.014}$, with a correlation coefficient r = 0.99.

The mature signal crayfish males, trapped in Lake A. Nevardas, were used for investigation of somatic ratios (wet, %). The mean values of somatic indices of signal crayfish of 45-75 g wet weight varied for heart 0.14-0.24%, eyestalks - 0.16-0.23%, nerval cord - 0.09-0.17%, green glands - 0.25-0.38%, gonads - 0.36-0.9%, digestive tract - 1.56-4%, and digestive gland - 3.03-5.87%, respectively.

Mean concentrations of xenobiotics in whole crayfish and in various tissues correlated to the variations of the amount of heavy metals in the environment (Bagatto & Alikhan 1987, Chamber 1995, Viikinkoski et al. 1995). Toxic substances are accumulated through nutrient links and direct absorption mostly in the digestive tract, digestive gland and kidney. The digestive gland is the main regulatory organ in crustacean species, and as such involved to be the prime site for metal storage and detoxication (Bryon 1968). The concentrations of heavy metals in the crayfish body are regulated to constant level until metal bioavailability exceeds in high threshold, when regulation breaks down and net accumulation begins (Rainbow 1988). It is important to have knowledge on heavy metal levels of tissues of crayfish used as food 9viikinkoski et al. 1995). The tolerance level of signal crayfish to environmental pollutants, such as heavy metals, in Lithuanian conditions was not examined.

Zinc, copper and chromium constitute essential three metals for animals. Nickel is generally thought to be biologically non-essential heavy metal, which enters the animal by following the same biochemical pathways as essential elements. Zn and Cu appear to diffuse passively (probably as a soluble complex) down gradients created by adsorption of membrane surfaces and are bound by blood proteins metallothioneins (Mirenda 1986). The digestive gland of crayfish accumulated zinc from water and food and excreted the amount of zinc with feces (Bryan 1968).

The mean values of some heavy metals (Zn, Cu, Cr, Ni), established in signal crayfish tissues, are as follows: copper: 0.77 mg/kg wet weight in hepatopancreatic tissue, 1.69 mg/kg in muscles and 2.15 mg/kg in exoskeleton. The relatively high concentration of Cu, observed in the exoskeleton (Fig. 26.4), reflected of storage capacity of this tissue for copper. Copper has also been shown to be a regulated metal in crayfish, this is related to the essential biochemical role of this trace metal in the production of respiratory protein haemocyanin (Bryan 1968).

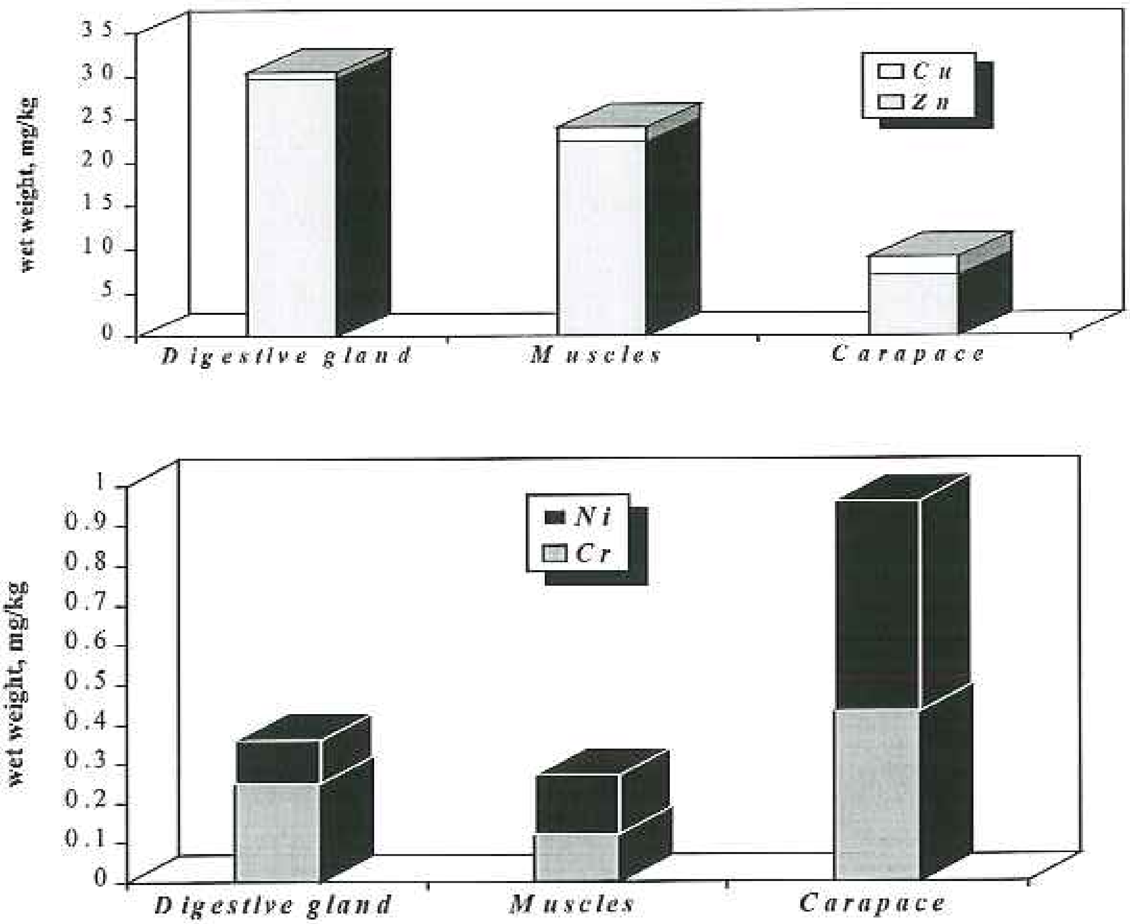


Figure 4 *Accumulation of heavy metals in organs and tissues of signal crayfish Pacifastacus leniusculus Dana.*

The limits within which copper is regulated are closely adjusted to the average concentration of all copper sources in a habitat, Hopkin et al. (1985) suggested that storage instead of excretion of copper may be a method employed by crustacean species to conserve energy. The maximal allowable level copper in soft tissues of crayfish is permitted by the International Regulations is between 20-50 mg/kg^{-1} wet weight (Maranhao et al. 1995).According to our data (mean level of copper in muscles is 1.69 mg/kg wet weight), *P. leniusculus* from Lake A. Nevardas can be suitable for consumption as food.

The highest concentration of zinc was observed inside hepatopancreatic tissues of signal crayfish (29.7 mg/kg wet weight) and the lowest in exoskeleton (6.92 mg/kg wet weight) (Fig. 4). The similar amount of zinc in exoskeleton was noticed in crayfish *Orconectes virilis* (Mirenda 1986). Average values of chromium in the tissues of signal crayfish varied from lowest level in muscle (0.12 mg/kg) to maximum in exoskeleton (0.43 mg/kg). Relatively, the highest concentration of nickel was also noticed in exoskeleton (0.52 mg/kg), the same amount level of this trace metal was detected in the digestive gland and muscle tissue - 0.11 and 0.15 mg/kg respectively.

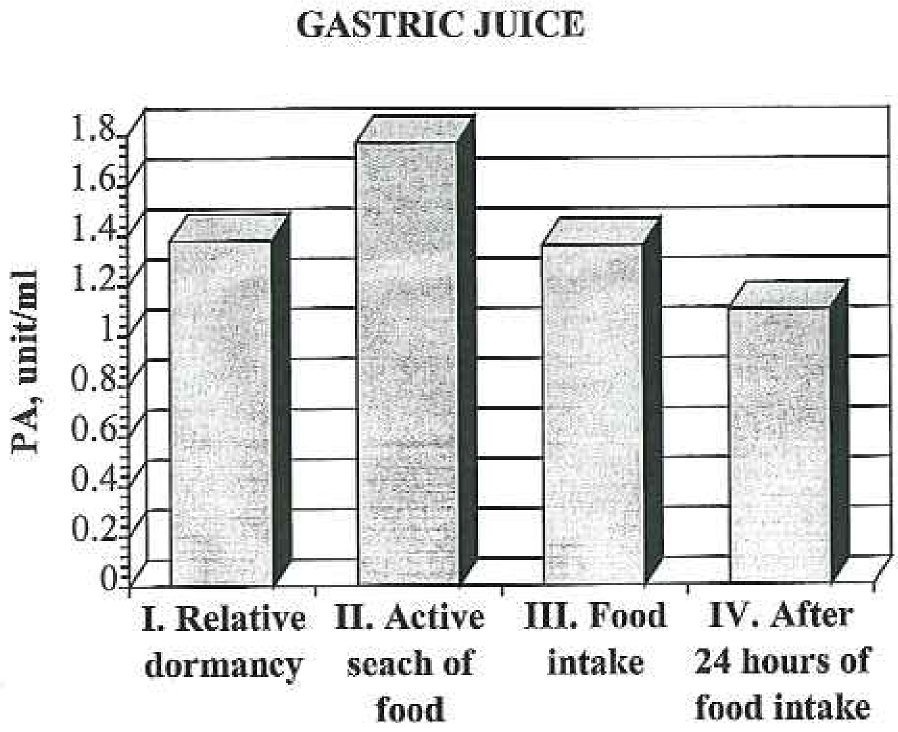
Thus, the general relationship between the signal crayfish tissue (digestive gland, muscles, exoskeleton) and heavy metal concentrations was: Zn>Cu>Ni>Cr. The greatest amount of Zn was detected in the digestive gland, while crayfish exoskeleton accumulates the relatively highest amounts of Cr, Cu and Ni.

The main food sources of crayfish are macrophytes, invertebrates and organic matter (Nyström & Graneli 1997). Cannibalism frequently occurs in crayfish populations (Holdich et al. 1995). Crayfish activity is mainly affected by temperature and light, food availability and the presence of predators (Westin & Gydemo 1982). Food availability is an important regulating factor of growth, activity and the number of mature females of signal crayfish (Nyström & Graneli 1997). According to authors, the increased activity during daytime in the ponds where signal crayfish were unfed, was likely an effect of food storage.

It is known (Van Wormhoudt 1973), that the level of the activity of digestive enzymes in the digestive gland and digestive tract of decapod crustaceans is dependent directly on the intensity of food consumption and reflects activity of animals. Responses of feeding behaviour are related to physiological changes in the organism, however, there exists an independent endogenic system, possessing its own inner rhythm (Fingerman 1987). Enzymatic activity in the digestive system of crayfish is influenced by quality and quantity of food, water temperature, photoperiod and molting.

Combined studies of signal crayfish behaviour of feeding and digestion physiology were carried out under natural (Lake A. Nevardas) and experimental conditions. The analysis of qualitative characteristics of feeding behaviour has revealed two phases: search for food and food manipulation. Each phase in its turn falls into a number of aspects: passive search for food, active search for food, food transportation, food intake, removal of food remnants (Doroshenko 1984). Any aspect is characterized by a complex series of movements of crayfish organs. During "relative dormancy", before food introduction rare streaking movements of antennules, idle movements of walking legs were observed, chelae were folded, antennae - on the back. The aspect "passive search" started at once after the food stimulus had been introduced, an increased rhythm of streaking movements of antennules, searching movements of antennae, digging movements of chelae, idle movements of walking legs were observed. The whole complex of movements helps crayfish to receive information about the stimulus which has changed the environment, and move on to the next aspect of the feeding behaviour - "active search for food". Such sequence of work of crayfish organs is stipulated by functional system of the distant analysis of the environment, the chemoreception. By means of distant chemoreceptors situated on antennules and dactilopodites of walking legs, chelae and antennae the crayfish determines the place of concentration of the feeding stimulus (Derby & Attema 1982). During the active search for food the following was observed: walking in the live box, turn round backwards to the corner of the box, stops, groping of the food usually by one antenna, maximal rhythm of the antennular flicking. The approach towards the food was characterized by walking high on raised legs, open and raised chelae, active searching movements of antennae. The "capture of food" is usually performed by one chela, rarely by both chelae and a walking leg. The capture of food is followed in most cases by the transportation of food, sometimes by food intake on the spot. During food transportation fast movement backwards to the starting point and food intake were observed. The aspect "food intake" is characterized by: intensive work of mouth parts and walking legs, holding, tearing and pushing the food, while the crayfish is swaying upwards and downwards. Food intake was followed by wiping movements of walking legs, turn-around, digging movements of closed chelae, circular movements of antennae, removal of food remnants. For the comfort behaviour the work of separate organs analogical to the aspect "relative dormancy" is characteristic: rare streaking movements of antennules, antennae are on the back, chelae are folded, walking legs perform idle movements.

We have investigated the activity level of proteinase in the digestive system of *P. leniusculus* males under different aspects of feeding behaviour (searching for food, food intake, after food intake, "relative dormancy") during premolt (stages D_1-D_3) and postmolt (stages A-B) periods of the intermolt cycle. A relatively high level of the proteolytic activity (PA) has been observed in the first experimental group of crayfish (PA - 1.38 unit/ml in the gastric juice and 0.12 unit/wet weight in the digestive gland), during the aspect "relative dormancy" (the crayfish did not display food-capturing activity for 3-4 hours after the introduction of food stimulus). As the animals enter a new aspect, i.e. search for food, an increase of the proteolytic activity by 28.3% in the gastric juice and by 25.0% in the digestive gland, in comparison with the first experimental group, is observed (Fig. 5). The maximum enzymatic activity in the gastric juice at the active search for food is probably caused by the rhythm of secretion of the digestive juice of hungry crayfish.



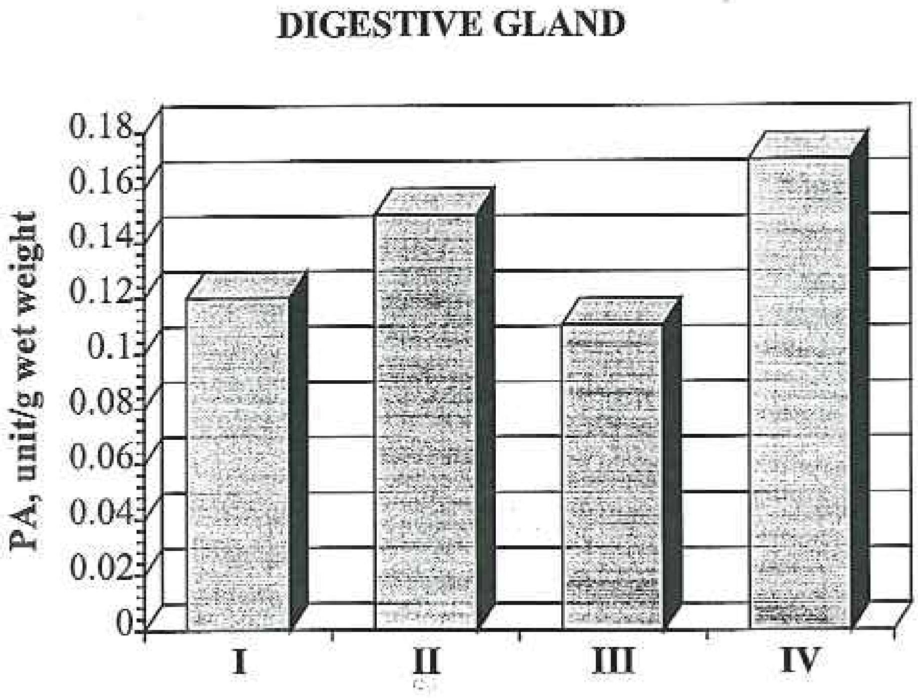


Fig. 5 *Proteolytic activity (PA) in the digestive system of Pacifastacus leniusculus males under different aspects of the feeding behaviour*

The proteolytic activity decreased after food intake (fresh fish). Food serves as a stimulus, uninhibiting digestive centers, the digestive juice is consumed for the hydrolysis of nutritives, at the same time an intensive synthesis of digestive enzymes takes place. At the period of active splitting of food proteins on the second day (24 h after food intake), a significant increase to the maximum level of proteolytic activity in the digestive gland has been observed (Fig. 5). The hydrolysis of the food proteins takes place both in the digestive tract and in the digestive gland, when food particles are split to constituent aminoacids. Aminoacids serve for the synthesis of specific proteins of the organism, necessary for the growth of new tissues and development af the crayfish organs.

P. leniusculus juveniles were reared under semi-natural conditions, the water temperature in the aquarium being optimal (+20°C) for the growth and development. The juveniles, kept from the 2nd stage (June) in the aquaria at Lake A. Nevardas and fed on different food, were growing and developing differently. Maximal absolute volume increment (1.78 g) was observed in the 1st group of juveniles, fed on a mixture of plant and animal food and detritus (June-September). Minimal increment (0.68 g) was found in the group of crayfish fed on *Chara*. Linear increment was the highest in the 1st group (1.53 cm), while in the group "*Chara*" (0.77 cm) it was the lowest. The length and volume increment of juveniles fed on detritus from the littoral zone of the lake was 0.77 cm and 0.90 g correspondingly and turned to be higher than that of young-of-the-year, fed on *Chara*. When fed on fish (2nd group) and mixed food (1st group), the juvenile yield was the same and made up 92.3%; in the 3rd (*Chara*) and 4th (detritus) groups - only 76.9%.

As it is known (Goldman et al. 1975), *P. leniusculus* is an omnivorous animal, besides plant and animal food it consumes also detritus. Detritus ensures the growth and development of crustaceans for a long time, its nutritive value is not lower than that of animal food and is higher than algae. Organic detritus matter may be hydrolyzed by digestive enzymes. The activity of digestive enzymes in the organism of crustaceans depends on the intensity of food consumption and varies notably during the period of postembryonic development (Van Wormhoudt 1973).

The maximal level of the proteolytic activity in the digestive gland and digestive tract of *P. leniusculus* young-of-the-year was observed when they were fed on fish (Fig 6). It should be noted that a comparatively high proteolytic activity was observed in the digestive system of juveniles fed on detritus, what corresponds with the data obtained during the studies on the influence of food on the level of metabolism of *Astacus astacus* juveniles (Mackeviciene 1979). Minimal level of proteolysis in the digestive gland was noticed when crayfish were fed on *Chara*, what agrees with the data on the influence of food on the growth rate of young-of-the-year and the amount of microorganisms in the digestive tract (Mackeviciene & Mickeniene 1988). Protein content in the digestive system of juveniles was the highest in crayfish fed on detritus and fish (Fig. 6). Studies on the influence of food on the level of protein metabolism of *P. leniusculus* juveniles revealed that the diet of crayfish reared under semi-natural conditions can consist not only of animal and plant food but also of detritus. Studies of endocrine regulation in freshwater crayfish indicated that these crustaceans have a rich collection of vertebrate steroid hormones, i.e. glucocorticoids (hydrocortisone and corticosterone) and sex hormones (testosterone, progesterone, estradiol) (Nikitina 1982). According to Fingerman (1987), the progress of aquaculture of decapod crustaceans is closely connected with the achievements of endocrinology. The studies on the level of hormones, one of the physiological parameters of adaptability of crayfish, are necessary when studying physiological characteristics of native and alien species of crayfish.

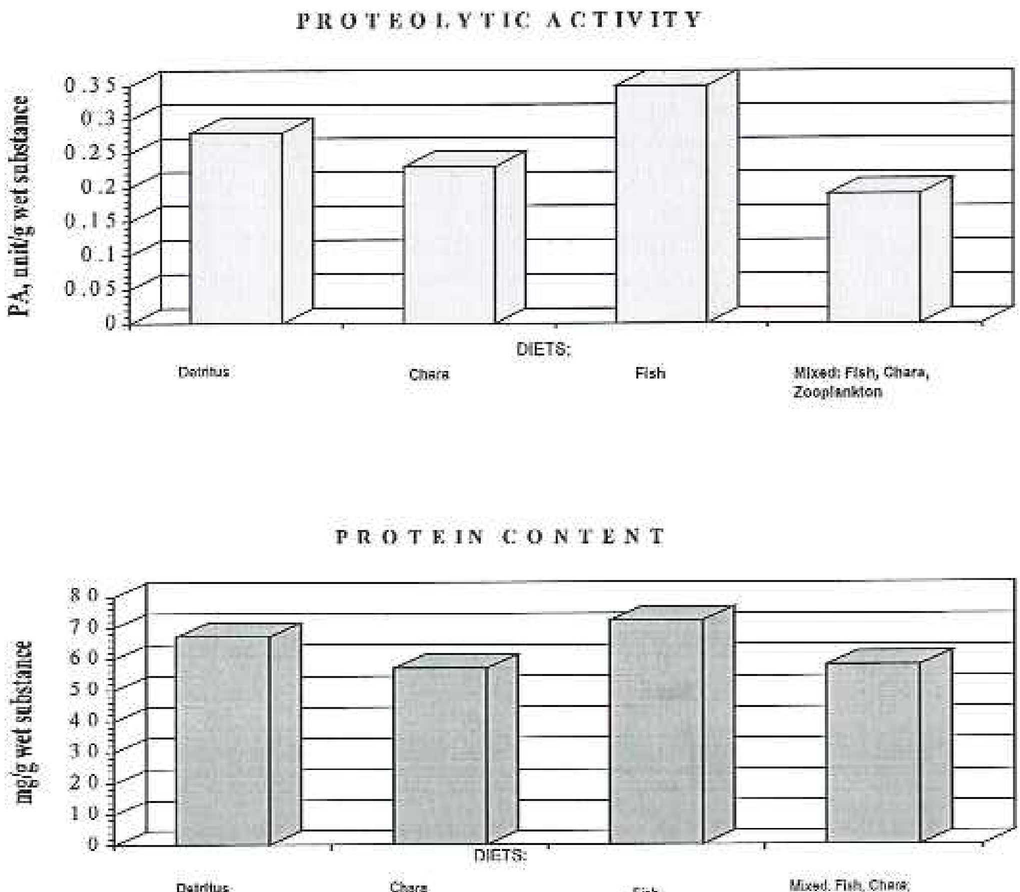


Fig. 6 *Influence of feeding on the level of protein accumulation and proteolytic activity in the digestive system of one-year-old juveniles of Pacifastacus leniusculus.*

We found that the concentration of steroid hormones varied in organs and tissues of signal crayfish males (Fig. 7). According to our data, the level of accumulation of corticosterone exceeds the concentration of hydrocortisone. Organs and tissues in decreasing order of glucocorticoid concentrations are as follows: heart>nerve cord>eyestalks>green gland>exoskeleton>muscles>digestive gland. The level of glucocorticoids varied differently at separate stages of the intermolt cycle (Fig. 7). Changes in hormone concentrations in the course of the intermolt cycle suggest that glucocorticoids can be involved in the regulation of metabolic reactions ensuring crayfish molt.

Vertebrate sex steroid hormones have been determined in all the studied organs and tissues of *P. leniusculus*. The level of testosterone accumulation is comparatively higher than of estradiol (Fig. 7).

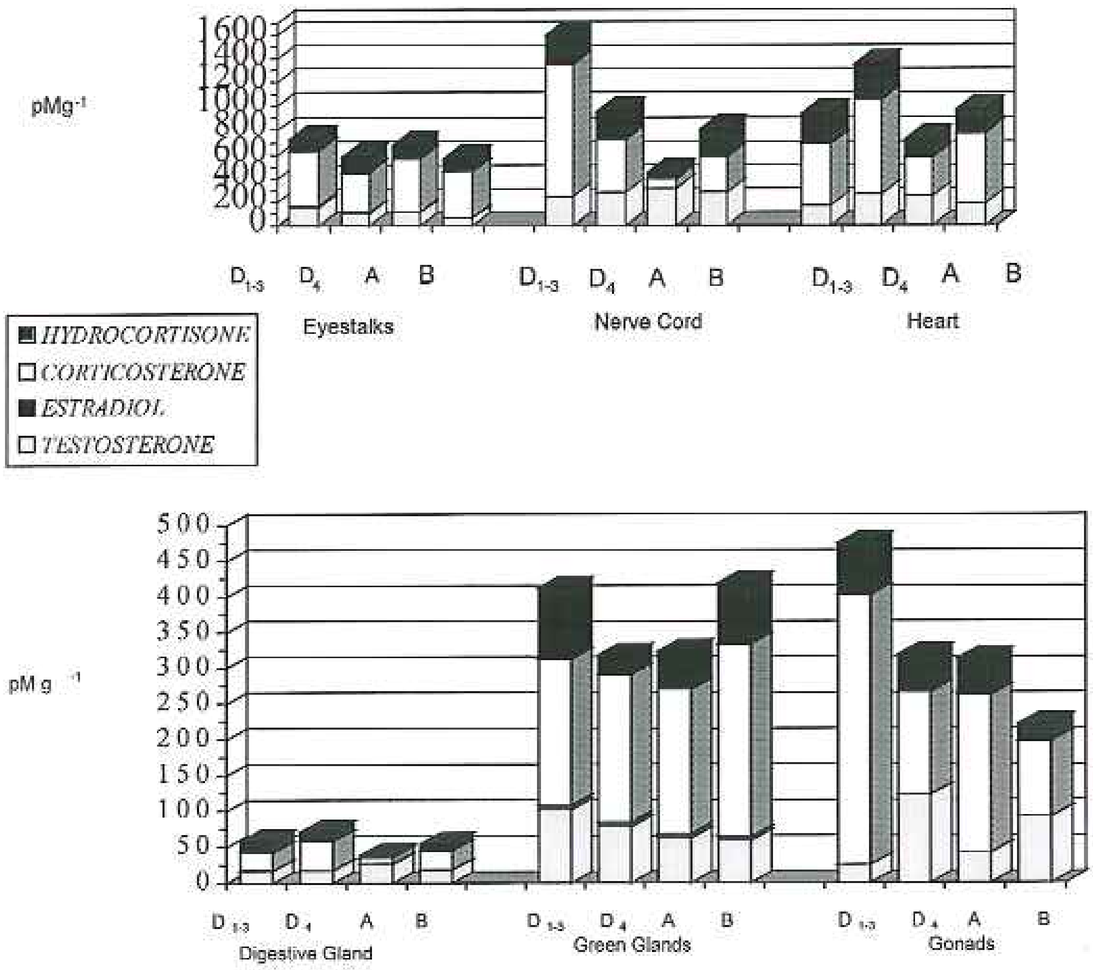


Fig. 7 *Concentration of steroid hormones of Pacifastacus leniusculus (Dana) males at separate stages of the intermolt cycle.*

The maximum concentration of estradiol has been found in eyestalks, while that of testosterone is in the nerve cord. The minimum content of estradiol has been determined in the gonads of *P. leniusculus*, while that of testosterone is in muscles and exoskeleton. Significant fluctuations in concentration of sex hormones at different stages of the intermolt cycle have been observed (Fig. 7).

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Part 3

Conclusions and recommendations

Management of freshwater crayfish - Conclusions and recommendations from the Nordic-Baltic workshop

A main focus of the workshop presentations and group work was on management of crayfish: main problems, practical actions and research needs. During the group work, the participants were divided in two groups; 1) Restoration, reintroduction and culture, and 2) Legislation/regulations, public information and monitoring, chaired by Paula Henttonen and Lennart Edsman, respectively. Current knowledge, experiences, problems and research needs related to different topics within the group subjects were discussed. Based on the group work, country presentations, and discussions throughout the workshop, the following conclusions and recommendations regarding crayfish management are raised:

Conclusions:

- Native crayfish populations have been greatly reduced during this century and are still declining in many areas in the Nordic-Baltic countries.
  Main reasons are: Spread of non-native, plague-carrying species, especially signal crayfish (*Pacifastacus leniusculus*) and spiny-cheek crayfish (*Orconectes limosus*), spread of crayfish plague, different kinds of pollution, and physical habitat degradation.
- It is possible to re-establish native crayfish populations in plague-stricken localities providing that no non-native, plague-carrying crayfish have been established. In polluted waters, crayfish can be restocked if water quality improves.
- There is relatively little knowledge on the cost-benefit effects of habitat improvements in physically degraded crayfish localities.
- Crayfish material for re-stocking includes a gradient of size categories, from newly hatched to mature adults. Recommendations of different categories are given by Erkamo et al. (this report).
- Young crayfish for restocking purposes can successfully be produced by intensive (indoor) culture methods. Crayfish production for consumption still rely on extensive or semi-intensive (juvenile production indoor) methods. Intensive production of crayfish for consumption still is in the experimental stage.
- National regulations for crayfish catching (season, minimum size, catching methods) exist in all Nordic-Baltic countries except Sweden (where local rules still exist), but the regulations differ very much. Control and enforcement are necessary to make the regulations effective.

- Presence of non-native species requires species-specific management. Effective management of crayfish (protection of native species, locally adapted regulations, enhancement efforts and sustainable exploitation) rely on updated information on the distribution, abundance, and harvest of the crayfish populations and species, i.e. on mapping and monitoring schemes. Public information and education is also a prerequisite for good management.
- Protection and exploitation of crayfish populations are closely linked. Those who exploit will also protect and enhance the population.

Recommendations:

- Objectives of crayfish management should be:
  1) Protection, restoration and enhancement of native crayfish
  2) Sustainable exploitation of crayfish populations
- A database of crayfish distribution and abundance, including diseases and parasites, should be established and continuously updated by a responsible institution.
- Spread of non-native crayfish species to new areas should be banned and strictly enforced. Good communication and agreement between neighbouring countries regarding distribution and spread of the non-native species is needed.
- Native crayfish populations should be re-established and strengthened when possible.
- Reviews of current knowledge, as well as more controlled experiments, on restoration/habitat improvement and reintroduction/strengthening of crayfish populations are needed.
- Monitoring/test-fishing methods should be adapted to the aim of the study (e.g. survey of localities in a large area to map occurence, long-term monitoring to register change over time, monitoring of a single locality to evaluate effects of exploitation, etc.). Always ask: Why monitor? Consider available resources, and then design the monitoring/test-fishing scheme. When monitoring for comparative purposes a standardised methodology should be used.
- National catching regulations should be evaluated at intervals, against the background of new biological data, practical management experiences from authorities at different levels and also experiences from other countries. The national regulations should be flexible so that adaptations can be made according to local conditions (e.g. lowering of minimum size in stunted populations).
- The network of Nordic-Baltic crayfish researchers and managers should be further strengthened. Individual contacts should be maintained and further developed, joint projects should be initiated, and Nordic-Baltic meetings/workshops should be arranged at regular intervals.

Appendix 1

Nordic-Baltic Workshop on Freshwater Crayfish Research and Management
May 23-26, 1998, Sagadi Training Centre, Estonia

LIST OF PARTICIPANTS

Name	Institution	Address
DENMARK		
Bjarne Styrishave	Roskilde University	P.O. Box 260, DK-4000 Roskilde, Denmark
Berit Bojsen	Roskilde University	P.O. Box 260, DK-4000 Roskilde, Denmark
Søren Berg	Danish Institute for Fisheries Research, Dept. of Inland Fisheries	Vejlsøvej 39, DK-8600 Silkeborg, Denmark
ESTONIA		
Jaanus Tuusti	Sagadi Training Centre	EE-2123 Sagadi, Estonia
Leelo Kukk	Ministry of Environment, Dept. of Fishery	Kopli 76, EE-0004 Tallinn, Estonia
Nikolai Laanetu	Tartu State University	Kalevi 69-1, EE-2400 Tartu, Estonia
Margo Hurt	Võru County Government, Environment Department	Karja 17 A, EE-2710 Võru, Estonia
Mati Kivistik	Haanja Nature Park	pk. 37, EE-2710 Võru, Estonia
Tiit Paaver	Estonian Agricultural Academy Dept. of Fish Farming	Kreutzwaldi 1, EE-2400 Tartu, Estonia
Aime Reier	Ministry of Environment	Toompuiestee 24, EE-001 Tallinn, Estonia
FINLAND		
Ari Mannonen	FGFRI Evo Research Station	Rahtijarventie 291, FIN-16970 Evo, Finland
Esa Erkamo	FGFRI Evo Research Station	Rahtijarventie 291, FIN-16970 Evo, Finland
Pietari Paasonen	University of Kuopio	P.O.Box 1627, FIN-70211 Kuopi, Finland
Timo Halonen	University of Kuopio	P.O.Box 1627, FIN-70211 Kuopio, Finland
Paula Henttonen	University of Kuopio	P.O.Box 1627, FIN-70211 Kuopio, Finland
Tero Ahvenharju	University of Joensuu	Niskakatu 29 C 27, FIN-80100 Joensuu, Finland
Teuvo Järvenpää	FGFRI	Paum, FIN-08506 Lohja as. Finland
LATVIA		
Egils Tinte	Ozolin Crayfish Farm	KURZEME Center, Pilsetas Laukums 3 Kuldiga, LV-3300, Latvia
August Arens	Latvian Biotechnology	KURZEME Center, Pilsetas Laukums 3 Kuldiga, LV-3300, Latvia
Gatis Kalniod	Agricultural Academy	KURZEME Center, Pilsetas Laukums 3 Kuldiga, LV-3300, Latvia
LITHUANIA		
Aloyzas Burba	Institute of Ecology	Akademijos 2, LT-2600 Vilnius, Lithuania
Ramune Bucinskiene	Vilnius University	Ciurlionio 21/27, LT-2001 Vilnius, Lithuania
Lina Vozgirdaite	Vilnius University	Ciurlionio 21/27, LT-2001 Vilnius, Lithuania
Liongina Mickeniene	Institute of Ecology	Akademijos 2, LT-2600 Vilnius, Lithuania
Tadas Karaliunas	Vilnius University	Ciurlionio 21/27, LT-2001 Vilnius, Lithuania
Tomas Kalesinskas	Vilnius University	Ciurlionio 21/27, LT-2001 Vilnius, Lithuania
Guoda Mackeviciene	Institute of Ecology	Akademijos 2, LT-2600 Vilnius, Lithuania
NORWAY		
Olav Åse	University of Oslo	Hagalivn. 31B, N-1342 Jar, Norway
Jan Erlend Bråthen	University of Oslo	Sognsv.85, Postboks 5431 N-0858 Oslo, Norway
Trond Taugbøl	Eastern Norway Research Institute	P.O. Box 1066 Skurva, N-2601 Lillehammer, Norway
RUSSIA		
Valeri Fedotov	St. Petersburg Scientific Research Centre	18 Korpusnaya str., 197042 St. Petersburg, Russia
Svetlana Bykadorova	St. Petersburg Scientific Research Centre	18 Korpusnaya str., 197042 St. Petersburg, Russia
SWEDEN		
Lennart Edsman	Institute of Freshwater Research	S-17893 Drottningholm, Sweden
Per Nyström	Lund University	Ecology Building, S-22362 Lund, Sweden
Björn Tengelin	Hushållsselskapet	Box 275, S-58102 Linköping, Sweden
Tommy Odelström	Institute of Freshwater Research	Erken Lab, Norrmalma 4200, S-76173 Norrtälje, Sweden
ENGLAND		
John Foster	The Environment Agency	Oving Road, Chichester, West Sussex, PO20 6AG, England

Appendix 2

Nordic-Baltic Workshop on Freshwater Crayfish Research and Management
May 23-26, 1998, Sagadi Training Centre, Estonia

ORAL AND POSTER PRESENTATIONS

ORAL:

Author(s)	Title
Søren Berg	Crayfish legislations and management in Denmark
Jan Erlend Bråthen	Interactions between Canadian waterweed and crayfish in L. Steinsfjorden
Aloyzas Burba	Crayfish situation in Lithuania
Lennart Edsman	Crayfish situation in Sweden
Esa Erkamo, Teuvo Jarvenpaa, Jorma Kirjavainen and Jouni Tulonen	The significance of crayfish size at the time of release on stocking results of noble crayfish and signal crayfish
Valeri Fedotov, Sergei Kholodkevich & Svetlana Bykadorova	Crayfish situation in the North-west of Russia
John Foster	Monitoring freshwater crayfish stocks in Great Britain
Margo Hurt & Mati Kivistik	Noble crayfish stocks in Põlva, Võru and Valga counties in Estonia in 1993-1997
Leelo Kukk	Crayfish situation in Estonia: legislation
Ari Mannonen & Kai Westman	Crayfish situation in Finland
Per Nyström	Impact of crayfish on the environment
Tommy Odelström	On crayfish aquaculture in Northern Sweden
Pietari Paasonen	Freshwater crayfish virus research in Finland: state of the art.
Bjarne Styrishave & Berit Bojsen	Crayfish situation in Denmark
Björn Tengelin	The organization of associations outside the authorities - and their role in crayfish management
Jostein Skurdal & Trond Taugbøl	Monitoring of crayfish populations in Norway
Trond Taugbøl & Jostein Skurdal	Crayfish situation in Norway
Egils Tinte	Latvian Crayfish Program
Jaanus Tuusti	Crayfish situation in Estonia
Lina Vozgirdaite	Fecundity of Lithuanian crayfish *Astacus astacus*, *Astacus leptodactylus* and *Orconenctes limosus* females in various natural habitats
Olav Åse	Responses of the noble crayfish, *Astacus astacus*, on chemical stimuli from predators

POSTER:

Tero Ahvenharju	Gastroliths formation and reabsorption in noble crayfish (*Astacus astacus*)and signal crayfish (*Pacifastacus leniusculus*) juveniles.
Ramune Bucinskiene	Crayfish diseases and parasites distribution and abundance in Lithuanian waters
Timo Halonen	Preliminary results on heavy metals in crayfish *Astacus astacus*
Tomas Kalesinskas, Anatolij Terentjev, Guoda Mackeviciene & Vytautas Mazeika	Distribution and population density of signal crayfish in Lithuania
Tados Karalinnas	Relationship between Lithuanian crayfish of different species: distribution, population parameters and habitats
Nikolai Laanetu	Dropping analyses of mink, *Mustela vison* and otter, *Lutra lutra* - one method to get current data on the distribution of noble crayfish in Estonia
Guoda Mackeviciene	Some characteristics of metabolism of signal crayfish *Pacifastacus leniusculus* Dana acclimatized in Lithuania
Liongina Mickeniene	Microflora of the digestive tract of signal crayfish *Pacifastacus leniusculus* Dana

Appendix 3

Nordic-Baltic Workshop on
Freshwater Crayfish Research and Management
May 23-26, 1998, Sagadi Training Centre, Estonia

Program

Saturday May 23

17:30 - 20:00	Registration Poster display	
20:00 -	Welcome address Welcome party	Director Jaanus Tuusti, Sagadi Training Centre

Sunday May 24
Chairman: Trond Taugbøl

9:00 - 9:15	Opening address	Trond Taugbøl, Eastern Norway Research Institute
9:15 - 10:00	Invited paper: "Impact of crayfish on the environment"	Per Nyström, Lund University, Sweden
10:00 - 10:15	The significance of crayfish size at the time of release on stocking results of noble crayfish and signal crayfish	Esa Erkamo, FGFRI Evo Research Station
10:15 - 10:30	Fecundity of Lithuanian crayfish *Astacus astacus*, *Astacus leptodactylus* and *Orconenctes limosus* females in various natural habitats	Lina Vozgirdaite, Vilnius University
10:30 - 11:00	**Coffee break**	
11:00 - 11:15	Interactions between Canadian waterweed and crayfish in L. Steinsfjorden	Jan Erlend Bråthen University of Oslo
11:15 - 11:30	Noble crayfish stocks in Põlva, Võru and Valga counties in Estonia in 1993-1997	Margo Hurt Võru County Government
11:30 - 11:45	Monitoring freshwater crayfish stocks in Great Britain	John Foster The Environment Agency, UK
11:45 - 12:00	Monitoring of crayfish populations in Norway	Trond Taugbøl Eastern Norway Research Institute
12:00-13:00	**Lunch**	

Sunday May 24, after lunch
Chairman: Lennart Edsman

13:00 - 13:15	Freshwater crayfish virus research in Finland: state of the art.	Pietari Paasonen, University of Kuopio
13:15 - 13:30	Responses of the noble crayfish, *Astacus astacus*, on chemical stimuli from predators	Olav Åse, University of Oslo
13:30 - 13:45	The organization of associations outside the authorities - and their role in crayfish management	Björn Tengelin, Hushållselskapet, Sweden
13:45 - 14:00	On crayfish aquaculture in Northern Sweden	Tommy Odelström Institute of Freshwater Research
14:00 - 15:00	Questions and discussions on today's presentations	
15:00 - 15:30	**Coffee break**	
15:30 - 17:00	**Poster session**	
17:00 - 19:00	**Excursion**	
19:00 -	**Dinner**	

Monday May 25
Chairman: Paula Henttonen

9:00 - 9:30	Crayfish situation in Sweden	Lennart Edsman, Institute of Freshwater Research
9:30 - 10:00	Crayfish situation in Lithuania	Aloyzas Burba, Institute of Ecology
10:00 - 10:20	Crayfish situation in Denmark	Bjarne Styrishave, University of Roskilde
10:20 - 10:40	Crayfish legislation and management in Denmark	Søren Berg, Danish Institute for Fish. Research
10:40 - 11:00	**Coffee break**	
11:00 - 11:30	Crayfish situation in Finland	Ari Mannonen FGFRI Evo Research Station.
11:30 - 12:00	Crayfish situation in Norway	Trond Taugbøl Eastern Norway Research Institute
12:00 - 13:00	**Lunch**	

Monday May 25, after lunch

Chairman: Ari Mannonen

13:00 - 13:20	Crayfish situation in Estonia	Jaanus Tuusti, Sagadi Training Centre
13:20 - 13:40	Crayfish situation in Estonia: Legislation	Leelo Kukk, Ministry of Environment
13:40 - 14:15	Latvian Crayfish Program	Egils Tinte Ozolin Crayfish Farm
14:15 - 14:45	Crayfish situation in Northwest Russia	Valeri P. Fedotov St. Petersburg Scientific Research Centre
14:45-15:00	Questions and discussions on today's presentations	
15:00 - 15:30	**Coffee break**	
15:30 - 18:00	Group work on the subject "Management of crayfish: main problems, practical actions and research needs". Two groups will discuss different topics within this subject (discussion "guide" will be provided)	Introduction to the group work: Trond Taugbøl Group chairmen: Lennart Edsman Paula Henttonen
19:00 -	**Dinner and party in Altja Inn**	

Tuesday May 26

9:00 - 11:00	Group work continues.....	
11:00-11.30	**Coffee break**	
11:30 - 13:00	Presentation of group work Joint recommendations Closing of the workshop	Group chairmen/secretaries Trond Taugbøl, Jaanus Tuusti
13:00-14:00	**Lunch**	
14:00	Departure from Sagadi to Tallinn	

Nordic-Baltic Workshop on Freshwater Crayfish Research and Management

May 23-26, 1998, Sagadi Training Centre, Estonia

A Nordic-Baltic workshop on freshwater crayfish research and management was held at Sagadi Training Centre, Estonia, May 23-26 1998. The workshop gathered 37 participants from 9 different countries. In total 21 oral and 8 poster presentations were given, and there was also group work. The purpose of the workshop was to exchange information and knowledge based on current research and mangement experiences, and discuss future research needs. The Nordic and Baltic countries have many of the management problems and challenges in common. Good communication, co-operation and co-ordination between researchers and managers in the different countries are of great importance in order to enhance crayfish management and research. This report presents submitted manuscripts of the oral/poster presentations and conclusions and recommendations from the workshop, based on group work, country presentations, and plenary discussions.

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