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Distribution of Crayfish Species in Austria with Special Reference to Introduced Species

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ABSTRACT

In Austria three native crayfish species occur: the noble crayfish (*Astacus astacus),* the stone crayfish (*Austropotamobius torrentium),* and the white-clawed crayfish *(Austropotamobius pallipes).* The narrow-clawed crayfish *(Astacus leptodactylus),* the signal crayfish *(Pacifastacus leniusculus),* the spiny-cheek crayfish *(Orconectes limosus)* and the red swamp crayfish *(Procambarus clarkii)* have been introduced. Although *A. astacus* occurs throughout Austria, it is restricted to lakes and larger streams with many hiding places and the possibility to burrow in loamy banks. *A. torrentium* is the most frequent crayfish, inhabiting smaller running waters at higher altitudes. Isolated populations of *A. pallipes* are known only from the Gitschtal in the Carinthian Gail Basin (var. *carinthiaca)* and from the Tyrolean Plansee (var. *trentinicus).* The native species are endangered. Crayfish have been diminished by several causes, mainly by the spread of the crayfish plague fungus *Aphanomyces astaci,* river regulations, water pollution and increased use of fertilizers and pesticides. At about 1900, *A. leptodactylus* was introduced from eastern Europe, but it is restricted to some lakes and former limestone-quarries. The Nearctic *P. leniusculus* and *O. limosus* have been introduced since 1970 by crayfish farmers because these species are plague-resistant. As they can out-compete native species and carry infectious diseases, their introduction caused an additional reduction of autochthonous populations. *P. clarkii* is not known from the wild, but can be obtained from fish markets, restaurants, and the aquarium trade. Following the examples of some other European countries, in Austria the public shall be made aware with the problems caused by releasing non-native or alien crayfish.

Key Words: Native species, alien species, protection, distribution, zoogeography, introduction, public awareness.

I. INTRODUCTION

The Federal Republic of Austria is situated in the centre of Europe. This small (83,900 km^2) but highly diverse country extends from about 46°22'N to 49°1'N (distance c 290 km) and from 9°31'E to 17°9'E (c. 580 km). The altitude varies from 115 m to 3,797 m above sea level. Five different types of landscapes can be distinguished: 70% are dominated by the Alps, formed by calcareous and rapid-weathering rocks. In the north of the Alps there is the Pre-Alpine Area that is continued in the north-east by the Pre-Carpathian Area. North of the Danubian Valley, there is a highland formed by slow-weathering rocks, granites and gneiss. The Viennese Basin is situated around the capital of Austria, in the east and south-east there are the Pannonian Lowlands. Approximately 46% of the country is covered by forests. In Austria, the separate Federal States (Bundeslander) are responsible for their own nature conservation and research related to species preservation. A national red data book of animal species was published by the Federal Ministry for Environment (Pretzmann 1994). In addition, each Bundesland also tries to publish red data books of selected groups of endangered animals. In Lower Austria, a series has started with vertebrates.

In general, the occurrence and distribution of crayfish is poorly known. Excellent knowledge was so far restricted to several local drainage-systems. Since some years people interested in crayfish regularly meet and discuss their problems at the University of Vienna. As a result a multi-author volume, entitled "Freshwater Crayfish in Austria", was published for the first time in November 1998 (Eder and Hödl

1988). This semi-scientific book was combined with a crayfish exhibition shown successively in three museums. In Austria, the public interest in freshwater crayfish is currently markedly increasing. The most important aims of the book and the exhibition were to increase public awareness of the possible risks of releasing alien crayfish into the wild, to summarize the current knowledge of the distribution of the six crayfish species found in Austria, and to review selected aspects of the biology and ecology of these animals.

Three native crayfish species are to be found in Austria: *Astacus astacus* (Linnaeus, 1758), *Austropotamobius torrentium* (Schrank, 1803), and *Austropotamobius pallipes* (Lereboullet, 1858). At least three introduced species occur regularly: *Astacus leptodactylus* Eschscholtz, 1823 from eastern Europe, and the Nearctic *Pacifastacus leniusculus* (Dana, 1852) and *Orconectes limosus* (Rafinesque, 1817). *Procambarus clarkii* (Girard, 1852) has so far not been found in the wild, but is on sale in aquarist shops as "Red Lobster". In Austria, outbreaks of the crayfish plague started in 1878, and between 1879 and 1904 approximately 75% of the populations *of A. astacus* were devastated (K.K. Statistische Zentralkommission 1907). *A. torrentium* and *A. pallipes* are relatively small and economically unimportant. Hence, they have rarely been transplanted by man. Their present-day distribution should rather be identical with their original distribution. On the other hand, the noble crayfish, *A. astacus,* has been an object of trade, commerce and zoological explorations in Europe for a long time. As it has been transplanted in all kinds of water-bodies, its original pattern of distribution cannot easily be reconstructed.

II. MATERIALS AND METHODS

For the first time, distribution data of freshwater crayfish all over Austria were recorded and compiled by the biogeographic database of Austria, ZOODAT (Forschungsinstitut für Umweltinformatik, J.W. Klein-Str. 73, A-4040 Linz). Data are from current Ph.D. theses for water-bodies in Carinthia and Styria, from research work done at the universities of Innsbruck (N-,E-,S-Tyrol, Vorarlberg) and Salzburg (Salzburg), and from observations by the author and the mentioned crayfish research team at the University of Vienna (Lower Austria). Additionally, announcements were made in newspapers, and the author got information by phone-calls. The information was noted when the person calling was able to identify the species. When this was not the case, crayfish were caught in the mentioned water-bodies and identified. Doubtful information (> 50% of the phone calls), however, was ignored, in order not to bias the excellent data available. For the ZOODAT database, a record was accepted as complete when it included the name of the species, the exact location of the water body by longitude (east of Greenwich) and latitude, the nearest village, the date of the observation (day-month-year), and the name of the observer. Additional remarks are possible for each record. The distribution data are shown on digital maps made available via the world-wide-web by governmental organizations of the United States. There is a huge variety for plotting the distribution points as well as the background information on maps (Malicky and Eder 1998).

III. RESULTS

As background information drainage systems and water-bodies are depicted in the maps, and the geographical distribution of the crayfish is illustrated by closed circles. 1,172 observations were compiled and computerized (Table I).

Native crayfish species

1,014 localities out of 1,172 or 86.52% are inhabited by native species (Table I).

1. The white-clawed crayfish (Austropotamobius pallipes)

In Austria, the white-clawed (white-footed) crayfish has a very restricted pattern of distribution, 28 localities out of 1,172 (2.39%) are inhabited by *A. pallipes* (Table I, Fig. 1). Isolated populations have been discovered in 1977-78 in the Gossering, the main river of the Gitschtal, southeastern Carinthia, and its leftside tributaries (Albrecht 1981). The tributaries of the Gossering are small, steep, woodland brooks with a coarse sediment of stones and rocks. In 1994 another location in the upper Gitschtal was discovered in a swampy area, draining into a small stream (Stoffelbauer Quelle at 760 m a.s.l., 46°40'49"N,

13°16'42"E; Machino and Füreder 1996) and in the Upper Drautal (Machino and Ftireder 1996). In 1994, a population of *A. pallipes* was found in the Gailtal at Reisach in a small muddy stream draining swampy wetlands. The occurrence seems to be restricted to the first 500 metres from the source (625 m a.s.l., 46°38'41"N, 13°09'14"E). White-clawed crayfish therefore have a wide range of habitat, including steep, fast-flowing stony brooks in the Gitschtal and flat muddy waters in the Gailtal. The present-day distribution of *A. pallipes* var. *carinthiaca* is believed to be autochthonous. The discovered populations are interpreted as the remainder of a formerly more widely distributed species.

Table I. Summary of the localities (distribution points) of freshwater crayfish in Austria. Saved, compiled and computerized by ZOODAT.

Crayfish species		No. of observations	Percentage %
Scientific name	**Common name**		
Austropotamobius pallipes	white-clawed crayfish	28	2.39
Astacus astacus	noble crayfish	452	38.57
Austropotamobius torrentium	stone crayfish	534	45.56
Sum of native species		1,014	86.52
Astacus leptodactylus	narrow-clawed crayfish	28	2.39
Pacifastacus leniusculus	signal crayfish	119	10.15
Orconectes limosus	spiny-cheek crayfish	11	0.94
Procambarus clarkii	red swamp crayfish	0	0.00
Sum of alien species		158	13.48
Sum of crayfish species		1,172	100.00

In 1994 the white-clawed crayfish was discovered in northwestern Tyrol near Reutte in the Plansee (976 m a.s.l., 47°28'10"N, 10°48'00"E) which is a part of the Lech valley. Most of the specimens caught in Plansee were taken at the western end of the lake, near its outlet in the smaller bay of the lake (Kleiner Plansee) and some in the outlet, the Archbach at Frauenbriinnele Bridge. Later the animals were also discovered at the east shore of Plansee near Fürchterlichhütte, in the Heiterwangersee and the Kreckelmooser See (Fureder and Machino 1995, 1999). These natural lakes are of glacial origin and oligotrophic. In the Archbach, the lower limit of the distribution is at a dam just above the Archbach gorge. In the gorge, discharge is reduced because water is diverted for electric power at the two dams upstream. The gorge is about 2 km long and consists of three waterfalls (Stuibenfälle). As the colonisation of the Archbach below the gorge by the white-clawed crayfish from the Plansee is almost impossible, the populations above the Archbach gorge are isolated. The Archbach flows into the River Lech, passing through Augsburg, Bavaria, and further into the River Danube.

The occurrence of the white-clawed crayfish in Plansee cannot be explained as an extension of its natural distribution. Native people report the traditional story that c. 70 years ago (i.e. 1920 to 1925) a Mr. Singer carried crayfish from the Reutte train station in a basket covered by moss to keep them wet and released them into the lake. Accordingly, the Plansee population was introduced by man, perhaps even much earlier than this story tells (Fureder and Machino 1995). For *A. pallipes* several historical examples of human introductions throughout Europe are reported (Albrecht 1983). Most probably the crayfish from Plansee originated from the Italian regions Trento or Bolzano. Morphological characteristics of *A. pallipes* var. *trentinicus* described by Albrecht (1982) resemble the specimens from Plansee (Fureder and Machino 1995). The present Italian provinces Trentino and Alto Adige was Austrian territory before World War I.

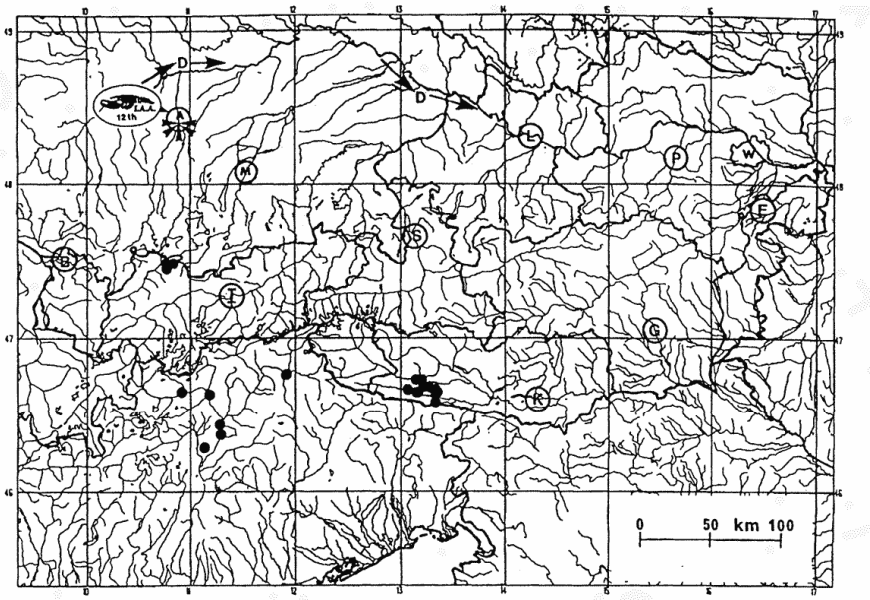

Figure 1. Distribution of *Austropotamobius pallipes* in Austria and South Tyrol, Italy. Capitals of the nine Federal States of the Republic of Austria: W = Vienna (VIENNA), E = Eisenstadt (BURGENLAND), P = St. Pölten (LOWER AUSTRIA), L = Linz (UPPER AUSTRIA), S = Salzburg (SALZBURG), G = Graz (STYRIA), K = Klagenfurt (CARINTHIA), I = Innsbruck (TYROL), B = Bregenz (VORARLBERG). D = River DANUBE and its flow direction (→). Thick black lines: borders of Austria and the federal states; M = Munich, A = Augsburg (Germany).

2. The stone crayfish (Austropotamobius torrentium)

In Austria, the stone crayfish is very frequently found. Five hundred and thirty-four localities out of 1,172 (45.56%) are inhabited by *A. torrentium* (Table I, Fig. 2). However, the species is rarely reported from Tyrol: the lower Archbach (below Mühl near Reutte) and the Haldensee (Füreder and Machino 1999). The first population seems to be autochthonous as it agrees with the distribution pattern in Bavaria (Bohl 1989) whereas the origin of the second is not yet known (Fureder and Machino 1999). *A. torrentium* typically inhabits cold and fast-flowing headwaters and springs in the mountains, but can also be found in cool standing water-bodies. In former times, *A. torrentium* was reported as being a starved noble crayfish. As it has never been stocked its actual distribution seems to be uninfluenced by human translocations.

The stone crayfish usually has a heavier and more calcified exoskeleton than the noble crayfish and can therefore withstand higher current velocities.

A. torrentium occurs preferably in the higher regions and is normally found in woodland headwaters, whereas *A. astacus* is found in the lower, deeper parts of the rivers. When both the noble crayfish and the stone crayfish occur in the same river, the species are usually separated *A. torrentium* preferring coarse stones and *A. astacus* loamy banks where it can burrow. Overlapping between the two species is not often observed (Bohl 1989, Troschel 1997a). As the woodland brooks in the mountains being inhabited by the stone crayfish are in some distance from human settlements, especially from urbanized areas, many of the populations have remained uninfluenced. The long distance to water-bodies inhabited by introduced species can be a positive factor for the conservation of native populations. The woodland brooks with their highly diverse ecological factors (variation in depth and width, substrate heterogeneity, current velocity and discharge) must be conserved as habitats for the stone crayfish.

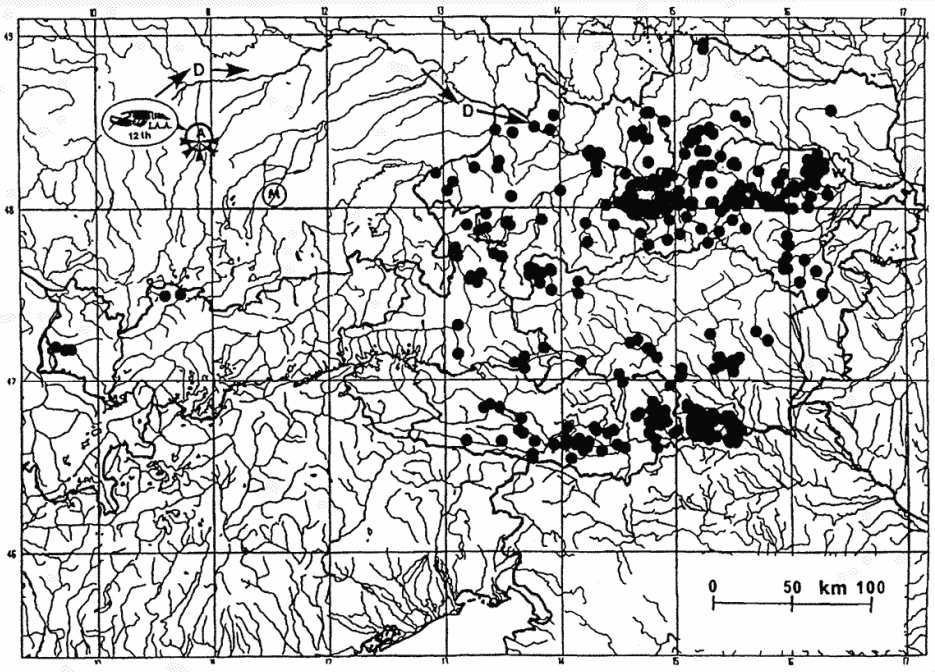

Figure 2. Distribution of *Austropotamobius torrentium* in Austria and South Tyrol, Italy.

3. The noble crayfish (Astacus astacus)

Four hundred and fifty-two localities out of 1,172 (38.57%) are inhabited by *A. astacus* (Table I, Fig. 3). Until the middle of the last century, the noble crayfish was widely distributed throughout Austria excluding the high mountains. *A. astacus* inhabited most lakes and rivers, and also the ditches connected to them. Historical records reported statistics of possible yields in lakes of 10 kg ha^{-1} $year^{-1}$ (Troschel 1997a). Some historical records go back to the year 1321 (Fureder and Machino 1999). Therefore the exploitation and trade of this resource was of considerable economic importance, as it is a high quality delicacy. In Austria outbreaks of the crayfish plague disease caused by *Aphanomyces astaci* started in 1878, and between 1879 and 1904 approximately 75% of the populations of *A. astacus* were devastated (K.K. Statistische Zentralkommission 1907). Water pollution and the canalisation and embankment of streams and rivers subsequently prevented successful re-colonisation of the noble crayfish. Hence, the species lost its economic importance. Highly diverse ecological factors in larger streams with many hiding places and the possibility to burrow in loamy banks are key factors for the occurrence of the noble crayfish. Human restocking most often failed (c. 15% of the restocking experiments were successful; Wintersteiger 1985). The favoured habitats of *A. astacus* are rivers with a width of about 3 m and a depth of at least 0.5 m, and also meso- and eutrophic lakes, ponds and gravel pits. Smaller brooks often lack suitable banks where the crayfish can burrow. In higher altitudes *A. astacus* is replaced by *A. torrentium.*

Today the noble crayfish is still widespread in Austria, but in many cases only single specimens are to be found during sampling. Smaller populations in running waters are often confined to isolated areas where they are most likely protected by a series of barriers from a plague infection (Bohl 1989, Keller 1997). However, most noble crayfish populations are unstable, and stocks in great rivers have been reduced. Noble crayfish stock material can be obtained from crayfish hatcheries for re-introduction projects (Hager 1996). Apart from the abiotic suitability of a selected river (morphological, physical, chemical parameters), basic biotic requirements for the sustainability of such projects are: (1) absence of other, especially American, crayfish species from the project area, to avoid displacement and transmission of crayfish plague (in this case natural and man-made barriers within a drainage system can be of advantage), and (2) absence (or low density) of specialized crayfish predators like eel, pike and perch.

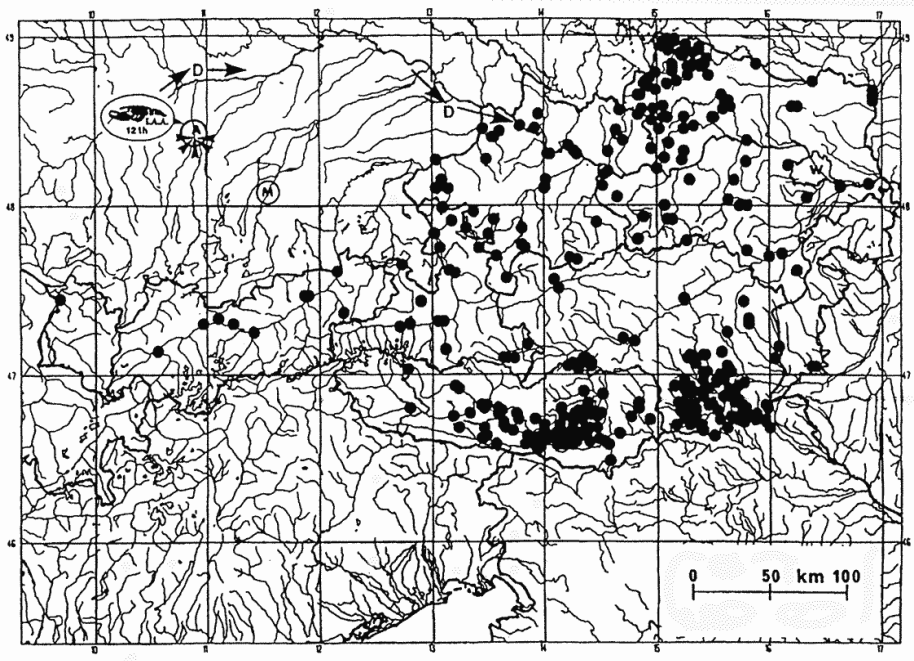

Figure 3. Distribution of *Astacus astacus* in Austria and South Tyrol, Italy.

Non-native (alien) crayfish species

One hundred and fifty-eight localities out of 1,172 or 13.5% are inhabited by non-native crayfish species (Table I).

1. The narrow-clawed crayfish or Turkish crayfish (Astacus leptodactylus)

The original distribution area of the narrow-clawed crayfish is Eastern Europe and the western parts of Asia, including states of the former USSR, Turkey and Turkmenia. Recently this species is extending its range towards Western Europe. The Caspian Sea, the Black Sea and the lower and middle Danube belong to the original area of *A. leptodactylus* (Entz 1912). In 1891 the narrow-clawed crayfish was introduced to Austria for re-stocking water bodies formerly inhabited by noble crayfish which were killed by crayfish plague. However, *A. leptodactylus* turned out to be not plague-resistant and most of the re-stocking experiments failed (Wintersteiger 1985).

Twenty-eight localities out of 1,172 (2.39%) are inhabited by *A. leptodactylus* (Table I, Fig. 4). The narrow-clawed crayfish was found in stagnant backwaters of the River Danube in eastern Lower Austria up to the eastern districts of Vienna. These observations seem to be the western-most natural records (Nesemann et al. 1995). In Hungary, the species is widespread and locally of high abundance, especially in the rivers Danube and Tisza (Thuranszky and Forro 1987). Surprisingly, even in the main course of the Danube, specimens of this crayfish species were caught as high upstream as river kilometre (= rkm) 1,672. (The kilometration of the second largest European river begins at its estuary with rkm 0.0; the centre of Vienna is situated at c rkm 1,930. The Austrian stretch of the River Danube has a distance of c 340 km: rkm 2,220-1,880). In Austria, the distribution of *A. leptodactylus* is restricted to some limestone quarries where it can reach population densities up to 15,000-20,000 adults per ha. It prefers eutrophic, soft-bottomed, muddy standing waters. The distribution is scattered, but nevertheless in a few lakes and gravel pits the narrow-clawed crayfish is of some economic importance.

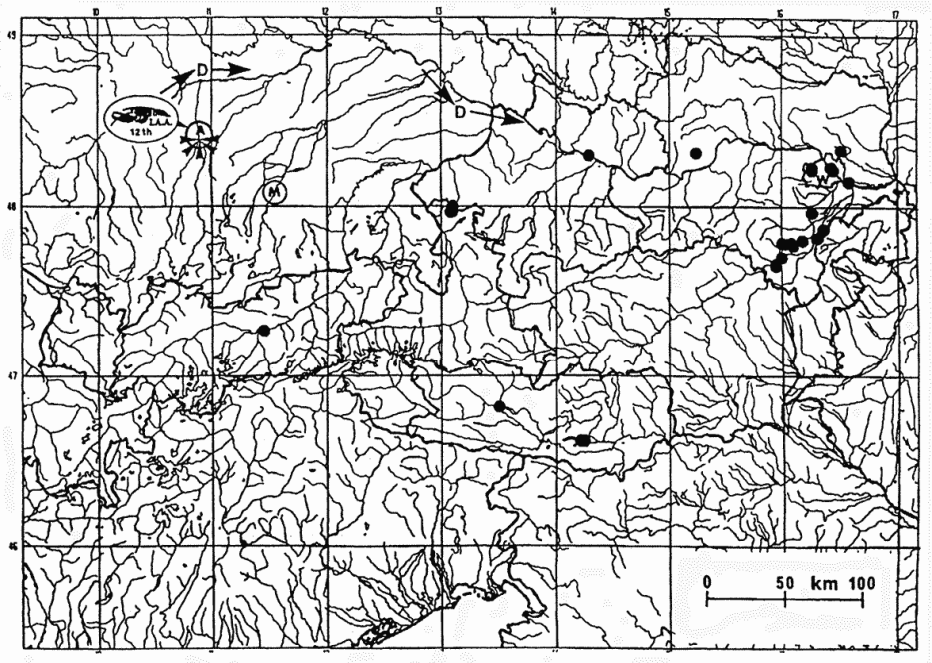

Figure 4. Distribution of *Astacus leptodactylus* in Austria and South Tyrol, Italy.

2. The signal crayfish (Pacifastacus leniusculus)

The original distribution of the signal crayfish was the north-west of North America between the Rocky Mountains and the Pacific coastline (Lowery and Holdich 1988). As this species is resistant to the crayfish plague fungus, some 2,000 specimens were imported directly from California into Austria during summer 1970. They were released into water bodies in Salzburg, Styria, Upper Austria and Lower Austria (Spitzy 1971, 1973). Unestam and Weiss (1970) isolated *Aphanomyces astaci* from *P. leniusculus* from the Sacramento River in California and Lake Tahoe, Nevada. Therefore the probability is high, that the imported specimens carried the pathogen. Today 119 localities out of 1,172 (10.15%) are inhabited by the signal crayfish (Table I, Fig. 5).

In Sweden, the noble crayfish was lost as a keystone-species in many aquatic ecosystems after outbreak of the plague. Eutrophication and spreading of macrophytes as observed in many lakes were probably due to the absence of crayfish from the trophic food chain (Abrahamsson 1966). Hence, the Simontorps Akvatiska Avelslaboratorium, an intensive hatchery of signal crayfish, was founded, and many specimens were exported all over Europe. The material for the second stocking experiments of Austrian waters with signal crayfish came also from Sweden (Spitzy 1971, 1973). Almost all of these stockings were successful, and as a delicacy in restaurants the species is accepted. Especially negative is the presence of signal crayfish in many water-bodies of the Salzkammergut, Austria's Lake District, as well as in the northwest of Lower Austria (Waldviertel), a hilly woodland with many traditional fish ponds, most of them populated with the noble crayfish (Pöckl 1998).

Unfortunately the habitat requirements of *A. astacus* and *P. leniusculus* are nearly the same. In contrast to the first species which is not plague-resistant the second is largely resistant and can act as a vector. Nowadays, the signal crayfish is widespread all over Austria, so that it can be characterised as an aggressive, invasive North American species. In all cases where both species have been observed at the same time in the same river, only the signal crayfish has survived and the noble crayfish has disappeared after 4-5 years. This phenomenon was also observed by Peay and Rogers (1999) for a Yorkshire river. *P. leniusculus* does not only transmit the plague fungus which kills native species, but is also more prolific by growing faster and producing more eggs and young. So the invader can easily outcompete the native species and is therefore a threat to them (Keller 1997). The signal crayfish is very good at climbing and escaping. Moreover, it burrows extensively into suitable substrates and is responsible for

the collapse of river banks. This behaviour was reported from England (Holdich and Rogers 1997, see also articles in Gherardi and Holdich 1999), but the author has also observed it in some streams in Lower Austria (Pöckl unpubl.). For all these reasons no further propagation of signal crayfish should be made in Austria (Pöckl 1998).

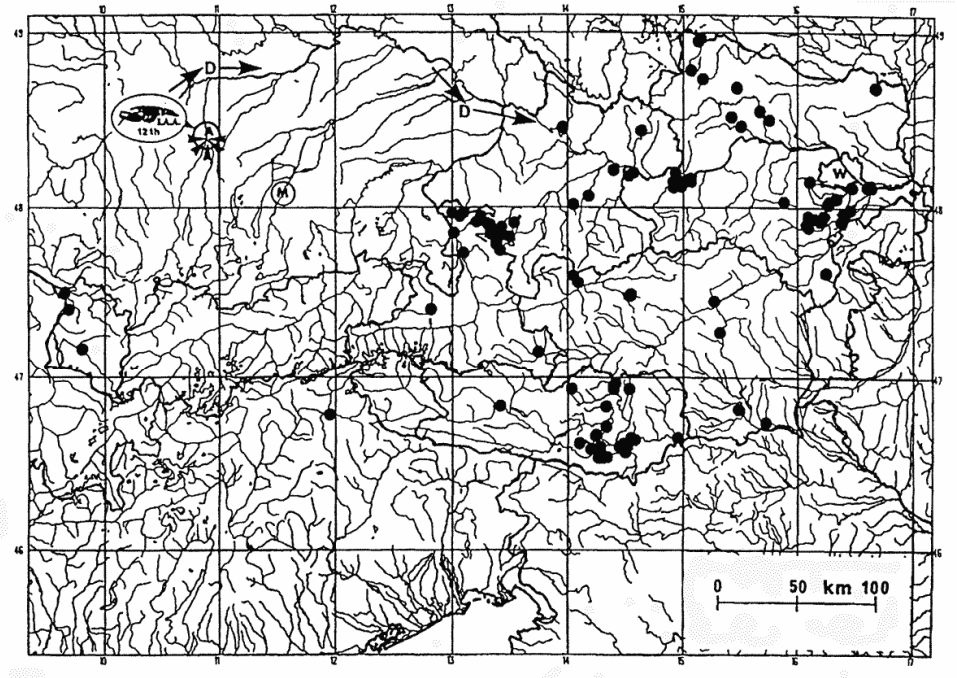

Figure 5. Distribution of *Pacifastacus leniusculus* in Austria and South Tyrol, Italy.

3. The spiny-cheek crayfish (Orconectes limosus)

As early as 1890 the spiny-cheek crayfish (see Holdich 1993 for terminology) has been introduced from Pennsylvania (USA) into the Oder river system (Germany) by Max von dem Borne. Now, this species of North American origin which is highly resistant to *Aphanomyces astaci,* is widespread in Germany and Northern France. North of the Pyrenees and Alps, *O. limosus* is a common and widespread crayfish and most of the river systems flowing into the Baltic Sea and North Sea as well as into the Atlantic Ocean are inhabited by this species (Troschel 1997a). Some 7,000 specimens of *O. limosus* were imported in 1970 into Austria and stocked in a number of lakes and gravel pits. As this species is not of first choice as a delicacy, no further stocking experiments were made for human consumption. As a bait item for use by anglers, however, it is still introduced to a number of water-bodies. Eleven localities out of 1,172 (0.94%) are inhabited by the spiny-cheek crayfish (Table I, Fig. 6). Living stocks were also transferred to localities in Bavaria and near Budapest.

Up to 1985, free living populations of *O. limosus* were not known from the Danube system. The spiny-cheek crayfish was first recorded in a back-water of the Hungarian Danube at rkm 1,654 (Thuranszky and Forro 1987) and in the Bavarian Danube near Ingolstadt (Nesemann 1987). Hence, in the 1980s two disjunct populations in the upper and middle course of the Danube could be distinguished. *O. limosus* is well known for its fast migration: from the River Rhine an advance of 5 km per year was reported (e.g. Mann 1985). A population of *O. limosus* was discovered for the first time in September 1991 in the Austrian Danube; the spiny-cheek crayfish lives in the Olhafen in the eastern part of Vienna (rkm 1,918). This isolated population possibly is the result of an unknown translocation by ships.

O. limosus prefers the shallow water of stony, often artificially protected banks of large lowland rivers and seems to be perfectly adapted to these types of running waters with periodical floods and droughts, always strictly following the level of the water (Pöckl 1992, 1998, Nesemann et al. 1995). The water in

the Ölhafen in the 22nd District of Vienna is oily and muddy and other aquatic organisms indicate bad quality. Nevertheless, the population of the spiny-cheek crayfish has reached a high density and seems to tolerate this polluted water pretty well. As the spiny-cheek crayfish prefers slow flowing, larger and warmer rivers it is usually not found in smaller streams at higher altitudes and is not so dangerous to our native species.

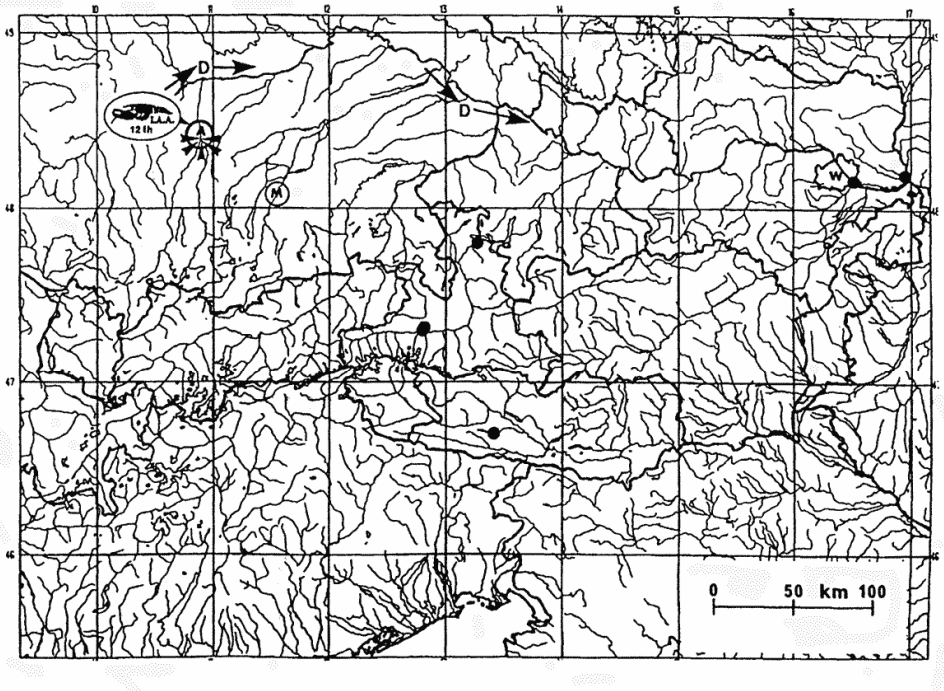

Figure 6. Distribution of *Orconectes limosus* in Austria and South Tyrol, Italy.

4. The American red swamp crayfish (Procambarus clarkii) - a danger for Austria!

This species has not been found in the wild in Austria, at least as far as we know: zero localities out of 1,172 (Table I). Unfortunately it is on sale in fish markets, restaurants, hotels and in aquarist shops as "Red Lobster". Specimens can legally be bought alive and kept in aquaria. Breeding populations of *P. clarkii* were discovered since 1996 in our neighbouring countries, Germany, Switzerland and Italy. In Baden-Württemberg (Germany) it has been found in a pond near Breisach upon Rhine: 200 m a.s.l., 48°02'N, 7°37'E (Troschel 1997b). In Switzerland breeding populations were found in the Schübelweiher and the Rumensee at Küsnacht (Kanton Zürich) and near Mellingen (Kanton Aargau). Some specimens were also found in the Katzensee (Kanton Zürich) (e.g. Frutiger et al. 1999). This aggressive species has a wide tolerance of environmental conditions. It prefers relatively still waters where it burrows extensively into suitable substrates. As it is able to walk long distances overland during night, it possibly can invade new territories and colonise new habitats. This invasive North American species is also skilled in climbing and escaping. It is thought that it escaped from garden pools into the wild or was brought there by hobby aquarists. Nobody has supposed that the species of subtropical origin (especially in Louisiana it is of considerable economic importance) will withstand winters in central Europe. In Switzerland the eradication *of P. clarkii* from the Schübelweiher was discussed and planned in detail by EAWAG / ETH Zürich, including the use of insecticides (Frutiger et al. 1999).

In the I.A.A. newsletter of August 1998, Dussling and Hoffmann (1998) reported on the discovery of a reproducing population of the calico crayfish *(Orconectes immunis)* in March 1998 in a tributary of the upper Rhine in Southwestern Germany (Baden-Württemberg): 10 males and 5 females, two of the last berried, were collected over a stretch of 200 m. As far as it is known, this is the first documentation of a population of *O. immunis* to be found in Europe. More and more foreign crayfish species have appeared

in the aquarist trade during the past years. It is presumed that the introduction of calico crayfish is due to the release of single specimens by aquarists.

IV. DISCUSSION

The introduction of "alien" species of crayfish in Europe causes considerable problems as they act as vectors of crayfish plague and are able to outcompete native species by higher reproductive capacities (Gherardi and Holdich 1999). Alien crayfish are now widespread in Western Europe and only the Republic of Ireland and Norway have managed to keep them out - but not crayfish plague. The disadvantages of alien crayfish seem to outweigh the benefits derived from them. The further spread of alien crayfish should therefore be prevented. In Europe by the year 2099 we can have a situation where either alien crayfish will be in all watersheds or where states and regions will still be free of aliens and the native crayfish viable and protected. The protection of native European crayfish should be a national aim in all states (Gherardi and Holdich 1999).

A management plan has to be realised: First, we have to know more about crayfish in Europe if we are to protect the native species and manage the problem with aliens. We must have an up-to-date picture of the distribution of native and alien crayfish in Europe. The author is aware that many regions in Austria are still poorly known. The ZOODAT database has to be updated regularly, at least once a year. Also the ecology and biology of each species has to be known in detail so that it should be possible to compare the habitat requirements, growth rates, the number of eggs and young and the time to reach sexual maturity. From these data the theoretical reproductive capacity can be calculated. We also should have a compilation of the current legislation in Europe. Austria is a Federal Republic and each Bundesland has its own responsibility for nature conservation and inland fisheries (Pöckl 1999). The United Kingdom (Holdich and Rogers 1997) and Switzerland (Schweizer Bundesrat 1993) are good examples for national states with a strict legislation. Since November 1993 everybody in Switzerland needs a concession for releasing non-native fish and crayfish in natural and artificial water-bodies (public and privately owned), including hatcheries, garden pools and aquaria. Strict legislation, however, does not prevent crime! Practical enforcement and public awareness are additional pre-requisites under any circumstances. The EC Habitats Directive has to be fulfilled in each member state.

Most people keeping foreign crayfish are absolutely not aware of the risks involved in releasing the specimens into the wild. Hobby aquarists consider it a human way of disposing of these pets but do not take into consideration the possible damage to the native populations of crayfish. Therefore the education of the public is of great importance in helping native species to survive. In Austria we are following the good examples given by Great Britain and Germany. We just have published a semi-scientific book outlining the species likely to be found and the problems caused by releasing alien species. This book, combined with a special exhibition, appeared on November 13th 1998 (Eder and Hödl 1998). Information about crayfish should be made available to hobby aquarists more frequently, so that they become aware of possible risks.

A good idea also is that a leaflet should accompany a crayfish when it is sold. When necessary, the aquarist should have the possibility to return the crayfish to the point of sale, or give them to the local Fish Health Service (Dehus 1998). Restaurant owners, hotels and fish markets should be made aware of the dangers of releasing non-native crayfish, such as *P. clarkii,* into the wild. Some of them use to release the crayfish which are not sold. By informing them of the possible damages of such actions, this practice will hopefully be brought to an end. Ways of eradicating alien crayfish by physical, chemical and biological methods, or by a combination of them, without destroying whole ecosystems have yet to be developed in detail (Holdich et al. 1999).

Last but not least global associations of scientists (astacologists, limnologists, freshwater biologists, etc.) and modern technologies of fast communication (world wide web, newsletters, international symposia) are most important for an effective international cooperation. Up to now the opportunities of fund-raising for astacological research are far from being exhausted. We hope that the publication of our semi-scientific book about crayfish species in Austria will be a substantial contribution for further fund-raising campaigns in Austria. Leaflets will also have to be published. Angling clubs and private owners are fond of stocking their water bodies with noble crayfish. Hatcheries then benefit by growing crayfish for stocking purposes, although the production of crayfish for human consumption in restaurants is still

not of considerable economic importance in Austria. The enthusiasm for aquaculture of alien species which has been en vogue in the 1970s has totally disappeared during the last decade -at least, as far as we know (Pöckl 1992, 1998, Hager 1996). Currently, we have a shortage of noble crayfish for stocking ponds. German hatcheries, however, are able to support material.

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REFERENCES

Abrahamsson, S. A. 1966. Dynamics of an isolated population of the crayfish *Astacus astacus* Linné. Oikos 17: 96-107.

Albrecht, H. 1981. Die Flußkrebse des westlichen Kärnten. Carinthia II 91: 267-274.

Albrecht, H. 1982. Das System der europäischen Flußkrebse (Decapoda, Astacidae): Vorschlag und Begründung. Mitteilungen aus dem Hamburgischen Zoologischen Museum und Institut 79: 187-210.

Albrecht, H. 1983. Besiedlungsgeschichte und ursprüngliche holozäne Verbreitung der europäischen Flußkrebse. Spixiana 6: 61-77.

Bohl, E. 1989. *Ökologische Untersuchungen an ausgewählten Gewässern zur Entwicklung von Zielvorstellungen des Gewässerschutzes: Untersuchungen an Flußkrebsbeständen.* Berichte der Bayerischen Landesanstalt für Wasserforschung, München. 237 pp.

Dehus, P. 1998. German initiative to prevent the release of aquarium crayfish into the wild. I.A.A. Newsletter 20 (1/2): 16.

Dussling, U. & Hoffmann, C. 1998. First discovery of a population of *Orconectes immunis* in Germany. I.A.A. Newsletter 20 (4): 5.

Eder, E. & Hödl, W. 1998. *Flußkrebse Österreichs*. Stapfia 58. Neue Folge 137. OÖ Landesmuseum, Linz. 284 pp.

Entz, G., Jr. 1912. Über die Flußkrebse Ungarns. Mathematische und naturwissenschaftliche Berichte aus Ungarn 30: 67-127.

Frutiger, A., Borner, S., Büsser, T., Eggen, R., Müller, R., Müller, S., Peter, A. & Wasmer, H. R. 1999. How to control unwanted *Procambarus clarkii* populations in Central Europe? Freshwater Crayfish 12: 714-726.

Füreder, L. & Machino, Y. 1995. Record of the white-clawed crayfish *Austropotamobius pallipes* (Lereboullet 1858) from Plansee (Tyrol, Austria). Berichte des Naturwissenschaftlich-Medizinischen Vereins in Innsbruck 82: 241-246.

Füreder, L. & Machino, Y. 1999. Past and present crayfish situation in Tyrol. Freshwater Crayfish 12: 751-764.

Gherardi, F. & Holdich, D. M. eds. 1999. *Crayfish in Europe as Alien Species* Crustaceans Issues 11. Balkema, Rotterdam. 299 pp.

Hager, J. 1996. *Edelkrebse: Biologie, Zucht, Bewirtschaftung. Praxisbuch.* Leopold Stocker Verlag, Graz, Stuttgart. 128 pp.

Holdich, D. M. 1993. Crayfish nomenclature and terminology: recommendation for uniformity. Finnish Fisheries Research 14: 149-155.

Holdich, D. M. & Rogers, W. D. 1997. The white-clawed crayfish, *Austropotamobius pallipes*, in Great Britain and Ireland with particular reference to its conservation in Great Britain. Bulletin Français de la Pêche et de la Pisciculture 347: 597-616.

Holdich, D. M., Gydemo, R. & Rogers, W. D. 1999. A review of possible methods for controlling nuisance populations of alien crayfish. In: *Crayfish in Europe as Alien Species* (Gherardi, F. & Holdich, D. M. eds), pp. 245-270. Crustaceans Issues 11. Balkema, Rotterdam.

Keller, M. 1997. Amerikanische Flußkrebse - eine tödliche Gefahr für unsere heimischen Arten! Fischer & Teichwirt 2: 58-62.

K. K. (Kaiserlich-Königliche) Statistische Zentralkommission 1907. Die Binnen-Fischerei in Österreich. Statistische Monatschrift, Neue Folge 12: 1-159.

Lowery, R. S. & Holdich, D. M. 1988. *Pacifastacus leniusculus* in North America and Europe, with details of the distribution of introduced and native crayfish species in Europe. In: *Freshwater Crayfish: Biology, Management and Exploitation* (Holdich, D. M. & Lowery, R. S. eds), pp. 283-308. Croom Helm (Chapman & Hall), London, Portland.

Machino, Y. & Füreder, L. 1996. Der Kärntner "*Sumpfkrebs*" im Gailtal. Österreichs Fischerei 49: 93-97.

Malicky, M. & Eder, E. 1998. ZOODAT - Krebse im Computer. In: *Flußkrebse in Österreich* (Eder, E. & Hödl, W. eds), pp. 109-114. Stapfia 58. Neue Folge 137. OÖ Landesmuseum, Linz.

Mann, H. 1985. Der amerikanische Flußkrebs (*Orconectes limosus*) und seine Einbürgerung in Mitteleuropa. Arbeiten des Deutschen Fischerei-Verbandes 37A: 23-29.

Nesemann, H. 1987. Erste Bestände des Amerikanischen Flußkrebses *Orconectes limosus* in der Donau (Crustacea: Decapoda: Cambaridae). Senckenbergia Biologia 67: 397-399.

Nesemann, H., Pöckl, M. & Wittmann, K. 1995. Distribution of epigean Malacostraca in the middle and upper Danube (Hungary, Austria, Germany). Miscellanea Zoologica Hungarica 10: 49-68.

Peay, S. & Rogers, D. 1999. The peristaltic spread of signal crayfish (*Pacifastacus leniusculus*) in the River Wharfe, Yorkshire, England. Freshwater Crayfish 12: 665-676.

Pöckl, M. 1992. Bestimmungsschlüssel für österreichische Flußkrebse (Klasse Crustacea, Unterklasse Malacostraca, Ordnung Decapoda, Abteilung Astacura). Lauterbornia 10: 1-8.

Pöckl, M. 1998. Verbreitung und Ökologie in Österreich vorkommender Flußkrebse. In: *Flußkrebse Österreichs* (Eder, E. & Hödl, W. eds), pp. 119-130. Stapfia 58. Neue Folge 137. OÖ Landesmuseum, Linz.

Pöckl, M. 1999. Freshwater crayfish in the legislation of Austria: federal, national and international laws. Freshwater Crayfish 12: 899-914.

Pretzmann, G. 1994. Rote Liste der Zehnfüßigen Krebse (Decapoda) und Schwebegarnelen. In: *Grüne Reihe des Bundesministeriums für Umwelt, Jugend und Familie, Band 2: Rote Listen gefährdeter Tiere Österreichs* (Gepp, J. ed.), pp. 279-282. Styria Medienservice, Verlag Ulrich Moser, Graz.

Schweizer Bundesrat 1993. *Verordnung zum Gesetz über die Fischerei. VBGF 923.01.* Schweizer Bundesrat, Bern. 13 pp.

Spitzy, R. 1971. Resistente amerikanische Krebse ersetzen die europäischen, der Krebspest erliegenden Arten. Salzburgs Fischerei 2: 18-25.

Spitzy, R. 1973. Crayfish in Austria, history and actual situation. Freshwater Crayfish 1: 9-14.

Thuránszky, M. & Forró, L. 1987. Data on the distribution of freshwater crayfish (Decapoda: Astacidae) in Hungary in the late 1950s. Miscellanea Zoologica Hungarica 4: 65-69.

Troschel, H. J. 1997a. In Deutschland vorkommende Flußkrebse: Biologie, Verbreitung und Bestimmungsmerkmale. Fischer & Teichwirt 9: 370-376.

Troschel, H. J. 1997b. *Procambarus clarkii* in Germany. I.A.A. Newsletter 19 (2): 8.

Unestam, I. & Weiss, D. W. 1970. Host-parasite relationship between freshwater crayfish and the crayfish disease fungus, *Aphanomyces astaci*. Responses to infection by a susceptible and a resistant species. Journal of General Microbiology 60: 77-90.

Wintersteiger, M. R. 1985. Zur Besiedlungsgeschichte und Verbreitung der Flußkrebse im Land Salzburg. Österreichs Fischerei 38: 220-233.