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# THE DISTRIBUTION OF NATIVE AND INTRODUCED SPECIES OF CRAYFISH IN AUSTRIA

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## Introduction

Crayfish are the largest invertebrates found in European freshwaters north of the Mediterannean region, where river-crabs *(Potamon)* also occur. Some crayfish attain body lengths greater than 25 cm and exceed 350 g in weight. These decapod crustaceans are omnivores, feeding on a wide variety of small invertebrates, fish, algae and higher aquatic plants, including some riparian vegetation. They also scavenge on dead and dying plants and animals. However, their quantitative role in the trophic economy of streams and lakes is not well understood, especially in relation to population biomass and potential competition with fish. Like the latter, however, crayfish have long been prized by man as a source of food, and in parts of Europe some species have been exploited commercially for many centuries. The most notable of these is the fishery based on the red-clawed or noble crayfish *Astacus astacus*, which was decimated by the lethal plague fungus *Aphanomyces astaci* in the late 19th and early 20th centuries. Importations of relatively large species from North America, which are resistant to the fungus but can act as carriers, has led to concerns for the continued existence and conservation of native European species, several of which are now listed as endangered species.

This account concentrates on the six species found in Austria, and the current state of knowledge on their distribution and laws affecting conservation. Although Austria is a relatively small country (ca. 83,900 $km^2$ in area) it is geographically highly diverse, ranging from lowland at altitudes of only 115 metres above mean sea-level, to mountains (the Alps) rising to 3,797 metres. Five differing landscapes can be distinguished, of which 70% is dominated by the Tyrolean Alps, formed by calcareous and rapid-weathering rocks. In the north of the Alps there is a Pre-Alpine region, which is continued in the north-east by the Pre-Carpathian region. North of the Danubian Valley, there is a highland formed by slow-weathering rocks of granites and gneiss. The Viennese Basin is situated around the capital of Austria, and in the east and south-east there are the Pannonian Lowlands. Approximately 46% of the country is covered by forests.

In Austria, nine separate Federal States (Fig. 1) are responsible for their own nature conservation and research related to the conservation of species. A

Table 1. Summary of the localities (distribution points) of freshwater crayfish in Austria, compiled and computerized by ZOODAT, the biogeographic database of Austria.

| Genus and species | Common name | Number of records |
|---|---|---|
| Native species | | |
| *Astacus astacus* | Noble crayfish | 452 |
| *Austropotamobius torrentium* | Stone crayfish | 534 |
| *Austropotamobius pallipes* | White-clawed crayfish | 28 |
| Introduced species | | |
| *Astacus leptodactylus* | Narrow-clawed crayfish | 28 |
| *Orconectes limosus* | Spiny-cheek crayfish | 11 |
| *Pacifastacus leniusculus* | Signal crayfish | 119 |

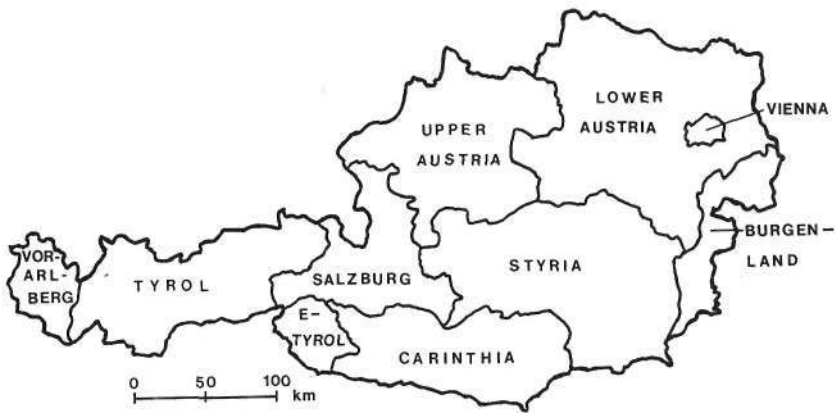


FIG. 1. The nine federal states in the Federal Republic of Austria. (Note: Eastern Tyrol is part of the federal state of Tyrol, and the city of Vienna is also a federal state).

national red data book of animal species was published by the Federal Ministry for Environment (Gepp 1994; Pretzmann 1994). In addition, each State also tries to publish red data books on selected groups of endangered animals. In Lower Austria, a series has started with vertebrates, and I have been asked to write a volume on freshwater crayfish.

## The current information-base for crayfish in Austria

In general, the occurrence and distribution of crayfish in Austria is poorly known, although information obtained by researchers and the general public, after careful checking, is increasing. Current records have been compiled for

the biogeographic database of Austria, ZOODAT (Forschungsinstiut fur Umweltinformatik, J. W. Klein-Str. 73, A-4040 Linz). For the ZOODAT database, a record was accepted as complete when it included the name of the species, the exact location of the waterbody 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 organisations of the USA, and much background information on the distribution maps is given by Malicky & Eder (1998). Distribution maps for the three native species and three introduced species of crayfish in Austria are also given in the recent book edited by Eder & Hodl (1998) (see below) and by Pöckl (1999a). Currently, we have 1172 records on ZOODAT, of which 1014 (86.5%) are for the native species and all but 28 of these records are for *Astacus astacus* and *Austropotamobius torrentium* (Table 1).

In recent years, researchers interested in crayfish have met regularly for discussions at the University of Vienna. As a result a multi-author volume, entitled *Flusskrebse Österreichs*, was published in November 1998 (Eder & Hodl 1998). This semi-scientific book is combined with a special exhibition shown successively in three museums in Austria, where public interest in freshwater crayfish is currently increasing markedly. The most important aims of the book and the exhibition is to raise public awareness on the possible risks of releasing alien crayfish into the wild, to summarise current knowledge on the distribution of the six crayfish species found in Austria, and to review selected aspects of the biology and ecology of these animals.

## The general distribution of native crayfish in Austria

Three native crayfish species occur in Austria: *Austropotamobius torrentium* (Schrank) which is relatively widespread, *A. pallipes* (Lereboullet) with a restricted distribution, and *Astacus astacus* L. which is widespread. The first two are relatively small species, economically unimportant, and probably were rarely transported by man. Hence their present-day distributions may be largely natural. In contrast the noble crayfish *A. astacus* is relatively large and regarded as a culinary delicacy. It has long been an object of trade, commerce and zoological explorations in Europe, and has been transplanted into a wide variety of water-bodies; therefore its original pattern of distribution cannot be reconstructed readily. All three are members of the family Astacidae; genetic differences between *Astacus* and *Austropotamobius* are described by Attard & Pasteur (1984).

## The native noble crayfish *{Astacus astacus)*

Until the middle of the 19th century, the noble crayfish (Plate 1) was widely

distributed throughout Austria, excluding the high mountains. It inhabited most of the country's lakes and rivers, and also the ditches connected to them. Historical records reported statistics that suggest annual yields from some lakes could have been 10 kg per hectare (Troschel 1997a). Some historical records go back to the year 1321 (Füreder & Machino 1999). Therefore the exploitation of this resource and trade was of considerable economic importance, as noble crayfish are a high quality delicacy.

In Austria, outbreaks of the crayfish plague disease caused by *Aphanomyces astaci* began in 1878, and between 1879 and 1904 ca. 75% of the populations of A. *astacus* were devastated (Anonymous 1906). Water pollution, and the channelisation and embankment of streams and rivers, subsequently prevented successful re-colonisation of the noble crayfish. Hence, the species lost its economic importance.

The presence of highly diverse ecological factors in larger streams, with many hiding places and the opportunity to burrow in loamy banks, are important for the occurrence of noble crayfish. Human re-stocking mostly failed; only ca. 15% of re-stocking experiments were successful (Wintersteiger 1985). The favoured habitats of A. *astacus* are rivers with a width of about 3 metres and a depth of at least 0.5 metres, and also meso- and eutrophic lakes, ponds and gravel-pits. Smaller brooks often lack suitable banks where the crayfish can burrow. At higher altitudes, A. *astacus* is replaced by A. *torrentium.*

The noble crayfish is still widespread in Austria, but in many cases only single specimens can be found. Small populations in running waters are often confined to isolated areas, where they are probably protected from plague infection by numerous barriers downstream (Bohl 1989; Keller 1997). However, most noble crayfish populations are unstable, and stocks in large rivers have been reduced.

Noble crayfish for re-stocking depleted or empty localities can be obtained from crayfish hatcheries (Hager 1996). Apart from the abiotic suitability of a selected river, i.e. its morphological, physical and chemical characteristics, basic biotic requirements for sustainable populations are the absence of other (especially American) crayfish species from the project area, and hence the absence of crayfish plague. (In this respect, natural and man-made barriers within a drainage system can be advantageous). The absence (or low density) of specialised crayfish predators, such as eel *Anguilla anguilla,* pike *Esox lucius* and perch *Percafluviatilis,* is also important.

### The native stone crayfish *(Austropotamobius torrentium)*

The stone crayfish (Plate 1) is frequently found throughout most of Austria. It typically inhabits cold and fast-flowing headwaters and springs in the mountains, but can also be found in cool, standing waterbodies. In former

times, *A. torrentium* was thought to be a malnourished noble crayfish (Smolian 1926). There are no historical records of translocation or artificial introductions for this species, so its present-day distribution may be fairly natural. The stone crayfish usually has a heavier and more calcified exoskeleton than the noble crayfish and can therefore withstand higher current velocities. In contrast to the noble crayfish, *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 rivers. When both species occur in the same river, they usually occupy separate habitats; *A. torrentium* prefers areas with coarse stones, whereas *A. astacus* prefers loamy banks where it can burrow. Overlapping between the two species is seldom observed (Bohl 1989; Miiller 1973; Troschel 1997a).

The woodland brooks in the mountains, where the stone crayfish occurs, are some distance from human settlements and especially from urbanised areas, and are ideal for the conservation of native crayfish populations. With their highly diverse physical characteristics (variation in depth and width, substrate heterogeneity, current velocity and discharge), these woodland brooks must be conserved as habitats for the stone crayfish.

### The native white-clawed crayfish *(Austropotamobius pallipes)*

The white-clawed (white-footed) or Atlantic stream crayfish has a very restricted distribution, recorded from only 28 localities throughout Austria. In 1977-78, isolated populations were discovered in the Gossering, the main river of the Gitschtal in south-western Carinthia, and in some tributaries (Albrecht 1981). The tributaries of the Gossering are small, steep and fast-flowing woodland brooks, with a coarse sediment of stones and rocks. In another location, crayfish were found in flat, muddy streams draining swampy wetlands; also in swampy streams of the Gailtal river and the Upper Drautal (Machino & Fiireder 1996). In 1994, white-clawed crayfish were discovered in the Plansee, north-western Tyrol. Most of the specimens caught in the Plansee were taken at the western end, near its outlet in the smaller bay of the lake (Kleiner Plansee), though some were found at other places in the lake and its outlet. Crayfish were also found in the Heiterwangersee and the Kreckel-mooser See (Füreder & Machino 1995). These two natural lakes are glacial in origin and oligotrophic.

A gorge below the outlet, and dams for hydroelectric power, make it unlikely that crayfish colonised the Plansee by natural means, and it seems probable that the Plansee population was deliberately introduced, in the 1920s and/or much earlier (Füreder & Machino 1995). Several historical examples of human introductions of *A. pallipes* throughout Europe have been reported (Albrecht 1983). The crayfish in the Plansee probably originated from the Italian regions of Trentino or Bolzano. Morphological characteristics of *A.*

*pallipes* var. *trentinicus,* described by Albrecht (1982), resemble those of specimens from the Plansee (Füreder & Machino 1995). The present Italian provinces of Trentino and Alto Adige were Austrian territory before World War I.

## Introductions and distribution of non-native (alien) species of crayfish

Three species of non-native (alien) crayfish have been recorded from a total of 158 localities in Austria (Table 1). They are *Astacus leptodactylus* Eschscholz from eastern Europe, and two Nearctic species: *Pacifastacus leniusculus* (Dana) and *Orconectes limosus* (Rafinesque). The latter is a member of the family Cambaridae. Another nearctic cambarid, *Procambarus clarkii* (Girard), so far has not been found in the wild but is on sale in aquarist shops as "Red Lobsters". A fifth astacid, *Astacus pachypus* Rathke, is a native of Europe but does not occur in Austria; this rare crayfish occurs in the Black and Caspian Seas (Albrecht 1982; Holdich 1992; Westman & Westman 1992).

## The alien narrow-clawed or Turkish crayfish *(Astacus leptodactylus)*

The original distribution area of the narrow-clawed crayfish (Plate 2) is eastern Europe and the western parts of Asia, including states of the former USSR, Turkey and Turkmania. Recently, this species is extending its range into western Europe and, from the Black Sea, it is spreading up the lower and middle Danube.

In Austria, outbreaks of the crayfish plague started in 1878 (see above). As re-stocking experiments with *A. astacus* were not successful, *A. leptodactylus* was introduced from eastern Europe in 1891. The experiment also failed because this species was not plague-resistant (Wintersteiger 1985).

At present, the narrow-clawed crayfish has been found in stagnant backwaters of the River Danube in eastern Lower Austria, as far up as the eastern districts of Vienna. These observations seem to be the western-most natural records (Nesemann et al. 1995). In Hungary, downstream, *A. leptodactylus* is widespread and locally abundant, especially in the Danube and in the River Tisza (Thuránszky & Forró 1987). Surprisingly, even in the main course of the Danube, specimens of the crayfish have been caught at river-kilometre 1672. (After the Volga, the Danube is the second longest European river (2850 km), and the mouth of its estuary on the Black Sea is designated as river-km 0; the centre of Vienna is situated upstream at river-km 1930. The Austrian stretch of the River Danube is ca. 340 km in length, and lies between river-kilometres 1880 and 2220 (Dieplinger et al. 1996; Humpesch 1996)). Additionally, in Austria *A. leptodactylus* occurs in some limestone-quarries where it can reach enormous population densities. 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.

### The alien signal crayfish *(Pacifastacus leniusculus)*

The signal crayfish naturally occurs in the north-west of North America, between the Rocky Mountains and the Pacific coastline. As this species is highly resistant to the crayfish plague fungus (e.g. see Gydemo 1992), some 2000 specimens were imported directly from California into Austria during the summer of 1970. They were released into waterbodies in Salzburg, Styria, Upper Austria and Lower Austria (Spitzy 1971, 1973; Wintersteiger 1985). Unestam & Weiss (1970) isolated *Aphanomyces astaci* from *P. leniusculus* collected in the Sacramento River in California, and Lake Tahoe in Nevada. Therefore the imported specimens probably carried the pathogen. Later, signal crayfish were also imported into Austria from a hatchery in Sweden (Spitzy 1971, 1973).

Currently, signal crayfish have been recorded from 119 localities throughout much of Austria. Regrettably, signals now occur in many waterbodies of the Salzkammergut, Austria's Lake District, and there are recent observations of signals in the north-western region of Lower Austria (Waldviertel). This is a hilly, woodland area, containing numerous traditional fish ponds, most of them populated with the noble crayfish (Pöckl 1998).

Unfortunately, the habitat requirements of *A. astacus* and *P. leniusculus* are very similar and the latter can be characterised as aggressive and invasive. In all cases where both species have been recorded in the same river, only the signal has survived and the noble crayfish has disappeared after some 4 to 5 years. This phenomenon was also observed in a river in Yorkshire, UK (Peay & Rogers 1999). *P. leniusculus* can spread fungal spores of the crayfish plague that kills the native species (Oidtmann & Hoffmann 1998), but the signal crayfish is also more prolific because it grows faster and produces more eggs and young. Thus the invader outcompetes the native species and is a danger to them (Keller 1997). The signal crayfish is very good at climbing and escaping from enclosures. Moreover, it burrows extensively into suitable substrata and is responsible for the collapse of river banks (Guan 1994). For all these reasons, no further propagation or movements of signal crayfish by man should be made in Austria (Pöckl 1998).

### The alien spiny-cheek crayfish *(Orconectes limosus)*

As early as 1890 the spiny-cheek crayfish (see Holdich 1992 for terminology) was introduced from Pennsylvania (USA) into the Oder river system in Germany, by Max von den Borne (Seligo 1895; Smolian 1926). This North American crayfish (Plate 2) is highly resistant to the plague fungus

*Aphanomyces astaci*, and is now widespread in Germany and Northern France (Müller 1973). North of the Pyrenees and Alps, *O. limosus* is a common and widespread crayfish; it inhabits most of the river systems flowing into the Baltic and North Seas, as well as those flowing into the Atlantic Ocean (Holthuis 1979).

In 1970, some 7000 specimens of *O. limosus* were imported into Austria and stocked in some lakes and gravel-pits (Spitzy 1971, 1973, Wintersteiger 1985). 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 waterbodies. Altogether, 11 localities have been recorded for Austria.

Live spiny-cheek crayfish were also transferred to localities in Bavaria and near Budapest (Thuranszky 1960), and were recorded from a backwater of the Hungarian Danube and in the Bavarian Danube during the 1980s (Nesemann 1987). A population of *O. limosus* was discovered in the Austrian Danube in 1991, in the Ölhafen in the eastern part of Vienna, at river-km 1918. This isolated population may be the result of an unknown translocation by boat-traffic on the Danube. The spiny-cheek prefers shallow water along the stony and often artificially protected banks of large lowland rivers, and seems to be perfectly adapted to this type of running water, with periodic floods and droughts, and it always strictly follows changes in water-level (Pöckl 1992, 1998; Nesemann et al. 1995).

An interesting fact is the ability of *O. limosus* to survive in channelised rivers and- to tolerate highly polluted water. The water in the Ölhafen, in the 22nd district of Vienna, is oily and muddy, and the presence of some other aquatic organisms indicates poor quality. Nevertheless, the population of the spiny-cheek crayfish has reached a high density in this locality.

Because *O. limosus* prefers slow-flowing, larger and warmer rivers, it is usually not found in smaller streams at higher altitudes and is not so dangerous to the native species of Austria.

## The alien red swamp crayfish *(Procambarus clarkii)*, a potential threat for Austria

So far, the red swamp crayfish (front cover illustration) has not been found in the wild in Austria but it is on sale in fish markets, restaurants, hotels and in aquarist shops under the name of "Red Lobsters". Specimens can be bought alive legally and kept in aquaria. Since 1996, wild breeding populations of *P. clarkii* have been discovered in the neighbouring countries of Germany, Switzerland and Italy.

This very aggressive species has a wide tolerance of environmental conditions. *Procambarus clarkii* prefers relatively still waters where it burrows extensively into suitable substrata. As it is able to walk long

distances, including overland travel at night, it potentially can invade new territories and colonise new habitats. This invasive North American species is also skilled at climbing and escaping from tanks and enclosures. Elsewhere, it may have escaped from garden pools into the wild or was taken there by hobby aquarists. However, it is not known if this subtropical crayfish (which is of considerable economic importance in Louisiana, south-eastern USA) will withstand the rigours of winters in central Europe, which might reduce or prevent the survival and spread of breeding populations in nature (Troschel 1997b).

In Switzerland, the eradication of *P. clarkii* from the Schübelweiher has been discussed and planned in detail, including the use of insecticides (Borner et al. 1997, 1998; Minder et al. 1997; Frutiger et al. 1999). Methods for eradicating non-native crayfish populations are being developed in the UK (Rogers & Holdich 1999).

## Dealing with the problems posed by introduced crayfish

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. Alien crayfish are now geographically widespread in Europe, and only the Republic of Ireland and Norway have managed to keep them out - but not the crayfish plague! The disadvantages of alien crayfish seem to outweigh the benefits derived from them, their further spread should be prevented, and the protection of native European crayfish should be a national aim in all countries (Holdich & Gherardi 1998; Gherardi & Holdich 1999). Pockl (1999a) discusses a management plan for the protection of native crayfish species in Austria and Europe, and to manage the alien crayfish populations.

A detailed compilation and consideration of current legislation in Europe is required. The UK and Switzerland are good examples of countries with a strict national legislation. Since November 1993, everyone in Switzerland needs a concession for releasing non-native fish and crayfish into natural or artificial waterbodies, both public and privately owned, including (cray)fish hatcheries, garden pools and aquaria (Rogers & Holdich 1997; Schweizer Bundesrat: VBGF 923.01). The situation is complex in Austria because it is a Federal Republic with nine states (Fig. 1), and each state (Bundesland) has its own sovereignty over law-making for numerous affairs, including fisheries, hunting and nature conservation (Pöckl 1999b). Unlike the Federal Republic of Gemany, Austria does not have a National Wildlife and Conservation Law, or a National Endangered Species Act. Instead there are nine respective laws and nine sets of differing regulations for fisheries and conservation, all of which apply to crayfish, plus national laws concerning the Penal Code, the Water Quality Act, and the Hygiene Act that is applicable to fish-shops and

markets. In addition, governments are responsible for ensuring that the EC Habitats Directive is fulfilled in each member state.

Strict legislation, however, does not prevent crime! Practical enforcement and public awareness are additional prerequisites under any circumstances. Even now, new species of alien crayfish are being found in Europe. The August 1998 Newsletter of the International Association of Astacology (IAA) reported the discovery of a reproducing population of the calico crayfish *Orconectes immunis*, in March 1998 (Dussling & Hoffmann 1998). This North American cambarid crayfish was found in the upper Rhine, in south-western Germany (Baden-Wurttemberg), where 10 males and 5 females - two of them berried - were collected over a stretch of 200 metres. It is presumed that the introduction of calico crayfish is due to the release of single specimens by aquarists.

Most people holding imported foreign crayfish are unaware of the risks involved in releasing specimens into the wild. From discussions with hobby aquarists it is clear that crayfish are sometimes released into nearby streams when they are no longer desired. Many consider that this is the kindest method of disposal for unwanted pets, but do not take into consideration the possible damage to populations of native species. Therefore, educating the public about the risks is of great importance in helping native species to survive, and in Austria we are now following the good examples given by Great Britain and Germany (Holdich & Rogers 1997; Dehus 1998). As mentioned in an earlier section of this article, a semi-scientific book outlining the species likely to be found, and the problems caused by releasing alien species, has been published recently. This book, combined with a special exhibition, appeared in November 1998 (Eder & Hödl 1998).

Fortunately, many people have a positive regard for crayfish and would like to help in preserving the native species. Angling clubs and private owners are fond of stocking their waterbodies with noble crayfish. Hatcheries then benefit by growing this crayfish for stocking purposes, although its production for human consumption in restaurants is not of great economic importance in Austria. Currently, we have a shortage of noble crayfish for stocking ponds, but some are obtained from German hatcheries. The enthusiasm for alien species, in vogue during the 1970s, appears to have disappeared during the last decade (Pöckl 1992, 1998; Hager 1996).

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