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## Introduction of the White-Clawed Crayfish *Austropotamobius pallipes* in Europe

by

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**Synopsis:** Many introductions of the white-clawed crayfish *Austropotamobius pallipes* in western and southern Europe are listed in order to show that the species has also been involved in the extension of its geographic distribution by man as frequently recorded for the noble crayfish *Astacus astacus*. Strictly speaking, *A. pallipes* would not be native to Portugal, Spain, Ireland, Scotland, Liechtenstein and Austria. At least seven French Departments received non-French *A. pallipes* into their waters. The genetic studies could follow a "wrong track" during the analyses if the introduced populations are treated as native. But also the genetic studies are able to reveal introduction cases.

### 1. Introduction:

The white-clawed crayfish *Austropotamobius pallipes* (LEREBOULLET, 1858) is today reported from Montenegro (MACHINO & ĐURIŠ 2004) and other 17 European countries/regions (HOLDICH 2002). It was considered less attractive than the noble crayfish *Astacus astacus* (LINNAEUS, 1758) regarding its smaller size for human exploitation (LAURENT 1988), although it can reach a respectable size (up to 12 cm total length).

Through human history, crayfish introductions were common practices in Europe (e.g. FÜREDER & MACHINO 1999) and thus their geographical distributions were often modified (ALBRECHT 1983). For the noble crayfish, the narrow-clawed crayfish *Astacus leptodactylus* ESCHSCHOLTZ, 1823, the white-clawed crayfish and the stone crayfish *Austropotamobius torrentium* (SCHRANK, 1803), such cases occurred (LAURENT 1988; HOLDICH 2002). As the white-clawed crayfish is small and less appreciated in a culinary respect, its introduction seems to have been carried out less, compared to *A. astacus* and *A. leptodactylus* (LAURENT 1988). However, recent advances in genetic studies as well as field observations reveal the white-clawed crayfish introduction not being so rare - its geographical

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distribution seems to have been modified by man radically. In this paper we give an overview of known and unknown introductions to provide essential basic information useful when it comes to explain the biogeography of *A. pallipes*.

## 2. Methods:

Literature data as well as unpublished data were analyzed and *A. pallipes* introduction records were compiled as many as possible. Because of differing accessibility and availability of data, numbers of results are unbalanced. For example, herein among other countries, we concentrated on France and Austria as particular case stories.

We listed countries from West to East. Old names of places were converted into today's. Also information obtained during the field observations 1994-2003 were taken into account.

## 3. Records of white-clawed crayfish introductions:

### Portugal

The origin of the Portuguese white-clawed crayfish would be the Spanish crayfish introduced into the Angueira River at São Martinho de Angueira by a French engineer around 1880 (MACHADO 1931; NOBRE 1935: xvii; CORREIA 1981). There were other introductions also: the Spanish *A. pallipes* was introduced into the Sever River in the end of the 1960s and the French *A. pallipes* was stocked into the Cértima Brook (year unknown) (ALMAÇA 1989, 1990). Before the *A. pallipes* introduction program carried out in 1977-1979, the species was already present in the Angueira, Cértima, Ferreiros, Maças, Sabor, Sever and Azibo Rivers (PEREIRA 1979; CORREIA 1981; ALMAÇA 1989, 1990). According to ALMAÇA (1990), the introduction program 1977-1979 was carried out in:

- the Azibo River in 1978 and 1979 from the Angueira
- the Anguiar Brook in 1978 and 1979
- the Massueime River in 1978 and 1979
- the Teja Brook in 1978 and 1979
- the Côa River in 1978 and 1979
- the Corvo River in 1978 and 1979
- the Alge Brook in 1977 and 1978
- the Sever River in 1978 and 1979.

During the *A. pallipes* introduction program 1977-1979, the Tortulhas Brook also received this animal, but the exact introduction year is not indicated in the literature (ALMAÇA 1990; CORREIA et al. 1996).

According to CORREIA et al. (1996), *A. pallipes* from the Fresno and Azibo Rivers were stocked in 1993 into the Penacal, Sabor, Maças and Angueira Rivers as well as into the Ferreiros Brook.

The type locality of the so-called Iberian crayfish *A. pallipes lusitanicus* (MATEUS, 1934) is the Angueira River at São Martinho de Angueira, but the population died out in 1986 (ALMAÇA 1990; CORREIA et al. 1996). The introduced stocks survived for some while,

but they decreased to two populations in 1996 (BERNARDO et al. 1997) and to only one in 1997 (MACHINO 1997 unpub. data). This last population from the Tortulhas Brook disappeared in 1999 (IACONELLI 1999 pers. com.), probably due to the public works carried out in 1999 in the brook just above the crayfish area (MACHINO 2000 unpub. data).

## Spain

*Austropotamobius pallipes* was introduced around Lojo (Province of Granada) in the 1860s (VINSAC 1893).

According to PARDO (1941: 38 and 120), this animal was not native to Catalonia, but it was introduced around Olot in Province of Girona with success (no precise year). And he continues to mention the followings. The introduction into the Miera River (Province of Santander) in 1933 was successful. It was not native to Province of Asturias, but it was introduced into Lake Lago Enol (1039 m above sea level) near Covadonga with success around 1900. In Province of Navarra, the crayfish was introduced into the Cidacos River with success in the 1930s, but the introduction(s) into the Bidasoa drainage failed.

TORRE CERVIGON & RODRIGUEZ MARQUES (1964) mention the following introductions. The crayfish was not native to Province of Lleida but introduced with success into the Urgel and Piñana Canals. In Province of Tarragona, it was introduced into the La Cenia River in 1921 and 1960 as well as into the Estrets River (no precise year).

MARGALEF (1953) mentions that it is difficult to indicate the original distribution of crayfish in Spain because of the introduction by man.

Into the Matarraña River (Province of Teruel) the crayfish was introduced in the beginning of the 20th century (BOLEA 1995). The same author indicates the crayfish (*A. pallipes*) would not be native to Province of Huesca.

Since the mid-1980s, stocking program of *A. pallipes* has been carried out in Province of Alava. 2,811 individuals were stocked in 1991 and 5,541 individuals in 1992. The strains come from six isolated populations and are purposed for 14 new suitable areas (PINEDO & ASENSIO 1992).

Translocations of natural stocks to ponds were successful in Basque Countries Region and Province of Navarra. 25 % of the present populations in Province of Alava (Basque Countries) and 10 % in Province of Navarra originate from translocations of pond-raised *A. pallipes* (ALONSO et al. 2000).

For the protection purpose, 40,000 summerlings of *A. pallipes* were produced in Castilla-La Mancha Region annually, and Province of Cuenca alone produced 270,946 individuals between 1989 and 1997 (ALONSO & MARTÍNEZ 1998). As a result, several populations were established in Provinces of Cuenca and Guadalajara. In Cuenca, 35 % of the populations originate from the (re)stocking program (ALONSO et al. 2000).

For the protection program of the local white-clawed crayfish in Province of Granada, introductions of the local strain into new waters have begun and some shows bright results with hope (ALBA TERCEDOR & GIL SÁNCHEZ 1999; GIL SÁNCHEZ 1999).

According to the information available from Spain up to now, the crayfish of the Castèth Brook at Bossòst (Garonne drainage, Province of Lleida) is the unique population of the subspecies *A. pallipes pallipes* (LEREBoullet, 1858) in Spain. There was a small hotel by the brook in the end of the 19th century. It seems that the hotel would have introduced the crayfish into the brook in order to improve the food menus for the French travelers (GONZÁLEZ DÁVILA 1996 pers. com.). Morphological observation of the crayfish indicates it is *A. pallipes pallipes* (MACHINO 1995 unpub. data), thus it was brought from France, and not from Spain because the Iberian crayfish differs from *A. pallipes pallipes* morphologically. The Castèth crayfish population is endangered now. A field observation of 1995 revealed that the reforestation with coniferous trees seems to be damaging the crayfish habitat (MACHINO 1995 unpub. data). Formerly it probably flowed in the prairie (i.e. good habitat for crayfish), but now the brook flows in the middle of the big coniferous forest. (N.B. One of us, MACHINO, saw some conserved specimens of morphologically-*A. pallipes pallipes* from Province of Alava, but the exact location was not communicated).

The Iberian crayfish (except those from the Garonne drainage) have some similarity to the Italian crayfish morphologically (KARAMAN 1962) and genetically (SANTUCCI et al. 1997; GRANDJEAN et al. 2000a; IACONELLI 2001; MACHINO et al. in prep.). An almost absence of genetic diversity in the Spanish crayfish has already been reported by GRANDJEAN et al. (2000a). Also an absence of genetic diversity of a partial DNA sequence of cytochrome oxydase subunit I (COI) was found among Spanish and Portuguese populations (MACHINO et al. in prep.). Hence a possible arthropogenic origin (i.e. Italian crayfish stocked into Spain) was proposed by ALBRECHT (1983) and GRANDJEAN et al. (2000a). IACONELLI (2001) indicates a partial COI sequence of the Spanish crayfish is exactly identical with that of the crayfish from Emilia-Romagna Region of Italy. Then a question arises "when the introduction?". In the mid-19th century this animal was very common in central Spain (PAZ GRAELLS 1864). In the 1860s, crayfish of the Sierra de Guadarrama was famous for his black colour and big size (SOUBEIRAN 1867: 629). CUYNAT (1845), who stayed in Catalonia during 1824-1827, reports crayfish near Barcelona (not necessarily in contradiction to PARDO 1941: 38 & 120). This animal was already known in Aragón in 1784 (ASSO Y DEL RÍO 1784 in BOLEA 1995). In the end of the 18th century, the crayfish market was well known in Castilla (PARDO 1941: 101). And people of Numancia, an ancient town destroyed in 133 B.C. near Soria, seem to have known crayfish (GARCÍA DE DIEGO 1947). On the other hand, however, ALBRECHT (1983) indicates the crayfish would have been unknown on the Iberian Peninsula in 1642, and Miguel de Cervantes Saavedra (1547-1616) may not have known crayfish in Spain (PARDO 1941: 96-97). So the crayfish introduction(s) would have been done very long time ago or around the turn of the 17th to 18th century. Then an enigma arises: why the introduction(s) from Italy instead of France? And another enigma emerges, because crayfish were present in Spain long time ago on the geological scale. A fossil remain of crayfish very close to today's is known from Las Hoyas (Province of Cuenca) of the Lower Cretaceous (GARASSINO 1997). This ancient crayfish lived in eutrophic lakes (RABADÀ 1990). The origin of the Iberian crayfish looks to be the Italian cray-

fish introduced by man, but we don't have the direct and definitive prove for this hypothesis yet.

### **Ireland**

The non-nativeness of *A. pallipes* was easily supposed, as Ireland has no native primary freshwater fishes (see GILES 1994). But the presence can be dated back as early as 1772 (RUTTY 1772 in THOMPSON 1843; THOMAS & INGLE 1971). THOMPSON (1843) indicates several introductions carried out in the second half of the 18th century and till 1840. REYNOLDS (1982) noticed that these old records of the Irish crayfish presence generally attributed to an introduction from somewhere else.

Indeed, after the genetic analyses, GOUIN et al. (2003) revealed that the Irish crayfish would originate from an artificial stocking of *A. pallipes* of the western French strain.

### **Scotland**

The crayfish is not native to. One of the oldest records indicates that the introduction was carried out in the mid-19th century. 1,100 individuals of *A. pallipes* were brought to Scotland by Lord Breadalbane, presumably for introduction into the River Tay (BUCKLAND & LOWE 1862; MAITLAND et al. 2001). Also crayfish were released into waters in Lanarkshire, Dunbartonshire, Argyllshire and Renfrewshire around that time (MAITLAND et al. 2001).

Today two populations are known: Loch Croispol near Durness (THOMAS 1992) and a small reservoir in the lower Clyde drainage (MAITLAND et al. 2001). The *A. pallipes* introduction was carried out in 1945 into the former (THOMAS 1992) and before 1950 into the latter (MAITLAND et al. 2001). It is suggested that the animals of the reservoir in the lower Clyde may be descendents of the crayfish stocked by Lord Breadalbane (MAITLAND et al. 2001).

A small number of white-clawed crayfish was introduced into a fish farm in West Lothian (Central Lowlands) in 1975, but disappeared in 1978 because of a pollution (JAY & HOLDICH 1981).

As the signal crayfish *Pacifastacus leniusculus* (DANA, 1852) has now been established in some Scottish waters, need of survey and control on the signal crayfish has become urgent in order to protect the Scottish white-clawed crayfish (MAITLAND et al. 2001).

### **Wales**

To Wales *A. pallipes* is believed to be native. But several introduction efforts were made for its protection. This species was introduced into the Irfon River (a tributary of the Wye River) around 1800 (JONES 1805 in STALER 2002). And recently, it was stocked into the Rivers Neath, Taff, Usk and upper Wye (HOLDICH & REEVE 1991). Its presence in the Templeton Brook (southwest Pembrokeshire) may have originated from an introduced stock too (HOLDICH & REEVE 1991).

## England

White-clawed crayfish is considered as native and has been known for quite a long time. There were records from Hungerford in 1668, from Oxfordshire in 1677 and 1686 and from Staffordshire in 1677 and 1686 (see THOMAS & INGLE 1971). Its introduction was quite common in the past, too (THOMAS & INGLE 1971): e.g. Sir Christopher Medcalfe brought crayfish from southern England to Yorkshire and introduced them into the "pool Semur" (River Baint drainage) in the 18th century; a large number of crayfish were introduced into the River Rye (North Yorkshire) in 1922.

In a river between Burford and Bibury (Gloucestershire and Oxfordshire), the crayfish (*A. pallipes*) disappeared by 1898. Then it was reintroduced later and became abundant again in 1930 (DUFFIELD 1933). There may be a confusion on which rivers the author meant, since it seems to be impossible to know which river was involved in between the Windrush, Leach and Coln Rivers, as stated by the author.

In North Yorkshire, the Ure River (= Yore River) near Hawes may have received crayfish (*A. pallipes*) from the Doe River (WILLIAM 1907 in DUFFIELD 1933). Both rivers are located in Yorkshire Dales National Parks today.

DUFFIELD (1933: 194) mentioned without precision that he knew several cases of *A. pallipes* stocking.

At the end of the 19th century some crayfish (species not specified but probably *A. pallipes*) were introduced into the Thames River (Oxfordshire) before the epidemic decimated the crayfish (DUFFIELD 1936).

In 1918, *A. pallipes* was reintroduced into the Evenlode River (Oxfordshire) whose crayfish disappeared around 1900. They became abundant again in 1935 (DUFFIELD 1936). Native crayfish introductions are continued today, e.g. into the River Leven (Tees drainage) (HOLDICH & REEVE 1991: precise year not mentioned).

## France

*Austropotamobius pallipes* was established in the Deûme River near Bourg-Argental (Department of Loire) after an introduction carried out by Mr. Verdier in the first half of the 19th century (FOURNET 1853).

In a crayfish farm at Clairefontaine-en-Yvelines (Department of Yvelines), Mr. Sauvadon used *A. pallipes* (mentioned under "écrevisses grises") for his first trial in May 1856, but without success. His crayfish farm became successful with *Astacus astacus* later (SAUVADON & SOUBEIRAN 1865).

3,200 specimens of *A. pallipes* from Saint-Jean-de-Buèges (Department of Hérault) were introduced into the Lez and Mosson Rivers (both in Department of Hérault) in 1859 (GAVINI 1860).

In the Lez River 10 km above Montpellier (Department of Hérault), several trials of crayfish stockings were carried out (years not specified) but without success (MINGAUD 1904).

Between 1859 and 1871 (year not specified), 200 specimens of *A. pallipes* were once stocked into Lake Lac Pavin (Department of Puy-de-Dôme) (RICO 1876a). It was so successful that the crayfish started to impede the fish catching (GRISARD 1889: 455). RICO (1876b) also introduced *A. pallipes* with success into waters of "Ecole de Pisciculture" (=fish farm school) at Clermont-Ferrand, and of Beaulieu at Chamalières (Department of Puy-de-Dôme).

In 1886 Mr. C. Vacher introduced *A. pallipes* into the Iton River (place not specified either in Department of Eure or in that of Orne). They originated from around Argentan (Department of Orne). This introduction was recorded as a successful one (GRISARD 1887: 243 - 244).

In 1882 a crayfish mass-death occurred in the Ligoure River and surroundings (Saint-Jean-Ligoure and Saint-Priest-Ligoure, Department of Haute-Vienne), but some local populations of *A. pallipes* were believed to have escaped the disease, particularly around Nexon and Saint-Germain-les-Belles (LE PLAY 1895). From these populations, the crayfish restocking the Ligoure area started for several years. In 1895, the crayfish of the Ligoure River seemed to have recovered (LE PLAY 1895).

In the fountain "Fontaine de Nîmes" in Nîmes (Department of Gard), *A. pallipes* was established after several years that the water was used for keeping crayfish alive in cages. Some specimens escaped and reproduced (MINGAUD 1904: he mentions under "écrevisse à pattes rouges *Astacus fluviatilis*").

*A. pallipes* of Department of Aveyron was introduced into the Œuf River near Pithiviers (Department of Loiret) in autumn 1904 and the recapture occurred in September 1909, thus the species was established (DROUIN DE BOUVILLE 1910).

In a brook at Magny-Maubert and in another at Bozon (both places near Servance, Department of Haute-Saône), crayfish disappeared around 1907. After the restocking effort of *A. pallipes*, they re-appeared in 1919 (ANDRÉ & LAMY 1935).

2,000 local crayfish were caught in different brooks and introduced into the Aube River below Auberive (Department of Haute-Marne) in 1910 (MARCHAL 1911). The author did not specify the crayfish species, but it must have been *A. pallipes* as this species lives in the upper Aube River (ARRIGNON 1990).

In the 1920s, *A. pallipes* from the Cévennes Mountains of the Massif Central were stocked into tributaries of the River Fium Alto in Corsica. The introduction was successful and its geographic extension continues naturally as well as artificially by man within the river drainage (LAURENT & SUSCILLON 1962; ATTARD & VIANET 1985; ARRIGNON et al. 1999).

Lake Lac des Gaillants (1015 m a.s.l.) at Chamonix (Department of Haute-Savoie) has *A. pallipes*. Its origin must be of introduction by man, as this is an artificial lake (it was a gravel pit in the beginning of the 20th century) and as no crayfish are present in the surrounding areas (LAURENT 1985).

In October 1982, 68 specimens of *A. pallipes* (19 ♂ and 49 ♀) of Lake Lac des Gaillants were stocked into the Chaussette Brook (tributary of the Parmand Brook at Moye,

Department of Haute-Savoie). And again, 23 June 1983, 23 females of *A. pallipes* carrying eggs from the same lake were introduced into this brook. However, the verification of 25 June 1984 revealed a negative result (PELLETAN 2002; PELLETAN & CAUDRON 2003; LAURENT unpub. data).

Around the 1970s, *A. pallipes* lived in a left-bank tributary of the Dranse River at Thonon-les-Bains (Department of Haute-Savoie), above the bridge of the road to Evian. As no crayfish are present in the vicinity, this crayfish presence probably originated from an introduction by man. The population seems to be extinct as a recent investigation in 2001 failed to find the animal (LAURENT unpub. data).

In the 1970s, an introduction of *A. pallipes* took once place by a fishing guard into the Vion Brook (a left-bank tributary of Lake Léman, Department of Haute-Savoie). It was of a local origin near by. The introduction was successful because they were observed for several years. However, they disappeared without visible reasons in the 1980s (LAURENT unpub. data).

In 1990, about 20 specimens of *A. pallipes* from Canton of Genève (Switzerland) were introduced into a cold-water pond at Orcier (Department of Haute-Savoie). The population was almost establishing, but the care was paid only for the fish and the crayfish were forgotten. Today *A. pallipes* lives no longer in the pond (LAURENT unpub. data).

Field observation allowed us to get crayfish introduction information:

- The Torgan River (Agly drainage, Department of Aude) received crayfish from the Sou River at Laroque-de-Fa (Aude drainage, Department of Aude).
- The crayfish of the Sou River at Laroque-de-Fa originates from an introduction carried out in 1928 or 1929 by a farmer at Borde Grande (Laroque-de-Fa) who brought crayfish from the Montagne Noire Mountain (north of Department of Aude).
- The crayfish of the Pauze Brook at Camps-sur-Algy (Department of Aude) would have originated from an introduction carried out after 1965 (precise year unknown).
- The Roc de la Cabanette Brook at Montgaillard (Department of Aude) would have received crayfish, but the precise year unknown and the results unknown.

A translocation program for saving *A. pallipes* of the Ay drainage (Department of Ardèche) has been under way since 2001. The population was under threat of extinction. So 25 males and 25 females were transplanted into a tributary of the Ay River in 2001 (WATT 2002 pers. com.).

The crayfish fishing season 2002 in Department of Ardèche enabled obtaining the following information. Around 1990, the fishing association of Alboussière would have stocked *A. pallipes* of the Morge Brook at Champis into the Chaudoreille Brook near Boffres. Also a private fisherman once stocked *A. pallipes* of the Glo Brook near Saint-Julien-Labrousse into the Chaudoreille Brook in the 1990s.

In Department of Drôme, some "we-heard-that" information was obtained. The presence of *A. pallipes* in the Omblèze Brook at Omblèze (headwaters of the Gervane River) would originate from an introduction of crayfish stock coming from Department of Ain (year unspecified). The crayfish distribution pattern around this brook seems to indicate the

introduction origin too (MACHINO 2001/2002 unpub. data).

One of us (MACHINO) was told by a fisherman from Department of Isère that he unofficially carried out *A. pallipes* introductions into three waters in the Chartreuse Mountain in the 1990s in order to have his secret crayfish fishing streams. Of the three waters, two revealed to be successful. On the crayfish protection point of view, however, these introductions cannot be welcome. Because the fisherman mixed crayfish of different origins. In both waters, he introduced French *A. pallipes* and Italian *A. pallipes* together, as he knew one population of the Italian crayfish living in Department of Isère (see below).

In Tables 1, 2 and 3, information on crayfish introductions from other sources are listed.

### **Case of Department of Pyrénées-Orientales in France**

This department is considered not having crayfish as native species, since none of the important literatures on local fauna as well as none of the French crayfish documents mentioned crayfish from this department, such as DELON (1802/1807), COMPANYO (1861/1864), RAVERET-WATTEL (1885), COMBES & LOUDEL (1909) and ANDRÉ & LAMY (1935).

The first mention of crayfish is by ANONYMOUS (1927): 3 May 1927, the department council voted for an introduction of crayfish into the Agly drainage and the order was handed to the Fishing Federation of Pyrénées-Orientales. But we don't know whether the introduction was really carried out then.

In 1959, the Boulzane Brook (Agly drainage) was the only river having crayfish in this department, according to the information given by the Fishing Federation of Pyrénées-Orientales (SUSCILLON 1960), and this crayfish was *A. pallipes pallipes* morphologically (SUSCILLON 1960; LAURENT & SUSCILLON 1962). Also a crayfish introduction was carried out in a neighbouring river in 1958, but without success (SUSCILLON 1960).

According to local information, people of the village Maureillas-las-Illas did not know that crayfish were present in the Las Illas River until the 1960s. Frenchmen from Algeria ("pieds-noirs") started to exploit the crayfish after the Independent War of Algeria (the war ended 1962). This information indicates the crayfish stocking once occurred between 1963 and 1969 (precise year unknown). The crayfish is still present in the Las Illas River around Las Illas village and its tributaries (the Clos de Rodouldces, the Ravin de Riu and the Ravin du Pont de Niergue). But its absence in the headwaters of the Las Illas River and in those of the tributaries indicates that the colonization from the introduction point below has not reached these upper waters with nice habitat yet. The morphological information on the crayfish indicates that it is *A. pallipes fulcisianus* (NINNI, 1886) from Italy (= *A. pallipes italicus* (FAXON, 1914)) (MACHINO 1995 unpub. data).

During the field observation, also some other information became available.

In September 1948, one kilogram of *A. pallipes* caught in the Cesse River at La Caunette (Aude drainage, Department of Hérault) were introduced into the Ribeille Brook below Eus and the species was established (DERROJA 1997 pers. com.). But the crayfish disappeared in the 1960s after water pollution of the canal "Llosa d'Irrigation" by a factory at

Olette.

According to local information, the River Lentilla received crayfish from Eus around the 1960s, but they did not establish. Also crayfish would have been stocked into a brook near Millas but the precise place and year are unknown nor the results and the origin.

*Austropotamobius pallipes* were introduced into the Agly River at Saint-Paul-de-la-Fenouillet in 1982 with success (Table 1).

Field observations enabled us to collect the next information:

- The Reynès River at Can Guillet has *A. pallipes fulcisianus* (MACHINO 1996 unpub. data).
- The Desix River at Rabouillet has *A. pallipes fulcisianus* (MACHINO 1995 unpub. data).

**Table 1:** *A. pallipes* introductions into French waters mentioned in ARRIGNON (1990)<sup>1)</sup>. The introductions were apparently successful unless mentioned "Without success".

| French Department       | Water             | Place                       | Date            | Nota   |
|-------------------------|-------------------|-----------------------------|-----------------|--|
| Alpes-de-Haute-Provence | Adou de Granges   | Marcoux                     | 1985            |  |
| Hautes-Alpes            | Adoux de Montrond | Montrond                    | 1984            |  |
| id.                     | Fontenil          | La Roche-de-Rame            | 1960 & 1984     |  |
| id.                     | Montgardine       | Mongardin                   | 1984            |  |
| id.                     | Vance             | Chorges                     | 1984            | 350 specimens introduced.  |
| Ariège                  | Bousquet          | Ventenac                    | 1985 & 1988     |  |
| id.                     |                   | Couffet near Loubens        | 1985            |  |
| id.                     | Dalou             | Dalou                       | 1985            |  |
| id.                     | Nèdé              | Augirein                    | 1987            |  |
| Charente                |                   | Chez Dubois near Benest     | ? <sup>2)</sup> | Without success.   |
| id.                     | Tude              | Chavenat                    | ?               | Reintroduction.  |
| Dordogne                | Crempselie        | Saint-Hilaire-d'Estissac    | ?               |  |
| id.                     | Donzelle          | Bussac                      | ?               |  |
| Eure-et-Loir            | Vinette           | Marolles-les-Buits          | 1985            | Reintroduction. From a fish farm at Saint-Mars-la-Brière (Department of Sarthe). |
| Gers                    | Barbut            | Aubiet                      | 1970            |  |
| id.                     | Bérant            | Eauze                       | 1983            |  |
| id.                     | Cédon             | Artiguedieu near Seissan    | 1972 & 1973     | Both introductions with crayfish from Spain.                                     |
|                         | Lassalle          | L'Isle-de-Noé               | 1965            |  |
|                         | Montchabreau      | Barran                      | 1982            |  |
| Lot                     | Nègre-Garrigues   | Saint-Jean-Lagreste         | 1980            |  |
| Hautes-Pyrénées         | Souy              | Ossun                       | 1989            | 1,100 specimens introduced.  |
| Pyrénées-Orientales     | Agly              | Saint-Paul-de-la-Fenouillet | 1982            |  |
| Deux Sèvres             | Pamproux          | Sainte-Eanne                | 1978            |  |
| Vienne                  | Boivre            | Lavausseau                  | ?               |  |
| id.                     | Loubatière        | id.                         | 1989            |  |
| id.                     | Mortaigues        | Queaux                      | 1981            |  |
| id.                     |                   | Les Rivières near Ligugé    | 1980            |  |

<sup>1)</sup> The report also indicates an introduction of *A. pallipes* into the Pamphiot Brook at Allinges (Department of Haute-Savoie) in 1982. But it was not *A. pallipes*, it probably was *Astacus leptodactylus* as the introduced animals were "big crayfish" bought on a market in Genève (Switzerland) (Laurent unpub. data).

<sup>2)</sup> "?" indicates the introduction year is unknown or unspecified in the sources.

- The Bafsels Brook (the Rome River system) has *A. pallipes pallipes* (MACHINO 1995 unpub. data).
- The Forquets Brook (the Rome River system) has *A. pallipes*, but the subspecies could not be determined morphologically (MACHINO 1995 unpub. data).
- The Villelongue Brook has crayfish whose morphology is apparently *A. pallipes fulcisanus* (MACHINO 1997 unpub. data).

**Table 2:** *A. pallipes* introductions into French waters mentioned in VIGNEUX (1979)<sup>1)</sup>. The introductions were apparently successful unless mentioned "Without success".

| French Department              | Water              | Place  | Date                         | Nota   |
|--------------------------------|--------------------|--|------------------------------|--|
| Bouches-du-Rhône<br>Hérouville | Encanaux<br>Buèges | Auriol   | 1959<br>1965                 | 10 kg of crayfish introduced.<br>Reintroduction with crayfish from Spain.  |
| id.                            | Jaur               | Olarques   | 1965                         | Reintroduction with crayfish from Spain.   |
| id.                            | Lamalou            | Saint-Martin-de-Londres  | See nota                     | Reintroduction with crayfish from Spain. The reintroduction was carried out in 1965 and the population survived till 1982, but disappeared then (REYNIER 1996 pers. com.). |
| Lot-et-Garonne                 | Tolzac             | Varès  | Till 1935<br>ca. 1969        | Without success.<br>Without success. Crayfish from Italy.  |
| Savoie<br>id.                  | Savigny            | Near Aix-les-Bains<br>Property Ossola at Pont<br>Royal near Chamousset | ? <sup>2)</sup><br>Till 1966 | Crayfish from Eastern Europe <sup>3)</sup> .<br>Without success. From a fish farm at Jassens-Rioter (Department of Ain).   |
| Vienne                         | Not specified      | Not specified  |                              |  |

<sup>1)</sup> The report also indicates an introduction of *A. pallipes* from Germany into a pond at Damvillers (Department of Meuse). But it was not *A. pallipes*, it was *Astacus leptodactylus* (MACHINO 1996 unpub. data).

<sup>2)</sup> "?" indicates the introduction year is unknown or unspecified in the sources.

<sup>3)</sup> The origin must be the former Yugoslavia.

**Table 3:** *A. pallipes* introductions into waters of Department of Ariège, France (CLÉMENT & DURECU 1983)<sup>1)</sup>.

| Brook/River   | Place                                    | Date                     | Number                        | Nota  |
|---------------|--|--------------------------|-------------------------------|---|
| Bagen         | Biert                                    | 24 Sept. 1983            | 43 ♂, 55 ♀                    | Restocking.   |
| Castet d'Aleu | Aleu                                     | 24 Sept. 1983            | 22 ♂, 34 ♀                    | Restocking.   |
| Monesple      | near Montégut-<br>Plantaurel             | 7 Sept. 1983             | 30 ♂, 55 ♀                    | Also introduction in September 1982; Recapture in 7 August 1983 and 4 September 1983. |
| Alsès Herm    | L'Herm                                   | 29 Sept. 1983            | 61 ♂, 49 ♀                    | Also introduction in September 1982; Recapture in 2 August 1983 and 2 September 1983. |
| Montoulieu    | Montoulieu                               | 1983 (day not specified) | not specified                 |   |
| Caraybat      | La Tuilerie near<br>Saint-Paul-de-Jarrat | 4 Oct. 1983              | 60 summerlings <sup>2)</sup>  |   |
| id.           | Belbèze near Saint-<br>Paul-de-Jarrat    | 11 Aug. 1983             | 150 summerlings <sup>2)</sup> |   |

<sup>1)</sup> For the introductions of 1982 and 1983, they originate from the Volp River at Mathilot near Montardi (Department of Ariège).

<sup>2)</sup> The strain is of the Volp River at Mathilot near Montardi (Department of Ariège).

Thus the crayfish stocking was quite common in this department and some were carried out independently without the Fishing Federation of Pyrénées-Orientales. As the French *A. pallipes* and the Italian ones were stocked into this department which did not have crayfish earlier, their geographical distribution does not show any logical biogeographic pattern but something similar to mosaic patch works.

### **Introduction of non-French *A. pallipes* into French waters**

A fisherman informed one of us (MACHINO) about a crayfish brook in the Chartreuse Mountain, not far from Grenoble (Department of Isère). This is a no name brook and it was verified in 1997. The crayfish morphology showed it was *A. pallipes fulcisianus* (MACHINO 1997 unpub. data).

In Department of Gers, the Cédon River received the Spanish *A. pallipes* in 1972 and 1973 (Table 1).

In Department of Hérault, the Buèges, Jaur and Lamalou Rivers were stocked with the Spanish *A. pallipes* in 1965 (Table 2).

After genetic analyses on *A. pallipes* from France, SOUTY-GROSSET et al. (1997) revealed that the crayfish of Lake Lac Pavin (Department of Puy-de-Dôme) showed two types of *A. pallipes*, one belonging to the French and the other to the Italian. To this lake, *A. pallipes* was not native. The French one was introduced around the 1860s by RICO (1876a). Hence the genetic data indicate the Italian crayfish also would have been stocked into the lake later.

The Nationaal Natuurhistorisch Museum Leiden has *A. pallipes* collections from Lake Lac Chauvet (Department of Puy-de-Dôme) (Catalogue No. 10319, date 24 August 1955). The consultation of the collection resulted in the fact that their rostrum is like in the Italian or Spanish white-clawed crayfish but not like in the French one (MACHINO 1999 unpub. data).

In Department of Pyrénées-Orientales, the Italian *A. pallipes* lives in the Reynès, Las Illas, Villelongue and Desix Rivers (see above). Genetic analyses were carried out for the case of the Las Illas River. This river would have two types of *A. pallipes*, the one from Spain and the other from the central Apennine Peninsula (SOUTY-GROSSET et al. 1997; IACONELLI 2001).

In Department of Savoie, the Savigny River received Italian *A. pallipes*, but ended without success (Table 2). Also would-be-the-Yugoslavian *A. pallipes* were stocked near Chamousset (Table 2).

*Austropotamobius pallipes* of the Sublon, Lauron, Mède and Auzon Rivers (Ouvèze drainage, Department of Vaucluse) showed a morphology very similar to the Italian one (SUSCILLON 1960; LAURENT & SUSCILLON 1962) but these were not classified as Italian white-clawed crayfish. This observation pushed ALBRECHT (1980, 1982) to give rise a new taxon *rhodanicus* with the description given by LAURENT & SUSCILLON (1962), but he did not see the crayfish with his own eyes. One of us (MACHINO 1996 unpub. data) saw the specimens studied by them, concluded that the crayfish were *A. pallipes fulcisianus*, and did

not prove Albrecht's opinion as a new taxon. The determination error by SUSCILLON (1960) and LAURENT & SUSCILLON (1962) occurred because they compared with only one type of *A. pallipes* from the Napoli area (Italy) while *A. pallipes fulcisanus* shows very high morphological polymorphism within the territories of Italy and the former Yugoslavia (KARAMAN 1962; ALBRECHT 1982). LAURENT & SUSCILLON (1962) believed most introductions of non-French *A. pallipes* failed in French waters, but they found four successful cases in Department of Vaucluse without noticing it in fact. The fact, that *A. pallipes pallipes* lives in all southeast France and down to Liguria Region in Italy (SUSCILLON 1960; LAURENT & SUSCILLON 1962; NASCETTI et al. 1997; SANTUCCI et. 1997; IACONELLI 2001; MACHINO 1997 unpub. data), indicates these four isolated populations of *A. pallipes fulcisanus* in Department of Vaucluse originate from an introduction.

GRANDJEAN et al. (2000b) reported the Italian white-clawed crayfish from "Garrel" somewhere in France, but the place was not described and we could not locate it.

Recently a crayfish population of would-be-an-Italian *A. pallipes* has been found in Department of Drôme. The morphological data do not let determine whether it is French or Italian (MACHINO 2003). We'll carry out genetic analyses soon in order to resolve the taxonomic problem.

### Algeria

In December 1862, 200 crayfish from Grenoble (France) were released into a creek in a fish farm of Miliana. They lived till February 1864, then disappeared (PICHON & TOURNIL 1864). The authors do not specify the crayfish species, but it is probably *A. pallipes* because the crayfish market of Grenoble was mostly provided by the surrounding areas of La Mure (Department of Isère, France) at that time (BROCCHI 1894).

### Switzerland

In Canton of Fribourg, *A. pallipes* of the Sonnaz River disappeared after a crayfish plague. So *A. pallipes* restocking was carried out in 1917 from the Longivue River or the Guin Brook (MUSY 1918).

It seems several *A. pallipes* introductions would have been carried out in Cantons of Vaud, Fribourg and Neuchâtel, but many without success (CARL 1920). The introduction effort was also negative in La Punt (=Ponte; 1694 m a.s.l.) and Churwalden (1249 m a.s.l.) in the beginning of the 20th century (both places in Canton of Graubünden) (CARL 1920). Into the Grand-Canal (Canton of Vaud), several introductions of *A. pallipes* were carried out but without success (MURISIER 1922).

In Canton of Graubünden, crayfish stocking was historically quite active. For example, around 1780, several crayfish were brought from Canton of Sankt-Gallen (probably *Astacus astacus*; ANONYMOUS 1780; AM STEIN 1857). Mr. Andreas von Ott (1767-1828) brought crayfish from Holland (probably *Astacus astacus*; OBRECHT & NIGGLI 1929). However, CARL (1917) found only *A. pallipes* there (see also BOTT 1972). The *A. pallipes*

presence in Graubünden was so disjointed that a possible old-time stocking was logically suggested (CARL 1920; ALBRECHT 1982, 1983; LÖRTSCHER et al. 1998; LARGIADÈR et al. 2000). Morphological and genetic analyses showed the crayfish of Graubünden belonged to the Italian white-clawed crayfish, i.e., group *A. pallipes fulcisianus* complex (ALBRECHT & HAGEN 1981; ALBRECHT 1982; LÖRTSCHER et al. 1998; LARGIADÈR et al. 2000).

In Canton of Valais, several *A. pallipes* introductions were carried out. In Valais Central, four introduction trials were carried out in the mid-1990s, but remain without success as none of crayfish were seen again during the post-stocking observations 1996-1997. In Haut Valais, the Milibach Brook near Visp (=Viège) has *A. pallipes* since an introduction carried out in the mid-1990s (MARCHESI et al. 1998a).

In 1997, 402 specimens of *A. pallipes* (203 ♂ and 199 ♀) were stocked into several waters of Canton of Valais (MARCHESI et al. 1998b). They were released into next eight waters of:

- Bas Valais: gravel lake of La Sablière at Collombey-Muraz; Canal du Bois Noir at Saint-Maurice.
- Valais Central: Le Vernay at Martigny; overflow-accumulation pond near Sion Airport; Pond Etang des Crêtes at Sierre; Pond Etang de Rare des Rêches near Sierre.
- Haut Valais: Leukerfed Est (near Leuk); Pond Mare de Grosseia near the Baggersee area (Raron).
- At the same time, recent genetic studies reveal some, if not all, populations of *A. pallipes* from Canton of Valais belonged to the Italian white-clawed crayfish, and an introduction by man is one of the most plausible explanations (LÖRTSCHER et al. 1998; LARGIADÈR et al. 2000).

In Canton of Genève, a stocking of *A. pallipes* seems to have been successful in two brooks (Eaux Chaudes de Russin and Eaux Froides de Dardagny) according to DÄNDLIKER et al. (2001). They also found usefulness of an artificial shelter (DÄNDLIKER et al. 2001). Its shape is something like a half egg-shell, it is made of mortar and has three openings at the bottom. The dimension is 20 cm long × 12 cm wide × 7 cm high. When the shelter is simply put on the bottom, crayfish can enter through the openings. These shelters were used in the waters where natural hiding places were scarce. The artificial shelters revealed to be efficient for the areas without flood (e.g. spring or watercress bed). For the other areas, however, the artificial shelters tend to be turned upside down by the current and/or to plunge into the ground sediment.

### **Liechtenstein**

In Liechtenstein, *A. pallipes* is not considered as a native species.

2 April 1985, 109 specimens of white-clawed crayfish from the Schnauserbach Brook near Ilanz (Canton of Graubünden, Switzerland) were introduced into the Canal Scheidgraben and its headwaters Lake Quellseen of the Nature Protection Area Äscher

(BOHL 1996, 1998). In 1995, a verification on the crayfish establishment was carried out and the population size was estimated to at least 2000 individuals (BOHL 1997).

### Austria

In this country, *A. pallipes* has been reported from only two provinces: Tyrol and Carinthia.

In Province of Tyrol, *A. pallipes* was found for the first time by BOHL (1989) in Lake Heiterwanger See. FÜREDER & MACHINO (1995) revealed that its neighbour lake, Lake Plansee, is the main distribution of the crayfish. Lake Heiterwanger See and Lake Plansee probably had no crayfish naturally. All documents but one on fisheries history of Province of Tyrol since the time of Kaiser Maximilian I (1459-1519) mentioned only fishes and no crayfish from Lake Plansee and Lake Heiterwanger See, although these documents enabled us to analyze the Tyrolean crayfish history in quite detail (see FÜREDER & MACHINO 1999). Only HIBLER (1921) mentioned that a crayfish plague decimated the crayfish population of Plansee. But we found no record on crayfish plague in Plansee. We therefore think HIBLER's information unfounded.

*Austropotamobius pallipes* was stocked into Lake Plansee by the fisherman Mr. Singer, who brought the crayfish from the railway station of Reutte in the first half of the 20th century (FÜREDER & MACHINO 1995). The railway has connected Reutte with Augsburg via Kempt since 1905 and with Innsbruck via Garmisch-Partenkirchen since 1913.

By natural diffusion, the crayfish extended its range from Lake Plansee to Lake Heiterwanger See and the Archbach Brook above the Stuiben Waterfalls. Also the Plansee crayfish was stocked into Kreckelmooser See in the 1980s by fisherman Mr. W. Ernst (FÜREDER & MACHINO 1994 unpub. data). Combining the genetic analyses and data (GRANDJEAN et al. 2000b, 2002; LARGIADÈR et al. 2000; IACONELLI 2001; MACHINO et al. in prep.), it appears that the Plansee crayfish are most similar to *A. pallipes* from Lombardia whereas different from Carinthia and Slovenia as well as from Bruneck in South Tyrol.

In Province of Carinthia, *A. pallipes* only lives in tributaries of the Rivers Gössering (Gitsch Valley), Gail (Gail Valley) and Upper Drave (Upper Drave Valley) (PETUTSCHNIG 2001a, 2001b). It was a big sensation when Henning Albrecht discovered it in the Danube drainage for the first time in 1977 (ALBRECHT 1980, 1981).

The Carinthian *A. pallipes* has been believed to be native to Carinthia. However literature analyses, biogeographic data and genetics analyses show somewhat different points of view:

- Many documents on history, geography, natural science and fisheries of the Upper Drave, Gail and Gitsch Valleys were studied. For example, SANTONINO's travel 1485-1487 indicated crayfish around Villach (Carinthia) and in the Štajersko area (Slovenia) but gave no crayfish information from East Tyrol and Upper Carinthia (where the Upper Drave, Gail and Gitsch Valleys lie) although he visited these areas (VALE 1943). Several other documents mentioned *A. astacus* from the lakes Tristacher See

(East Tyrol), Weißensee (Carinthia) and Pressegger See (Carinthia). Crayfish citations were extremely rare outside these three lakes indeed. Only two documents have been found up to now. KELLER (1894) was unspecific when mentioning the occurrence of crayfish in chalk-stream springs ("Lauen") along the Gail River. But from his description we can assume that it was not *A. torrentium* but possibly either *A. pallipes* or *A. astacus*. Probably the crayfish were not much known there, since the author (KELLER 1894) wished that more attention should be paid on this animal. The second document (ANONYMOUS 1907) indirectly indicated *A. pallipes* occurring in Carinthia where it was known under the name "Sumpfkrebs" (see FÜREDER & MACHINO 1996). The literature analyses indeed did not clarify whether *A. pallipes* is native or exotic. The crayfish documents are too scarce. The only indication is *A. pallipes* must have been stocked before the turn of the 19th to 20th century if it is not native to Carinthia.

- Today in Upper Carinthia, five crayfish species, i.e. *A. pallipes*, *A. torrentium*, *A. astacus*, *Orconectes limosus* (RAFINESQUE, 1817) and *Pacifastacus leniusculus* occur (PETUTSCHNIG 2001ab). On the biogeographic point of view, the two former species are of importance here. The distribution pattern of *A. pallipes* and *A. torrentium* is very clear, they don't overlap their distribution (MACHINO 1997a; PETUTSCHNIG 2001ab). However, this distribution pattern cannot be explained when the post-glacial (re)colonizations are taken into account, as the ice-sheets covered their distribution area several times during the glaciation (HANTKE 1993) while they had to maintain the segregation in the glacial refugia. Because these two species generally do not live together in same rivers or brooks. Only once the coexistence has been reported in the Krka River near Knin, Croatia (KARAMAN 1929).
- On the genetic point of view, recent analyses show very little polymorphism in *A. pallipes* of Carinthia and in *A. torrentium* of the Gail Valley (Carinthia) and of Tarvisio (Italy) (MACHINO et al. in prep.). In the case of *A. torrentium*, its present distribution is regarded as a result of the post-glacial colonization. For the Carinthian *A. pallipes*, either the post-glacial colonization naturally or the introduction of one strain from Italy or the former Yugoslavia are considered possible. Although, as mentioned above, the introduction is more realistic than natural colonization, a definitive proof for the hypothesis of the artificial origin is still missing. Through genetic analyses we are still looking for the mother population which was stocked into the Carinthian waters.

The literature analyses also reveal an enigma on the crayfish fishing in Lienzer Klause on the Drave River near Lienz (East Tyrol, Austria) presented by Kaiser Maximilian I (Habsburg Emperor, 1459-1519) in his famous book "Fischereibuch 1504". It shows a crayfish fishing scene in a river, which is probably the most famous crayfish picture in the world (see the front cover of Freshwater Crayfish, 1973, vol. 1). The crayfish species has been believed to be *A. astacus*, or *A. pallipes* as another possibility (FÜREDER & MACHINO 1999). Although often considered, the place in the picture has never been proved to be

Lienzer Klause. The "Fischereibuch Kaiser Maximilian I 1504", where the painting is included, does not specify the location where the crayfish scene was painted. Only on the back of the painting, armorial bearings of the County of Gorizia (in 1500 the territories were attached to Austria) gave evidence that the location was presumably a river within the County of Gorizia (UNTERKIRCHER 1967: also the crayfish scene at morning dawn probably). Until today it was not possible to find a landscape within the former territories of the County of Gorizia corresponding exactly to the picture. Only Lienzer Klause was considered as merely one of the possible places with such a canyon landscape (see UNTERKIRCHER 1967). However, when Lienzer Klause was observed for several times and compared to the picture, little correspondence was found. It is also interesting that, except the record of Tristacher See, no documents mentioned crayfish from East Tyrol. If Lienzer Klause had crayfish in the 17th or 18th century, it should have been recorded somewhere in Tyrolean documents as Tyrol (including East Tyrol) is one of the best recorded provinces in Europe for providing the historical fisheries facts. If the picture shows a river of the County of Gorizia as mentioned by UNTERKIRCHER (1967), it could also belong to the Soča (= Isonzo) drainage, the Drave drainage or the Adige (= Etsch) drainage.

### Italy

The crayfish commerce with *A. pallipes* was very active in Italy. This is supposed to be mainly for consumption but also should have enabled crayfish stockings as living animals were transported.

Rieti town and its adjacent areas were in fact a main distribution center of crayfish for the Italian market (VINCIGUERRA 1899).

Weekly 100 kg of crayfish were gathered in Popoli (Province of Pescara) from Bussi sul Tirino (Province of Aquila) and Capestrano (Province of Aquila), and shipped to Milano. 1.5 tons of crayfish were sent from Sulmona (Province of Aquila) to Milano annually, and 3.0 tons would have been shipped from Cittaducale (Province of Rieti) to Milano between October 1896 and April 1897 (VINCIGUERRA 1899). Crayfish of Province of Perugia and Province of Rieti (around the town Rieti with the Velino and Turano Rivers, their tributaries and Lakes Ripasottile and Cantalice) were widely sent to Italian towns (Napoli, Roma, Firenze, Livorno, Genova, Torino, Mantova, Verona, Padova) and French towns (Modane, Paris, Lyon, Marseille) (VINCIGUERRA 1899). About 100 kg of crayfish from Province of Como and around Varese town were shipped to Lugano (Switzerland) annually in the holiday season, and as many from Province of Sondria (particularly around Morbegno) to Switzerland (particularly to Sankt Moritz in Canton of Graubünden) (VINCIGUERRA 1899). Although the crayfish stock decreased, Italy exported 1.0 ton *A. pallipes* a year to France until the 1950s and 1960s (MANCINI 1988).

VINCIGUERRA (1899) could not determine the origin of the *A. pallipes* population in a small lake near Mormanno (Province of Cosenza) whether natural or of introduction.

For protection of native crayfish, *A. pallipes* were stocked into several waters (MAN-

CINI 1986) in:

Province of Firenze: 650 individuals through 1979-1980.

Province of Terni: 200 kg a year for 1975-1977, 1979-1982.

Province of Rieti: 82 kg through 1982-1983.

Province of Frosinone: 15 kg through 1981-1983.

Province of Aquila: through 1979-1982.

Province of Avellino: 10 females with eggs in 1982.

6,520 individuals of young *A. pallipes* which hatched in the crayfish farm of Flambro at Talmassons (Province of Udine) were stocked into five waters in Friuli-Venezia Giulia Region around 1990 (DE LUISE 1988, 1991). But for the introduction, we don't know whether the fisheries administration of Friuli-Venezia Giulia Region takes the genetic contamination into account. Morphological analyses of the crayfish samples conserved in the Museo Friulano di Storia Naturale in Udine revealed this region had two types of *A. pallipes fulcisianus* (MACHINO 1997 unpub. data).

Around 1991, several individuals of *A. pallipes* of the Resia Valley (Tagliamento drainage, Province of Udine) were introduced into a brook near Tarvisio (Danube drainage, Province of Udine) (MACHINO 1996). This brook near Tarvisio is one of the only two waters which have *A. torrentium* naturally on the whole Italian territories today (MACHINO unpub. data). MACHINO observed this brook every year between 1996 and 2003 and the *A. pallipes* introduction seems to have failed fortunately. Only one dead adult male of *A. pallipes* was found in 1997 (MACHINO 1997 unpub. data).

Also on the Plaine Piano di Fusine (Province of Udine, Danube drainage), there is one brook which received *A. pallipes* around 1987 and *A. torrentium* around 1992. Local people seemed to know the crayfish there, but it was already extinct when MACHINO started the crayfish observation in the region. Only two chelae of the same individual were found in 1997, but these are too small to determine the species (MACHINO 1997 unpub. data).

Since the end of the 19th century Italy has been making great effort on trying the crayfish farm with *A. pallipes* (NINNI 1889; VINCIGUERRA 1899; MANCINI 1986; DE LUISE 1988, 1991). Although they generally reared the species only for a short time and did not last long, they produced *A. pallipes* for a while. We don't know the fate of these crayfish either being stocked into natural waters or being shipped for market, because no results are published generally. The crayfish stocking by the Flambro crayfish farm (DE LUISE 1991) is one of the rare introductions which are published. In 1997, no crayfish farm with *A. pallipes* existed in Italy (GHERARDI et al. 1999).

The genetic data of *A. pallipes* from the Visone Brook at Grogcardo (Po drainage, Province of Alessandria) suggest that the crayfish would have been introduced from the central or southern Apennine Peninsula (IACONELLI 2001).

Currently, a species protection program is carried out, conducted by the University of Innsbruck and the Province of Bolzano (FÜREDER et al. 2002, 2003). In addition to several protection measures, crayfish rearing and re-introduction into several water-bodies are being performed. Two source populations, *A. pallipes* from the brooks Angelbach and

Krebusbach, have been transferred to intact freshwaters in 2002 and 2003, e.g. the brook Mäanderbach near Bruneck and some waters in Grante Moos near Sterzing. More details will be available in FÜREDER et al. (submitted).

### **Slovenia**

In 1952 or 1953, an introduction of *A. pallipes* of the Idrija River was carried out by Mr. Jože Kurinčič into a brook at Svino (near Kobarid), this brook is called "Potok" (MACHINO 1997b). The animals were introduced above the waterfall near Svino, which is a natural barrier for their colonization from the downstream. The stocking was successful and the crayfish still live there.

### **4. Discussion and conclusion:**

The present publication provides a lot of evidence that the introduction of *A. pallipes* was a common practice in western and southern Europe.

Crayfish were historically valuable animals for human food in Europe. Certainly, *A. astacus* was the most commercially-important species. But, when this species was not available, it was replaced by *A. pallipes* which went on the dinner table. In many countries like in Spain, southern France and Italy, crayfish management has become necessary in order to increase the income of fisheries but also to preserve these animals valuable ecologically and economically. Several management and protection measures have been proposed and installed since several centuries. The crayfish stocking was logically planned and has been carried out successfully.

Recent advances in genetic studies have started to contribute to the biogeographic understanding of the *A. pallipes* distribution in Europe. Correct analyses are sometimes put into difficulty as the results have to be based on only the natural distribution while the sampling is done without knowing whether the target populations are native or not. Some recent papers treated allochthonous populations as native and developed unfounded opinions and views. Given the fact that only very few data on crayfish introductions are available, it is easy to fall on a "bad scientific trap" (treating an introduced population as a native). Therefore biogeographic analyses (including genetic data) should be extremely careful when developing a hypothesis.

On the other hand, the genetic methods can be powerful tools discovering unusual populations with illogical distribution. They can offer a result proving that the studied populations are of introduction origin, as done for Portugal, Spain, Ireland (see above). Morphological analyses generally reveal such things, but the genetic methods are more reliable when the morphology is tricky or unspecific.

To know whether the sampled populations are (or would be) native or not, several indications can be taken from literature, fishermen's information, crayfish morphology and distribution pattern. A stocked population extends the range from the introduction point. It

takes time for the crayfish to colonize every good habitat. Four decades after the crayfish introduction into the Las Illas River (Department of Pyrénées-Orientales, France), the crayfish are present neither in the headwaters of the river and tributaries nor in the tributaries of the lower Las Illas yet, although the habitats are good.

ALBRECHT (1983) first tried to draw the original distribution of the European crayfish species in order to study the crayfish biogeography. The geomorphologic conception is very important, because the crayfish's range extension requires hydrographic connections. Although recently the post-glacial colonization mechanism has been understood more and more (HEWITT 1993, 1996, 1999), the crayfish distribution has been modified by human activities. Thus the crayfish biogeographic studies should take the human influence into account, including also the smaller species.

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