Crayfish and aquatic conservation: Species protection programs on indigenous crayfish In Tyrol (Austria and Italy)

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ABSTRACT

Autochthonous crayfish of the alpine countries (*Austropotamobius torrentium*, *Austropotamobius pallipes* and *Astacus astacus)* have been exposed to various threats and their populations still are strongly decreasing. Like in many endangered species, the decrease of native freshwater crayfish as well as their acute threat has been portrayed as a consequence of human activities. This is especially the case in the alpine countries, the Austrian and Italian Tyrol, where - when compared to the historical situation and mirrored within the recent distribution studies – a continuing decrease of native populations is observable. In ongoing species protection programs carried out in the Austrian and Italian Tyrol, we undertake measures to enhance the situation of all three indigenous species. Three case studies – one ongoing in the catchment of the River Lech – each considering another autochthonous species demonstrate how water management activities combined with crayfish research offers excellent potentials for crayfish protection. In a European-wide perspective, the herein illustrated species action plans are considered very important because they a) deal with some of the last populations of the priority species *A. pallipes* and *A. torrentium* within the region (Annex II, Fauna Flora Habitat Directive), b) provide evidence of historical and cultural importance of crayfish in the region, and c) present effective conservation action in their implementation at scientific, management as well as public level.

Keywords: *Austropotamobius torrentium*, *A. pallipes*, *Astacus astacus*, nature conservation, endangered species, FFH directive

Introduction

Throughout the world, changing patterns of land use have resulted in the loss of natural habitat and the increasing fragmentation of that which remains. Not only have these changes resulted in altered habitat conditions and configuration, but they have modified the rates and intensity of many ecological processes essential for ecosystems to retain their integrity. As a consequence, many landscapes that are being used for productive purposes such as agriculture, grazing, and forestry, are suffering species declines and losses. As a result, adjacent landscape entities are experiencing the same effects. This is also the case for freshwater ecosystems where especially running waters were subject to various changes. For the purpose of a variety of land use, flood protection and hydropower development, many rivers have been altered into canals, often accompanied with artificial migration barriers. In the Alpine countries, the result was a decrease of natural or semi-natural river habitats. In Austria, for example, a decrease of about 80 % was recorded (Muhar et al. 2000).

Aquatic environments are highly dependent on catchment properties. Ecosystem condition and ecosystem function are often influenced by land-use practises and state of development or degree of industrialisation of a region. In mountainous areas like the Alps, colonisation combined with agriculture, industrialisation and traffic route development has been concentrated in habitable, cultivable and accessible land. All together, they have posed a great variety of threats on the previously available natural ecosystems. As a consequence, freshwater systems have experienced multiple alterations in these densely populated areas, like river regulation, habitat fragmentation and water abstraction (Dynesius and Nilsson, 1994), together responsible for habitat loss and depletion in the Alpine region (Füreder *et al.*, 2002a).

The decrease of native freshwater crayfish in many European countries as well as their acute threats, have been portrayed as a consequence of human activities (Gherardi and Holdich 1999, Skurdal and Taugbol 2001, Füreder et al. 2002b, 2002c, Füreder et al. 2006). Their decline is usually attributed to the crayfish plague, caused by *Aphanomyces astaci* Schikora, a fungus formerly endemic to North America but introduced to Europe towards the end of the 19th century (e.g., Ackefors 2000), but also to the multiple degradation of rivers and lakes by human activities. Direct effects on crayfish in addition to inexperienced or careless crayfish management (stocking of allochthonous species) still cause the decline of autochthonous crayfish populations in several European regions (Souty-Grosset et al. 2006). Accordingly, in Austria both the noble crayfish *Astacus astacus* (Linnaeus, 1758), recorded in North/East Tyrolean waters since the Middle Ages (Füreder and Machino, 1999a), and the autochthonous stone crayfish *Austropotamobius torrentium* (Schrank, 1803) have been considered as highly endangered species (Pretzmann, 1994). In the Italian province of South Tyrol (Autonome Provinz Bozen) the autochthonous white-clawed crayfish

Austropotamobius pallipes (Lereboullet, 1858) was also reported to be highly threatened (Baldassi, 1993; Adami and Gasser, 1994; Hellrigl and Thaler, 1996, Füreder et al. 2003). In the habitat directive of the European Union, *A. pallipes* and *A. torrentium* are listed in Annex II (*A. torrentium* a priority species) and together with *A. astacus* also in Annex V.

In recent investigations we have been focusing on the present situation of freshwater crayfish and the level of threats (Füreder and Hanel, 2000; Füreder et al., 2002b) in Tyrol, where until the end of last century only little written information on freshwater crayfish was available (see Füreder et al., 2002c). Füreder et al. (2003) provided some suggestions, how threatened freshwater crayfish species may be used to address scientific and management issues as a protection measure. Consequently, species protection programs were initiated in the Austrian and Italian Tyrol, each considering the specific situation in the region and the concerned species.

The aims of this paper were a) to summarize details and threats on the endangered species' populations in the regions of the Austrian and Italian Tyrol, b) to give a general outline of the proposed and partly implemented species action plans, and in three case studies each considering another autochthonous species, c) to demonstrate how water management activities combined with crayfish research can be used for crayfish protection.

Study area and methods

Tyrol is composed of three parts, divided by the Austrian-Italian border, i.e. North Tyrol (Austrian Tyrol, except the Drave basin), East Tyrol (Austrian Tyrol of the Drave basin), and South Tyrol (Italian Tyrol, Autonome Provinz Bozen). To provide information on the present crayfish situations in the Austrian and Italian Tyrols, all available data from field work carried out since 1994 in this area were considered for a distribution map (Fig. 1, Table 1).

Soon it became clear, that only well balanced and well considered actions were needed to increase awareness at various levels for the endangered crayfish species. In adjustment with international activities, comprehensive protection measures and methods were defined in action plans for the species. Considering the knowledge of historical evidence gained by earlier studies (Füreder and Machino, 1999a; Oberkofler 2000) together with the present distribution of crayfish, priority areas for protection measures on the individual species were defined (Fig. 1). We summarized ecological data from field work for the individual species (e.g. Oberkofler 2000; Füreder & Hanel 2000; Füreder 2002; Füreder et al. 2002b, 2002c; Oberkofler et al. 2002; Sint & Füreder 2004; Declara 2004) in the areas of priority actions together with physico-chemical parameters. For an overview, population densities (CPUE-data from traps and hand catch) were summarized for the considered areas or habitats (Table 2).

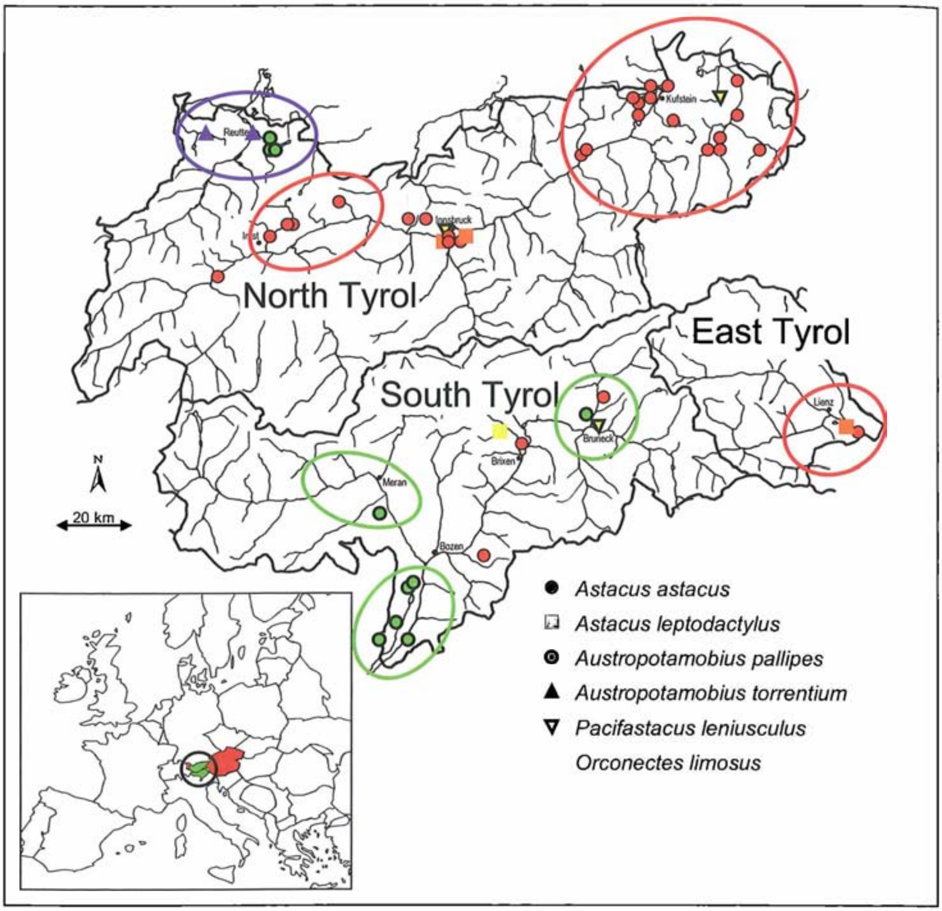

Fig. 1: Distribution of crayfish in North, East and South Tyrol. Priority areas were defined based on historical data and results from recent studies: blue - Außerfern region, where *A. torrentium* is highly threatened; red – three areas, where *A. astacus* occurs in one or a few waters; green – three areas where A. pallipes still exists in only a few waters. In all areas species conservation measures were proposed (see Tab. 4 for details).

Distribution update on indigenous crayfish species in Austrian and Italian Tyrol

The freshwater crayfish inventories and subsequent investigations resulted in records of five species being found in the Austrian province of North/East Tyrol while in the Italian province of South Tyrol four species live (Fig. 1, Tab. 1 and 2). In North and East Tyrol, the noble crayfish *Astacus astacus* (Fig. 2) and the stone crayfish *Austropotamobius torrentium* (Fig. 3) are considered indigenous, and in South Tyrol the white-clawed crayfish *Austropotamobius pallipes* (Fig. 4) only. Three non-indigenous species occur in North/East Tyrol (Füreder 2002), *i.e.*, the European narrow-clawed crayfish *Astacus leptodactylus* Eschscholz, 1823, the white-clawed crayfish *A. pallipes* and the signal crayfish *Pacifastacus leniusculus* (Dana, 1852), which were all introduced within the last century. For the region of South Tyrol, non-indigenous species are the noble crayfish *A. astacus* (Oberkofler et al. 2002), the signal crayfish *P. leniusculus* (Füreder and Machino, 1999b), and the spiny-cheek crayfish *Orconectes limosus* (Rafinesque, 1817) (Füreder et al. 2002c).

Tab. 1: Species of freshwater crayfish in the Austrian and Italian Tyrol, number and type of aquatic habitats. Note: lake and lake-outlet are treated as 2 habitat types. Numbers without re-introductions.

	N-Tyrol		S-Tyrol		E-Tyrol	
Species	Number	Habitat types	Number	Habitat types	Number	Habitat types
A. astacus Linnaeus 1758	40	Lakes, lake-outlets, meadow streams	3	Meadow stream, pond and querry pond	1	Querry pond
A. leptodactylus Eschscholz 1823	2	Querry ponds			1	Querry pond
A. pallipes (Lereboullet 1858)	6	Lake, lake-outlet, river, querry pond	7	Streams		
A. torrentium (Schrank 1803)	3	River, lake, lake-outlet				
P. leniusculus (Dana 1852)	2	Querry pond, pond	1	Meadow stream		
O. limosus (Rafinesque 1817)			1	Pond, wetland		

Tab. 2: A selection of freshwaters having crayfish populations in the areas North, East and South Tyrol. Type: lotic - running waters, lentic - standing waters; habitat complexity condition: 1 – good, 2 – moderate, 3 – insufficient; crayfish species: ASA *A. astacus*; AUP *A. pallipes*; AUT *A. torrentium*; population densities (CPUE-data from traps and/or hand catch): 1 – good, 2 - moderate, 3 – few individuals; considered/sampled reach length or shore length in Meter.

Location	lentic/lotic	Altitude (m a.s.l.)	Habitat condition	Species	Population charactistics*	populated reach
Archbach	lotic	840	1	AUT	2	50
Archbach	lotic	840	1	AUP	3	50
Angelbach	lotic	519	1	AUP	1	750
Berglsteiner See	lotic	714	1	ASA	2	100
Ritscherbach	lotic	245	2	AUP	2	100
Freundsheimer Weiher	lentic	890	2	ASA	2 - 3	60
Frauensee Ausrinn oben	lotic	550	1 - 2	ASA	3	50
Frauensee Ausrinn unten	lotic	540	1	ASA	2	25
Gießbach Staben	lotic	554	3	AUP	3	50
Gruberteich	lotic	720	3	ASA	3	200
Krebsgraben Gurgltal	lotic	780	3	ASA	3	10
Haldensee	lentic	1124	1	AUT	2 - 3	100
Hechtsee	lentic	544	1	ASA	1 - 2	300
Hüttenmühlsee	lentic	860	1	AUT	2	100
Hüttenmühlsee	lentic	860	1	AUP	3	100
Haldensee Ausrinn	lotic	1124	2	AUT	2	20
Hintersteiner See	lentic	882	1 - 2	ASA	2 - 3	100
Hyppolithbach	lotic	670	1	AUP	1	150
Krebsbach Mieming	lotic	890	2	ASA	2	300
Krebusbach	lotic	1020	1	AUP	2	(200) 600
Krummsee	lotic	540	1	ASA	3	150
Morsbach	lot./lent.	540	2 - 3	ASA	3	100
Möserer See	lentic	1284	1	ASA	2	(300) 750
Nikolsdorfer Weiher	lentic	640	1	ASA	3	150
Pfrillsee	lentic	612	1	ASA	2 - 3	(300) 500
Plansee	lentic	976	1	AUP	1	(200) 6000
Thiersee	lentic	616	1	ASA	2	(250) 1400
Wiesbach Gais	lotic	839	2	ASA	1	100
Wildsee Seefeld Ausrinn	lotic	1180	2	ASA	1	150
Wildsee Seefeld	lentic	1180	2	ASA	2 - 3	20

Owing the mountainous topography of both provinces, freshwater crayfish generally occur at lower elevations in lakes and rivers of the bigger valleys, where temperature regime and channel stability enable the successful survival of crayfish populations (Fig. 1). Whereas in North Tyrol two freshwater habitats with crayfish are situated above 1000 m a.s.l., i.e. Haldensee (1126 m) with *A. torrentium* and Möserer See (1260 m) with *A. astacus*, in South Tyrol only one location is situated above 1000 m a.s.l., the Krebusbach (1030 m) with *A. pallipes*. All the other locations of indigenous and non-indigenous species are lower.

We concluded a strong decrease in the number of crayfish waters, given that in South Tyrol about 50 locations were recorded in the literature (Füreder et al. 2002b). The comparison with former distribution studies in South Tyrol showed that even within the last two to three decades, the crayfish situation became worse (Füreder *et al.*, 2002b), and new data re-emphasizes the ongoing trend. Whereas the non-indigenous crayfish *A. astacus* and *O. limosus* increased in records, *Austropotamobius pallipes* populations either declined in size or even became extinct in different parts of the province (Füreder et al. 2002c).

Also in North Tyrol, the stone crayfish *Austropotamobius torrentium* is highly endangered due to its isolated populations. Continuous natural and anthropogenic impact (floods, river engineering, hydropower) have been threatening especially the Archbach populations.

As all indigenous crayfish species are endangered through different causes, species protection measures were proposed for several areas in the Austrian and Italian Tyrol (Table 3). Due to the small size and the fragmented status of the populations, individual protection measures were applied. However in all cases, only well designed measures and sound activities always considering the threatened crayfish species may insure the survival of these populations. The measurements proposed and up to now implemented partly (see the following case studies) will ensure the survival of freshwater crayfish in these areas, but only in the case of a continuation and finalisation of measures.

Case study 1: *Austropotamobius torrentium* in the Außerfern region

The Archbach is the outlet of the Plansee and a tributary of the River Lech in the Außerfern region in North Tyrol near the Bavarian border. It is regulated in several stretches and the water is used for hydropower. One of the effects is an artificial fluctuation of water level which can reach significant extents (up to 1 m) in some stretches. There, in the case of low flow, a large part of the river bottom falls temporally dry, reducing the potential habitat of crayfish and other aquatic invertebrates considerably, whereas at high flow the river channel can show bank-full conditions. Generally, these changes occur daily.

In an earlier investigation (Füreder & Machino 1994), we found stone crayfish being distributed in five sections of a river stretch of about 2 km. Where stone crayfish occurred, river sections were merely characterised by high and moderate current velocities, dense riparian vegetation and more or less larger rocks. Usually, rock size correlated with the size of the crayfish. In the areas where water level fluctuations were observed, the crayfish only occurred in the deepest areas, whereas areas temporally subject to water level decrease had no crayfish.

Fig. 2: The noble crayfish *A. astacus* from Nikolsdorfer Weiher in East Tyrol. This species was used for breeding and re-introduction into the Tristacher Seebach, which was formerly populated by this species (Foto: L. Füreder).

Fig. 3: The white-clawed crayfish *A. pallipes* is subject of comprehensive protection measures in the province of South Tyrol in Italy. Four good but also endangered populations exist in the area - two of them were used for breeding and introductions into several new suitable habitats (Foto: A. Declara).

Fig. 4: The stone crayfish *A. torrentium* (left) is found in Archbach and Haldensee (Außerfern, North Tyrol), today together with the white-clawed crayfish *A. pallipes* (right) (Foto: L. Füreder).

Fig. 5: Necessary engineering measures for flood protection were implemented in the Archbach considering habitat requirements of the indigenous stone crayfish. Today these rocks with some vegetation cover provide a complex habitat for the highly threatened crayfish *A. torrentium* (Foto: L. Füreder).

The impoundment Hüttenmühlsee also has crayfish, a river section characterised by low current velocities to stagnant waters and finer sediments than the other areas. There, crayfish were found underneath rocks, from the near-bank areas down to greater depths. During several investigations carried out over the last 5 years, a decrease of stone crayfish in the areas was observed. Interestingly, the second crayfish species (*A. pallipes*) occurring in the same river system (Heiterwanger See, Plansee and outlet, which is the Archbach), was discovered recently to occur in the stone crayfish area. The for North Tyrol non-indigenous white-clawed crayfish obviously had migrated from its habitat down to the lower Archbach stretches (Sint et al. 2005). Now, in the Hüttenmühlsee and to a lesser extent below the impoundment, the two *Austropotamobius* species occur sympatrically (Table 4).

Table 4: Catch of A. pallipes in the former habitats of A. torrentium in Hüttenmühlsee (HMS) and Archbach at the Schretter hydropower plant (ABU)

Date	Location	Number (Species)	Ratio AUT AUP
20./21.9.04	HMS	8 (AUP)	7
14.10.04	HMS	13 (AUP)	2.23
15.10.04	HMS	8 (AUP)	1
21.9.04	ABU	1 (AUP)	33
14.10.04	ABU	2 (AUP)	5.5

The suggestions we asked 10 years ago (Füreder & Machino 1996), how to protect this valuable crayfish population in the Archbach, were to a major part considered positively by the responsible authorities. In the necessary river engineering activities habitat conditions were planned according to safety standards but also according to the habitat demands of the stone crayfish. Despite these positive attempts, unforeseen events (several catastrophic floods) und thoughtless practice by other institutions (railway bridge construction with enormous habitat impairments in 2004) caused several succeeding impacts. Ongoing excavation works are causing an increase of fine suspended material which is now covering large areas of the bottom sediments.

Tab. 3 (on following pages): Framework of the crayfish protection plans in North, South and East Tyrol: Protection measures, aims and implementation (ICS indigenous crayfish species, NICS non-indigenous crayfish species; AUT A. torrentium; AUP A. pallipes; ASA A. astacus; ASL A. leptodactylus; PCL P. leniusculus; OSL O. limosus)

Protection measure(s)	Aim(s)	Implementation Außerfern	Implementation South Tyrol	Implementation East Tyrol
Distribution study	Knowledge about the distribution of indigenous and non-indigenous crayfish	Started in 1994 ICS: AUT; NICS: AUP (Füreder & Machino 1995, 1996, 1998, 1999a, 1999b; Machino & Füreder 1998; Füreder 2000)	Started in 1994 ICS: AUP; NICS: ASL, OSL, PCL (Füreder & Oberkofler 2000; Füreder et al. 2002a, 2002b; Machino 1997; Oberkofler 2000; Oberkofler et al. 2002;	Started in 1994 ICS: ASA; NICS: ASL (Füreder2000; Füreder & Hanel 2000; Sint & Füreder 2003)
Historical information	Knowledge about crayfish species distribution in the past	Started in 1994 Füreder & Machino 1998, 1999	Started in 1994 Füreder & Machino 1998, 1999	Started in 1994 Füreder & Machino 1998, 1999
Habitat assessment	Knowledge about habitat conditions, integrity and impairments as well as anthropogenic impacts (including freshwater habitat, riparian zone and catchment)	Started in 1998; today habitat assessments are available for all records	Started in 1998; today habitat assessments are available for all records, even including many historical sites (Declara 2004; Füreder et al. 2002a; 2002b; Oberkofler 2000) Intensive and detailed characterisation of source and potential target habitats	Started in 2000; today habitat assessments are available for Tristacher Seebach which was the subject of protection measures, incl. proposed habitat improvement measures (Füreder & Schwarzenberger 2002)
Characterisation of crayfish populations	Knowledge about qualitative and quantitative features of the crayfish populations	Start 2002 One to several assessments per year in Archbach and Haldensee	Start 2002 One to several assessments	Qualitative and quantitative characterisation of source population for breeding and reintroduction
Definition and designation of program areas and potential crayfish habitats	By 2006, several intact crayfish populations shall exist in all potential distribution areas within Astrian and Italian Tyrol	In North Tyrol: 1 program area for AUT (Außerfern, two sites: Archbach, Haldensee with Berger Ache); 3 program areas for ASA (lakes near Kufstein, streams around Kirchberg, Gurgltal)	In South Tyrol: 4 populations for AUP (Angelbach, Krebusbach, Hypolitbach, Ritscherbach); Program areas for AUP (Vinschgau, Bruneck; Unterland, Überetsch)	In East Tyrol: 1 for ASA (Tristacher Seebach) Program area for ASA: Tristacher See and Seebach
Designation of habitat and species	Existing crayfish habitats shall be protected; designation of habitat and species protection areas; take	AUT protected by law (Tiroler Naturschutzgesetz) Although next to Natura 2000, river	AUP protected by law (Südtiroler Naturschutzgesetz), FFH-directive Only some habitats, i.e.	ASA protected by law (Tiroler Naturschutzgesetz);

Protection measure(s)	Aim(s)	Implementation Außerfern	Implementation South Tyrol	Implementation East Tyrol
Extension of existing crayfish habitats	Through structural alteration (restoration), elimination of migration barriers and/or unfavourable habitat conditions, so that crayfish may spread actively	In Archbach project planned (Archbachsiedlung), but not executed by 2006	Several projects were proposed, discussed at various meetings, until today not executed	Through comprehense restoration measures in Tristacher Seebach, the potential habitat of crayfish was enlarged
Restoration of polluted, desolated or channelised freshwater habitats, which carry relict crayfish population	Human impacts shall be attenuated or eliminated to enable the recovery of weakened populations	Habitat demands of AUT were taken into account in flood protection measures (Archbach above Schretter Wehr and small area in Hüttenmühlsee)	Several projects were proposed, discussed at various meetings, until today not executed	Restoration of Tristacher Seebach: habitat conditions were optimised over a 2 km length
(Re)Introductions, foundation of new crayfish populations	By breeding and subsequent re-introduction, new crayfish populations and locations shall be founded	Pilote studies in 2004 (source: crayfish from Haldensee; new habitat: Stinksee) 2005: no success because of floods Adult catch, breeding, release in 2006 (ongoing)	Pilote studies in 2001 (source: Angelbach, Krebusbach; new: Mäanderbach, Grante Moos) 2002, 2003 (see Tab. 5) not continued	Pilote study in 2001 (source Nikolsdorfer Weiher, release Tristacher Seebach) 2003, 2004 (same proc.)
Creation of regional gene pools	Genetic diversity and uniqueness shall be obtained by defining and/or creating isolated gene pool habitats	Activities planned for 2007	Activities planned for 2007	Activities planned for 2007
Monitoring	Monitoring of the development of crayfish populations and the success of habitat improvements and (re)introductions	No funding	No funding	No funding
Public relations; outreach activities	Building of public awareness, various information on crayfish distribution, value and threats	Presentations at various events, book "Flusskrebse in Tirol" Füreder (2000), newspaper articles, TV, radio	Presentations at various events, folder, book (in prep.), newspaper articles, TV, radio	Presentations at various events, book "Flusskrebse in Tirol" (Füreder 2000), folder

Especially in the case of the highly threatened stone crayfish it becomes evident that without well defined measures for its protection this species will disappear in Tyrol. Without accompanying activities like breeding and (re-)introductions together with a restoration and extension of habitable areas to a significant extent, the probability of survival of the relict population is very low. In the planned activities for flood protection and river habitat improvement, we proposed several measures for the support of the threatened crayfish populations. We hope that suggested measures will hopefully be continued and implemented rapidly.

Surprisingly, the stone crayfish occurring in the program area of a LIFE Nature project was withdrawn by the EU-commission from the project activities when this project was applied. The explanation was that this species was not included into the FFH directive. The conservation value of this least studied and threatened species (Füreder & Souty-Grosset 2005) increased several years later (since 2005 this species is listed in Annex II and V of the FFH directive), hopefully still early enough for this species to recover. For protection measures and subsequent monitoring within the well funded LIFE-Nature activities no support was available. Without generous support from the local communities and the water authorities in Innsbruck and Reutte a success would not have been made possible.

Case study 2: *Astacus astacus* in Eastern Tyrol

In East Tyrol two of the oldest known populations of the noble crayfish vanished suddenly in the late 1990s (Füreder 2002, Füreder & Hanel 2000). Tristacher See was already mentioned in 1504 in the "Hunting and Fishing Book" of Emperor Maximilian I holding crayfish (Unterkircher 1967). In August 1996, noble crayfish populations were still observed in Tristacher See and Seebach, but in 1998 both locations were found without any crayfish. The cause of the extinction still remains unclear, since neither a sign of non-indigenous crayfish introduction nor any other identifiable threat was apparent. Habitat assessments carried out in 2002 resulted in the recording of degraded reaches, caused by new settlement and land use activities (Füreder & Schwarzenberger 2001). It is not likely, that the habitat impairment is connected with the extinction of noble crayfish, since the species disappeared in the lake as well a considerable distance upstream.

Not only the historic value of this old crayfish site but also the general decrease of crayfish waters in our region, gave rise to a proposal for a species protection plan. As part of it, a project was started in 2001 with the objective of improving the habitat for *A. astacus* in the Tristacher Seebach (Füreder & Schwarzenberger 2001), to re-introduce the species into the stream and to give an estimate of its suitability and the potential effect of habitat conditions on the reintroduced population.

Breeding and stocking activities were performed in 2002 and 2003, when female crayfish carrying eggs were caught in Nikolsdorfer Weiher, a query pond in the area holding a dense noble crayfish population. The females were brought to a crayfish hatchery in Göstling (R. Pekny, Lower Austria) and returned to the Seebach after releasing their young in July. The young-of-the-year were kept in the hatchery over summer and then brought to the Seebach. They were stocked in different river stretches were restoration measures had been applied earlier.

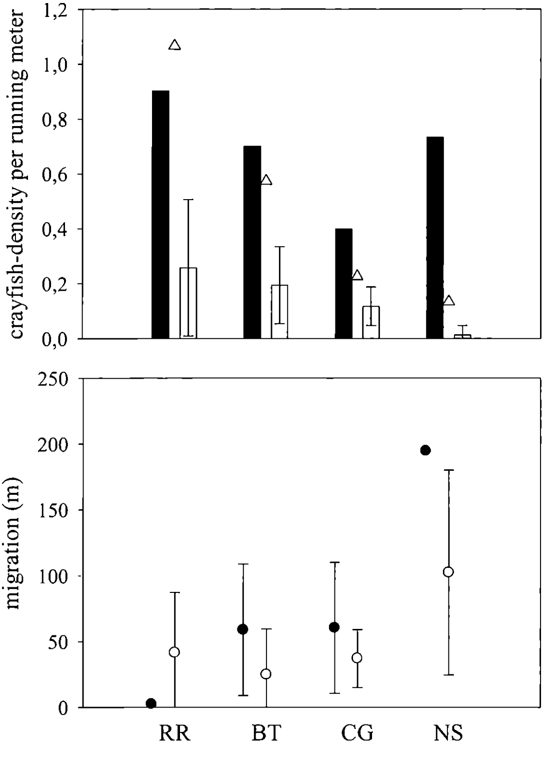

Fig. 6: Field experiments performed with the re-introduction of *A. astacus* in Tristacher Seebach at sites along a gradient of substrate complexity (RR rip-rap with highest shelter availability, BT bricks and tubes, providing moderate shelter; CG cages with little shelter, NS no shelter). Upper graph shows the initial density of released crayfish (black columns), maximum density ever observed (triangles) and the mean of observed crayfish (grey columns). Lower graph showes the observed migrations in Meter -at maximum shelter, no migration and at no shelter highest migration distances were observed (Sint & Füreder 2004).

In addition, adult crayfish (females and males) were transferred from Nikolsdorfer Weiher to the Seebach (Sint & Füreder 2004). The crayfish were released in four areas that differed in shelter quality and quantity. After several days of observation, we found that crayfish densities corresponded greatly to the gradient of shelter quality and quantity. Not only the densities followed this gradient (highest crayfish densities in highest shelter availability) but also the migration distances of individual crayfish, being maximal in areas with no or little shelter (Fig. 6).

Generally, little is known about the success of introductions and even less is known about the post-release behaviour and migration of crayfish in crayfish protection programs. Combined with our re-introduction activities, the breeding experiments and observations on habitat requirements and post-stocking activities provided interesting results. These demonstrated that the success of crayfish (re-)introductions might be enhanced with simple measures. In optimizing habitat conditions one can make sure that the animals come across appropriate shelter immediately after stocking. These measures, in our study, reduced the migration of crayfish, which is considered a problem after introduction into new habitats.

It still is to hope that the combined stocking with adults out of a dense population with juveniles bred under controlled conditions remains successful. Future observations will proof the potential success.

Case study 3: *Austropotamobius pallipes* in South Tyrol

In South Tyrol, only a few freshwaters carry healthy native populations of *A. pallipes*, i.e., Angelbach, Krebusbach, Hyppolithbach and Ritscherbach (Füreder et al. 2002c, Füreder et al. 2003, L. Füreder unpubl. data, Declara 2004), and one of the non-indigenous species *A. astacus*, i.e. Wiesenbach (Füreder et al. 2002c). At a few other sites very small populations of *A. pallipes* are native (Füreder et al. 2003); the exotic species *O. limosus* and *P. leniusculus* have established small to medium-size populations (Fig. 1, Tab. 3).

South Tyrol in particular has experienced a great loss of natural and structurally intact aquatic systems in cultivatable regions, which is only 1/6 of the whole country after subtracting rock mass (>20 %), forest (~40 %), and mountain pastures (>20 %). Already in the 19th century infrastructure measures were initiated that enabled the region to become the “Garden of Europe” within the 20th century (Feuerstein, 1999). Exhaustive river regulation and reclamation of land in extensive wetland areas fostered a rapid development of fruit production and viniculture, but also a great loss of natural aquatic systems.

Only from historical landscape descriptions and maps, details about the various freshwater types and also occurring species, among them freshwater crayfish, can the former situation be derived (Müller, 1997). Most of the historical and remaining crayfish sites are located in intensively cultivated areas. Only a few examples, which contain the healthy populations, are surrounded by a less managed environment.

The analysis of catchment properties and habitat characteristics in 125 freshwater habitats (predominantly streams and rivers, since few South Tyrolean crayfish occur in standing waters; Füreder et al. 2003) showed that crayfish locations had predominantly moderate to poor catchment and habitat conditions. In freshwaters of historical crayfish records but now extinct populations, catchment and habitat conditions were even worse. Locations with lacking evidence of crayfish occurrence had somewhat better conditions, perhaps because proportionally more intact than impaired waters were inspected for potential crayfish sites.

Our data and literature review on historical records provided evidence that freshwater crayfish had a wider distribution in several areas of South Tyrol (Füreder and Machino, 1999a; Füreder and Hanel, 2000; Oberkofler 2000). These historical crayfish records were located especially in the broader main valleys, where variable water bodies and courses had developed under natural conditions (from wetlands, ponds, and slow to fast flowing rivers), as well as on higher plateaus. In a mountainous area like Tyrol, these flat and exposed areas were ideal for settlement and cultivation. Channel alteration and drainage measures of wetlands were the consequence of increasing land-use activities. Although in most cases the actual cause for crayfish loss and decline is difficult to ascertain, land use and cultivation practices seem to be one of the major threats to native freshwater crayfish (Schenk et al. 1977, Baldassi 1993).

Land use accompanied with lack of natural habitats or riparian vegetation was considered to be the major cause for the decline of populations (Füreder et al. 2002c). Besides the negative effect of habitat loss, point or non-point contaminants from agricultural use may have threatened the native crayfish. Biological threats, to some extent also a consequence of human activities, include the presence of non-indigenous freshwater crayfish species or high densities of predatory fish. The situation of indigenous crayfish in South Tyrol corresponds greatly to other European regions, where also these threats have been identified (for a review see Füreder et al. 2006).

Four intact and healthy indigenous populations of *A. pallipes* were identified for the area of South Tyrol and it was proposed to use the two denser ones for breeding and introduction activities into 6 waters in 2003 and 7 waters in 2004 (Table 5). We identified habitat conditions, seasonal changes of population quality and quantities, monitored breeding success and characterised target habitats (Declara 2004, Füreder unpubl. data). These activities were proposed to being continued, for which the fisheries and water authorities declared themselves being responsible. It remains to hope that the future of freshwater crayfish will not follow the history of freshwater fish in many countries, where a vital trade and introduction of non-indigenous species have altered the distribution pattern. For several fish species it is almost impossible to re-construct the distribution of indigenous populations and their original habitats and biotopes.

Tab. 5: Breeding and introduction activities in South Tyrol (2002 and 2003). * Krebusbach fell dry in summer 2003, no ♂♂ were caught.

Source (Date of catch)	# of ♀♀ with eggs	# of eggs (total)	Date of stocking	# of ♀♀ stocked	# of ♀♀ died in hatchery	# of ♂♂ stocked	Target habitat	Date of stocking	# of YOY stocked	Target habitat
Angelbach (02.05.02)	25	970	29.06.02	23	2	11	Uenznerbach (Wiesen)	26.10.02	32	Grante Moos (Sterzing)
								26.10.02	33	Tscharser Au (stream)
								26.10.02	32	Schludernser Au –Weiher (Schluderns)
Krebusbach (08.05.02)	11	575	29.06.02	10	1	7	Mäanderbach (Sand i.T.)	25.10.02	120	Mäanderbach
								26.10.02	120	Trudnerbach
Angelbach (19.05.03)	50	2350	30.07.03	50	0	35	Schludernser Au	14.10.03	55	Grante Moos (Sterzing)
								15.10.03	55	Tscharser Au (Tschars)
								15.10.03	55	Schludernser Au
									54	Wurmedbach (left tributary)
Krebusbach (19.05.03)	51	2142	30.07.03	51	0	0*	Trudnerbach (Neumarkt)	14.10.03	124	Mäanderbach
									124	Trudnerbach (Neumarkt)
								15.10.03	123	Felixer W.

Freshwater crayfish as surrogate species in conservation management

Based on threatened species' records, on average worldwide, freshwater biodiversity was considered to be more threatened than terrestrial (Allan and Flecker, 1993; Williams *et al.*, 1993; McAllister *et al.*, 1997; Riccardi and Rasmussen, 1999). Abell *et al.* (2002) summarized from those species considered in the 1996 IUCN (The World Conservation Union) Red List, 20 % of reptiles, 25 % of amphibians, and 34 % of fishes (mostly freshwater) were threatened. At a regional scale, the projected mean future extinction rate for North American freshwater fauna was considered to be about five times greater than that for terrestrial fauna. There is no evidence that this number is too high for Europe. Among many other aquatic animals, indigenous crayfish species are particularly threatened by various impacts (Füreder et al. 2006).

In cultivatable regions of the Alps, also in Tyrol, a considerable loss of natural and structurally intact aquatic systems was recorded (Muhar et al. 2000). Exhaustive river regulation and reclamation of land in wetland areas fostered a rapid development of land use activities, settlement and traffic route building. From historical landscape descriptions and maps, details about the various freshwater types and also occurring species, among them freshwater crayfish, the former situation can be derived (Müller, 1997). Most of the historical and remaining crayfish sites are located in intensively cultivated areas. Only a few examples, which contain the healthy populations, are surrounded by a less managed environment.

An assessment of habitats based on species inventories always carries problems, as long they are not managed with explicit objectives. In extensively cultivated regions arguments for biological conservation and nature protection often fail because of the existing economic pressures on land. The value of a natural or certain habitat may be justified by high species diversity or by optimal structural environment for a particular species, which seems to be an effective argument for freshwater crayfish.

In North/East Tyrol and South Tyrol, the results of our current crayfish inventories provided water authorities, environmental protection agencies and the public with the alarming fact that compared to their historical distribution freshwater crayfish had dramatically declined. Decreasing populations and population or species extinction have been reported from other European regions, e.g., Ireland (Matthews and Reynolds, 1995) and Great Brittain (Holdich and Rogers, 1997), Spain (Gil-Sánchez and Alba-Tercedor, 2002), France (Vigneux, 1997), Italy in general (Gherardi *et al.*, 1999), Germany (Bohl, 1999) and Switzerland (Büttiker, 1987, Mickasch, 1999), demonstrating that this problem exists at a much larger spatial scale.

Several good reasons exist to consider species protection as the most important demand in natural conservation. Habitat protection may be on the short run a prerequisite for the survival of many species, however on the long run many biotopes will continue to loose their integrity due to ongoing land use and global and climate change. Attempts to prevent further loss of biological diversity from such landscapes requires the capacity to define the spatial, compositional, and functional attributes that must be present if the needs of plants and animals are to be met.

Species conservation is faced with big problems especially in the field of invertebrate ecology and entomology: where to start? For example, in Austria about 10.000 species of dipterans and 10.000 species of hymenopterans occur, or several 100 species of aquatic insects. It would be very inefficient, to select some of the many insect species randomly to use them for species conservation programs. Because of the high number of species to consider, wise and effective priorities in conservation have to be defined.

Changes of water quality, ecosystem health or ecosystem integrity have often been recorded by assessing assemblages of bioindicator species like fish and macroinvertebrates or by monitoring water or sediment chemistry (Moog and Chovanec, 2000; ÖNORM M 6232, 1995). Although widely applied throughout Europe, disadvantages of using macroinvertebrates (e.g., aquatic insects) in water quality assessments are that assemblages may vary from place to place, information on species distribution is still fragmentary, and monitoring activities are labour and cost intensive. Only a few species are found throughout a wide range of habitat across Europe, causing water quality monitoring to be national rather than international. An auspicious alternative approach may therefore be the use of a keystone species (-group) widely distributed and well known in Europe.

In freshwaters, the largest active and long-lived invertebrates are freshwater crayfish (e.g., Holdich 2001, Holdich 2002), which have received some attention in European countries as attractive animals for recreational fishing (Skurdal and Taugbol, 2001), in some regions over several hundred years. Historical evidence is provided for some countries demonstrating also their cultural value (as a lenten meal or delicacy at feasts; Füreder and Machino 1999a).

In conservation biology often one or a small number of species are used as surrogate species (*sensu* Caro and O'Doherty, 1999) to portray conservation problems. They may be used in various ways, e.g., to indicate the extent of various types of anthropogenic impacts (health indicator species), to track population changes of other species (population indicator species), to locate areas of high biodiversity (biodiversity indicator species), to act as "umbrellas" for the requirements of sympatric species (umbrella species) or to attract the attention of the public (flagship species). Due to their attributes and peculiarities, freshwater crayfish were considered to be adequate surrogate species fulfilling the majority of the above stated prerequisites (Füreder et al. 2003).

Given these various adequate attributes of freshwater crayfish as surrogate species (including indicator species, umbrella species and flagship species qualities) ongoing endangered species conservation programs will besides advancing the crayfish situation certainly help to restore combined with freshwater habitat improvements.

Conclusions: major concerns and optimistic considerations

Human alteration of the environment is having unprecedented effects on the distribution and abundance of species, ecosystems, and the genetic variability of organisms. Species are currently being lost globally at a rate that is about 100 times faster than the average natural rate, and tens of thousands of other species are already committed to future extinction because of the recent worldwide loss of their habitat (Millennium Ecosystem Assessment 2005). The primary loss of biodiversity are demographic, economic, and institutional factors, including increasing demands for land an biological resources due to the growth in the human population, world production, consumption and trade, associated with a failure of people and markets to take into account the long-term consequences of environmental changes and the full array of biodiversity values.

The situation of freshwater crayfish in the Austrian and Italian Tyrol is a dramatic example of some of these causes. The loss, fragmentation, and degradation of habitats; the overexploitation of biological resources; the introduction of non-native species; and at a few locations, the pollution of water has during the last century caused a decrease of the distribution area of three indigenous crayfish species. It is to be expected that not only indigenous crayfish are concerned, but also vertebrate and other invertebrate species associated with freshwater habitats. The loss of species and genetic variability is essentially irreversible, and therefore poses serious threats to sustainable development and the quality of life of future generations.

On the other hand, the executions of the protection programs on freshwater crayfish in the Austrian and Italian Tyrols potentially provide good perspectives. However this still challenges governance. There may have been so far insufficient awareness and recognition among decision makers and the general public of the importance of species diversity and habitat conditions on the multiple ecosystem services humankind depends on. Freshwater crayfish have been known and appreciated in the area since the Middle Ages (see famous painting of the crayfish catch in the hunting and fishery book of Emperor Maximilian I), at least several decades ago. The high cultural and historical value should be considered adequately.

Policy and decision makers but also the public have to understand that environmental management (e.g., river engineering to prevent flood protection) has to take into account also biological deficiencies at regional and international level. The decrease of species and decline of intact and functioning ecosystems is not only the interest of a specific region, community or family. Continuous consideration, awareness and information of the public together with serious implementation of the proposed actions have to be realised within the designated areas. The proposed measures would only cover a minimum of the projects costs (in ‰), but are usually not taken into account. River engineers, environmental protection officers and scientists have started to work together for the sustainable development of indigenous crayfish populations in the Austrian and Italian Tyrol. These activities at all levels have to be continued.

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References

Abell, R., Thieme, M., Dinerstein, E., Olson, D., 2002. A Sourcebook for Conducting Biological Assessments and Developing Biodiversity Visions for Ecoregion Conservation. Volume II: Freshwater Ecoregions. World Wildlife Fund, Washington, DC, USA.

Ackefors, H.E.G., 2000. Freshwater crayfish farming technology in the 1990s: a European and global perspective. Fish and Fisheries 1, 337-359.

Adami, V., Gasser, M., 1994. Rote Liste der gefährdeten Zehnfußkrebse (Decapoda) Südtirols. In: Abt. f. Landschaft- u. Naturschutz, Autonome Provinz Bozen-Südtirol (ed), Rote Listen gefährdeter Tiere Südtirols. Amt für Landschaftsplanung, Autonome Provinz Bozen-Südtirol, Bozen/Bolzano, pp. 23-33 + 348-349.

Allan, J.D., Flecker, A.S., 1993. Biodiversity conservation in running waters: Identifying the major factors that threaten destruction of riverine species and ecosystems. BioScience 43, 32-43.

Baldassi, L., 1993. Il gambero (Austropotamobius pallipes italicus) nelle acque correnti dell'Alto Adige distribuzione spaziale in relazione alle caratteristiche ambientali e alla qualità delle acque. Tesi di Laurea, Dipartimento di Biologia Evoluzionistica Sperimentale, Facoltà di Scienze Matematiche, Fisiche e Naturali, Università degli Studi di Biologna, Bologna, pp. 1-74, 6 pl. + 1 map.

Bohl, E., 1999. Crayfish stock situation in Bavaria (Germany) – attributes, threats and chances. In: Keller, M., Keller, M.M., Oidtmann, B., Hoffmann, R., Vogt, G., (eds). Freshwater Crayfish 12, Weltbild Verlag, Augsburg, pp. 765-777

Büttiker, B., 1987 Concerning crayfish in Switzerland. In: Goeldlin de Tiefenau, P., (Ed.), Freshwater Crayfish 7, Musée Zoologique Cantonal, Lausanne, pp. 2-5.

Caro, T.M., O'Doherty, G., 1999. On the use of surrogate species in conservation biology. Conservation Biology 13, 805-814.

Declara, A., 2004. Lebensraumcharakterisierung und Bestandserhebung an zwei Dohlenkrebsgewässern in Südtirol als Basis für Wiederansiedlung. – Diplomarbeit, Universität Innsbruck: 1-136.

Dynesius, M., Nilsson, C., 1994. Fragmentation and flow regulation of river systems in the northern third of the world. – Science 266: 753-762.

Feuerstein, G., 1999. Grundzüge der Landwirtschaft Südtirols. Der Schlern 73, 778-784.

Füreder, L., 2002. Flusskrebse in Tirol: Vorkommen, Verbreitung, ökologische Bedeutung und Gefährdung. Natur in Tirol, Naturkundliche Beiträge der Abteilung Umweltschutz, Band 10.

Füreder, L., Souty-Grosset, C., 2005. European native crayfish in relation to land-use and habitat deterioration, with a special focus on *Austropotamobius torrentium*. Bull. Fr. Pêche Piscic. 376-377: 487-845.

Füreder, L., Hanel, R., 2000. Flusskrebse in Gewässern Nord- und Osttirols: Verbreitung, ökologische Bedeutung und Schutzmaßnahmen. Berichte d. naturwissenschaftlich-medizinischen Vereins Innsbruck 87, 221-241.

Füreder, L., Machino Y 1999a. Past and present situation of freshwater crayfish in Tyrol (Austria and northern Italy). In: Keller, M., Keller, M.M., Oidtmann, B., Hoffmann, R., Vogt, G., (eds). Freshwater Crayfish 12, Weltbild Verlag, Augsburg, pp. 751-764.

Füreder, L., Machino, Y 1999b. Les écrevisses exotiques dans le Tyrol du Sud (Italie). L'Astaciculteur de France 61, 2-6.

Füreder, L., Machino, Y 1996. Das letzte natürliche Vorkommen des Steinkrebses *Austropotamobius torrentium* (SCHRANK 1803) in Tirol. – Ber. nat.-med. Verein Innsbruck, **83**: 211-219.

Füreder, L., Machino, Y 1995. Record of the White-clawed Crayfish *Austropotamobius pallipes* (LEREBOULLET 1858) from Plansee (Tyrol, Austria). – Ber. nat.-med. Verein Innsbruck, **82**: 241-246.

Füreder, L., Edsman, L., Holdich, D., Kozák, P., Machino, Y Pöckl, M., Renai, B., Reynolds, J., Schulz, H., Schulz, R., Sint, D., Taugbol, T., Trouilhé, M.C., 2006. Indigenous crayfish habitat and threats. Pages 25-47 in: Souty-Grosset, C., Holdich, D.M., Noel, P.Y., Reynolds, J.D., Haffner, P. (eds): Atlas of crayfish in Europe. – Muséum national d'Histoire naturelle, Paris, Patrimoines naturels 64: 187pp.

Füreder, L., Oberkofler, B., Leiter, J., Thaler B., 2003. *Austropotamobius pallipes* in South Tyrol: heritage species and bioindicator. Bulletin Francais de la Pêche et de la Pisciculture, 370-371: 81-96.

Füreder, L., Schwarzenberger, R., 2001. Tristacher Seebach Projektbetreuung zur Schaffung von flusskrebsgerechten Strukturen. Wiederansiedlung von Edelkrebsen. – Universität Innsbruck, Institut für Zoologie und Limnologie (unpubl. report).

Füreder, L., Vacha, C., Amprosi, K., Bühler, S., Hansen, C.M.E., Moritz, C., 2002a. Reference conditions of alpine streams: Physical habitat and ecology. Water, Air & Soil Pollution, Focus 2, 275-294.

Füreder, L., Oberkofler, B., Machino, Y., 2002b. Flusskrebse in den Gewässern Südtirols: Verbreitung, ökologische Bedeutung und Gefährdung. Berichte d. naturwissenschaftlich-medizinischen Vereins Innsbruck 89, 179-200.

Füreder, L., Oberkofler, B., Hanel, R., Machino, Y 2002c. Freshwater crayfish in South Tyrol (Italy): distribution and protection measures of endangered *Austropotamobius pallipes*. Bulletin Francais de la Pêche et de la Pisciculture, 367, 651-662.

Gherardi, F., Holdich, D.M., 1999. Crayfish in Europe as alien species. How to make the best of a bad situation. Crustacean Issues 11, A.A. Balkema, Rotterdam, Brookfield, pp. 1-299.

Gherardi, F., Baldaccini, G.N., Ercolini, P., Barbaresi, S., De Luise, G., Mazzoni, D., Mori, M., 1999. The situation in Italy. In: Gherardi, F., Holdich, D.M. (eds). Crayfish in Europe as alien species. How to make the best of a bad situation. Crustacean Issues 11, A.A. Balkema, Rotterdam, Brookfield, pp. 107-128.

Gil-Sánchez, J.M., Alba-Tercedor, J., 2002. Ecology of the native and introduced crayfishes *Austropotamobius pallipes* and *Procambarus clarkii* in southern Spain and implications for conservation of the native species. Biological Conservation 105, 75-80.

Hellrigl, K., Thaler, B., 1996. Klasse Krebstiere Crustacea. In: Hellrigl, K., (ed), Veröffentlichungen des Naturmuseums Südtirol, Bozen/Bolzano, Band 1: Die Tierwelt Südtirols, pp. 250-261.

Holdich, D.M., 2001. Biology of freshwater crayfish. Blackwell Science, Oxford, pp. 1-702 (+51 colour plates).

Holdich, D.M., 2002. Distribution of crayfish in Europe and some adjoining countries. Bulletin Francais de la Pêche et de la Pisciculture 367, 611-650.
Holdich, D.M., Rogers, W.D., 1997 The white-clawed crayfish, *Austropotamobius pallipes*, in Great Brittain and Ireland with particular reference to its conservation in Great Brittain. Bulletin Francais de la Pêche et de la Pisciculture 347, 597-616.
Matthews, M.A., Reynolds, J.D., 1995. A population study of the white-clawed crayfish *Austropotamobius pallipes* (Lereboullet) in an Irish reservoir. Biology and Environment: Proceedings of the Royal Irish Academy 95B, 99-109.
McAllister, D.E., Hamilton, A.L., Harvey, B., 1997 Global freshwater biodiversity: Striving for the integrity of freshwater ecosystems. Sea Wind 11, 1-140.
Mickasch, T.M., 1999. Distribution of *Austropotamobius pallipes* and *Orconectes limosus* in the Swiss Midlands. In: Keller, M., Keller, M.M., Oidtmann, B., Hoffmann, R., Vogt, G., (Eds.). Freshwater Crayfish 12, Weltbild Verlag, Augsburg, pp. 796-800.
Moog, O., Chovanec, A., 2000. Assessing the Ecological Integrity of Rivers: Walking the line among ecological, political and administrative interests. In: Jungwirth, M., Muhar, S., Schmutz, S. (eds), Assessing the Ecological Integrity of Running waters, Hydrobiologia 422/423, pp. 99-109.
Muhar, S., Schwarz, M., Schmutz, S., Jungwirth, M., 2000. Identification of rivers with high and good habitat quality: methodological approach and application in Austria. Pages 343-358 in Jungwirth M., Muhar S., Schmutz S. (eds): Assessing the ecological integrity of runnung waters. Developments in Hydrobiology. Hydrobiologia 422/423.
Müller, F., 1997 Die Eyrser Auen – einer der letzten Reste der ursprünglichen Talbodenlandschaften im Vinschgau. Der Schlern 71, 34-75.
Oberkofler, B.M., 2000. Vorkommen und Verbreitung von Flusskrebsen (Astacidae, Decapoda) in den Gewässern Südtirols. – Diplomarbeit, Insitut f. Zoologie u. Limnologie, Universität Innsbruck: 1-95 (+Anhang).
Oberkofler, B., Machino, Y., Füreder, L., 2002. Occurrence of the noble crayfish (*Astacus astacus*) in Italy. Berichte d. naturwissenschaftlich-medizinischen Vereins Innsbruck 89, 201-210.
ÖNORM M 6232, 1995. Austrian Standards M 6232 - Guidelines for the ecological survey and evaluation of flowing surface waters. – Österreichisches Normungsinstitut, Vienna, pp. 1-38.
Pretzmann, G., 1994. Rote Liste der Zehnfüßigen Krebse (Decapoda) und Schwebegarnelen (Mysidacea) Österreichs. In: Gepp, J. (ed), Rote Listen gefährdeter Tiere Österreichs. Grüne Reihe, Band 2, Bundesministerium für Umwelt, Jugend und Familie, Wien, pp. 31-34 + 279-282 + 336.
Riccardi, A., Rasmussen, J.B., 1999. Extinction rates of North American freshwater fauna. Conservation Biology 13: 1220-1222.
Schenk, I., Ladurner, F., Wieser, H., 1977 Krebsvorkommen in Südtirol. Tätigkeitsbericht des Biologischen Labors Leifers (Bozen) 1: 149-165 + 1Foto + 1Tafel.
Sint, D., Füreder, L., 2004. Reintroduction of *Astacus astacus* L. in East Tyrol, Austria. – Bull. Fr. Pêche Piscic. 372-373: 301-314.
Sint, D., Dalla Via, J., Füreder, L., 2006. The situation of the genus *Austropotamobius* in the Außerfern Region (Tyrol, Austria) with a population overlap of *A. torrentium* and *A. pallipes*. Bull. Fr. Pêche Piscic.
Skurdal, J., Taugbol, T., 2001. Crayfish of commercial importance. *Astacus*. In: Holdich, D.M., (ed), Biology of freshwater crayfish. Blackwell Science, Oxford, pp. 467-510.

Souty-Grosset, C., Holdich, D.M., Noel, P.Y., Reynolds, J.D., Haffner, P., 2006. Atlas of crayfish in Europe. – Muséum national d'Histoire naturelle, Paris, Patrimoines naturels 64: 187pp.
Skurdal, J., Taugbol, T., 2001. Crayfish of commercial importance. *Astacus*. In: HOLDICH D.M., (Ed.), Biology of freshwater crayfish. Blackwell Science, Oxford, pp. 467-510.
Unterkircher, F., 1967 Das Tiroler Fischereibuch Maximilians I. Verlag Styria, Graz, 2 Bände (Faksimileband: 112 pp+12 Tafeln; Textband: 152 pp).
Vigneux, E., 1997 «Lightning survey» on the astacology of the genus *Austropotamobius* in Europe. Bulletin Francais de la Pêche et de la Pisciculture 347, 589-594.
Williams, J.D., Warren, M.L.Jr., Cummings, K.S., Harris, J.L., Neves, R.J., 1993. Conservation status of freshwater mussels of the United States and Canada. Fisheries 18, 6-22.

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