Pacifastacus leniusculus **System:** Freshwater

Kingdom	Phylum	Class	Order	Family
Animalia	Arthropoda	Malacostraca	Decapoda	Astacidae

Common name Pacific crayfish (English), Californian crayfish (English), signal crayfish (English)

Synonym *Astacus leniusculus* , Dana, 1852
Potamobius leniusculus , Ortmann, 1902
Pacifastacus leniusculus , Bott, 1950

Similar species *Astacus astacus*

Summary Pacifastacus leniusculus is a large, hardy cool temperate freshwater crayfish that is found in rivers and lakes. It is endemic to northwestern USA and southwestern Canada, from where it was introduced into more southerly states, as well as into Europe and Japan. Pacifastacus leniusculus is an aggressive competitor and has been responsible for displacing indigenous crayfish species wherever it has been introduced. In addition, it acts as a vector for the crayfish plague fungus, Aphanomyces astaci, to which all non-North American crayfish are susceptible, but to which it is relatively immune. Pacifastacus leniusculus is a large, relatively fast-growing species with high fecundity. Consequently, it has proved a good aquacultural species and supports capture fisheries in the western USA and Europe, particularly in Finland and Sweden.

view this species on IUCN Red List

Species Description
The cephalothorax is smooth with two pairs of post-orbital ridges, the anterior pair with an apical spine; and no spines on shoulders of the carapace behind cervical groove; the areola between branchiocardiac grooves is obvious. The rostrum sides are smooth and more or less parallel until the apex; the acumen is very pointed with prominent shoulders; and a simple median carina down whole length. Its claws are robust and smooth on both surfaces, the underside is red in colour; with a single tubercle on the inner side of the fixed finger; and a white-turquoise patch on top of the junction of fixed and moveable fingers; adult males are massive either lengthways or in width. Males are up to 16cm in length from tip of rostrum to end of telson, females up to 12cm; much larger individuals have been recorded, i.e. 95mm carapace length. The weight is typically 60 and 110g at 50 and 70mm carapace length. Its colour bluish-brown to reddish-brown, occasionally light- to dark-brown (David Holdich., pers. comm., 2005).

Lifecycle Stages
Pacifastacus leniusculus has a typical life cycle of a member of the crayfish family Astacidae, and which is therefore very similar to that of indigenous European crayfish. The eggs hatch into miniature crayfish that stay with the mother for three stages, the third stage gradually becoming more and more independent of the mother. Juveniles undergo as many as 11 moults during their first year, but by age 3 this is reduced to two moults per year, and by age 4 onwards to one moult per year (Lewis, 2002).

Uses
Commercially harvested in the western USA, mainly in Washington and Oregon States, although a larger harvest is obtained from the introduced population in the Sacramento River (Lewis, 2002). It was originally hoped that stocking *P. leniusculus* into European waters would revive catches of crayfish to their pre-plague levels, particularly in Sweden and Finland (Skurdal *et al.* 1999), this has not proved to be the case. In Sweden the catch in 1996 was 265 tonnes (compared to 52 for *A. astacus*) and that cultured amounted to 42 tonnes (compared to 12 for *A. astacus*). The catch of *P. leniusculus* in Finland in 2001 was 22 tonnes (compared to 57.5 for *A. astacus*). However, the Finnish catch of *P. leniusculus* is increasing and is estimated to double every 1-2 years. In 2004 it exceeded 50% of the catch (Erkamo *et al.* 2004). *P. leniusculus* fetches approximately half the price as *A. astacus* in Finland and Sweden. The introduced species has done better in southern Sweden than in the north and in Finland, and this may be a consequence of the cool climatic conditions in the latter two regions (Henttonen & Huner, 1999). In Europe as a whole in 1994 a total of 355 tonnes of *P. leniusculus* originated from capture fisheries and 51 tonnes from culture. This represents only 9% of European capture fisheries and 32.5% of culture fisheries (Ackefors, 1998, 1999).

Habitat Description
Pacifastacus leniusculus occupies a wide range of habitats from small streams to large rivers (e.g. Columbia River) and natural lakes, including sub-alpine lakes, such as Lakes Tahoe and Donner (Lowery & Holdich, 1988; Lewis, 2002). However, it also grows well in culture ponds. It is tolerant of brackish water and high temperatures. It does not occur in waters with a pH lower than 6.0. *P. leniusculus* is very active and migrates up and down rivers, as well as moving overland around obstacles. However, their rate of colonisation is relatively slow and may only be about 1 km yr-1. In one stream in England it took 17 years for them to spread 12 km downstream (Stanton, 2004). Their burrows can reach high densities, i.e.14 m-1, and they can have a serious impact on bank morphology, causing them to collapse. It was considered to be a non-burrowing species, but in Europe in constructs burrows under rocks or in river and lake banks (Guan, 1994; Sibley, 2000).

Reproduction
The breeding cycle is typical of a cool temperate zone species, although *P. leniusculus* grows faster and reaches a greater size than its counterparts. Size at maturity is usually 6-9cm TL at an age of 2-3 years, although maturity can occur as early as 1 year. Mating and egg laying occurs during October in the vast majority of populations. Egg incubation time ranges from 166 to 280 days. In natural populations hatching occurs from late March to the end of July depending on latitude and temperature. Egg numbers usually range from 200 to 400, although some individuals of 66mm CL have been reported as having over 500 eggs. Based on the use of the lipofuschin technique it has been estimated that some individuals can live 16 years, and other estimates state that it may be as long as 20 years. Some individuals may grow to a large size, i.e. 95mm CL, but this may not represent a great age, but that of a fast-growing newly introduced population that encounters little competition. Estimates of survivorship to age 2 vary from 10-52%, being dependent on both abiotic and biotic factors. Competition and cannibalism can greatly affect survival in dense populations. Stebbing *et al.* (2003) demonstrated for the first time the presence of a sex pheromone, released during the breeding season by mature females, that stimulates courtship and mating behaviour in male *P. leniusculus*.

Nutrition
As an opportunistic polytrophic feeder, *P. leniusculus* will eat anything that is available, including other crayfish. The diet was found to shift from aquatic insects in juveniles, to more plant material in adults in some American populations (Lewis, 2002). However, Guan & Wiles (1997) found that cannibalism increased with size and that more animal than plant material was consumed by adults in a British river.

General Impacts
Pacifastacus leniusculus displays opportunistic polytrophic feeding habits, although more animal than plant material may be consumed if available. It can have a considerable impact on populations of macro-invertebrates, benthic fish, and aquatic plants (Guan & Wiles 1997; Nyström, 1999; Lewis, 2002), it also has been used to clear weed from ponds on fish farms. Griffiths *et al.* (2004) found that the presence of *P. leniusculus* significantly reduced the number of Atlantic salmon using shelters in artificial test arenas. Sooty crayfish (see *Pacifastacus nigrescens* in IUCN Red List of Threatened Species), a native to the western USA, has become extinct partly due to interspecific competition with *P. leniusculus*, which was introduced into its range. *P. leniusculus* has also been implicated in causing a reduction in the range of the already narrowly endemic shasta crayfish (see *Pacifastacus fortis* in IUCN Red List of Threatened Species) in the western America (Taylor, 2002).
P. leniusculus was introduced into Japan from Portland, Oregon five times during 1926 to 1930, where it has reduced the range of the indigenous *Cambaroides japonicus* on the island of Hokkaido (Hiruta, 1996; Kawai & Hiruta, 1999). It has also been found in some lakes on Honshu (Hiruta, S., 2005, pers. Comm.). In Europe, it has extirpated populations of the indigenous crayfish species, particularly the white-clawed crayfish (see *Austropotamobius pallipes* in IUCN Red List of Threatened Species in England (Holdich, 1999; Hiley, 2003). However, in Finland it coexisted with the noble crayfish, (see *Astacus astacus* in IUCN Red List of Threatened Species), in a lake for 30 years, before reproductive interference led to the demise of the latter species (Westman *et al.* 2002). Its main impact has been as a vector of the crayfish plague fungus, *Aphanomyces astaci*, which has caused large-scale mortalities amongst indigenous European crayfish populations, particularly in England (Alderman, 1996). The disease has recently been confirmed in *P. leniusculus* from western Hungary, which could have serious implications for indigenous crayfish in the Danube catchment (Kiszely, 2004).

Management Info
There are no documented control agents for the successful management of *P. leniusculus* available at this time (Holdich *et al.* 1999). Trapping is size selective and the smaller individuals remaining take advantage of the lack of competition to grow rapidly (Sibley, 2000). Preventing the further introduction of this species into new bodies of water is one of the few options available. Educating the public to the environmental risks this species pose and identifying new populations are key elements to stopping the spread of this species where it is not wanted. Stebbing *et al*. (2003, 2004) have researched into the possibilities of using pheromones to attract male *P.leniusculus* into traps. Stringent legislation has been applied to *P. leniusculus* in Britain, which effectively makes it a 'pest' and bans the keeping of it in Scotland and Wales and much of England (Holdich *et al.* 2004). Despite this *P. leniusculus* continues to spread and may well cause the extinction of the single indigenous crayfish species within 30 years (Hiley, 2003; Sibley, 2003). Work is in progress in the UK to assess the use of natural pyrethrum again nuisance populations of *P. leniusculus* in enclosed waterbodies (Peay, 2005).

Pathway
P. leniusculus was first introduced into Japan from North America for use as food in 1928 (Kawai *et al.* 2002b).

Principal source:

Compiler: National Biological Information Infrastructure (NBII) & IUCN/SSC Invasive Species Specialist Group (ISSG)

Review: Dr D. M. Holdich, EMEC Ecology, England.
\ Dr M. P�ckl, Institute of Ecology and Conservation Biology, Department of Limnology, University of Vien Austria

Pubblication date: 2005-04-26

ALIEN RANGE

[1] AUSTRIA
[1] FRANCE
[1] SWEDEN
[4] FINLAND
[6] JAPAN
[10] UNITED KINGDOM

Red List assessed species 6: EX = 1; EN = 1; VU = 1; DD = 2; LC = 1;

Astacus astacus **VU**
Austropotamobius pallipes **EN**
Cambaroides japonicus **DD**
Astacus leptodactylus **LC**
Austropotamobius torrentium **DD**
Pacifastacus nigrescens **EX**

BIBLIOGRAPHY

53 references found for **Pacifastacus leniusculus**

Managment information
Ackefors, H. G. 2000. Freshwater crayfish farming technology in the 1990s: A European and global perspective. Fish and Fisheries 1: 337-359.
Summary: Information on description, economic importance, distribution, habitat, history, growth, and impacts and management of species.
Centre for Environment, Fisheries & Aquaculture Science (CEFAS)., 2008. Decision support tools-Identifying potentially invasive non-native marine and freshwater species: fish, invertebrates, amphibians.
Summary: The electronic tool kits made available on the Cefas page for free download are Crown Copyright (2007-2008). As such, these are freeware and may be freely distributed provided this notice is retained. No warranty, expressed or implied, is made and users should satisfy themselves as to the applicability of the results in any given circumstance. Toolkits available include 1) FISK- Freshwater Fish Invasiveness Scoring Kit (English and Spanish language version); 2) MFISK- Marine Fish Invasiveness Scoring Kit; 3) MI-ISK- Marine invertebrate Invasiveness Scoring Kit; 4) FI-ISK- Freshwater Invertebrate Invasiveness Scoring Kit and AmphISK- Amphibian Invasiveness Scoring Kit. These tool kits were developed by Cefas, with new VisualBasic and computational programming by Lorenzo Vilizzi, David Cooper, Andy South and Gordon H. Copp, based on VisualBasic code in the original Weed Risk Assessment (WRA) tool kit of P.C. Pheloung, P.A. Williams & S.R. Halloy (1999).
The decision support tools are available from:
http://cefas.defra.gov.uk/our-science/ecosystems-and-biodiversity/non-native-species/decision-support-tools.aspx [Accessed 13 October 2011]
The guidance document is available from http://www.cefas.co.uk/media/118009/fisk_guide_v2.pdf [Accessed 13 January 2009].
FRS Freshwater Laboratory. UNDATED. *Signal crayfish - an unwelcome addition to Scottish streams.*
Gherardi, F. & Holdich, D. M. (eds) 1999. Crayfish in Europe as alien species - how to make the best of a bad situation? Crustacean Issues 11. A. A. Balkema, Rotterdam: 299 p.
Guan, R-Z. 1994. Burrowing behaviour of signal crayfish, *Pacifastacus leniusculus* (Dana), in the River Great Ouse, England. Freshwater Forum 4: 155-168
Guan, R-Z. & Wiles, P. R. 1997. Ecological impact of introduced crayfish on benthic fishes in a British lowland river. Conservation Biology 11(3): 641-647.
Hewitt, C.L, Campbell, M.L. and Gollasch, S. 2006. Alien Species in Aquaculture. Considerations for responsible use. IUCN, Gland, Switzerland and Cambridge, UK. viii + 32 pp.
Summary: This publication aims to first provide decision makers and managers with information on the existing international and regional regulations that address the use of alien species in aquaculture, either directly or indirectly; and three examples of national responses to this issue (New Zealand, Australia and Chile).
Available from: http://data.iucn.org/dbtw-wpd/edocs/2006-036.pdf [Accessed 22 September 2008]
Hiley, P. D. 2003. The slow quiet invasion of signal crayfish (*Pacifastacus leniusculus*) in England – prospects for the white-clawed crayfish (*Austropotamobius pallipes*), in Holdich D. M. & Sibley, P. J. (Eds), Management & Conservation of Crayfish. Proceedings of a conference held in Nottingham on 7th November, 2002. Environment Agency, Bristol: 127-138.
Holdich, D. M. 1999. The negative effects of established crayfish populations. In Gherardi, F. and Holdich, D.M. (eds.) *Crustacean Issues 11: Crayfish in Europe as Alien Species (How to make the best of a bad situation?)* A.A. Balkema, Rotterdam, Netherlands: 31-48.
Summary: This chapter gives a good overview of the negative effects of crayfish populations on the environment. Global case studies are documented and general management solutions are mentioned.
Holdich, D. M., Gydemo, R. and Rogers, W.D. 1999. A review of possible methods for controlling nuisance populations of alien crayfish. In Gherardi, F. and Holdich, D.M. (eds.) *Crustacean Issues 11: Crayfish in Europe as Alien Species (How to make the best of a bad situation?)* A.A. Balkema, Rotterdam, Netherlands: 245-270.
Summary: This chapter gives an informative overview of methods of controlling crayfish, with an overview of the advantages and disavdantages of different methods and a good review of recent research.
Kirjavainen, J. and Sipponen, M. 2004. Environmental Benefit of Different Crayfish Management Strategies in Finland, *Fisheries Management and Ecology 11*: 213 - 218.
Summary: This article includes historical information about the introduction of *P. leniusculus* into Finland and some of its environmental effects (eg: transmission of the crayfish fungus plague). It focuses on interspecific competition between the Noble crayfish (*Astacus astacus*) (native in Europe, including Scandinavia, and considered vulnerable by the IUCN, 1996). Mentions Finland s role as Europe s largest commercial producer of *A. astacus*.
Nakata, K. and Goshima, S. 2003. Competition for Shelter of Preferred Sizes Between the Native Crayfish Species *Cambaroides japonicus* and the Alien Crayfish Species Size, Journal of Crustacean Biology 23 (4): 897 - 907.
Summary: Outlines the interspecific competition between *P. leniusculus* and *C. japonicus* for available shelters.
Peay, S. 2005. Drastic action. Crayfish NEWS 27 (1): 5.

Pockl, M. and Pekney, R. 2002. Interaction between native and Alien Species of Crayfish in Austria: Case Studies [Abstract], Bulletin Francais de la Peche et de la Pisciculture 367:763 - 776.
Summary: History of introduction and distribution of *P. leniusculus* in Austria.
Stebbing, P.D. , Watson, G.J., Bentley, M.G., Fraser, D., Jennings, R., Rushton, S.P., Sibley, P.J. 2003. Reducing the Threat: the Potential use of Pheromones to Control Invasive Signal Crayfish[Abstract], Bulletin Francais de la Peche et de la Pisciculture 370-371.
Summary: The potential application of the pheromones in controlling *P. leniusculus* populations.
Stebbing, P. D., Watson, G. J., Bentley, M. G., Fraser, D., Jennings, R. & Sibley, P. J. 2005. Evaluation of the capacity of pheromones for control of invasive non-native crayfish: part 2. English Nature Research Report No. 633. English Nature, Peterborough: 46 p.
Westman, K. 2002. Alien crayfish in Europe: negative and positive impacts and interactions with native crayfish, in Lepp&#xfffd;koski, E., Gollasch, S. & Olenin, S. (Eds), Invasive aquatic species of Europe. Distribution, impacts and management. Kluwer Academic Publishers, Dordrecht, Boston, London: 76-95.
Westman, K., Savolainen, R. & Julkunen, M. 2002. Replacement of the native crayfish *Astacus astacus* by the introduced speceis *Pacifastacus leniusculus* in a small, enclosed Finnish lake: a 30-year study. Ecography 25: 53-73.

General information
Ackefors, H. 1999. The positive effects of established crayfish introductions in Europe. In Gherardi, F. and Holdich, D.M. (eds.) *Crustacean Issues 11: Crayfish in Europe as Alien Species (How to make the best of a bad situation?)* A.A. Balkema, Rotterdam, Netherlands: 49-62.
Summary: This chapter overviews the commercial benefits gained from crayfish harvestinjg in Europe.
Alderman, D. J. 1996. Geographical spread of bacterial and fungal diseases of crustaceans. Reviews Science and Technology Office International Epizooitology 15: 603-632.
Alderman, D. J., Holdich, D. M. & Reeve, I. D. 1990. Signal crayfish acting as vectors in crayfish plague in Britain. Aquaculture 86: 3-6.
BBC News. 2003. *North American signal crayfish has now been found in northern England, the last stronghold of Britain s native white-clawed crayfish, already extirpated from most of southern England by the larger, more aggressive invader, pollution and habitat loss.* November 17, 2003.
Changeux, T. 2003. *Technical note: Changes in crayfish distribution in Metropolitan France according to the national surveys performed by the Conseil sup&#xfffd;rieur de la p&#xfffd;che from 1977 to 2001*. Bull. Fr. P&#xfffd;che Piscic., 2003, 370-371: 17-41
Summary: A review of the success of management strategies and the status of *P. leniusculus* in France.
Erkamo, E., Järvenpää, T., Mannonen, A. & Tulonen, J. 2004. Ravut - Kräftor, in Kalavarat 2004. SVT Maa-, metsä- ja kalatalous 60: 67-71
Global Biodiversity Information Facility (GBIF), 2010. *Pacifastacus leniusculus*.
Summary: Available from: http://www.gbif.net/species/13828545/ [Accessed 15 June 2010]
Griffiths, S.W., Collen, P. and Armstrong, J.D. 2004. Competition for Shelter Among Over-wintering Signal Crayfish and Juvenile Atlantic Salmon, *Journal of Fish Biology 65*: 436 - 447.
Summary: Study on the effects of interspecific competition between *P. leniusculus* and Atlantic salmon for refuges on salmon densities.
Henttonen, P. & Huner, J. V. 1999. The introduction of alien species of crayfish in Europe: a historical introduction, in Gherardi, F. & Holdich, D. M. (Eds), Crayfish in Europe as alien species. How to make the best of a bad situation. A. A. Balkema, Rotterdam: 13-22.
Hiruta S. 1996. The presence of signal crayfish in Hokkaida, Japan. Crayfish NEWS 19 (1): 12.
Holdich, D. M. 2002. Present distribution of crayfish in Europe and some adjoining countries. Bulletin Fran&#xfffd;ais de la P&#xfffd;che et de la Pisciculture 367: 611-650
Holdich, D. M., Sibley, P. J. & Peay, S. The white-clawed crayfish &#xfffd; a decade on. British Wildlife 15 (3):153-164.
ITIS (Integrated Taxonomic Information System), 2005. Online Database *Pacifastacus leniusculus*.
Summary: An online database that provides taxonomic information, common names, synonyms and geographical jurisdiction of a species. In addition links are provided to retrieve biological records and collection information from the Global Biodiversity Information Facility (GBIF) Data Portal and bioscience articles from BioOne journals.
Available from: http://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=97326 [Accessed 25 February 2008]
Kawai, T. & Hiruta, M. 1999. Distribution of crayfish (*Pacifastacus leniusculus* and *Cambaroides japonicus*) in Lake Shikaribetsu and Shihoro, Hokkaido, Japan. Crayfish NEWS 21 (3): 11.
Kiszely, P. 2004. Signal crayfish in Hungary &#xfffd; a vector of *Aphanomyces* &#xfffd; doomed future for *Astacus* in the Danube catchment area. Crayfish NEWS 26 (4) 6-7.
Lewis, S. D. 2002. *Pacifastacus*, in Holdich, D. M. (Ed.), Biology of freshwater crayfish. Blackwell Science, Oxford: 511-540
Lilley, J. H., Cerenius, L. & S&#xfffd;der&#xfffd;ll, K. 1997. RAPD evidence for the origin of crayfish plague outbreaks in Britain. Aquaculture 157: 181-185.
Lowery, R. S. & Holdich, D. M. 1988. *Pacifastacus leniusculus* in North America and Europe, with details of the distribution of introduced and native crayfish species in Europe, in Holdich, D. M. & Lowery, R. S. (Eds), Freshwater crayfish: biology, management and exploitation. Croom Helm, London: 283-308.
Machino, Y. & Holdich, D. M. 2005. Distribution of crayfish in Europe and adjacent countries: updates and comments. Freshwater Crayfish 15: (in press).
Nakata, K., Hamano, T., Hayashi, K. and Kawai, T. 2002. Lethal Limits of High Temperature for two Crayfishes, the Native Species *Cambaroides japonicus* and the Alien Species *Pacifastacus leniusculus* in Japan, *Fisheries Science 68*(4): 763 - 767.
Summary: A comparison of temperature tolerance of *P. leniusculus* and *C. japonicus*.
Nakata, K., Tanaka, A. and Goshima, S. 2004. Reproduction of the Alien Crayfish Species *Pacifastacus leniusculus* in Lake Shikaribetsu, Hokkaido, Japan, *Journal of Crustacean Biology 24*(3): 496 - 501
Summary: This article includes historical information about the introduction of *P. leniusculus* into Japan. It mentions the impact of *P. leniusculus* on the native crayfish *Cambaroides japonicus*, which is considered to be endangered according to the Japanese Fisheries Agency (1998) and the Environment Agency (2000).

Nystrom, P. 1999. Ecological impact of introduced and native crayfish on freshwater communities: European perspectives. In Gherardi, F. and Holdich, D.M. (eds.) *Crustacean Issues 11: Crayfish in Europe as Alien Species (How to make the best of a bad situation?)* A.A. Balkema, Rotterdam, Netherlands: 63-85.
Summary: This chapter outlines and compares the possible effects of introduced and European native crayfish on macrophytes, algae, invertebrates, amphibians and fish.
Rogers, W. D. & Holdich, D. M. 1995. Crayfish production in Britain. Freshwater Crayfish 10: 585-596
Rural News. 2004. *Destructive creature found in Tweed*. Countryside.
Sibley, P. 2000. Signal crayfish management in the River Wreake catchment, in rogers, D. & Brickland, J. (Eds), Crayfish Conference Leeds. Environment Agency, Leeds: 95-108.
Sibley, P. J. 2003. The distribution of crayfish in Britain, in Holdich, D. M. & Sibley, P. J. (Eds), Management & Conservation of Crayfish. Proceedings of a conference held in Nottingham on 7th November, 2002. Environment Agency, Bristol: 64-72.
Skurdal, J., Taugb l, T., Burba, A., Edsman, L., S derb ck, B., Styrishave, B., Tuusti, J. & Westman, K. 1999. Crayfish introductions in the Nordic and Baltic countries, in Gherardi, F. & Holdich, D. M. (Eds), Crayfish in Europe as alien species. How to make the best of a bad situation. A. A. Balkema, Rotterdam: 193-219.
Stanton, J. A. 2004. Burrowing behaviour and movements of the signal crayfish. Unpublished PhD. thesis, University of Leicester, UK. 169 p.
Stebbing, P. D., Bentley, M. G. & Watson, G. J. 2003. Mating behaviour and evidence for a female released courtship pheromone in the signal crayfish *Pacifastacus leniusculus*. Journal of Chemical ecology 29 (2): 463-473.
St hr, S. 2002. *The Signal Crayfish, established in Sweden for good or for worse*. Swedish Museum of Natural History.
Summary:
Sv rdson, G. 1995. The early history of signal crayfish introduction into Europe. Freshwater Crayfish 8: 68-76.
Taylor, C. A. 2002. Taxonomy and conservation of native crayfish stocks, in Holdich, D. M. (Ed.), Biology of freshwater crayfish. Blackwell Science, Oxford: 236-257
Usio, N., Konishi, M. and Nakano, S. 2001. Species Displacement Between an Introduced and A vulnerable Crayfish: The Role of Aggressive Interactions and Shelter Competition, *Biological Invasions 3*(2): 179 - 185.
Summary: Inferiority in aggressive interactions and shelter occupancy may be a critical disadvantage for *C. japonicus* if shelters are limited in natural situations.
Vorburger, C., Ribi, G. 1999. Aggression and Competition for Shelter Between a Native and an Introduced Crayfish in Europe, *Freshwater Biology 42*: 111 - 119
Summary: A study on agonistic behaviour between *P. leniusculus* and *A. torrentium* (a crayfish native to Europe). Concludes that although neither species is inherently dominant *P. leniusculus* would still have an advantage because in a natural situation it is the larger and faster growing of the two species.
Westman, K., Savolainen, R. and Julkunen, M. 2002. Replacement of the Native Crayfish *Astacus astacus* by the Introduced Species *Pacifastacus leninsculus* in a Small, Enclosed Finnish Lake: a 30-year Study, *Ecography 25*(1): 53 - 73.
Summary: Examines the occurrence of *Astacus astacus* and *P. leniusculus* in Slicklampi, Finland. Reason for the decline in the population; Reproductive interference between two species; Effect of interspecific mating on eggs.