Chapter 3
Global Diversity and Conservation of Freshwater Crayfish (Crustacea: Decapoda: Astacoidea)

Tadashi Kawai and Keith A. Crandall

Abstract The number of species in the three families of freshwater crayfish worldwide (Astacidae, Cambaridae, and Parastacidae) are updated by region. These are: Astacidae, western North America (5 species) and Europe (5 species), Cambaridae, eastern North America and Mexico (423 species) and Asia (6 species), and Parastacidae, Oceania (153 species), South America (12 species), and Madagascar (7 species). The conservation status of 611 species of crayfish worldwide is discussed, based on global assessments from the IUCN (International Union for Conservation of Nature) Red List protocols as well as regional assessments on governmental endangered species lists. The current threats to endangered species of crayfish include habitat destruction, water diversion, pollution, and threats from exotic species of crayfish (such as *Pacifastacus leniusculus*, *Procambarus clarkii* and *Cherax*) that have been introduced to other parts of the world where they are having an increasing impact. New threats posed by the parthenogenetic marbled crayfish *Procambarus fallax* f. *virginalis* to freshwater ecosystems in Europe and Madagascar are also discussed.

Keywords Alien crayfish · Conservation · Species diversity · IUCN Red List

3.1 Introduction

Freshwater crayfish (Astacoidea) globally comprise three families: the Astacidae and Cambaridae (Astacoidea) in the northern hemisphere, and the Parastacidae (Parastacoidea) in the southern hemisphere. Crayfish belong to the Decapoda, the largest crustacean taxon, and are conspicuous freshwater macroinvertebrates (Holdich 2002). Crayfish are easy to collect (Crandall 2016) and to raise in captivity

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and so over the years have become one of the best-studied crustacean taxa, serving as model organisms in zoology since Victorian times (Stebbing 1893; Huxley 1896). Freshwater crayfish have also long been exploited in inland aquaculture.

The International Association of Astacology founded in Hinterthal, Austria in 1972, has organized biannual international symposia and published the peer-reviewed journal "Freshwater Crayfish", from the 1970s to the 1990s. Significant recent multi-authored publications on crayfish include "Freshwater Crayfish: Biology, Management and Exploitation" (Holdich and Lowery 1988), and "Biology of Freshwater Crayfish" (Holdich 2002), and "Management of Freshwater Geodiversity, Crayfish as Bioindicators" (Reynolds and Souty-Grosset 2013) that all address the increasing need for the sustainable management of crayfish. Other major milestones include molecular studies on the phylogeny and global diversity of crayfish (Crandall and Buhay 2008), and the International Union for Conservation of Nature (IUCN) Red List conservation assessments of every known species of crayfish worldwide (Richman et al. 2015). Here we report on the extinction risks of all crayfish in the world by analyzing the patterns of population changes and threats as a guide for crayfish conservation (Richman et al. 2015). Equally important, we highlight the gaps in knowledge that still exist across all families of crayfish. In addition, the recent multi-authored volume "Freshwater Crayfish: Global Overview" (Kawai et al. 2015) focuses on the threats to all crayfish posed by the spread in several countries of the parthenogenetic marbled crayfish that arose in aquaria in Germany in the 1990s.

This chapter provides the latest information on crayfish biodiversity in every part of their range (eastern North America and Mexico, western North America, Central America, South America, Asia, Oceania, Madagascar, and Europe) as well as describing their conservation status and the major threats. Introduced species of crayfish can have a serious impact on native ecosystems which has been well documented for native European crayfish populations (Holdich 1999). A number of species of North American crayfishes have been introduced to other parts of the world and are spreading rapidly. The current global spread of alien species of crayfish in many parts of the world, and the threats posed by these exotic species, are summarized based on new data (Fig. 3.1).

3.2 Global Diversity

Freshwater crayfish (Astacidea) are distributed in the temperate parts of the northern and southern hemispheres. In North America the Cambaridae range from the eastern part of the continent as far south as Mexico, while the Astacidae (*Pacifastacus*) are found in the western part of the continent west of the Rocky Mountains. In Europe there are five species of astacids (in the genera *Astacus* and *Austropotamobius*), while in eastern Asia there are six species of cambarids (in the genus *Cambaroides*) (Fig. 3.1). The species richness of crayfish is significantly different among geographical regions with North American cambarids forming the

Fig. 3.1 Updated distribution of native species of freshwater Crayfish

most diverse group in the world. For example, North America has 423 species of Cambaridae and 5 species of Astacidae; Asia has 6 species of Cambaridae, Europe has 5 species of Astacidae, South America has 12 species of Parastacidae, Oceania has 153 species of Parastacidae, and Madagascar has 7 species of Parastacidae.

Scholtz (2002) and Vogt (2016, this book Chap. 6) suggest that direct development in freshwater decapods evolved as an adaptation to freshwater by their marine ancestors, and that extended maternal care has been responsible for the high rates of endemism and speciation. Freshwater crayfish have the most sophisticated paternal care between a mother and her offspring of all freshwater decapods. Although there are small differences in physiological and behavioral adaptations among the three families of crayfish from different parts of the world, molecular phylogenetic studies indicate that the group is monophyletic and that all crayfish share a common ancestor that invaded freshwaters only once. Two families of crayfish (Parastacidae and North American Cambaridae) produce an anal thread that connects recently hatched juveniles to the pleopods of the mother, and it is the third stage moult juveniles that become independent, whereas Asian Cambaridae and European Astacidae all lack an anal thread and it is the second stage moult juveniles that become independent. Scholtz and Kawai (2002) interpreted the regional differences in species richness shown by the three families of crayfish in terms of differences in the behavior and morphology of the juveniles. Those authors suggested that it was the more advanced maternal care of Parastacidae and North American Cambaridae that has contributed to their species richness, but they noted

that there were two exceptions. For example, although the Madagascan Parastacidae (7 species) and the South American Parastacidae (13 species) have relatively advanced maternal care both groups have a low species richness.

3.3 Global Distribution and Zoogeography

All species of crayfish live their entire lives in freshwater and are unable to extend their distribution to other aquatic envoronments, but there are three notable exceptions to this: For example, *Astascus leptodactylus*, *Pacifastacus leniusculus*, and *Procambarus clarkii* can tolerate high salinities and occur naturally in brackish water estuaries and salt marshes (Kawai and Takahata 2010; Scholtz 2002). Hobbs (1988) explained the enigmatic distribution of these latter species as a reflection of significant variations in their external body shape, and suggested that some ancestors of crayfish had independently entered and colonized freshwater from marine habitats at different times, and that crayfish were therefore polyphyletic. On the other hand, the molecular phylogeny of the crayfish by Crandall et al. (2000a, b) supports the monophyly of the group. The oldest crayfish fossils date from the Triassic period which implies that this group originated on the single super continent of Pangea (Scholtz 2002; Bracken-Grissom et al. 2014). The supercontinent subsequently split up over time eventually forming the modern continents, with each continental piece carrying with it ancient crayfish populations that then diversified in isolation to produce the present global distribution patterns (Toon et al. 2010).

However, there are two enigmatic distributions that are difficult to explain. First, although the majority of the Cambaridae are found in eastern North America and Mexico, there is a small population in eastern Asia. Second, although the majority of the Astacidae are found in western North America (USA and Canada), there are some species of this family in western Europe (Fig. 3.1). Recent molecular analyses (Crandall et al. 2000a; Ahn et al. 2006; Braband et al. 2006; Owen et al. 2015) pointed out that the Asian Cambaridae and American Cambaridae may be polyphyletic and that the Asian cambarids (*Cambaroides*) may be a primitive stem group of all northern hemisphere crayfish.

3.4 Habitat

Freshwater crayfish live in streams, rivers, lakes, and marshes, and are completely dependent on permanent freshwater their whole lives. If the water levels of their habitat fall, or the stream bed dries up, then crayfish construct a verical burrow down to the water table so that their burrow has layer of water in the botton and

humid air above it (Grow 1981). Fluctuations of water levels in freshwater habitats is commonplace and often seasonal, and construction of burrows is therefore a common adaptative behavior in crayfish (Kawai and Takahata 2010). The ability to dig a vertical burrow into muddy substrata is seen in the European Astacidae (Füreder 2015), North American Astacidae (Koese and Soes 2011), Madagascan Parastacidae (Jones et al. 2007), North American Cambaridae (Hobbs 1942), Asian Cambaridae (Kawai and Takahata 2010), Oceanaian Parastacidae (Riek 1969), and South American Parastacidae (Rudolph and Almerão 2015).

Constructing burrows is a trait that is also seen in marine lobsters (e.g., *Homarus americanus*) which are a sister group to the crayfish, as well as in the marine mantis shrimp *Oratosquilla oratoria* (Matsuura and Hamano 1984; Scholtz 2002). The oldest fossil burrows of crayfish are from freshwater depositis dating back to the Triassic or Jurassic (Hasiotis and Kirkland 1997; Hasiotis and Thomas 1997), which indicates that the ancestors of crayfish may well have constructed burrows (Kawai and Takahata 2010).

3.5 Regional Diversity, Distribution, and Conservation

3.5.1 Eastern North America and Mexico

3.5.1.1 Taxonomy and Population Levels

Eastern North America and Mexico has the most diverse crayfish fauna in the world and new species are still being described (Crandall and Buhay 2008) (Table 3.1). This region harbours 371 species in 11 genera and one family (Cambaridae), with three genera, *Cambarus*, *Orconectes*, and *Procambarus* that account for over 80 % of all camabarid species.

The IUCN Red List conservation status assessments identify species that are under the greatest risk of extinction, as well as providing critical information on each species including data on distribution and their ecology, population trends, and genetics (Rodrigues et al. 2006). The IUCN Red List uses detailed quantitative criteria to assign species to nine categories (Least Concern, Near Threatened, Vulnerable, Endangered, Critically Endangered, Extinct in the Wild, and Extinct, Data Deficient, and Not Evaluated) based on biological indicators of population levels such as rapid population declines, small population sizes, and the degree of threat. The Least Concern and Near Threatened categories indicate species that are presently doing well, while the threatened categories (VU, EN, CR) indicate that there is a significant risk of extinction (IUCN 2013). Species in Table 3.1 are marked by 2 "Endangered" which indicates that they have been petitioned for listing as endangered species based on regional criteria from governmental agencies such as the U.S. Fish and Wildlife Service (Thoma 2015). This list does not include

Table 3.1 Taxonomy and assessment information of Eastern North America and Mexico

Scientific name	IUCN Red List criteria	Regional criteria	English name
Barbicambarus cornutus (Faxon) 1884	Least concern		Bottlebrush Crayfish
Barbicambarus simmonsi Taylor and Schuster, 2010			
Bouchardina robisoni Hobbs, 1977	Data deficient		Bayou Bodcau Crayfish
Cambarellus blacki Hobbs, 1980	Data deficient		Cypress Crayfish
Cambarellus diminutus Hobbs, 1945	Data deficient		Least Crayfish
Cambarellus lesliei Fitzpatrick and Laning, 1976	Least concern		Angular Dwarf Crawfish
Cambarellus ninae Hobbs, 1950	Least concern		Aransas Dwarf Crawfish
Cambarellus puer Hobbs, 1945	Least concern		Swamp Dwarf Crayfish
Cambarellus schmitti Hobbs, 1942	Data deficient		Fontal Dwarf Crayfish
Cambarellus shufeldtii (Faxon, 1884)	Least concern		Cajun Dwarf Crayfish
Cambarellus texanus Albaugh and Black, 1973	Least concern		Brazos Dwarf Crayfish
Cambarus acanthura Hobbs, 1981			
Cambarus aculabrum Hobbs and Brown, 1987	Least concern	Endangered	
Cambarus acuminatus Faxon, 1884	Critically endangered		Benton County Cave Crayfish
Cambarus aldermanorum Cooper, 2010	Least concern		Acuminate Crayfish
Cambarus angularis Hobbs and Bouchard, 1994	Least concern		Angled Crayfish
Cambarus asperimanus Faxon, 1914	Least concern		Mitten Crayfish
Cambarus bartonii (Fabricius, 1798)	Least concern		Appalachian Brook Crayfish
Cambarus batchi Schuster, 1976	Least concern		Bluegrass Crayfish
Cambarus bouchardi Hobbs, 1970	Near threatened		Big South Fork Crayfish
Cambarus brachydactylus Hobbs, 1953	Data deficient		Shortfinger Crayfish
Cambarus brimleyorum Cooper, 2006	Data deficient		Valley River Crayfish
Cambarus buntingi Bouchard, 1973	Least concern		Longclaw Crayfish
Cambarus carinirostris Hay, 1914	Least concern		Rock Crayfish
Cambarus catagius Hobbs and Perkins, 1967	Data deficient		Greensboro Burrowing Crayfish
Cambarus causeyi Reimer, 1966	Least concern		Boston Mountains Crayfish
Cambarus chasmodactylus James, 1966	Least concern		New River Crayfish
Cambarus chaugaensis Prins and Hobbs, 1969	Least concern		Chauga River Crayfish
Cambarus clivosus Taylor, Soucek and Organ, 2006	Vulnerable		Short Mountain Crayfish

(continued)

Table 3.1 (continued)

Scientific name	IUCN Red List criteria	Regional criteria	English name
Cambarus conasaugaensis Hobbs and Hobbs, 1962	Data deficient		Mountain Crayfish
Cambarus coosae Hobbs, 1981	Least concern		Coosa Crayfish
Cambarus coosawattae Hobbs, 1981	Near threatened		Coosawattee Crayfish
Cambarus cracens Bouchard and Hobbs, 1976	Endangered		Slenderclaw Crayfish
Cambarus crinipes Bouchard, 1973	Least concern		Hairyfoot Crayfish
Cambarus cryptodytes Hobbs, 1941	Least concern		Dougherty Plain Cave Crayfish
Cambarus cumberlandensis Hobbs and Bouchard, 1973	Least concern		Cumberland Crayfish
Cambarus cymatilis Hobbs, 1970	Endangered		Conasauga Blue Burrower
Cambarus davidi Cooper, 2000	Least concern		Carolina Ladle Crayfish
Cambarus deweesae Bouchard and Etnier, 1979	Least concern		Valley Flame Crayfish
Cambarus diogenes Girard, 1852	Least concern		Devil Crawfish
Cambarus distans Rhoades, 1944	Least concern		Boxclaw Crayfish
Cambarus doughertyensis Cooper and Skelton, 2003	Data deficient		Dougherty Burrowing Crayfish
Cambarus dubius Faxon, 1884	Least concern		Upland Burrowing Crayfish
Cambarus eeseeohensis Thoma, 2005	Vulnerable		Grandfather Mountain Crayfish
Cambarus elkensis Jezerinac and Stocker, 1993	Vulnerable		Elk River Crayfish
Cambarus englishi Hobbs and Hall, 1972	Least concern		Tallapoosa Crayfish
Cambarus extraneus Hagen, 1870	Data deficient		Chickamauga Crayfish
Cambarus fasciatus Hobbs, 1981	Data deficient		Etowah Crayfish
Cambarus friaufi Hobbs, 1953	Least concern		
Cambarus gentryi Hobbs, 1970	Least concern		Linear Cobalt Crayfish
Cambarus georgiae Hobbs, 1981	Least concern		Little Tennessee River Crayfish
Cambarus girardianus Faxon, 1884	Least concern		Tanback Crayfish
Cambarus graysoni Faxon, 1914	Least concern		Twospot Crayfish
Cambarus halli Hobbs, 1968	Least concern		Slackwater Crayfish
Cambarus hamulatus (Cope, 1881)	Least CONCERN		Prickly Cave Crayfish
Cambarus harti Hobbs, 1981	Endangered		Piedmont Blue Burrower
Cambarus hatfieldi Loughman, 2013			
Cambarus hiwasseensis Hobbs, 1981	Least concern		Hiwassee Crayfish
Cambarus hobbsorum Cooper, 2001	Least concern		Rocky River Crayfish
Cambarus howardi Hobbs and Hall, 1969	Least concern		Chattahoochee Crayfish

(continued)

Table 3.1 (continued)

Scientific name	IUCN Red List criteria	Regional criteria	English name
Cambarus hubbsi Creaser, 1931	Least concern		
Cambarus hubrichti Hobbs, 1952	Data deficient		Salem Cave Crayfish
Cambarus hystricosus Cooper and Cooper, 2003	Least concern		Sandhills Spiny Crayfish
Cambarus jezerinaci Thoma, 2000	Data deficient		Spiny Scale Crayfish
Cambarus johni Cooper, 2006	Least concern		Carolina Foothills Crayfish
Cambarus jonesi Hobbs and Barr, 1960	Vulnerable		Alabama Cave Crayfish
Cambarus laconensis Buhay and Crandall, 2009	Critically endangered		Lacon Exit Cave Crayfish
Cambarus latimanus (LeConte, 1856)	Least concern		Variable Crayfish
Cambarus lenati Cooper, 2000	Near threatened		Broad River Stream Crayfish
Cambarus longirostris Faxon, 1885	Least concern		Longnose Crayfish
Cambarus longulus Girard, 1852	Least concern		Atlantic Slope Crayfish
Cambarus ludovicianus Faxon, 1884	Least concern		Painted Devil Crayfish
Cambarus maculatus Hobbs and Pflieger, 1988	Least concern		Freckled Crayfish
Cambarus manningi Hobbs, 1981	Least concern		Greensaddle Crayfish
Cambarus miltus Fitzpatrick, 1978	Least concern		Rusty Grave Digger
Cambarus monongalensis Ortmann, 1905	Least concern		Monongahela Crayfish
Cambarus nerterius Hobbs, 1964	Near threatened		Greenbrier Cave Crayfish
Cambarus nodosus Bouchard and Hobbs, 1976	Least concern		Knotty Burrowing Crayfish
Cambarus obeyensis Hobbs and Shoup, 1947	Critically endangered		Obey Crayfish
Cambarus obstipus Hall, 1959	Least concern		Sloped Crayfish
Cambarus ortmanni Williamson, 1907	Least concern		Ortmann's Mudbug
Cambarus parrishi Hobbs, 1981	Data deficient		Hiwassee Headwaters Crayfish
Cambarus parvoculus Hobbs and Shoup, 1947	Least concern		Mountain Midget Crayfish
Cambarus pecki Hobbs, 1967	Endangered		Phantom Cave Crayfish
Cambarus polychromatus Thoma Jezerinac and Simon, 2005	Least concern		Paintedhand Mudbug
Cambarus pristinus Hobbs, 1965	Data deficient		Pristine Crayfish
Cambarus pyronotus Bouchard, 1978	Data deficient		Red-black Crayfish
Cambarus reburrus Prins, 1968	Least concern		French Broad Crayfish
Cambarus reduncus Hobbs, 1956	Least concern		Sickle Crayfish
Cambarus reflexus Hobbs, 1981	Least concern		Pine Savannah Crayfish
Cambarus robustus Girard, 1852	Least concern		Big Water Crayfish

(continued)

Table 3.1 (continued)

Scientific name	IUCN Red List criteria	Regional criteria	English name
Cambarus rusticiformis Rhoades, 1944	Least concern		Depression Crayfish
Cambarus sciotensis Rhoades, 1944	Least concern		Teays River Crayfish
Cambarus scotti Hobbs, 1981	Least concern		Chattooga River Crayfish
Cambarus setosus Faxon, 1889	Near threatened		Bristly Cave Crayfish
Cambarus smilax Loughman Simon and Welsh, 2011			
Cambarus speciosus Hobbs, 1981	Near threatened		Beautiful Crayfish
Cambarus speleocoopi Buhay and Crandall, 2009	Endangered		Sweet Home Alabama Crayfish
Cambarus sphenoides Hobbs, 1968	Least concern		Triangleclaw Crayfish
Cambarus spicatus Hobbs, 1956	Data deficient		Broad River Spiny Crayfish
Cambarus stockeri Thoma, 2011			Ambiguous Crayfish
Cambarus striatus Hay, 1902	Least concern		Ambiguous Crayfish
Cambarus strigosus Hobbs, 1981	Data deficient		Lean Crayfish
Cambarus subterraneus Hobbs, 1993	Critically endangered		Delaware County Cave Crayfish
Cambarus tartarus Hobbs and Cooper, 1972	Critically endangered		Oklahoma Cave Crayfish
Cambarus tenebrosus Hay, 1902	Least concern		Cavespring Crayfish
Cambarus theepiensis Loughman, 2013			
Cambarus thomai Jezerinac, 1993	Least concern		Little Brown Mudbug
Cambarus truncatus Hobbs, 1981	Near threatened		Oconee Burrowing Crayfish
Cambarus tuckasegee Cooper and Schofield, 2002	Near threatened		Tuckasegee Stream Crayfish
Cambarus unestami Hobbs and Hall, 1969	Least concern		Blackbarred Crayfish
Cambarus veitchorum Cooper and Cooper, 1997	Critically endangered		White Spring Cave Crayfish
Cambarus veteranus Faxon, 1914	Data deficient		Big Sandy Crayfish
Cambarus williami Bouchard and Bouchard, 1995	Near threatened		Brawleys Fork Crayfish
Cambarus zophonastes Hobbs and Bedinger, 1964	Critically endangered	Endangered	Hell Creek Cave Crayfish
Distocambarus carlsoni Hobbs, 1983	Data deficient		Mimic Crayfish
Distocambarus crockeri Hobbs and Carlson, 1983	Data deficient		Piedmont Prairie Burrowing Crayfish
Distocambarus devexus (Hobbs, 1981)	Data deficient		Broad River Burrowing Crayfish
Distocambarus hunteri Fitzpatrick and Eversole, 1997	Vulnerable		Saluda Burrowing Crayfish
Distocambarus youngineri Hobbs and Carlson, 1985	Vulnerable		Newberry Burrowing Crayfish

(continued)

Table 3.1 (continued)

Scientific name	IUCN Red List criteria	Regional criteria	English name
Fallicambarus burrisi Fitzpatrick, 1987	Data deficient		Burrowing Bog Crayfish
Fallicambarus byersi (Hobbs, 1941)	Least concern		Lavender Burrowing Crayfish
Fallicambarus caesius Hobbs, 1975	Least concern		Timberlands Burrowing Crayfish
Fallicambarus danielae Hobbs, 1975	Near threatened		Speckled Burrowing Crayfish
Fallicambarus devastator Hobbs and Whiteman, 1987	Least concern		Texas Prairie Crayfish
Fallicambarus dissitus (Penn, 1955)	Data deficient		Pine Hills Digger
Fallicambarus fodiens (Cottle, 1863)	Least concern		Digger Crayfish
Fallicambarus gilpini Hobbs and Robinson, 1989	Near threatened		Jefferson County Crayfish
Fallicambarus gordoni Fitzpatrick, 1987	Near threatened		Camp Shelby Burrowing Crayfish
Fallicambarus harpi Hobbs and Robison, 1985	Near threatened		Ouachita Burrowing Crayfish
Fallicambarus hortoni Hobbs and Fitzpatrick, 1970	Critically endangered		Hatchie Burrowing Crayfish
Fallicambarus houstonensis Johnson, 2008	Least concern		Houston Burrowing Crayfish
Fallicambarus jeanae Hobbs, 1973	Vulnerable		Daisy Burrowing Crayfish
Fallicambarus kountzeae Johnson, 2008	Least concern		Big Thicket Burrowing Crayfish
Fallicambarus macneesei (Black, 1967)	Least concern		Old Prairie Digger
Fallicambarus oryktes (Penn and Marlow, 1959)	Near threatened		Flatwoods Digger
Fallicambarus petilicarpus Hobbs and Robison, 1989	Endangered		Slenderwrist Burrowing Crayfish
Fallicambarus strawni (Reimer, 1966)	Least concern		Saline Burrowing Crayfish
Fallicambarus wallsi Johnson, 2011			
Faxonella beyeri (Penn, 1950)	Least concern		Sabine Fencing Crayfish
Faxonella blairi Hayes and Reimer, 1977	Least concern		Blair's Fencing Crayfish
Faxonella clypeata (Hay, 1899)	Least concern		Ditch Fencing Crayfish
Faxonella creaseri Walls, 1968	Near threatened		Ouachita Fencing Crayfish
Hobbseus attenuatus Black, 1969	Data deficient		Pearl Riverlet Crayfish
Hobbseus cristatus (Hobbs, 1955)	Data deficient		Crested Riverlet Crayfish
Hobbseus orconectoides Fitzpatrick and Payne, 1968	Endangered		Oktibbeha Riverlet Crayfish
Hobbseus petilus Fitzpatrick, 1977	Data deficient		Tombigbee Riverlet Crayfish
Hobbseus prominens (Hobbs, 1966)	Least concern		Prominence Riverlet Crayfish

(continued)

Table 3.1 (continued)

Scientific name	IUCN Red List criteria	Regional criteria	English name
Hobbseus valleculus (Fitzpatrick, 1967)	Endangered		Choctaw Riverlet Crayfish
Hobbseus yalobushensis Fitzpatrick and Busack, 1989	Endangered		Yalobusha Riverlet Crayfish
Orconectes acares Fitzpatrick, 1965	Least concern		Redspotted Stream Crayfish
Orconectes alabamensis (Faxon, 1884)	Least concern		Alabama Crayfish
Orconectes australis (Rhoades, 1941)	Least concern		Southern Cave Crayfish
Orconectes barri Buhay and Crandall, 2008	Data deficient		Cumberland Plateau Cave Crayfish
Orconectes barrenensis Rhoades, 1944	Least concern		Barren River Crayfish
Orconectes bisectus Rhoades, 1944	Vulnerable		Crittenden Crayfish
Orconectes blacki Walls, 1972		Endangered	Calcasieu crayfish
Orconectes burri Taylor and Sabaj, 1998	Near threatened		Blood River Crayfish
Orconectes carolinensis Cooper and Cooper, 1995	Least concern		North Carolina Spiny Crayfish
Orconectes castaneus Johnson, 2010			
Orconectes causeyi Jester, 1967	Least concern		
Orconectes chickasawae Cooper and Hobbs, 1980	Least concern		Chickasaw Crayfish
Orconectes compressus (Faxon, 1884)	Least concern		Slender Crayfish
Orconectes cooperi Cooper and Hobbs, 1980	Least concern		Flint River Crayfish
Orconectes cristavarius Taylor, 2000	Least concern		Spiny Stream Crayfish
Orconectes cyanodigitus Johnson, 2010			
Orconectes deanae Reimer and Jester, 1975	Least concern		Conchas Crayfish
Orconectes difficilis (Faxon, 1898)	Least concern		Painted Crayfish
Orconectes durelli Bouchard and Bouchard, 1995	Least concern		Saddle Crayfish
Orconectes erichsonianus (Faxon, 1898)	Least concern		Reticulate Crayfish
Orconectes etnieri Bouchard and Bouchard, 1976	Least concern		Ets Crayfish
Orconectes eupunctus Williams, 1952	Vulnerable		Coldwater Crayfish
Orconectes forceps (Faxon, 1884)	Least concern		Surgeon Crayfish
Orconectes harrisonii (Faxon, 1884)	Least concern		Belted Crayfish
Orconectes hartfieldi Fitzpatrick and Suttkus, 1992	Vulnerable		Yazoo Crayfish
Orconectes hobbsi Penn, 1950	Data deficient		Pontchartrain Painted Crayfish
Orconectes holti Cooper and Hobbs, 1980	Data deficient		Bimaculate Crayfish
Orconectes hylas (Faxon, 1890)	Least concern		Woodland Crayfish
Orconectes illinoiensis Brown, 1956	Least concern		
Orconectes immunis (Hagen, 1870)	Least concern		Calico Crayfish

(continued)

Table 3.1 (continued)

Scientific name	IUCN Red List criteria	Regional criteria	English name
Orconectes incomptus Hobbs and Barr, 1972	Vulnerable		Tennessee Cave Crayfish
Orconectes indianensis (Hay, 1896)	Least concern		Indiana Crayfish
Orconectes inermis Cope, 1972	Least concern		Unarmed Crayfish
Orconectes jeffersoni Rhoades, 1944	Endangered		Louisville Crayfish
Orconectes jonesi Fitzpatrick, 1992	Data deficient		Sucarnoochee River Crayfish
Orconectes juvenilis (Hagen, 1870)	Least concern		Kentucky River Crayfish
Orconectes kentuckiensis Rhoades, 1944	Least concern		Kentucky Crayfish
Orconectes lancifer (Hagen, 1870)	Least concern		Shrimp Crayfish
Orconectes leptogonopodus Hobbs, 1948	Least concern		Little River Creek Crayfish
Orconectes limosus (Rafinesque, 1817)	Least concern		Spinycheek Crayfish
Orconectes longidigitus (Faxon, 1898)	Least concern		Longpincered Crayfish
Orconectes luteus (Creaser, 1933)	Least concern		Golden Crayfish
Orconectes macrus Williams, 1952	Least concern		Neosho Midget Crayfish
Orconectes maletae Walls, 1972	Data deficient		Kisatchie Painted Crayfish
Orconectes marchandi Hobbs, 1948	Near threatened		Mammoth Spring Crayfish
Orconectes margorectus Taylor, 2002	Near threatened		Livingston Crayfish
Orconectes medius (Faxon, 1884)	Least concern		Saddlebacked Crayfish
Orconectes meeki (Faxon, 1898)	Least concern		Meek's Short Pointed Crayfish
Orconectes menae (Creaser, 1933)	Least concern		Mena Crayfish
Orconectes mirus (Ortmann, 1931)	Least concern		Wonderful Crayfish
Orconectes mississippiensis (Faxon, 1884)	Data deficient		Mississippi Crayfish
Orconectes nais (Faxon, 1885)	Least concern		Water Nymph Crayfish
Orconectes nana Williams, 1952	Least concern		Midget Crayfish
Orconectes obscurus (Hagen, 1870)	Least concern		Allegheny Crayfish
Orconectes occidentalis Johnson, 2010			
Orconectes ozarkae, Williams, 1952	Least concern		Ozark Crayfish
Orconectes palmeri (Faxon, 1884)	Least concern		
Orconectes pardalotus Wetzel et al. 2005	Endangered		Leopard Crayfish
Orconectes pellucidus (Tellkampf, 1844)	Least concern		Mammoth Cave Crayfish
Orconectes perfectus Walls, 1972	Least concern		Complete Crayfish
Orconectes peruncus (Creaser, 1931)	Vulnerable		Big Creek Crayfish
Orconectes placidus (Hagen, 1870)	Least concern		Bigclaw Crayfish
Orconectes propinquus (Girard, 1852)	Least concern		Northern Clearwater Crayfish
Orconectes punctimanus (Creaser, 1933)	Least concern		Spothanded Crayfish
Orconectes putnami (Faxon, 1884)	Least concern		Phallic Crayfish
Orconectes quadruncus (Creaser, 1933)	Vulnerable		St. Francis River Crayfish

(continued)

Table 3.1 (continued)

Scientific name	IUCN Red List criteria	Regional criteria	English name
Orconectes quinebaugensis Mathews and Warren, 2008	Data deficient		
Orconectes rafinesquei Rhoades, 1944	Least concern		Rough River Crayfish
Orconectes raymondi Thoma and Stocker, 2009			
Orconectes rhoadesi, Hobbs, 1949	Least concern		Fishhook Crayfish
Orconectes ronaldi Taylor, 2000	Least concern		Mild River Crayfish
Orconectes rusticus (Girard, 1852)	Least concern		Rusty Crayfish
Orconectes sanbornii (Faxon, 1884)	Least concern		Sanborn's Crayfish
Orconectes saxatilis Bouchard and Bouchard, 1976	Vulnerable		Kiamichi Crayfish
Orconectes sheltae Cooper and Cooper, 1997	Critically endangered	Endangered	Shelta Cave Crayfish
Orconectes shoupi Hobbs, 1948	Endangered	Endangered	Nashville Crayfish
Orconectes sloanii (Bunday, 1876)	Least concern		Sloan's Crayfish
Orconectes spinosus (Bundy, 1877)	Least concern		Coosa River Spiny Crayfish
Orconectes stannardi Page, 1985	Least concern		Little Wabash Crayfish
Orconectes stygocaneyi Hobbs, 2001	Least concern		Caney Mountain Cave Crayfish
Orconectes taylori Schuster, 2008	Vulnerable		Crescent Crayfish
Orconectes texanus Johnson, 2010			
Orconectes theaphionensis Simon, Timm and Morris, 2005	Data deficient		Sinkhole Crayfish
Orconectes tricuspis Rhoades, 1944	Least concern		Western Highland Crayfish
Orconectes validus (Faxon, 1914)	Least concern		Powerful Crayfish
Orconectes virginiensis Hobbs, 1951	Data deficient		Chowanoke Crayfish
Orconectes virilis Hagen, 1870	Least concern		Virile Crayfish
Orconectes williamsi Fitzpatrick, 1996	Least concern		Williams Crayfish
Orconectes wrighti Hobbs, 1948	Vulnerable		Hardin Crayfish
Procambarus ablusus Penn, 1963	Least concern		Hatchie River Crayfish
Procambarus acherontis (Lonnberg, 1894)	Endangered		Orlando Cave Crayfish
Procambarus acutissimus (Girard, 1852)	Least concern		Sharpnose Crayfish
Procambarus acutus (Girard, 1852)	Least concern		White River Crayfish
Procambarus advena (LeConte, 1856)	Least concern		Vidalia Crayfish
Procambarus alleni (Faxon, 1884)	Least concern		Florida Crayfish
Procambarus ancylus Hobbs, 1972	Least concern		Coastal Plain Crayfish
Procambarus angustatus (LeConte, 1856)	Extinct	Endangered	Sandhills Crayfish
Procambarus apalachicolae Hobbs, 1942	Endangered	Endangered	Coastal Flatwoods Crayfish

(continued)

Table 3.1 (continued)

Scientific name	IUCN Red List criteria	Regional criteria	English name
Procambarus attiguus Hobbs and Franz, 1992	Critically endangered	Endangered	Silver Glen Springs Cave Crayfish
Procambarus barbatus (Faxon, 1890)	Least concern		Wandering Crayfish
Procambarus barbiger Fitzpatrick, 1978	Data deficient		Jackson Prairie Crayfish
Procambarus bivittatus Hobbs, 1942	Least concern		Ribbon Crayfish
Procambarus blandingii (Harlan, 1830)	Least concern		Santee Crayfish
Procambarus braswelli Cooper, 1998	Data deficient		Waccamaw Crayfish
Procambarus brazoriensis Albaugh, 1975	Endangered		Brazoria Crayfish
Procambarus capillatus Hobbs, 1971	Data deficient		Capillaceous Crayfish
Procambarus caritus Hobbs, 1981	Least concern		Poor Crayfish
Procambarus ceruleus Fitzpatrick and Wicksten, 1998	Least concern		Blueclaw Chimney Crawfish
Procambarus chacei Hobbs, 1958	Least concern		Cedar Creek Crayfish
Procambarus clarkii (Girard, 1852)	Least concern		Red Swamp Crayfish
Procambarus clemmeri Hobbs, 1975	Least concern		Cockscomb Crayfish
Procambarus cometes Fitzpatrick, 1978	Endangered		Mississippi Flatwoods Crayfish
Procambarus connus Fitzpatrick,1978	Data deficient		Corrollton Crayfish
Procambarus curdi Reimer, 1975	Least concern		Red River Burrowing Crayfish
Procambarus delicatus Hobbs and Franz 1986	Critically endangered		Big-cheeked Cave Crayfish
Procambarus dupratzi Penn, 1953	Least concern		Southwestern Creek Crayfish
Procambarus echinatus Hobbs, 1956	Least concern		Edisto Crayfish
Procambarus econfinae Hobbs, 1942	Endangered		Panama City Crayfish
Procambarus elegans Hobbs, 1969	Data deficient		Elegant Creek Crayfish
Procambarus enoplosternum Hobbs, 1947	Least concern		Black Mottled Crayfish
Procambarus epicyrtus Hobbs, 1958	Least concern		Humpback Crayfish
Procambarus erythrops Relyea and Sutton, 1975	Endangered		Santa Fe Cave Crayfish
Procambarus escambiensis Hobbs, 1942	Endangered		Escambia Crayfish
Procambarus evermanni (Faxon, 1890)	Data deficient		Panhandle Crayfish
Procambarus fallax (Hagen, 1870)	Least concern		Deceitful Crayfish
Procambarus ferrugineus[a]	Least concern		Osage Burrowing Crayfish
Procambarus fitzpatricki Hobbs, 1972	Least concern		Spiny-tail Crayfish
Procambarus franzi Hobbs and Lee, 1976	Endangered		Orange Lake Cave Crayfish
Procambarus geminus Hobbs, 1975	Least concern		Twin Crawfish
Procambarus geodytes Hobbs, 1942	Data deficient		Muddiver Crayfish
Procambarus gibbus Hobbs, 1969	Data deficient		Muckalee Crayfish

(continued)

Table 3.1 (continued)

Scientific name	IUCN Red List criteria	Regional criteria	English name
Procambarus gracilis (Bundy, 1876)	Least concern		Prairie Crayfish
Procambarus hagenianus (Faxon, 1884)	Least concern		Southern Prairie Crayfish
Procambarus hayi (Faxon, 1884)	Least concern		Straightedge Crayfish
Procambarus hinei (Ortmann, 1905)	Least concern		Marsh Crayfish
Procambarus hirsutus Hobbs, 1958	Least concern		Shaggy Crayfish
Procambarus horsti Hobbs and Means, 1972	Endangered		Big Blue Spring Cave Crayfish
Procambarus howellae Hobbs, 1952	Least concern		Ornate Crayfish
Procambarus hubbelli (Hobbs, 1940)	Least concern		Jackknife Crayfish
Procambarus hybus Hobbs and Walton, 1957	Least concern		Smoothnose Crayfish
Procambarus incilis Penn, 1962	Least concern		Cut Crayfish
Procambarus jaculus Hobbs and Walton, 1957	Least concern		Javelin Crayfish
Procambarus kensleyi Hobbs, 1990	Least concern		Free State Chimney Crawfish
Procambarus kilbyi (Hobbs, 1940)	Least concern		Hatchet Crayfish
Procambarus lagniappe Black, 1968	Near threatened		Lagniappe Crayfish
Procambarus latipleurum Hobbs, 1942			
Procambarus lecontei (Hagen, 1870)	Least concern		Mobile Crayfish
Procambarus leitheuseri Franz and Hobbs, 1983	Endangered		Coastal Lowland Cave Crayfish
Procambarus leonensis Hobbs, 1942	Least concern		Blacknose Crayfish
Procambarus lepidodactylus Hobbs, 1947	Data deficient		Pee Dee Lotic Crayfish
Procambarus lewisi Hobbs and Walton, 1959	Data deficient		Spur Crayfish
Procambarus liberorum Fitzpatrick, 1978	Least concern		Osage Burrowing Crayfish
Procambarus litosternum Hobbs, 1947	Data deficient		Blackwater Crayfish
Procambarus lophotus Hobbs and Walton, 1960	Least concern		Mane Crayfish
Procambarus lucifugus (Hobbs, 1940)	Least concern		Vampire Crayfish
Procambarus lunzi (Hobbs, 1940)	Data deficient		Hummock Crayfish
Procambarus luxus Johnson, 2011			
Procambarus lylei Fitzpatrick and Hobbs, 1971	Endangered		Shutispear Crayfish
Procambarus machardyi Walls, 2006	Critically endangered		Caddo Chimney Crayfish
Procambarus mancus Hobbs and Walton, 1957	Least concern		Lame Crayfish
Procambarus marthae Hobbs, 1975	Data deficient		Crisscross Crayfish
Procambarus medialis Hobbs, 1975	Data Deficient		Pamlico Crayfish

(continued)

Table 3.1 (continued)

Scientific name	IUCN Red List criteria	Regional criteria	English name
Procambarus milleri Hobbs, 1971	Endangered		Miami Cave Crayfish
Procambarus morrisi Hobbs and Franz, 1991	Critically endangered		Putnam County Cave Crayfish
Procambarus natchitochae Penn, 1953	Least concern		Red River Crayfish
Procambarus nechesae Hobbs, 1990	Least concern		Neches Crayfish
Procambarus nigrocinctus Hobbs, 1990	Least concern		Blackbelted Crayfish
Procambarus nueces Hobbs and Hobbs, 1995	Least concern		Nueces Crayfish
Procambarus okaloosae Hobbs, 1942	Least concern		Okaloosa Crayfish
Procambarus orcinus Hobbs and Means, 1972	Endangered		Woodville Karst Cave Crayfish
Procambarus ouachitae Penn, 1954	Least concern		Ouachita River Crayfish
Procambarus paeninsulanus (Faxon, 1914)	Least concern		Peninsula Crayfish
Procambarus pallidus (Hobbs, 1940)	Near threatened		Pallid Cave Crayfish
Procambarus parasimulans Hobbs and Robison, 1986	Least concern		Bismark Burrowin Crayfish
Procambarus pearsei (Creaser, 1934)	Data deficient		Carolina Sandhills Crayfish
Procambarus penni Hobbs, 1951	Data deficient		Pearl Blackwater Crayfish
Procambarus pentastylus Walls and Black, 2008	Data deficient		
Procambarus petersi Hobbs, 1981	Data deficient		Ogeechee Crayfish
Procambarus pictus (Hobbs, 1940)	Near threatened		Spotted Royal Crayfish
Procambarus planirostris Penn, 1953	Least concern		Flatnose Crayfish
Procambarus plumimanus Hobbs and Walton, 1958	Least concern		Croatan Crayfish
Procambarus pogum Fitzpatrick, 1978	Data deficient		Bearded Red Crayfish
Procambarus primaevus (Packard, 1881)			Brushnose Crayfish
Procambarus pubescens (Faxon, 1884)	Data deficient		
Procambarus pubischelae Hobbs, 1942	Data deficient		Hookless Crayfish
Procambarus pycnogonopodus Hobbs, 1942	Data deficient		Stud Crayfish
Procambarus pygmaeus Hobbs, 1942	Least concern		Christmas Tree Crayfish
Procambarus raneyi Hobbs, 1953	Data deficient		Disjunct Crayfish
Procambarus rathbunae (Hobbs, 1940)	Data deficient		Combclaw Crayfish
Procambarus regalis Hobbs and Robison, 1988	Data deficient		Regal Burrowing Crayfish
Procambarus reimeri Hobbs, 1979	Data deficient		
Procambarus rogersi (Hobbs, 1938)	Data deficient		Field Crayfish
Procambarus seminolae Hobbs, 1942	Least concern		Seminole Crayfish
Procambarus shermani Hobbs, 1942	Least concern		Gulf Crayfish
Procambarus simulans (Faxon, 1884)	Least concern		Southern Plains Crayfish

(continued)

Table 3.1 (continued)

Scientific name	IUCN Red List criteria	Regional criteria	English name
Procambarus spiculifer (LeConte, 1856)	Least concern		White Tubercled Crayfish
Procambarus steigmani Hobbs, 1991	Data Deficient		Parkhill Prairie Crayfish
Procambarus suttkusi Hobbs, 1953	Least concern		Choctawhatchee Crayfish
Procambarus talpoides Hobbs, 1981	Least concern		Mole Crayfish
Procambarus tenuis Hobbs, 1950	Data deficient		Ouachita Mountain Crayfish
Procambarus texanus Hobbs, 1971	Data deficient		Bastrop Crayfish
Procambarus troglodytes (LeConte, 1856)	Least concern		Eastern Red Swamp Crayfish
Procambarus truculentus Hobbs, 1954	Least concern		
Procambarus tulanei Penn, 1953	Least concern		Giant Bearded Crayfish
Procambarus verrucosus Hobbs, 1952	Least concern		Grainy Crayfish
Procambarus versutus (Hagen, 1870)	Least concern		Sly Crayfish
Procambarus viaeviridis (Faxon, 1914)	Least concern		Vernal Crayfish
Procambarus vioscai Penn, 1946	Least concern		Percy's Creek Crayfish
Procambarus youngi Hobbs, 1942	Data deficient		Florida Longbeak Crayfish
Procambarus zonangulus Hobbs and Hobbs, 1990	Data deficient		Southern White River Crayfish
Troglocambarus maclanei Hobbs, 1942	Near threatened		Spider Cave Crayfish

[a]*Procambarus ferrugineus* is junior synonym of the species, *Procambarus liberorum*

subspecies and fossil species, and updated regional species lists based on the latest monographs of freshwater crayfish by regional taxonomic specialists (Thoma 2015).

3.6 Distribution

The river basins in the Atlantic drainage in the USA have more species than any other continent. The rich species diversity is particularly concentrated in the southeastern United States between the Ozark Mountains of Missouri and Arkansas, and new species are still being described. In the Appalachian Mountains species abundance is concentrated in the southern range in eastern Tennessee, northern Georgia, and western South Carolina and North Carolina (Thoma 2015).

3.7 Conservation

Crayfish conservation in the United States has risen in importance in recent years and several works have highlighted the numbers of rare and threatened species (Master 1990; Taylor et al. 2007). Some 371 species are known from the Atlantic drainages of Canada and the USA, of which 86 (23.2 %) are too poorly known to assess (Data Deficient). The IUCN Red List shows 53 (14.3 %) species of crayfish in Canada and USA to be threatened with extinction, while the U.S. Fish and Wildlife Service (USFWS) (Center for Biological Diversity 2010), additionally lists 8 species, total 61 species (total 16.4 % of the fauna) as endangered. It is likely that many of the newly described species of crayfish that have a small population and a restricted distribution are in a threatened category when their formal conservation assessments have been made.

Lodge et al. (2000) discussed the spread of crayfish species in North America and have evaluated the effects of non-native species on the indigenous fauna. Alien invasive species of crayfish impact both indigenous species of crayfish and fish, especially those species that rely on submerged aquatic vegetation (Lodge et al. 1998a, b). Despite this, some forty political units in Canada and the United States do not regulate the use of, or movement of, crayfish within their boundaries. Because of this it is likely that more non-native crayfish populations will become established in the U.S. and Canada and that this will increase the number of endangered species in these two countries (Thoma 2015).

3.7.1 North America, Pacific Drainages

Pacifastacus leniusculus has three subspecies (Miller 1960) but recent molecular analyses by Sonntag (2006), Larson et al. (2012), and Larson and Williams (2015) suggest that all three subspecies should properly be recognized as valid species (Table 3.2). About 40 % of North American species of crayfish living in the Pacific drainages are threatened with extinction and another 20 % are Data Deficient.

Table 3.2 Taxonomy and assessment information of Western North America, Pacific drainages

Scientific name	IUCN Red List criteria	English name
Pacifastacus connectence (Faxon, 1914)	Data deficient	Snake River Pilose Crayfish
Pacifastacus fortis (Faxon, 1914)	Critically endangered	Placid Crayfish or Shasta Crayfish
Pacifastacus gambelii (Girard, 1852)	Least concern	Pilose Crayfish
Pacifastacus leniusculus (Dana, 1852)	Least concern	Signal Crayfish
Pacifastacus nigrescens (Stimpson, 1857)	Extinct	Sooty Crayfish

3.8 Distribution

The native range of the genus *Pacifastacus* lies in the Columbia River system, but there is a lack of clarity of their exact historic distributions prior to widespread human-related introductions because it is known that *P. leniusculus* has been introduced into the U.S. states of California, Nevada, and Utah (Larson and Olden 2011, 2013; Martinez 2012),. This is proving to be a barrier to our understanding of the endemic range of these crayfish (Riegel 1959; Abrahamsson and Goldman 1970; Johnson 1986).

3.9 Conservation

The IUCN Red List for the North American Pacific drainages records one endangered species (*Pacifastacus fortis*), and another species (*P. nigrescens*) that is now extinct. The U.S. Endangered Species Act (http://explorer.natureserve.org/statusus.htm) (U.S. ESA) is the primary legislation that affords federal legal protection to threatened and endangered species in the United States, and is administered by the U.S. Fish and Wildlife Service (USFWS) (http://endangered.fws.gov/) and U.S. National Marine Fisheries Service (NMFS) (http://www.nmfs.noaa.gov/prot_res/overview/es.html). Recently, the U.S. Endangered Species Act recognised *P. fortis* as endangered, and *P. gambelii* and *P. connectens* as being of least concern. However, Bouchard (1977) assigned *P. fortis* as "Threatened" under the U.S. ESA, which was upgraded to "Endangered" in 1988 (Singleton 1987). Bouchard (1977) suggested that *P. nigrescens* was probably extinct owing to the effects of urbanization in the San Francisco area coupled with the impacts of the invasive crayfish *P. leniusculus*. *Pacifastacus fortis* appears highly impacted by range expansions of non-native species such as *P. leniusculus* and the cambarid *Orconectes virilis* (Eng and Daniels 1982; Light et al. 1995; Ellis 1999). Recent research has evaluated behavioral interactions between *P. fortis* and *P. leniusculus* (Pintor et al. 2008), and management actions have included the design and construction of impassable barriers to crayfish aimed at preventing the further spread of invasive species into critical habitats for *P. fortis* (Ellis 2005). The conservation status of the three nominal subspecies of *P. leniusculus* is as follows: *P. l. klamathensis* and *P. l. trowbridgii* are endangered, whereas *P. l. leniusculus* is not endangered.

3.10 Distribution

The crayfish of Mexico and Central America range from sea level wetlands and salt marshes to highland streams above 3000 m in parts of central Mexico (Table 3.3). Although the natural habitat of crayfish is generally limited to freshwater, species

Table 3.3 Taxonomy and assessment information of Mexico and Central America

Scientific name	IUCN Red List criteria
Cambarellus alvarezi Villalobos, 1952	Extinct
Cambarellus areolatus Faxon, 1885	Critically endangered
Cambarellus chapalanus Faxon, 1898	Near threatened
Cambarellus chihuahuae Hobbs, 1980	Extinct
Cambarellus lermensis Villalobos, 1943	Least concern
Cambarellus occidentalis Faxon, 1898	Least concern
Cambarellus patzcuarensis Villalobos, 1943	Endangered
Cambarellus prolixus Villalobos and Hobbs, 1981	Critically endangered
Cambarellus zempoalensis Villalobos, 1943	Least concern
Procambarus acanthophorus Villalobos, 1948	Least concern
Procambarus achilli López, Mejia and Alvarez, 2003	Least concern
Procambarus atkinsoni (Ortmann, 1913)	Data deficient
Procambarus bouvieri (Ortmann, 1909)	Endangered
Procambarus caballeroi Villalobos, 1944	Least concern
Procambarus catemacoensis Rojas, Alvarez and Villalobos, 2000	Critically endangered
Procambarus cavernicola Mejia-Ortiz, Hartnoll and Viccon-Pale, 2003	Vulnerable
Procambarus chacalli López-Mejia, Alvarez and Mejia-Ortiz, 2004	Data deficient
Procambarus citlaltepetl Rojas, Alvarez and Villalobos, 1999	Vulnerable
Procambarus clarkii (Girard, 1852)	Least concern
Procambarus contrerasi (Creaser, 1931)	Endangered
Procambarus cubensis (Erichson, 1846)	Data deficient
Procambarus cuetzalanae Hobbs, 1982	Near threatened
Procambarus cuevachicae (Hobbs, 1941)	Least concern
Procambarus digueti (Bouvier, 1897)	Endangered
Procambarus erichsoni Villalobos, 1950	Data deficient
Procambarus gonopodocristatus Villalobos, 1958	Least concern
Procambarus hidalgoensis López-Mejia, Alvarez and Mejia Ortis, 2005	Least concern
Procambarus hoffmanni (Villalobos, 1944)	Least concern
Procambarus hortonhobbsi Villalobos, 1950	Endangered
Procambarus llamasi Villalobos, 1954	Least concern
Procambarus maya Alvarez, López-Mejia and Villalobos, 2007	Data deficient
Procambarus mexicanus (Erichson, 1846)	Least concern
Procambarus mirandai Villalobos, 1954	Least concern
Procambarus niveus Hobbs and Villalobos, 1964	Data deficient
Procambarus oaxacae Hobbs, 1973	Least concern
Procambarus olmecorum Hobbs, 1987	Least concern
Procambarus ortmannii (Villalobos, 1949)	Critically endangered
Procambarus paradoxus (Ortmann, 1906)	Critically endangered
Procambarus pilosimanus (Ortmann, 1906)	Least concern

(continued)

Table 3.3 (continued)

Scientific name	IUCN Red List criteria
Procambarus regiomontanus (Villalobos, 1954)	Critically endangered
Procambarus riojai (Villalobos, 1944)	Least concern
Procambarus roberti Villalobos and Hobbs, 1974	Endangered
Procambarus rodriguezi Hobbs, 1943	Data deficient
Procambarus ruthveni (Pearse, 1911)	Vulnerable
Procambarus sbordonii Hobbs, 1977	Data deficient
Procambarus strenthi Hobbs, 1977	Data deficient
Procambarus teziutlanensis (Villalobos, 1947)	Data deficient
Procambarus tlapacoyanensis (Villalobos, 1947)	Data deficient
Procambarus toltecae Hobbs, 1943	Least concern
Procambarus williamsoni (Ortmann, 1905)	Data deficient
Procambarus vazquezae Villalobos, 1954	Near threatened
Procambarus veracruzanus Villalobos, 1954	Data deficient
Procambarus zapoapensis Villalobos, 1954	Data deficient
Procambarus villalobosi Hobbs, 1967	Data deficient
Procambarus xilitlae Hobbs and Grubbs, 1982	Data deficient
Procambarus xochitlanae Hobbs, 1975	Data deficient
Procambarus zapoapensis Villalobos, 1954	Near threatened
Procambarus zihuateutlensis Villalobos, 1950	Endangered

such as *P. clarkii* have been recorded from brackish water habitats (Huner and Barr 1991), and another species (*P. maya*) has been collected from a salt marsh with a salinity of 5.5 ppt in the Sian Ka'an Nature Reserve in Quintana Roo, Mexico about 1 km from the coast (Alvarez et al. 2011). Crayfish are not evenly distributed throughout Mexico and Central America. In Mexico, the majority of species are found along the Gulf of Mexico slope, while a less diverse group occurs along the Trans-Mexican Volcanic Belt, and a few species form a third disjunctive group distributed on the Pacific versant. Crayfish diversity reaches a high point along the Gulf of Mexico slope in a region where the States of Veracruz, Hidalgo, and Puebla come together (Armendáriz 2011).

3.11 Conservation

The IUCN published conservation assessments of all cambarid species of crayfish (IUCN 2013; Richman et al. 2015). In 2010 the Secretariat of Environment and Natural Resources (in Spanish: Secretaría del Medio Ambiente y Recursos Naturales, SEMARNAT) published the Mexican Red List of threatened species that is known as Nom-059-Semarnat-2010 (SEMARNAT 2010), which is an updated

version of the IUCN Red List. These two reports included the same number of species with 30.5 % of the Mexican and Central American species endangered and another 28.8 % Data Deficient.

In Mexico and Central America only a few species of crayfish have been used for aquaculture. The U.S. red swamp crayfish *Procambarus clarkii* has been introduced into a number of lakes and ponds in northern Mexico and has since spread to the states of Tamaulipas, Nuevo Leon, Coahuila, Durango, Chihuahua, Sonora, Baja California, and Chiapas (Campos and Rodríguez-Almaraz 1992; Hernández et al. 2008). Torres and Álvarez (2012) found that one non-native population of *P. clarkii* was genetically more similar to each other than to other introduced populations *of P. clarkii* found elsewhere in Mexico and Costa Rica, although overall genetic variation within this species was low. In addition, populations of *Orconectes virilis* (which is native to the northeastern parts of North America) have now become established in Mexico (Campos and Contreras 1985). And the Australian redclaw crayfish, *Cherax quadricarinatus,* was brought into Mexico in 1995 to start experimental cultures but some have escaped and established wild populations. Mendoza-Alfaro et al. (2011) reviewed the status of *C. quadricarinatus* in Mexico, but there have been no studies that have focused on the impact of this alien species on the native fauna, especially in nearby Tamaulipas and San Luis Potosi, where there is an important hotspot of native crayfish species diversity.

3.12 South America

The genus *Parastacus* includes taxonomically problematic species such as *P. saffordi, P. pilimanus,* and *P. varicosus* whose external morphological characters closely resemble each other (Table 3.4). Unfortunately, the type series of *P. saffordi* and *P. varicosus* comprise only a few specimens and the type specimens of *P. pilimanus* have been lost. This remains a difficult problem because no additional specimens of these three species have been collected since their original descriptions (Buckup and Rossi 1980; Rudolph and Almerão 2015).

3.13 Distribution

Thirteen species of crayfishes are native to South America and are distributed in southern Brazil, Uruguay, northeast and southern Argentina, and central-southern Chile (Crandall et al. 2000a, b; Buckup 2003; Rudolph 2013), with Chile (six species) hosts the greatest diversity (Rudolph 2010).

Table 3.4 Taxonomy and assessment information of South America

Scientific name	IUCN Red List criteria	Regional criteria
Parastacus brasiliensis (von Martens, 1869)	Near threatened	
Parastacus defossus Faxon, 1898	Data deficient	Near threatened
Parastacus laevigatus Buckup and Rossi, 1980	Data deficient	
Parastacus nicoleti (Philippi, 1882)	Data deficient	Near threatened or vulnerable
Parastacus pilimanus (von Martens, 1869)	Least concern	
Parastacus pugnax (Poeppig, 1835)	Data deficient	Least concern or vulnerable
Parastacus saffordi Faxon, 1898	Data deficient	
Parastacus varicosus Faxon, 1898	Data deficient	
Samastacus spinifrons (Philippi, 1882)	Data deficient	Least concern or vulnerable
Virilastacus araucanius (Faxon, 1914)	Data deficient	Vulnerable
Virilastacus jarai Rudolph and Crandall, 2012		Critically endangered
Virilastacus retamali Rudolph and Crandall, 2007	Data deficient	Endangered
Virilastacus rucapihuelensis Rudolph and Crandall, 2005	Data deficient	Endangered or critically

Regional criteria based on Almerão et al. (2014) and Rudolph and Almerão (2015)

3.14 Conservation

The differences between the conservation status of the South American species of crayfish reported by the IUCN Red List and that reported by the Regional Evaluation agencies are mainly due to differences in the protocols used (Almerão et al. 2014; Buckup 2010; Rudolph and Crandall 2007, 2012; Marques et al. 2002; MMA 2013a, b). For example, the IUCN Red List shows 7.7 % of South American parastacids as threatened with extinction (and 10 species (76.9 %) as Data Deficient), while the Regional Criteria considers 6 species (46.2 %) to be endangered. Threats to the South American parastacid species are mostly from the negative impacts of human activities. In Uruguay and Brazil stream channel diversion and water pollution have affected natural crayfish habitat, while in Chile deforestation for agriculture is the main threat (Rudolph and Almerão 2015). Introduced alien crayfish such as *Procambarus clarkii* (Girard 1852) are also posing new threats to the freshwater ecosystems of South America, because this U.S. species has been recorded to occur in Ecuador and Brazil (Magalhães et al. 2005; Silva and Bueno 2005; Torres and Álvarez 2012). Species Distribution Models (SDMs) have demonstrated that *P. clarkii* represents a potentially serious threat to large areas of southern South America (Paraguay, Chile, Argentina, Uruguay and Brazil) (Palaoro et al. 2013). Several other non-native species of crayfish have also been introduced into South America from Australia: *Cherax quadricarinatus* (von

Martens 1868), *C. tenuimanus* Smith 1912, and *C. cainii* (Austin and Bunn 2010) (Lawrence and Jones 2002; Mendoza-Alfaro et al. (2011)). These Australian species have been cultivated in commercial farms in Ecuador, Paraguay, Colombia, Peru, Uruguay, Argentina, and Chile, and it is likely that these alien species will become a greater threat to South American Parastacidae in the future.

3.15 Oceania (Australia, New Guinea, New Zealand)

The freshwater crayfish of Oceania all belong to the Parastacidae (Holdich 2002). Eleven out of the 15 genera of the Parastacidae are found in Oceania, with 9 genera endemic to Australia (*Astacopsis*, *Engaeus*, *Engaewa*, *Euastacus*, *Geocharax*, *Gramastacus*, *Ombrastacoides*, *Spinastacoides*, and *Tenuibranchiurus* (cf., Riek 1969, 1972; Hobbs 1988; Hansen and Richardson 2006)), one genus (*Cherax*) that is found in Australia, New Guinea, and nearby islands (Clark 1936; Holthuis 1986), and one genus (*Paranephrops*) that lives in New Zealand (Archey 1915; Hopkins 1970) (Table 3.5).

3.16 Distribution

The eleven parastacid genera found in Oceania: *Astacopsis* (Tasmania), *Cherax* (Australia and some offshore islands and New Guinea), *Engaeus* (Victoria and Tasmania), *Engaewa* (western Australia), *Euastacus* (eastern and southeastern Australia), *Geocharax* (Victoria and Tasmania), *Gramastacus* (southeastern Australia), *Ombrastacoides* (Tasmania), *Paranephrops* (New Zealand), *Spinastacoides* (Tasmania), and *Tenuibranchiurus* (central and eastern Australia) (Furse 2014; Lukhaup and Herbert 2008).

3.17 Conservation

The crayfish fauna of Oceania has a significantly high species diversity with 153 species in 11 genera. The threat levels and conservation status of each genus can be summarized as follows: *Astacopsis* spp. are threatened by habitat loss and degradation due to land clearance or by catchment disturbance for agriculture, forestry, or mining. The largest species, *A. gouldi*, is still threatened by illegal fishing (Threatened Species Sect. 2006) and is listed as Vulnerable under Tasmanian and Commonwealth of Australia legislation.

The common threats to *Cherax* have been identified by Wells et al. (1983) as habitat destruction, pollution, human exploitation, and the introduction of exotic species. The 2010 IUCN Red List assessed 17 species (50 %) in the genus *Cherax*

Table 3.5 Taxonomy and assessment information of Oceania (Australia, New Guinea, New Zealand)

Scientific name	IUCN Red List criteria	English name
Astacopsis franklinii (Grey, 1945)	Least concern	
Astacopsis gouldi Clark, 1936	Endangered	Tasmanian Giant freshwater Lobster
Astacopsis tricornis Clark, 1936	Least concern	
Cherax austini Coughran and Hobson, 2012		
Cherax barretti Clark, 1941		
Cherax boschmai Holthuis, 1949		
Cherax buitendijkae Holthuis, 1949		
Cherax cainii Austin and Ryan, 2002	Least concern	Smooth Marron
Cherax cairnsensis, Riek, 1969		
Cherax cartacoolah Short, 1993		
Cherax cid Furse and Dawkins, 2012		
Cherax communis Holthuis, 1949		
Cherax crassimanus Riek, 1967		
Cherax cuspidatus Riek, 1969	Least concern	
Cherax depressus Riek, 1951		Orange-fingered Crayfish
Cherax destructor Clark, 1936	Vulnerable	Yabby
Cherax dispar Riek, 1951	Least concern	
Cherax glaber Riek, 1967		
Cherax holthuisi Lukhaup and Pekny, 2006	Data deficient	
Cherax leckii Coughran, 2005	Critically endangered	
Cherax longipes Holthuis, 1949		
Cherax murido Holthuis, 1949		
Cherax nucifraga Short, 1991	Data deficient	
Cherax pallidus Holthuis, 1949	Endangered	
Cherax panaicus Holthuis, 1949		
Cherax papuanus Holthuis, 1949	Vulnerable	
Cherax parvus Short and Davie, 1991	Data deficient	
Cherax peknyi Lukhaup and Herbert, 2008	Data deficient	
Cherax preissi (Erichson, 1846)	Least concern	
Cherax punctatus Clark, 1936		
Cherax quadricarinatus (von Martens, 1868)	Least concern	Red-claw, Tropical Blue Crayfish
Cherax quinquecarinatus (Gray, 1845)	Least concern	
Cherax rhynchotus Riek, 1951	Least concern	
Cherax robustus Riek, 1951		
Cherax rotunadus Clark, 1941		

(continued)

Table 3.5 (continued)

Scientific name	IUCN Red List criteria	English name
Cherax setosus (Riek, 1951)		Setose Yabby
Cherax solus, Holthuis, 1949		
Cherax tenuimanus (Smith, 1912)	Critically endangered	Marron
Cherax urospinosus Riek, 1969	Data deficient	
Cherax wasselli Riek, 1969		
Engaeus affinis Smith and Schuster, 1913	Data deficient	
Engaeus australis Riek, 1969	Near threatened	Lilly Pilly Burrowing Crayfish
Engaeus cisternarius Suter, 1977	Least concern	
Engaeus cunicularius (Erichson, 1846)	Least concern	
Engaeus curvisuturus Horwitz, 1990	Data deficient	
Engaeus cymus (Clark, 1936)	Least concern	
Engaeus disjuncticus Horwitz, 1990	Endangered	
Engaeus fossor (Erichson, 1846)	Least concern	
Engaeus fultoni Smith and Schuster, 1913		
Engaeus granulatus Horwitz, 1990	Critically endangered	
Engaeus hemicirratulus Smith and Schuster, 1913	Least concern	
Engaeus karnanga Horwitz, 1990	Data deficient	
Engaeus laevis (Clark, 1941)	Data deficient	
Engaeus lengana Horwitz, 1990	Least concern	
Engaeus leptorhynchus Clark, 1936	Least concern	
Engaeus lyelli (Clark, 1936)	Least concern	
Engaeus mairener Horwitz, 1990	Least concern	
Engaeus mallacoota Horwitz, 1990	Critically endangered	Malacoota Burrowing Crayfish
Engaeus martigener Horwitz, 1990	Endangered	Furneax Burrowing Crayfish
Engaeus merosetosus Horwitz, 1990	Least concern	
Engaeus nulloporius Horwitz, 1990	Data deficient	
Engaeus rientalis Clark, 1941		
Engaeus orramakunna Horwitz, 1990	Near threatened	Mount Arthur Burrowning Crayfish
Engaeus phyllocercus Smith and Schuster, 1913	Endangered	Narracan Burrowing Crayfish
Engaeus quadrimanus Clark, 1936	Least concern	
Engaeus rostrogaleatus Horwitz, 1990	Vulnerable	Strzelecki Burrowing Crayfish
Engaeus sericatus Clark, 1936	Least concern	
Engaeus spinicaudatus Horwitz, 1990	Critically endangered	Scottsdale Burrowning Crayfish

(continued)

Table 3.5 (continued)

Scientific name	IUCN Red List criteria	English name
Engaeus sternalis (Clark, 1936)	Critically endangered	Warracul Burrowing Crayfish
Engaeus strictifrons (Clark, 1936)	Least concern	
Engaeus tayatea Horwitz, 1990	Least concern	
Engaeus tuberculatus Clark, 1936	Least concern	
Engaeus urostrictus Riek, 1969	Vulnerable	
Engaeus victoriensis Smith and Schuster, 1913	Near threatened	
Engaeus yabbimunna, Horwitz, 1994	Vulnerable	Burnie Burrowing Crayfish
Engaewa pseudoreducta Horwitz and Adams, 2000	Critically endangered	
Engaewa reducta Riek, 1967	Endangered	Dunsborough Burrowing Crayfish
Engaewa similis Riek, 1967	Least concern	
Engaewa subcoerulea Riek, 1967	Least concern	
Engaewa walpolea Horwitz and Adams, 2000	Endangered	Walpole Burrowing Crayfish
Euastacus angustus Coughran and Dawkins, 2013		
Euastacus armatus (von Martens, 1866)	Data deficient	Murray River Crayfish, Murray Spiny Crayfish
Euastacus australasiensis (H. Milne Edwards, 1837)	Least concern	
Euastacus balanesis Morgan, 1988	Endangered	
Euastacus bidawalus Morgan, 1986	Endangered	
Euastacus bindal Morgan, 1989	Critically endangered	
Euastacus binzayedi Coughran and Furse, 2013		
Euastacus bispinosus Clark, 1936	Vulnerable	Glenelg River Crayfish, Prickley-backs
Euastacus brachythorax Riek, 1969	Endangered	
Euastacus clarkae Morgan, 1997	Critically endangered	
Euastacus claytoni Riek, 1969	Endangered	
Euastacus crassus Riek, 1969	Endangered	Alpine Spiny Crayfish
Euastacus dalagarbe Coughran, 2005	Critically endangered	
Euastacus dangadi Morgan, 1997	Least concern	
Euastacus dharawalus Morgan, 1997	Critically endangered	Fitzroy Falls Crayfish
Euastacus diversus Riek, 1969	Endangered	Orbost Spiny Crayfish
Euastacus eungella Morgan, 1988	Critically endangered	

(continued)

Table 3.5 (continued)

Scientific name	IUCN Red List criteria	English name
Euastacus fleckeri (Watson, 1953)	Endangered	
Euastacus gamilaroi Morgan, 1997	Critically endangered	
Euastacus girurmulayn Coughran, 2005	Critically endangered	
Euastacus gumar Morgan, 1997	Endangered	
Euastacus guruhgi Coughran, 2005	Critically endangered	
Euastacus guwinus Morgan, 1997	Critically endangered	
Euastacus hirsutus (McCulloch, 1917)	Endangered	
Euastacus hystricosus Riek, 1951	Endangered	
Euastacus jagabar Coughran, 2005	Critically Endangered	
Euastacus jagara Morgan, 1988	Critically endangered	
Euastacus kershawi Smith, 1912	Least concern	Spinybacks, Gippsland Spiny Crayfish
Euastacus maccai McCormack and Coughran, 2008	Endangered	
Euastacus maidae (Riek, 1956)	Critically endangered	
Euastacus mirangudjin Coughran, 2002	Critically endangered	Ochre-bellied Crayfish
Euastacus monteithorum Morgan, 1989	Critically endangered	
Euastacus morgani Coughran and McCormack, 2011		
Euastacus neodiversus Riek, 1969	Endangered	
Euastacus neohirsutus Riek, 1956	Least concern	
Euastacus pilosus Coughran and Leckie, 2007	Endangered	
Euastacus polysetosus Riek, 1951	Endangered	
Euastacus reductus Riek, 1969	Least concern	
Euastacus rieki Morgan, 1997	Endangered	
Euastacus robertsi Monroe, 1977	Critically endangered	
Euastacus setosus (Riek, 1956)	Critically endangered	
Euastacus simplex Riek, 1956	Vulnerable	
Euastacus spinichelatus Morgan, 1997	Endangered	
Euastacus spinifer (Heller, 1865)	Least concern	

(continued)

Table 3.5 (continued)

Scientific name	IUCN Red List criteria	English name
Euastacus sulcatus Riek, 1951	Vulnerable	
Euastacus suttoni Clark, 1941	Vulnerable	New England Crayfish
Euastacus urospinosus (Riek, 1956)	Endangered	
Euastacus valentulus Riek, 1951	Least concern	
Euastacus woiwuru Morgan, 1986	Near threatened	
Euastacus yanga Morgan, 1997	Least concern	
Euastacus yarraensis (McCoy, 1888)	Vulnerable	Yarra Spiny Crayfish
Euastacus yigara Short and Davie (1993)	Critically endangered	
Geocharax falcata Clark, 1936	Vulnerable	
Geocharax gracilis Clark, 1936	Least concern	
Gramastacus insolitus Riek, 1972	Near threatened	Western Swamp Crayfish
Gramastacus lacus McCormack, 2014		
Ombrastacoides asperrimanus Hansen and Richardson, 2006	Near threatened	
Ombrastacoides brevirostris Hansen and Richardson, 2006	Least concern	
Ombrastacoides decemdentatus Hansen and Richardson, 2006	Least concern	
Ombrastacoides denisoni Hansen and Richardson, 2006	Critically endangered	
Ombrastacoides dissitus Hansen and Richardson, 2006	Near threatened	
Ombrastacoides huonensis Hansen and Richardson, 2006	Least concern	
Ombrastacoides ingressus Hansen and Richardson, 2006	Data deficient	
Ombrastacoides leptomerus (Riek, 1951)	Least concern	
Ombrastacoides parvicaudatus Hansen and Richardson, 2006	Critically endangered	
Ombrastacoides professorum Hansen and Richardson, 2006	Data deficient	
Ombrastacoides pulcher (Riek, 1967)	Vulnerable	
Paranephrops planifrons White, 1842	Least concern	
Paranephrops zealandicus (White, 1847)	Least concern	
Spinastacoides catinipalmus Hansen and Richardson, 2006	Least concern	
Spinastacoides inermis (Clark, 1939)	Least concern	
Spinastacoides insignis (Clark, 1939)	Least concern	
Tenuibranchiurus glypticus Riek, 1951	Endangered	Swamp Crayfish

(three Australian and two New Guinean species) to be threatened with extinction, with another 5 species considered to be Data Deficient.

A number of species of *Engaeus* are restricted-range endemics (Horwitz 1990; Harvey 2002) whose habitat is threatened by agricultural activities (including ploughing), dam construction, and clearance of riparian vegetation (Richardson and Doran 2008). Approximately 60 % of the species of *Engaeus* are listed as VU or EN by the IUCN Red List, or as endangered by State legislation (the Commonwealth Environment Protection and Biodiversity Conservation Act), while four species of *Engaeus* (*E. granulatus, E. spinicaudatus, E. sternalis*, and *E. urostrictus*) are considered to be Critically Endangered by both the IUCN Red List and the State legislation.

Species of burrowing crayfish in the genus *Engaewa* require moist habitats, and arid conditions render them vulnerable to extinction (Wardell-Johnson and Horwitz 1996). Identified threats to *Engaewa* include the drainage of swamps for agriculture, and dam construction (Horwitz 1995; Horwitz and Adams 2000). About 40 % of species of *Engaewa* are assessed by the IUCN Red List as Least Concern.

The extensive distribution of *Euastacus* exposes many of the species in this genus to a broad array of threats including habitat destruction, pollution and reduced water quality, the introduction of exotic species, and illegal collection by humans (Furse and Coughran 2011). The 2010 IUCN Red List assessment listed 82 % of the species of *Euastacus* as threatened, 16 % as Least Concern, and 2 % as Data Deficient. The emerging threats to *Euastacus* are discussed in Furse (2014), including the effects of global climate change which especially threaten cool adapted organisms such as the members of this genus (Horwitz 1990).

Threats to species of *Geocharax* include habitat alteration, trampling by cattle, and phosphate run-off in agricultural areas (March and Robson 2006). Although *G. gracilis* is assessed as Least Concern by the 2010 IUCN Red List, the conservation status of this species was recently upgraded to Endangered under state legislation in Victoria.

Ombrastacoides denisoni is listed as Critically Endangered by the IUCN Red List and as a Priority Species by the Tasmanian Forest Practices Authority, and is currently listed as threatened under Tasmanian or Commonwealth legislation.

The 2010 conservation assessment of *Paranephrops* in the IUCN Red List is Least Concern, but populations of two species (*P. planifrons* and *P. zealandicus*) are now declining due to the combined effects of habitat reduction through the draining of wetlands, collection for human consumption, and predation by exotic species (Whitmore et al. 2000).

The distribution of all species of *Spinastacoides* extends throughout western Tasmania and each species in this genus has an extensive range (Hansen and Richardson 2006), but climate change is a potential threat (but none of these species are currently threatened).

Tenuibranchiurus is a monotypic genus that is endemic to the central and eastern coastal regions of Australia. One species (*T. glypticus*) is assessed by the IUCN Red List as Endangered, but it is not listed as threatened by any of the Australian

conservation protocols. The main threats to species of *Tenuibranchiurus* are habitat destruction, pollution, and salt water intrusion (Furse et al. 2015).

In summary, 40.5 % of Oceanian parastacid species are listed as threatened with extinction and 7.8 % of species are Data Deficient.

3.18 Madagascar

Seven species of parastacid crayfish in the genus *Astacoides* Guérin, 1839 are endemic to Madagascar (Boyko 2015; Boyko et al. 2005) (Table 3.6).

3.19 Distribution

Crayfishes in the genus *Astacoides* are unevenly distributed in Madagascar. All of them are restricted to an inland area of about 60,000 km^2 in the southeast highlands between 18° and 25°S and 46° and 48°E, from the Hauts Plateau near Anjozorobe in Analamanga Region, 90 km north-east of Antananarivo, to the Isaka Valley int eh Anosy Region some 700 km to the south (Hobbs 1987; Rabeharisoa 1996). Reports suggesting a broader range (Dixon 1992) including the Masoala peninsula (approximately 17°S, 50°E) and the mountains of Andapa (approximately 14°S, 49°E) are uncorroborated and not supported by specimens (Crandall 2003).

Table 3.6 Taxonomy and assessment information of Madagascar

Scientific name	IUCN Red List criteria	Malagasy name
Astacoides betsileoensis Petit, 1923	Endangered	Orana mena or Oramaintso or Orana Satria or Anjatsy or Pepeo or Orambanonga or Orambato
Astacoides caldwelli Bate, 1865	Endangered	Orana Mena
Astacoides crosnieri Hobbs, 1987	Data deficient	Orampotoka or Orambory or Oramalemy
Astacoides granulimanus Monod and Petit, 1929	Least concern	Orandambo
Astacoides hobbsi Boyko, 2005	Data deficient	Orapotsy
Astacoides madagascariensis H. Milane Edward and Audouin, 1839	Data deficient	Orambato or Orana Maintso or Orana Mainty or Orana Satria or Oramaintso
Astacoides petiti Monod and Petit, 1929	Data deficient	Orambato

3.20 Conservation

Threats to *Astacoides* in Madagascar include overharvesting, habitat loss, and competition with introduced species. Crayfish harvesting is common throughout the range of *Astacoides* (Jones et al. 2005, 2006, 2007), and a recent study in and around Ranomafana National Park (Jones et al. 2005) suggested that the harvest of *A. granulimanus* is potentially sustainable under the current conditions. However, the effect of harvesting on other species such as *A. betsileoensis* that have a lower fecundity is a cause for concern. Differences in reproductive strategy influence a species' vulnerability to harvesting (Milner-Gulland and Lhagvasuren 1998; Kokko et al. 2001), but aquaculture is not a viable solution, given the slow growth rates of *Astacoides* (Jones et al. 2007). Crandall (2003) suggested that the recent destruction of most of the lowland forests of Madagascar has had little impact on crayfish populations in the highlands (between 800 and 2000 m above sea level, asl) because slash-and-burn activities in Madagascar tend to be below 900 m asl. However, habitat loss at low altitudes could become a very serious threat to Madagascar's crayfish because habitat destruction is taking place throughout that island and could spread to higher altitudes (Hawkins and Horning 2001). Other threats to Madagascar's crayfish come from the introduction of non-native crayfishes and from the predatory Asian snake-head fish, *Channa maculata* (whose local name: is fibata) (Raberisoa et al. 1996). These threats suggest that the IUCN Red List assssments that list 28.6 % of Malagasy crayfish as endangered may prove to be an underestimate, especially because the vast majority of the species (57.1 %) are too poorly known to assess (Data Deficient).

There are no species of crayfish found naturally anywhere on continental Africa, but five species of crayfish have been introduced there, from North America (*Procambarus clarkii,* and *P. fallax*), Australia (*Cherax destructor, C. quadricarinatus, C. tenuimanus*), and Europe (the marbled crayfish). There are notable populations of alien crayfish established in South Africa (Holdich 1999), Sudan, Kenya, Uganda, Zambia, and Zimbabwe. *Procambarus clarkii* has spread rapidly from the intial release points of introduction in Kenya (Hobbs et al. 1989; Howard and Matindi 2003; Foster and Harper 2007).

In 2005 biologists at the University of Antananarivo in Madagascar noticed that an unusual non-native decapod (the marbled crayfish or Marmorkrebs) was being sold at markets close to the capital by fishermen who had collected them locally. To date, the marbled crayfish has been found only in the vicinity of Ambohimangakely (Antananarivo), most commonly in rice fields (Jones et al. 2007). Marbled crayfish are likely to compete with native *Astacoides* species, and have the potential to transmit the crayfish plague, *Aphanomyces astaci* that is lethal to crayfish (Jones et al. 2006; Kawai et al. 2013; Feria and Faulkes 2011). Marbled crayfish grow rapidly, much faster than species of *Astacoides* (that are among the slowest growing of all crayfish) (Jones et al. 2007). Marbled crayfish also are six times more fecund than species of *Astacoides* and marbled crayfish can breed more than once per year, compared to *Astacoides* that breeds once a year (Jones et al. 2005). Because of

Table 3.7 Taxonomy and assessment information of Europe

Scientific name	IUCN Red List criteria	English name
Astacus astacus (Linnaeus, 1758)	Vulnerable	Noble Crayfish
Astacus leptodactylus Eschscholtz, 1823	Least concern	Narrow-clawed crayfish or Slender-clawed Crayfish
Astacus pachypus Rathke, 1837	Data deficient	Thick-clawed Crayfish
Austropotamobius torrentium (Schrank, 1803)	Data deficient	Stone Crayfish
Austropotamobius pallipes (Lereboullet, 1858)	Endangered	White-clawed Crayfish

these attributes, marbled crayfish have an immense potential to outcompete native crayfish and may even be able to outcompete Madagascar's endemic freshwater crabs (Cumberlidge et al. 2004). To date, marbled crayfish have not been found in the high altitude forested areas where *Astacoides* lives (Jones et al. 2007), but their present wild range overlaps with the distribution of several species of freshwater crabs.

3.21 Europe

3.21.1 Taxonomy and Conservation

Five indigenous species of astacid crayfish occur in European freshwaters (Table 3.7).

3.22 Distribution

Four European species, *Astacus astacus, A. leptodactylus*, *Austropotamobius pallipes*, and *A. torrentium* are heavily consumed for food and have long been translocated between Euopean countries and islands (Füreder et al. 2009). The range of *A. astacus* extends from Russia and Ukraine in the east, to Finland, Sweden, and Norway in the north, to Greece in the south, and the United Kingdom and France in the west. The occurrence of this species within Andorra, Cyprus, UK, Liechtenstein, Luxembourg, Morocco and possibly Montenegro and Italy, is probably the result of introductions from neighbouring countries (Kouba et al. 2014). *Astacus leptodactylus* is presently found in 32 countries (Holdich et al. 2009), including extensive areas in Russia and Ukraine (Kouba et al. 2014), and in southeast Europe including Bulgaria (Stoynov et al. 2013; Trichkova et al. 2013),

Romania (Györe et al. 2013), Serbia (Simić et al. 2008), and Croatia (Maguire 2009; Maguire and Gottstein-Matočec 2004; Maguire et al. 2011). *Astacus pachypus* is reported to occur in Azerbaijan, Kazakhstan, European Russia, and Ukraine (Holdich et al. 2009). *Austropotamobius pallipes* has a wide distribution throughout Europe (Holdich et al. 2009), with its western limits in Portugal (but it is now thought to be extinct there), its eastern limits in Montenegro, its southern limits in Spain, and its northern limits in Scotland. *Austropotamobius torrentium* is found in at least 20 countries in central and southeastern Europe (Holdich et al. 2009; Kouba et al. 2014) including Bosnia and Herzegovina (Trožić-Borovac 2011), Serbia, Montenegro (Simić et al. 2008), and Germany (Groß et al. 2008; Martin et al. 2008). It is likely that the populations of this species in England may have originally been introduced there from France (Kouba et al. 2014; Grandjean et al. 1997; Diéguez-Uribeondo et al. 2008), and that populations in Sardinia may also be the result of past introductions (Bertocchi et al. 2010).

3.23 Conservation

The IUCN Red List assesses 40 % of astacids as endangered with another 40 % being too poorly known to assess (Data Deficient). EU countries have a regional list of criteria for the designation of endangered species (the EU Habitat Directive) that has 6 criteria or levels (http://lhnet.org/eu-habitat-directive/). The EU Habitat Directive protocols assess 60 % of European astacid species as endangered species. *Austropotamobius torrentium* is Data Deficient according to the IUCN Red List, but it is an endangered species according to the EU Habitat Directive regional criteria Appendix V (animal and plant species of community interest whose capture in the wild and exploitation may be subject to management measures). This situation is complicated by the fact that *A. pallipes* may be a species complex formed by two distinct species, *A. pallipes* and *A. italicus* (Fratini et al. 2005) according to molecular analyses by Santucci et al. (1997), Grandjean et al. (2002), and Pedraza-Lara et al. (2010). Reports of the recent population and distribution trends of *Astacus pachypus* are considered here to be speculative (Kouba et al. 2014).

A number of European species of indigenous crayfish are in decline and there are growing concerns that unless there is concerted action to conserve them they will be progressively replaced by invasive non-indigenous crayfish species in most or all of their range (Peay and Füreder 2011; Tricarico et al. 2010; Weinländer and Füreder 2009). North American and Australian crayfish species have been introduced into European freshwaters since the end of the 19th century. For example, U.S. crayfish such as the spiny-cheek crayfish, *Orconectes limosus*, the signal crayfish, *Pacifastacus leniusculus*, and the red swamp crayfish, *Procambarus clarkii*, have all been introduced into European waters between 1890 and the mid-1970s. Similarly, Australian crayfish such as *Cherax destructor* and *C. quadricarinatus,* and North American crayfish such as *Orconectes immunis, O. limosus, O. juvenilis, O.* cf. *virilis, Procambarus* cf. *acutus,* have all been

recorded from European freshwaters (Füreder 2015). The Marmorkrebs or marbled crayfish (Scholtz et al. 2003) appears to be a hybrid that originated in captivity in aquaria in Germany and reproduces by parthenogenesis (virgin females produce fertile eggs without needing to mate with a male) which is the first time that this strategy has been reported for any decapod crustacean. The marbled crayfish was formally named as *Procambarus fallax* form *virginalis* (Martin et al. 2010). Rumors of the existence of the marbled crayfish first surfaced in online discussions by amateur aquarium enthusiasts, who were aware of an enigmatic crayfish species of unclear origin. Marbled crayfish were first sold by an aquarium shop in Germany in the mid-1990s (Vogt et al. 2004). Since then, reports of wild populations of marbled crayfish living in European freshwaters include Germany (Martin et al. 2010; Chucholl and Pfeiffer 2010; Chucholl et al. 2012), the Netherlands (Holdich and Pöckl 2007), Italy (Marzano et al. 2009), Sweden (Bohman et al. 2013), and Slovakia (Stloukal 2009).

3.24 Asia

3.24.1 Taxonomy and Conservation

3.25 Distribution

Large areas of Asia lack crayfish but there is a single genus *Cambaroides* that is native to the eastern corner of the continent in far-eastern Russia (ranging from the northern part of Sakhalin Island, the Amur River and the Ussuri River basin), the Korean Peninsula, northern China, Mongolia, and Hokkaido and northern Honshu in Japan (Kawai 2012; Kawai and Arai 2000; Kawai et al. 2015) (Table 3.8).

3.26 Conservation

The IUCN Red List shows that four species (*Cambaroides dauricus, C. japonicus*, *C. schrenckii, C. similis)* are too poorly known to assess (Data Deficient), and that two species (*C. wladiwostokensis* and *C. koshewnikowi*) have not been assessed (NA). However, the Government of Mongolia protects *C. dauricus* as an endangered species (Ministry for Nature and the Environment at Mongolia 1997), and The Environmental Agency and other official organizations of Japan have designed *C. japonicus* as an endangered species (Kawai and Fitzpatrick 2004). In Russia, *C. schrenckii* was listed as threatened in the Red Data book of the Sakhalin region in the Russian Federation (as *Cambaroides sachalinensis* Birstein and Vinogradow 1934, a junior synonym of *C. schrenckii*) (Kawai et al. 2013; Labay 2000). Populations of *Cambaroides wladivostokiensis* in Russia have been declining

Table 3.8 Taxonomy and assessment information of Asia

Scientific name	IUCN Red List criteria	Regional criteria	Russian name	Chinese name	Mongolian name	Japanese name	Korean name
Cambaroides dauricus (Pallas, 1773)	Data deficient		Daursky Rechnoy Rak	东北黑螯虾 Dōngběi hēi áo xiā or Rako (Changu-F and Chun-Lin 1959; Hart 1994) or dong bei la gu	Hafuchi (Ministry for Nature and the Environment at Mongolia 1997; Kawai and Arai 2000)		
Cambaroides japonicus (De Haan, 1841)	Data deficient			日本黑螯虾 Rìběn hēi áo xiā		Zarigani or Nihon-Zarigani (Kawai and Fitzpatrick 2004)	
Cambaroides similis (Koelbel, 1892)	Data deficient			朝鲜黑螯虾 Cháoxiǎn hēi áo xiā			Kajae (Kawai and Min 2005)
Cambaroides schrenckii (Kessler, 1874)	Data deficient			南京黑螯虾 Nánjīng hēi áo xiā			
Cambaroides wladiwostokensis Birstein and Winogradow, 1934		Endangered Species		海參崴黑螯虾 Hǎishēnwǎi hēi áo xiā			
Cambaroides koshewnikowi Birstein and Winogradow, 1934		Extinct					

Regional criteria based on Kawai et al (2015)

sharply over the past several decades due to habitat loss, particularly along the rivers flowing into the Peter the Great Bay which is where their main distribution lies (Barabanshchikov 2003; Marin 2013). *Cambaroides koshewnikowi* (Starobogatov 1995) is found in the Amur River delta, the Nikolaevsk-na-Amure estuary, and in the Tatar Strait where it lives in both fresh water and brackish water. However, there have been no records of *C. koshewnikowi* for the last 30 years and it may even be extinct (Kawai et al. 2015). In Korea, *C. similis* is ranked as a "monitored species", which means that this crayfish is a candidate for recognition as an endangered species (Kored 2015). The criteria used in the Korean red list protocols are evaluated and updated every 5 years based on monitoring. The most recent evaluation recognises *C. similis* as an endangered species (G. S. Min, personal communication). The IUCN Red List records all species of *Cambaroides* as Data Deficient (Richman et al. 2015), but recent research (Kawai and Takahata 2010; Labay 2000; present chapter) suggests that all species of *Cambaroides* might be threatened with extinction in their native ranges, and that one species may already be extinct. Clearly, conservation actions are urgently needed.

Interestingly, *C. schrenckii* has been illegally introduced by anglers into Russian freshwaters beyond its natural range since the 1970s, and has also been legally live-stocked in rivers and water reservoirs in and near Vladivostok (Barabanshchikov 2003; Kawai and Min 2005). Subsequently, the range of this species has expanded on its own following flooding and now includes rivers and reservoirs in the Bay of Peter the Great and in the eastern part of Primorye region as well as basins of the Ussuri River and Khanka Lake (Barabanshchikov 2003). In those areas where *C. schrenckii* is an alien species it has had a negative impact on native crayfishes such as *C. dauricus* and *C. wladivostokiensis* that are now endangered because their populations have drastically declined or have become locally extinct following contact with *C. schrenckii* (Barabanshchikov 2003).

Astacus leptodactylus Eschscholtz, 1823 is a large-sized species that is endemic to Europe and which impacts the European river ecosystems wherever it is found (Füreder 2015). In August 2012, this western European crayfish was reported from Siberia in far-eastern Russia (Kawai et al. 2015) which will probably become a new threat to the native ecosystems in Asia.

In 1997 KBS, a broadcasting company in South Korea, announced that the red swamp crayfish, *Procambarus clarkii* had been found for the first time in a lake in Yongsan Park, Seoul City. This crayfish population has now become well established in water bodies around Seoul and its distributional range is slowly increasing. Live individuals of *P. clarkii* are imported into Korea from other Asian countries and sold at pet shops in markets in major cities such as Seoul, and it is highly probable that some of these individuals have been released in the rivers around Seoul City (HS Ko, personal communication).

Two exotic species of crayfish, *P. clarkii* and *Pacifastacus leniusculus*, have been introduced into Japan. *Procambarus clarkii* was introduced into Kamakura City, Honshu on 12th May, 1927 by a private company (Kawai and Kobayashi 2006), and has since spread across the Japanese Archipelago. *Procambarus leniusculus* was released into Hokkaido Prefecture on 28th July, 1930, and was

subsequently released in Shiga Prefecture, on 4th November, 1927, by the Japanese Government (Kawai et al. 2003). Current localities of *P. leniusculus* are Hokkaido, Fukushima, Nagano, Chiba, Fukui, Shiga, where they are having a negative impact on native Japanese ecosystems (Nakata and Goshima 2003, 2006). In 2007, several individuals of the parthenogenetic marbled crayfish *Procambarus fallax* f. *virginalis* (Scholtz et al. 2003) were collected from Sapporo City, Hokkaido, Japan (Kawai and Takahata 2010). This is of concern because this parthenogenetic highly fecund macroinvertebrate has the portential to constitute a serious threat to freshwater systems in Japan, especially if it gains access to rice fields (Faulkes et al. 2012). So far, there have been no further records of the marbled crayfish in Japan.

It is likely that *P. clarkii* has not invaded the Primorye Territory in far-eastern Russia near to the border with China but this crayfish is intensively cultured by China in large ponds (Kawai et al. 2015).

3.27 Threats and Conservation Issues

Recent molecular studies have shown that several widespread species of crayfish (such as *Cambaroides japonicus* (Koizumi et al. 2012) and *Pacifastacus leniusculus* (Larson and Williams 2015) may be species complexes that include one or more cryptic species (Füreder 2015). The presence of possible cryptic new species is of concern to crayfish taxonomists and conservation specialists because the number of endangered species is likely to increase if some of the existing species prove to include cryptic new species with a small population and a narrow distribution.

The IUCN Red List is the most reliable source when seeking the conservation status of a species, but it needs to updated regularly every time new data on a species population levels, distributional ranges, or threats are collected. Richman et al. (2015) summarizes the results of a global conservation assessment of every species of crayfish known, and draws on the expertise of 23 crayfish specialists from a number of countries. The IUCN Red List includes data on the major global threats to species-rich geographical regions such as climate-change, logging, invasive species, disease, urban development, agriculture, dam management, harvesting, pollution, and human disturbance (Richman et al. 2015). However, the IUCN Red List contains many Data Deficient species that are often assessed as endangered when regional conservation protocols are applied. For example, all Asian cambaroid crayfishes are assessed as Data Deficient by the IUCN Red List, but all of them are assessed as endangered species (and one of these, *Cambaroides koshewnikowi*, may even be extinct).

Freshwater crayfish distribution globally is mostly in the temperate regions of the world (Fig. 3.1) where urbanization and agricultural exploitation are intense. Crayfish are aquatic animals that depend on permanent water sources and they reproduce by direct development rather than producing planktonic larval stages, and this adaptation alone contributes to their isolation, high speciation rate, and endemism. Gelder and Williams (2015) point out that crayfish have numerous kinds of

Fig. 3.2 Current distribution of the signal crayfish, *Pacifastacus leniusculus*

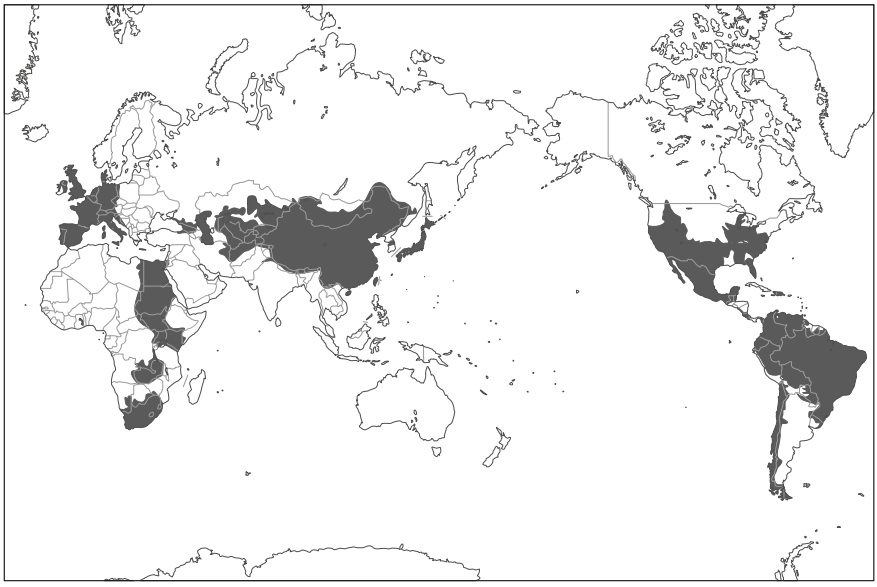

Fig. 3.3 Current distribution of the red swamp crayfish *Procambarus clarkii*

symbiontic organisms on their bodies that would also become extinct should crayfish species disappear. The introduction of alien crayfish species is prohibited in Oceania because non-native crayfish species particularly impact restricted-range endemic endangered species. Figures 3.2 and 3.3 show the native distributions of freshwater crayfish in Africa, Asia, Europe, and North, Central, and South America, as well as the expanding ranges of alien species such as *Procambarus clarkii* and *P. leniusculus* in Europe, Japan, Africa, and South America.

The native range of *P. clarkii* spans from northern Mexico to a number of states in the USA including Florida, Illinois, New Mexico, Oklahoma, Tennessee, and Texas. *Procambarus clarkii* has been widely introduced across the globe in the past 20 years not only to other states in the USA (Alabama, Arizona, Arkansas, California, Georgia, Hawaii, Idaho, Indiana, Maryland, North Carolina, Nevada, Ohio, Oregon, South Carolina, Utah, and Virginia, West Virginia), but also to Europe (Belgium, Cyprus, France, Germany, Italy, Majorca, The Netherlands, Portugal, Spain, Switzerland, United Kingdom), Central and South America (Belize, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, Venezuela), Africa (Egypt, Kenya, South Africa, South Sudan, Sudan, Uganda, Zambia, Zimbabwe), and Asia (China, Japan, Philippines, Taiwan) (Hobbs et al. 1989; Holdich 1999; Howard and Matindi. 2003; Foster and Harper 2007) (http://maps.iucnredlist.org/map.html?id=153877). Furthermore, recent studies have reported the presence of *P. clarkii* in Austria (Füreder 2015), Brazil (Amazon, Paraguay/Lower Parana River Basin, San Paolo) (Magalhães et al. 2005; Silva and Bueno 2005; Torres and Álvarez 2012), Mexico (Chiapas Region, Alvarez and Villalobos 2015), and South Korea (near Seoul City, Kawai pers. obs.).

Although the native range of *P. leniusculus* is well known in the western colder regions of North America, it is still not sufficiently understood in detail (Larson and Olden 2011, 2013; Martinez 2012). Given this provisio, *P. leniusculus* has been introduced into many countries well beyond its native range over the last century including Austria, Belgium, Czech Republic, Croatia, Cyprus, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Russian Federation (Europe), Slovenia, Slovakia, Spain, Sweden, Switzerland, and the United Kingdom (Füreder 2015; Hefti and Stucki 2006), as well as in Japan (Kawai and Takahata 2010), and some of the U.S. western states including California, Nevada, and Utah. The areas where the distributions of alien crayfishes overlap and co-exist are noticeably expanding.

Other North American cambarid species (*Orconectes immunis, O. juvenilis, O. limosus, O.* cf. *virilis, Procambarus* cf. *acutus, P. fallax* f. *virginalis*), and Australian parastacid species (*Cherax destructor,* and *C. quadricarinatus*) have been introduced into Europe and *Orconectes virilis* and *Cherax quadricarinatus* have been introduced into Central America. Populations of Australian parastacids *Cherax destructor, C. quadricarinatus, C. tenuimanus,* and the North American cambarid *P. clarkii* are have become established in many parts of continental Africa, and the parthenogenetic marbled crayfish *P. fallax* f. *virginalis* is established and is spreading in Madagascar. The parthenogenetic marbled crayfish represents a new threat for global crayfish conservation because this alien species outcompetes native

crayfish and has the potential to transmit crayfish plague (Jimenez and Faulkes 2010; Jones et al. 2007; Kawai and Takahata 2010; Feria and Faulkes 2011).

3.28 Conclusion

1. Freshwater crayfish are mainly distributed in the temperate parts of the southern and northern hemispheres, although there is a significant difference in the species richness among geographical regions. The most species rich area is found in the USA and Mexico, east of the Rocky Mountains, with 432 species represented by 11 genera one family (Cambaridae) while the most species-poor region is far-east Asia with only 6 species in a single genus, *Cambaroides*.
2. All members of Astacoidea can construct burrows, which is probably an apomorphic adaptation for life in freshwater.
3. The conservation status of all crayfish species worldwide has been assessed using the IUCN Red List protocols as well as by regional governmental red data lists. It is clear that there are a significant number of species that are threatened with extinction: 22.1 % of Cambaridae in Canada and the USA, 40 % of American Astacidae, 29.3 % of American Cambaridae (in Mexico and Central America), 69.2 % of South American Parastacidae, 34 % of Oceanian Parastacidae, 28.6 % of Madagascan Parastacidae, 40 % of European Astacidae, and 100 % of Asian Cambaridae (Table 3.9).
4. The present range of two alien crayfishes, *Pacifastacus leniusculus* and *Procambarus clarkii,* has been updated here. The distributional ranges of these two species are spreading in Asia, Africa, South America, and Europe and their impact on the native ecosystems and native species of crayfishes is becoming of increasing global concern. The new threat presented by the exotic

Table 3.9 Summary of the 2010 IUCN Red List and regional red list of freshwater crayfish (data: Kawai et al. 2015)

	Total of species number	Data deficient	IUCN endanger species[a]	Update based on local red list
Atlantic side of North America	371	86	53	55
Pacific side of North America	4	1	1	
Middle America	59	17	18	18
South America	13	10	1	6
Oceania	153	12	62	
Africa	7	4	2	
Europe	5	2	2	3
Asia	6	4	0	6

[a]Endangered species according to the following categories; "Vulnerable, Endangered, Critically Endangered, Extinct in the wild, and Extinct" and not endangered species "Least Concern, and Near Threatened". "Not Evaluated and Data Deficient"

parthenogenetic marbled crayfish, *Procambarus fallax* f. *virginalis* which was first found in European aquaria, has now been reported living in wild populations in Europe, Madagascar, and Asia (only one record).

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