Taxonomy, distribution and ecology of the Setose Yabby, *Cherax setosus* (Riek, 1951)

Robert B. McCormack and Jason Coughran

Abstract.— Although it occurs near one of Australia's largest cities, there is a remarkable lack of information on the Setose Yabby, *Cherax setosus*. The morphology of the species has never been thoroughly described, and basic information on its distribution and ecology is required. In this paper, we give a thorough redescription of the species and present data on its distribution, habitat and general biology. *Cherax setosus* is a medium-sized crayfish with a lowland, coastal distribution extending from just south of Taree to just north of Morisset in eastern New South Wales, a northeast-southwest distance of approximately 150km. The species is rarely found in permanent aquatic habitats in the area, but builds extensive burrow networks in minor, ephemeral habitats such as gullies, roadside ditches, stump holes, swamps and pastures. Although it appears to be relatively common across its range, the species may be susceptible to impacts such as reproductive interference with the translocated crayfish *C. destructor* and predation on juveniles by the introduced plague minnow, *Gambusia holbrooki*.

Introduction

Cherax setosus (Riek, 1951) (Fig. 1) was originally described by Riek (1951) as a subspecies of *Cherax rotundus* Clark, 1941, and was later reclassified by Austin (1986) as a subspecies of *C. destructor* Clark, 1936. The taxonomic position of the species has also been discussed by various other authors (Riek, 1969; Sokol, 1988; Austin, 1996; Lawrence *et*

al., 1998, 2002a). Most recently, however, and using modern genetic techniques, Austin *et al.* (2003) and Munasinghe *et al.* (2004) have confirmed that full specific rank is warranted.

Although *C. setosus* is known from a few sites near Newcastle (New South Wales), one of Australia's largest cities, little is known about the species. Lawrence *et al.* (2002b) described the habitat at one site where the species was collected for laboratory studies, but after subsequent highway construction that site no longer exists (Lawrence *et al.*, 2002b). The laboratory studies did, however, identify a potentially important role for *C. setosus* in the aquaculture industry. Although not commonly farmed itself, the species can be crossed with the Victorian 'albidus' strain of *Cherax destructor* to produce sterile, all-male hybrid offspring with increased vigor (Lawrence *et al.*, 1998, 2000).

Despite this aquaculture interest, *C. setosus* has remained poorly understood and, consequently, there are no specific management measures in place at present. A detailed description of the species is still lacking, and virtually nothing has been published on its biology or ecology. These research gaps on *C. setosus* are clearly inadequate given its apparent restriction to a rapidly developing area. Another current concern is that the translocated yabby species *C. destructor* is becoming widely established across eastern New South Wales (Coughran *et al.*, 2009) and may threaten the endemic aquatic fauna, including the endemic yabby *C. setosus*. It is therefore imperative that these fundamental research gaps on *C. setosus* are addressed.

To facilitate future research and

Fig. 1. The Setose Yabby, *Cherax setosus* (Riek, 1951). Photograph of large male specimen (39.65 mm OCL, 37 gram, ACP 2646). The distinctive patch of setae extending across the outer half of the ventral surface of the propodus (inset) is a reliable feature to readily distinguish the species in the field. In particular, the invading yabby *C. destructor* Clark, 1936 lacks this feature.

management initiatives, we provide a detailed morphological description of *Cherax setosus*, record general information about its distribution and ecology, and discuss conservation and management considerations.

Materials and Methods

Crayfish surveys were undertaken as part of both the broad Australian Crayfish Project (ACP) and a targeted sub-project on *Cherax setosus* (Project #100045, Australian Aquatic Biological 2008). Site co-ordinates and altitude were recorded using a Magellan Explorist 600 handheld GPS. Crayfish were collected using a variety of methods to suit the conditions at each survey site. Because *Cherax setosus* inhabits ephemeral habitats, the use of traps was largely restricted to periods following storm events, when ephemeral sites contained sufficient water depth for the physical trap dimensions. At some very shallow sites, a spade was used to

remove ~50mm of substrate to allow for a trap to be set with the entrance holes below the waterline. Traps were set for up to one hour, or left overnight and checked the following morning. Both opera house traps (630mm x 470mm x 180mm, 90mm entrance hole) and box traps (430mm x 260mm x 260mm, 40mm entrance hole) were used, with a variety of baits including assorted meats, fish, dried dog biscuits and wet dog food sausage.

Spotlight surveys were undertaken at some sites but yielded a limited number of specimens, and were generally found to be unproductive. Scoop nets were used to sample some sites that held sufficient water. At sites with insufficient water for other methods, manual excavation of burrows with a spade or trenching tool was required to retrieve animals.

Voucher material was retained where appropriate, and all retained specimens were placed in transport containers with a small amount of water and some vegetation

Fig. 2. Distribution of the Setose Yabby, *Cherax setosus* (Riek, 1951), indicated with black circles. Translocated populations of *C. destructor* Clark, 1936 are depicted with an 'X'. Rivers, lakes and wetlands are shaded grey.

from the site and returned to the laboratory. Specimens were then euthanized by freezing for at least 24 hours and subsequently stored in clear, labelled specimen jars containing 70% ethanol. Tissue samples were retained in cell lysis buffer from selected specimens for subsequent DNA analysis, as part of the broader ACP.

Voucher material was compared with specimens of two similar taxa from Queensland and Victoria (O'Brien *et al.*, 2009; McCormack and Raadik, unpublished data), and with specimens of the inland species *Cherax destructor*. A thorough morphological description was prepared for *C. setosus* based on this retained voucher material and the type material, held at the Australian Museum. Measurements of Propodal Length (PL), Propodal Width (PW), Total Carapace Length (TL) and Ocular Carapace Length (OCL) were made using

digital Vernier callipers. Other abbreviations include: AM, Australian Museum; NSW, New South Wales.

Results

Distribution and Biology

Specimens of *C. setosus* were recorded from numerous sites in lowland (<200m a.s.l.), coastal habitats between Taree and Morisset (Fig. 2), a northeast-southwest distance of around 150km. The main drainage basins within that range are the Hunter, Karuah and Myall Rivers. Its distribution penetrates inland to areas near Cessnock and Singleton, although it appears to be present in much lower densities in these inland areas. We determined the overall extent of occurrence (EOO) for the species in this study to be approximately 5,800km², the third largest distribution of all *Cherax* species

found in New South Wales.

Taxonomic Description

Cherax setosus (Riek 1951)

(Figs. 1 and 3)

HOLOTYPE: AM P4739, Male (OCL 34.35mm), Booral, Karuah River, Port Stephens, NSW (32°29'S 151°58'E), collected by D.G. Stead, 10th November 1911. **PARATYPE:** AM P4740, Male (OCL 31.63mm), Booral, Karuah River, Port Stephens, NSW (32°29'S 151°58'E), collected by D. G. Stead, 10th November 1911. **TOPOTYPES:** AM P4741, 2 Males (OCL 12.38-18.76mm), 2 Females (OCL 16.25-18.62mm), Booral, Karuah River, Port Stephens, NSW (32°29'S 151°58'E), collected by D.G. Stead, 10th November 1911.

Other Material Examined.— AM P4675, 2 Females (OCL 19.69-21.66mm), creek near Newcastle, NSW (32°56'S 151°46'E), collected by D.G. Stead, May 1907. AM P72105, Male, OCL 39.43mm, Tea Gardens, NSW (32°40'S 152°10'E), collector unspecified, February, 1977. AM P16819, 3 Males (OCL 26.42-32.32mm), 7 Females (OCL 23.23-35.14mm), from burrows in side of dam, Pokolbin (10 miles west of Cessnock), Hunter Valley, NSW (32°48'S 151°17'E), 1 with young, collected by D. Beeman, 1st February 1969. ACP 513, Male (OCL 37.88mm), Swan Bay, NSW (32.66°S 151.89°E), collected by R.B. McCormack, 22nd December 2006. ACP 514, Male (OCL 47.3mm), Pindimar, NSW (32.62°S 151.08°E), collected by R.B. McCormack, 22nd December 2006. ACP 759, Male (OCL 40.37mm), below weigh station, eastern side of highway, Wallaroo SF, NSW (32.66°S 151.85°E), collected by R.B. McCormack, T. McCormack and J. Moylan, 13th May 2007. ACP 821, Female (OCL 35.01mm), J. Renshaw Drive, Trib Buttai Creek, NSW (32.82°S 151.54°E), collected by R.B. McCormack, 13th September 2007. ACP 938, Male (OCL 46.08mm), tributary of Bundabah Ck, Pindimar, NSW (32.63°S 152.09°E), collected by R.B. McCormack and N. Meyrick, 9th December 2007. ACP 1545, Male (OCL 33.1mm), Eagleton Rd, Columbey

National Park, NSW (32.39°S 151.73°E), collected by R.B. McCormack, 23rd November 2008. ACP 1572, Male (OCL 25.66mm), corner Blackhill Rd and J Renshaw Dr, NSW (32.82°S 151.58°E), collected by R.B. McCormack, 28th November 2008. ACP 1577, Female (OCL 30.15mm), Swamp Creek, Neath, NSW (32.82°S 151.42°E), collected by R.B. McCormack, 28th November 2008. ACP 1582, Male (OCL 33.01mm), Vincent St, Cessnock, NSW (32.85°S 151.35°E), collected by R.B. McCormack, 28th November 2008. ACP 1601, Female (OCL 36.33mm), drain along Mt Faulk Rd, NSW (32.03°S 151.46°E), carrying eggs, collected by R.B. McCormack, 28th November 2008. ACP 1637, Male (OCL 24.92mm), Stoney Ck, Blackalls Park, NSW (33.00°S 151.56°E), collected by R.B. McCormack, 2nd December 2008. ACP 2153, Male (OCL 43.15mm), Swamp, Old Swan Bay Rd, Wallaroo State Forest, NSW (32.67°S 151.89°E), collected by R.B. McCormack, 24th June 2009. ACP 2154, Male (OCL 43.16mm), Swamp, Old Swan Bay Rd, Wallaroo State Forest, NSW (32.67°S 151.89°E), collected by R.B. McCormack, 24th June 2009. ACP 2156, Male (OCL 40.00mm), Swamp, Old Swan Bay Rd, Wallaroo State Forest, NSW (32.67°S 151.89°E), collected by R.B. McCormack, 24th June 2009. ACP 2157, Male (OCL 46.58mm), Swamp, Old Swan Bay Rd, Wallaroo State Forest, NSW (32.67°S 151.89°E), collected by R.B. McCormack, 24th June 2009. ACP 2158, Male (OCL 43.88mm), Swamp, Old Swan Bay Rd, Wallaroo State Forest, NSW (32.67°S 151.89°E), collected by R.B. McCormack, 24th June 2009. ACP 2166, Male (OCL 39.12mm), tributary of Reedy Creek, Wallaroo State Forest, NSW (32.64°S 151.91°E), collected by R.B. McCormack, 24th June 2009. ACP 2434, Male (OCL 29.90mm), Standen Drive, Branxton, NSW (32.66°S 151.31°E), collected by R.B. McCormack, 29th September 2009. ACP 2646, Male (OCL 39.65mm), Swamp off Haynes Rd, Wallaroo State Forest, NSW (32.66°S 151.88°E), collected by R.B. McCormack, 19th January 2010 (Figures 1, 3). ACP 2675, Female (OCL 30.22mm), Cook Dr, Swan Bay, NSW (32.66°S 151.90°E), carrying eggs,

Fig. 3. Photographs of preserved large male specimen, ACP2646: whole animal (upper), sternal keel (left lower) and chela (right lower).

collected by R.B. McCormack, 27th January 2010.

Diagnosis.— Rostrum broad and short (Fig. 3), reaching to base or middle of 3rd antennal segment, apex with small blunt acumen spine. Rostral carinae raised and smooth, lacking marginal spines and terminating in a rounded boss. Dorsal surface of cephalon smooth, lacking any development of a median carina. Post-orbital ridges distinct, with or without a small spine at anterior end. Antennal squame inflated distal to midlength. Suborbital spine small to tiny. Interantennal spine broader than long. Areola narrow, approximately 13.5 times as long as wide at narrowest point, positioned towards anterior end. Dactylus

lacking any development of marginal spines at base. Lateral and dorsal surface of propodus punctuated, lateral margin curved and fully calcified. 6-11 mesial propodal spines, only extending anteriorly to around 80% of propodal palm length. Distinct patch of setation extending across much of ventral propodal surface. 1 large, broad and hooked mesial carpal spine. Sternal keel deeply excavated between lateral processes to the first and second pereopods, resulting in a spine-like projection at the first pereopods. Lateral processes to the 5th pereopods fused directly together, with no development of any additional calcified plate or spine.

Rostrum.— Rostrum broad and short,

extending to base or near midlength of 3rd antennal segment, generally $0.23 \times \text{OCL}$ and gently curved downward. Apex of rostrum blunt and flat with small, blunt, upturned spine covered with a tuft of long setae. Rostral carinae slightly raised, smooth, lightly setose along base, and just reaching beyond anterior end of postorbital ridge. Carinae lacking spines at apex, terminating in smooth rounded boss. Intercarinate region broad, smooth, slightly convex, punctuated and lightly to moderately setose.

Cephalon.— Dorsal surface of cephalon smooth, lacking any development of a median carina. Post-orbital ridges distinct, with or without a small, blunt to sharp spine at anterior end, and with a rounded bump posteriorly. Postorbital ridge length approximately $0.24 \times \text{OCL}$. Antennal squame short, around $0.16 \times \text{OCL}$, extending to just posterior of rostrum apex; widest point of inflation distal to midlength. Squame generally lacking marginal spines (3 specimens with twin spines towards apex on one side only) and terminating in short, sharp, conical spine. Suborbital spine small, generally sharp and pointed forward. Cephalon moderately to densely punctuated dorsally, with light setation and tubercles on lateral surfaces. Basipodite antennal spine present, generally small (in many cases just a stub) but on some specimens very large, sharp and curved. Coxopodite spines present, generally with at least 1 large spine and one or 2 smaller spines. Interantennal spine distinctive and very broad in shape (1.15 times as wide as long) with a serrated, toothed, raised margin bearing twin, small, sharp spines at apex, central area generally smooth and swollen in the very centre. Antennal flagella long, approximately $1.86 \times \text{OCL}$, extending to start of sixth abdominal somite.

Thorax.— Areola extremely narrow anteriorly, gradually increasing in width posteriorly. Areola length usually around $13.5 \times$ width at narrowest point (specimens from the upper Hunter region have a broader areola, length $\sim 8.5 \times$ width), with the narrowest point situated closer to the cephalon. Cervical and branchiocardiac grooves deeply impressed; small tubercles

common along groove laterally, occasionally with 1-2 small, sharp spines. Carapace moderately to densely punctate along dorsal surface. Setose tubercles along lateral sides, sprouting single or double short, bristly setae.

Abdomen.— Abdomen length on average $1.4 \times \text{OCL}$. Somites with light punctuation dorsally and light setation laterally.

Tailfan.— Telson U-shaped with small, sharp, broad spine near midlength of each lateral margin (many specimens with 2 spines one side). Dorsal surface of telson with punctuations anteriorly, and setose tubercles posteriorly. Posterior membranous section with moderate setation. Uropods longer than telson, and outer rami marginally longer than inner rami. Inner rami lightly setose and each having one large, sharp spine at caudolateral corner and a longitudinal median carina terminating in a large, sharp, upturned central spine. Outer rami lightly setose, each having one spine at caudolateral corner on dorsal surface and a longitudinal median carina terminating in one small to medium, sharp, slightly upturned spine. Transverse suture on dorsal surface of outer rami relatively straight with 11-23 spines along the lateral three quarters of its width. On ventral surface, suture smooth along its length until terminating laterally in a distinct, sharp spine (additional to, and larger than, the caudolateral spine). Posterior margin of tailfan moderately setose.

Keel.— Sternal keel deeply excavated between lateral processes to the 1st and 2nd pereopods, the excavation leaving a spine-like projection at the base of the 1st pereopods. Keel raised and sharp between the lateral processes to the second and fourth pereopods, apart from a distinct notch just posterior to the lateral processes to the 3rd pereopods. Lateral processes to the 5th pereopods separate from keel and fused directly together, with no development of any additional calcified plate or spine.

Propodus.— Propodus stout, twice as long as wide. Mesial propodal margin very distinct, starting as a rolled ridge at carpal articulation and progressing to 6-11 mesial propodal spines. Mesial spines increasing in size anteriorly towards midlength of mesial margin, thereafter decreasing in size

to approximately 80% of mesial propodal margin. Anterior section of mesial margin smooth, apart from development of a spine-like projection at terminus. Apex of propodus sharp, pointed and curved inward, with numerous small teeth extending to dactylar articulation. One large, distinctive tooth offset ventrally from all others. Lateral propodal margin smooth and completely calcified. Dorsal propodal surface with light punctuations increasing in size and number laterally, and a light mottling pattern noticeable on live animals. Setation present along dorsal propodal surface along base of mesial propodal spine ridge. Longer and sparser setae present along dorsal cutting edge of propodal finger. Very distinctive patch of long, dense setae extending across much of ventral propodal surface (Figure 1 inset).

Dactylus.— Apex of dactylus pointed, sharp and strongly incurved. Anterior third of dactylus usually lacking teeth, posterior two thirds containing numerous teeth extending to dactylar articulation. One large tooth offset ventrally from all others. Long setae present ventrally along length of cutting edge, and less developed on dorsal surface with just a touch of setation along dorsal cutting edge near articulation. No mesial dactylar basal spines.

Carpus.— Only 1 large, very broad mesial carpal spine. 1 large ventral carpal spine. Usually 2 – 3 small to medium ventromesial spines with broad bases that occasionally fuse into a raised ridge. Light to moderate setation at propodal articulation.

Merus.— Dorsal surface of merus generally smooth, with 3-13 small, blunt spines or raised lumps (generally only the anterior-most spine properly developed). Setation absent.

Colouration.— Colour varies greatly with populations. There are two common colours, green or brown with a blue tinge, and two less common colours, a bright blue and a very deep blue that is almost black. On most specimens there is an orange tinge to the tip of the claws and the ventral edge of the chelae, and an orange to red colouration in the joints. Ventrally, crayfish are light cream in colour. These crayfish do not have a prominent mottling pattern on their claws like *Cherax destructor*. The mottling pattern

that is present is very subtle and hard to see on most specimens, depending on the colour variety.

Sexes.— Although we have not recorded quantitative reproductive data, our general field observations suggest that *C. setosus* is a relatively prolific species that breeds in summer, commencing around the start of September and continuing until April. It would also appear that a large proportion of all adult females breed, at least once per year (some observations suggest a small proportion breed more than once per year). Clutch size for breeding females usually ranges from approximately 70 to 300 eggs. Interestingly, no intersex specimens have yet been recorded for this species.

Size.— The largest specimens in the ACP collection reach a maximum weight of 64g, and a maximum length of 46.58mm OCL (ACP 938 and 2157). However, during surveys for this species by the senior author in the 1980s, larger specimens were recorded, with a maximum weight of up to 95g for males and just below 80g for females. Females above 20g are generally reproductively mature.

Discussion

Distribution and Biology

Cherax setosus was collected from ephemeral creeks, streams, swamps, wetlands and depressions in the ground (Fig. 4). Roadside drains that channel small flows also provide an important habitat for this species. Rainfall is relatively high in this coastal area, and any low-lying area that receives ephemeral water provides a potential habitat for this species. At many sites, the species was recorded in cleared paddocks, lawns or vehicle wheel ruts. The species constructs extensive burrows along the water's edge, with multiple entrance holes and multiple corridors and chambers. Burrows were often capped with clay in dry conditions, presumably to limit moisture loss.

Few specimens were collected from habitats in permanent water, despite considerable sampling effort. However, crayfish were occasionally found taking up

Fig. 4. Examples of *C. setosus* habitats and burrows (clockwise from top right): rural drainage ditch; burrows in drainage ditch; burrow plugged with clay; semi-permanent, shallow lagoon; swamp; roadside puddles; burrows along water's edge in vehicle wheel rut (above); vehicle wheel rut.

temporary residence (i.e., without burrows) under debris along the banks of permanent

streams following storm events. On one occasion following a major storm event, the species was also recorded from an estuary.

More commonly, specimens were found in isolated puddles after the water had receded from temporarily flooded land areas. It is conceivable that the species takes advantage of flood conditions to disperse along drainage lines and overland. Sampling indicated that eels were common in habitats with permanent water, and the presence of a large predator such as this may influence the distribution of *C. setosus*. Crayfish were not captured from any sites at which eels were observed.

This species was reproductively active during the warmer months, from September to March. Eggs are large and tan to dark burgundy in colour, and clutches that were counted typically contained 70-300 eggs. Based on observations of captive females by the senior author, development takes around eight to 10 weeks from fresh-laid eggs to release of juveniles. Females that have been retained in captivity have bred two or three times per year, and two different breeding periods were also identified in the wild during our surveys: a primary breeding phase during which most females carried clutches (Sep-Dec), and a secondary phase during which a small proportion of females carried clutches (Jan-Mar). White tail disease, burn spot disease and ectocommensals were commonly observed.

Our trapping data indicate that *C. setosus* are nocturnally active, and we also observed animals actively wandering in aquatic habitats searching for food. Animals were occasionally active during the day at sites with deeper water (~200mm), or where the water was turbid or contained dense weed habitats. Provided surface water was present, animals could be readily enticed from their burrows with baits during the day or night. This species actively hunts live food, and during spotlight surveys crayfish were observed feeding on tadpoles, frogs, earth worms, shrimp and fish. *Cherax setosus* co-occurs with several other crayfish species, including *Euastacus reductus* Riek, 1969, *E. spinifer* (Heller, 1865), a currently undescribed species of *Gramastacus*, and a translocated pest species, *C. destructor*.

Conservation Status

At 5,800km², the overall EOO for this

species can be considered as restricted. However, although there are no specific data on its environmental tolerance, its persistence in cleared agricultural areas, roadside ditches and private lawns suggests that it is generally tolerant of anthropogenic impacts. Given that it occurs in ephemeral habitats, which are often filled, drained or concreted in urban areas, it may be susceptible to urban development. Indeed, the species has not been recorded from some major urban areas, but it is otherwise common and locally abundant across its range. There is no indication that the species has been, or may be, in decline, and under current IUCN criteria (IUCN SPWG, 2008) it is assessed as 'Least Concern'.

However, the species may be susceptible to reproductive interference from the translocated *C. destructor*. This inland species has recently become established at numerous sites across coastal New South Wales (Coughran *et al.*, 2009), including five known sites within the distribution of *C. setosus* (Figure 2). The five sites include two forestry dams, two proximal sites in a creek/drain system, and one site where *C. destructor* was collected in vehicle wheel ruts. Cross-breeding experiments between *C. setosus* and various strains of *C. destructor* have resulted in sterile, all-male hybrid off-spring (Lawrence *et al.*, 1998, 2000), and the establishment of *C. destructor* within the distribution of *C. setosus* is therefore of considerable concern. These sites of establishment need to be closely monitored, and the feasibility of eradicating the translocated *C. destructor* should be assessed. *Cherax destructor* has also become established at several sites in the area immediately surrounding the distribution of *C. setosus*, to the north (north of Taree), south (south of Morisset) and west (south of Singleton and Muswellbrook). Education programs should be initiated in an attempt to prevent further introductions of *C. destructor* outside its natural range.

The plague minnow *Gambusia holbrooki* (Girard, 1859) is prevalent throughout the distribution of *C. setosus*, and may be impacting on juveniles. Plague minnows develop extremely dense aggregations in the shallow, ephemeral habitats that *C. setosus*

occurs in, and use the larger burrows of adult crayfish as refuges during drying events: it is not uncommon when excavating burrows at sites lacking surface water to find plague minnows surviving in the sub-surface burrow water, awaiting the next rainfall event. Plague minnows have had detrimental impacts on a range of Australian aquatic fauna (NSW NPWS, 2003; Pyke, 2005), and research into the impacts of this exotic fish on *C. setosus* is recommended.

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Addresses: (RBM) Australian Crayfish Project, c/- Australian Aquatic Biological Pty Ltd, P.O. Box 3, Karuah, NSW, Australia, 2324.; (JC) Environmental Futures Centre, Griffith School of Environment, Gold Coast Campus, Griffith University, Queensland, Australia, 4222.

E-mail: (RBM) rob@aabio.com.au; (JC) j.coughran@griffith.edu.au

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