

DISTRIBUTION AND CONSERVATION STATUS OF TWO ENDEMIC TASMANIAN CRUSTACEANS, *ALLANASPIDES HICKMANI* AND *ALLANASPIDES HELONOMUS* (SYNCARIDA: ANASPIDIDAE)

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(with one text-figure, three plates and three tables)

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Extant representatives of the ancient crustacean family Anaspididae (Syncarida) are restricted to the island state of Tasmania, Australia. The most recently described species, *Allanaspides helonomus* Swain, Wilson, Hickman & Ong, 1970 and *A. hickmani* Swain, Wilson & Ong, 1971, were described from buttongrass moorland in southwestern Tasmania. Large areas of their habitat were subsequently inundated for hydroelectric power generation. We surveyed the extant distributions of *A. hickmani* and *A. helonomus*, assessed potential threats to the species, and reviewed their conservation status against state, national and international criteria. *A. hickmani* is restricted to a single catchment and occurs in a very small number (<10) of highly fragmented subpopulations on the margins of two hydroelectric impoundments. *A. helonomus* has a substantially larger range and Area of Occupancy spanning three separate catchments, and is now known to also occur in the Lake Pedder hydro-electric impoundment. Both species are listed as vulnerable on the IUCN Red List. This listing appears warranted for *A. hickmani* based on its restricted Area of Occupancy and the small number of extant subpopulations. However, *A. helonomus* no longer appears to fulfil the IUCN criterion for vulnerable. Neither species appears to be eligible for listing as vulnerable under the Australian *Environment Protection and Biodiversity Conservation Act 1999* and the Tasmanian *Threatened Species Protection Act 1995*. The current listing of *A. hickmani* as rare under the Tasmanian *Threatened Species Protection Act 1995* appears warranted as extant subpopulations may be at risk of extinction. The level of risk for *A. helonomus* is considerably lower than is the case for *A. hickmani*, and *A. helonomus* may not be eligible for listing as rare. The potential impacts of climate change on buttongrass moorland may present the most serious long-term threat to the two *Allanaspides* species.

Key Words: threatened species, IUCN Red List, EPBC, impoundments, climate change, buttongrass moorland, Tasmania, *Allanaspides hickmani*, *Allanaspides helonomus*

INTRODUCTION

The superorder Syncarida is a group of small to minute crustaceans known to have existed as early as the Carboniferous period (Schram 1984, 2003). Syncarids were known only from fossil representatives for some 45 years before the first living representative, the “shrimp-like” *Anaspides tasmaniae* Thomson, 1892 (Anaspididae), was discovered living in mountain pools in Tasmania (Schram 1984). A further two extant genera in the Anaspididae (*Paranaspides* and *Allanaspides*) have since been described from Tasmania, including *Allanaspides helonomus* Swain, Wilson, Hickman & Ong, 1970 (Marsh Pygmy Shrimp) and *A. hickmani* Swain, Wilson & Ong, 1971 (Hickman’s Pygmy Shrimp). All extant representatives of the Anaspididae bear a close resemblance to the fossil syncarids, and can be regarded as “living fossils” (Schram & Hessler 1984, Dawson 2003).

The two species of *Allanaspides* are of particular conservation concern because both have limited distributions and both have lost a large proportion of their original range as a result of inundation for hydroelectric power generation (Driessen *et al.* 2006). In 1986, both species were listed as vulnerable on the International Union for Conservation of Nature (IUCN) Red List. Neither species is listed under the Australian *Environment Protection and*

Biodiversity Conservation Act 1999 (EPBCA). However, in 1995 *A. hickmani* was listed as rare under the Tasmanian *Threatened Species Protection Act 1995* (TSPA).

The two *Allanaspides* species are similar in general appearance and size (≤15 mm in length), but differ in the shape and colouration of the unique ion-exchange organ (fenestra dorsalis) found on the cephalothorax of both species. Both *A. hickmani* and *A. helonomus* have adopted a semelparous life cycle lasting around 14–15 months and with little overlap in generations (Swain 2000, Driessen & Mallick 2007). Juveniles first begin to appear around late February (late summer) and reach sexual maturity several months later. Reproduction and egg-laying occur from around June onwards, with eggs apparently remaining dormant over the summer months (December to February) until hatching the following year (Driessen & Mallick 2007). For both species of *Allanaspides*, the survival of eggs over the dry summer months is of critical importance for populations to survive and persist into the following year.

Both *Allanaspides* species were first recorded in pools in buttongrass moorland within the Gordon River and Serpentine River drainage systems prior to inundation of the two valleys for hydroelectric power generation (Swain *et al.* 1970, 1971). The flooding created a new impoundment, Lake Gordon, and it greatly enlarged the

pre-existing Lake Pedder. The two species are thought to have evolved in adjacent catchments during the Quaternary from a common lake-dwelling ancestor (Knott 1975). *A. hickmani* was first recorded from McPartlan Pass (which straddles the lowest point in the catchment divide between Lake Gordon and Lake Pedder, pl. 1), and at Trappes Inlet (subsequently inundated by the Lake Pedder impoundment) (Swain *et al.* 1970, 1971, R. Swain unpublished data; fig. 1). Post-inundation surveys for *Allanaspides* by Horwitz (1988, 1989) located a single additional population of *A. hickmani* at Coronation Bay on the western shore of Lake Pedder (fig. 1).

Allanaspides helonomus was first recorded from a site (now inundated) near the original Lake Pedder within the Serpentine drainage system, with a second record from McPartlan Pass on the Lake Gordon side of the catchment divide (Swain *et al.* 1970). Post-inundation surveys by Horwitz (1988, 1989) located *A. helonomus* at several additional locations around the margins of Lake Pedder and at a site in the Crossing Plains area which is located in the Port Davey catchment to the south of Lake Pedder (fig. 1). Neither *A. helonomus* or *A. hickmani* were recorded in crayfish burrows or moorland pools during freshwater invertebrate surveys of the lower Gordon River, Denison and Olga River plains and Rookery Plains (Richardson & Swain 1978). *Allanaspides* species are commonly found in small pools, often less than 2 m in diameter and only a few centimetres deep, in buttongrass moorlands. It has been assumed that both *Allanaspides* species are obligatory pool-dwellers which do not occur in lake-waters (Horwitz 1990, Driessen *et al.* 2006). Surveys of the macro-invertebrate fauna of the original Lake Pedder (Bayly *et al.* 1966) and of nearby Lake Edgar (Knott & Lake 1974) prior to their inundation failed to record the presence of *Allanaspides*. Invertebrate surveys of both the Lake Pedder and Lake Gordon impoundments have also failed to record either *Allanaspides* species (Lake 2001, M. Driessen unpublished data). However, a number of *A. helonomus* were collected in 1997 during a diving survey at a depth of 24 m in the channel between Sprent Basin and Bell Basin in Lake Pedder (Nigel Forteach, pers. comm.) (fig. 1). Although this information and a photograph of a specimen were forwarded to the Tasmanian Inland Fisheries Service at the time, we did not become aware of this observation until November 2008 when a slide of the *A. helonomus* specimen was given to one of the authors (MD).

Here, we review the conservation status of *A. hickmani* and *A. helonomus* at international, national and state scales. This review is based on recent distributional surveys for both species and an assessment of potential threats.

MATERIALS AND METHODS

Allanaspides searches in buttongrass moorland

Areas of *Allanaspides* habitat to be searched were identified using 1:25,000 topographical maps and knowledge of the

vegetation and topography of the area. Potential habitat included areas of flat or gently sloping (slope ≤ 5 degrees) buttongrass moorland which contained standing pools. *Allanaspides* spp. rarely occur in buttongrass moorland on steeper slopes due to a shortage of standing pools especially those containing crayfish (*Ombastacoides* spp. and *Spinastacoides* spp.) burrows which appear to provide refuge for *Allanaspides* during summer months when the majority of surface pools dry out (Swain 2000, Driessen & Mallick 2007). Surveys of potential habitat commenced within the previously-known range of the species and then systematically expanded out until the species were not recorded. Because of limited road access in this part of Tasmania, most sites were accessed by foot, boat (to shorelines) and helicopter (table 1). Surveys were conducted during November and December when most *Allanaspides* have attained their maximum size and animals are easiest to detect.

Once on site, an initial assessment was made for the presence of surface pools at least three centimetres in depth that included crayfish burrows. Where suitable pools were present, pools were sampled within a 100 m radius of a central point (this area is referred to as a search "site"). Occasionally, slow-moving streams or seeps and pools shallower than 3 cm were also sampled.

Suitable pools were checked initially by eye for the presence of *Allanaspides*. Any individuals detected by eye were caught using sieves (10 cm diameter, 1 mm pore size) and identified to species on site (pl. 2). Particular attention was given to the deeper areas around the entrance to crayfish burrows. If no *Allanaspides* were observed, the sieve was vigorously swirled through the pool, stirring up the water column which was then sieved. The products of sieving were then emptied into a plastic tray and searched by eye for *Allanaspides*.

At each site between five and 30 pools were sampled depending on the number of pools present within a 100 m radius. For sites with numerous pools and where *Allanaspides* were present, an *Allanaspides* individual was generally found within the first five pools sampled (M. Driessen unpublished data). Therefore, a site where five or more suitable pools were searched without locating any *Allanaspides* was classed as a "not present" site.

Lake searches for *Allanaspides*

Lake surveys were conducted over two days in 2009 (Lake Pedder) and over three days in 2010 (Lake Gordon). The survey in Lake Pedder included snorkelling and plankton net tows, while only plankton net tows were used to survey Lake Gordon. A plankton net with a 40 by 40 cm steel frame opening was used to survey for *Allanaspides* in both impoundments (pl. 3). To survey a location in the lake, the net was slowly dragged along the lake bottom for 2–5 m before lifting to the surface, decanting any material into a plastic tray and checking for *Allanaspides*.

Snorkelling was restricted to depths of less than 1.5 m because tannin in the water caused loss of visibility at greater depths. Snorkeling was conducted at two locations in Lake Pedder; on either side of an isthmus at the southern

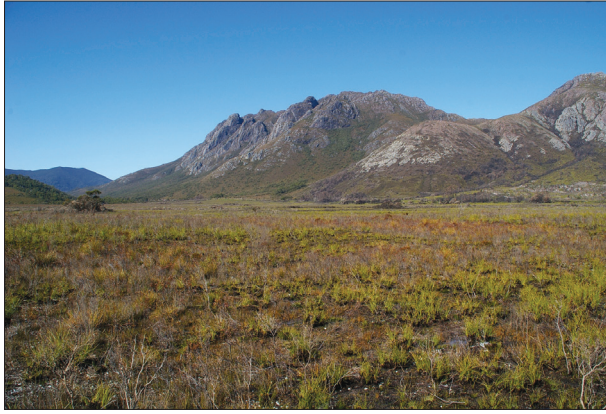


PLATE 1 — Buttongrass moorland at McPartlan Pass where both *Allanaspides hickmani* and *A. helonomus* occur in pools. (Photo: M. Driessen)



PLATE 2 — Surveying for *Allanaspides* in moorland pools using a dip net and sorting tray. (Photo: B. Heap)

FIG. 1 — Location of survey sites for *Allanaspides hickmani* and *A. helonomus* in southwest Tasmania. Figure includes sites surveyed where *Allanaspides* were recorded by Swain *et al.* (1970, 1971) and Horwitz (1988, 1990) and sites surveyed but where no *Allanaspides* were recorded by Richardson & Swain (1978), Horwitz (1988, 1990) and Lake (2001). Shaded areas = water bodies. Solid triangles = *A. helonomus* sites, solid circles = *A. hickmani* sites, crosses = sites where *Allanaspides* were not recorded, blue symbols = lake sites, black symbols = non-lake sites. Location of catchment boundaries and selected place names are also shown. Solid black line = coastline, dashed lines = catchment boundaries, thin black line = location of Lake Pedder prior to inundation.

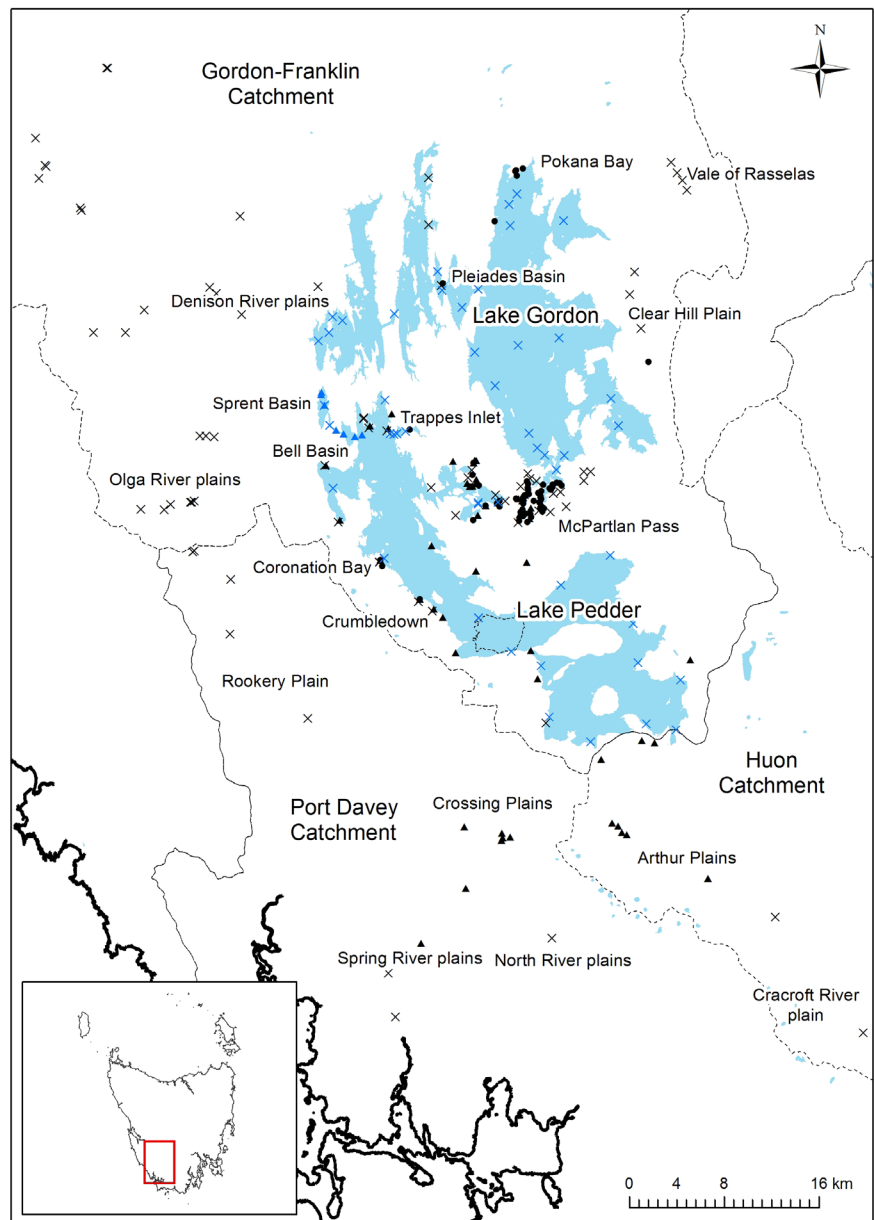


TABLE 1 — Details of searches for *Allanaspides*

Year	Month	Person days ¹	Area searched	Access methods
2001	Nov-Dec	18	McPartlan Pass area, Vale of Rasselas	foot
2002	Nov	6	Shorelines of Lake Gordon and Lake Pedder	boat
2004	Nov	2	Arthur Plains	foot
2004	Dec	2	Crossing Plains, Arthur Plains	helicopter
2006	Nov	6	Denison River, Maxwell River, Olga River, Hardwood River, upper Davey River, Crossing Plains, Spring River, Arthur Plains, North River, Adams River, Clear Hill Plains	helicopter
2009	Nov	6	Waters of Lake Pedder	boat
2010	Dec	9	Waters of Lake Gordon	boat

¹ number of personnel × number of days searching



PLATE 3 — Surveying for *Allanaspides* in Lake Gordon using a plankton net. (Photo: M. Driessen)

end of Coronation Bay (three snorkelers for 15 min. each side of the isthmus), and near the McPartlan Canal (two snorkelers for 30 min.).

Sampling in Lake Pedder was confined to the part of the impoundment north of the original Lake Pedder (fig. 1) due to time constraints and because a dozen lakeshore sites to the south of the original Lake Pedder were surveyed from 1975 to 1989 with no *Allanaspides* recorded (Lake 2001). A total of 28 tows at eight locations around the impoundment ranging in depth from 2–28 m were conducted on the first day. On the second day the extent of the known *A. helonomus* population in the lake was surveyed in a systematic manner starting within Sprent Basin and heading out through Bell Basin into the main part of the impoundment (fig. 1).

Sampling in Lake Gordon was designed to cover as much of the lake area as possible and to include a range of depths and substrate types. Attention was also given to parts of the lake adjacent to known buttongrass moorland populations of *A. hickmani* (Wedge Inlet near McPartlan Pass canal, Pleiades Basin, Pokana Bay and Adams Bay) (fig. 1).

Extant Area of Occupancy of *Allanaspides*

To estimate the extant Area of Occupancy of both *Allanaspides* species, we used a model based on vegetation and slope to predict potential *Allanaspides* habitat within the catchments where the species are known to occur.

Potential *Allanaspides* habitat was modelled as buttongrass moorland on flat or very gently sloping land (slope $\leq 5^\circ$). Buttongrass moorland vegetation communities included in the model were; MBS Buttongrass moorland with emergent shrubs; MBP Pure buttongrass moorland; MBR Sparse buttongrass moorland on slopes; MBW Western buttongrass moorland; and MSW Western lowland sedgeland (TASVEG database, Tasmanian Department of Primary Industries, Parks, Water and Environment). The extant Area of Occupancy for the two *Allanaspides* species was then calculated as the sum of all patches of *Allanaspides* habitat in catchments where the species are known or believed to occur.

RESULTS

Distribution of *Allanaspides hickmani*

Allanaspides hickmani was recorded at numerous sites in buttongrass moorland at McPartlan Pass, and the species appears to be common in remaining habitat at McPartlan Pass on both sides of the catchment divide (fig. 1). Searches of other remnant patches of moorland habitat around the shoreline of Lake Pedder confirmed the presence of *A. hickmani* at Coronation Bay (cf. Horwitz 1988), and located a second population in a small patch of moorland at Crumbledown also on the western shore of Lake Pedder (fig. 1). No other populations of *A. hickmani* were located around Lake Pedder (fig. 1). Searches of suitable habitat

around the shoreline of Lake Gordon located *A. hickmani* at Pokana Bay at the northern tip of the impoundment, on the western side of Pokana Bay, at Pleiades Basin, and in Clear Hill Plain area to the east of Lake Gordon (fig. 1).

Searches of suitable moorland habitat elsewhere within the Gordon–Franklin catchment (in the Denison River Plains and Olga River Plains to the west, and in the Vale of Rasselas and the northern end of Clear Hill Plain to the east) failed to locate additional populations of *A. hickmani*. The species was also not recorded in areas of suitable habitat in either the Huon or Port Davey catchments (fig. 1). In total, *A. hickmani* is now known to occur at three separate locations around Lake Pedder (McPartlan Pass, Coronation Bay and Crumbledown) and at five locations around Lake Gordon River (McPartlan Pass, Pokana Bay, west Pokana Bay, Pleiades Basin, Clear Hill Plain).

Surveys of the lake waters of both Lake Pedder and Lake Gordon failed to capture any *A. hickmani* (fig. 1).

Distribution of *Allanaspides helonomus*

Allanaspides helonomus was recorded at McPartlan Pass on both sides of the catchment divide, although on the Lake Gordon side of the divide *A. helonomus* is restricted to the westernmost section of the McPartlan Pass plain (fig. 1). Apart from McPartlan Pass, *A. helonomus* was not recorded in areas of suitable habitat elsewhere around Lake Gordon (fig. 1).

Allanaspides helonomus was recorded at numerous sites around the shoreline of Lake Pedder (fig. 1). *A. helonomus* was also recorded at several sites in the Arthur Plains in the Huon catchment (fig. 1). However, *A. helonomus* was not recorded in the Cracroft River plain to the south of the Arthur Plains despite the presence of flat buttongrass moorland which appeared to be suitable for the species, and the Arthur Plains appears to be the southerly most extent of *A. helonomus* within the Huon catchment (fig. 1).

Allanaspides helonomus was recorded at a number of sites in the Crossing Plains area in the Port Davey catchment, and the species was also recorded to the south of the Crossing Plains at two sites in the Spring River plains area (fig. 1). *A. helonomus* was not recorded in searches of suitable habitat in the North River plains area (west of Spring River plains), or from the Rookery Plains on the Hardwood River in the western part of the Port Davey catchment (fig. 1).

In the waters of Lake Pedder, *A. helonomus* was recorded in Sprent Basin, Bell Basin, from the mouth of Bell Basin, and in the main part of the impoundment immediately outside the mouth of Bell Basin (total area = 4.6 km²; fig. 1). Most locations where *A. helonomus* was found were 20 m depth or greater except within Sprent Basin where the species was recorded between 6 and 15 m depth. *A. helonomus* was not recorded in searches of the lake waters of Lake Gordon (fig.1).

Extant Area of Occupancy of *Allanaspides*

Allanaspides hickmani

Around Lake Gordon, most patches of predicted *Allanaspides* habitat which were searched were found to support

A. hickmani. We therefore estimated the extant Area of Occupancy of *A. hickmani* around Lake Gordon as the sum of all patches of *Allanaspides* habitat (including all searched patches where *A. hickmani* was recorded plus several small patches of habitat which were not searched) minus those patches of habitat which were searched but where *A. hickmani* was not recorded. Using this method, the total Area of Occupancy for *A. hickmani* around Lake Gordon was estimated to be 13.3 km² (table 2).

In contrast, around Lake Pedder, only a small fraction of the predicted *Allanaspides* habitat was found to support *A. hickmani*. The extant Area of Occupancy for *A. hickmani* around Lake Pedder therefore included only those patches of habitat (at McPartlan Pass and the two sites on the western shore of the impoundment) which contained at least one record of *A. hickmani* (total area = 6.7 km²; table 2).

The total Area of Occupancy of *A. hickmani* was therefore estimated to be 20.0 km² (table 2).

Allanaspides helonomus

Around Lake Gordon, *A. helonomus* has been recorded in only a small area of the McPartlan Pass plain (fig. 1). The extant Area of Occupancy of *A. helonomus* within the Gordon catchment was therefore calculated as the sum of habitat patches at McPartlan Pass which were searched and where

TABLE 2 — Estimated areas of extant Area of Occupancy for *Allanaspides hickmani* and *A. helonomus* by catchment and location

Catchment and location	Area of habitat (km ²)
<i>Allanaspides hickmani</i>	
McPartlan Pass (Lake Gordon side)	4.9
Clear Hill Plain	4.1
Pokana Bay (Lake Gordon)	3.3
Additional small areas around Lake Gordon	1.0
McPartlan Pass (Lake Pedder side)	3.4
Crumbledown (Lake Pedder)	1.5
Coronation Bay (Lake Pedder)	1.8
<i>A. hickmani</i> total	20.0
<i>Allanaspides helonomus</i>	
Lake Pedder	4.6
McPartlan Pass (Lake Gordon side)	0.2
Total area around Lake Pedder	37.5
Arthur Plains (Huon catchment)	33.0
Crossing Plains (Port Davey catchment)	40.3
Spring River Plains (Port Davey catchment)	14.3
<i>A. helonomus</i> total	129.9

A. helonomus was recorded (total area = 0.2 km²; table 2).

In contrast, around Lake Pedder, the majority of patches of suitable moorland habitat which were searched were found to support *A. helonomus*. We therefore estimated the Area of Occupancy for *A. helonomus* around Lake Pedder as the sum of all patches (searched and unsearched) of suitable habitat (total area = 37.5 km²; table 2).

The Arthur Plains, Crossing Plains, and Spring River Plains involved extensive tracts of potential *Allanaspides* habitat which received relative little sampling effort. For these extensive but poorly sampled areas of habitat, including only patches of habitat containing an *A. helonomus* record is likely to significantly underestimate the species' Area of Occupancy. Therefore, for the Arthur Plains, Crossing Plains and Spring River Plains, all patches of potential *Allanaspides* habitat within a sub-catchment containing at least one record of *A. helonomus* were assumed to support the species (Arthur Plains, 33.0 km²; Crossing Plains, 40.3 km²; Spring River Plains, 14.3 km²; table 2). The Cracroft River plain was not included in the Area of Occupancy estimate because no *A. helonomus* was found there and a watershed boundary exists between it and the Arthur Plains.

The estimated Area of Occupancy for *A. helonomus* in the lake waters of Lake Pedder was 4.6 km². The total Area of Occupancy for *A. helonomus* was therefore estimated to be 130 km² (table 2).

DISCUSSION

Allanaspides in lake waters

All documented records of *Allanaspides* prior to the present study have been from pools in buttongrass moorland (Swain *et al.* 1970, 1971, Horwitz 1988, 1989, Driessen *et al.* 2006, Driessen & Mallick 2007), and it has been assumed that both *A. hickmani* and *A. helonomus* are obligate pool-dwellers that do not occur in lake-waters proper (cf. Driessen *et al.* 2006). A survey of the macro-invertebrate fauna of the original Lake Pedder prior to its inundation by Bayly *et al.* (1966) did not record any (at that time undescribed) *Allanaspides*. Sampling by Bayly *et al.* (1966) included plankton net tows in the shallow littoral zone of the lake, and handnet, dredge and grab samples of the benthos in the littoral zone and in the deeper parts of the lake. It therefore seems reasonable to conclude that *Allanaspides* did not occur in the waters of the original Lake Pedder. The finding of *A. helonomus* within the waters of the Lake Pedder impoundment is therefore unexpected, and has significant implications for the conservation of the species.

The distribution of *A. helonomus* in Lake Pedder appears to be confined to deeper waters (>20 m) in the vicinity of Sprent and Bell Basins (fig. 1). The depth of the majority of Lake Pedder is less than 15 m (Kiernan 2001). The absence of the species from shallower parts of Lake Pedder may explain why the species was not detected during previous invertebrate surveys which focused on the littoral zone of the impoundment (Lake 2001, M Driessen unpublished data).

The reasons why *A. helonomus* occurs only in one section

of Lake Pedder may relate to a combination of sheltered aspect, substrate type and depth. The Sprent and Bell are deep basins (> 20 m in depth) located over the original Serpentine River valley. These basins are also situated in the northwestern part of the impoundment and are sheltered from northwesterly and westerly wind action. A combination of sheltered aspect and deep waters with reduced wave action allows the formation of a silty substrate (Davies 2001) which may be required by *A. helonomus* to survive in lake waters. Surveys in another Tasmanian lake, Great Lake in the Central Highlands, have shown that silty substrates and algal beds, which are important habitats for a range of fauna including the anaspidid syncarid *Paranaspides lacustris*, only occur on shorelines sheltered from pre-frontal north-westerly and westerly winds (Davies & Fulton 1987, Davies 2001).

Predation by fish, including both native galaxids and introduced trout, may constrain the distribution of *A. helonomus* to deeper parts of the lake and explain the absence of the species from shallower waters. In the tannin-rich waters of southwestern Tasmanian lakes, fish predation may be limited to shallower waters with sufficient light for fish to locate prey by sight (Guthrie & Muntze 1993). Areas of the lake with deeper water plus a silty substrate may therefore provide a refuge for *A. helonomus* from intense levels of fish predation which occur elsewhere in the shallower parts of the impoundment.

Allanaspides hickmani is known to occur adjacent to the shoreline of Lake Pedder, yet the species was not recorded within the impoundment. *A. hickmani* appears to have very similar ecological requirements to *A. helonomus*, and the two species occur sympatrically in buttongrass moorland over part of their range (Horwitz 1988, present study), and are occasionally found in the same pool together (M. Driessen unpublished data). It is not clear why *A. hickmani* does not occur in those parts of Lake Pedder which support *A. helonomus*.

Both species of *Allanaspides* occur adjacent to the shoreline of Lake Gordon. However, neither species was recorded within Lake Gordon, despite the presence of sheltered, deep-water bays similar to the Sprent and Bell basins in Lake Pedder. Why neither species of *Allanaspides* occur in Lake Gordon is not known, but may relate to significant differences in the limnological attributes of the two impoundments. The generally shallower waters of Lake Pedder do not undergo significant stratification, so that the entire water column remains oxygenated year round, including water in the deeper parts of the impoundment (HydroTasmania 2011). In contrast, Lake Gordon stratifies each year with consequent anoxia below the thermocline, which in the colder months can occur at depths of around 30–40 m (Steane & Tyler 1982). These periodic periods of anoxia at depth may be the reason why neither species of *Allanaspides* has been able to establish in Lake Gordon.

Extant Area of Occupancy, inundation, and loss of *Allanaspides* habitat

Based on the known distributions of *A. hickmani* and *A. helonomus*, and assuming that neither *Allanaspides* species

occurs in lake waters, Driessen *et al.* (2006) estimated the extant Area of Occupancy for *A. hickmani* and *A. helonomus* to be 21 km² and 54 km², respectively. Driessen *et al.* (2006) also estimated the area of *Allanaspides* buttongrass moorland habitat inundated for hydro-electric impoundment to be 117 km² for the Lake Gordon impoundment and 191 km² for the Lake Pedder impoundment. This corresponded to a loss of 78% of the original habitat area for *A. helonomus* and 85–94% for *A. hickmani*.

Given that *A. hickmani* does not occur in the waters of either impoundment, and the estimate of extant Area of Occupancy for *A. hickmani* in the present study (20 km²) is similar to the earlier estimate in Driessen *et al.* (2006) (21 km²), the estimate by the latter study of 85–94% of *A. hickmani* habitat lost through inundation remains unchanged.

For *A. helonomus*, the upgraded estimate of extant Area of Occupancy in buttongrass moorland (125 km²), as well as the finding that *A. helonomus* occurs in the waters of Lake Pedder, requires a reconsideration of the estimate of habitat loss through inundation for this species. An updated estimate of *A. helonomus* habitat lost through inundation is 186.4 km², or 59% of the species' original range (Driessen *et al.* 2006; table 2).

Threats to *Allanaspides*

Prior to the present study, *A. hickmani* was only known from three disjunct localities in two adjacent drainage systems, with one of these locations (Trappes Inlet) having been inundated by flooding of the Serpentine catchment. Based on the results of the present study, *A. hickmani* is now known to occur at a total of eight sites on the periphery of Lake Pedder and Lake Gordon. The four new populations of *A. hickmani* located on the northern and eastern shoreline of Lake Gordon represent a significant extension in its known range, although the patches of habitat containing *A. hickmani* are relatively small (all <5 km² in area; table 2). McPartlan Pass represents the largest area of *A. hickmani* habitat still extant (4.9 km²; table 2), and successful management of the buttongrass moorland at McPartlan Pass will be crucial

in ensuring the security of *A. hickmani* in the long term.

Prior to the present study, *A. helonomus* was known from a single locality at McPartlan Pass and from several locations around the margin of Lake Pedder (all in the Gordon–Franklin catchment), and from a single record in the Crossing Plains in the Port Davey catchment (Horwitz 1988, 1990). The results of the present study significantly extend the known distribution of *A. helonomus* within the Gordon–Franklin and Port Davey catchments, document the species in a third catchment (Huon), and expand the species' known habitats to include part of the water of Lake Pedder. Given the substantially larger extant distribution of *A. helonomus* spanning three major catchments and the fact that the species also occurs in lake waters, *A. helonomus* is likely to be much less vulnerable to threatening processes and stochastic events compared to *A. hickmani* (table 3).

Horwitz (1988, 1990) identified further inundation and fire as potential threats to *Allanaspides* species. A relatively minor increase in the level of either impoundment would inundate much of the remaining *A. hickmani* habitat which has survived on the margins of the current impoundments (Horwitz 1990). However, an increase in the impoundments' capacity is very unlikely, so further inundation does not pose an immediate risk to the species.

Buttongrass moorland is a pyrogenic community which requires repeated burning for the community to persist (Brown 1999), so the fauna associated with the buttongrass moorland (including *Allanaspides*) is presumably also adapted to repeated firing. However, very hot or excessively frequent firing of buttongrass moorland has the potential to damage the underlying peat (Horwitz 1990), thus a broad-scale, hot wildfire which burned a large proportion of the remaining *Allanaspides* habitat in a single event could pose a potential threat, particularly to the small number of remaining populations of *A. hickmani*. The peats of southwest Tasmania are also likely to become increasingly flammable under the predicted trend of warmer drier climates (Bowman 2008).

Perhaps of greatest concern to both *Allanaspides* spp. is the potential impact of global warming because the peatlands they occur in are predicted to be particularly vulnerable

TABLE 3 — Summary of information on principal criteria for threatened species listing for *Allanaspides hickmani* and *A. helonomus*

Criteria	<i>Allanaspides hickmani</i>	<i>Allanaspides helonomus</i>
Reduction in population size (in early 1970s)	85–94%	59%
Current or future declines	Unknown	Unknown
Extreme fluctuations (numbers, area, populations)	No	No
Extant Area of Occurrence	427 km ²	939 km ²
Extant Area of Occupancy	20 km ²	130 km ²
Population size	Unknown	Unknown
Fragmented populations	Yes (severe)	Yes
Extant populations	<10	Many

to climate change (Bowman 2008, DPIPWE 2010). The predicted changes in climate for Tasmania under a high and low CO₂ emissions scenario predict a mean increase in annual temperature of around 2.9 °C (high emissions scenario) and 1.6 °C (low emissions scenario) (Grose *et al.* 2010). Total annual rainfall is not predicted to change for the state as a whole; however a significant change in the spatial pattern of rainfall is predicted. For western Tasmania, rainfall is predicted to increase in winter and to decrease in summer. The cumulative effects on evaporation are predicted to be an increase in pan evaporation for the state of up to 19%, with the change in evaporation greatest in the north and west and greatest in summer (Grose *et al.* 2010).

The climate of southwest Tasmania is believed to be marginal for the formation of the blanket bogs which support buttongrass moorland, and small shifts in prevailing conditions, such as a rise in mean annual temperatures, could potentially cause the peats to degrade (Bridle *et al.* 2003), with far-reaching consequences to pool-dwelling species such as *Allanaspides*. The size, depth and longevity of surface pools in buttongrass moorland are also strongly influenced by the dryness of a particular season, and surface pools can be very scarce or absent in a dry summer (Swain 2000, Driessen & Mallick 2007). The sub-surface water in crayfish burrows is presumably more buffered against drying out during summer, although in prolonged periods of summer dryness many crayfish burrows can be without free water for several weeks (Swain *et al.* 1987). The impact of prolonged periods of summer dryness on these two semelparous species is limited by their capacity to produce diapausing eggs (Swain 2000, Driessen & Mallick 2007). However, a climatic shift leading to even a small fall in the water table and sub-surface drying-out of the peat could have a major impact on the ability of both *A. hickmani* and *A. helonomus* to survive in buttongrass moorland.

Threatened species status of *Allanaspides hickmani* and *A. helonomus*

We now consider the conservation status of *Allanaspides hickmani* and *A. helonomus* under international (IUCN), national (EPBCA) and state (TSPA) guidelines.

The IUCN, EPBCA and TSPA listing guidelines all have a criterion based on population decline over the recent past (i.e., over the last 10 years or within the past three generations of the species, whichever is the longer). Both *A. hickmani* and *A. helonomus* have undergone a significant reduction in range (59% and 85–94%, respectively) due to inundation of the Gordon and Serpentine catchments for hydroelectricity (Driessen *et al.* 2006 and the present study). However, inundation occurred over 30 years ago, making the species ineligible for listing under this criterion.

Both *A. hickmani* and *A. helonomus* were listed as Vulnerable on the IUCN Red List in 1986 under the IUCN criterion D2: population very small or restricted, with a very restricted Area of Occupancy (typically less than 20 km²) or number of locations (typically five or fewer) such that the species is prone to the effects of human activities or stochastic events within a very short time period. Based

on the results of the present study, an IUCN listing of Vulnerable appears to be warranted for *A. hickmani* (Area of Occupancy estimated to be 20 km²). However, *A. helonomus* no longer fulfils the IUCN criterion D2 for Vulnerable (Area of Occupancy estimated to be 130 km²).

Neither the EPBCA nor the TSPA have a criterion corresponding to the IUCN criterion D2 for vulnerable. Under the EPBCA and TSPA, a species may be listed as Vulnerable if it has a restricted geographic distribution (Extent of Occurrence <20,000 km² or Area of Occupancy <2000 km²) and its geographic distribution is precarious for the survival of the species based on the species fulfilling two of three sub-criteria: (1) highly fragmented or occurring in a limited number ($n < 10$) of locations; (2) a continuing decline in range, habitat quality, subpopulations or numbers; and (3) extreme fluctuations in range, subpopulations or numbers.

Allanaspides helonomus fulfils the EPBCA and TSPA criterion for a restricted geographic distribution (Extent of Occurrence = 939 km² and Area of Occupancy = 125 km²). However, *A. helonomus* does not fulfil any of the three sub-criteria; the species is not highly fragmented and is now known from three major catchments with numerous subpopulations; there is also no evidence for a continuing decline; and there is no evidence for extreme fluctuations in range or numbers. Therefore, *A. helonomus* is unlikely to qualify as Vulnerable under EPBCA or TSPA.

Allanaspides hickmani fulfils the EPBCA and TSPA criterion for a restricted geographic distribution (Extent of Occurrence = 427 km² and Area of Occupancy = 20 km²). Furthermore, unlike *A. helonomus*, *A. hickmani* occurs in a limited number (<10) of small and highly fragmented populations, and the species is likely to fulfil the first sub-criteria for Vulnerable. However, there is no evidence that *A. hickmani* is subject to a continuing decline or extreme fluctuations in range or numbers. Therefore *A. hickmani* is also unlikely to qualify as Vulnerable under EPBCA or TSPA.

The TSPA differs from the EPBCA in having an additional listing category of Rare. A species may be listed as Rare if it has “a small population that is not endangered or vulnerable but is at risk”. The indicative criteria for assessing a species as “at risk” include an Extent of Occurrence <2000 km². The current listing of *A. hickmani* as Rare under the TSPA appears warranted based on the species’ restricted Extent of Occurrence (427 km²), the small number highly fragmented subpopulations confined to a single catchment, and the stochastic risk of extinction of subpopulations.

Allanaspides helonomus is currently not listed as Rare under the TSPA. Based on the results of the present study, *A. helonomus* fulfils the extent of occurrence criterion for listing as rare (Extent of Occurrence = 939 km²). However *A. helonomus* occurs in a relatively large number of populations spanning three major catchments and is now known to also occur in the waters of Lake Pedder. Its level of risk appears to be significantly lower than is the case for *A. hickmani* and although it has a restricted distribution there is no indication it is currently at risk

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