Distribution, habitat and conservation of two threatened stag beetles, *Hoplogonus bornemisszai* and *H. vanderschoori* (Coleoptera: Lucanidae) in north-east Tasmania

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ABSTRACT

The distribution and habitat of two stag beetles, *Hoplogonus bornemisszai* and *H. vanderschoori* (Coleoptera: Lucanidae) listed under the Tasmanian *Threatened Species Protection Act 1995* were investigated. The number of sites of occurrence for *H. bornemisszai* was increased from 4 to 28 and its extent of occurrence was calculated to be 1,200 ha (12 km^2). The number of sites of occurrence for *H. vanderschoori* was increased from 3 to 22 and its extent of occurrence was 9,510 ha (95 km^2). Both species appeared to have patchy distributions and occurred at variable population densities. *H. vanderschoori* was found predominantly in wetter forest types than *H.bornemisszai* including rainforest and mixed forest types, but was not found in regenerating wet eucalypt forest. The ranges of the two species did not overlap. However, the range of *H. bornemisszai* is contiguous with that of another threatened stag beetle, *H. simsoni*. Together, the ranges of the three species indicate the presence of a biogeographical mosaic. Only 20% of potential habitat for *H. bornemisszai,* and 30% for *H. vanderschoori,* occurs in reserves or areas bound by a conservation covenant. Conservation measures are recommended for the maintenance of populations of these species in areas subject to forestry activities.

Key words: Lucanidae; beetles; Hoplogonus; threatened species; invertebrate conservation; distribution; forestry; biogeographical mosaic.

Introduction

Tasmania has approximately 30 species in the beetle family Lucanidae (stag beetles) (Semmens *et al.* 1992; Meggs 1997), several of which are listed under the Tasmanian *Threatened Species Protection Act 1995*. *Hoplogonus bornemisszai* (Bartolozzi 1996a) and *H. vanderschoori* (Bartolozzi 1996b) were discovered in 1994/95 (G. Bornemissza pers. comm.). Both species were added to the schedules of the TSPA in late 1999. *H. bornemisszai* was listed as Endangered due to its limited distribution and continuing population decline, suspected to be due to an observed decline in quality of habitat resulting from forestry activities (clear-felling and plantation establishment practices) (DPIWE 2002). *H. vanderschoori* was listed as Vulnerable due to its restricted distribution and occurrence at very low population densities (DPIWE 2002).

The genus *Hoplogonus* can be readily identified by the humeral spines (or spurs) on the elytra and the shape of the mandibles of the adult male distinguishes the three species (Figure 1). All *Hoplogonus* species are flightless and adults are up to 24 mm long. The largest endemic stag beetle in Tasmania, Simson's stag beetle *H. simsoni* (Parry, 1875), has been the focus of a detailed study investigating its habitat, distribution and conservation requirements (Meggs 2003; Meggs *et al.* 2003a and b). In addition, the distribution, habitat characteristics and

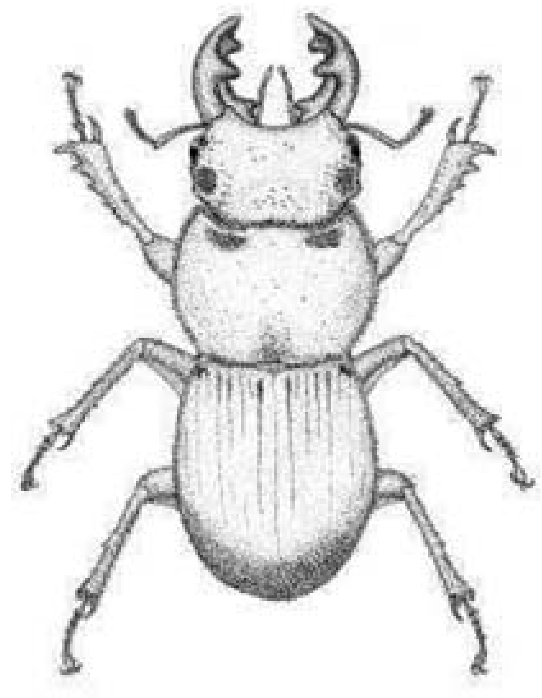

Figure 1. Line drawings depicting male specimens of a) *H. bornemisszai*.

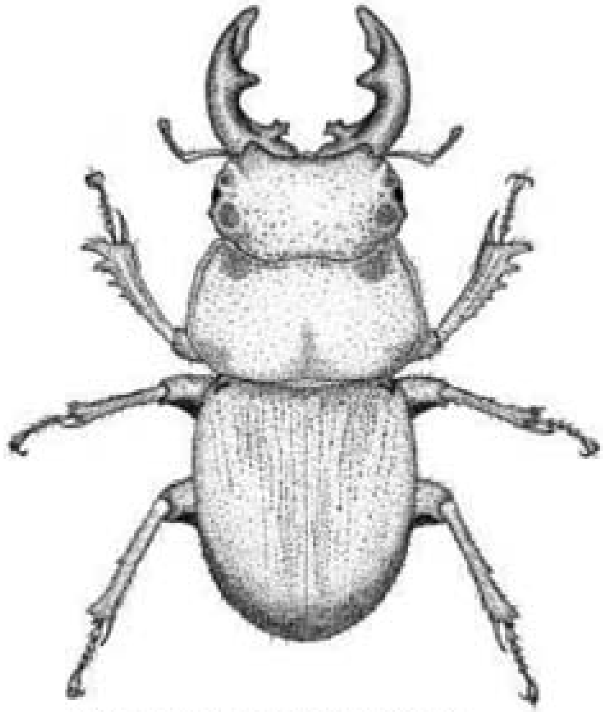

Figure 1. b) *H. vanderschoori* (Karen Richards 1999).

conservation requirements of the Mt Mangana stag beetle *Lissotes menalcas* (Westwood 1855) and the broad-toothed stag beetle *L. latidens* (Westwood 1855), have received attention (Michaels 1996 and 1999; Meggs and Taylor 1999; Meggs and Munks 2003). In contrast, there have been no detailed studies of *H. bornemisszai* and *H. vanderschoori*. Prior to this study, *H. bornemisszai* had been recorded from only four sites, all within an area of less than 5 km^2, approximately one kilometre to the southeast of the known range boundary for *H. simsoni* in the north-east of Tasmania (Meggs 1997). Similarly, *H. vanderschoori* had been recorded from only three sites to the south-west of the range of *H. simsoni* making its known range less than 10 km^2 (Meggs 1997). The known range of *H. bornemisszai* had been identified as having potential for production forestry on both public and private land.

The Tasmanian *Forest Practices Code* (Forest Practices Board 2000) requires that threatened species listed under the Tasmanian *Threatened Species Protection Act 1995*, or the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*, be taken into account during planning and implementation of any forestry operations. A process and associated planning tool have been developed over the past six years to meet this requirement (Munks and Taylor 2000; Forest Practices Board 2001; Forest Practices Board and DPIWE 2001). An important step in the process involves the development of management objectives and prescriptions to cater for threatened fauna in areas subject to production forestry activities. For management prescriptions to be effective, they must be based on knowledge of the distribution and habitat of the species, as well as the specific threats to the species from land-use practices within its range, particularly in 'off-reserve' areas. This study aimed to gather information on the distribution and habitat of *H. bornemisszai* and *H. vanderschoori* to aid the development of conservation measures to assist their recovery.

Methods

Study area

All field work was conducted in areas that included the seven previously known sites of H. bornemisszai and H. vanderschoori in north-east Tasmania (Figure 2). The forest in the study areas consisted predominantly of wet eucalypt forest communities, with some mixed forest and rainforest. Mixed forest was distinguished from wet eucalypt forest by the presence of rainforest species such as *Nothofagus cunninghamii* (myrtle) and *Atherosperma moschatum* (sassafras) as dominant understorey species (Hickey and Wells 1999; Forest Practices Board 2002).

The *H. bornemisszai* study area and the *H. vanderschoori* study area are underlain by Devonian granite/adamellite plus patches of metamorphosed Mathinna Beds (siltstones, sandstones and mudstones) and Devonian granodiorite and granite, respectively (Burrett and Martin 1989; McClenaghan 1998). The region is subject to relatively high annual rainfall (averaging 1200 mm annually at Pyengana) at low elevations. Moist easterly winds generated by low-pressure systems over the Tasman Sea are lifted by coastal hills, resulting in intense orographic rainfalls in the study areas (Mesibov 1988).

Animal survey

The forests surveyed were stratified into five forest types:

Mature wet eucalypt forest: forest 70+ years old dominated by eucalypts generally exceeding 40 m in height with an understorey dominated by wet sclerophyll (broad-leaved) shrubs.

Mixed forest: forest 70+ years old with an understorey of rainforest species and an overstorey of eucalypts frequently exceeding 50 m in height.

Regenerated wet eucalypt forest: wet forest in coupes that had been subject to clearfell, burn and sow silviculture (Forestry Commission 1994). The regenerated forests were aged between 12 and 14 years at the time of this study (Forestry Tasmania unpublished data).

Rainforest: forest with trees taller than 8 m, dominated by myrtle and sassafras.

Damp eucalypt forest: forest dominated by eucalypts with shrubs more than 2 m in height as the dominant understorey. Several shrub layers are present containing similar proportions of wet sclerophyll and dry sclerophyll (narrow-leaved) shrubs.

The first three forest types were found in both species' study areas. No rainforest occurred within the *H. bornemisszai* study area and no damp eucalypt forest occurred within the *H. vanderschoori* study area.

Three to 14 replicate sites in each forest type (a total of 26) were sampled between January and February 1999 within the *H. bornemisszai* study area. Similarly, within the *H. vanderschoori* study area 3 to 14 replicate sites within each forest type (a total of 36) were sampled during the same period. Sites were selected to sample the range of environments present within a particular survey location (i.e. different slopes, aspects and topographic positions).

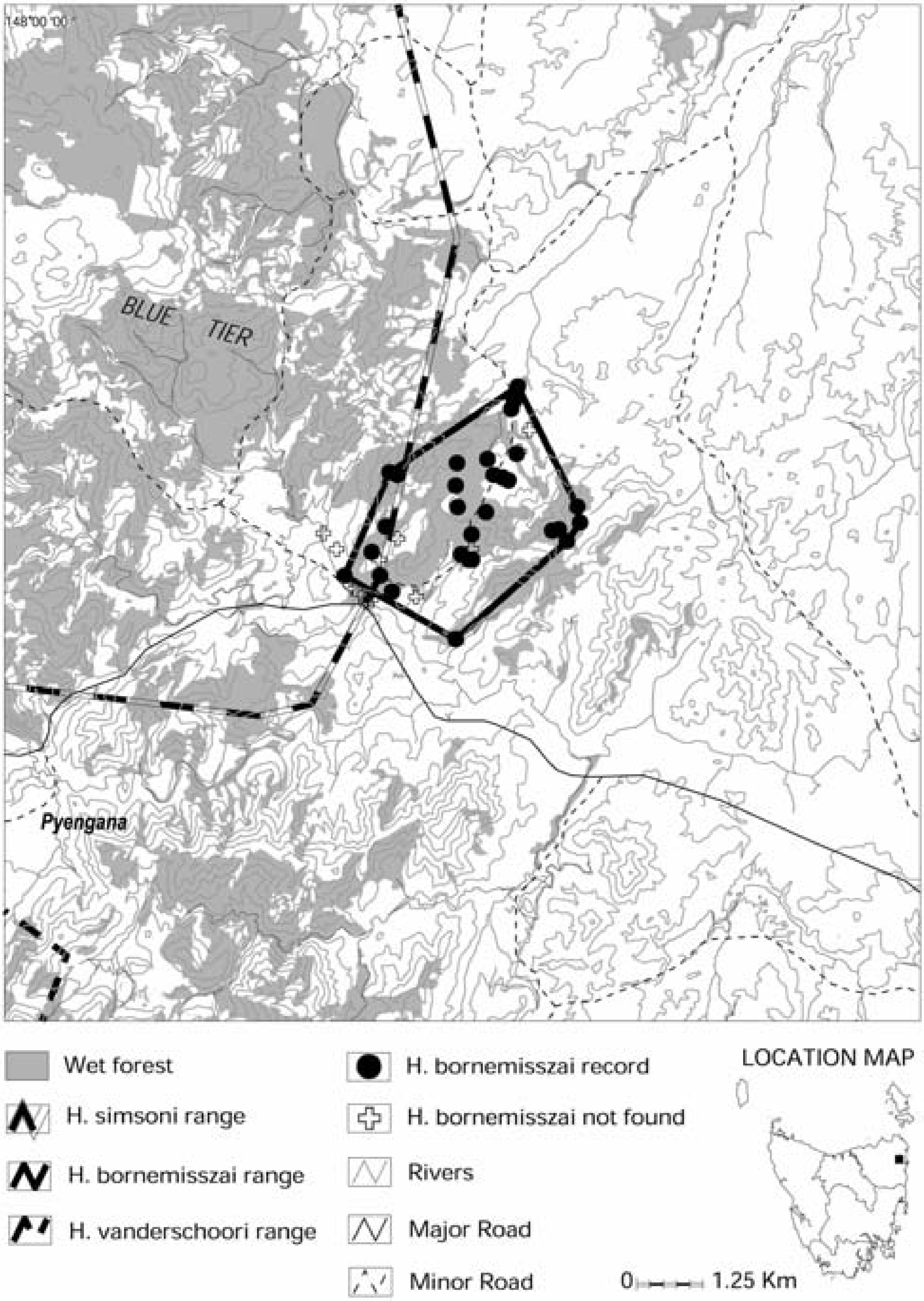

Figure 2. Location of sites surveyed for *H. bornemisszai* and *H. vanderschoori*. Sites where the species were found and sites where they were not found are presented.

a) *H. bornemisszai* sites with south-east boundary of *H. simsoni* range.

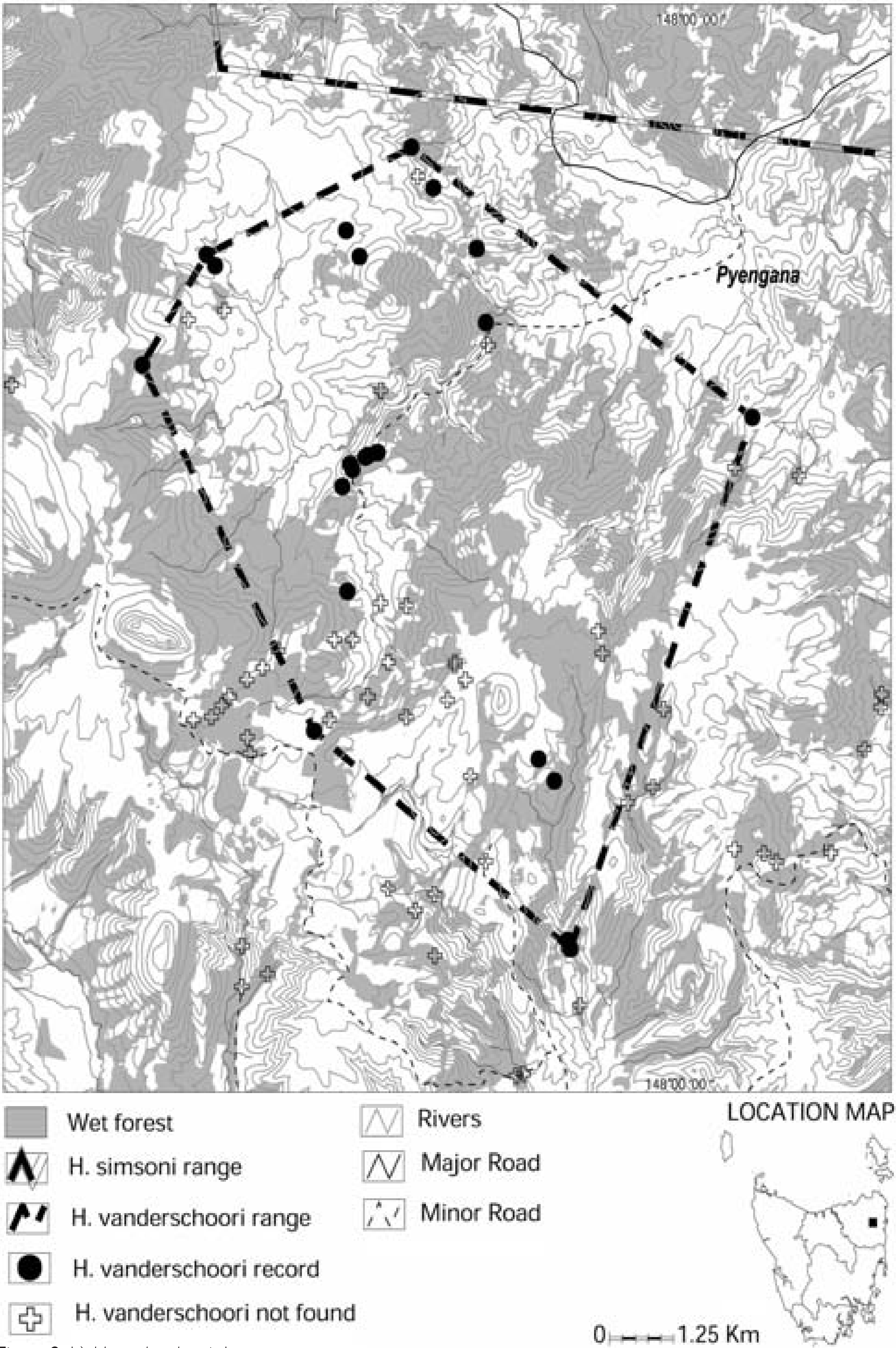

Figure 2. b) *H. vanderschoori* sites.

Survey sites were at least 300 m apart, and all were at least 50 m from roads and other disturbed areas such as paddocks. The number of sites surveyed differed between forest types due to access difficulties in some locations and the limited extent of some forest types. Every effort was made to cover the widest possible area and range of forest types. Survey sites were also located in planned future forestry coupes within and overlapping the species' known ranges and in formally reserved areas.

At each site, six 1 m^2 plots were searched for beetles following the method of Meggs *et al.* (2003a). The plots were haphazardly placed within a 10 m radius, attempting to sample all potential microhabitats. The plots were then systematically searched by looking through the leaf litter and under logs (which could be easily rolled) for live *Hoplogonus* species and body parts of dead ones. Live beetles were recorded and released at the site of capture. Parts of dead beetles were recorded and lodged with the Forestry Tasmania Insect Collection (Hobart). Identifiable body parts included the head of the male and the head of the female and the thorax and abdomen.

The total number of beetles was recorded for each site. This was calculated as the sum of the minimum number of either *H. bornemisszai* or *H. vanderschoori*, known to have been alive in the six plots within a site. The minimum number of beetles known to have been alive in each plot was calculated from dead body parts plus any live individuals found in each plot. In addition, the density of beetles (sum of the minimum number of either *H. bornemisszai* or *H. vanderschoori* known to have been alive/6 m^2) was estimated for each site. This estimation of density may result in over-estimates since the dead parts of the beetles sampled may represent an accumulation from more than one active season. However, other studies have shown that it is as reliable method of estimating relative abundance as other methods, i.e. pitfall traps (Mesibov *et al.* 1995; Meggs *et al.* 2003a). Hand-collecting was used in this study because of its efficiency relative to pitfall trapping and because it is a non-destructive sampling method which is important when surveying a threatened species.

In addition to the sites surveyed in 1999, data were collected on the presence or absence of the species during surveys of proposed logging coupes, as part of the forestry planning procedures (Munks and Taylor 2000). Thirteen sites were surveyed for *H. vanderschoori* and eight for *H. bornemisszai* during 1999-2004. Data was also collected on the presence or absence of *H. vanderschoori* in 2003, during a survey of 28 sites in potential habitat outside the eastern and southern edges of the species range.

Habitat variables

At each site surveyed in 1999, seven readily determined habitat variables anticipated to be predictors of beetle distribution and abundance, were recorded as per Meggs *et al.* (2003a):

Altitude (m): Altitude of the site to the nearest 10 m from 1:25, 000 topographic maps.

Distance to nearest stream: 1 = 0-25 m, 2 = 25+ m.

Forest type: A description of community floristics and structure at the site.

Leaf litter depth: depth to soil surface in three categories: 1 = <1 cm, 2 = 1-3 cm, 3 = >3 cm.

Leaf litter cover: 1 = <50%, 2 = >50%.

Aspect: N, S, E, W, none.

Slope: 1 = <5^o, 2 = 5-20^o, 3 = >20^o.

Data analyses

Due to the small sample sizes, non-parametric tests were used. The Wilcoxon signed rank test (Meddis 1984) was used to test a number of hypotheses about the relative density of beetles (number of individuals/m^2 for each site) and the categories of habitat variables measured at each site. The hypotheses were based on the results of a study on a similar stag beetle, *Hoplogonus simsoni*, in which a lower altitude, slope less than 5^o, a litter layer less than 3 cm, easterly aspect and a mature wet forest structure were the main characteristics of optimal habitat (Meggs *et al.* 2003a). The mean number of each species of beetle found per site for each forest type were tested for equality using a Kruskal-Wallis test (Meddis 1984). The Kruskal-Wallis test was also used for hypotheses that compared more than two levels of a particular habitat variable and the occurrence of the beetles. Due to small sample sizes, exact and Monte Carlo two-sided p-values were derived using SAS software (SAS Institute Inc. 1999) Levels of statistical significance were set at 0.05.

The range of each species was calculated as the land area contained within the smallest convex polygon that contained all sites of occurrence (IUCN Species Survival Commission 1994).

Results

Distribution of *H. bornemisszai and H. vanderschoori*

H. bornemisszai was recorded from 16 of the 26 sites surveyed in 1999 (Figure 2a). No live beetles were found. Ninety-four dead individuals were identified from body parts. *H. bornemisszai* was also found at the eight additional sites surveyed during 1999 and 2004 as part of the forestry planning procedures. Hence, the species has now been recorded from 28 sites (including 4 previously known sites, Meggs 1997), doubling its known range to 12 km^2 (1,200 ha) (Figure 2a). In the south-west of the range of *H. bornemisszai*, *H. simsoni* and *H. bornemisszai* were found to co-occur.

The relative densities of *H. bornemisszai* at each site surveyed in 1999 (number of individuals/m^2 for each site) ranged from 0.2 - 3.5/m^2. The mean (± SD) density for all the sites where the beetle occurred was 0.9794/m^2 ± 1.0055 (n = 16) and the beetle occurred at 3.5/m^2 at only one site. In 50% of the sites sampled it occurred at densities less than one per square metre. The beetle appeared to be patchily distributed within the forest types sampled.

H. vanderschoori was recorded from 6 of the 36 sites surveyed in 1999 (Figure 2b). One live specimen was found. Thirteen dead individuals were identified from body parts. Thirteen additional *H. vanderschoori* localities were obtained from coupe surveys conducted during

2001 - 2004 (K. Richards and J. Meggs unpublished data). No specimens were found at the 28 sites in potential habitat outside the eastern and southern edges of the species range surveyed in 2003.

H. vanderschoori has now been recorded from 22 sites (including 3 previously known sites, Meggs 1997), extending its previous known extent of occurrence from about 10 km^2 to nearly 95 km^2 (9,510 ha) (Figure 2b). The gap between the known range of *H. simsoni* and *H. vanderschoori* is now approximately 900 m. 83% of sites surveyed within its range in 1999 yielded no specimens. The relative densities of *H. vanderschoori* at each site surveyed in 1999 ranged from 0.2- 1.2/m^2. The mean (± SD) density for all the sites were the beetle occurred was 0.3890/m^2 ± 0.3897 (n = 6) and it occurred at 1.2/m^2 at only one site.

Forest types, habitat variables and the occurrence of *H. bornemisszai* and *H. vanderschoori*

H. bornemisszai was found in all the forest types sampled in 1999 including the three sites in 14-year old wet eucalypt forest regenerating after clearfell burn and sow (CBS) (Table 1). It occurred in 67% of sites sampled in mature wet eucalypt forest and damp forest, and 50% of sites in mixed forest. However, there was no significant difference between the density of beetles in the four different forest types ($\chi_3 = 0.38$, p = 0.9440).

In the drier north of the species' range most specimens were collected from within riparian areas and not from surrounding forest. None of the habitat variables measured was found to significantly influence the density of *H. bornemisszai*.

H. vanderschoori was found in rainforest, mixed and wet eucalypt forest but was not found in the three sites sampled in 12-year old wet eucalypt forest regenerating after CBS. The latter sites were adjacent to or within areas of wet forest that had been converted to eucalypt plantation. It was found in 21% and 29% of the sites sampled in rainforest and mixed forest, respectively but only occurred in 8% of the sites sampled in wet eucalypt forest (Table 1). However, there was no significant difference between the density of beetles in the four different forest types ($\chi_3 = 1.98$, p = 0.5773).

Most specimens were found amongst leaf litter but one individual male (dead) was found under a log. Significantly higher densities of beetles were found at sites where leaf litter was less than 3 cm deep (s=306,n = 36, exact p = 0.02). In addition, significantly higher densities of beetles were found at sites with a slope greater than 5° ($\chi_2 = 5.87$, p = 0.0280). No other habitat variables were found to be associated with the density of *H. vanderschoori*.

Discussion

Distribution and habitat

The results of this study have significantly increased the number of sites of occurrence for both *H. bornemisszai* and *H. vanderschoori* and have increased their known ranges to approximately 12 km^2 and 95 km^2, respectively. It is unlikely that future searches will significantly extend the range of either species. Much of the current known range of *H. bornemisszai* (Figure 2a) is surrounded by unsuitable habitat (e.g. dry eucalypt forest). The results of this study show that there is a minor overlap in the occurrence of *H. simsoni* and *H. bornemisszai* in the western section of the range of *H. bornemisszai*. *H. bornemisszai*, however, has not been found elsewhere within the range of *H.simsoni*, despite inhabiting apparently similar forest types (Meggs *et al.* 2003a). The eastern and northern boundary of *H. vanderschoori* (Figure 2b) is predominately surrounded by unsuitable habitat (eg. drier forest types, plantation and cleared land), and searches outside the eastern boundary failed to find the species (Figure 2b). Although there is unsurveyed suitable habitat to the west of the range of *H. vanderschoori*, it is unlikely that future searches in this region will extend this western boundary by more than 1 km due to the limited extent of this habitat.

The area where the species occur is of particular ecological and evolutionary interest. It forms the northeast corner of an invertebrate bioregion (Plomleys Island) defined by the presence of a number of species of invertebrates that are endemic to the region (Mesibov 1994, 1996). These include the land snail *Anoglypta launcestonensis* (Reeve 1853), the centipede *Tasmanophilus* sp. NE45, and the millipedes *Gasterogramma* sp. 5 and *Lissodesmus* sp. NE4 (Mesibov 1994). Plomleys Island is also defined by the absence of well-mapped species that range up to the bioregional boundary, including a threatened species of velvet worm, *Tasmanipatus barretti* (Ruhberg *et al.* 1991), species in the land snail genus *Tasmaphena* and the millipedes *Lissodesmus alisonae* (Jeekel 1984), *Lissodesmus* sp. E1 and paradoxosomatid n.sp. (Mesibov 1996). The eastern and western boundaries of Plomleys Island are distinct faunal breaks where species assemblages change over a relatively short distance (Mesibov 1994). The results of this study assist the definition of the eastern boundary, known as the Goulds Country Break (Mesibov 1994). The stag beetles *H. bornemisszai* and *H. simsoni* and the velvet worm *Tasmanipatus barretti* meet on this break along a front that is about 21 km long and 2 km wide (Mesibov pers. comm.). The break is associated with a steep environmental gradient in the area, where there is a sharp transition from wet eucalypt to dry eucalypt forest (Meggs 1997).

Forest Type	% of sites with H. bornemisszai	% of sites with H. vanderschoori
Wet eucalypt	67% (6)	8% (12)
Mixed forest	50% (14)	29% (7)
Regenerated wet eucalypt	100% (3)	0% (3)
Damp eucalypt	67% (3)	Not applicable
Rainforest	Not applicable	21% (14)

Table 1. Percentage of sites sampled (in 1999 survey) in each forest type where *H. bornemisszai* and *H. vanderschoori* were found. The numbers of sites sampled in each forest type are shown in parentheses.

The distributions of the three stag beetle species (Figure 3) appear to form a biogeographic mosaic in the landscape similar to that observed for a large number of Tasmanian millipede lineages (Mesibov 2003). It is possible that these three *Hoplogonus* species evolved, through allopatric speciation, from an ancestral species whose range was fragmented due to glaciation or other climatic change. A significant proportion of the range of *H. simsoni* coincides with a glacial refugium (PLUC 1997), possibly indicating that *H. simsoni* is closest to the ancestral species. It is also possible that selective pressures have been sufficiently strong on the periphery of its range to result in parapatric speciation. The genetic differentiation of *Hoplogonus* species would be an interesting subject for future research.

The results of the present study suggest that both *H. bornemisszai* and *H. vanderschoori* are patchily distributed throughout their ranges and are found at low densities. The highest density estimates obtained for *H. bornemisszai* and *H. vanderschoori* (3.5 individuals/m^2 and 1.2 individuals/m^2 per site, respectively) were much lower than those obtained for *H. simsoni*, surveyed in the same way, which has been recorded at densities greater than 10/m^2 (Meggs *et al.* 2003a). The apparent absence of *H. bornemisszai* and *H. vanderschoori* at some sites may have been misleading due to their low density and cryptic habits. The discovery of *H. vanderschoori* during incidental surveys conducted in 2002, near to sites where in 1999 searches by the same individuals failed to detect the species, tends to support this view (Figure 2b). Despite the absences of specimens at some sites, the direct searching method we used has been shown in other studies to be more efficient than pitfall trapping (Mesibov *et al*. 1995; Meggs *et al*. 2003a).

H. vanderschoori appeared to inhabit wetter forest types than *H. bornemisszai*; mixed forest and rainforest. All the forest types sampled were utilised by *H. bornemisszai*, including damp eucalypt forest where it was found predominantly in the wetter riparian areas. Meggs and Munks (2003) found that, in the drier part of its range, the threatened broad-toothed stag beetle *Lissotes latidens*, in the south-east of Tasmania, also occurred predominantly in the moist riparian areas. Other studies of ground-dwelling invertebrates have identified the importance of riparian environments to individual species (Richardson and Devitt 1984; Brennan 2000). This preference for riparian areas may be attributed to the cool, moist microclimate provided by riparian areas compared with upslope habitats and the greater development of litter in riparian sites due to higher biomass of vegetation and lower frequency of fires.

The broad characteristics of habitat where *H. bornemisszai* and *H. vanderschoori* are found (e.g. wet forest, low altitude, leaf litter, logs) are similar to those of *H.simsoni* (Meggs *et al.* 2003a). There is, however, minor variation in the characteristics of habitat where each *Hoplogonus* species occurs in highest densities. For example, in contrast to *H. simsoni*, the densities of *H. vanderschoori* were significantly higher at sites with moderate slopes (5^o – 20^o+) and leaf litter less than 3 cm deep. The preference for leaf litter and logs suggests that a forest structure which provides a cool moist microclimate is important for both *H. bornemisszai* and *H. vanderschoori* as found in studies of other forest-dwelling ground beetles in evergreen forests (Niemela and Spence 1994; Ings and Hartley 1999; Meggs *et al.* 2003a).

The unreserved wet and mixed forest within the range of *H. bornemisszai* and *H. vanderschoori* is currently harvested by the clearfell, burn and sow silvicultural regime (Forestry Commission 1994). The absence of *H. vanderschoori* at sites in wet and mixed forest regenerating after such practices was not surprising. Studies have recorded significant effects on invertebrates immediately after clearfelling, including a reduction in individuals, change in community structure, complete loss of species and invasion by new species (Huhta *et al.* 1967;Vlug and Borden 1973; Lenski 1982; Curry *et al.* 1985; Szysko 1991; Niemela *et al.* 1993; Michaels and McQuillan 1995; Taylor *et al.* 2000). These impacts on soil and litter fauna can be exacerbated by regeneration burning after clearfelling (Huhta *et al.* 1967; Madden *et al.* 1976; Vlug and Borden 1973; Neumann 1991; Strehlow *et al.* 2002). Unlike *H. vanderschoori*, *H. bornemisszai* was, however, found at three sites in 14-year old forest regenerating after clearfell, burn and sow practices. Similarly, Meggs *et al*. (2003a) also found *H. simsoni* in regenerated wet forest. Madden *et al*. (1976) and Moldenke and Lattin (1990) demonstrate the importance of moist refuges provided by structures, such as decaying logs and rocks, within the harvest area in allowing invertebrate species to survive regeneration burns. As suggested for *H. simsoni* (Meggs *et al*. 2003a), the presence of such refuges may have enabled *H. bornemisszai* to persist following the clearfell, burn and sow operations. Alternatively, the harvested sites sampled in this study may have been recolonised by *H. bornemisszai* from adjacent undisturbed forest. It is likely that after 14 years the microclimate suitable for litter and soil fauna had recovered to some extent (Madden *et al.* 1976).

Although plantation sites were not sampled in this study, previous surveys have failed to find any of the *Hoplogonus* species in plantations established close to known localities of the species (Meggs 1997; K. Richards, unpublished data; Meggs *et al.* 2003a). This is likely to be a consequence of the divergence of these forest's microhabitats from the natural forest habitat of the species and the intensive nature of plantation forest management. The latter includes a high level of soil disturbance that is likely to have a significant impact on the edaphic *Hoplogonus* larvae. This impact may be exacerbated over successive rotations (15-30 year intervals), having a significant cumulative impact on populations of the beetles. It is tempting to speculate that the absence of *H. vanderschoori* at the sites regenerating after clearfell, burn and sow is because these sites were adjacent to or within areas that had been converted to plantation.

Conservation considerations

The lack of knowledge of the characteristics and extent of habitat occupied by *H. bornemisszai* and *H. vanderschoori*, at the time of their listing as threatened in 1999, severely hampered the development of management prescriptions to minimise adverse effects of habitat disturbance. Such information was urgently required due to the intensification of forestry activites in 'off-reserve' areas in the north-east of the State, where these species occur, following Tasmania's Regional Forest Agreement (Commonwealth of Australia and State of Tasmania 1997; Munks and McArthur 2001; Lindenmayer and Franklin 2002). Although the dataset in this study is small, the patterns in habitat preference that have emerged make ecological sense and are consistent with the broad habitat preference of the more intensively

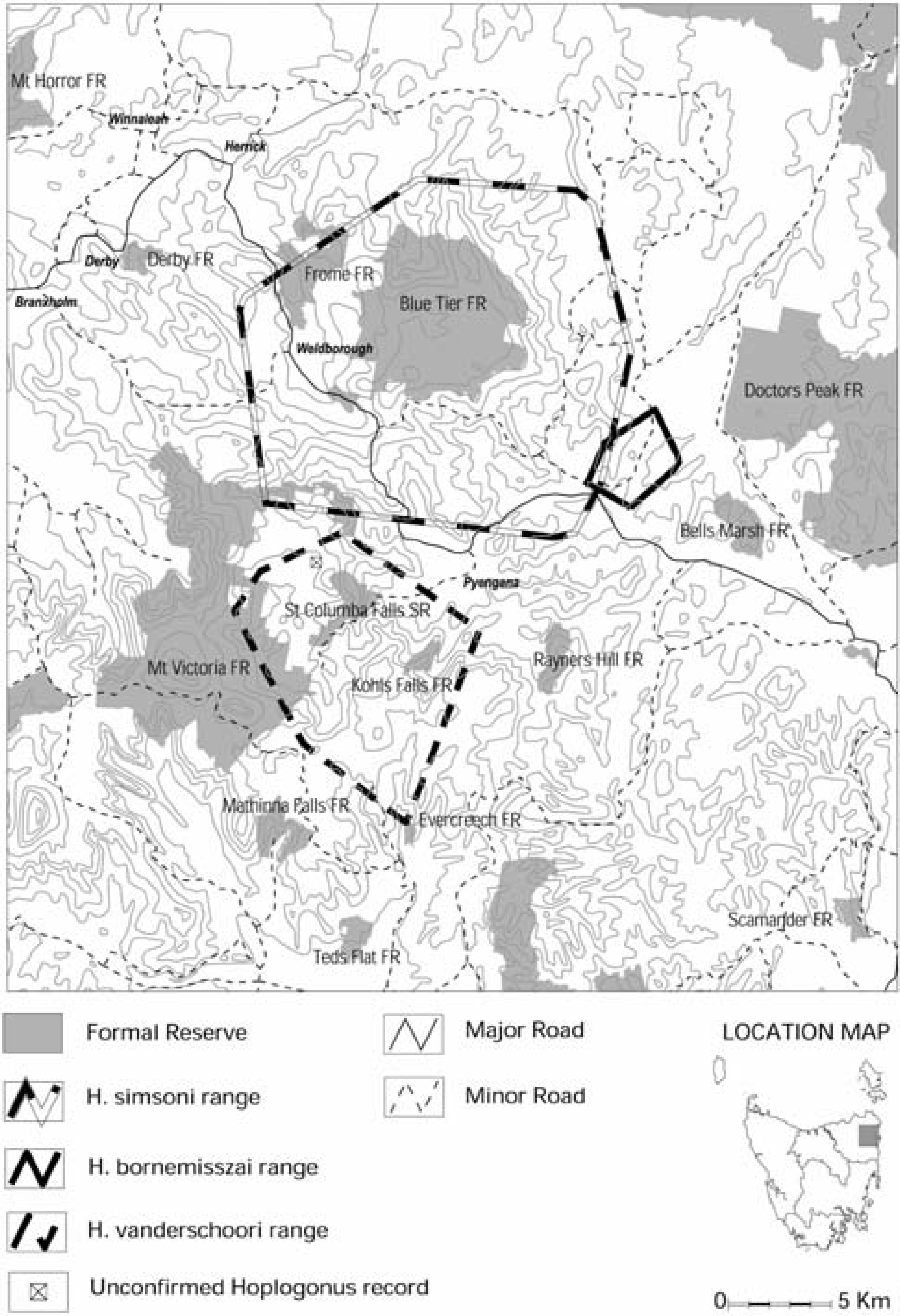

Figure 3. Ranges of *H. bornemisszai, H. vanderschoori* and *H. simsoni* in the north-east of Tasmania.

studied *H. simsoni* (Meggs 2003; Meggs *et al.* 2003a,b). Surveys for both *H. bornemisszai* and *H. vanderschoori* will continue as part of the planning process in place, which is designed to ensure that threatened fauna are taken into account in forestry areas (Munks and Taylor 2000). The results of these future surveys will further our knowledge of the species, habitat preferences. In the meantime, despite the small dataset, we feel that the information collected in this study provides a basis for evaluating the existing conservation status of the species. It also enables a prediction to be made of the distribution of habitats important to the species and the areas where conservation of *H. bornemisszai* and *H. vanderschoori* would conflict most strongly with planned forestry activities.

Although this study increased the range and number of known sites of both *H. bornemisszai* and *H. vanderschoori* the results do not alter their threatened status. *H. bornemisszai* and *H. vanderschoori,* should remain listed under the Tasmanian *Threatened Species Protection Act 1995* as endangered and vulnerable, respectively, mainly due to the potential decline in quality of habitat for the species in the absence of mitigation measures. Only 20% of *H. bornemisszai* potential habitat and 30% of potential habitat for *H. vanderschoori* is currently reserved or bound by a covenant that precludes forestry activities (Table 2). The remaining 79% of *H. bornemisszai* potential habitat and 71% of *H. vanderschoori* potential habitat is in unreserved private or State forest (Table 2). 54% of the unreserved habitat for *H. bornemisszai* and 37 % of the unreserved *H. vanderschoori* habitat has been identified as having potential for wood production to meet sustainable yield targets (Forestry Tasmania 2002; Table 2). Five hundred and twenty hectares of potential habitat for *H. vanderschoori* has already been converted to hardwood plantation and another 210 hectares has been identified as having potential for conversion to plantation in the next 10 years (Forestry Tasmania, unpublished data).

Given the restricted range, limited reservation of potential habitat and the continuing threat of disturbance due to forestry and agriculture within the range of both *H. bornemisszai* and *H. vanderschoori*, the application of 'off-reserve' conservation measures are important to ensure their long-term survival. To assist their recovery, maintenance of existing viable populations should include exclusion of potential threats to the quality of habitat and hence their extent of occurrence. Specifically, there should be no conversion of potential habitat to plantation or clearing for agriculture within the range of either species. In addition, there should be a moratorium on clearfell, burn and sow silviculture in potential habitat within the small range of *H. bornemisszai* until the potential long-term effect of this practice on the habitat of this endangered species has been reviewed. Although, in this study, the species was found to occur in forest regenerating after clearfell, burn and sow practices, caution should be exercised in drawing conclusions due to the small number of coupes sampled in this study. Without sampling over time, it cannot be established whether populations in harvested areas are in decline, increasing, or stable (e.g. Koivula 2002; Strehlow *et al*. 2002). Clearfell, burn and sow silviculture and plantation establishment within the range of both species should be reviewed following the results of a long-term study (now in its fourth year) looking at the impacts of these forestry practices on the related species, *H. simsoni* (S. Munks, J. Meggs, M. Wapstra and K. Richards, unpublished data).

Table 2. The quantity of potential habitat for *H. bornemisszai* (wet, mixed and damp eucalypt forest) and *H. vanderschoori* (wet and mixed eucalypt forest and rainforest) in various land tenure and land-use categories. The figures in parentheses represent the percentage of the total potential habitat available to the species within their range.

Land tenure/use	Potential H. bornemisszai habitat (ha)	Potential H. vanderschoori habitat (ha)
Formal reserves[1]	0 (0%)	1340 (24%)
Informal reserves[2]	100 (14%)	320 (6%)
State forest (couped)[3]	380 (54%)	2060 (37%)
State forest (uncouped)[4]	70 (10%)	1000 (18%)
Other public land	0 (0%)	20 (1%)
Private property covenant[5]	45 (6%)	0 (0%)
Private property other	105 (15%)	860 (15%)
Total	**700 (100%)**	**5610 (100%)**

Source: Forestry Tasmania 18/02/2004

[1] These include dedicated reserves (e.g., national parks, state reserves, forest reserves etc.) whose status is secure, requiring action by the Tasmanian Parliament for revocation.

[2] These include areas, other than formal reserves, identified as Protection Zones or other administrative reserves on public land. It includes some areas protected by management prescription under the *Forest Practices Code* on public land (e.g., wildlife habitat strips). It does not include areas protected by management prescription under the *Forest Practices Code* on private land or areas set aside to protect Comprehensive, Adequate and Representative reserve values on private land.

[3] Areas identified as potentially available for wood production.

[4] Areas identified as potentially unavailable for wood production primarily due to operational constraints and economic factors. This also includes some areas protected by management prescription under the *Forest Practices Code* on public land (e.g., streamside reserves).

[5] Private property covenant established under the Tasmanian Private Forest Reserve Program, under which forestry activities are precluded in the covenanted area.

The present study illustrates the value of basic survey information on the distribution and habitats used by a listed invertebrate species, in a situation where there is urgency for conservation action due to continuing threats. Ideally, much more detailed knowledge of the physiological and ecological requirements of a threatened species and its long-term responses to disturbance should be obtained to ensure the development of effective conservation measures. However, such information is unlikely to be available in the near future for these species or for many of the other invertebrates listed on the Tasmanian *Threatened Species Protection Act, 1995*. Currently single species studies are driven by the need for land managers to meet the legislative requirement to protect a particular invertebrate species listed under the Tasmanian *Threatened Species Protection Act, 1995*. But such studies are relatively expensive, especially in the light of the 154 invertebrate species currently listed under the Tasmanian *Threatened Species Protection Act, 1995* (DPIWE 2001). Mesibov *et al.* (2002) discuss the inefficiency of single species studies for the conservation of Tasmania's invertebrate diversity in general. Although, conservation measures resulting from single species studies also benefit ecologically similar co-occurring species, measures to meet the broader aim of conserving invertebrate diversity outside the ranges of threatened species are also required.

Acknowledgements

This study was funded by Forestry Tasmania, with substantial in-kind support from the Forest Practices Board. Jamie McKimmie, Beris Hansberry and Helen Otley provided field assistance for the 1999 survey. Michael MacDonald conducted the range boundary survey in 2003. Local landowners are thanked for allowing access to their properties. Luke Ellis (Forestry Tasmania) prepared the GIS analyses. Bob Mesibov, Graham Wilkinson and Alastair Richardson made comments on earlier drafts of the paper. Comments from two anonymous referees improved an earlier draft of this paper.

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