DISTRIBUTION, HABITAT AND CONSERVATION STATUS OF *ENGAEUS GRANULATUS* (DECAPODA: PARASTACIDAE) AND RELATED SPECIES OF FRESHWATER BURROWING CRAYFISH IN CENTRAL NORTHERN TASMANIA

by Alastair MM Richardson, Mark Wapstra and Ryan Francis

(with four figures and two tables)

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The distribution and habitat of *Engaeus granulatus* are reviewed. The species is restricted to a relatively small area in central northern Lutruwita/Tasmania between Devonport in the west, Asbestos Range in the east and Sheffield to the south. The habitat of *E. granulatus* includes swamps, floodplains of small creeks, poorly-drained areas in paddocks and roadside/railway ditches. The range of *E. granulatus* overlaps to varying degrees with *E. mairener, E. nulloporius, E. fossor, E. cisternarius*, *E. cunicularius* and *E. excavator*. It is not possible to identify the species by reference to characteristics of the burrow or habitat (although it can be a useful guide). Burrow excavation remains the only means of identifying the occupant pending development of non-invasive means, such as eDNA. With the recent description of *E. excavator* from within the core range of *E. granulatus*, and the overlap with five other species, the conservation status of *E. granulatus* is probably even more tenuous than previously thought: while its extent of occurrence remains similar, its area of occupancy within this extent may be significantly less than previously suggested.

Key Words: burrowing crayfish, *Engaeus*, Tasmania, Australia, conservation status.

INTRODUCTION

Burrowing crayfish in the genus *Engaeus* are found in southeastern Australia, including northern and western Lutruwita/Tasmania. The genus was last revised by Horwitz (1990) and since then two further species have been described (Horwitz 1994, Richardson 2024). Most species of *Engaeus* are primary burrowers (*sensu* Hobbs 1981) and several species construct type 3 burrows (Horwitz & Richardson 1986), i.e., burrows that store water above the water table, making them among the world's most terrestrialised crayfish. The burrowing lifestyle constrains dispersal of juveniles, especially if the burrows are not in direct contact with surface water, with the result that several *Engaeus* species are short-range endemics. Small, geographically restricted populations of these essentially sedentary animals render them vulnerable to habitat changes and stochastic events, so some of them are of conservation concern. In Tasmania, five species are currently listed under Tasmania's *Threatened Species Protection Act 1995* (TSPA) and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBCA), three as nationally endangered (table 1).

The central north burrowing crayfish, *Engaeus granulatus* Horwitz 1990, has a restricted distribution between Devonport in the west, Asbestos Range in the east and Sheffield to the south (fig. 1). Its range includes intensive farming on productive agricultural soils, the Devonport conurbation, the Railton limestone quarry, cement works and associated rail line, and other developments, all of which have severely fragmented its populations leading to its endangered status (Doran 2000). Burrows of this species are vulnerable to activities that involve excavation or lowering of the water table, for example in maintaining roadside and rail-side drains, installing irrigation systems or developing subdivisions. Even if the crayfish survives its burrow being excavated it does not have the ability to dig a new burrow fast enough to survive, and if the water table is lowered below the bottom of the burrow the crayfish will die from desiccation.

Horwitz *et al.* (1990) suggested that *E. granulatus* forms a clade with two other species: *E. mairener* Horwitz 1990 and *E. nulloporius* Horwitz 1990, and a preliminary genetic analysis suggests that the recently identified *E. excavator* Richardson 2024 can be added to this clade (Richardson unpubl. data). The species within the clade are morphologically similar, varying only in sternal pore arrangements, setation and granulation on the claws. Further, the chela, abdomen and carapace sizes and ratios are similar. The morphological similarities are mirrored by their habitat preferences, with all four species predominantly constructing type 2 burrows, often in clay subsoils in areas containing shallow groundwater, or around springs and seeps.

Burrowing crayfish present special problems for the environmental surveys required for proposed developments:

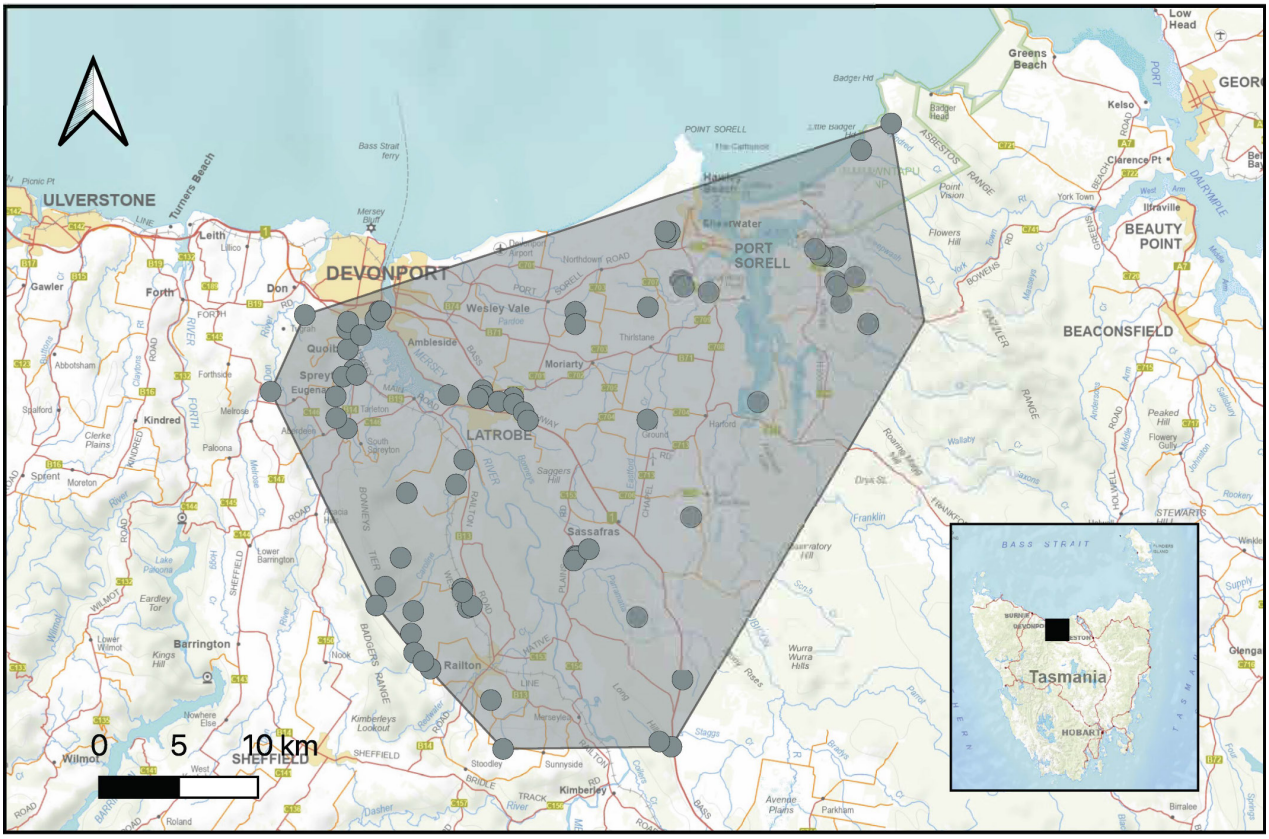

FIG. 1 — Minimum convex polygon representing the geographical range of *Engaeus granulatus* (grey dots) from reliable NVA records (Base map: ListMap).

TABLE 1 — *Engaeus* species in Lutruwita/Tasmania and their conservation listing under the Tasmanian *Threatened Species Protection Act 1995* (TSPA) and Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999* (EPBCA).

Species	TSPA	EPBCA
Engaeus cunicularius		
E. cisternarius		
E. disjuncticus		
E. excavator		
E. fossor		
E. granulatus	EN[1]	EN
E. laevis		
E. lengana		
E. leptorhynchus		
E. mairener		
E. martigener	VU[2]	EN
E. nulloporius		
E. orramakunna	VU	VU
E. spinicaudatus	EN	EN
E. tayatea		
E. yabbimunna	VU	VU

[1] Endangered; [2] Vulnerable

their burrows are not always easy to find, and when found it may require hours of labour to extract and identify the crayfish species. Furthermore, excavation destroys the burrow and can damage surrounding habitat, so excavation should be avoided where possible. Richardson *et al.* (2008) suggested that *E. granulatus* occupies an exclusive central range, leading to the assumption that crayfish burrows found within that core range, at sites of interest in land management issues for example, could be assigned to *E. granulatus,* thus avoiding the need for excavations. However, as records have accumulated, that assumption has been increasingly challenged.

This paper summarises the current state of knowledge on *E. granulatus* and associated crayfish species and makes recommendations for assessing burrowing crayfish occurrences in the central north region. We seek to answer two questions: is there an exclusive core range within which any burrow can be assumed to be that of *E. granulatus,* and can we identify the total range of *E. granulatus* with enough accuracy to set a boundary beyond which burrows do not need to be checked for *E. granulatus* in the event of proposed development activities?

METHODS

The Tasmanian *Natural Values Atlas* (www.naturalvaluesatlas.tas.gov.au) (NVA), contains the most current records of freshwater crayfish in the state. As well as casual records going back many decades, all records from recent environmental surveys must be lodged in this database as a permit condition, hence it provides the best available data to assess current species' ranges. However, burrowing crayfish present a special issue with this system in that it is not always clear whether records are of a specimen reliably identified in the hand, or simply the presence of a burrow that has been assumed to be of a particular species. This has been particularly the case for *E. granulatus*, because of an expectation that it has an exclusive core range.

Records of *E. granulatus* and the following species were extracted from the NVA on 26 May 2025: *E. mairener, E. nulloporius, E. fossor, E. cisternarius* and *E. cunicularius*. The ranges of these burrowing species all appear to be contiguous with, or overlap, that of *E. granulatus*. A further species, *E. disjuncticus* Horwitz 1990, can be found within 12 km of the *E. granulatus* range, and an envelope including all its known records would overlap with *E. granulatus*. *E. disjuncticus*, as the name suggests, has an anomalous, disjunct range, but it is currently unclear whether the separate occurrences are natural or the result of under-collecting, so it has been excluded from this analysis.

E. granulatus records were filtered to minimise the chance of misidentification, or records based simply on burrows. Only records from collectors with known expertise in identification were accepted, and within these all records with 'assumed' in the Notes field were rejected.

Crayfish records were mapped and analysed using QGIS Ver 3.38. Minimum convex polygons were constructed around the filtered records of each species using the Minimum Bounding Geometry routine in QGIS. Areas of polygons and overlaps were determined using the QGIS Field Calculator.

RESULTS

The NVA yielded 273 records of *Engaeus granulatus*, but after filtering, these were reduced to 86. The range as defined by the most reliable records only deviates a little from the all-records range. In the southeast, records from Browns Creek, and south of Drys Sugarloaf, are well outside the reliable records range, but in both cases the collectors recorded the identification as 'assumed'. To the north, two other unverified records would extend the range slightly westwards across Devonport and close to the coast. Within a 5 km buffer around the reliable records range, there are at least seven records of three other *Engaeus* species, giving some indication of crayfish surveys that have <u>not</u> located *E. granulatus*.

The distributions of six other *Engaeus* species overlap with that of *E. granulatus*: *E. fossor, E. cisternarius, E. mairener, E. cunicularius, E. nulloporius* and *E. excavator*. Minimum convex polygons are a crude but objective way of representing the range of a species from a set of point records. Convex polygons were created for all species and overlaid on that of *E. granulatus* (fig. 2A–F). The current known range of *E. excavator* is very small and lies completely within the range of *E. granulatus* on the eastern outskirts of Latrobe (fig. 2A). The degree to which these species overlap with the range of *E. granulatus*, their habitat and the likelihood that their burrows might be confused with those of *E. granulatus,* have been summarised (table 2).

E. fossor and *E. cisternarius* both have very large ranges in the west of Tasmania. *E. fossor* penetrates the west and south of the *E. granulatus* range (fig. 2B) and its habitat requirements are similar to those of *E. granulatus* (Suter & Richardson 1977, Horwitz 1990). *E. cisternarius* also overlaps from the west (fig. 2C), but its burrows are usually type 3 (i.e., perched above the water table, Horwitz & Richardson 1986) so are unlikely to be fully sympatric with, or confused with, those of *E. granulatus*. However, where *E. cisternarius* and *E. granulatus* are sympatric, the locations of burrows need to be carefully scrutinised, as the microhabitat change can occur over less than 1 m. *E. cisternarius* burrow systems have entrances in the walls of gullies, often on steep slopes, above surface waters and seeps, often without visible chimneys. *E. granulatus* and *E. fossor* burrows have visible chimneys in areas with surface water or areas that are saturated and muddy.

E. mairener has an extensive range in northeastern Tasmania. It has the largest overlap with *E. granulatus*, extending from its eastern boundary to the Mersey River (fig. 2D). *E. mairener* constructs type 2 burrows in a range of habitats from stream floodplains to open paddocks (Horwitz 1990, Richardson pers. obs.).

E. cunicularius appears to have a near-coastal range, at least in the central north. The few records within the range of *E. granulatus* (fig. 2E) are all within 1–2 km of the coast. It constructs burrows close to creeks: type 1b burrows with entrances above and below the water, and older, more complex type 2 burrows a little further away (Horwitz 1990).

The recently described *E. excavator* has currently the smallest known range overlap with *E. granulatus* (fig. 2A). *E. excavator* is known from just two sites a few kilometres apart on the outskirts of Latrobe (Richardson 2024). At both sites the species was found in established paddocks, in deep type 2 burrows in predominantly clay soils.

Finally, *E. nulloporius* has a small overlap in the southeast of the range of *E. granulatus* (fig. 2F). It constructs type 1b and type 2 burrows, usually in clay soils close to creeks and swamps. Horwitz (1990) recorded it in sympatry with *E. granulatus* near Elizabeth Town, though this record is not in the NVA.

DISCUSSION

When the ranges of these six species of *Engaeus* are superimposed on the range of *E. granulatus* (fig. 3), there is little evidence that *E. granulatus* has an exclusive range. Only a narrow strip of land, about 19 km long and 4–9 km

TABLE 2 — Species of *Engaeus* with ranges overlapping, or very close to, that of *Engaeus granulatus,* showing the percentage overlap of their minimum convex polygons ranges; burrow type, (following Horwitz & Richardson 1986) and likelihood of confusion with *E. granulatus*

Species	% range overlap	Burrow type[1]	Burrows may be confused with *E. granulatus*?	Reference
Engaeus fossor	28.8	2	Yes	Suter & Richardson (1977), Horwitz (1990)
E. mairener	42.3	1b, 2	Yes	Horwitz (1990)
E. cisternarius	2.5	3	Unlikely due to habitat, but differences are subtle	Suter & Richardson (1977), Horwitz (1990)
E. cunicularius	16.6	1b, 2	Only within 2–3 km of coast, but beware estuaries	Horwitz ((1990)
E. excavator	<0.1	2	Yes	Richardson 2024)
E. nulloporius	1.6	2	Yes	Horwitz (1990)

[1] Burrow type 1b associated with standing water, burrow entrances above and below the surface; burrow type 2 not directly associated with surface water, but always descending to the water table; burrow type 3 not associated with standing water but perched above the water table

wide, from Tugrah to south of Sassafras, is not overlapped by any of the other species based on present records (fig. 3). Part of this strip is close to the Mersey estuary, which could potentially be habitat of *E. cunicularius*, and much of the northern part is within the area identified by Richardson (2024) as potential habitat for *E. excavator*. Even though there appears to be a small part of the range of *E. granulatus* exclusive of all other species, it would be risky to assume that every burrow there belongs to that species.

Is it possible to distinguish *E. granulatus* burrows by their external form or by the microhabitat? Only in a very few cases can crayfish be identified by their burrow openings, and even then, identification is unreliable (Richardson & Swain 1991). Only experienced observers can suggest a species' identity from burrow form and microhabitat. *E. granulatus* has been found in a range of habitats from swamps, floodplains of small creeks (Horwitz 1990, Richardson *et al.* 2008), poorly drained areas in paddocks, and in ditches and drains associated with road and rail infrastructure. *E. fossor* and *E. mairener* are both commonly found in swamps and floodplains, while *E. mairener, E. nulloporius* and *E. excavator* can also be found in damp patches in paddocks usually colonised by species of rush (*Juncus* spp.) and sedge (e.g., *Carex* spp., *Gahnia* spp., *Lepidosperma* spp.). The differences between the habitat preferences of Tasmanian burrowing crayfish can be subtle, usually in terms of soil drainage, water table depth and soil type (Suter & Richardson 1977, Richardson & Horwitz 1988, Richardson & Swain 1991, Hopgood-Douglas 2005), but with the current state of knowledge it is not possible to distinguish *E. granulatus* burrows from those of these other species in the field.

How precisely can the range of *E. granulatus* now be defined? It is impossible to state confidently where a species does not occur, but where other species of crayfish have been identified outside the *E. granulatus* range but in suitable habitat, then its absence can be inferred. Figure 4 shows the occurrences of other *Engaeus* species near the range of *E. granulatus*, with nominal 2 km and 5 km buffers. While there are some records of other species to the south and west of the range, there are large zones to the east and southeast without crayfish records, where the edge of the range remains uncertain.

It is unlikely that the minimum convex polygon precisely marks the edge of the range of *E. granulatus*: burrows within a buffer of at least 2 km should be checked along its western boundary, and to 5 km or more along the southern and eastern boundary. Environmental domain modelling by Richardson *et al.* (2008) suggested that suitable conditions for *E. granulatus*, in terms of climate and topography, exist to the east of the Asbestos and Dazzler ranges, but its presence there has not yet been confirmed.

Given the landscape in which it occurs, with further developments likely in agriculture, industry and housing, *E. granulatus* will remain a conservation issue. We have shown that it is no longer safe to assume that all burrows within its range are that species, so directly identifying the burrow occupant will be necessary through excavation of the burrow. Recent developments in eDNA techniques (Dawkins *et al.* 2024) offer the possibility of identifying burrow occupants from eDNA present in material ejected from the burrow. This technique shows great promise, but at this time it has not been used on Tasmanian burrowing crayfish. To implement it will require DNA sequencing of all the potential species. It is also worth noting that Dawkins *et al.* (2024) were only able to identify crayfish DNA in slightly over 50% of the burrows sampled, so surveys will need to sample large numbers of burrows. We strongly recommend the development and refinement of this approach for investigating Tasmanian burrowing crayfish.

The current endangered status of *E. granulatus* remains appropriate and there is no evidence that it could be downlisted under either the EPBCA or TSPA. Furthermore, its status on the EPBCA should be reviewed to assess whether it would qualify as Critically Endangered given its area of occupancy within its predicted range will be further reduced as a result of new records of other species of *Engaeus*. However, this would require further survey effort. At this time, no other species of *Engaeus* included in this paper warrant listing on either legislation. Although the

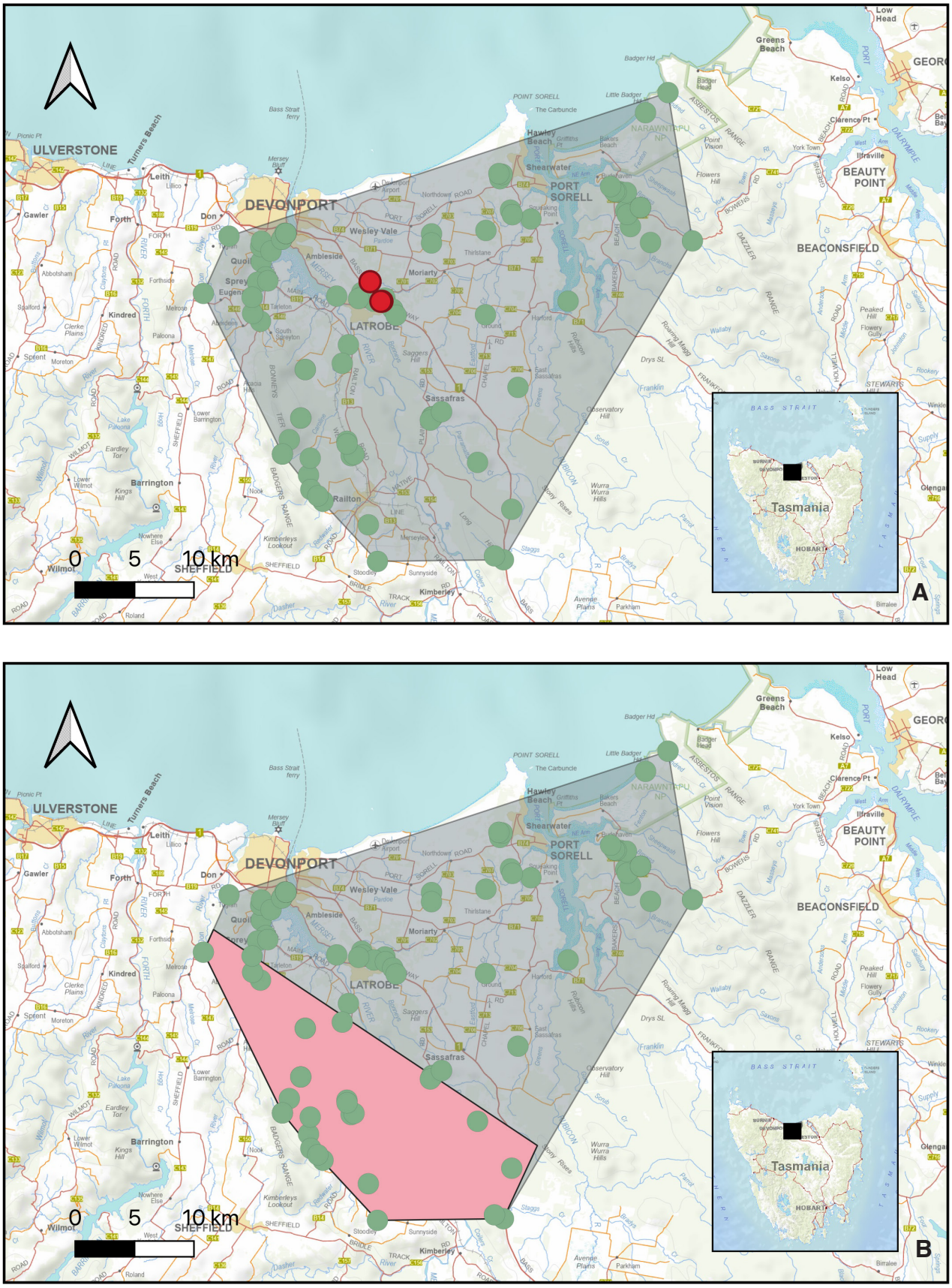

FIG. 2 — **A** Range of *Engaeus granulatus* and the two locations where *E. excavator* has been found (red dots). (Base map: ListMap). **B** Range of *Engaeus granulatus* overlapped by *E. fossor* (pink polygon) (Base map: ListMap).

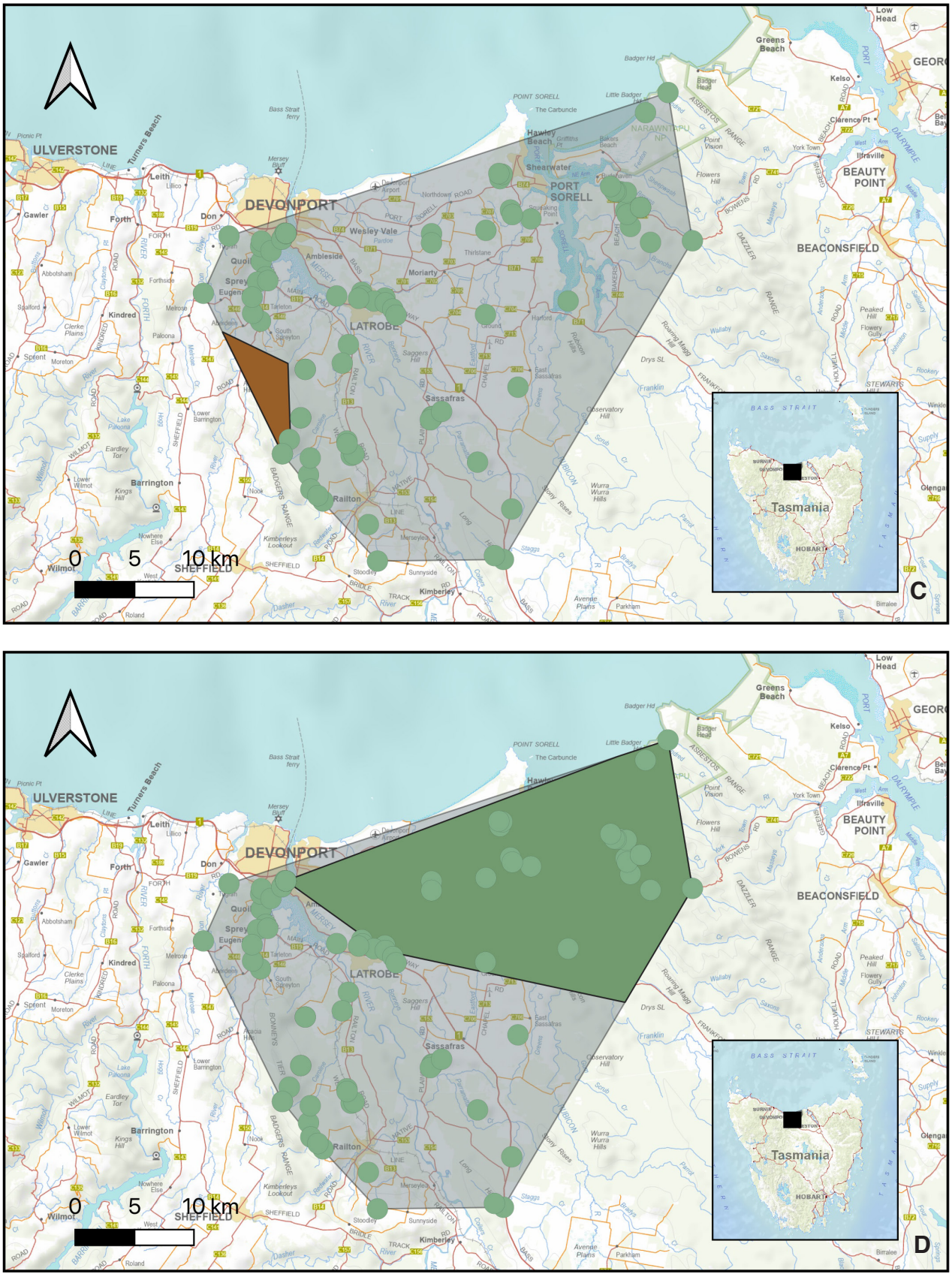

FIG. 2 — **C** Range of *Engaeus granulatus* overlapped by *E. cisternarius* (brown polygon) (Base map: ListMap); **D** Range of *Engaeus granulatus* overlapped by *E. mairener* (green polygon) (Base map: ListMap).

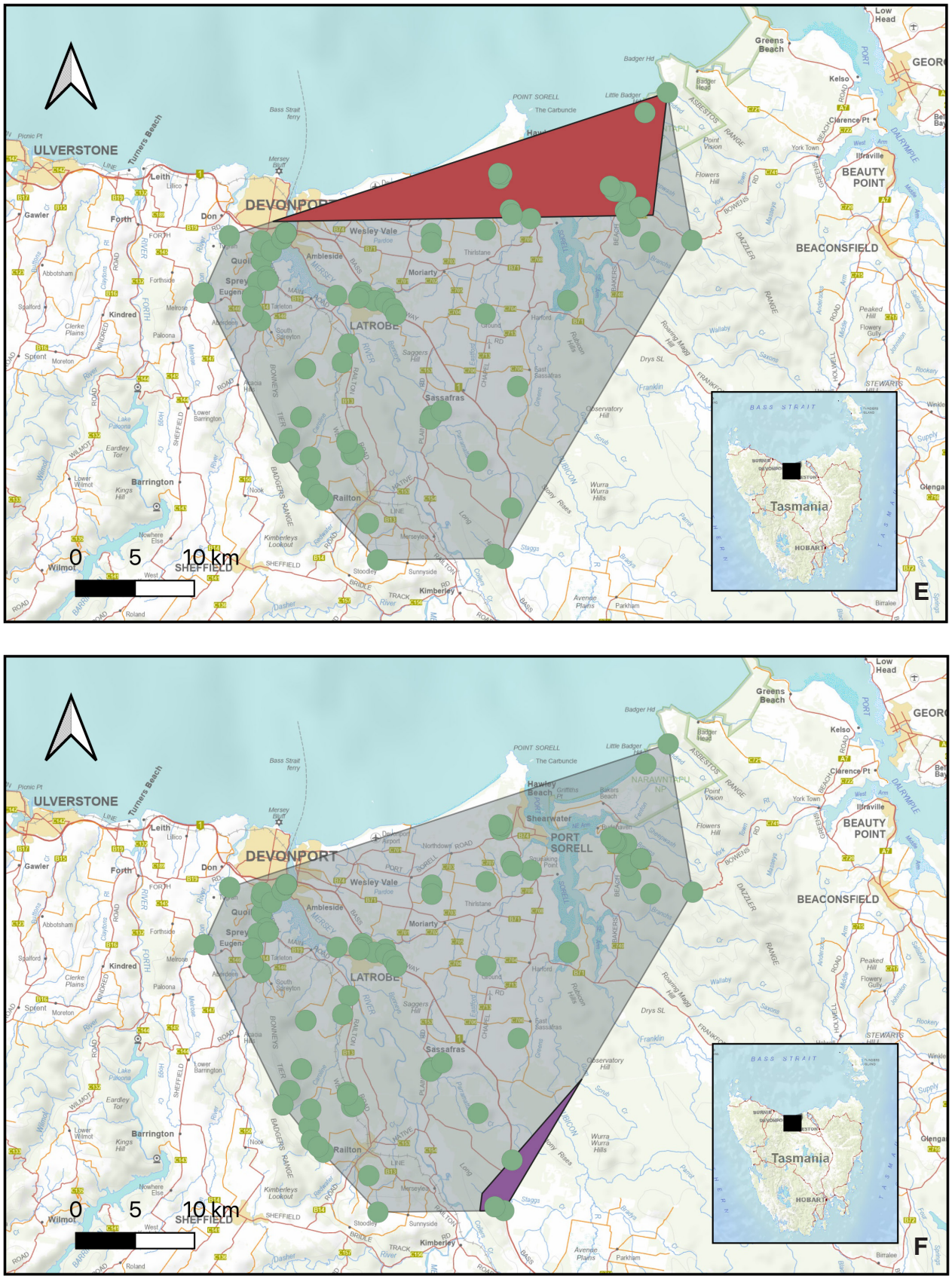

FIG. 2 — **E** Range of *Engaeus granulatus* overlapped by *E. cunicularius* (maroon polygon). The range of *E. cunicularius* is probably exaggerated by records further from the coast, outside the *E. granulatus* range to the east (Base map: ListMap). **F** Range of *Engaeus granulatus* overlapped by *E. nulloporius* (purple polygon) (Base map: ListMap).

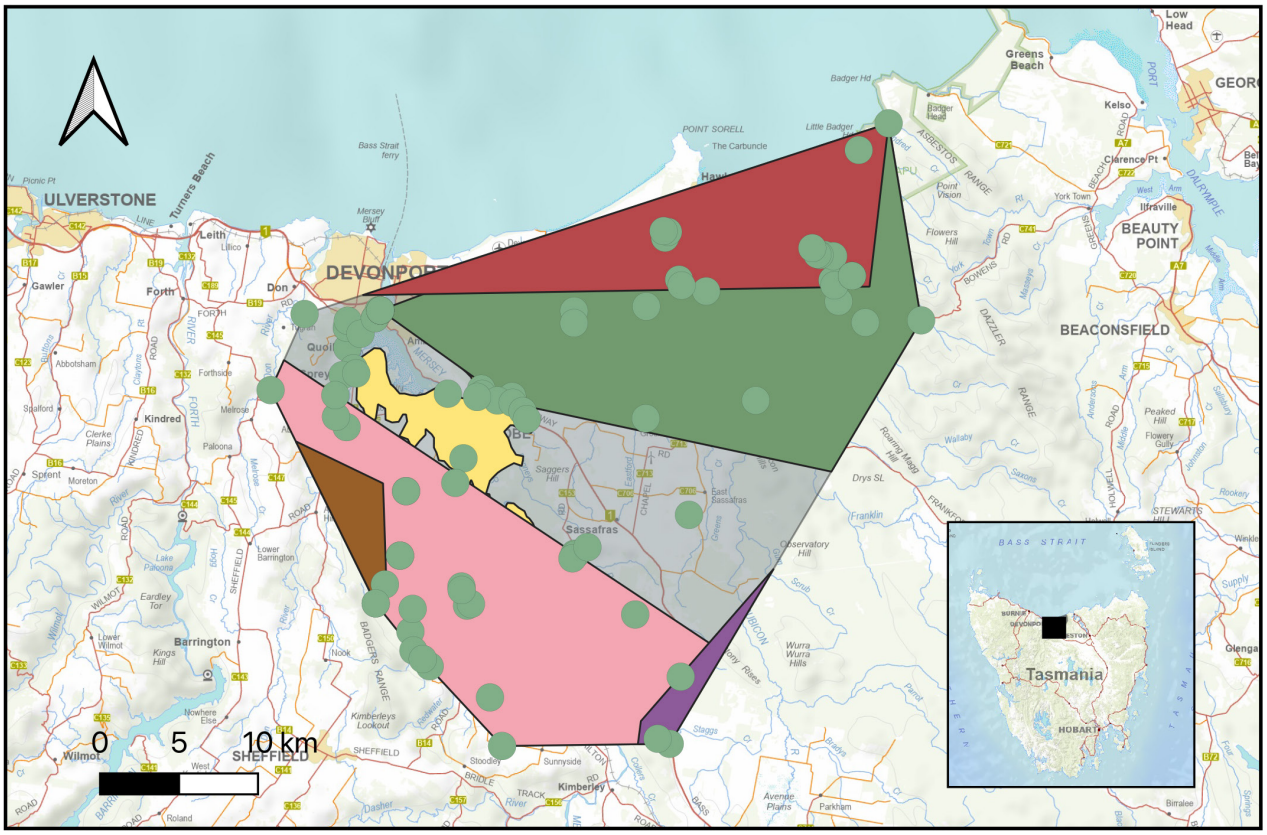

FIG. 3 — Range of *Engaeus granulatus* showing overlaps with other *Engaeus* spp.: *E. cisternarius* (brown), *E. fossor* (pink), *E. nulloporius* (purple), *E. mairener* (green) and *E. cunicularius* (maroon). The yellow polygon encloses land below 10 m asl, potential habitat for *E. excavator* (Richardson 2024). (Base map: ListMap).

current known range of *E. excavator* is very small, based on the conclusion of Richardson (2024) that without any further data on its range and area of occupancy, any assessment of its conservation status, beyond an informal assessment as data-deficient, is impossible. However, the possibility that *E. excavator* is a narrow-range endemic species must not be ignored, and we emphasise the need for an intensive survey to clarify its status, and in doing so provide clarification of the status of *E. granulatus* in a substantial part of its range.

Our results show that the management of *E. granulatus* is legislatively and practically more complicated than previously thought. The assumption that *E. granulatus* is the occupant of burrows within the current known range (i.e., the minimum convex polygon around apparently reliable records) is simply not tenable: at least six other species co-occur, to varying extents, with this species. This assumption almost certainly resulted in the recently-described *E. excavator* being overlooked. Since excavating burrows in dry paddocks without mechanical assistance involves many hours of work it is easy to see why surveyors might lean on the assumption that such burrows belong to *E. granulatus*, whereas they might equally belong to *E. excavator* or indeed *E. mairener.*

Under the EPBCA, activities that directly impact on the habitat of the listed *E. granulatus* may warrant referral under the Act or a permit under the TSPA. When burrows are present in an area, this can lead to long-term and complex approval conditions for a project, with considerable costs involved. In these cases, identifying the occupying species is a critical component of any management strategy. However, this comes with its own challenges. At present, excavation is the only way to identify the species present, an activity that in itself may be subject to both Commonwealth and State permit requirements, and one that is, at least in temporary terms, destructive. Under the TSPA, permits have been (and continue to be) issued under Section 51 (through the *Threatened Species Protection Regulations 2016*) to knowingly take specimens of a listed taxon. But there is a bootstrapping problem here: until a burrow is excavated and its occupant identified, there is no way of knowing whether it is a listed species, and thus whether a listed species has been 'knowingly taken'. Without direct evidence of the species present, this is almost certainly an untenable legal position. Similarly, under the Tasmanian *Nature Conservation Act 2002* (through the *Nature Conservation (Wildlife) Regulations 2021*), permits to take specially protected wildlife (which is how *E. granulatus* is listed) and products of the species (which is how burrows have been interpreted) are issued: again, under the potentially false assumption that the species involved is *E. granulatus*. This legal position taken by officers of the Department of Natural Resources and Environment Tasmania (NRE Tas) is probably tenuous – clearly until a successful excavation has occurred and a specimen is in hand, one does not 'know' if an action would impact a listed taxon. At least under

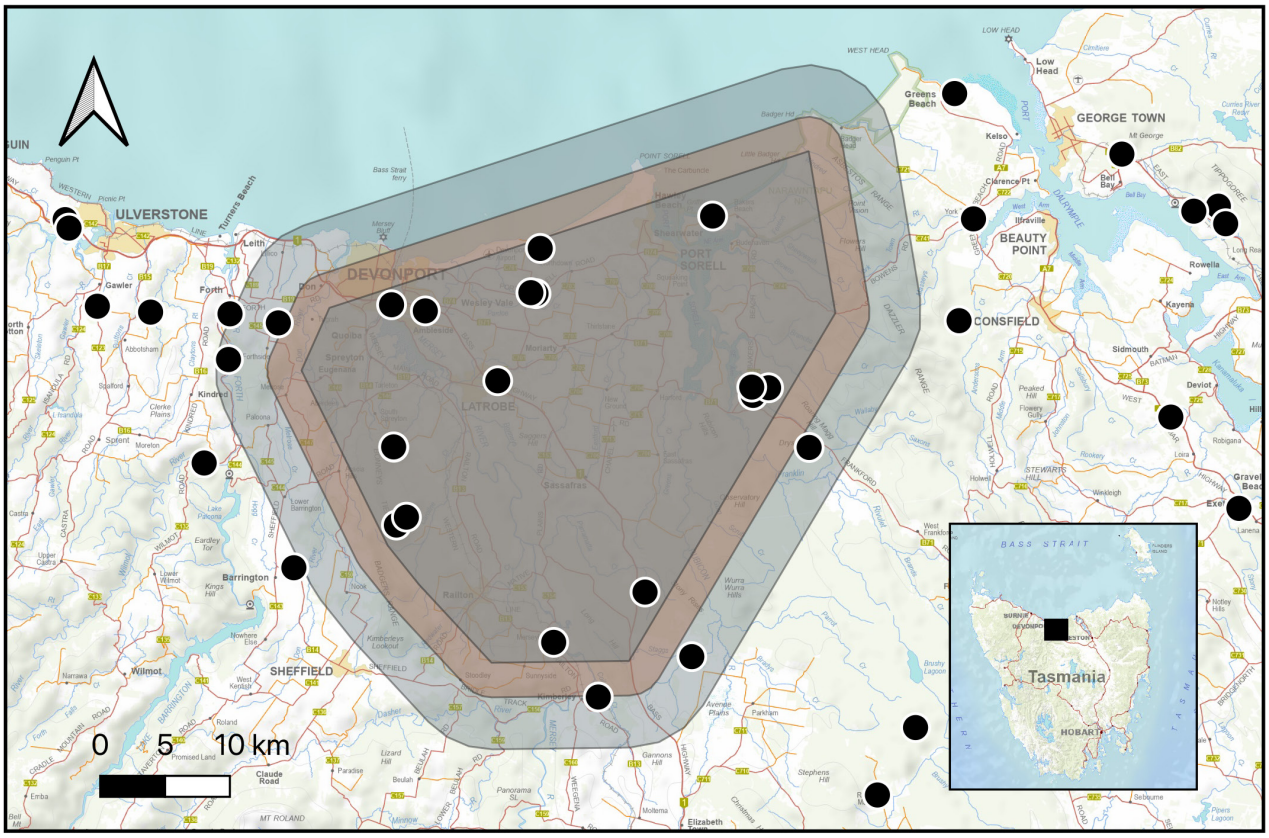

FIG. 4 — Range of *Engaeus granulatus* with 2 km and 5 km buffers, plus records of other *Engaeus* species (black dots) (Base map: ListMap).

Section 51 of the TSPA, 'a person must not **knowingly**, without a permit – (a) take, keep, trade in or process any **specimen of a listed taxon** of flora or fauna' (our emphasis added in bold). For the record, permits are also required for survey and handling of any members of the Parastacidae under the Tasmanian *Inland Fisheries Regulations 2019*.

We are aware of the potential implications of the findings presented here. No longer is assumption a valid approach to the management of a State- and Commonwealth-listed species of *Engaeus*. While excavation is certainly not a preferred survey option, at present it is the only viable one that yields results that can usefully inform management. Unfortunately, we also know that manual excavation is not always successful and mechanical assistance may be required (this is absolutely the case for *E. excavator*).

We urge all researchers and naturalists to ensure records of *Engaeus* are provided to the *Natural Values Atlas*, even if simply as *Engaeus* sp. (to alert land managers to the possible presence of a threatened species). It is imperative that the known and potential range boundaries of *E. granulatus* be updated regularly to ensure it is safeguarded during new and existing developments: all too often, this species has been overlooked due to lack of information.

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