BENTHIC MACROINVERTEBRATE COMMUNITIES OF HIGH-CONSERVATION VALUE THIRSTY AND LITTLE THIRSTY LAGOONS, CAPE BARREN ISLAND, TASMANIA

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(with one table and six text-figures)

Hirst, A., Alpine, J. & Crawford, C. 2006 (30.xi): Benthic macroinvertebrate communities of high conservation value Thirsty and Little Thirsty Lagoons, Cape Barren Island, Tasmania. *Papers and Proceedings of the Royal Society of Tasmania* 140: 17–23. https://doi.org/10.26749/rstpp.140.17 ISSN 0080- 4703. Marine Research Laboratories, Tasmanian Aquaculture and Fisheries Institute, University of Tasmania, Private Bag 49, Hobart, Tasmania 7000, Australia. (AH*, JA, CC). *Author for correspondence.

This study represents the first account of the invertebrate ecology and biology of the estuarine Thirsty and Little Thirsty coastal lagoons on Cape Barren Island, Tasmania. Due to its remoteness, Thirsty Lagoon is one of the most pristine coastal lagoon systems in Tasmania and is, therefore, an important reference point against which to measure future human impacts in coastal lagoons in the Bass Strait islands, and in south-eastern Australia generally. The system comprises two interconnected lagoons. The lower of the two lagoons, Thirsty Lagoon, is connected to the sea by an open channel allowing tidal exchange. This exchange maintains salinities in the lower reaches at or near seawater concentrations. As the basin is shallow, rates of evaporation are high, particularly in summer, elevating salinity levels and resulting in periodic drying-out of sections of the lagoonal system. At the time of our visit in late summer, freshwater input from feeder streams was minimal and there was little tidal exchange between Thirsty and, the upper lagoon, Little Thirsty. As a consequence salinities in Little Thirsty were very high (ca. 60). These coastal lagoons, and one other sampled, supported a low diversity of invertebrate fauna that is typical of coastal lagoons elsewhere in Tasmania. The fauna included marine polychaete worms, molluscs, small crustaceans and high densities of a dipteran larvae in Little Thirsty Lagoon. The fauna found in the lower reaches of Thirsty Lagoon include a number of invertebrate species that are typically marine in origin, while the upper reaches were dominated by species that commonly occur in estuaries elsewhere, albeit in low salinity or brackish waters. Despite very high salinities and periodic evaporation, Little Thirsty and Thirsty lagoons supported high densities of invertebrates that may constitute an important food source for visiting migratory and wading birds.
Key Words: hypersaline, coastal lagoons, benthos, Thirsty Lagoon, Little Thirsty Lagoon, Cape Barren Island.

INTRODUCTION

Cape Barren Island (4473 ha) is a remote island situated off the southern tip of Flinders Island in Bass Strait. Due to its isolated location and small population, large tracts of land, especially on the east coast, are almost entirely free from human impacts. The geology of Cape Barren Island is dominated by granite ridges surrounded by coastal lowlands of unconsolidated sands forming a complex of beach ridges and sand dunes containing many lagoons and swamps. Coastal lagoons are a feature of the eastern coastline of Flinders and Cape Barren islands where sand dunes block drainage to the coast. Rainfall is low, and follows a mediterranean pattern with higher rainfalls in winter than summer. Freshwater catchments are small, so that many of the smaller streams flow only after good rainfalls and therefore freshwater input into these lagoons is episodic. Coastal lagoons on the east coast of Cape Barren Island have special significance and have been listed as both internationally important wetlands (under the Ramsar convention) and as having high estuarine conservation significance (Edgar *et al.* 1999a).

The Thirsty Lagoon system is the largest estuarine system in the Ramsar-listed Cape Barren Island lagoons and is located on the remote east coast of Cape Barren Island (40°24'S, 124°26'E). This lagoon was assigned the highest conservation significance (Class A) under a statewide assessment of the conservation significance of Tasmanian estuaries (Edgar *et al.* 1999a), on the basis of having the most pristine catchment of any of the Bass Strait island estuaries; however, due to its remoteness it was not visited. As a consequence, baseline information on the morphology and biology of this estuarine system is lacking, impeding future planning. In an effort to address these knowledge gaps a visit to Thirsty Lagoon was undertaken in March 2005 with the aim of (1) making direct observations on the morphology of the Thirsty/Little Thirsty Lagoon system; (2) collecting environmental data (salinity and dissolved oxygen concentrations); and (3) sampling benthic macroinvertebrate communities from soft-sediment habitats in the lagoons.

MATERIALS AND METHODS

Description of Lagoons and Sites

Thirsty Lagoon is a shallow coastal lagoon with a permanent opening to the sea. The opening comprises a channel approximately 40 m wide and 1–2 m deep that crosses a significant sand bar at the entrance to the lagoon. At its widest point the lagoon is approximately 1 km across, but less than 0.4 m deep (fig. 1). A number of small creeks feed the lagoon from the coastal dunes to the east and from adjoining heathland to the west. Few of these creeks were flowing at the time of our visit. Thirsty is connected to Little Thirsty Lagoon, directly to the south, via a narrow channel (shown in fig. 1). Little Thirsty Lagoon is a shallow (<15 cm depth), hypersaline lagoon (see Results) that was observed to visibly shrink during the period of this visit (8–10 March 2005), due to evaporation. Because of its small size, salinity may vary greatly in response to rainfall and stream flows – it is fed by a small creek directly to the south (fig. 1). It is conceivable that during winter this lagoon may be brackish or even fresh in character. The tidal connection between these

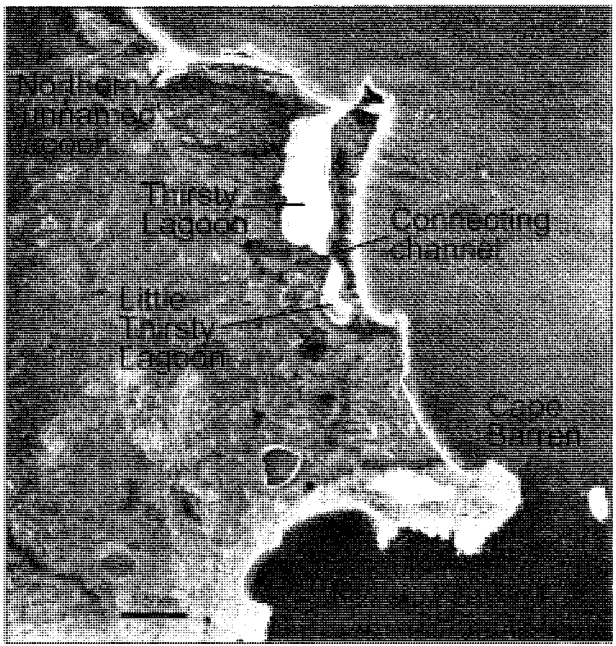

FIG. 1 — Aerial view of Thirsty Lagoon, Little Thirsty Lagoon and a small unnamed coastal lagoon off to the northwest.

two lagoons appears ephemeral and at the time of our visit, tidal inundation from the coast did not reach Little Thirsty Lagoon, leaving this body of water isolated from the lower, Thirsty Lagoon.

A small marine lagoon directly to the northwest of Thirsty Lagoon was also sampled (fig 1). This inlet is unnamed and hereafter we refer to it as the 'Northern Lagoon'. An opening to the sea is maintained only at high tide when the rising waters spill over a sand bar at the entrance to the inlet. Two small creeks, visible on the aerial photograph, feed a lagoon that in places reached 1.0 m in depth. At the time of our visit the flow of freshwater into the Northern Lagoon was clearly greater than to Thirsty and Little Thirsty lagoons.

FIELD METHODS

Salinity and dissolved oxygen measurements were made and benthic invertebrate communities sampled at eleven sites throughout Thirsty, Little Thirsty and the Northern lagoons during a visit to the area during 8–10 March 2005. Sites were chosen to represent conditions throughout the geographic extent of the lagoons (fig. 2). Four sites were sampled from Thirsty Lagoon, two at either end of the connecting channel, three sites in Little Thirsty Lagoon and two sites in the Northern Lagoon, one in the channel just behind the sandbar and the other in the lagoon proper adjacent to a creek entrance. The position of each site was marked in the field using GPS.

Sampling of the benthic invertebrate fauna was undertaken as close as possible to low tide using a 15-cm-diameter PVC sediment corer inserted to a depth of 10 cm. Four replicate cores were collected at each site from shallow subtidal sediments, adjacent to the low water mark (except for site 3 which was located in the middle of Thirsty Lagoon). Sediment cores were sieved in the field through a 1.0 mm mesh sieve and the portion retained on the sieve fixed in 10% formalin-seawater solution. Salinity and dissolved oxygen concentrations were measured at each site using WTW conductivity/temperature and dissolved oxygen meters. Dissolved oxygen was measured in mg O_2 per litre of water (mg/L), whilst salinity measurements are expressed as dimensionless practical salinity units (UNESCO 1985). All fieldwork was done on foot, precluding more extensive sampling of the area.

Samples were sorted in the lab under a binocular microscope. Invertebrate taxa, where possible, were identified to species and counted. Invertebrate specimens have been lodged with the Tasmanian Museum and Art Gallery, Hobart. Species and total abundances were expressed as numbers per m^2 based on the mean of the four replicate samples collected per site. Abiotic and biological data were superimposed onto maps of the lagoons using ArcGIS v9 GIS software.

RESULTS

Environmental Conditions

Sites displayed a clear gradient of increasing salinity from the marine entrance of Thirsty Lagoon to the upper reaches of Little Thirsty Lagoon (fig. 3). Whilst salinities in the lower reaches of Thirsty Lagoon were 36, corresponding with marine conditions, hypersaline conditions prevail in the shallow waters of Little Thirsty Lagoon and all sites recorded salinities in excess of 60. The elevated salinity observed on this visit was probably the result of evaporation in the absence of any significant freshwater input from feeder creeks and/or the input of tidal waters from Thirsty Lagoon. It is unclear how long these conditions prevail, but hypersaline conditions may persist over much of the summer months interrupted only by significant rainfall or unusually high tides. Based on our observations it is also conceivable that this lagoon dries out entirely and is, in effect, an evaporative basin. High salinities, nevertheless, imply irregular connection between Thirsty and Little Thirsty and the presence of wrack (i.e., kelp and other seaweeds originating from the open coast) in Little Thirsty supports the view that these two bodies are at least temporarily connected throughout the year.

Waters within the lagoons were generally well oxygenated. With the exception of the connecting channel, dissolved oxygen levels exceed 7.0 mg/L (fig. 4). This is likely to be because the lagoons are extremely shallow precluding stratification and are well mixed by the wind. There was no association between salinity and dissolved oxygen concentrations with dissolved oxygen concentrations towards the mouth only marginally higher (7.9 compared to 7.4 mg/L at the upper L. Thirsty sites).

Invertebrate Communities

Twenty invertebrate taxa were collected from the Cape Barren lagoons during this visit (table 1). The most common taxa were chironomid insect larvae, the gastropods *Batillariella estuarine* (Tate, 1893) and *Ascorhis victoriae* (Tenison Woods, 1878), the bivalve *Arthritica semen* (Menke, 1843) and the polychaete worm *Simplisetia aequisetis* (Augener, 1913). All species collected from Little Thirsty Lagoon and the Northern Lagoon were also found in Thirsty Lagoon. In general, invertebrate species richness declined from Thirsty to Little Thirsty Lagoon, although the latter sites supported comparable numbers of species to the two sites sampled

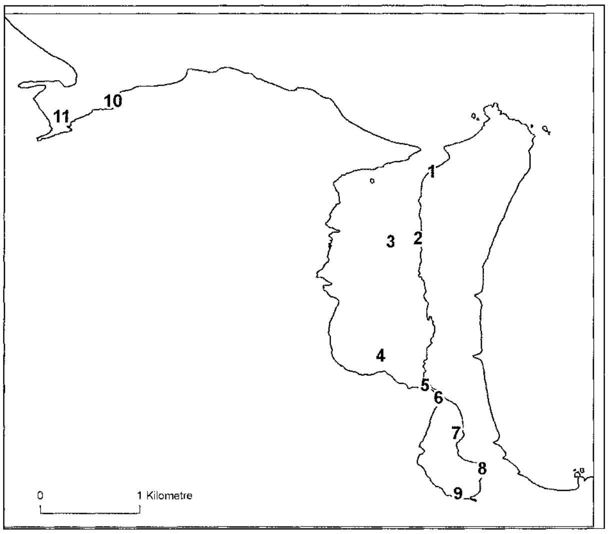

FIG. 2 — Map of the lagoons showing the position of the 11 sites referred to in this study.

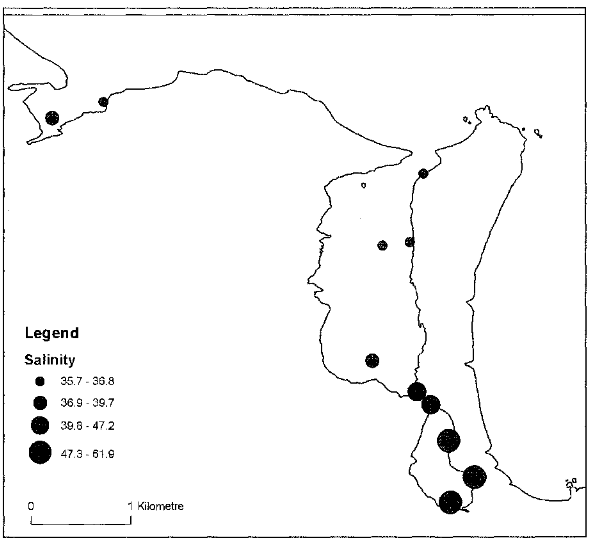

FIG. 3 — Salinity recorded at each of the sites.

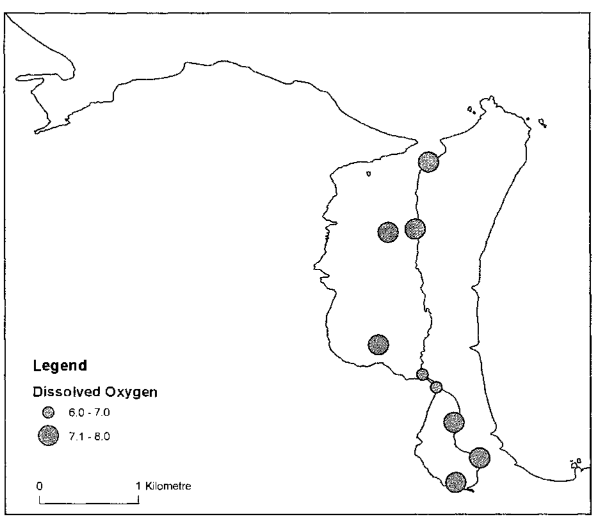

FIG. 4 — Dissolved oxygen concentrations (mg O_2/L) recorded at each of the sites. Note dissolved oxygen measurements were not taken for the Northern Lagoon.

from the Northern Lagoon (fig. 5). No similar pattern was discernable in terms of invertebrate densities between lagoons. The highest densities were recorded in the channel interconnecting the two lagoons (fig. 5), swelled by high abundances of *B. estuarina*, *A. victoriae*, *A. semen*, *S. aequisetis* and the amphipod *Paracorophium* sp.

Distribution and Abundance of Common Invertebrate Species

The gastropod *B. estuarina* was widely distributed throughout the lagoons and was collected at all sites sampled in this study (fig. 6A). It was most abundant in the mid and upper reaches of Thirsty Lagoon including the channel, although still occurred at densities in excess of 500 individuals m^{-2} at site 8 in Little Thirsty Lagoon. By comparison, a number of invertebrate species including the bivalve *Paphies erycinea* (Lamark, 1819) (fig. 6B), the polychaetes worms *Perinereis vallata* (Grube, 1858) (Nereididae) and *Chlymenella* sp. (Maldanidae), the amphipod *Paracalliope* sp. and nemertean worms were primarily restricted to the lower reaches of Thirsty Lagoon (table 1).

Little Thirsty and the interconnecting channel were characterised by high densities of Chironomidae larvae (fig. 6C), but *S. aequisetis* (fig. 6D), *A. semen* (fig. 6E) and *Paracorophium* sp. (fig. 6F) were also abundant at these sites. Chironomid larvae, *S. aequisetis*, *B. estuarina* and *A. semen* were all found at densities in excess of 150 individuals m^{-2} at sites with salinities in excess of 60. Despite the marine conditions prevalent in the Northern Lagoon, samples collected contained only a restricted fauna comprising eight species in total (table 1). The most abundant species were the gastropods *A. victoria*, *B. estuarina*, and the polychaete *S. aequisetis*. Chironomid larvae were notably absent from these two sampling sites.

DISCUSSION

Biology of Thirsty Lagoon

Thirsty Lagoon is characteristic of seasonally hypersaline estuaries/coastal lagoons found elsewhere in the world (Largier *et al.* 1997). Cape Barren Island has a mediteranean climate, with dry summers, and the lagoon is fed by a small catchment with streams that flow irregularly and comprises a shallow evaporative basin. The salinity regime in these lagoons may therefore follow a similar pattern to that found among seasonally hypersaline estuaries on the south-west coast of Western Australia (Hearn *et al.* 1994) and the Californian coast (Largier *et al.* 1997) that alternate between classical estuary during winter (net dilutive basin) and hypersaline estuary (net evaporative basin) during the drier, summer months. The separation of Thirsty and Little Thirsty Lagoons is likely to further exacerbate the hypersaline conditions observed in Little Thirsty Lagoon, as the upper basin becomes periodically isolated from the remainder of the system preventing the incursion of tidal waters that may depress overall salinities. The presence of wrack in Little Thirsty, however, supports the view that these two bodies are at least temporarily connected throughout part of the year.

Many of the invertebrate fauna associated with Cape Barren lagoons are common and conspicuous components of estuarine faunas elsewhere in Tasmania (Edgar *et al.* 1999a,b)

TABLE 1
Distribution and mean abundance (no./m^2) of invertebrate species collected from Cape Barren lagoons in March 2005

	Thirsty Lagoon						Little Thirsty Lagoon			Northern Lagoon	
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11
Crustacea											
Paracalliope sp.	58.8	0	2.8	0	1.4	0	0	0	0	0	0
Paracorphium sp.	0	0	28	7	127.4	211.4	4.2	28	29.4	19.6	1.4
Urohaustorius sp.	2.8	0	0	0	0	0	0	0	0	0	0
sphaeromatid isopods	0	7	16.8	11.2	0	0	0	0	0	0	0
Mollusca											
Arthritica semen	0	0	0	14	550.2	378	7	245	0	5.6	28
Ascorhis victoriae	0	0	0	0	92.4	275.8	1.4	8.4	0	33.6	138.6
Batillariella estuarina	5.6	1716.4	331.8	904.4	518	158.2	16.8	358.4	1.4	11.2	105
Coxiella striata	0	0	0	0	1.4	8.4	19.6	2.8	8.4	0	0
Katelysia scalarina	0	0	4.2	0	0	0	0	0	0	0	0
Salinator fragilis	0	2.8	0	29.4	1.4	0	0	0	0	8.4	0
Paphies erycinea	0	131.6	551.6	16.8	0	1.4	0	0	0	0	0
Xenostrobus inconstans	0	0	0	7	0	0	0	0	0	0	0
Polychaeta											
Capitella sp.	1.4	23.8	4.2	8.4	0	5.6	26.6	22.4	26.6	1.4	2.8
Perinereis vallata	0	48.2	11.4	65.3	0	0	1.4	0	0	0	1.4
Simplisetia aequisetis	2.8	58.2	2.8	4.3	110.7	210	1.4	76.6	198.7	18.4	44
Malacoceros sp.	1.4	46.2	0	15.4	0	0	0	0	0	0	0
Clymenella sp.	0	0	79.8	0	0	0	0	0	0	0	0
Scoloplos normalis	0	0	5.6	0	0	0	0	0	0	0	0
Nemertea	0	0	14	0	0	0	0	0	0	0	0
Insecta											
Chironomidae spp.	4.2	21	14	15.4	1229.2	1243	579.6	263.2	509.6	0	0

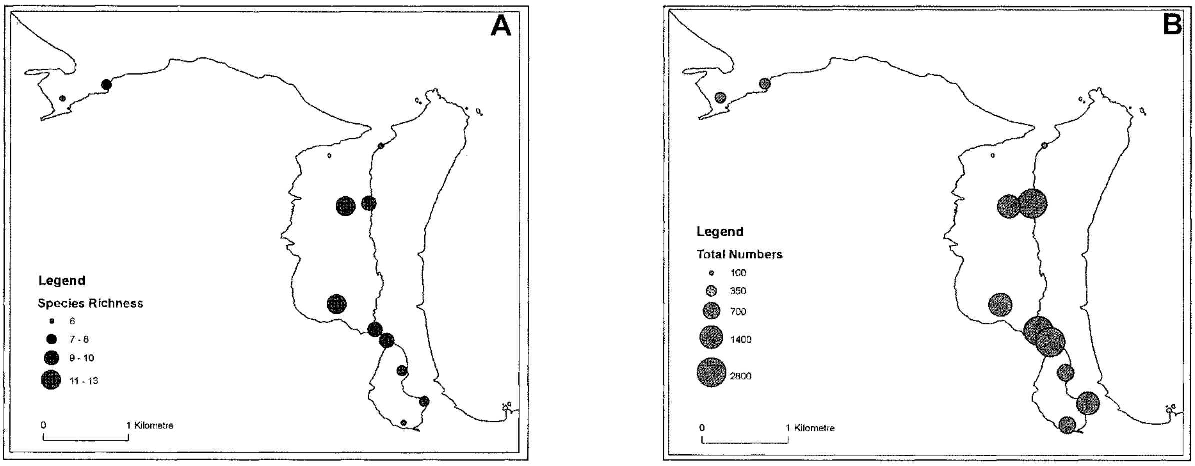

FIG. 5 — (A) Invertebrate species richness and (B) faunal densities (no. individuals m^{-2}) recorded at each of the sites.

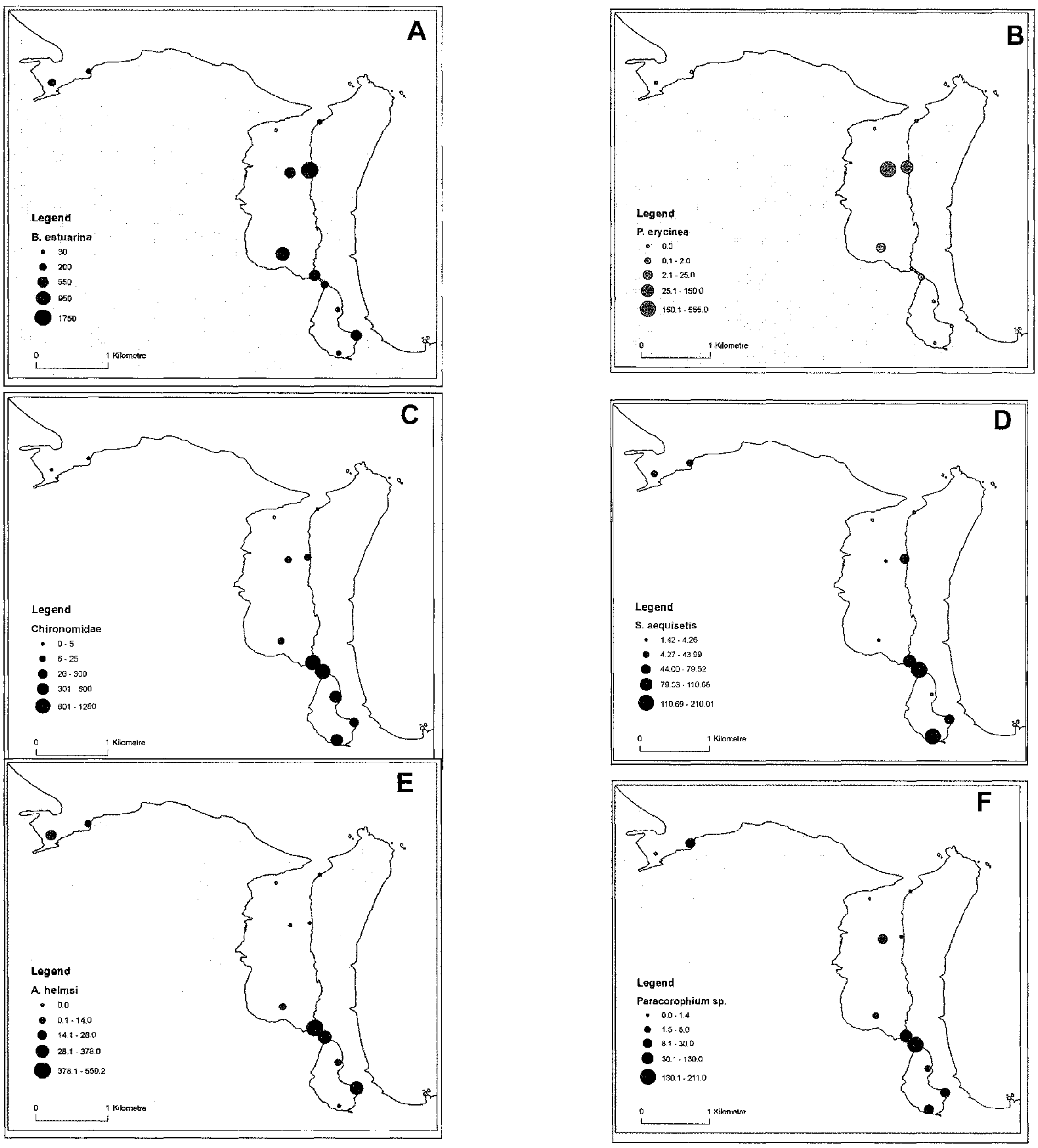

FIG. 6 — Densities (no. individuals m^{-2}) of the (A) gastropod Batillariella esturarina; *(B) bivalve* Paphies erycinea; *(C) Chironomid insect larvae; (D) polychaete worm* Simplisetia aequisetis; *(E) bivalve* Arthritica semen; *and (F) amphipod* Paracorophium *sp. at each site.*

and southeastern Australia (Hirst 2004). In particular *A. victoriae*, *B. estuarina*, *Paracorophium* sp. and *S. aquisetis* have widespread distributions. Whilst coastal lagoons do not support distinct faunal communities (Barnes 1994), they generally support impoverished faunas in comparison to other estuarine systems (Barnes 1994, Edgar *et al.* 1999b). We collected only 20 species on this visit, whilst a similar level of sampling in meso-tidal river estuaries in north-west Tasmania, one month later, produced about 50 species per estuary (Hirst *et al.* 2005). The low species richness of coastal lagoons has been attributed to their smaller size, greater uniformity of habitats, isolation (or at least partial isolation) from the sea through the formation of a barrier at the entrance limiting the recruitment of species with marine life-histories or affinities (Barnes 1994) and greater environmental extremes (e.g., salinity, anoxia) (Barnes 1994).

In terms of the species composition of the fauna, Thirsty Lagoon most resembles Cameron Inlet, a barred coastal lagoon on the east coast of Flinders Island with recorded summer salinities exceeding 50 (Edgar *et al.* 1999a). Thirsty Lagoon, by comparison, had a substantial marine opening allowing significant tidal exchange at the time of our visit. This facilitated the influx and survival of species with greater marine affinities such as the polychaetes *Perinereis vallata* and *Clymenella* sp. (Maldanidae) and the bivalve *Paphies erycinea* (Edgar *et al.* 1999b). In general, these species were restricted to the lower reaches of Thirsty Lagoon where salinities were close to marine (~ 36). In comparison, Little Thirsty and the upper reaches of Thirsty Lagoon are dominated by a range of invertebrate species that are typically confined to estuaries. These include *S. aequisetis*, *Paracorophium* sp. and *A. victoriae* (Edgar *et al.* 1999b), whilst the chironomid larvae are often typical of the brackish upper reaches of estuaries (Hirst *et al.* 2005). *S. aequisetis* and *Paracorophium* sp. are usually associated with the upper reaches of estuaries where salinities are typically diluted by freshwater input, but are capable of tolerating a wide range of salinities (Edgar *et al.* 1999b). Both are widely distributed throughout the Cape Barren lagoons.

Hypersalinity is a common phenomenon in coastal lagoons in Brazil (da Silva *et al.* 2005) and Mexico (Vega-Cendejas & de Santillana 2004) – where it is more or less a permanent condition – and California (Largier *et al.* 1997) and south-western Western Australia (Hearn *et al.* 1994) where it is linked to seasonal changes in net freshwater input and evaporation Research has focused on documenting changes in structure from marine (generally adjacent to the mouth) to hypersaline regions of coastal lagoons, rather than following seasonal changes in hypersalinity. In general these studies found that the species richness of fish (Vega-Cendejas & de Santillana 2004) and benthic macroinvertebrate (da Silva *et al.* 2005) assemblages declined with increasing salinity and that hypersaline regions supported a restricted fauna of estuarine specialists. Unlike hypersaline coastal lagoons in Brazil and Mexico, where high salinity conditions remain throughout the year, salinities in the Thirsty Lagoon system are likely to vary considerably (although data are lacking at this point). The invertebrate assemblages in Little Thirsty Lagoon will, therefore, need to tolerate not just high, but also possibly very low, ambient salinities and dramatic changes to salinity over potentially very short time-frames. Typically the species found in Little Thirsty Lagoon are associated with low salinities indicative of the upper regions of estuarine ecosystems (Hirst 2004). The same physiological adaptations that allow estuarine species to tolerate low and changing salinities presumably also pre-adapt them to high salinities, although the upper limits of such tolerances are unknown (Edgar *et al.* 1999b).

The other characteristic that makes many of the species found in Little Thirsty Lagoon suited to life in a periodically isolated, hypersaline coastal lagoon is the possession of a direct-developing life-history. Juvenile animals hatch directly from the brood-pouch of the amphipod *Paracorophium* sp. and from embryo tubes constructed by the polychaete *S. aequisetis* (Wilson 2000) rather than arriving from the plankton. Similarly, the most abundant element of the Little Thirsty fauna, the chironomid larvae, hatch from eggs laid by the mobile (i.e., aerial), adult chironomid (midge) in the shallow lagoon waters. Recruitment of these species is not reliant upon the arrival of larvae from the plankton, as is the case for many other marine invertebrates, and consequently these populations are largely self-replenishing. This is critical in a system which is episodically disconnected from the open sea and which may undergo periodic contraction due to evaporation.

We suggest on the basis of this survey, and surveys carried-out by Edgar *et al.* (1999a) as part of a broad-scale survey of Tasmanian estuaries, that there is no specific hypersaline estuarine-fauna, only a fauna adapted to highly variable salinities indicative of the mid and upper regions of estuaries generally. In part, this is because hypersaline conditions are likely to be an ephemeral, rather than a permanent feature of coastal lagoons in southeastern Australia.

Conservation Significance of Thirsty Lagoon

Thirsty and Little Thirsty lagoons comprise extensive areas of intertidal and shallow subtidal sediments that form important feeding habitats for visiting migratory birds, chiefly waders. Up to 25000 migratory waders are believed to come to Tasmania every year during the summer months, many of them to the Furneaux group of islands. Flocks of up to 4000 migratory waders have been observed on Logans Lagoon and Cameron Inlet, Flinders Island (Edgecombe 1986). Flinders and Cape Barren Island also represent convenient stopping-off points for migratory birds moving to and from south-eastern Tasmania on their migratory journeys. Despite high salinities, and evidence of periodic evaporation and drying-out, these lagoons still supported high densities of macroinvertebrates that are commonly found among the diets of wading birds (e.g., bivalves, worms and crustaceans; Dann 1987).

As Thirsty Lagoon was not visited in a statewide assessment of the conservation significance of Tasmanian estuaries, but nevertheless assigned the highest conservation significance, Edgar *et al.* (1999a) suggested that a field survey was required to confirm that the estuary had been placed in the appropriate estuarine group (i.e., coastal lagoon), and if possible should include sampling of the biota of the estuary (invertebrates, fish). Thirsty Lagoon is typical of coastal lagoons on the east coast of Flinders Island. It is very shallow with water depths <0.5 m, receives minimal and/or episodic freshwater input from feeder streams and is subject to highly elevated salinities particularly in the upper reaches. Like Logans Lagoon and Camerons Inlet (Edgar *et al.* 1999a), sections of Thirsty Lagoon appear to periodically evaporate exposing intertidal sand flats during the summer months. Thirsty Lagoon, however, differs from these two coastal lagoons by having a significant opening to the sea allowing tidal exchange between the open coast and the lagoon – potentially ameliorating evaporation and depressing salinities in its lower sections (i.e., likely to remain closer to marine conditions). We therefore support Edgar *et al.*'s (1999a) conservation assessment of this estuary as it remains one of the few coastal lagoons in Tasmania that is situated within a catchment that is almost entirely free of human impacts. This is important because coastal lagoon systems tend to be susceptible to human impacts because contaminants are more likely to accumulate within the system due to limited tidal exchange (Webster & Harris 2004), requiring more careful management than other estuarine systems.

Acknowledgements

We would like to thank R. Mount (TAFI) for creating the GIS Maps, and R. Wilson (Museum Victoria) and L. Turner (Tasmania Museum and Art Gallery) for help with identification of invertebrates, and G. Edgar for comments on a previous version of the manuscript. The visit to this region was funded by NHT Priority Action Project: "NRM for isolated Communities: building the capacity of aboriginal islanders to manage their own natural resources". We also thank Renee Lowry, NRM Facilitator for the Furneaux region, for organising and coordinating the trip to Cape Barren Island.

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(accepted 3 July 2006)