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Anthropogenic water bodies as drought refuge for aquatic macroinvertebrates and macrophytes

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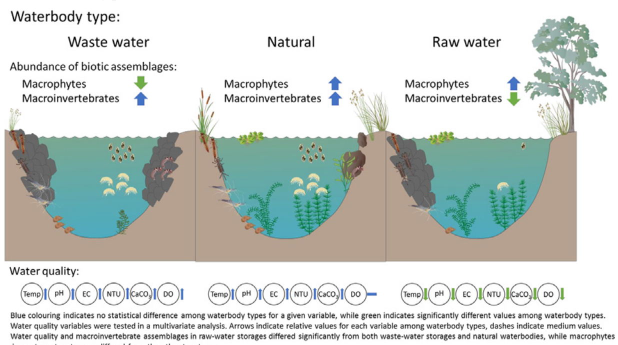
HIGHLIGHTS

- As disturbance becomes more frequent or severe, habitat for aquatic biota declines.
- Aquatic biota in waste and raw-water storages was compared to natural water bodies.
- Macroinvertebrates in waste-water storages were comparable to natural water bodies.
- Macrophytes in raw-water storages were comparable to natural water bodies.
- Anthropogenic storages could potentially offer important refuge during disturbance.

GRAPHICAL ABSTRACT

Blue colouring indicates no statistical difference among waterbody types for a given variable, while green indicates significantly different values among waterbody types. Water quality variables were tested in a multivariate analysis. Arrows indicate relative values for each variable among waterbody types, dashes indicate medium values. Water quality and macroinvertebrate assemblages in raw-water storages differed significantly from both waste-water storages and natural waterbodies, while macrophytes in waste-water storages differed from the other two types.



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ABSTRACT

Ecological research associated with the importance of refuges has tended to focus on natural rather than anthropogenic water bodies. The frequency of disturbances, including drought events, is predicted to increase in many regions worldwide due to human-induced climate change. More frequent disturbance will affect freshwater ecosystems by altering hydrologic regimes, water chemistry, available habitat and assemblage structure. Under this scenario, many aquatic biota are likely to rely on permanent water bodies as refuge, including anthropogenic water bodies. Here, macroinvertebrate and macrophyte assemblages from waste-water treatment and raw-water storages (i.e. untreated potable water) were compared with nearby natural water bodies during autumn and winter 2013. We expected macroinvertebrate and macrophyte assemblages in raw-water storages to be representative of natural water bodies, while waste-water treatment storages would not, due to degraded water quality. However, water quality in natural water bodies differed from raw-water storages but was similar to waste-water treatment storages. Macroinvertebrate patterns matched those of water quality, with no differences occurring between natural water bodies and waste-water treatment storages, but assemblages in raw-water storages differed from the other two water bodies. Unexpectedly, differences associated with raw-water storages were attributable to low abundances of several taxa. Macrophyte assemblages in raw-water storages were representative of natural water bodies, but were less diverse and abundant in, or absent from, waste-water

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treatment storages. No clear correlations existed between any habitat variables and macroinvertebrate assemblages but a significant correlation between macrophyte assemblages and habitat characteristics existed. Thus, there were similarities in both water quality and macroinvertebrate assemblages between natural water bodies and waste-water treatment storages, and similarities in macrophyte assemblages between raw-water storages and natural water bodies. These similarities illustrate that anthropogenic water storages support representative populations of some aquatic biota across the landscape, and thus, may provide important refuge following disturbance where dispersal capabilities allow.

1. Introduction

The conservation of freshwater biodiversity has recently received much attention in aquatic ecology (Dudgeon et al., 2006). Freshwater ecosystems are highly vulnerable and the proportion of species at risk of extinction compared with terrestrial and marine ecosystems is exceptionally high (Strayer and Dudgeon, 2010; Collen et al., 2014). Further, freshwater habitats are disproportionately speciose relative to marine and terrestrial ecosystems, given that fresh waters cover 0.8% of the earth's surface, yet support 6% of all described species (Dudgeon et al., 2006). Declines in freshwater biodiversity have been associated with many anthropogenic drivers, but particularly climate-induced changes in hydrological regimes (Heino et al., 2009). For example, altered hydrological regimes are likely to interfere with the completion of aquatic life cycles, placing species at greater risk of local extinction (Bond et al., 2008). Thus, measures to enhance the likelihood of maintaining biodiversity are particularly important in freshwater ecosystems.

Physical disturbances occur in all aquatic ecosystems and are influential in structuring aquatic communities (Boix et al., 2010). Disturbances affecting freshwater biota can be either biotic (e.g. predation) or abiotic (e.g. drought), and natural (e.g. flood) or anthropogenic (e.g. chemical spill) (Magoulick and Kobza, 2003). Drought, like many other disturbances, is a natural feature of many aquatic ecosystems worldwide (Humphries and Baldwin, 2003) and is a recurrent phenomenon in Australia (Bond et al., 2008; Lake, 2011). However, the frequency and severity of drought events are predicted to increase under climate change (Steffen and Hughes, 2013), negatively affecting freshwater ecosystems, particularly lentic systems, due to reduced runoff and increased drying (Bond et al., 2008; Steffen and Hughes, 2013). The effects of drought occur at a regional scale, so have the potential to threaten not only individuals but entire populations of aquatic biota and biodiversity across relatively large spatial scales (Bond et al., 2008).

Strategies for surviving disturbance include physiological mechanisms such as desiccation-resistant propagules or aestivation, and behavioural mechanisms to access refuges. Examples of such behavioural mechanisms include burrowing to access moist sediment and groundwater or aerial relocation to permanent water sources (Robson et al., 2011). Refuges typically provide a physical space that is protected from disturbance and can act as a source of colonists for the surrounding landscape after the disturbance passes (Sedell et al., 1990). Refuges that retain permanent surface water during drought are essential for the maintenance of most aquatic populations within a landscape (Humphries and Baldwin, 2003). However, the presence of numerous refuges and refuge types within a landscape is important because a suitable refuge for one species may not be suitable for others with differing life history traits (Robson et al., 2011).

As the intensity of human demand and disturbance increases on aquatic ecosystems, freshwater biota may rely on aquatic habitats that are anthropogenic in origin to persist in a highly-modified landscape, particularly when the availability of natural refuges diminish (Chester and Robson, 2013). Several anthropogenic water bodies support biodiverse aquatic assemblages, including waste-water treatment storages, fire dams, urban ponds, golf course lakes, roadside ditches and agricultural ponds (Chester and Robson, 2013; Mackintosh et al., 2015). Anthropogenic wetlands are often small, but can contribute disproportionally to aquatic biodiversity within a region and, as such, several authors have argued for greater management priority for these habitats to help protect aquatic biodiversity (Davies et al., 2008; Halliday et al., 2015; Hill et al., 2016).

The ability for anthropogenic water bodies to act as potential refuges for aquatic biota has rarely been tested. Brainwood and Burgin (2009) investigated macroinvertebrate assemblages in farm dams in New South Wales, Australia and compared them with natural water bodies within the same landscape. Macroinvertebrate assemblages within farm dams were comparable to those of nearby natural lakes and ponds, and thus had valuable potential as drought refuges. Furthermore, these authors suggested that farm dams could also enhance connectivity among habitats that had been fragmented due to agricultural practices (Brainwood and Burgin, 2009). Another study in south-east Ireland demonstrated that macroinvertebrate assemblages in waste-water treatment storages were comparable to surrounding natural water bodies, again suggesting that anthropogenic water bodies could provide an important source of refuge during drought (Becerra Jurado et al., 2009). Numerous navigation canals in Europe contain diverse macrophyte assemblages, often including rare species (Goulder, 2008; Dorotovičová, 2013) and thus provide another good example of aquatic biota utilising man-made water bodies. In a study complementary to ours, Halliday et al. (2015) found no significant differences in fish, zooplankton and frog assemblages among natural water bodies, water-water treatment storages and raw-water storages (i.e. systems that store potable water prior to treatment) in south-west Victoria, Australia suggesting the utility of those storages as refuges for local fauna.

The primary aim of this study was to compare macroinvertebrate and macrophyte assemblages from waste-water treatment storages and raw-water storages with natural water bodies in south-west Victoria, Australia. Based on the definition of Sedell et al. (1990), we contend that, for a water body to constitute a refuge from drying, it must retain water when natural lakes are dry (i.e. protected from the disturbance) and support representative biota to act as a source of colonists. A secondary aim was to explore relationships among biotic assemblages, water quality and habitat variables to identify characteristics of anthropogenic water bodies that may facilitate their role as refuge habitat for macroinvertebrates during extended periods of drought. We expected that macroinvertebrate and macrophyte assemblages within raw-water storages would be representative of those within surrounding natural water bodies, whereas assemblages in waste-water treatment storages were expected to be depauperate due to relatively poor water quality.

2. Methods

2.1. Study location

A total of 18 water bodies were sampled across three water body types: raw-water storages (RWS); waste-water treatment storages associated with water reclamation plants (WRP); and natural water bodies (NWB), situated in south-west Victoria, Australia (Fig. 1), as per Halliday et al. (2015). Raw-water storages and waste-water treatment storages were managed by Wannon Water, a water authority operating