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MARINE & FRESHWATER RESEARCH

New South Wales rocky reefs are under threat

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ABSTRACT

Rocky reefs of New South Wales (NSW) are characterised by a mosaic of habitats, including kelp forest and urchin-grazed barrens. These habitats support a diversity of dependent species. Decades of research have demonstrated that kelps form extensive forests with distinctive fish and invertebrate faunas and the 'barrens' boulder habitat provides shelter and other resources for commercial fishes, charismatic fishes and invertebrates; the barrens are not deserts! The feeding activities of herbivorous invertebrates, particularly the black sea urchin (*Centrostephanus rodgersii*) determine the presence of barrens habitat. Some invertebrates survive only in the presence of urchins and are the food resources for many predatory fishes. The barrens habitat in NSW has been highly stable for decades and is critical for the diversity of reef-based organisms. Because of climate change, Tasmanian waters have warmed and as a result *C. rodgersii* larvae have dispersed southward from NSW. Importantly, the situation regarding *C. rodgersii* in Tasmania differs from the established pattern in NSW and this needs to be recognised in the approach to management of this species in the two states. Urchins in NSW should be appreciated as important habitat determiners and the removal of them for whatever purpose would have to be managed carefully.

Keywords: algae, conservation, echinoderms, fish, fisheries, habitats, invertebrates, reefs, temperate.

Background and perspective

The ecology of rocky reefs in New South Wales (NSW) is receiving renewed interest because of the events unfolding in Tasmania. The centre of attention is the black sea urchin (*C. rodgersii*) a NSW native that has extended its range to Tasmania where its grazing is altering the local seascape. The extent to which the abundance of these urchins on NSW rocky reefs is a natural phenomenon or reflects change owing to human impacts on reef ecology has been a focus of media and policy; however, extensive research points to the former. In NSW, this species is critical for the diversity of reef-based habitats to the south of Port Stephens (Glasby and Gibson 2020). Accordingly, the impact of increased fishing effort or culling in NSW could have a deleterious effect on reef habitats.

Rocky reefs are one of the most common and spectacular environments along the coast of NSW (Andrew 1999). Critically, habitat diversity plays a key role in the functioning of these reefs. The seascape (*sensu* Jones and Andrew 1993) is characterised by a mosaic of habitats, including shallow cunjevoi (the ascidian *Pyura stolonifera*) and turfing algae, whereas in deeper waters kelp forest and urchin grazed barrens abound (Fig. 1*a*, *b*). The macro algae *Ecklonia radiata* (order Laminariales) and *Phyllospora comosa* (order Fucales) can form extensive forests with distinctive fish and invertebrate fauna. On reefs beyond 12–15 m, colourful sponges are the most dominant form of life (Underwood *et al.* 1991). Boulders, rocky crevices and algae provide shelter and other resources for commercial and charismatic fishes (e.g. blue groper, bream and morwongs), as well as invertebrates (e.g. abalone and urchins). Black urchins also depend on shelter and move metres from shelter to feed on algae at night (Fletcher 1987; Andrew 1993).

A wide range of fishes depend on these diverse habitats for shelter, food and as spawning sites and most require multiple habitats to meet their needs (Curley *et al.* 2013*a*). Archival

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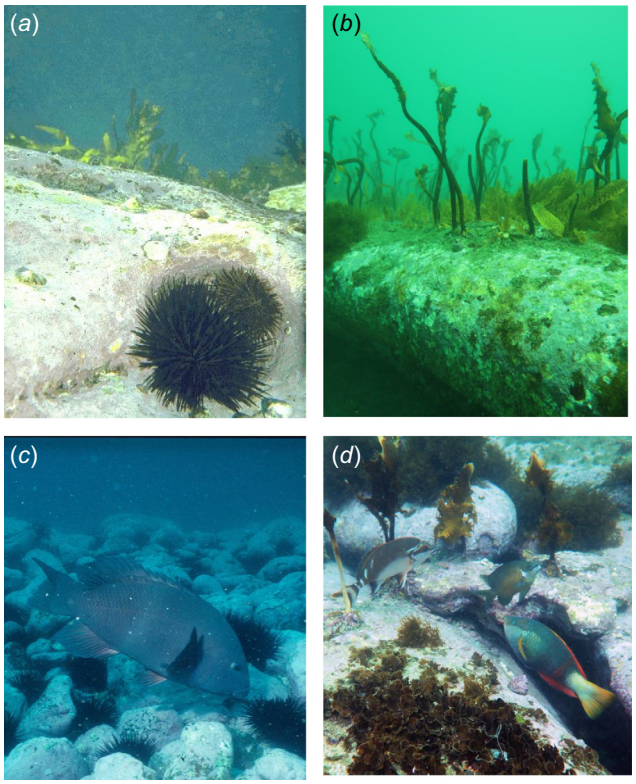

Fig. 1. (*a*) A habitat transition between kelp forest (*Ecklona radiata*) and urchin-grazed barrens. Here *Centrostephanus rodgersii* is with another species of urchin (*Heliocidaris tuberculata*) in a sandstone hollow engineered by the urchins, limpets that depend on the grazing of urchins abound nearby. Kelp is close on flatter rock and outside of the 'grazing halos' of the urchins, Botany Bay, NSW. (*b*) An ~1 m wide 'grazing halo' close to a crevice with abundant C. *rodgersii*. The *Ecklonia radiata* kelp forest behind has been severely damaged by a storms in 2022, recently recruited *E. radiata* is abundant where the canopy has been damaged. The condition of the kelp was unrelated to urchins. (*c*) Blue groper (*Achoerodus viridis*) foraging in urchin barrens, Coal Loader, Shell Harbour, NSW. (*d*) Three species of fish active in a small patch of barrens, from the left red morwong (*Cheilodactylus fuscus*), white ear damselfish (*Parma microlepis*) and crimson-banded wrasse (*Notolabrus gymnogenis*), Botany Bay, NSW.

aerial photography of reefs at some NSW sites has indicated that urchin-grazed barrens, be they small or more extensive areas with abundant crevices, have been a feature of the NSW seascape for ~50 years (Glasby and Gibson 2020). There is no indication that the representation of urchin-grazed barrens on reefs, to a depth of 10 m or less, has changed more than ±~10% (Glasby and Gibson 2020). Reef habitats have remained reasonably stable over this depth range and that is despite grazing pressures, storms and freshwater runoff that can wipe out stands of kelp in the top 5–6 m and cause mass mortality of urchins (Andrew and Underwood 1989; Andrew 1991; Davis *et al.* 2022).

The feeding activities of herbivores, particularly *C. rodgersii*, determine the presence of barrens habitat (Andrew 1991; Byrne and Andrew 2020). Although there are other invertebrates in the barrens such as limpets and top-shell snails (*Cellana*, *Patelloida* and *Australium* spp.) that graze algae, they can survive only in the presence of urchins (Fletcher 1987). It is this host of invertebrates that provides the food resources for many predatory fishes. Predatory fishes such as half-banded sea perch (*Ellerkeldia mccullochi*), wirrah (*Acanthistius* spp.), bream (*Acanthopagrus australis*) and cod (*Lotella rhacinus*) treat the barrens as their hunting ground for fishes and invertebrate prey, whereas others such as maori wrasse (*Ophthalmolepis lineolatus*) prefer a mix of barrens and algal habitats (Kingsford and Carlson 2010). Furthermore, some fishes such as the white-ear damselfish (*Parma microlepis*) that are endemic to south-east Australia depend on well-cropped algal resources in the barrens (Holbrook *et al.* 1994; Galaiduk *et al.* 2013) and this is also the habitat where they spawn (Tzioumis and Kingsford 1995). Although the term 'barrens' evokes a desert-like condition, research in NSW shows high fish and invertebrate biodiversity and abundance in the barrens (Curley *et al.* 2002) as well as a high diversity of microalgae (Coleman and Kennelly 2019).

Marine protected areas (MPAs) are popular locations for the public (e.g. Shelly Beach, Manly; Bushrangers Bay, Shell Harbour, Jervis Bay). The reason MPAs in NSW have a rich diversity of fishes is the mosaic of habitats they encompass. This, combined with protection (Curley *et al.* 2013*b*) from fishing, provides reefal environments that are enjoyed by many people in NSW. Fishers also enjoy rocky reefs for the fishes they provide (Kingsford *et al.* 1991) and their catches would be compromised in the absence of urchin-grazed barrens, especially catches of bream and wirrah.

As a result of climate change, the poleward flow of the East Australia Current (EAC) is intensifying and now extends ~400 km further south than previously, resulting in significant warming of south-eastern Australian waters (Ridgway 2007; Phillips *et al.* 2022). As a result of warming, Tasmanian waters have become more hospitable for the larvae of *C. rodgersii* propelled southward by the EAC from NSW (Byrne *et al.* 2022). Successful colonisation by the urchin (Ling *et al.* 2009), sometimes referred to as an 'invasion', has facilitated the loss of giant kelp (*Macrocystis*) and understorey kelps (e.g. *Ecklonia*). The range extension of *C. rodgersii* has clearly influenced the abundance of kelp. However, giant kelp is also threatened by warming (Mabin *et al.* 2019). Thus, the problem for Tasmania is NSW-sourced black sea urchin propagules, another urchin (*Heliocidaris erythrogramma*; Ling *et al.* 2010) and climate change. The emerging situation regarding *C. rodgersii* in Tasmania differs from the established pattern in NSW.

In other parts of the world urchins are important engineers in the 'phase shifts' between macroalgal and barrens as alternative ecological states in temperate (Elner and Vadas 1990; Filbee-Dexter and Scheibling 2014) and tropical reefs (Feehan and Scheibling 2014). Top-down affects from urchin predators such as otters (Estes *et al.* 2011) and lobsters

(Elner and Vadas 1990) can alter urchin densities. However, in the northern hemisphere, the fluctuations between kelp and barrens are often driven by sea urchin disease and mortality, which results in the return of kelp and, with a subsequent increase in urchins, the development of barrens (Steneck *et al*. 2002; Feehan and Scheibling 2014; McPherson *et al*. 2021; Smith *et al*. 2022). In some cases, the loss of urchins has caused massive and deleterious changes to marine ecosystems. For example, in the Caribbean the almost total loss of urchins (*Diadema* a cousin of *C. rodgersii*) has caused a great increase in the cover of macroalgae and the loss of hard coral (Hughes 1994); these reefs are struggling to recover after four decades. In the more than 40 years of research on *C. rodgersii* and the rocky reefs of NSW, such disease-driven phase shifts between urchin and kelp dominance have not been observed.

Should the black sea urchin fishery increase in NSW, be allowed in Marine Parks (as happened in 2019) and, should mass culling campaigns be considered? The consequences of urchin extraction can be learned from sea urchin fisheries elsewhere because there are, and have been, commercial catches of urchins worldwide. However, few fisheries are managed with robust stock assessment and even fewer have incorporated ecological information in management plans (Andrew *et al*. 2002). As for many aquatic and terrestrial ecosystems, a rich and diverse community of plants, predators herbivores and small prey depend on habitat diversity and urchins play a critical role in this on temperate reefs. Although barrens can remain functional with a drop in urchin density (Andrew and Underwood 1993), poorly managed culling is an ecological threat to the health of temperate habitat and a waste of a valuable resource. Further, although the urchin fisheries have the potential to be sustainable, unconstrained fishing effort would be unwise. A major loss of urchins through 'strip mining' would result in the loss of a key habitat and would threaten habitat richness and species diversity on reefs of NSW.

Because Tasmania is struggling with increased grazing pressures from a range shift of *C. rodgersii* and rising sea-water temperatures from the EAC, resulting in a loss of kelp, are these changes a sensible basis for advocating that urchins are bad in NSW? The answer should be an emphatic no. Organisms on reefs in NSW have co-existed with urchins well before humans arrived. Post-colonisation overfishing may have affected top predators such as lobsters and large fishes that prey on urchins (Gillanders 1995) and abalone, a potential competing grazer of algae and space. Seals have also been greatly affected by humans, but they are unlikely to be important predators of urchins because they focus on fish and cephalopods for prey (Gales *et al*. 1993). The extent to which the abundance of *C. rodgersii* on NSW reefs is influenced by such human impacts on reef ecology is not known. However, if anything, some predators on urchins in NSW, such as blue groper (Fig. 1*c*), have increased in number because they are protected, but the barrens persist as critical habitat. In addition, barrens also persist following the establishment of marine park sanctuary zones where lobsters and other predators have increased (Glasby and Gibson 2020; Knott *et al*. 2021). The recent moves to expand the fishery on *C. rodgersii* and to cull urchins with the intent of altering the underwater seascape is a concern. A reef dominated by macro algae is as good as any monoculture; it will reduce species diversity, catches of local fishes and the beauty of local reefs. Urchins in NSW should be recognised as important habitat determiners and intentional removal of them, for whatever purpose, would have to be managed carefully.

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