AUSTRALIAN MARINE SCIENCES ASSOCIATION

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Senate Standing Committees on Environment and Communications
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Dear Committee Members,

Re: Submission to Senate Inquiry on Climate-related Marine Invasive Species.

The Australian Marine Sciences Association (AMSA) welcomes the opportunity to provide input to the Senate Inquiry on climate-related marine invasive species. AMSA is Australia's largest professional association of marine scientists, with more than 700 members including many ecologists and fisheries scientists. For over 60 years, AMSA has promoted all aspects of marine science in Australia. AMSA has a long history of providing independent, evidence based, advice to government, industry and other key marine environmental stakeholders on a wide range of marine science issues. All of our submissions are publicly available here: https://www.amsa.asn.au/submissions.

This submission has been prepared after invitation to all our Members to contribute and draws on material in AMSA's position paper on climate change and its position paper on marine protected areas,.

Please feel free to contact me at the details below for further information.

Kind Regards

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***Australian Marine Sciences Association* Submission to Senate Inquiry on Climate-related Marine Invasive Species**

List of Recommendations

1. Recognize *Centrostephanus rodgersii* (black or long-spined urchin) as a native species within its historical range in New South Wales . The species is shifting its range southwards and in doing so is creating new habitats in Tasmania;

2. Prioritize region-specific research to understand predator-prey dynamics in 'urchin barren' habitats;

3. Recognise sea urchin barrens as a natural habitat important for biodiversity in New South Wales;

4. Ensure that sanctuary (no-take) zones are maintained with no sea urchin removals;

5. Prioritize research and management actions to ensure the sustainable harvest of *C. rodgersii,* which is a finite resource; and

6. Recognize that synergistic effects of anthropogenically induced climate change such as warming waters, increased storm action and freshwater influx which are highly deleterious to macroalgal forests and can compromise restoration efforts.

Executive Summary

Facilitated by anthropogenic climate change, specifically ocean warming and intensified southerly flow of the East Australia Current, the sea urchin *Centrostephanus rodgersii* (black or long-spined urchin) has extended its range from its historic centre in New South Wales southwards into Tasmania. As urchins eat seaweed, arrival of this species in Tasmania has been at the expense of kelp habitats. There is considerable interest in controlling these range extensions and sea urchin control is an emerging field of research with actions including augmentation of sea urchin predators (by introduction of lobsters and facilitating the presence of predators in sanctuary zones) and urchin culling schemes. Recent research suggests that these actions may not be effective with control of urchins by predators being overstated in Tasmania, and possibly also in NSW. There has also been targeted development of the Tasmanian sea urchin fishery. Synergistic climate-mediated effects of storms and marine heatwaves which are also deleterious for kelp have rarely been considered in kelp-loss models and future work should include these factors. As the ecological and evolutionary patterns of *C. rodgersii* differ across its native and extended ranges, it is crucial that the approaches adopted to manage this species be based on location specific evidence.

Background

Sea urchins are ecologically important as herbivorous grazers (Mann 1982, Ling et al. 2015, Ling and Keane 2018, Cresswell et al. 2022). They eat a range of plant and invertebrate food sources and when they occur in high densities, their feeding can create macroalgal-free 'urchin barren' habitats (Filbee-Dexter and Scheibling 2014, Ling and Keane 2021). Barrens typically have a cover of crustose coralline, turfing and filamentous algae and have a distinct biodiversity (Ayling et al. 1981, Underwood et al. 1991, Kingsford 2002). As ecosystem productivity can be lowered when sea urchins turn kelp habitats into barrens (Ling et al. 2015, Kawamata and Taino 2021), limiting sea urchin populations has become an issue in marine management. Various strategies seeking to mitigate effects of urchin grazing and protect kelp stocks have been employed, with mixed results.

Developing ways to mitigate urchin grazing in Tasmania is seen as important, because climate driven ocean warming and the intensifying southerly flow of the East Australia Current (Philips et al., 2022) has facilitated range extension of the sea urchin *Centrostephanus rodgersii* (black or long-spined urchin) from its native range in New South Wales (NSW) to Tasmania with consequent effects on the receiving ecosystem (Fogarty and Pecl 2021, Ling and Keane 2021, Byrne et al. 2022, Cresswell et al. 2022). Due to the warming of Tasmanian waters *C. rodgersii* can now prosper in the region (Byrne et al., 2022). This range extension has caused great concern and prompted research and management action (Ling and Keane 2021, Cresswell et al. 2022)

The situation in Tasmania has prompted a vilification of *C. rodgersii* in other states. In NSW it is not clear that this is warranted in ecosystems where barrens are a representative and stable natural habitat (Filbee-Dexter and Schiebling 2014, Glasby and Gibson 2020). A blanket-approach to management of the sea urchin is unlikely to be equally effective in all regions as outcomes are influenced by the ecology of urchin and kelp species found there, and these differ temporally and spatially (Trowbridge et al. 2019, Glasby and Gibson 2020, Byrne et al. 2022, Davis et al. 2022[b]). It remains unclear how much of the kelp loss seen in eastern Australia can be directly ascribed to grazing by *C. rodgersii*. Climate-driven effects of regional ocean warming, storm action and freshwater influx are additional stressors which kill kelp individually or in combination (Fogarty and Pecl 2021, Davis et al. 2022[a], Davis et al. 2022[b]) and which can hamper kelp-restoration efforts (Morris et al. 2020, Fogarty and Pecl 2021). The role of climate change stressors seem not to have been fully considered in kelp dynamics models as a contributing factor in the decline of kelp, compared to models focused on urchin grazing (Ling et al. 2009, Ling et al. 2015, Layton et al. 2020). Overall, while it is clear that urchins are conspicuous herbivores that can create and maintain barrens habitat, they may have been unfairly targeted in NSW where barrens are a long-stable representative habitat and natural state (Trowbridge et al. 2019, Glasby and Gibson 2020, Davis et al. 2022[a], Davis et al. 2022[b]).

Recent results from experiments in NSW and Tasmania have identified the need for future urchin management schemes to include a wider range of considerations (Glasby and Gibson 2020, Day 2020, Day et al. 2021, Davis et al. 2022a, Davis et al. 2022b, Smith et al. 2022). These include recognition that: (1) for many areas of Australia, urchin barrens are a natural state which exists within a habitat mosaic with other habitats like kelp, cunjevoi and seagrass. (2) desirable outcomes for different regions of Australia will be different and (3) these managed responses need to be developed on a case-by-case, location specific, basis.

In Tasmania, management strategies to combat the formation of barrens have been employed including (1) divers removing sea urchins by hand (Ling et al. 2010, Sanderson et al. 2015), (2) enhancing wild predator populations by actively transplanting predators reared in captivity into areas ostensibly affected by urchins (Redd et al. 2014, Ling and Keane 2021), (3) encouraging populations of natural urchin predators (such as lobsters and large fish) in sanctuary zones through implementation of no-fishing zones (Barrett et al. 2009, Edgar and Stuart-Smith 2009, Perkins et al. 2015) and (4) commercial harvest of urchins (Keane et al. 2019, Cresswell et al. 2021, Ling and Keane 2021). The efficacy of these strategies is mixed. The commercial fishery of urchins has limited grazing in some areas in the short term. However, the dispersal of the larval urchins from NSW into Tasmania is favoured under climate projections (Ling et al. 2009, Fogarty and Pecl 2021, Byrne et al. 2022) and so will, to some extent, offset fishery removals. No significant decrease in *C. rodgersii* biomass in Tasmania has been seen in ~15 years of fishing (Cresswell et al. 2019, 2020 and 2021). The results of augmentation of lobster populations as a control measure is also uncertain as the lobster in Tasmania does not appear to focus on sea urchins as prey (Smith et al. 2022[a]).

Urchins in their historic native range

In NSW urchin barrens typically cover ~50% of nearshore areas (Andrew and O'Neill 2000) and have been stable for some time (Glasby and Gibson 2020). When 'urchin barrens' habitats were first described in 1981 the term 'coralline flats' was used initially, due to their close association with crustose coralline algae (Ayling

1981) which supports a range of vertebrate and invertebrate species (Coleman et al 2019; Curley et al. 2002). Importantly, the barrens habitat in NSW supports a broad diversity of dependant species and have been shown to support higher species diversity than adjacent kelp areas (Curley et al. 2022).

Recently, it has been suggested that overfishing of sea urchin predators has resulted in an increase in sea urchin populations in NSW (Layton et al. 2020). However, the predator-prey dynamics for sea urchin populations in NSW are not well understood, and much has been assumed from work in other locations (Ling et al. 2015, Ling et al. 2019). The need for management intervention in NSW, where barrens are part of the natural mix of habitats and urchin predators are abundant in marine sanctuary zones including barrens, is not pervasive (Edgar et al. 2011, Coleman et al. 2015, Harasti et al. 2015, Lee et al. 2015, Day 2020, Knott et al. 2021).

In NSW, barrens areas maintained by *C. rodgersii* exist as part of a natural habitat mosaic along with kelp, cunjevoi, coral, seagrass and rock along the coast in parallel with long-standing (> 20 years) protection of a suite of urchin predators including the eastern rock lobster (*Sagmariasus verreauxi*), eastern blue groper (*Achoerodus viridis*) and pink snapper (*Chrysophyrus auratus*) in Jervis Bay (Barrett et al. 2006, Barrett et al. 2008[a]) Batemans Bay (Barrett et al. 2008[b]) and Port Stephens (Davis et al. 2015). Recent work in NSW (Day 2020, Day et al. 2021) suggests while *Sagmariasus verreauxi* is abundant, this lobster does not often eat *C. rodgersii* in the wild (Jeffs et al. 2013, Montgomery and Liggins 2013, Woodings et al. 2021). Therefore, while NSW sanctuary zones effectively conserve many species that prey on *C. rodgersii,* like *A. viridis* and *C. auratus*, none of the predicted transitions from barrens to macroalgae has been seen in the reserves (Coleman et al. 2015, Harasti et al. 2015, Lee et al. 2015, Malcom et al. 2016; Knott et al. 2021).

Urchins in their extended range

Recently it has been suggested that if the larval load of *C. rodgersii* dispersing to Tasmania from the Australian mainland could be stemmed by controlling urchin populations in NSW, then the climate-driven range extension of this species would be controlled more. Controlling urchin populations by hand-removal of urchins by divers can be successful (Miller and Shears 2022, Miller et al. 2022) but is a 'high effort' for 'little gain' approach, which is labour intensive, environmentally invasive and has inherent operational limitations associated with diver safety and the scale at which this work can be performed is severely limited in context with the vast populations of *C. rodgersii* and seasonal larval load in NSW. Recent work has shown than hand removal of urchins by divers is effective only at the local scale (Sanderson et al. 2015). *C. rodgersii* is a highly fecund species (Byrne and Andrew 2013) such that it does not require many adults to maintain the larval load. There is also an ethical issue associated with this approach. By what "right" do we remove a species from its natural range in order to interrupt an essentially "natural" response to changing environmental conditions. It is possible that such large-scale manipulation of a species in its natural range would be in contravention of the spirit, if not the letter of the Convention on Biological Diversity.

In Tasmania, transplanting captive-reared southern rock lobster (*Jasus edwardsii*) into *C. rodgersii* affected areas has limited grazing by urchin populations in the short-term (Ling and Keane 2021, Cresswell et al. 2022). These experiments used only large *J. edwardsii* transplanted into places with limited urchin abundance (Smith et al. 2022[a]). Other lobster translocations have shown a change in lobster diets towards eating sea urchins before and after transplantation into sanctuary zones (Redd et al. 2014). While this is a developing field of research, it is unlikely that such management actions could realistically (economically) be scaled up to the level of whole ecosystems (Trowbridge et al. 2019, Sanderson et al. 2015, Shears and Babcock 2002). Further, for *C. rodgersii* whether this can even be achieved is uncertain and it is not known whether short-term changes will be maintained long-term as barrens are known to operate over decadal and multi-decadal timeframes (Trowbridge et al. 2019, Glasby and Gibson 2020).

It is crucial that sanctuary zones are maintained into the future as these are effectively ecological experiments which will contribute to the development of evidence-based management decisions with respect to the barrens-macroalgal dynamic. This is a key research area as fundamental unknowns remain about urchin barrens in Australia, including whether urchin populations are unregulated due to a lack of predators in the first place (Lee et al. 2015, Trowbridge et al. 2019, Day et al. 2021, Davis et al. 2022b). Further, while culling urchins has been effective in the short term, it is not considered a feasible long-term solution (Sanderson et al. 2015, Morris et al. 2020). Since urchins are a high value product when processed for their roe (Blount et al. 2017, Baulch 2019) harvest of sea urchins is being considered to determine the viability of commercial exploitation to limit their numbers.

The situation unfolding in Tasmania with *C. rodgersii* is different to what has been observed in NSW nearshore ecosystems. These two ecosystems will require different management strategies, and this is rarely acknowledged when strategies are being developed.

Harvesting sea urchins

Populations of *C. rodgersii* offer opportunities for sustainable commercial harvest of urchin roe, which is a high-value product for international markets (Blount et al. 2017, Baulch 2019). Despite descriptions of *C. rodgersii* in Tasmania as an invasive species which causes negative ecosystem effects (Ling et al. 2009, Ling and Keane 2018, Ling and Keane 2021) recent commentary more appropriately describes *C. rodgersii* as a native species extending its range south (Cresswell et al. 2019, 2020, 2022). Although the recent report states that no significant reduction in urchin populations has been achieved in Tasmania with ~15 years of fishing *C. rodgersii*, augmenting the fishery through the subsidy scheme in Tasmania has resulted in the development of a novel fishery which is a net-positive both financially (Johnson et al. 2005, Sanderson et al. 2015, Cresswell et al. 2022) and socially (Carr and Minshul 2020, Campus 2022). Importantly, development of a sea urchin fishery offers the opportunity for indigenous communities to be stakeholders in commercial fishing.

The quality of sea urchin roe is significantly higher in kelp habitats compared to barrens such that these are the most valuable stock for commercial divers (Eurich et al. 2014, Ling and Keane et al. 2018, Ling and Keane et al. 2021, Cresswell et al. 2020). Therefore commercial harvesting does not contribute to the removal of urchins from barrens. Certainly, there is some overlap and commercial divers have contributed to controlling urchin barrens at small scales by removing urchins from the area they work in (Sanderson et al. 2015, Morris et al. 2020). To date, harvesting urchins commercially in NSW (Blount and Worthington 2002) or culling *C. rodgersii* in southern states (Tracey et al. 2014) has not impacted the larval flow into Tasmania, nor has commercial harvest in Tasmania reduced urchin populations there (Cresswell et al. 2019, 2020, 2022).

Climate Change

Climate change related stressors have been shown to cause wide spread mortality of macroalgal forests (Davis et al. 2022[a], Davis et al. 2022[b]). These climate-mediated effects include (1) increased freshwater influx associated with increased storm action killing marine plants (Davis et al. 2022[a]), (2) increased storm action directly ripping attached kelp from the sea floor (Davis et al. 2022[a], Davis et al. 2022[b]) and (3) ocean warming and marine heatwaves causing thermal mortality of kelp (Fogarty and Pecl 2021, Ling and Keane 2021, Cresswell et al. 2022). In addition to being an additional factor contributing to kelp forest loss (Carnell et al. 2020, Cresswell et al. 2022, Davis et al. 2022[a], Davis et al. 2022[b]), these impacts can hamper kelp restoration efforts and even make restoration impossible in some areas (Morris et al. 2020). The heating of regional waters has been intense in Tasmania leading to mortality of kelp (Mabin et al. 2019).

Moving forward, it must be recognised that climate-related phenomena contribute to the formation and persistence of macroalgal free areas of the sea floor, not all 'urchin barrens' have been caused by urchins alone (Trowbridge et al. 2019, Davis et al. 2022[a], Davis et al. 2022[b]). Increasing seascape variability has been shown along the path of the rapidly intensifying East Australian Current (EAC) Southern Extension in southeast Australia, a hotspot of ocean warming and ecosystem tropicalization (Phillips et al. 2022). The potential exists for the macroalgal free habitats attributed to *C. rodgersii* in Tasmania and Southern NSW are, at least in part, climate-mediated phenomena and that grazing urchins may be the symptom and not the sole cause (Davis et al. 2022[a], Davis et al. 2022[b]. The extent of kelp loss directly attributable to *C. rodgersii* remains unclear (Carnell et al. 2020, Cresswell et al. 2022, Davis et al. 2022a, Davis et al. 2022b).

Recent work suggests that urchin populations and the associated barrens grow and recede naturally on decadal or multi-decadal timeframes and that these changes scale with ecosystem productivity and sea temperature (Johnson et al. 2005, Trowbridge et al. 2019, Glasby and Gibson 2020). This is attested to by the relative stability of barrens habitats in NSW, fluctuations of the kelp-barrens mosaic involving *Strongylocentrotus purpuratus* (purple sea urchin) in California and *S.droebachiensis* (green sea urchin) in Norway where grazing urchin populations have undergone die-offs associated with high urchin population density, food limitation and disease (Smith et al. 2022[b]).

Reference List

Andrew, N.L. and O'Neill, A.L., 2000. Large-scale patterns in habitat structure on subtidal rocky reefs in New South Wales. *Marine and Freashwater Research*, **51**, pp.255-263.

Ayling, A.M., 1981. The role of biological disturbance in temperate subtidal encrusting communities. Ecology, **62**, pp.830-847.

Barrett, N.S., Buxton, C.D. and Edgar, G.J., 2009. Changes in invertebrate and macroalgal populations in Tasmanian marine reserves in the decade following protection. *Journal of Experimental Marine Biology and Ecology*, **370**, pp.104-119.

Barrett, N.S., Edgar, G.J., Polacheck, A.S., Lynch, T. and Clements, F., 2006. Ecosystem monitoring of subtidal reefs in the Jervis Bay Marine Park 1996-2005. Government Report.

Barrett, N.S., Edgar, G.J., Polacheck, A.S., Lynch, T. and Clements, F., 2008[a]. Ecosystem monitoring of subtidal reefs in the Jervis Bay Marine Park 1996-2007. Government Report.

Barrett, N.S., Stuart-Smith, R.D., Zagal, C.J., Polacheck, A.S., Lynch, T., Edgar, G.J. and Clements, F., 2008[b]. Baseline surveys of the subtidal reef biota of the Batemans Bay Marine Park 2005-2007. Government Report.

Baulch, T.J., 2019. Cracking the code: Defining roe quality of the long-spined sea urchin (*Centrostephanus rodgersii*) in Tasmania (Doctoral dissertation, University of Tasmania). Government Report.

Blount, C. and Worthington, D., 2002. Identifying individuals of the sea urchin *Centrostephanus rodgersii* with high-quality roe in New South Wales, Australia. *Fisheries Research*, **58**, pp.341-348.

Blount, C., Chick, R.C. and Worthington, D.G., 2017. Enhancement of an underexploited fishery–Improving the yield and colour of roe in the sea urchin *Centrostephanus rodgersii* by reducing density or transplanting individuals. *Fisheries research*, ***186***, pp.586-597.

Byrne, M. and Andrew, N., 2013. *Centrostephanus rodgersii.* In *Developments in aquaculture and fisheries science* (Vol. 38, pp. 243-256). Elsevier.

Byrne, M., Gall, M.L., Campbell, H., Lamare, M.D. and Holmes, S.P., 2022. Staying in place and moving in space: contrasting larval thermal sensitivity explains distributional changes of sympatric sea urchin species to habitat warming. *Global Change Biology*, **28**, pp.3040-3053.

Campus, P., 2022. Optimising the fishery of the under-exploited edible sea urchin, *Centrostephanus rodgersii* (Doctoral dissertation, University of Tasmania). Government Report.

Carnell, P.E., Ierodiaconou, D., Atwood, T.B. and Macreadie, P.I., 2020. Overgrazing of seagrass by sea urchins diminishes blue carbon stocks. *Ecosystems*, **23**, pp.1437-1448.

Carr, E. and Minshull, L., 2020. Towards a sustainable marine management regime.

Coleman, M. A., & Kennelly, S. J. 2019. Microscopic assemblages in kelp forests and urchin barrens. *Aquatic Botany*, **154**, pp. 66–71

Coleman, M.A., Bates, A.E., Stuart-Smith, R.D., Malcolm, H.A., Harasti, D., Jordan, A., Knott, N.A., Edgar, G.J. and Kelaher, B.P., 2015. Functional traits reveal early responses in marine reserves following protection from fishing. *Diversity and Distributions*, **21**, pp.876-887.

Cresswell, K., Hartmann, K., Gardner, C. and Keane, J., 2019. Tasmanian Longspined Sea Urchin Fishery Assessment 2018/19. Government Report.

Cresswell, K., Hartmann, K., Gardner, C. and Keane, J., 2020. Tasmanian Longspined Sea Urchin Fishery Assessment 2019/20. Government Report.

Cresswell, K., Hartmann, K., Gardner, C. and Keane, J., 2022. Tasmanian Longspined Sea Urchin Fishery

Curley, B. G., Kingsford, M. J., & Gillanders, B. M. 2002. Spatial and habitat-related patterns of temperate reef fish assemblages: implications for the design of Marine Protected Areas. *Marine and Freshwater Research,* **53**, p. 1197.

Davis, T.R, Laird, R., Gallen, and Harasti, D., 2015. Mapping sub-tidal habitats in the Eastern Port of Port Stephens. Government Report.

Davis, T.R., Champion, C. and Coleman, M.A., 2022[a]. Ecological interactions mediate projected loss of kelp biomass under climate change. *Diversity and Distributions*, **28**, pp.306-317.

Davis, T.R., Larkin, M.F., Forbes, A., Veenhof, R.J., Scott, A. and Coleman, M.A., 2022[b]. Extreme flooding and reduced salinity causes mass mortality of nearshore kelp forests. *Estuarine, Coastal and Shelf Science*. **275**, p.107960.s

Day, J., 2020. Urchin predation and marine park residency in the Eastern Rock Lobster (*Sagmariasus verreauxi*): an initial assessment of its potential to control urchin populations. Thesis available @UOWonline

Day, J.K., Knott, N.A., Swadling, D.S. and Ayre, D.J., 2021. Dietary analysis and mesocosm feeding trials confirm the eastern rock lobster (*Sagmariasus verreauxi*) as a generalist predator that can avoid ingesting urchin spines during feeding. *Marine and Freshwater Research*, **72**, pp.1220-1232.

Edgar, G. Valentine, J., Cooper, T., Stuart-Smith, R., Gudge, S. and Kerr, I., 2011. Ecological monitoring of reef fishes, invertebrates and macroalgae at Lord Howe Island Marine Park, New South Wales, 2006-2010. Government Report.

Eurich, J.G., Selden, R.L. and Warner, R.R., 2014. California spiny lobster preference for urchins from kelp forests: implications for urchin barren persistence. *Marine Ecology Progress Series*, **498**, pp.217-225

Filbee-Dexter, K. and Scheibling, R.E., 2014. Sea urchin barrens as alternative stable states of collapsed kelp ecosystems. *Marine Ecology Progress Series*, **495**, pp.1-25.

Fogarty, H.E. and Pecl, G.T., 2021. Lessons and recommendations for the climate adaptation of key Tasmanian fisheries. Adaptive management of fisheries in response to climate change. FAO Fisheries and Aquaculture Technical Paper, **667**, pp.245-258.

Glasby, T.M. and Gibson, P.T., 2020. Decadal dynamics of subtidal barrens habitat. *Marine environmental research*, **154**, p.104869.

Harasti, D., Lee, K.A., Gallen, C., Hughes, J.M. and Stewart, J., 2015. Movements, home range and site fidelity of snapper (*Chrysophrys auratus*) within a temperate marine protected area. *PLoS One*, **10**, p.e0142454.

Jeffs, A. G., Gardner, C., and Cockcroft, A, 2013. *Jasus* and *Sagmariasus* species. In 'Lobsters: Biology, Management, Aquaculture and Fisheries'. (Ed. B. L. Phillips) pp. 259–278 (Wiley: Chichester, UK.)

Johnson, C.R., Ling, S.D., Ross, D.J., Shepherd, S. and Miller, K.J., 2005. Establishment of the long-spined sea urchin (*Centrostephanus rodgersii*) in Tasmania: first assessment of potential threats to fisheries. Government Report.

Kawamata, S. and Taino, S., 2021. Trophic cascade in a marine protected area with artificial reefs: spiny lobster predation mitigates urchin barrens. *Ecological Applications*, **31**, p.e02364.

Keane, J.P., Mundy, C., Porteus, M. and Johnson, O., 2019. Can commercial harvest of long-spined sea urchins reduce the impact of urchin grazing on abalone and lobster fisheries?. IMAS-FA, University of Tasmania, Hobart. Government Report.

Kingsford, M., 2002. The distribution patterns of exploited girellid, kyphosid and sparid fishes on temperate rocky reefs in New South Wales, Australia. *Fisheries science*, **68**, pp.131-134.

Knott, N.A., Williams, J., Harasti, D., Malcolm, H.A., Coleman, M.A., Kelaher, B.P., Rees, M.J., Schultz, A. and Jordan, A., 2021. A coherent, representative, and bioregional marine reserve network shows consistent change in rocky reef fish assemblages. *Ecosphere*, **12**, p.e03447.

Lee, K.A., Huveneers, C., Macdonald, T. and Harcourt, R.G., 2015. Size isn't everything: movements, home range, and habitat preferences of eastern blue gropers (*Achoerodus viridis*) demonstrate the efficacy of a small marine reserve. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **25**, pp.174-186.

Ling, S.D. and Keane, J.P., 2018. Resurvey of the longspined sea urchin (*Centrostephanus rodgersii*) and associated barren reef in Tasmania. Government Report.

Ling, S.D. and Keane, J.P., 2021. Decadal resurvey of long-term lobster experimental sites to inform *Centrostephanus* control. Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Tasmania. Government Report.

Ling, S.D., Ibbott, S. and Sanderson, J.C., 2010. Recovery of canopy-forming macroalgae following removal of the enigmatic grazing sea urchin *Heliocidaris erythrogramma. Journal of Experimental Marine Biology and Ecology*, **395**, pp.135-146.

Ling, S.D., Johnson, C.R., Frusher, S.D. and Ridgway, K., 2009. Overfishing reduces resilience of kelp beds to climate-driven catastrophic phase shift. *Proceedings of the National Academy of Sciences*, **106**, pp.22341-22345.

Ling, S.D., Scheibling, R.E., Rassweiler, A., Johnson, C.R., Shears, N., Connell, S.D., Salomon, A.K., Norderhaug, K.M., Pérez-Matus, A., Hernández, J.C. and Clemente, S., 2015. Global regime shift dynamics of catastrophic sea urchin overgrazing. *Philosophical Transactions of the Royal Society B: Biological Sciences*, **370**, p.20130269.

Mabin, C.J., Johnson, C.R. and Wright, J.T., 2019. Physiological response to temperature, light, and nitrates in the giant kelp *Macrocystis pyrifera* from Tasmania, Australia. *Marine Ecology Progress Series*, **614**, pp.1-19.

Malcolm, H.A., Jordan, A., Creese, R.G. and Knott, N.A., 2016. Size and age are important factors for marine sanctuaries: evidence from a decade of systematic sampling in a subtropical marine park. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **26**, pp.1090-1106.

Miller, K.I. and Shears, N.T., 2022. The efficiency and effectiveness of different sea urchin removal methods for kelp forest restoration. *Restoration Ecology*, p.e13754.

Miller, K.I., Blain, C.O. and Shears, N.T., 2022. Sea urchin removal as a tool for macroalgal restoration: A review on removing “the spiny enemies”. Government Report.

Montgomery, S.S. and Liggins, G.W., 2013. Recovery of the eastern rock lobster *Sagmariasus verreauxi* off New South Wales, Australia. *Marine Biology Research*, **9**, pp.104-115.

Morris, R.L., Hale, R., Strain, E.M., Reeves, S.E., Vergés, A., Marzinelli, E.M., Layton, C., Shelamoff, V., Graham, T.D., Chevalier, M. and Swearer, S.E., 2020. Key principles for managing recovery of kelp forests through restoration. *Bioscience*, **70**, pp.688-698.

Perkins, N.R., Hill, N.A., Foster, S.D. and Barrett, N.S., 2015. Altered niche of an ecologically significant urchin species, *Centrostephanus rodgersii*, in its extended range revealed using an Autonomous Underwater Vehicle. Estuarine, *Coastal and Shelf Science*, **155**, pp.56-65.

Phillips LR, Malan N, Roughan M, Harcourt R, Jonsen I, Cox M, Brierley AS, Slip D, Wilkins A and Carroll G (2022) Coastal seascape variability in the intensifying East Australian Current Southern Extension. *Front. Mar. Sci.* **9**:925123

Redd, K.S., Ling, S.D., Frusher, S.D., Jarman, S. and Johnson, C.R., 2014. Using molecular prey detection to quantify rock lobster predation on barrens-forming sea urchins. *Molecular Ecology*, **23**, pp.3849-3869.

Sanderson, J.C., Ling, S.D., Dominguez, J.G. and Johnson, C.R., 2015. Limited effectiveness of divers to mitigate ‘barrens’ formation by culling sea urchins while fishing for abalone. *Marine and Freshwater Research*, **67**, pp.84-95.

Smith, J.E., Keane, J., Mundy, C., Gardner, C. and Oellermann, M., 2022[a]. Spiny lobsters prefer native prey over range-extending invasive urchins. *ICES Journal of Marine Science*, **79**, pp.1353-1362.

Smith, L.C, Byrne, B, Keryn, B.G., Lipscomb, D.L., Majeske, A.J., Tafesh-Edwards, G., 2022[b]. In *Invertebrate pathology*: *Ecological outcomes of echinoderm disease, mass die-offs, and pandemics* (pp. 563-588). Oxford Press.

Trowbridge, C.D., Little, C., Plowman, C.Q., Williams, G.A., Pilling, G.M., Morritt, D., Vazquez, Y.R., Dlouhy-Massengale, B., Cottrell, D.M., Stirling, P. and Harman, L., 2019. No ‘silver bullet’: Multiple factors control population dynamics of European purple sea urchins in Lough Hyne Marine Reserve, Ireland. *Estuarine, Coastal and Shelf Science*, **226**, p.106271.

Underwood, A.J., Kingsford, M.J. and Andrew, N.L., 1991. Patterns in shallow subtidal marine assemblages along the coast of New South Wales. *Australian Journal of Ecology*, **16**, pp.231-249.

Woodings, L.N., Murphy, N.P., Doyle, S.R., Hall, N.E., Robinson, A.J., Liggins, G.W., Green, B.S., Cooke, I.R., Bell, J.J. and Strugnell, J.M., 2018. Outlier SNPs detect weak regional structure against a background of genetic homogeneity in the Eastern Rock Lobster, *Sagmariasus verreauxi*. *Marine Biology,* **165**, pp.1-17.

Woodings, L.N., Murphy, N.P., Liggins, G.W., Miller, M.E., Ballinger, G.M., Lau, S.C. and Strugnell, J.M., 2021. Population genomics of the Eastern Rock Lobster, *Sagmariasus verreauxi,* during spawning stock recovery from over-exploitation. *ICES Journal of Marine Science*, **78**, pp.2448-2459.