Global change, phase-shifts & recovery potential of Tasmania's rapidly warming reef ecosystems

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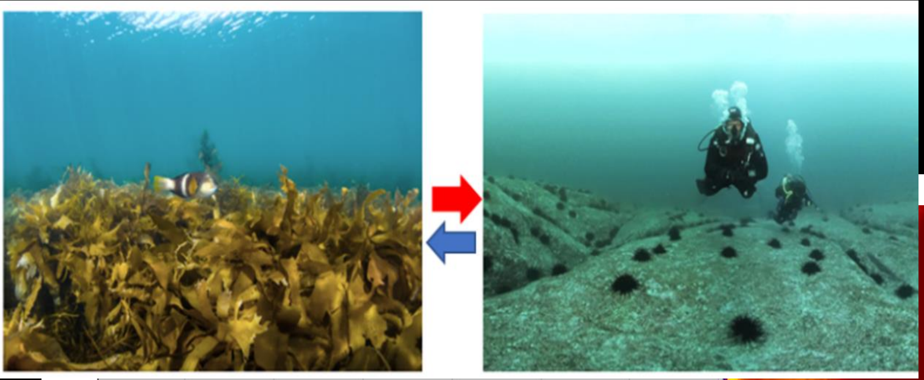
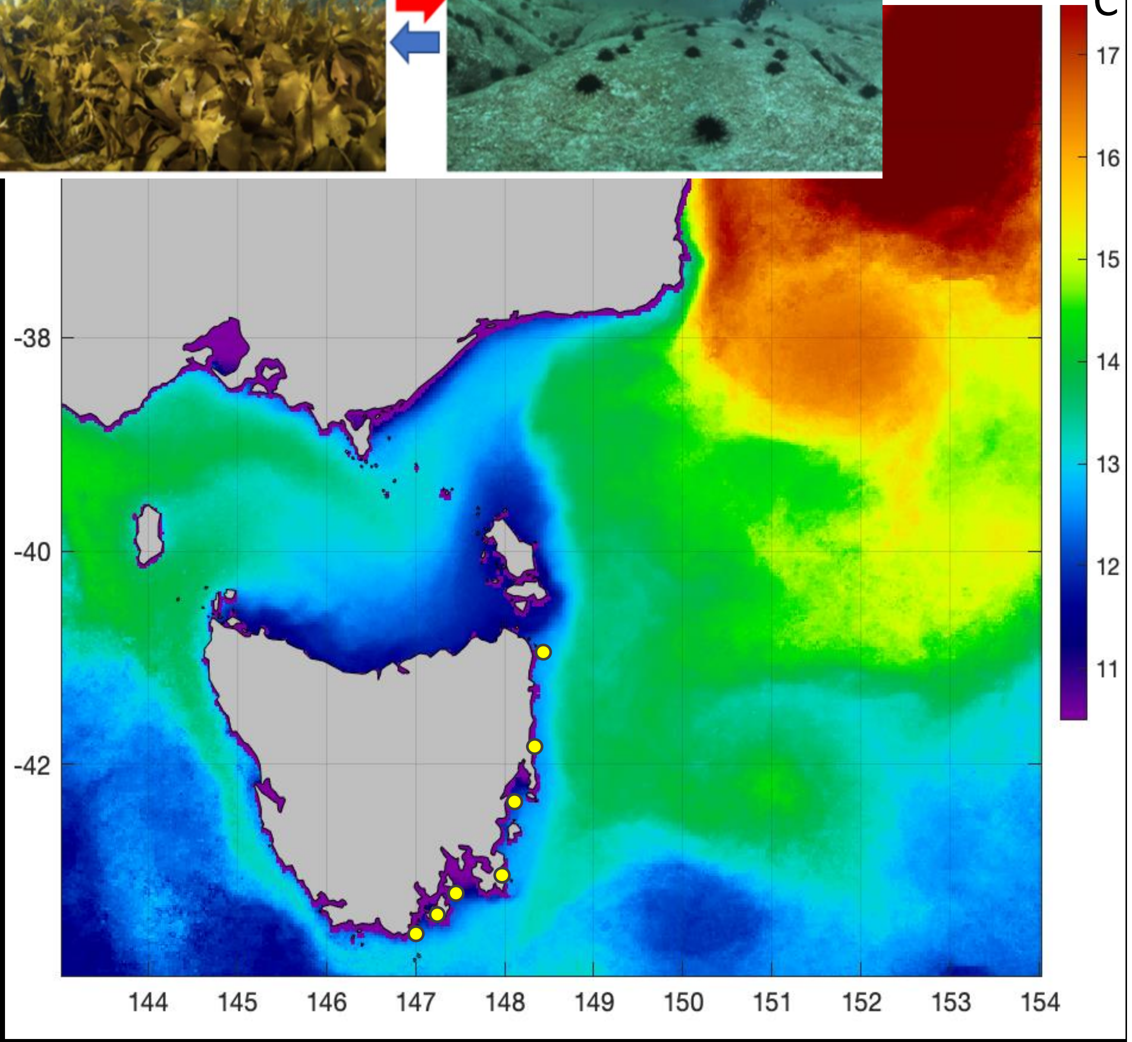
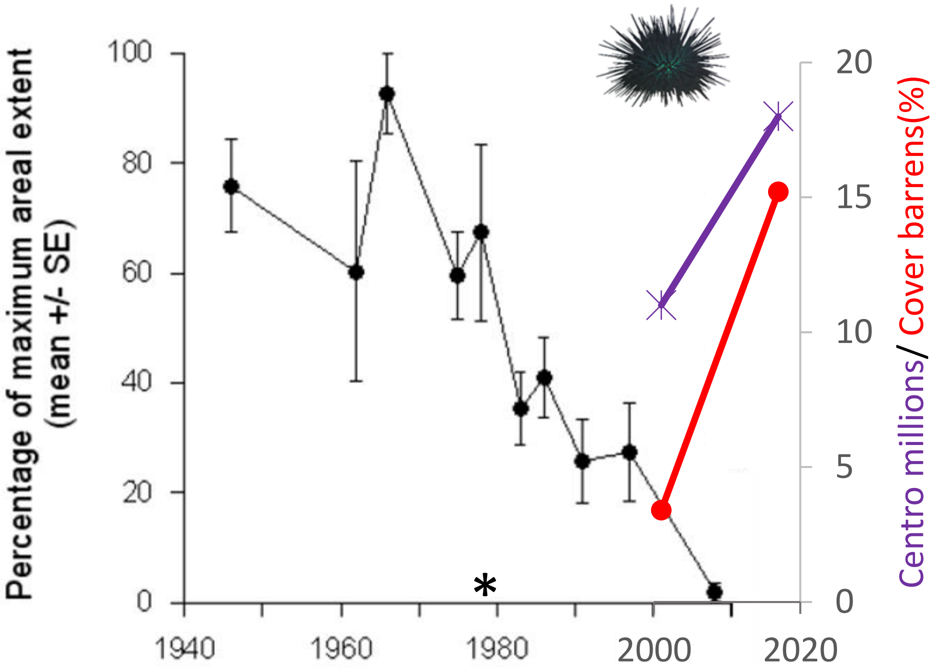
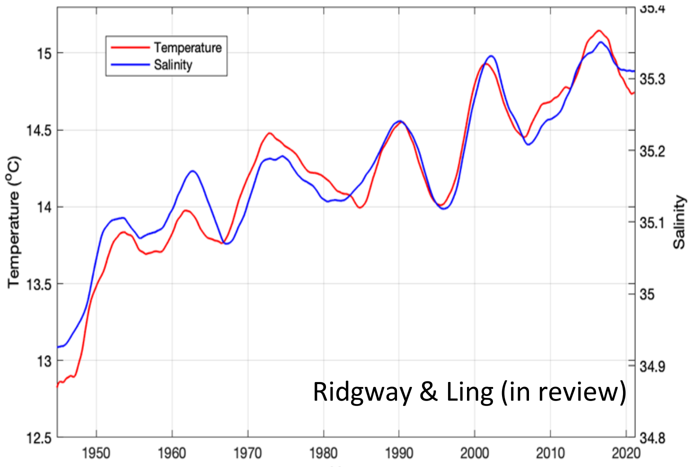
& ecological change on Tasmanian reefs



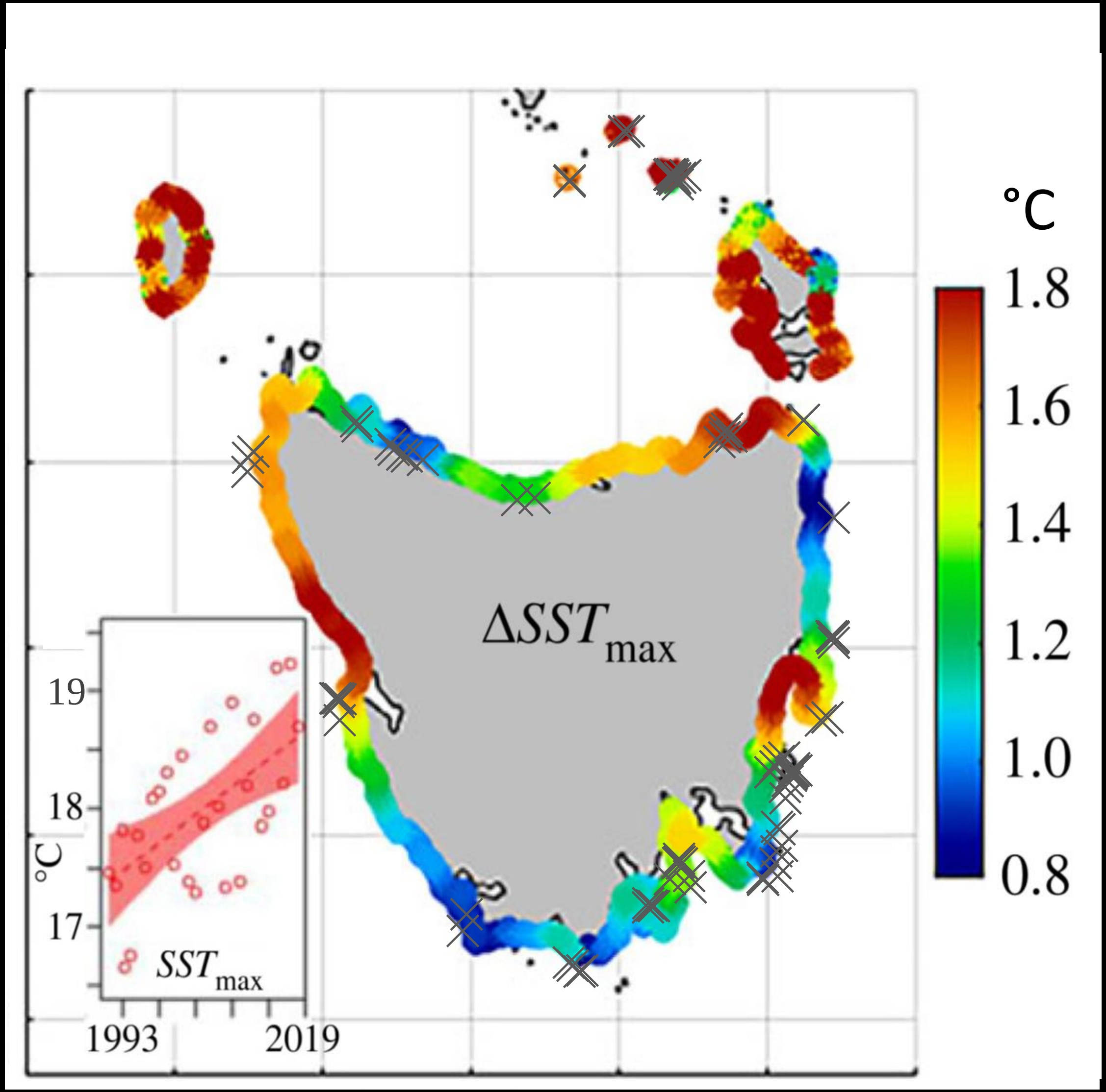


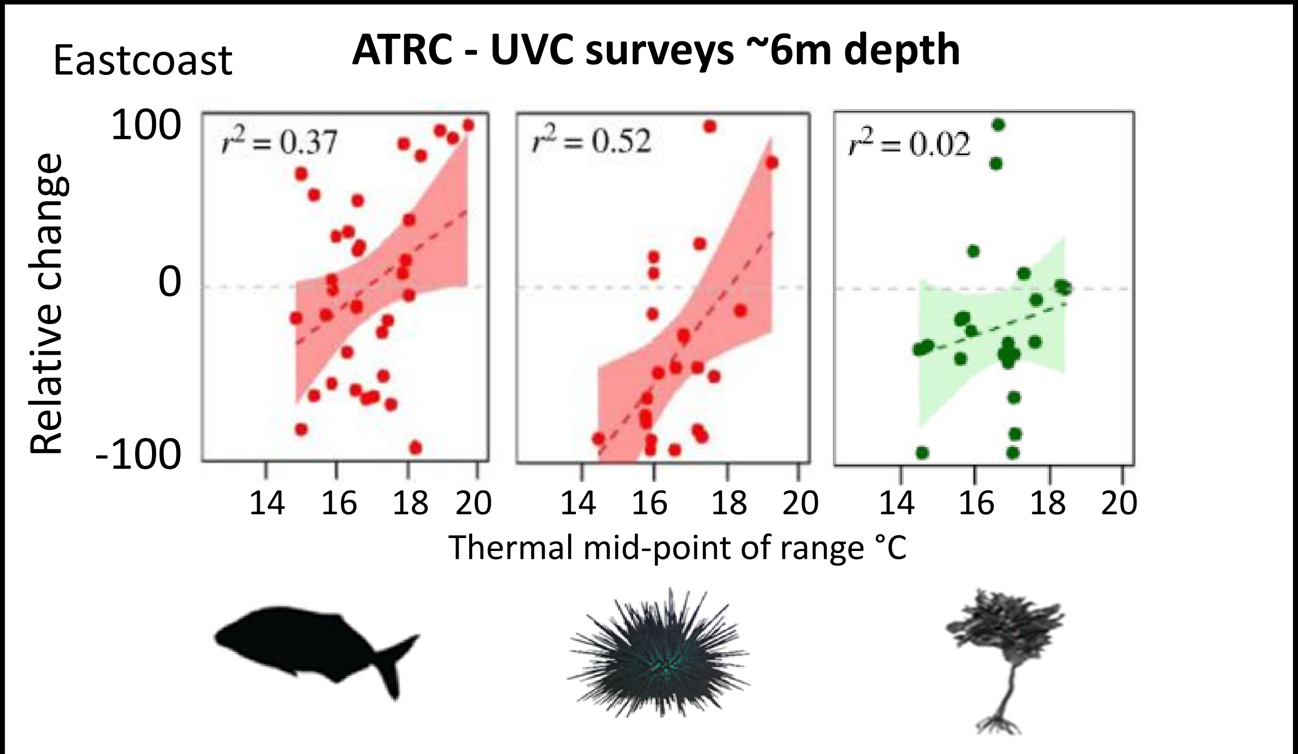
Surface canopy of giant kelp forests

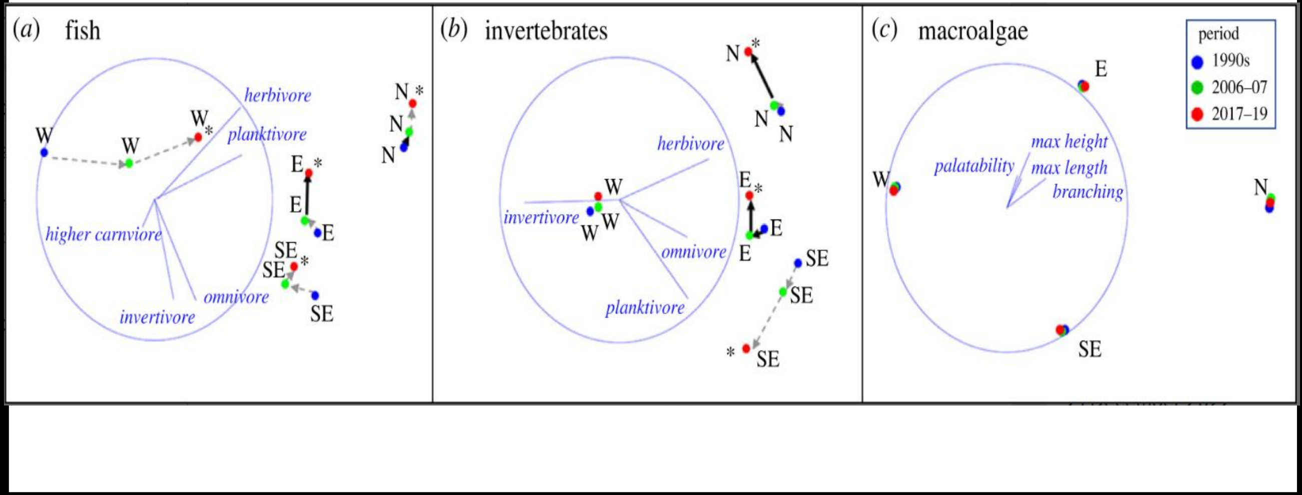




Coastal warming & ecological change on Tasmanian reefs



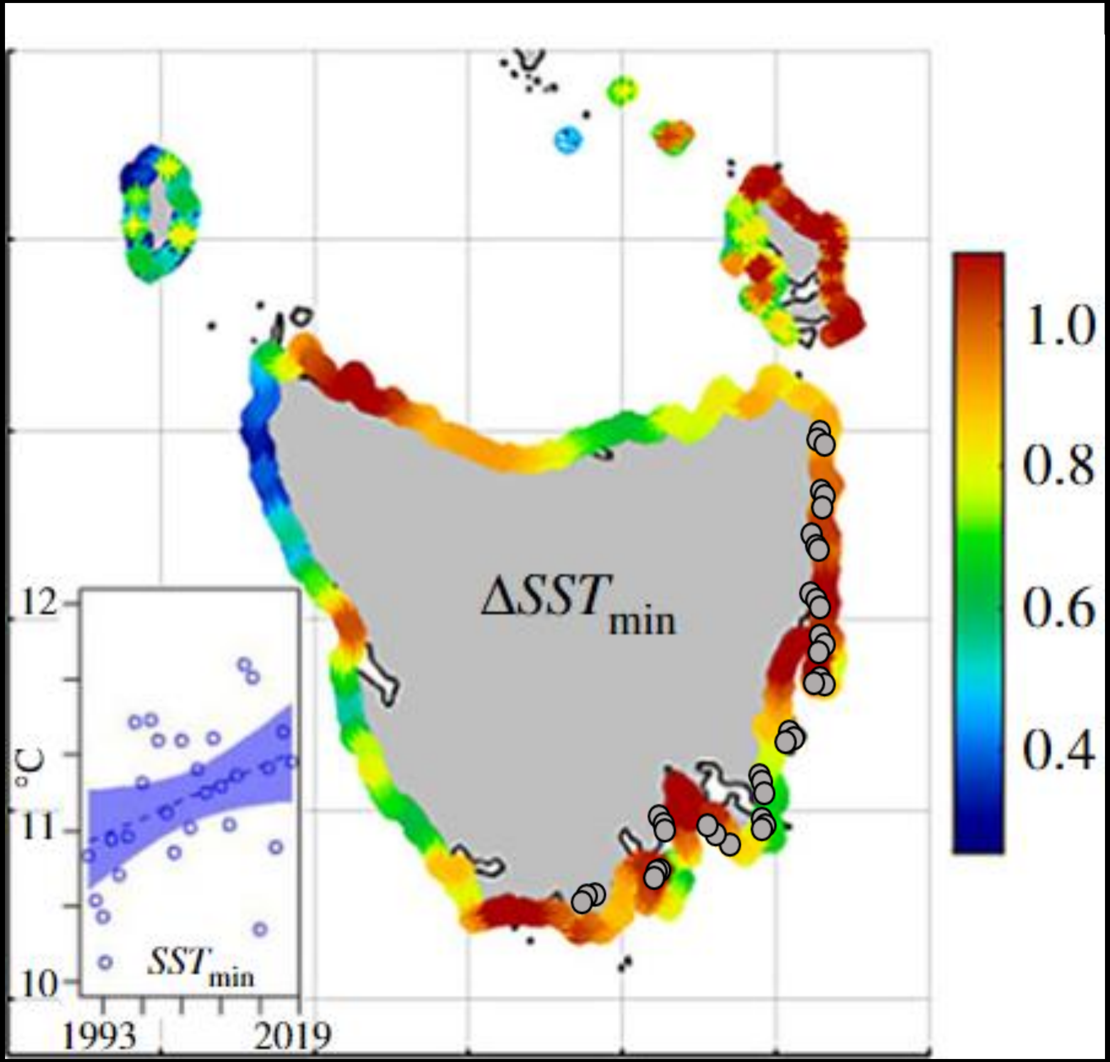


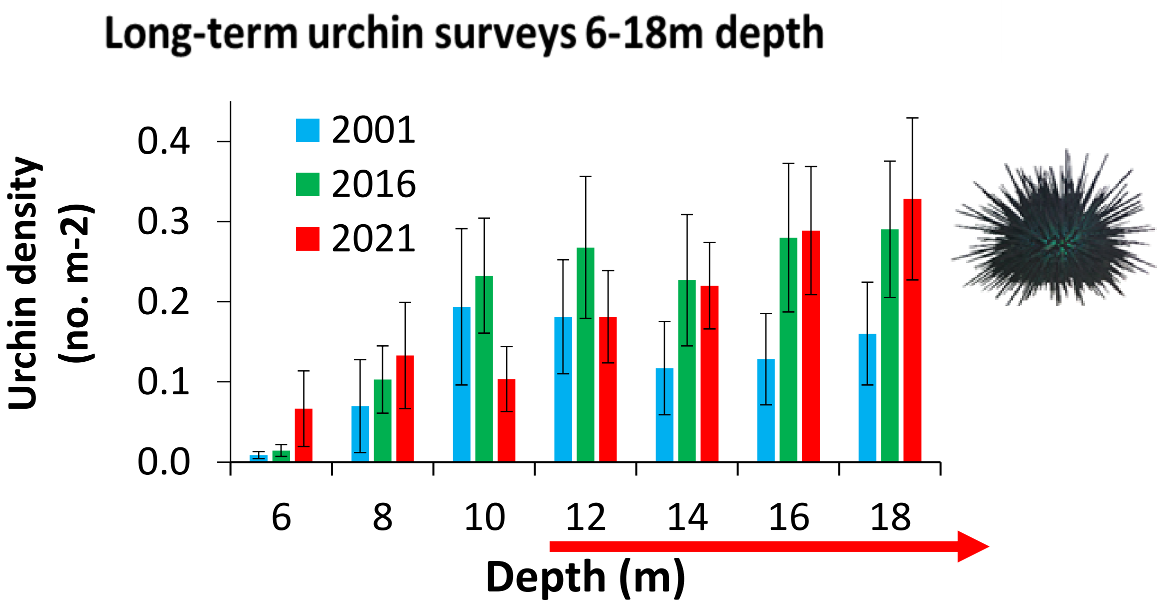


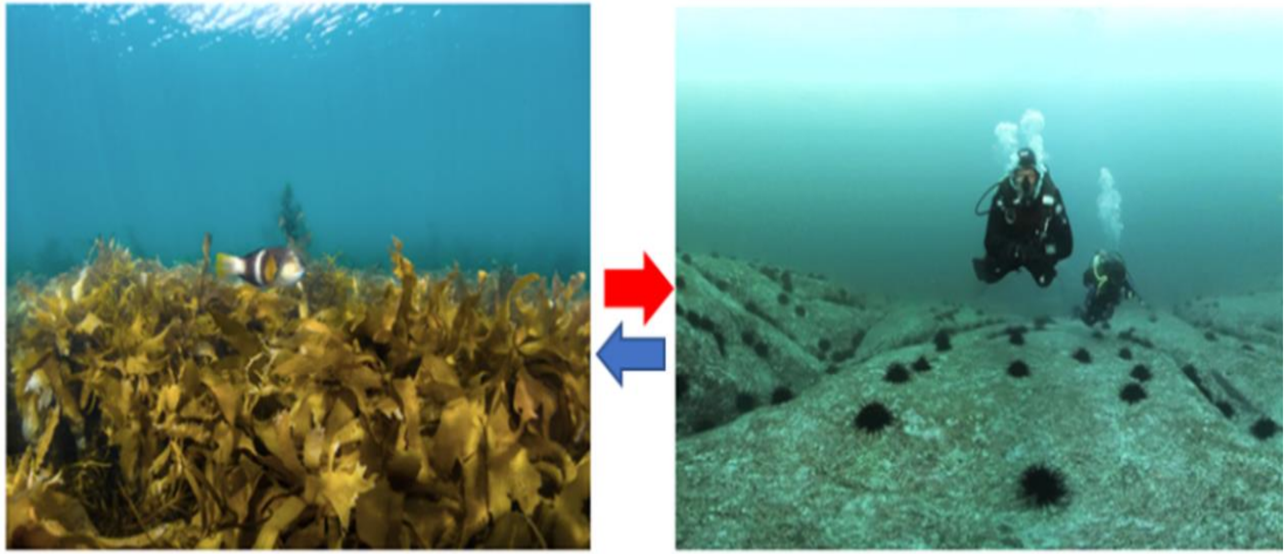
- Change greatest on fished reefs compared to MPAs

Bates et al. 2014; Ling et al. 2009

Coastal warming & ecological change on Tasmanian reefs



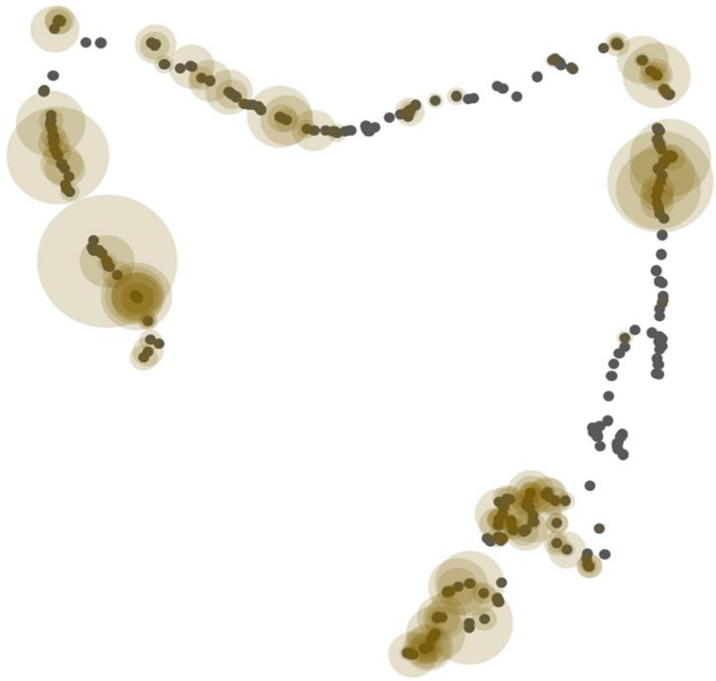




Ling & Keane 2018; Keane & Ling *unpub. data*

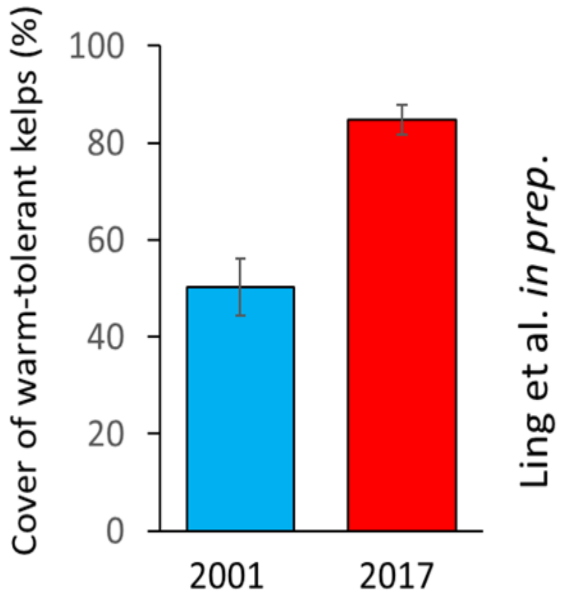
Coastal warming & ecological change on Tasmanian reefs

Beach-cast giant kelp 2020 (n=266 beaches)
largest bubble=157 individ. 500m^{-1}



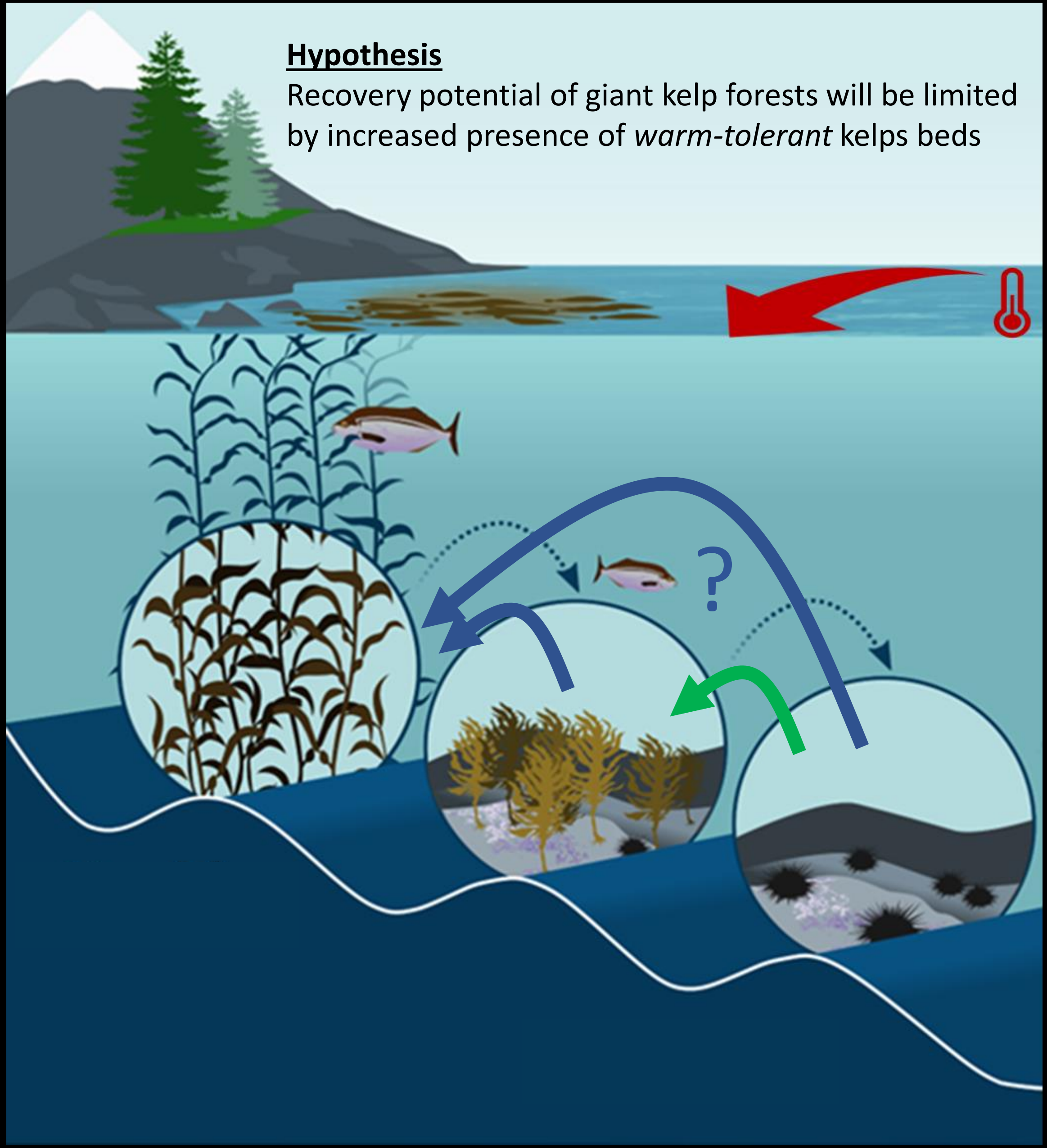
(Ling *unpub. data*)

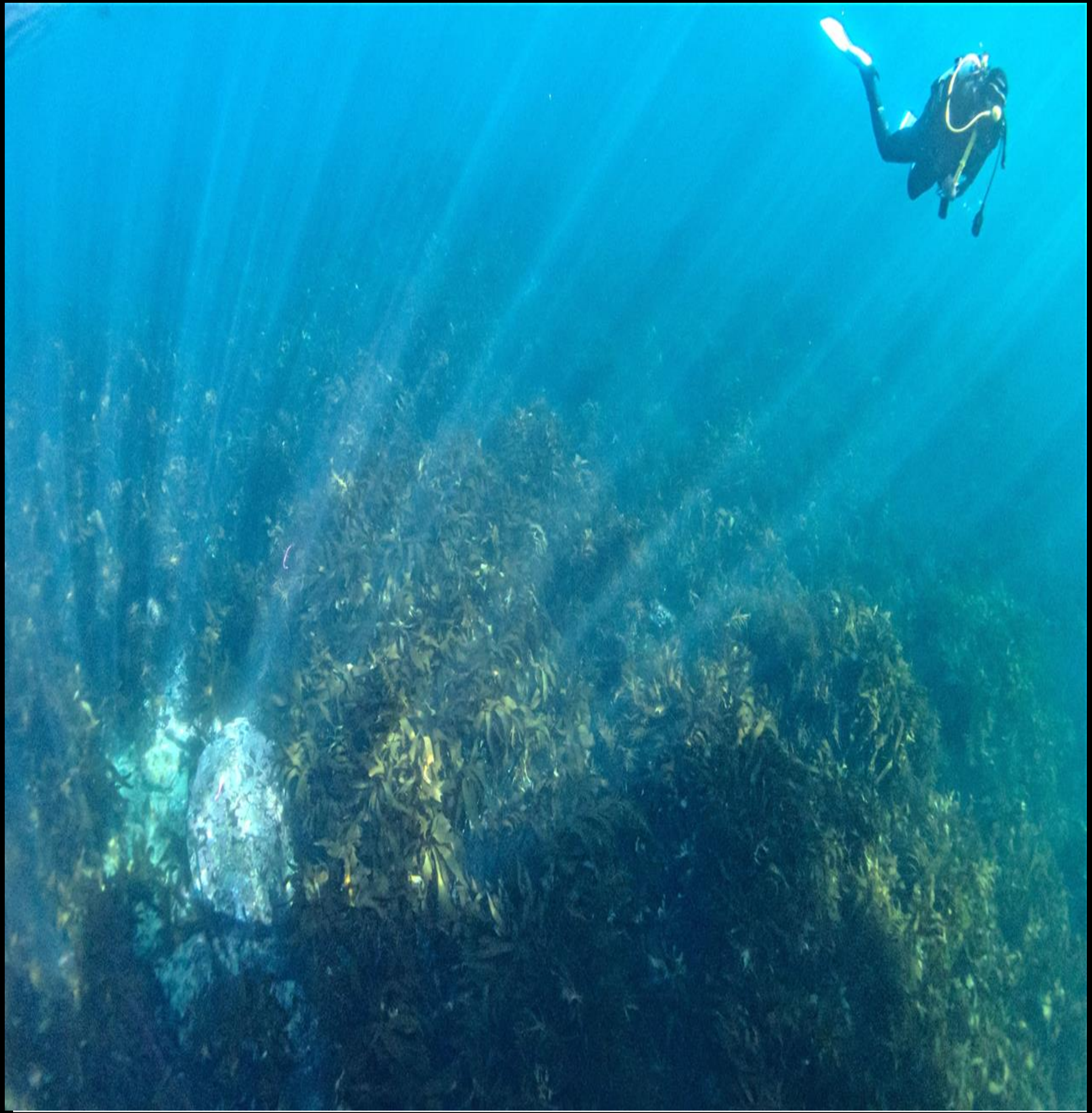
2001-2017 Taxa	Percent change
Phyllospora comosa	+13%
Ecklonia radiata	+16%
Macrocystis pyrifera	-42%



- Giant kelp forests list as endangered community but giant kelp as species still widespread

Altered ecology of eastern Tasmanian reefs





Recruitment limitation of giant kelp by competing *warm-tolerant* kelps beds

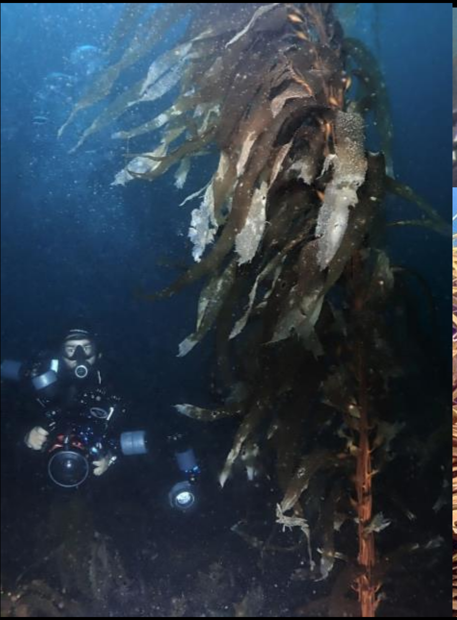
250,000 locally-sourced kelps out-planted

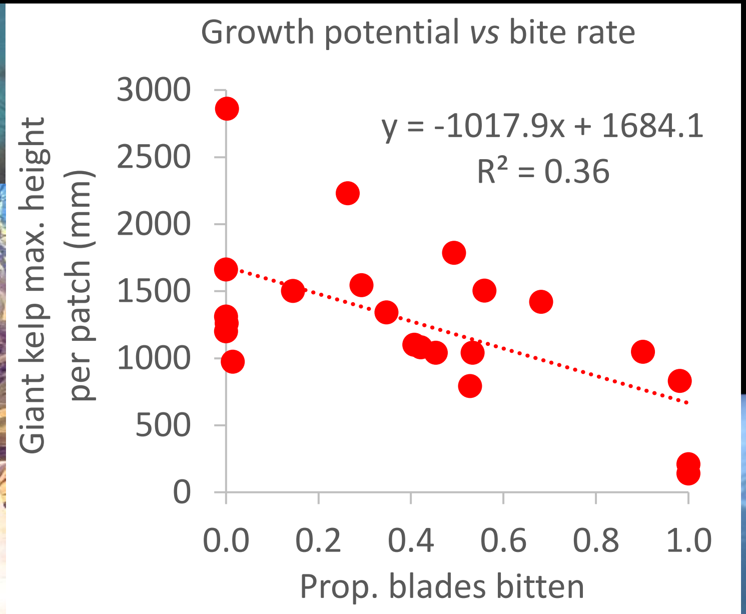
1-month after seeding

'Holdfast-graft' technique

5400% more recruitment of giant kelp on reef clear of warm-tolerant kelp

Growth potential of out-planted giant kelp

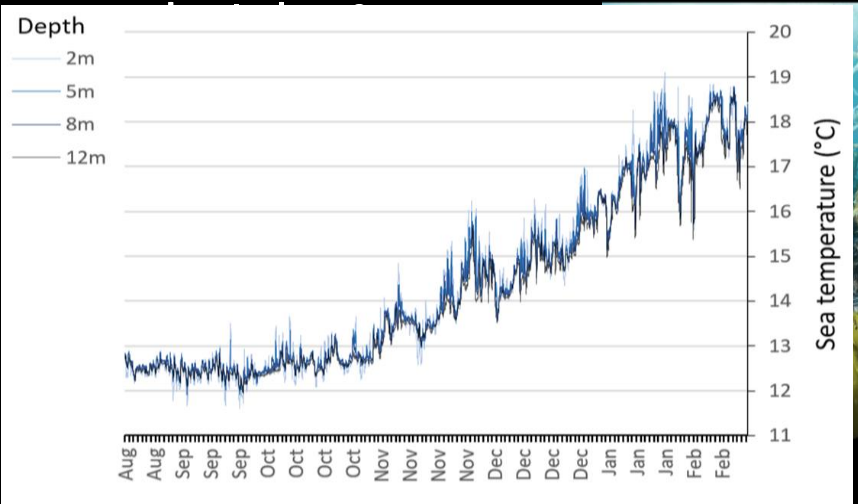




9-months
max. height 7 m

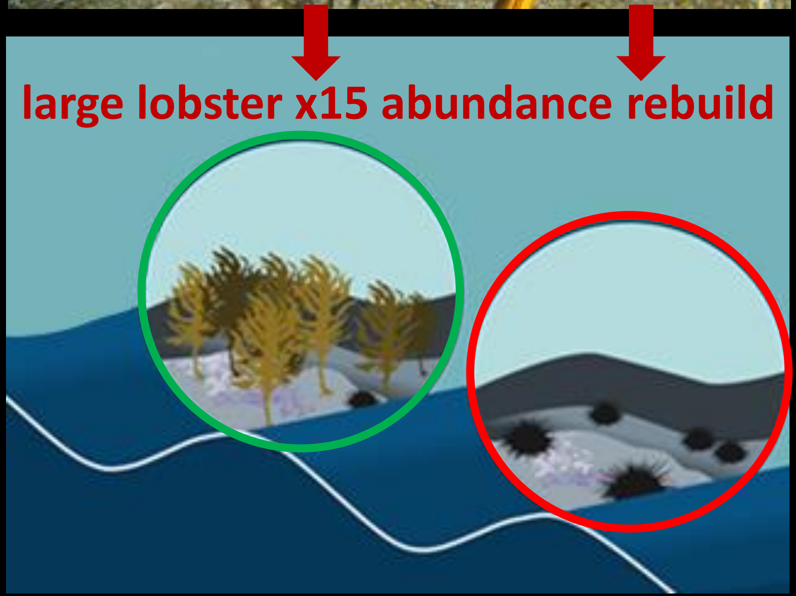
6-months
max. height 2.3 m

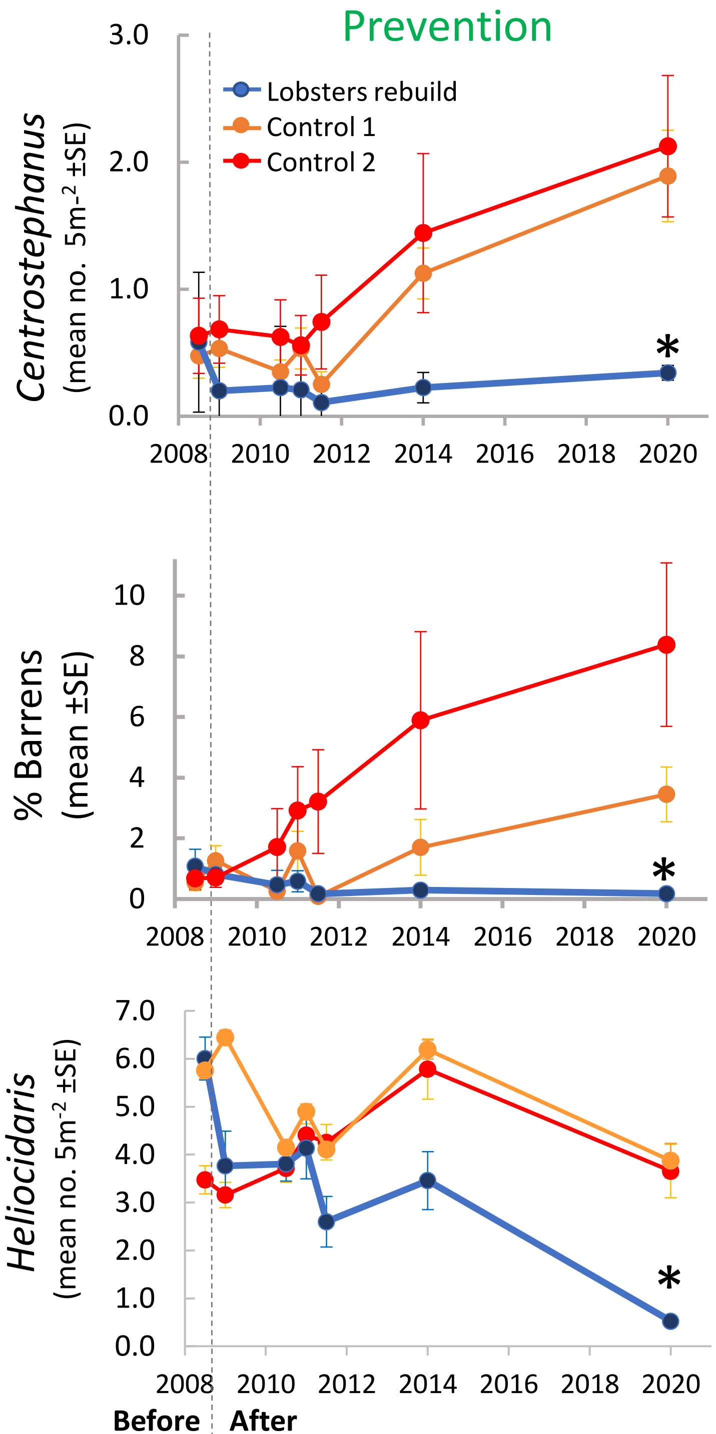
3-months

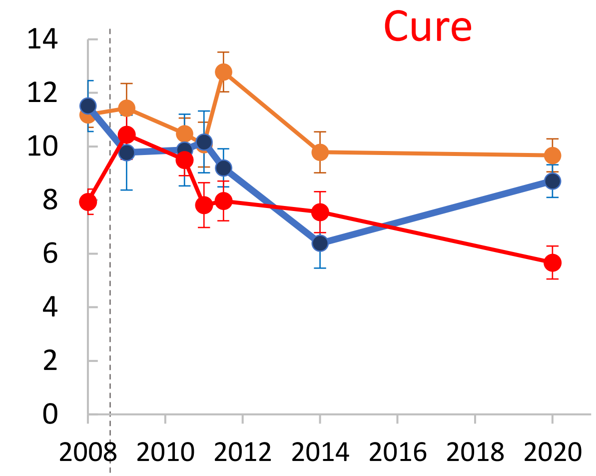


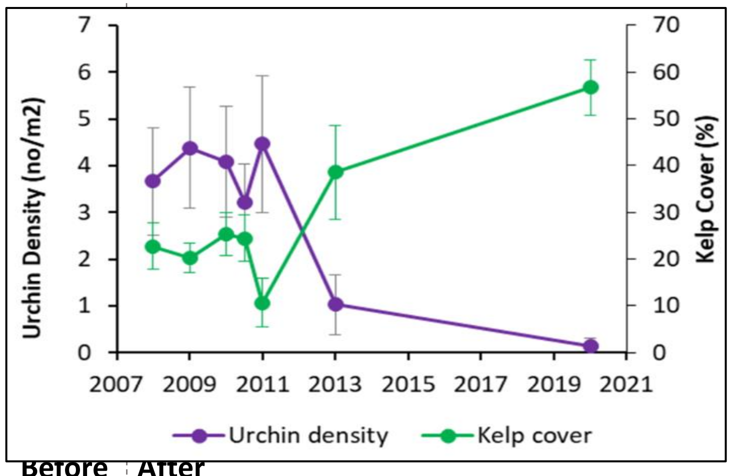
Rebuilding resilience of remnant & restored reefs

12-yr large-scale BACI exp.: prevention vs. cure



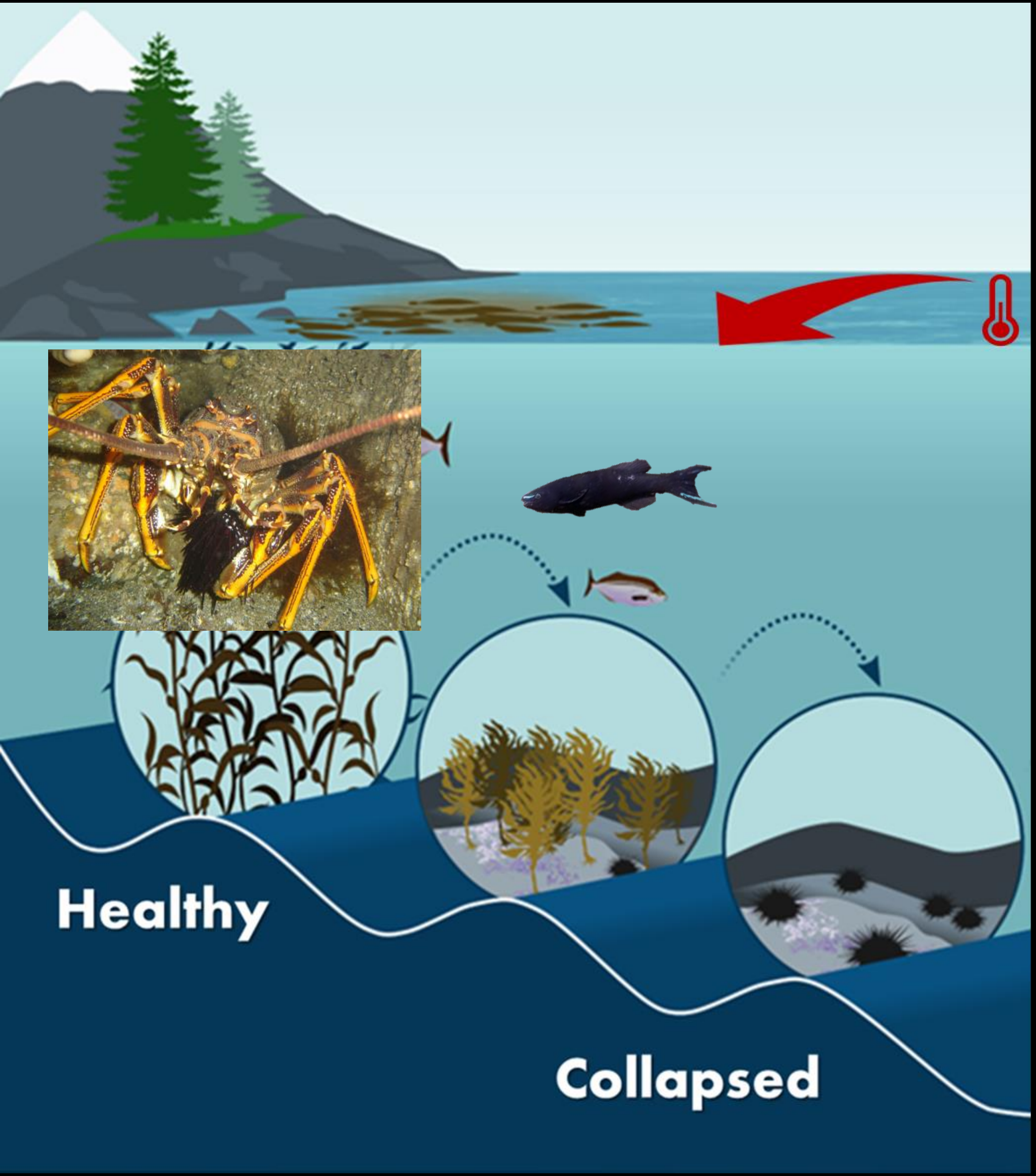






Ling & Keane 2021

Phase-shifts & recovery potential of Tasmania's rapidly warming reef ecosystems



- Rapid & widespread warming of Tasmanian coastal waters leading to profound shifts in the structure & function of reef communities
- Surveys & experiments have yielded much natural history understanding => indirect effects of warming are super important
- Grand challenge is now to scale-up solutions to ecologically meaningful scales => restoration industries
- Must restore whole-of-ecosystem structure & functioning to establish resilient restoration areas – *Reef EBFM*
- Currently nil policies for locally restored marine areas

The Guardian

‘Really worth a crack’: bringing Tasmania’s giant kelp forests back from the brink

Reseeding a half-hectare of seabed with microscopic giant kelp is a modest start to an ambitious aim: rebuilding an entire ecosystem

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by Adam Morton Climate and environment editor

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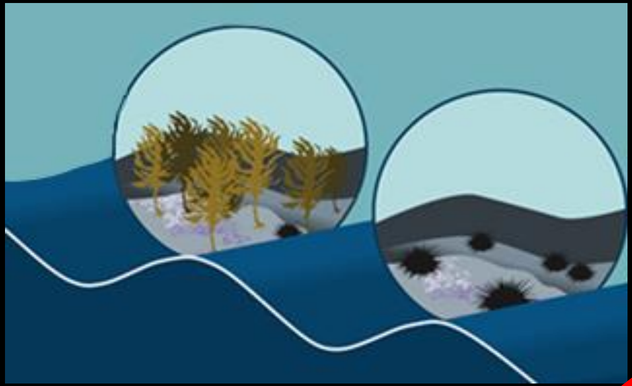
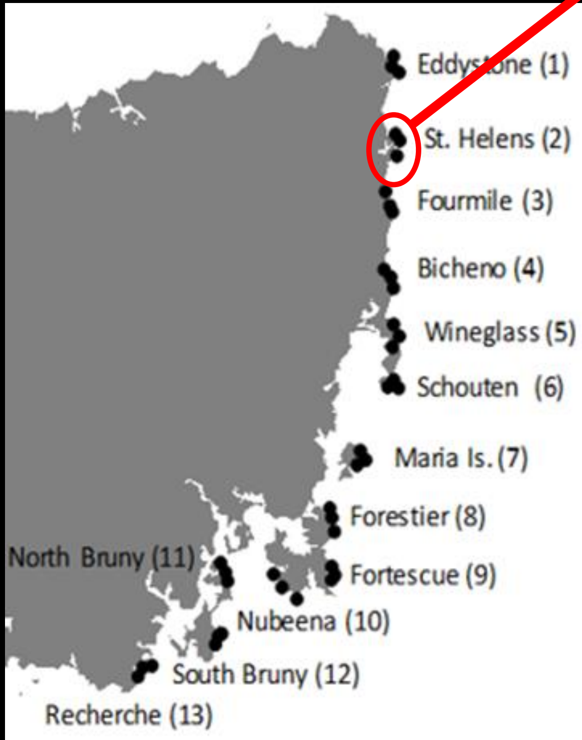
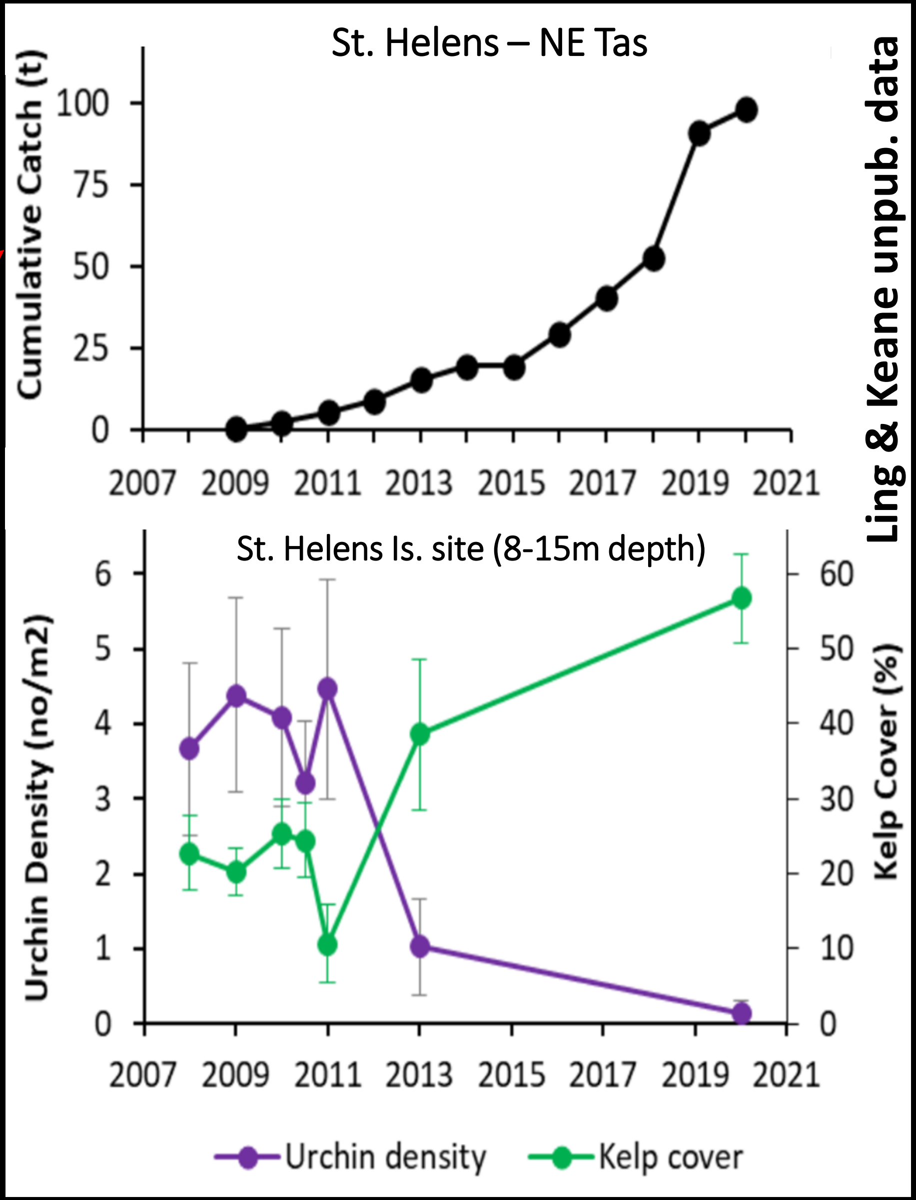
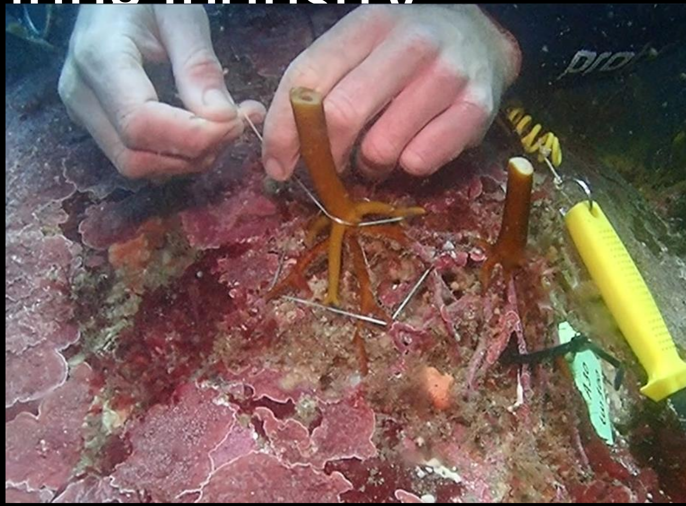
Extensive barrens recovery: urchin harvest & out-planting industry







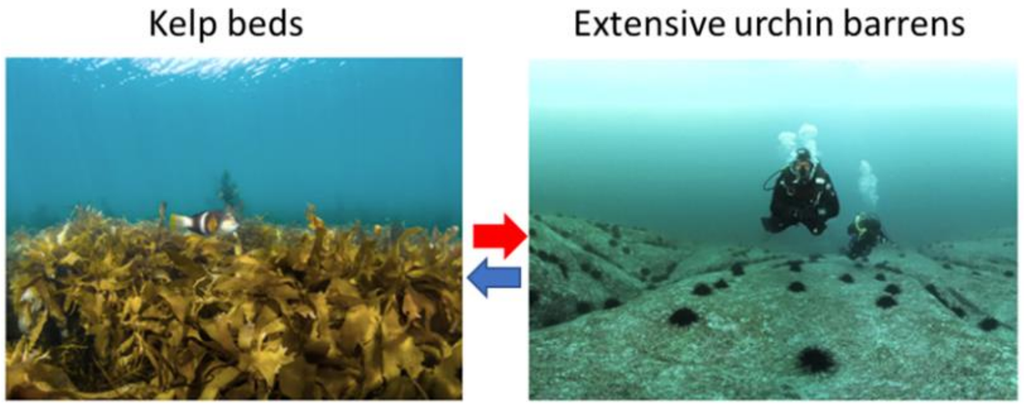


Abalone Industry Reinvestment Fund

AIRF

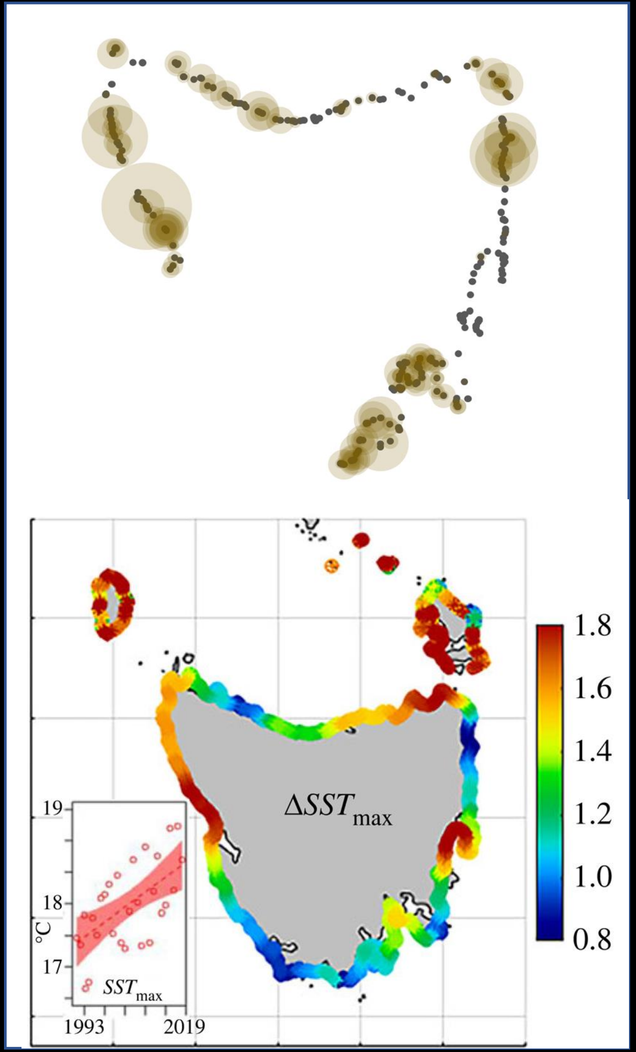
The Nature Conservancy Australia

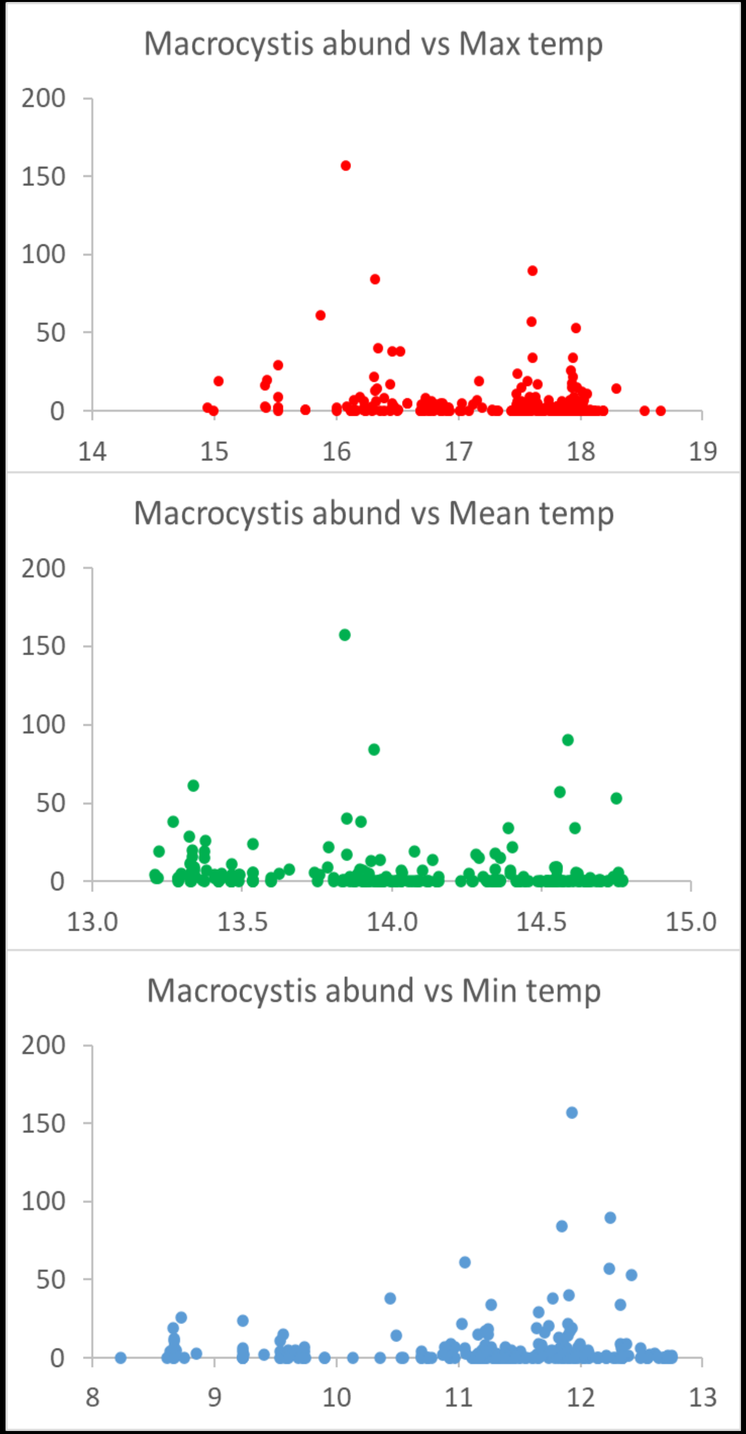
State-dependent Integrated Pest Management

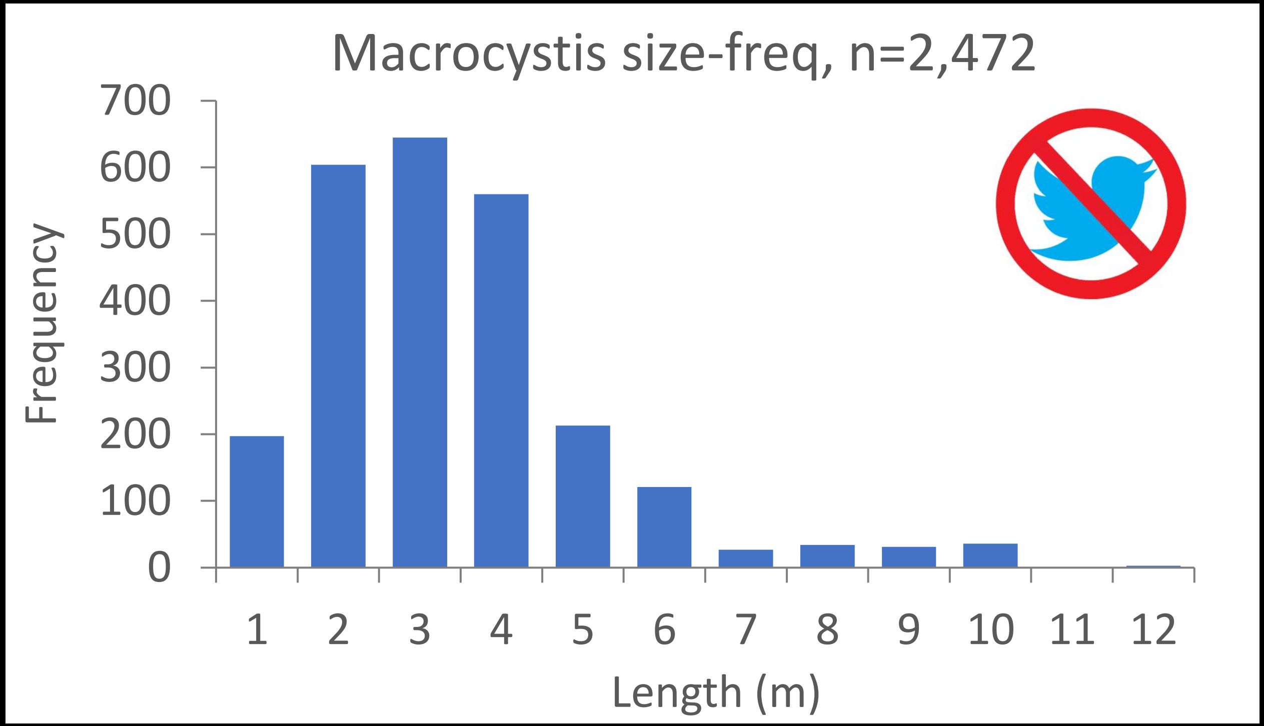


Urchin senate inquiry #38 IMAS submission

	Management option	Prevention (Kelp bed resilience)	Restoration (Recovery of extensive barrens)	Effective Depth Range	Timeframe to effective implementation and control [a]	Relative cost	Opportunities/ Benefits	Comments / limitations
Diver Based	Urchin Harvesting; Unrestricted	Yes, within limitations	Long term, extension (deepening) of kelp edge	0-25m[b]	Short to medium	Minimal-Industry driven	Low-cost; employment	Limited spatially by areas of economic value; size and quality selective; limited by depth and minimum densities; exploitation rates need to be high enough to significantly deplete stock.
	Urchin Harvesting; Subsidised	Yes, within limitations	Long term, extension (deepening) of kelp edge	0-25m[b]	Short	Low-Medium	Spatially directs harvests; incentivises processing sector; enhanced employment and economic activity	Size and quality selective; limited by depth
	Urchin Harvesting; Paid removals, all size classes	Yes	Yes	0-25m[b]	Immediate	Medium-High	Removes small urchins, more effective recovery, employment and economic activity, ideal for areas where no urchins are desired	Repeat visits may be required; can be costly
	Urchin Culling - contracted	Yes	Yes	0-25m[b]	Immediate	High	Employment; ideal if urchins have no economic value, i.e., in some extensive barrens	Repeat visits may be required; can be costly
	Urchin culling - Recreational	Yes	Limited by scale	0-25m[b]	Short	Low	Clearing urchins from recreational dive sites is a meaningful scale for recreational divers/tourist operators; Community engagement; Recreational culling campaigns 'derbies' can be a way of creating awareness and obtaining high participation.	Conflict with commercial sector; Other urchin species may be culled; spatial limitations. Reporting of recreational culling activities would require additional effort and would need coordination among individuals/ groups such that effort/ efficacy could be gauged.
	Urchin culling – Deep water	Yes		0-40 m	Immediate	Med-High	Protection of recreational dive sites, areas of high biodiversity and/or ecological importance. Protection of social values. Recreational culling of urchins to 40m using advanced dive technology (rebreathers) has been occurring in Tasmania for ca. 5 years.	Costly, particularly if applied at large scale.
	Urchin culling – during other commercial diving (fishing) activities	Yes; limited	No	0-20m	Immediate	Low	Opportunistic, low cost	Other fishing activities (e.g. abalone) only operate in healthy / incipient reef – limited by success of fishing activity. If fishing is good little time is spent culling. Furthermore, large barrens are avoided (swum around) and not culled given the time and effort taken to achieve a meaningful cull, but small patches with only several urchins can be culled efficiently.
Predator enhancement	Biological control: Predation lobsters	Yes; limited	No	0-40m+	Medium to long	Variable	Ecosystem benefit. Lobsters will also readily prey upon Shortspined Sea Urchins *Heliocidaris erythrogramma*, which also overgrazes kelp beds along sheltered coasts. Recruitment success of Longspined Sea Urchins is also higher on barrens formed by *H. erythrogramma*.	Short to medium Economic/Social costs (if cuts to recreational/ commercial fishing); Large biomass of large lobsters is required; potential negative impact of lobsters on other commercially important species as lobsters are generalist predators and will consume and drive down stocks of more preferred prey items (mussels, gastropods, short-spined urchins) before Centrostephanus; some localised barrens will persist in medium to longer-term, especially those occupied by large urchins which appear to have partial size-refuge to all but the largest lobsters.
	Biological control: Predation large fish (Eastern Blue Groper)	Yes; limited	?	0-40m+	Medium to long	Variable	Ecosystem benefits	Level of effectiveness unknown; Short to medium Economic/Social costs (if cuts to recreational/ commercial fishing); Some barrens will persist; Potential declines of other macroinvertebrates if prey-switching occurs.
R&D Limited	Urchin Ranching	No	Limited by scalability	0-25m[b]		Industry driven	Concept is to ranch urchins from barrens in aquaculture facilities; value adding, employment,	Size selective removals, untried commercially, scalability and economic viability uncertain for Longspined Sea Urchin
	Chemical control: Quickliming	No	Yes; limitations	0-40m+		Moderate to high	Largescale application	Uncertainty of social acceptance/ license; potential impact on other invertebrate species; application at depth untested (see Appendix #).
Novel/ Untired	Autonomous Robotic culling	NO	Plausible; potentially limited by scalability	0-40m+	uncertain	High/ Unknown	Potential application at depth on extensive barren grounds. Elimination of diving risks which increase with depth. Prototypes under development by Hullbot (https://hullbot.com/) in consultation with IMAS researchers (see **Appendices # & #**).	Technology currently limited with cost and effectiveness of culling urchins at meaningful scales unknown. Autonomous vehicles have demonstrated limited navigational capability within kelp beds, but more feasibly navigate on open barrens grounds. Will be required to operate at 30m+ to be effective and will need to ensure sufficient urchins are culled within defined areas to ensure local density can be reduced to the point of kelp and sessile invertebrate recovery in deeper water.
	Genetic control	?	?	0-40m+		Unknown		Trailed on other species (e.g. gambusia)
	Bio-tech control (triggering disease)	?	?	0-40m+		Unknown		

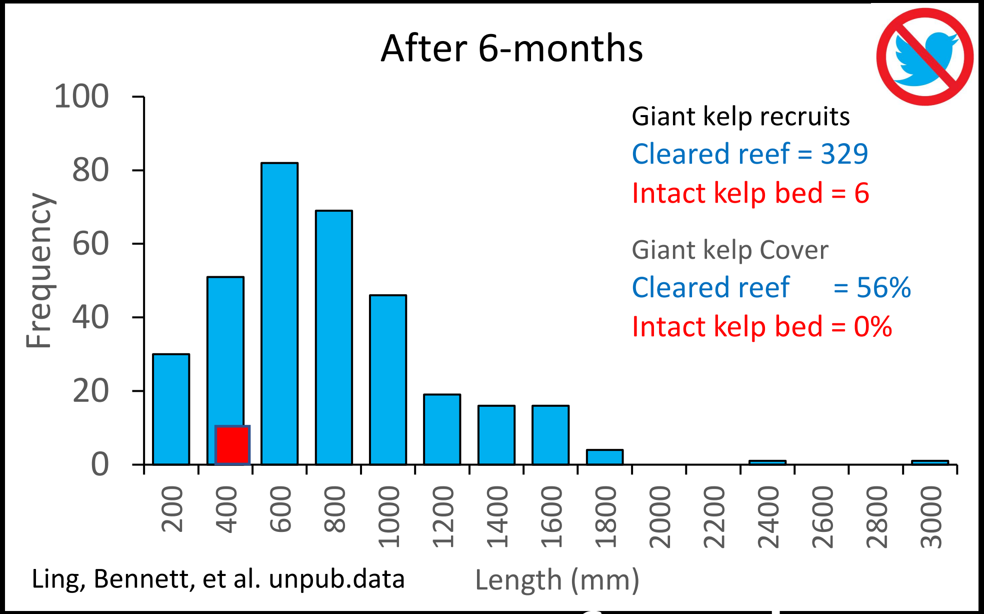

1.8
1.6
1.4
1.2
1.0
0.8
ΔSST max
19
18
17
°C
SST max
1993
2019


Macrocystis abund vs Max temp
200
150
100
50
0
14
15
16
17
18
19
Macrocystis abund vs Mean temp
200
150
100
50
0
13.0
13.5
14.0
14.5
15.0
Macrocystis abund vs Min temp
200
150
100
50
0
8
9
10
11
12
13



Macrocystis size-freq, n=2,472
700
600
500
400
300
200
100
0
Frequency
1
2
3
4
5
6
7
8
9
10
11
12
Length (m)

Growth potential of out-planted giant kelp



3-months
max. height 0.7 m

6-months
max. height 2.3 m

7-months
max. height 4.8 m

9-months
max. height 7 m

“Cleared” *vs* “Intact warm-tolerant kelp beds”

6-month results: