

Post-earthquake re-organisation of intertidal algal communities along the Kaikōura coastline



Tom Falconer, Shawn Gerrity, Tommaso Alestra, David Schiel



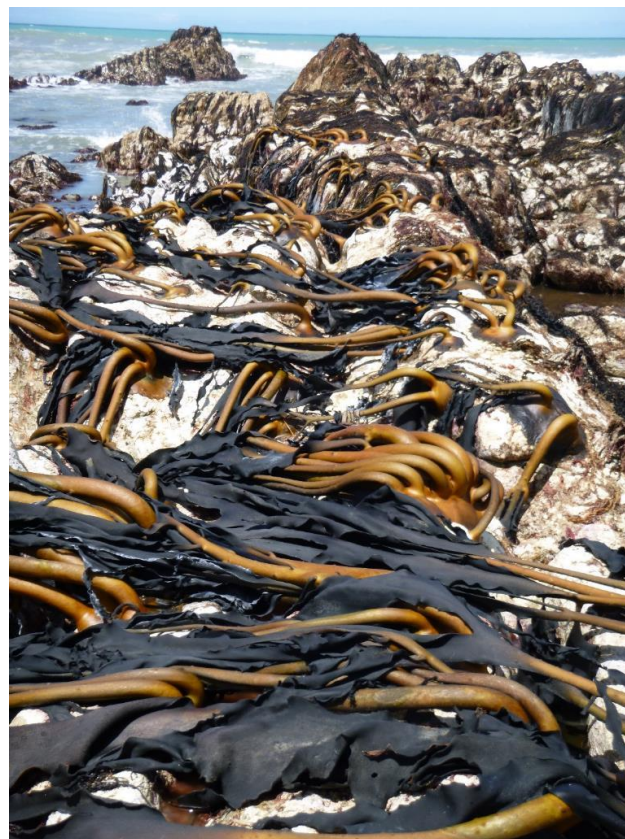
**MINISTRY OF BUSINESS,
INNOVATION & EMPLOYMENT**
HIKINA WHAKATUTUKI

Ministry for Primary Industries
Manatū Ahu Matua



Kaikōura Earthquake

- Occurred on the 14th of November 2016, magnitude 7.8.
- Multiple faults and is considered to be one of the most complex earthquakes ever studied.







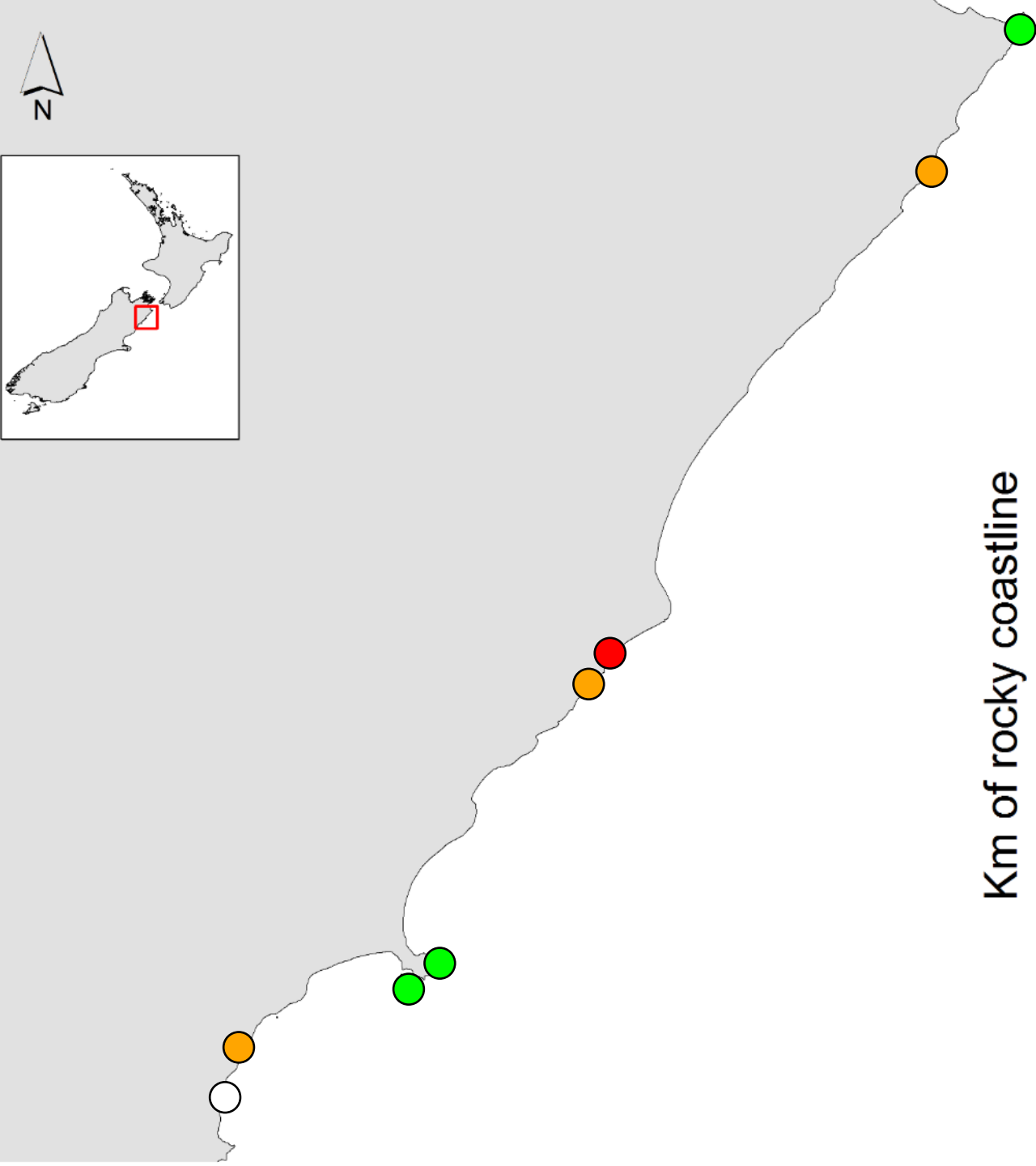
Pre-earthquake high tide line





Pre-earthquake high tide line

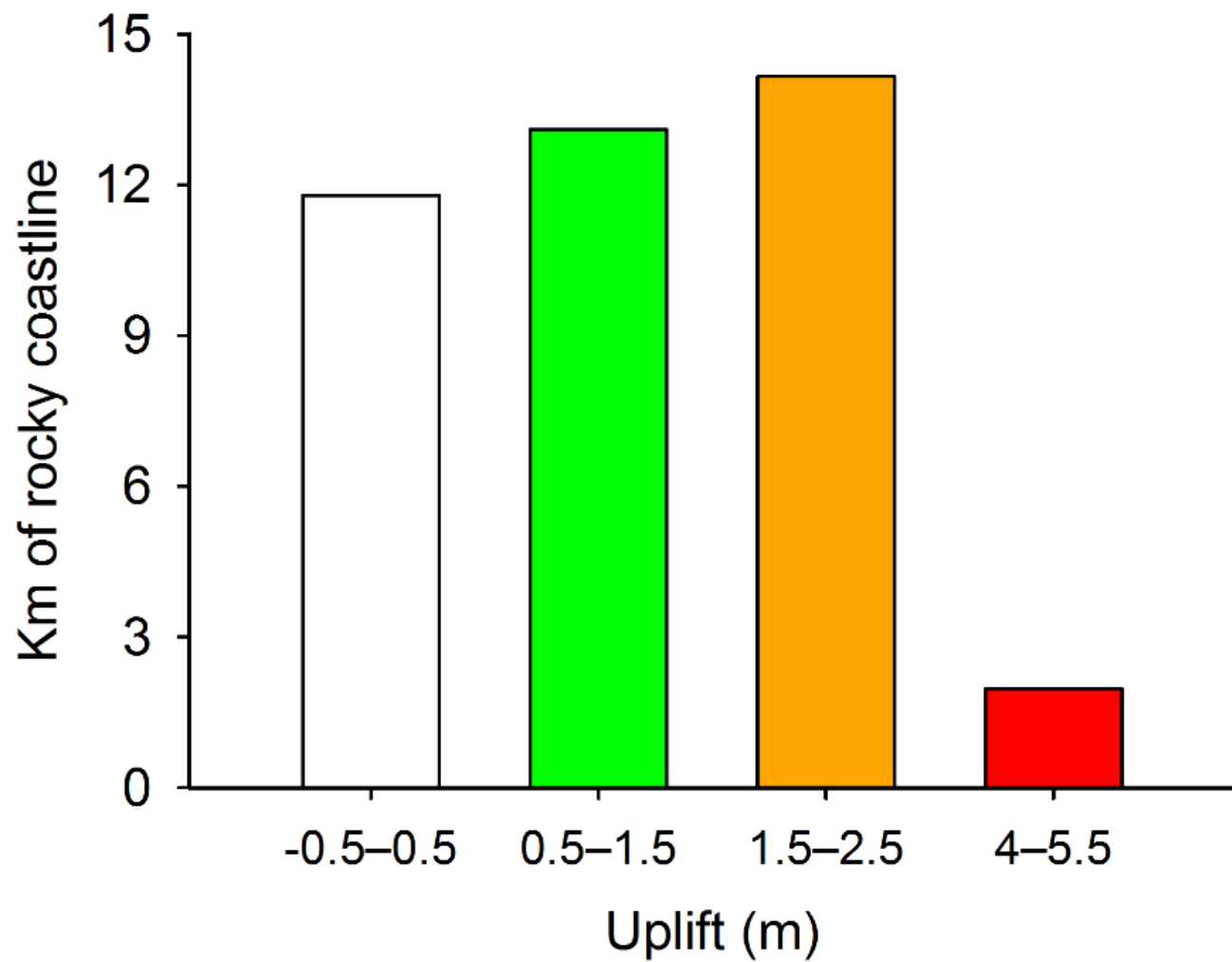
Post-earthquake high tide line

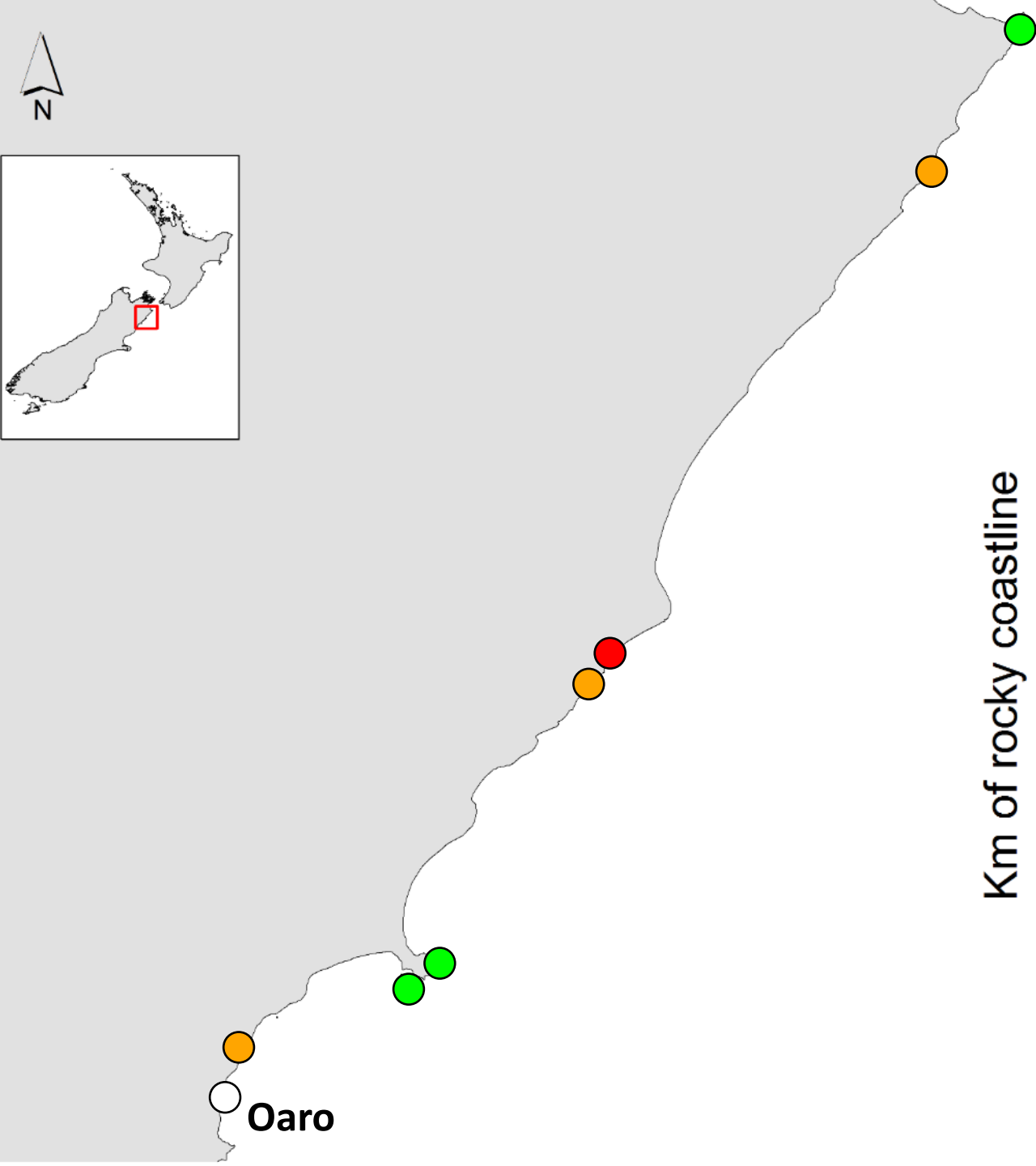


42 km of rocky reef habitat

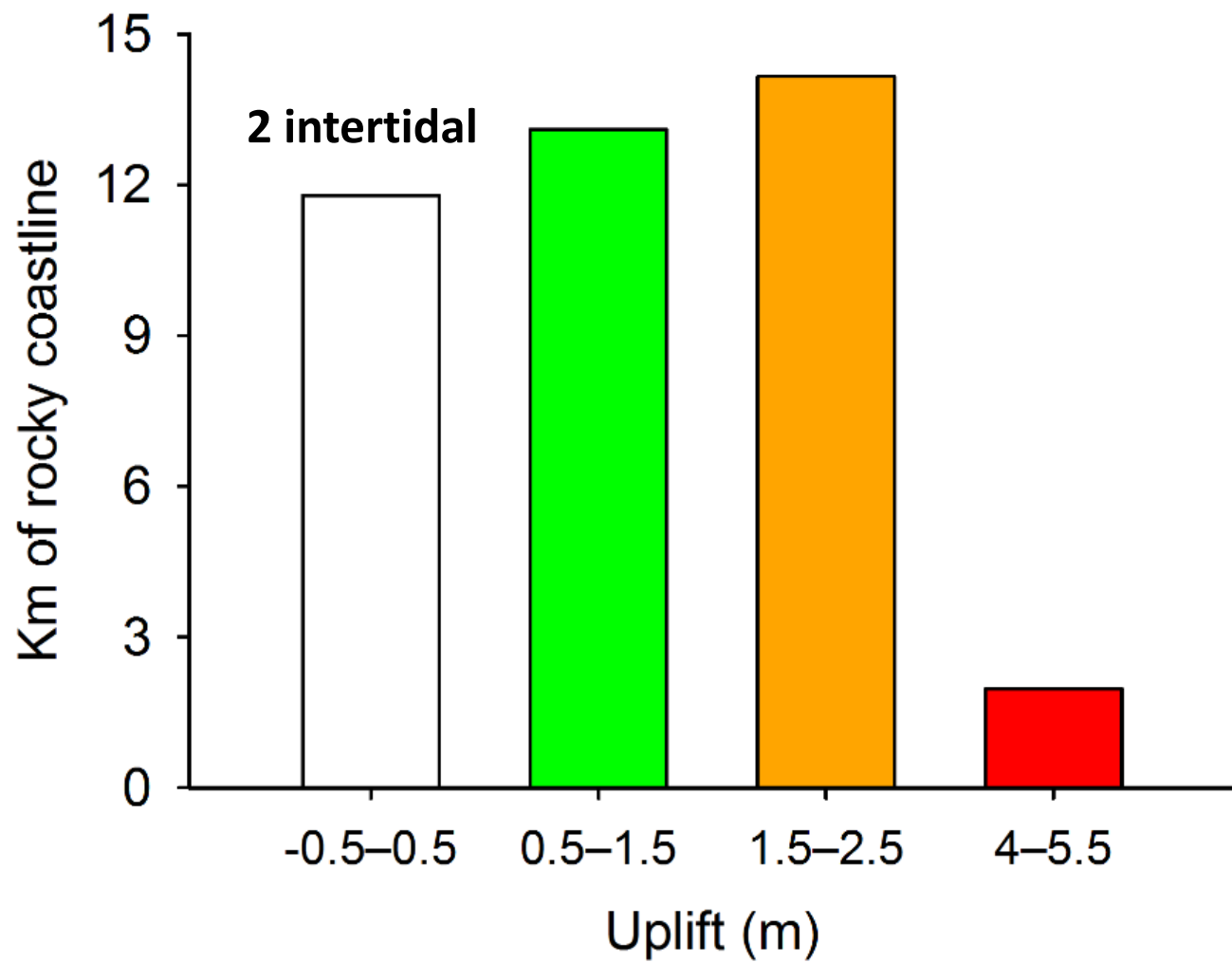
By Uplift

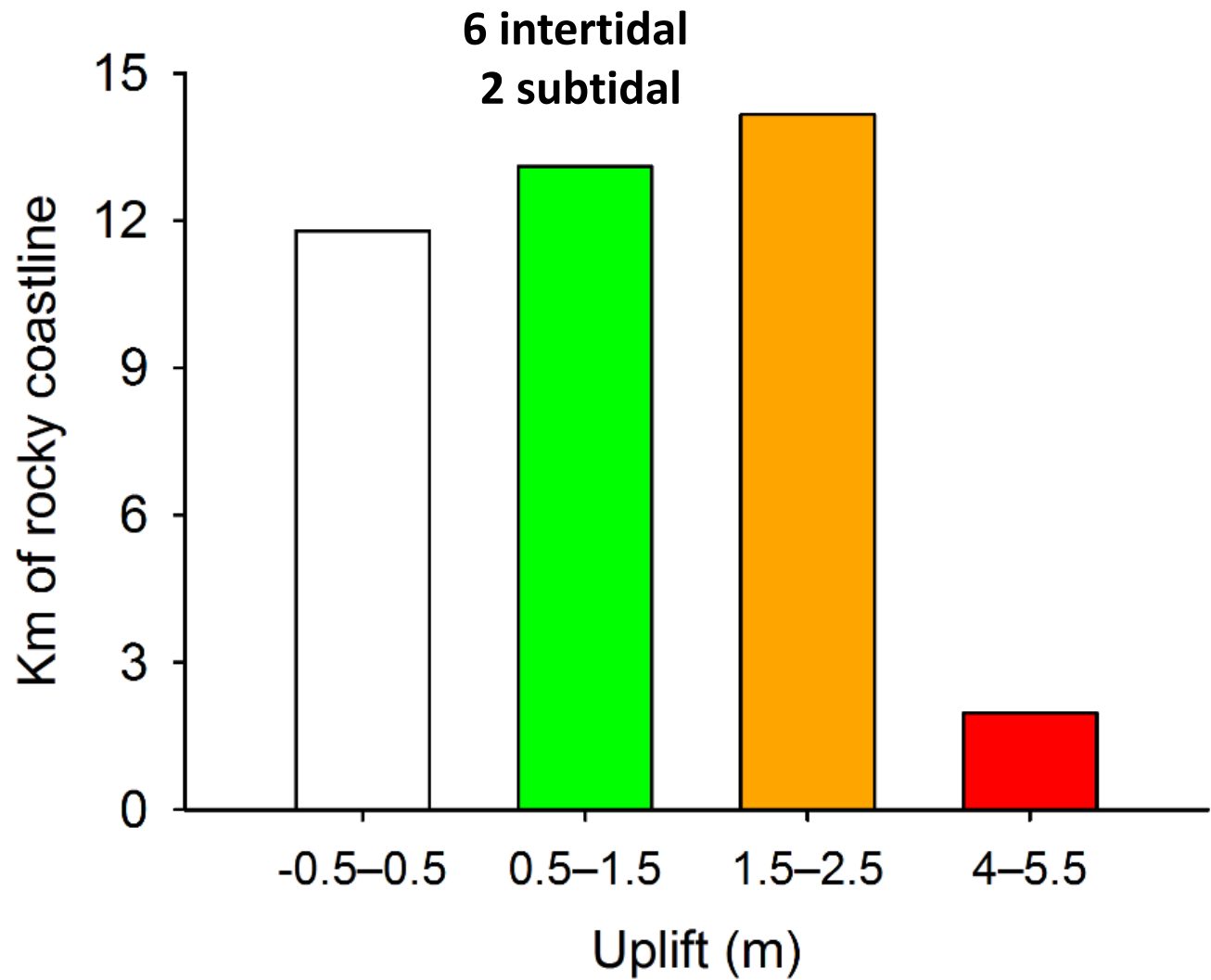
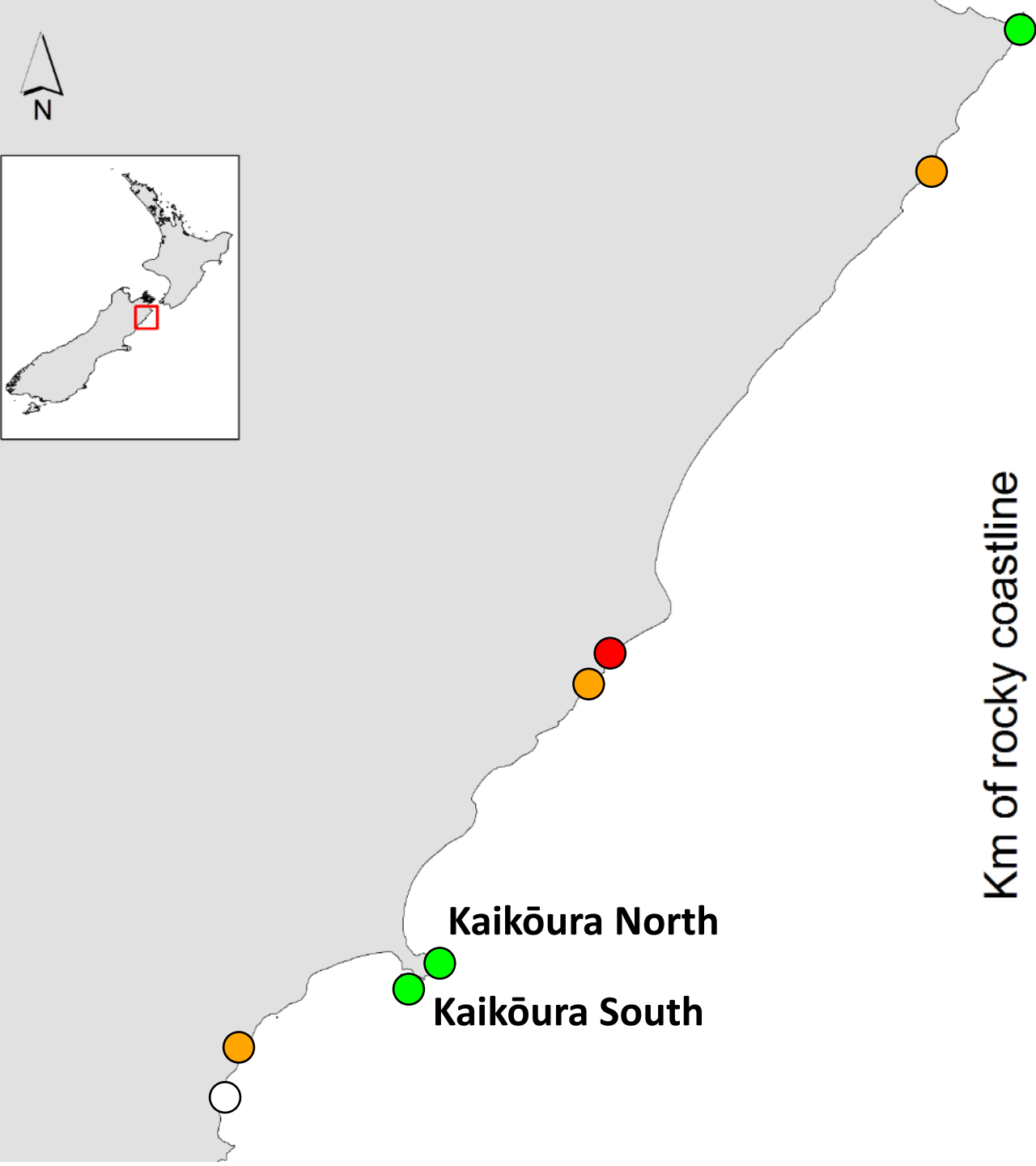
(from GNS and our calculations)

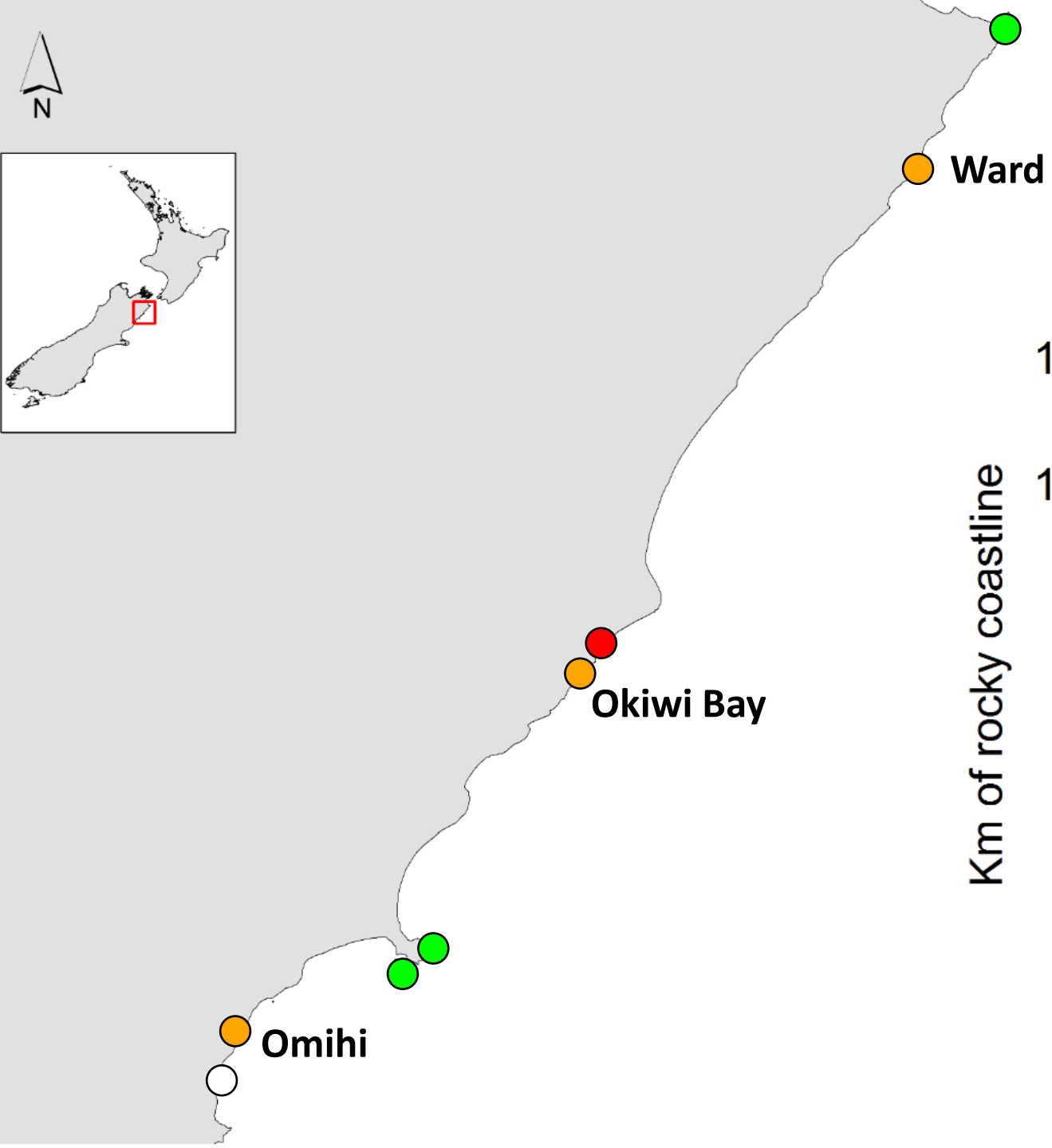




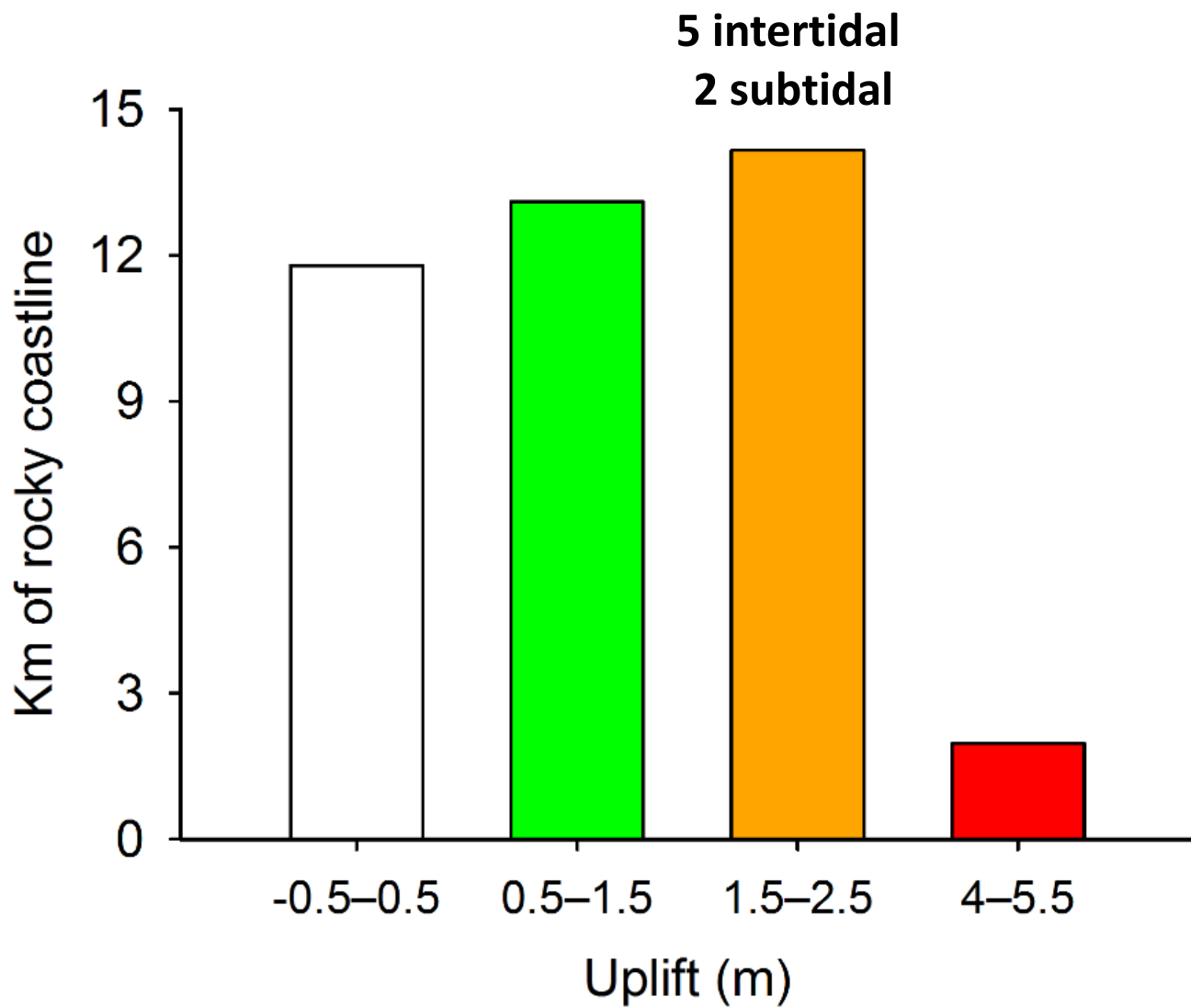
42 km of rocky reef habitat

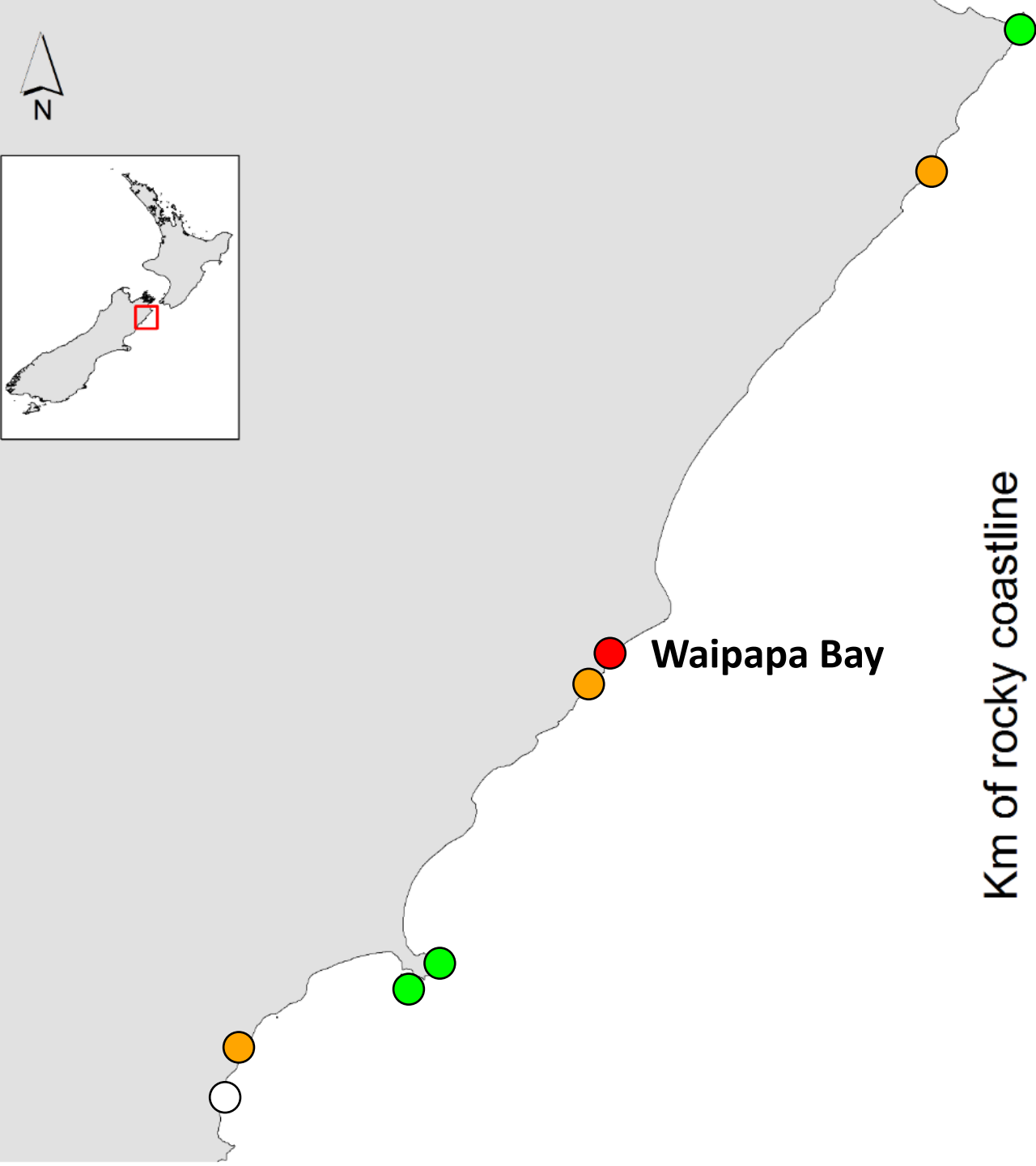




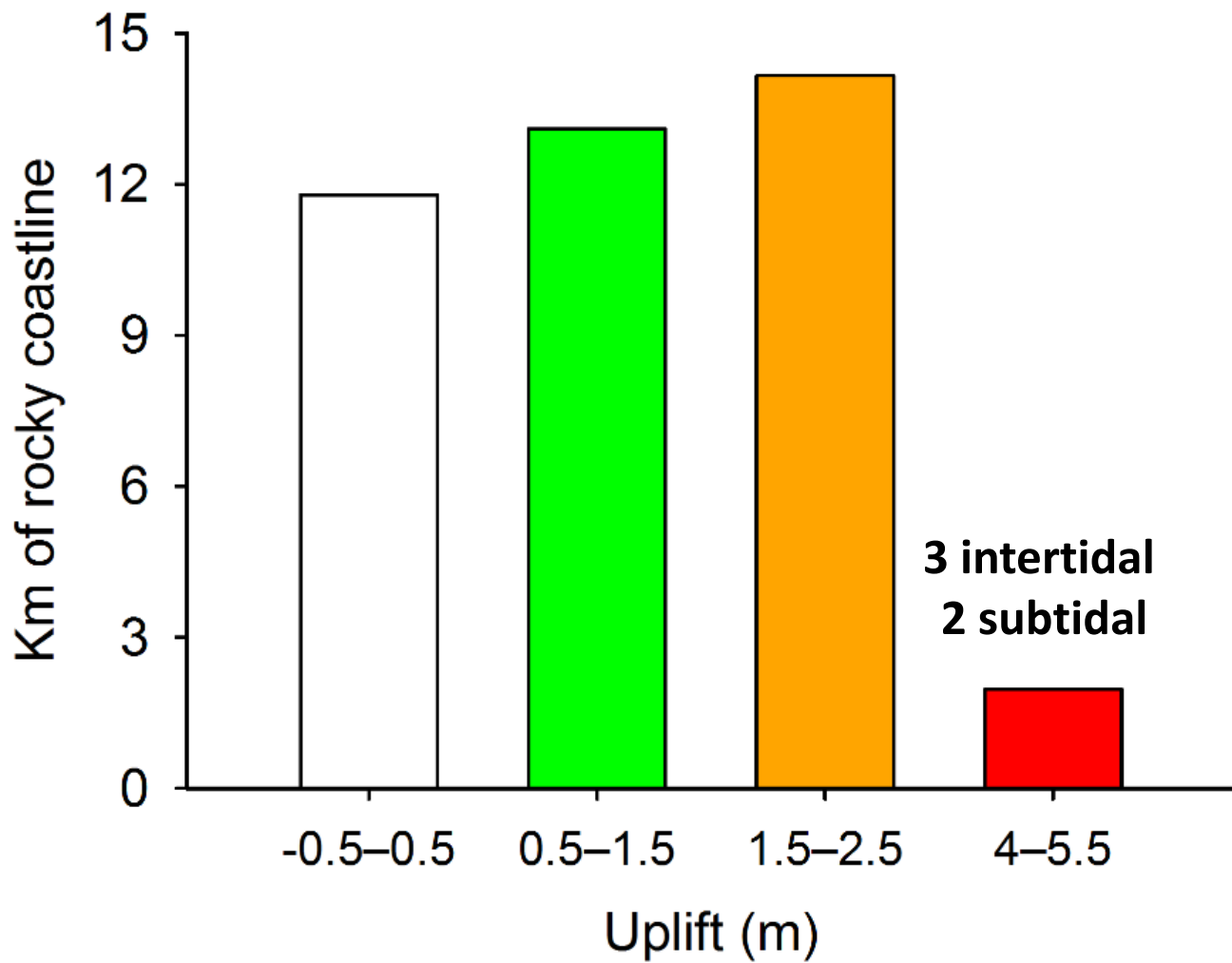


42 km of rocky reef habitat

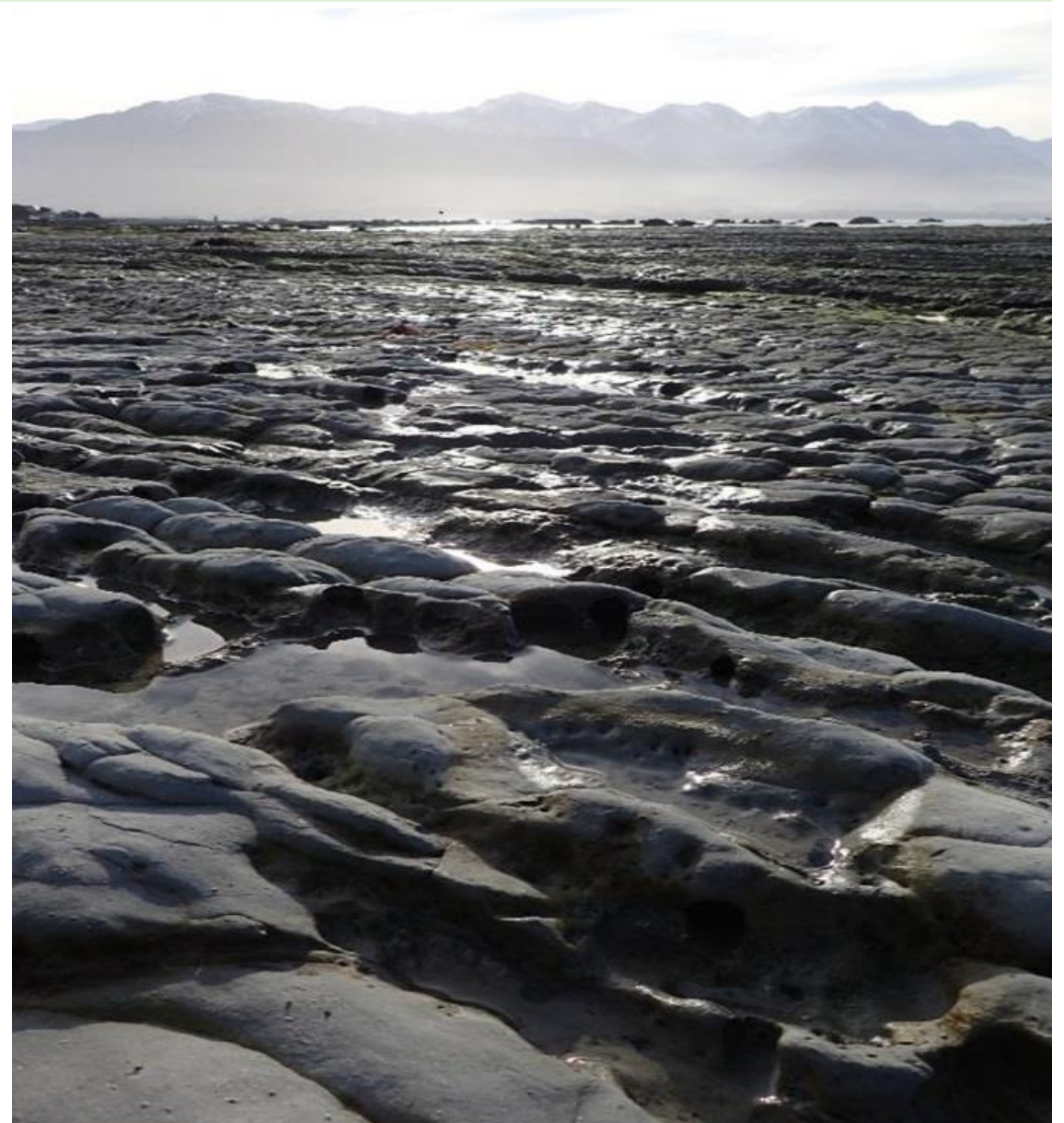




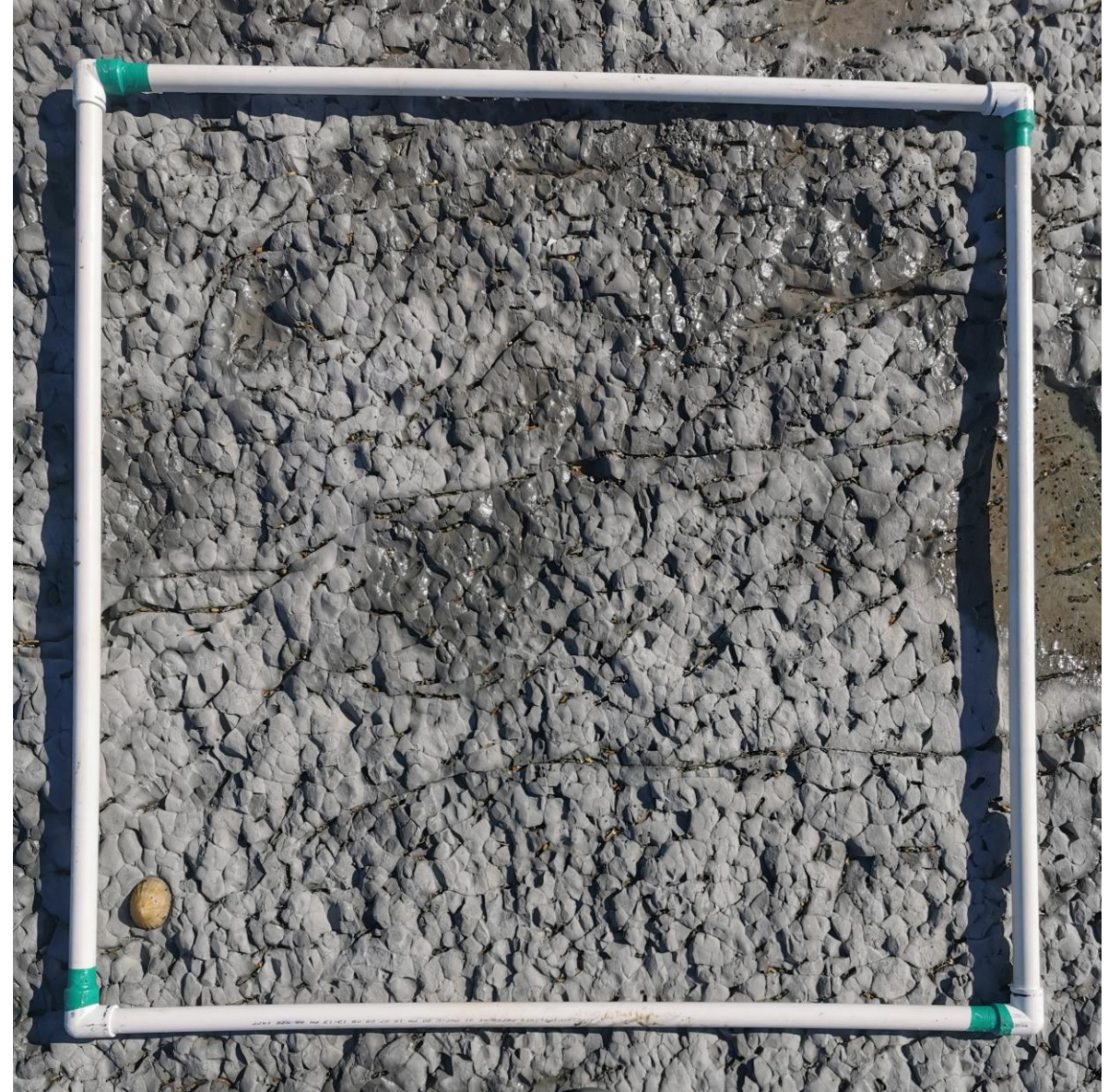
42 km of rocky reef habitat

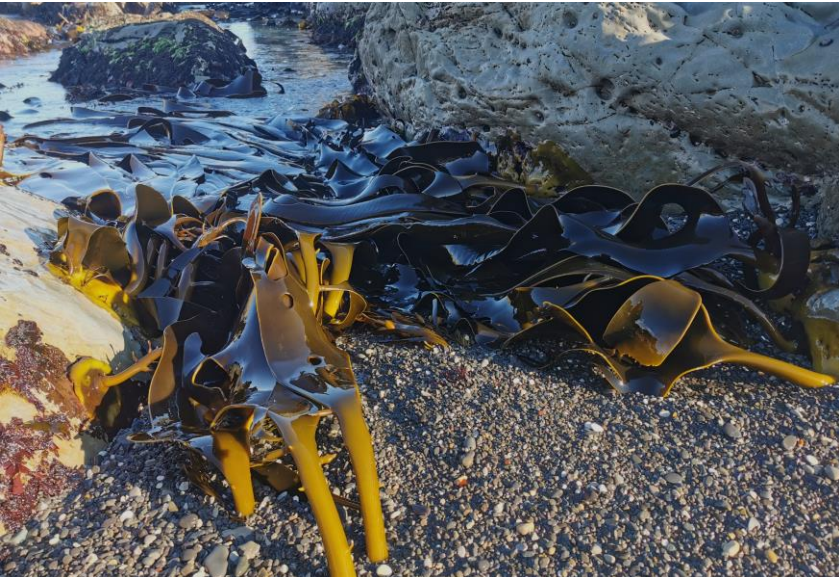


Uplifted reefs are still largely unvegetated
in the mid and high tidal zones



Uplifted reefs are still largely unvegetated
in the mid and high tidal zones





Diverse algal communities are confined to narrow low-shore areas,
BUT several key species are functionally extinct in some sites

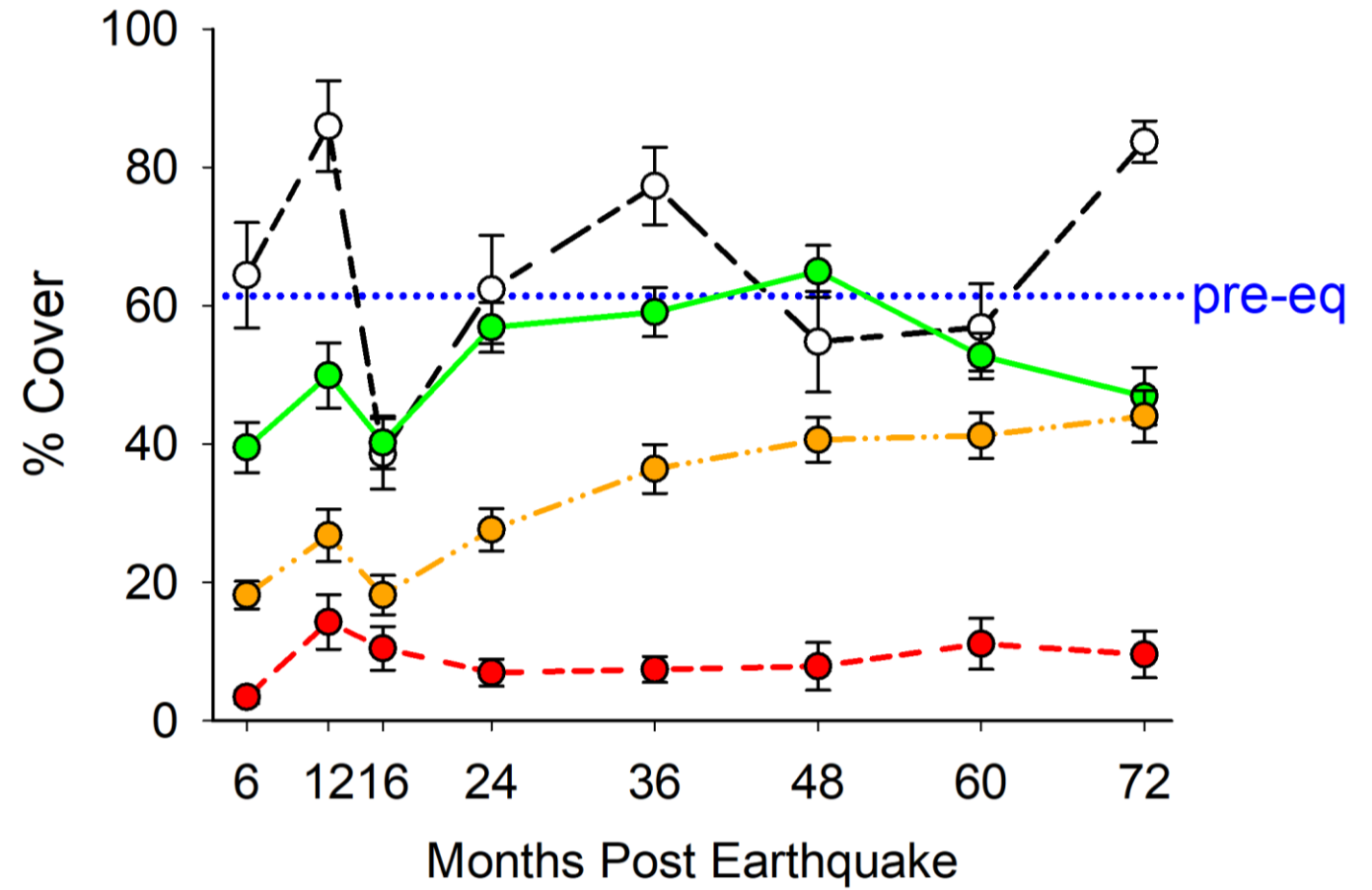
Methods

What's changing, what's recovering?

- Quantitative re-monitoring of 16 intertidal sites across 4 degrees of uplift
- 3 transects were established, one in each intertidal low-, mid-, and high-zone.
- All macroalgae, sessile and mobile invertebrates

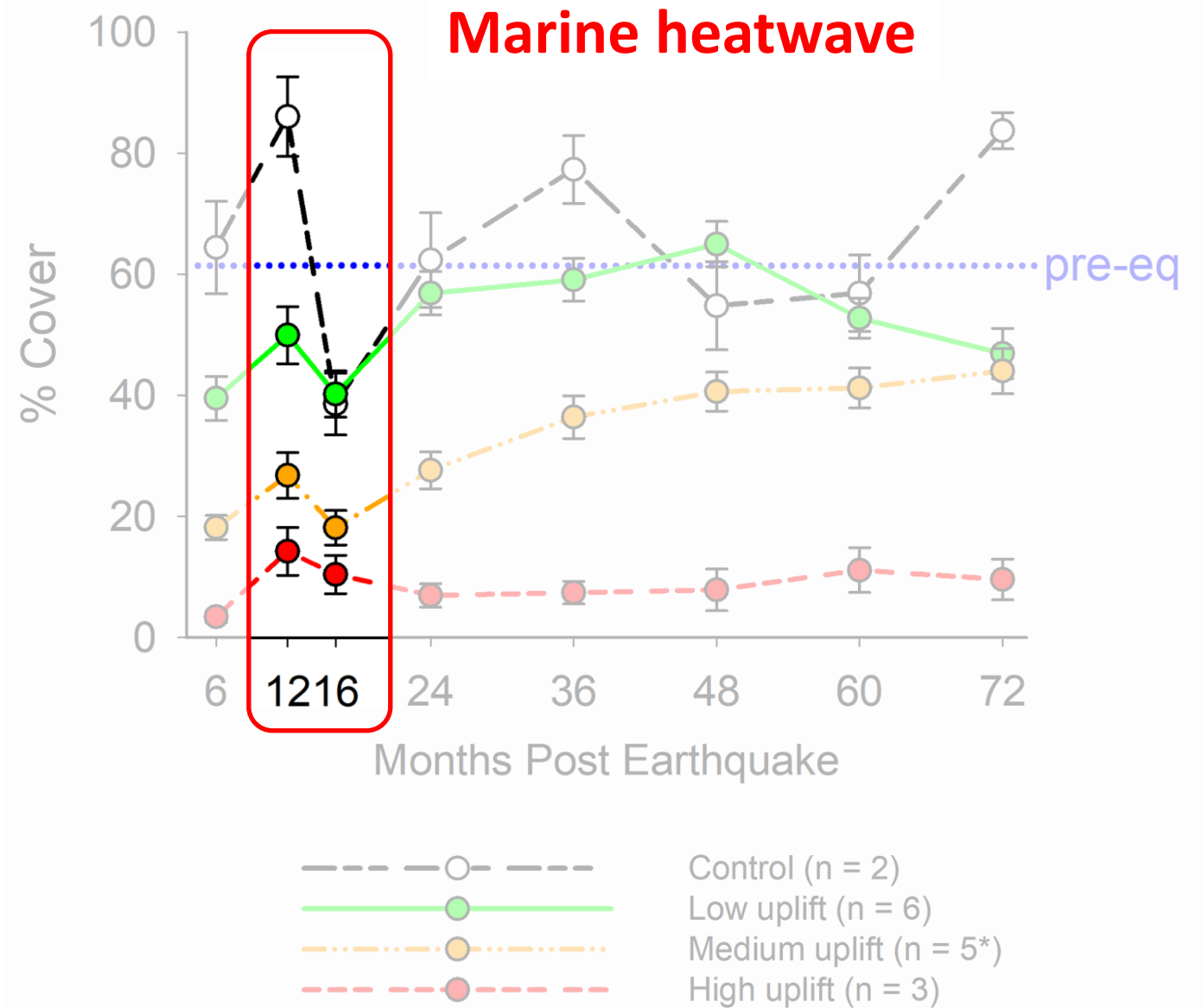


Large brown algae - low zone

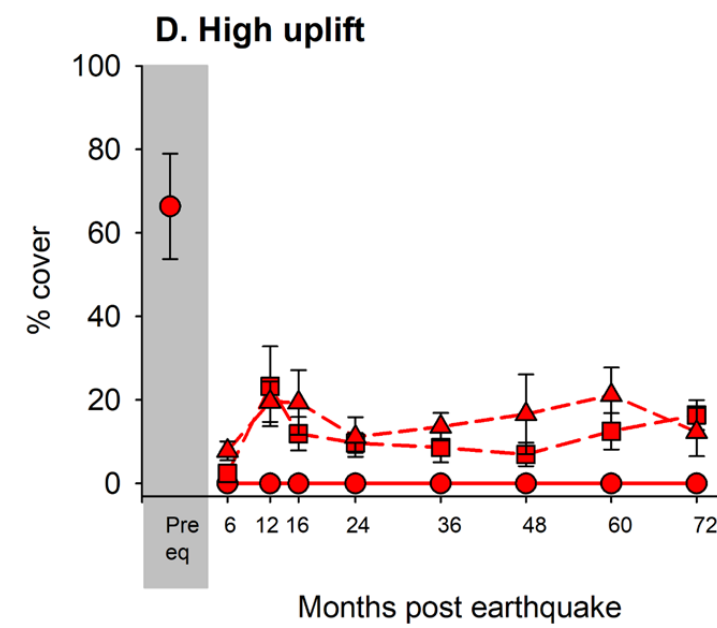
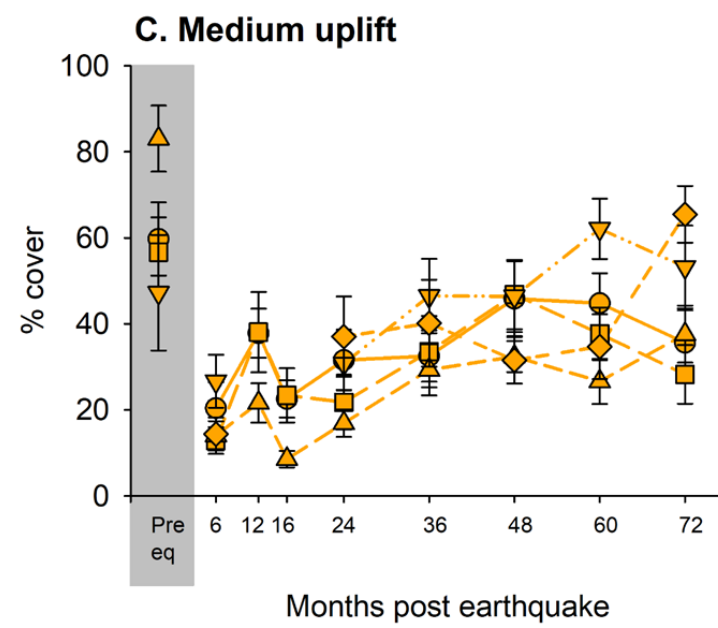
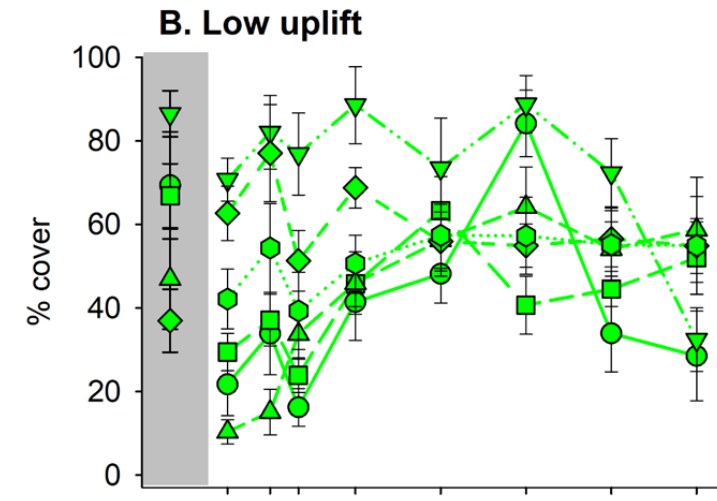
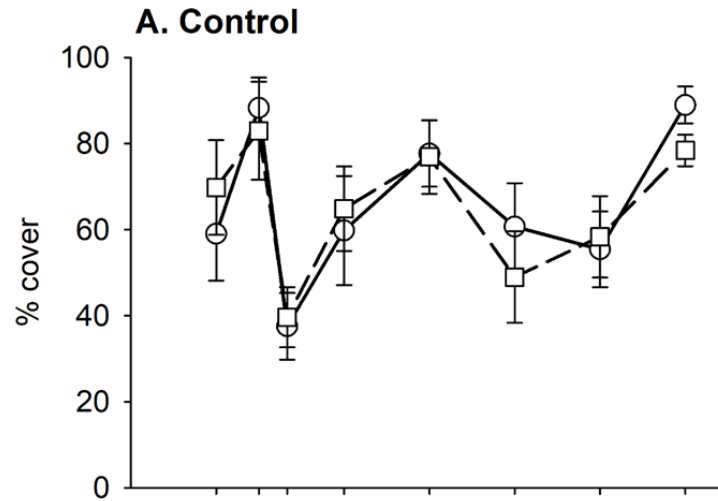


- Control (n = 2)
- Low uplift (n = 6)
- Medium uplift (n = 5*)
- High uplift (n = 3)

Large brown algae - low zone

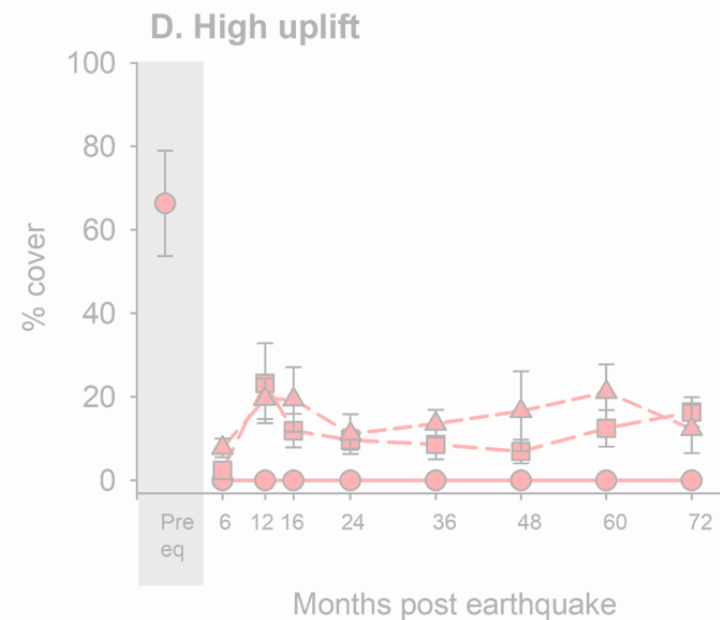
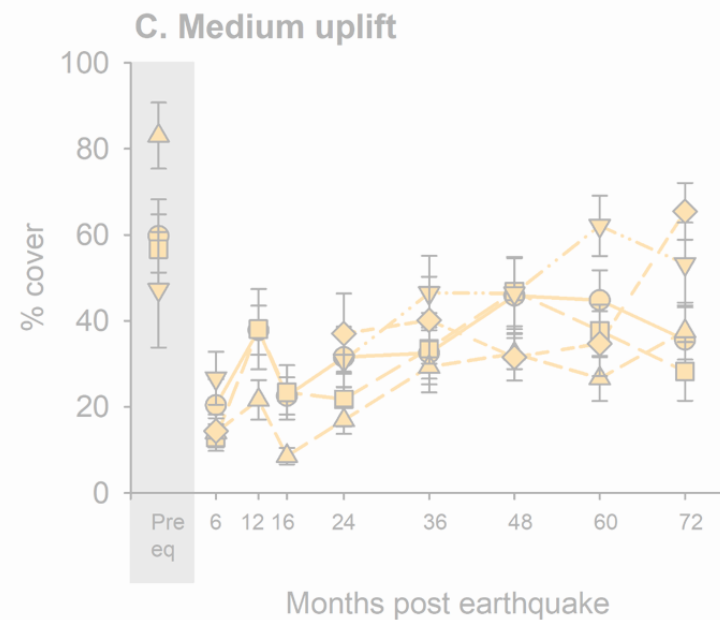
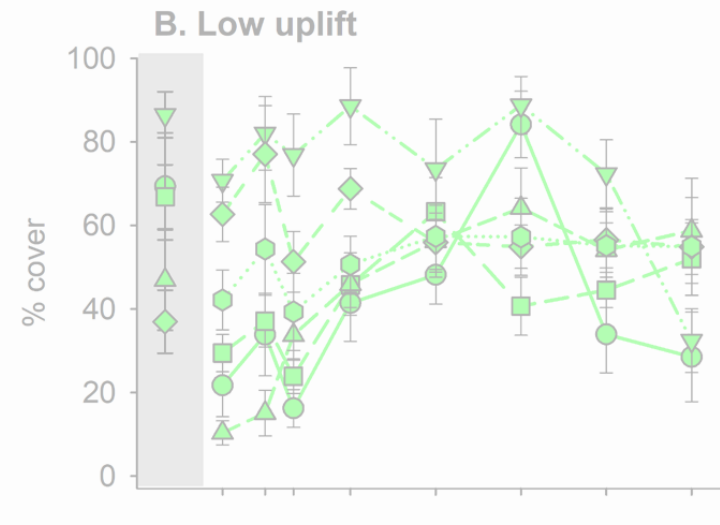
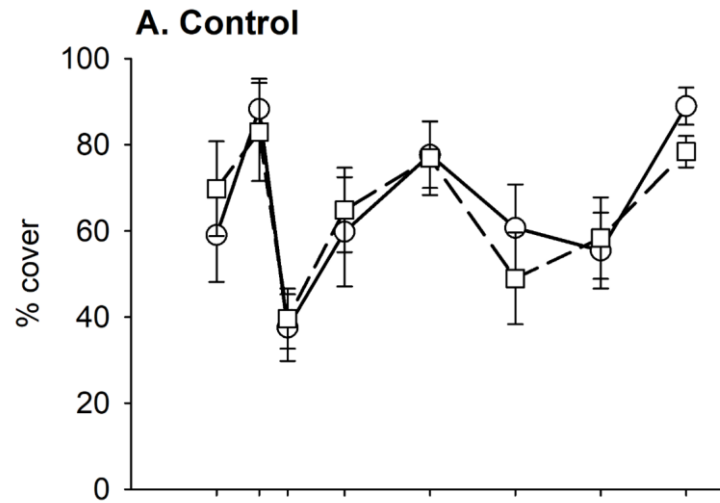


Large brown algae – by site



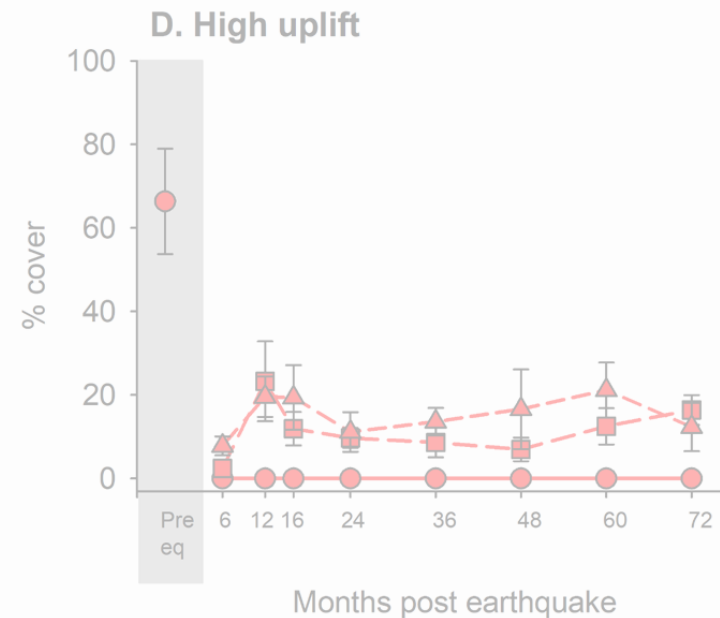
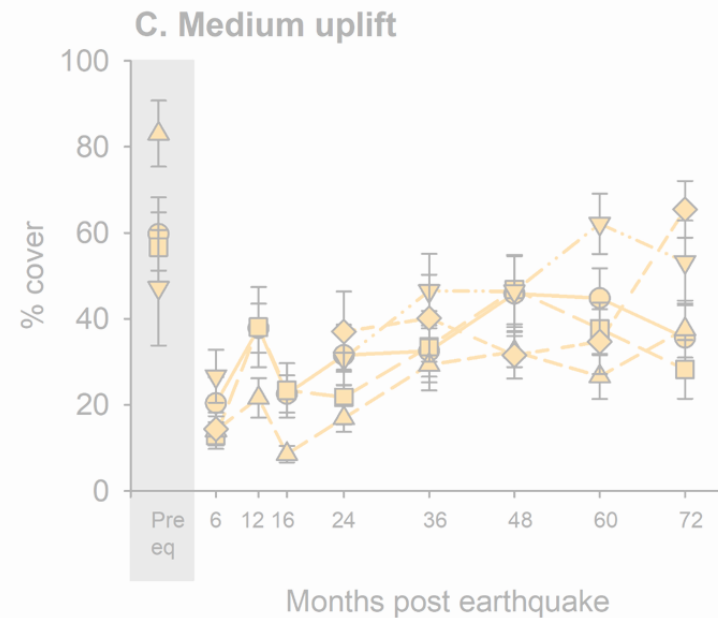
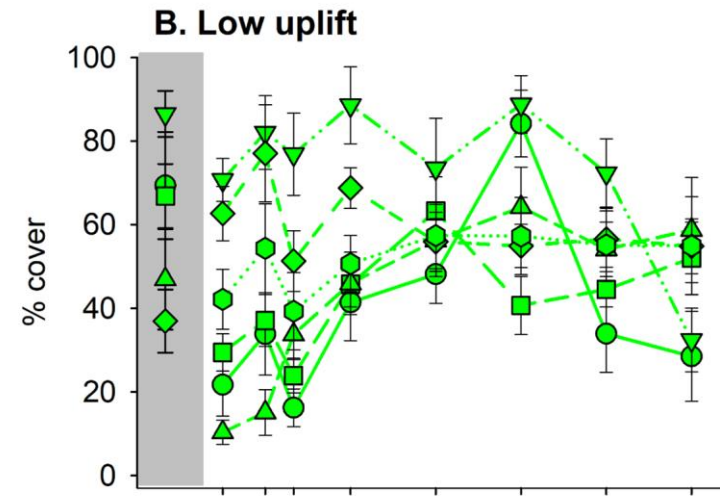
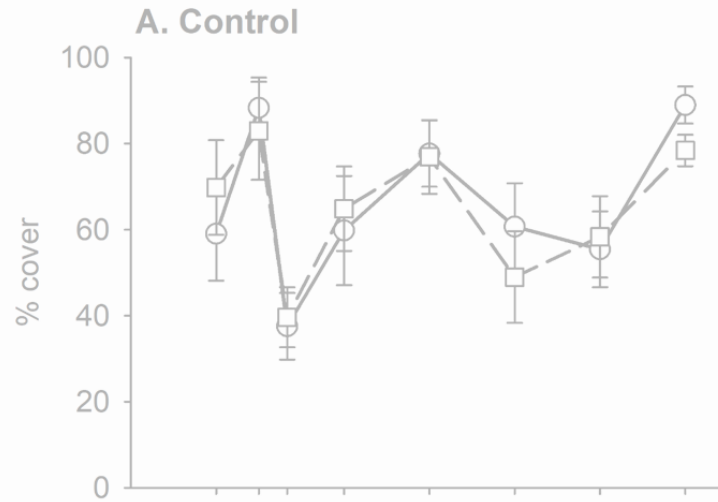
- Oaro 1
- Oaro 2
- Cape Campbell 1
- Cape Campbell 2
- ▲ Kaikoura North 1
- ▼ Kaikoura North 2
- ◆ Kaikoura South 1
- Kaikoura South 2
- Ward 1
- Ward 2
- ▲ Okiwi Bay
- ▼ Omihi 1
- ◆ Omihi 2
- Waipapa Bay 1
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- ▲ Waipapa Bay 3

Large brown algae – by site



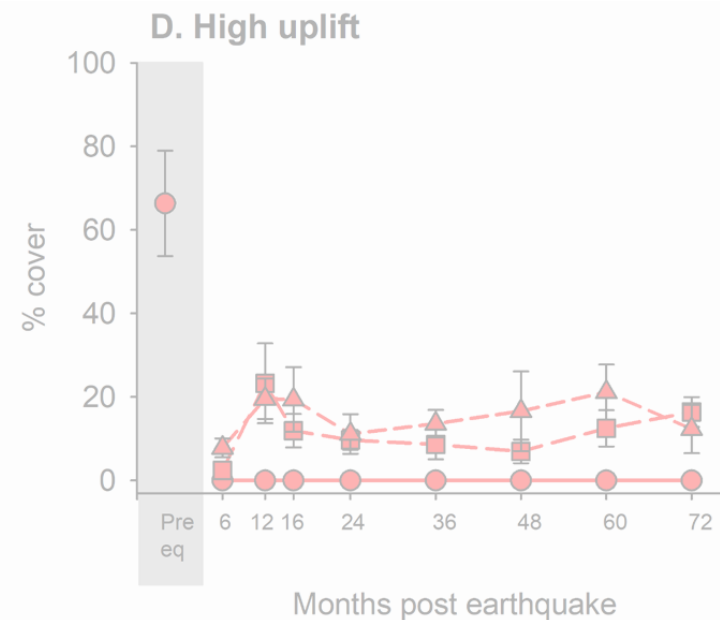
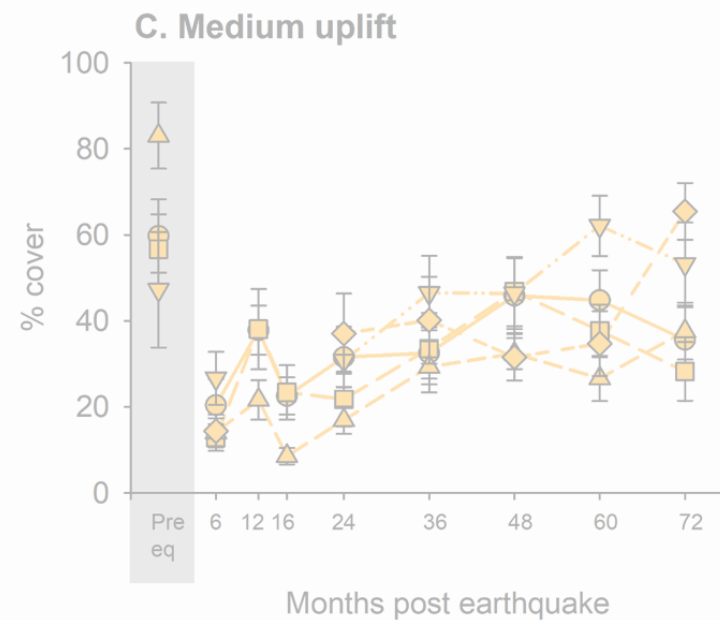
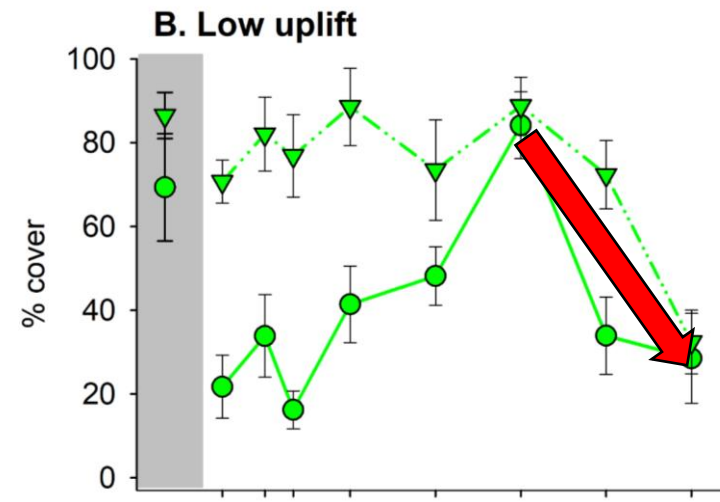
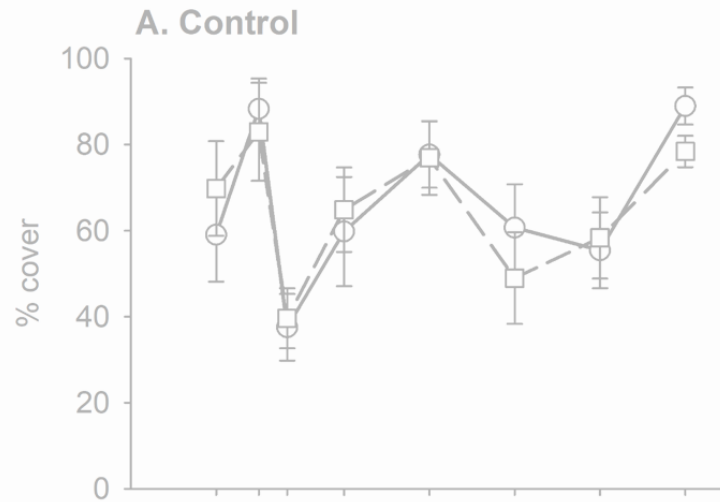
○ Oaro 1
□ Oaro 2

Large brown algae – by site



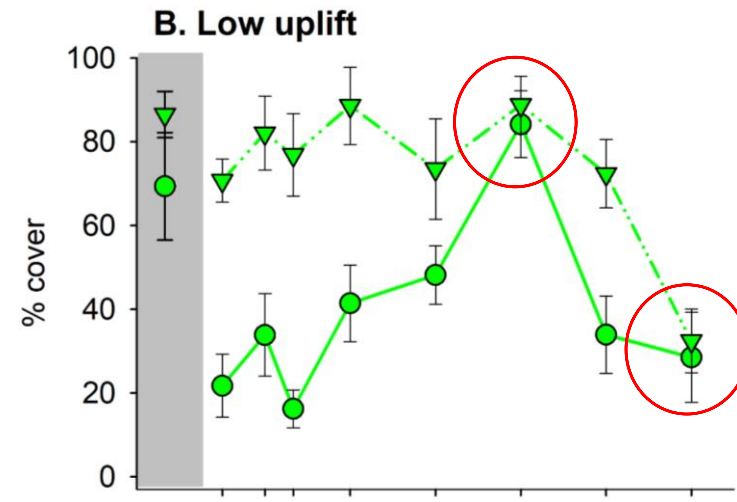
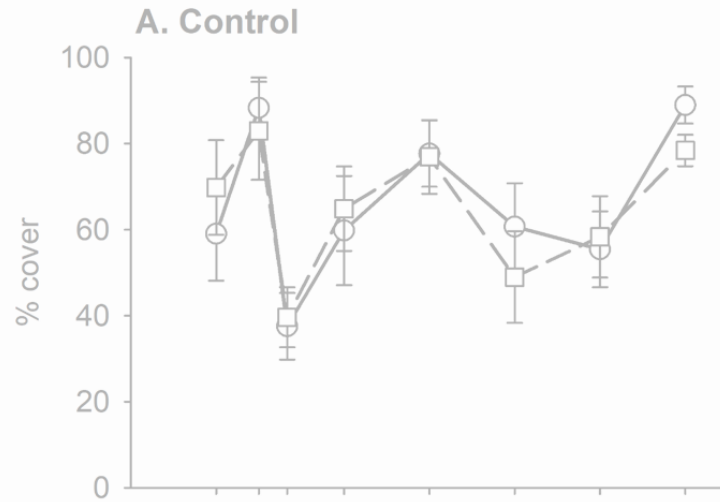
- Cape Campbell 1
- Cape Campbell 2
- ▲ Kaikoura North 1
- ▼ Kaikoura North 2
- ◆ Kaikoura South 1
- Kaikoura South 2

Large brown algae – by site



- Cape Campbell 1
- ▼ Kaikoura North 2

Large brown algae – by site



48 months



72 months



- Cape Campbell 1
- ▼ Kaikoura North 2



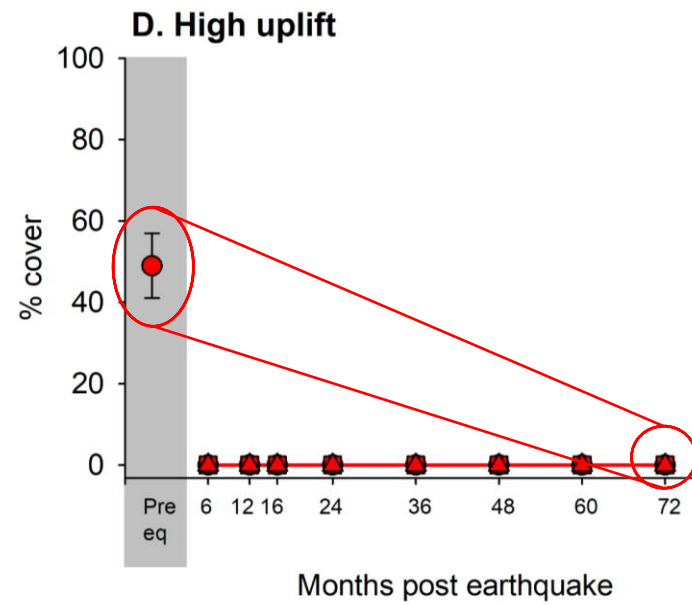
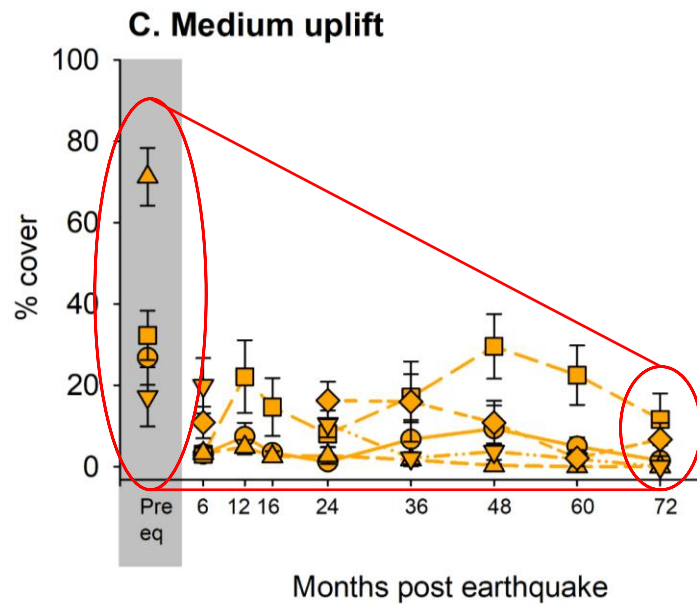
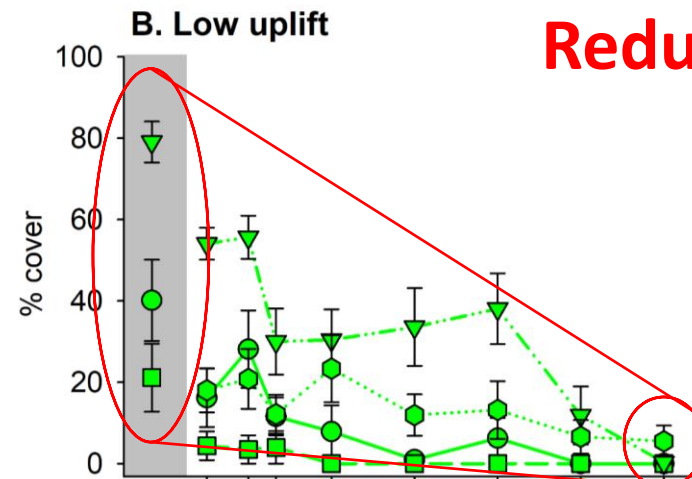
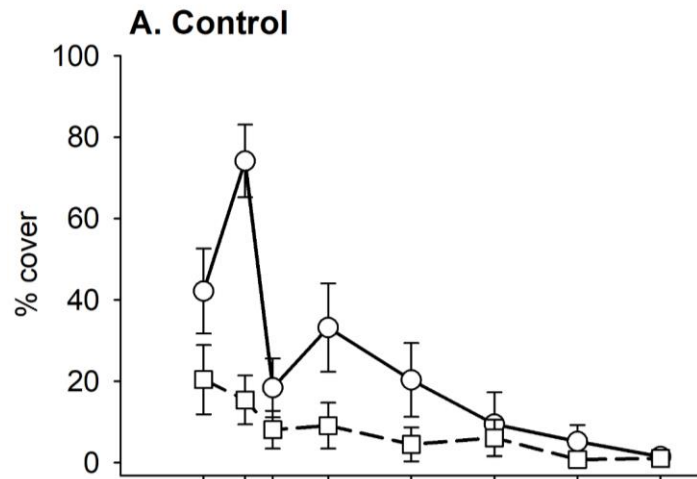
Bull kelp (*Durvillaea*)



Bull kelp (*Durvillaea*) - by site



Bull kelp (*Durvillaea*) - by site



- Oaro 1
- Oaro 2
- Cape Campbell 1
- Cape Campbell 2
- ▼ Kaikoura North 2
- Kaikoura South 2
- Ward 1
- Ward 2
- ▲ Okiwi Bay
- ▼ Omihi 1
- ◆ Omihi 2
- Waipapa Bay 1
- Waipapa Bay 2
- ▲ Waipapa Bay 3

Other large brown algae

Carpophyllum maschalocarpum

Cystophora scalaris

Cystophora retroflexa

Cystophora torulosa

Ecklonia radiata

Hormosira banksii

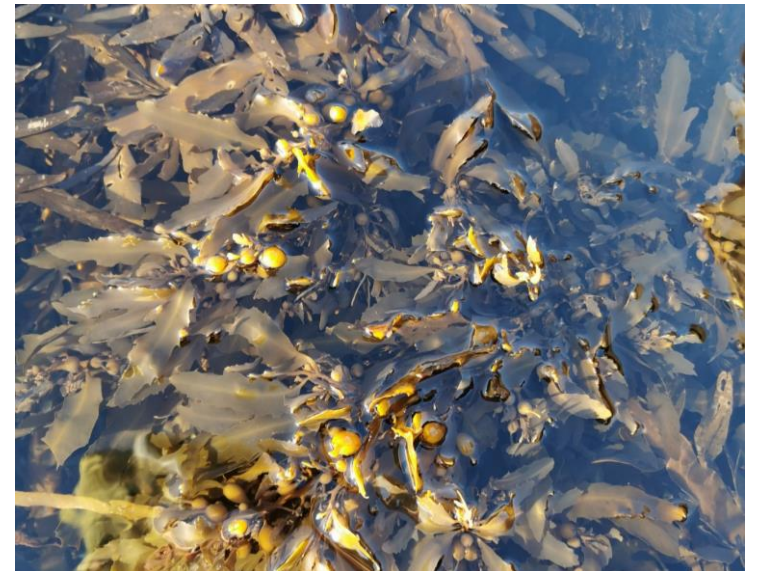
Landsburgia quercifolium

Lessonia variegata

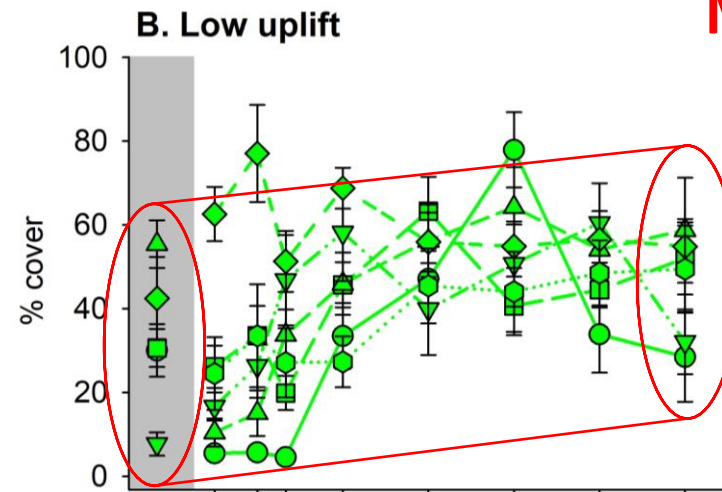
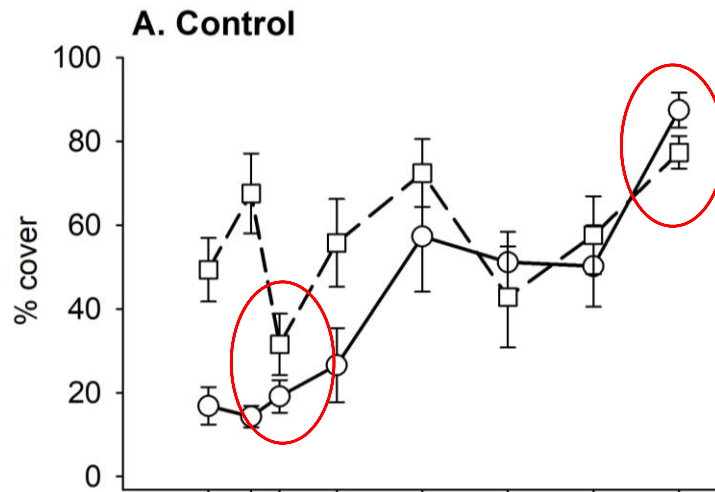
Macrocystis pyrifera

Marginariella boryana

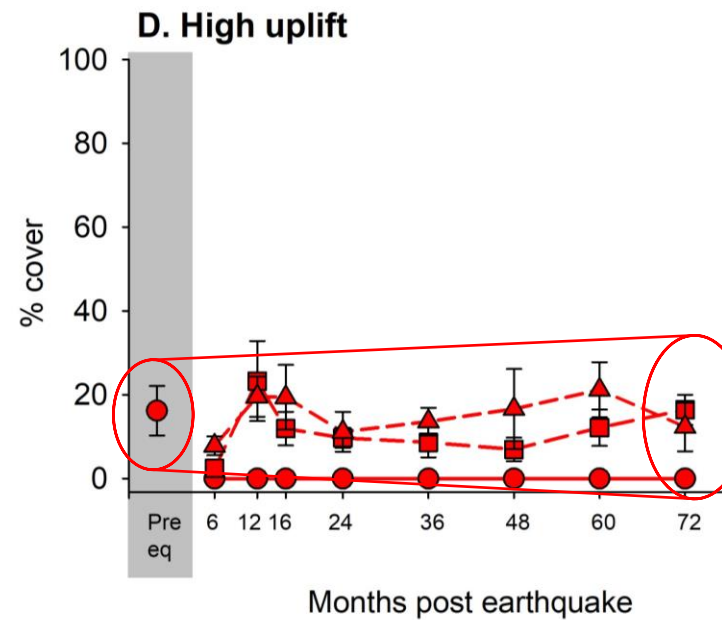
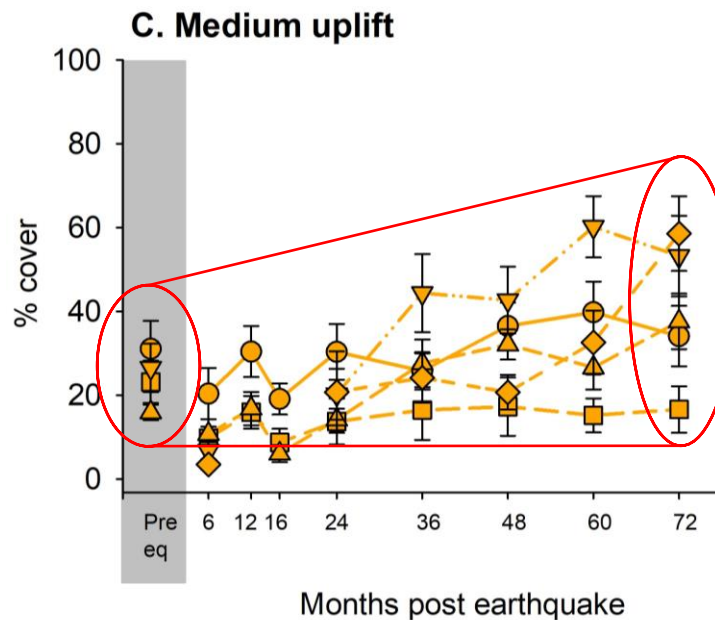
Sargassum sinclairii



Other large brown algae – by site

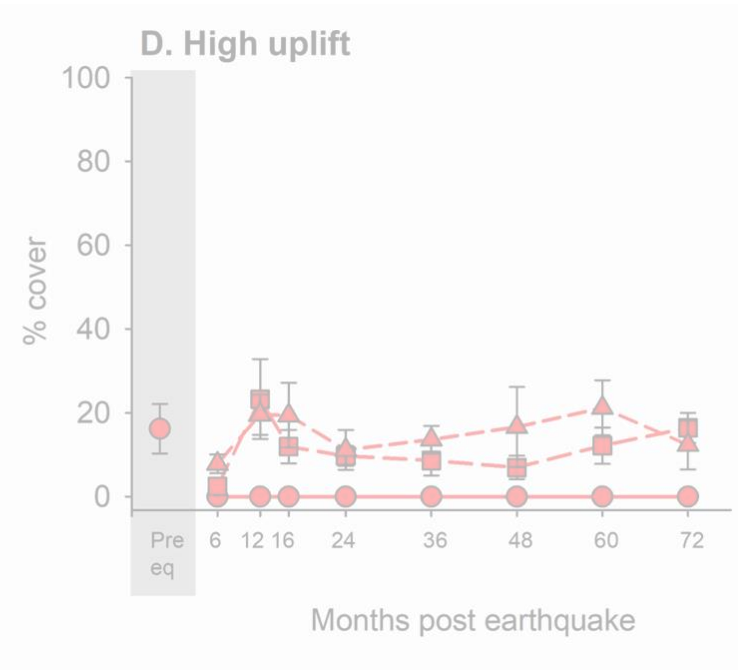
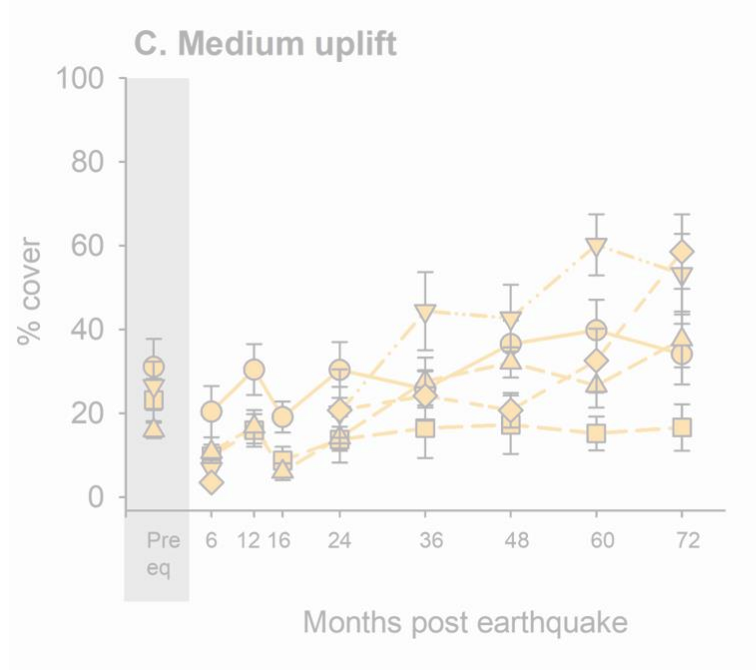
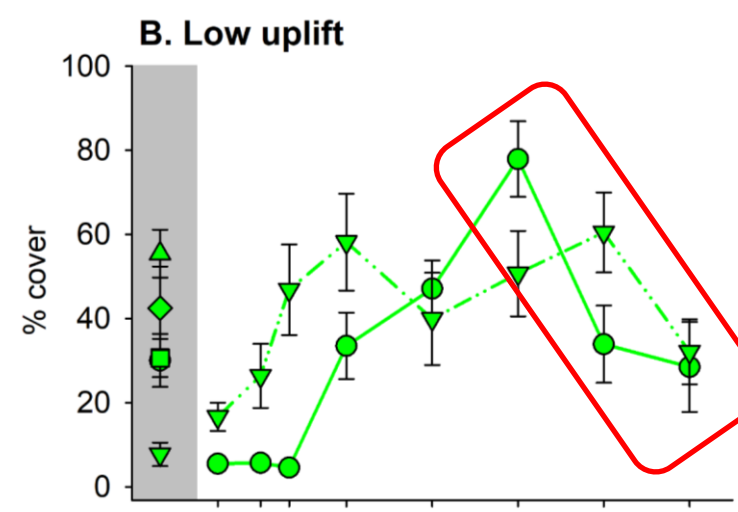
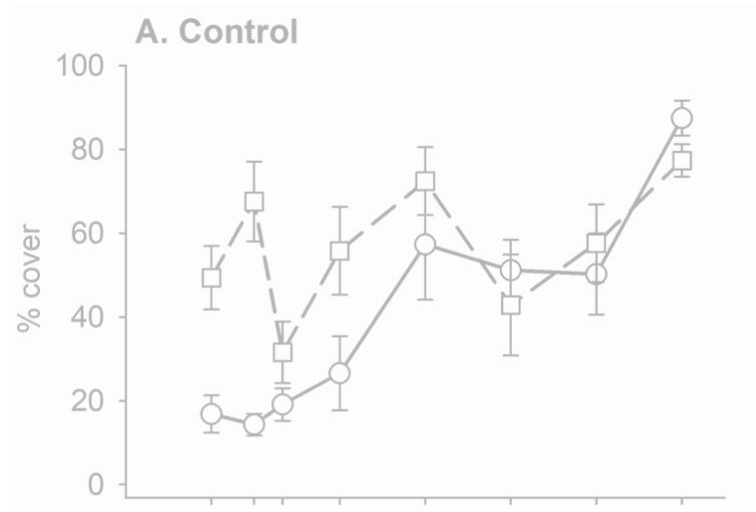


Mostly Increased abundance



- Oaro 1
- Oaro 2
- Cape Campbell 1
- Cape Campbell 2
- ▲ Kaikoura North 1
- ▼ Kaikoura North 2
- ◆ Kaikoura South 1
- Kaikoura South 2
- Ward 1
- Ward 2
- ▲ Okiwi Bay
- ▼ Omihi 1
- ◆ Omihi 2
- Waipapa Bay 1
- Waipapa Bay 2
- ▲ Waipapa Bay 3

Other large brown algae – by site



- Cape Campbell 1
- ▼ Kaikoura North 2

Shift in large brown algae composition



From bull kelp

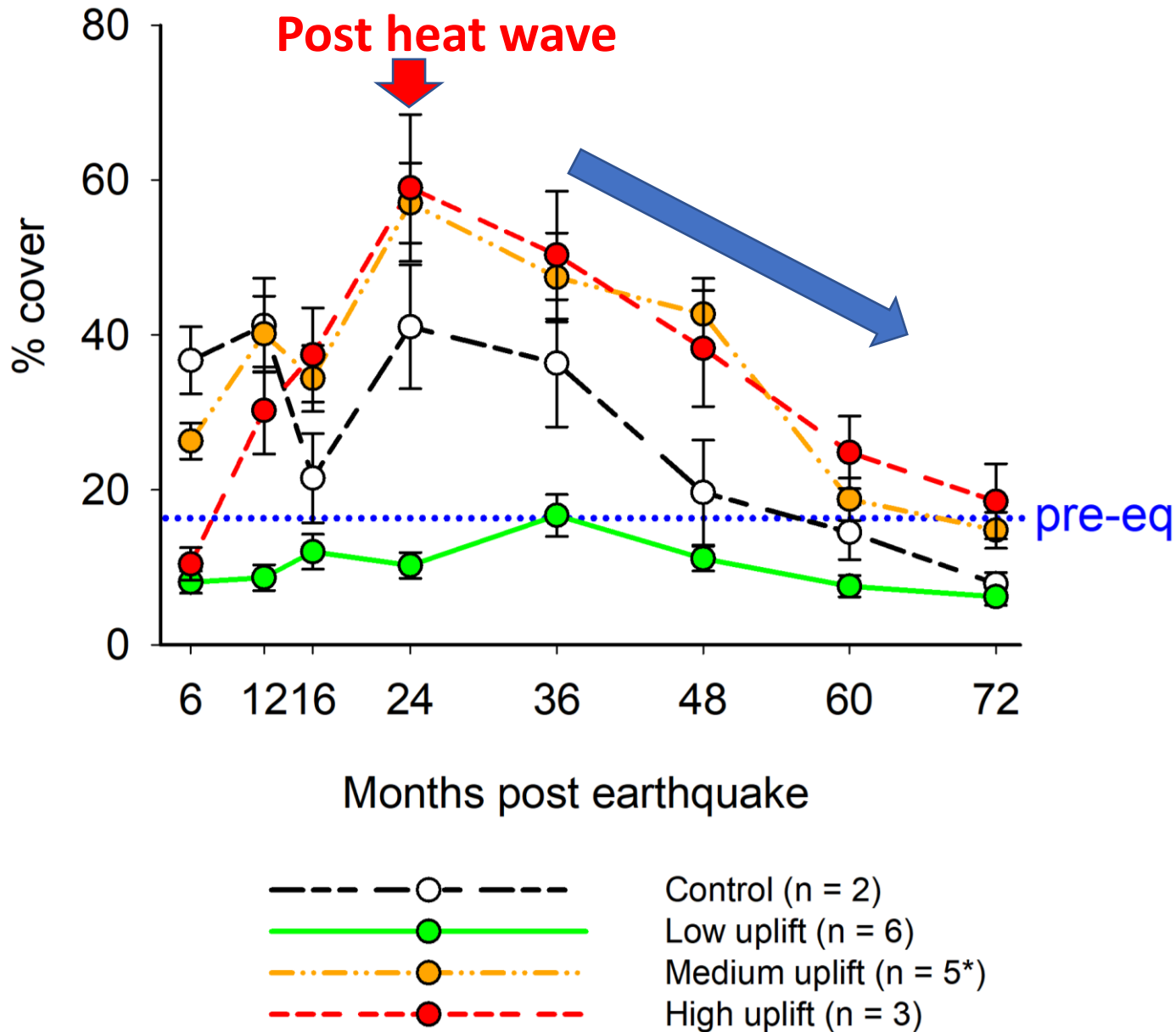


Other large brown algae

Red algae - low zone



Red algae - low zone





Conclusions



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- Uplifted reefs are still largely unvegetated



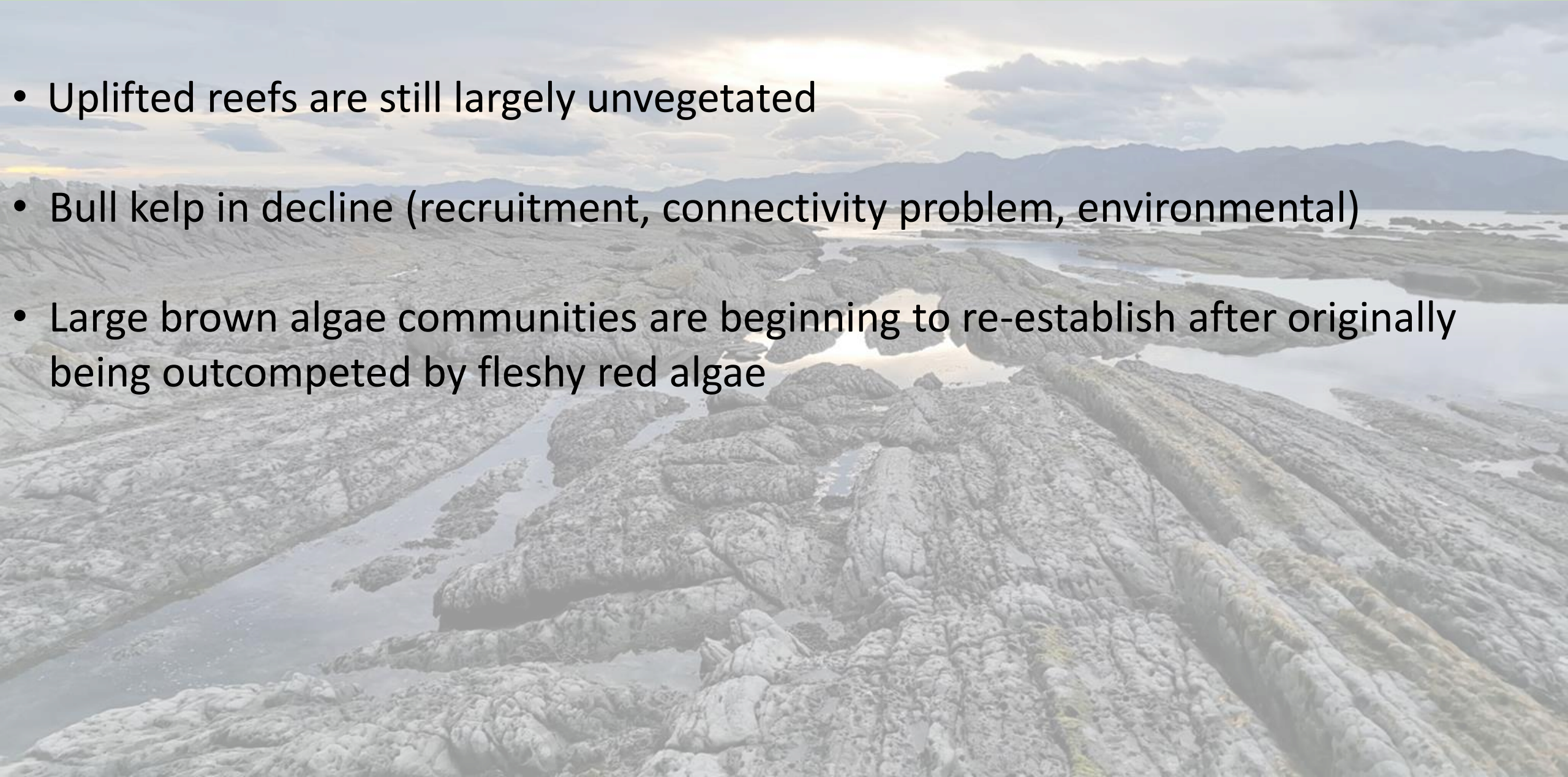
Conclusions

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- Dynamic environment with other stressors compounding the earthquake impact

Conclusions

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- Bull kelp in decline (recruitment, connectivity problem, environmental)
- Large brown algae communities are beginning to re-establish after originally being outcompeted by fleshy red algae
- Dynamic environment with other stressors compounding the earthquake impact
- Recovery trajectories are variable (taxa at some sites are stabilising while fluctuations occur at others)



References

- Falconer, T.R.L., Gerrity, S., Dunmore, R.A., Alestra, T., Crossett, D., Orchard, S. and Schiel, D.R. 2021. Rocky reef impacts of the 2016 Kaikōura earthquake: extended monitoring of nearshore habitats and communities to 4.5 years. New Zealand Aquatic Environment and Biodiversity Report, 47pp.
- Schiel, D.R., Gerrity, S., Orchard, S., Alestra, T., Dunmore, R., Falconer, T., Thomsen, M. and Tait, L.W. 2021. Cataclysmic disturbances to an intertidal ecosystem: loss of ecological infrastructure slows recovery of biogenic habitats and diversity. *Frontiers in Ecology and Evolution*, 9: 15pp.
- Falconer, T.R.L., Gerrity, S., Dunmore, R.A., Crossett, D., Orchard, S. and Schiel, D.R. 2022. Recovery of rocky intertidal and subtidal communities affected by the 2016 Kaikoura earthquake and coastal uplift disturbance. In Press



Methods

What's changing, what's recovering?

- Quantitative re-monitoring of 16 intertidal sites across 4 degrees of uplift



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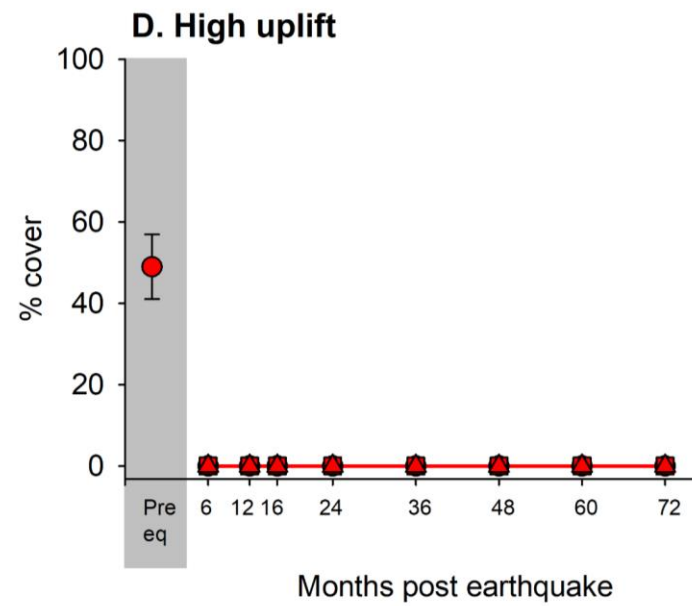
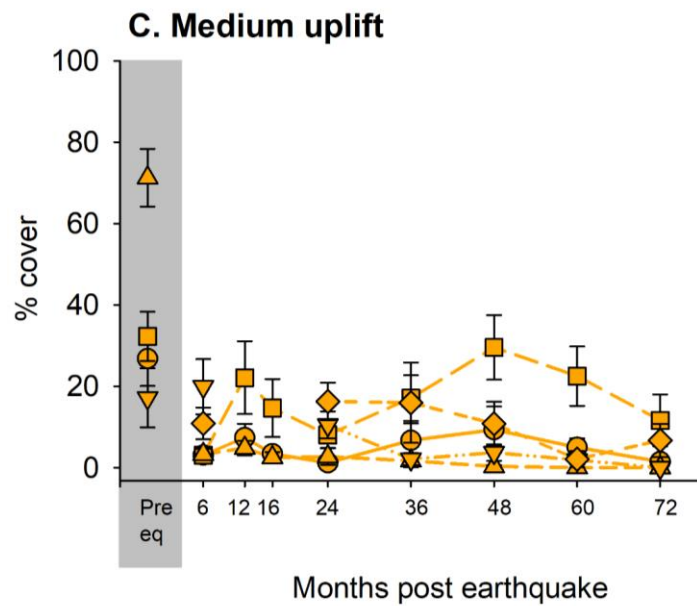
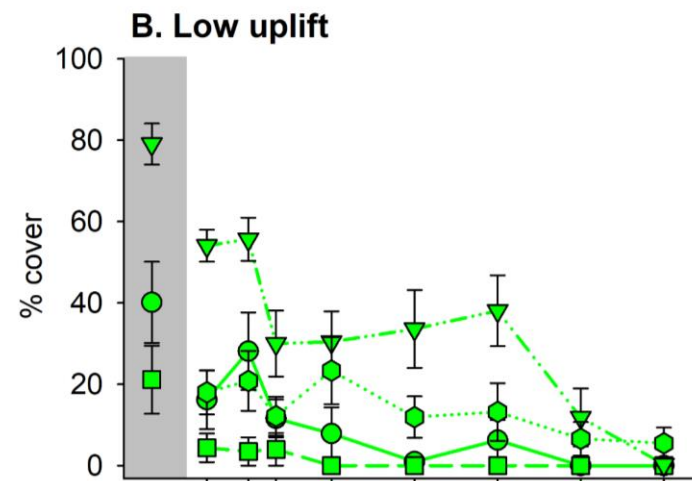
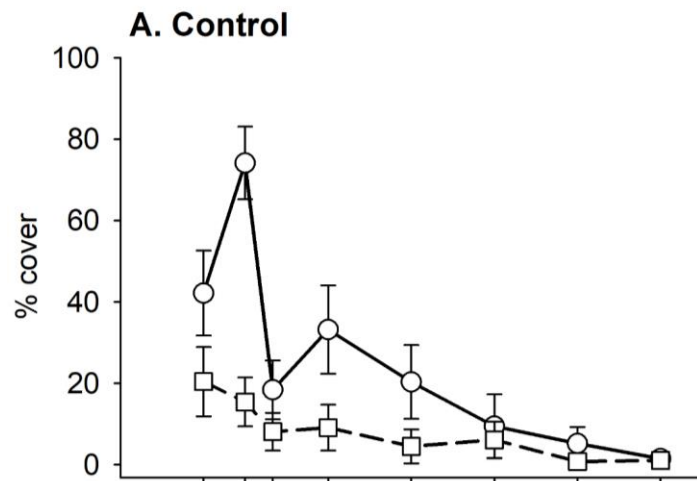


Bull kelp (*Durvillaea*)

- Dominant canopy-forming species
- Culturally significant (Taonga)
- Biogenic habitat
- Protective canopy during low tides

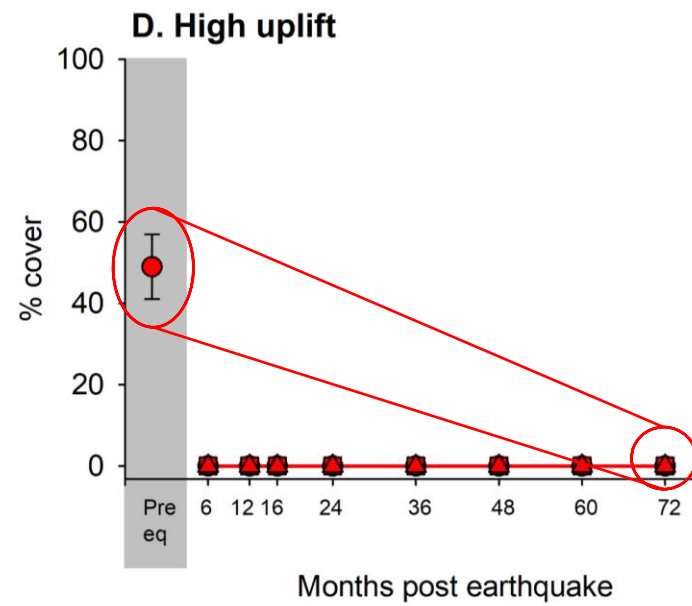
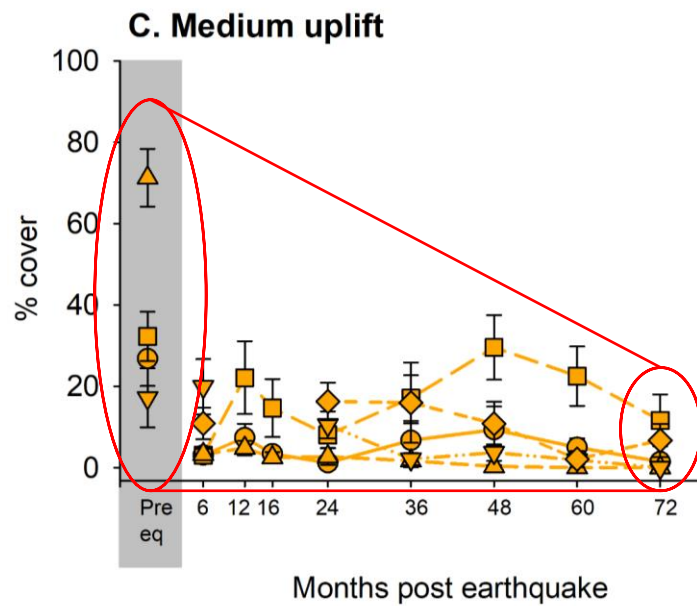
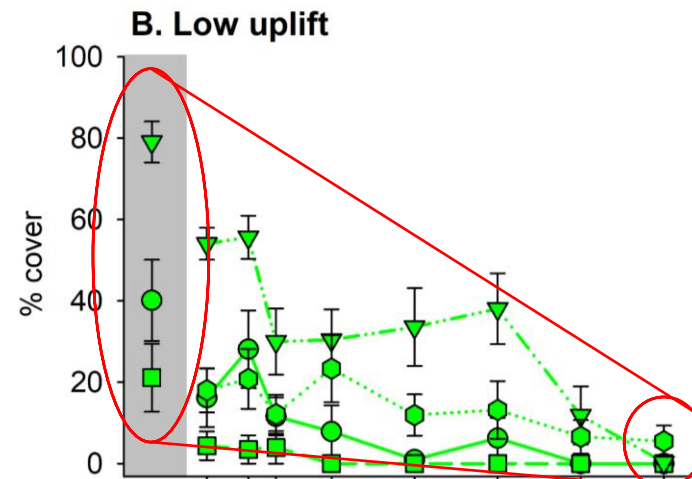
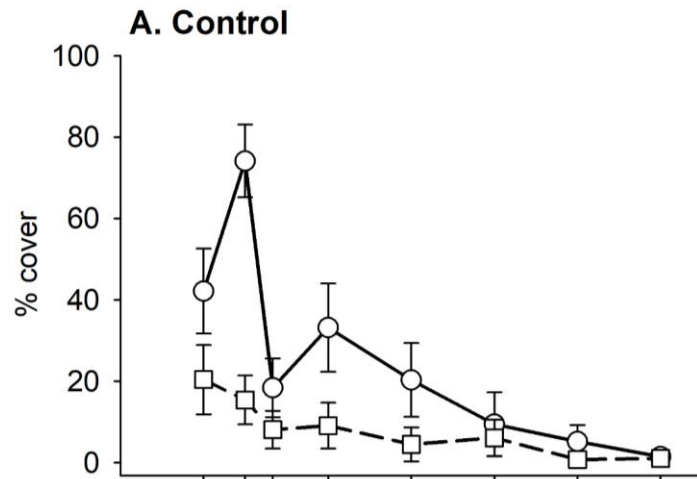


Bull kelp (*Durvillaea*) - by site



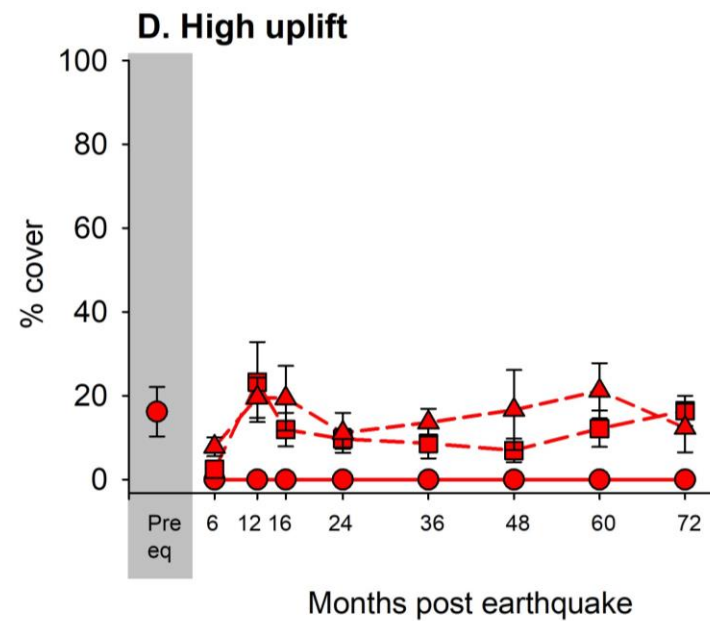
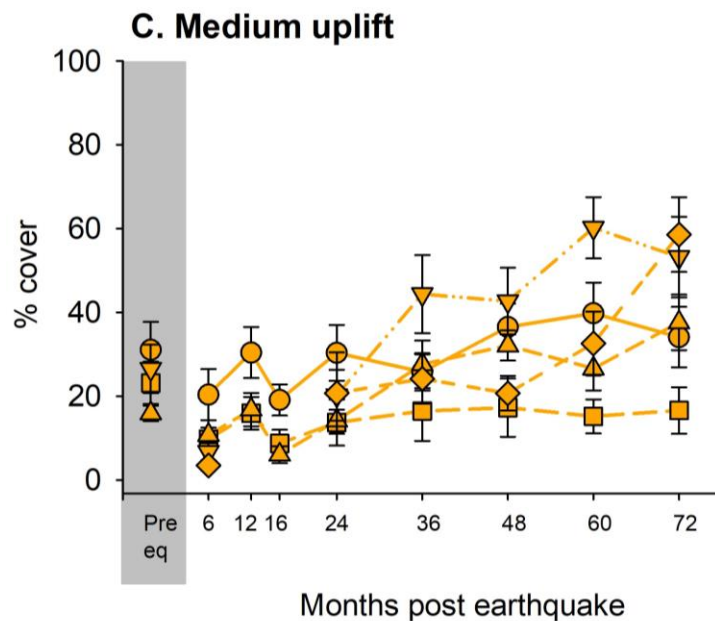
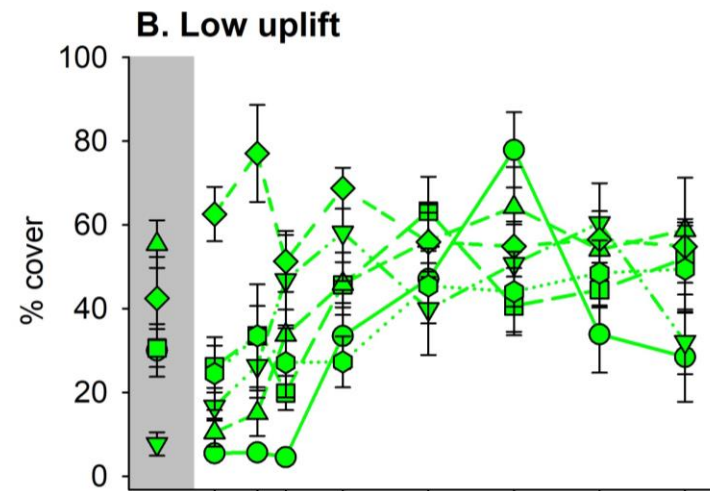
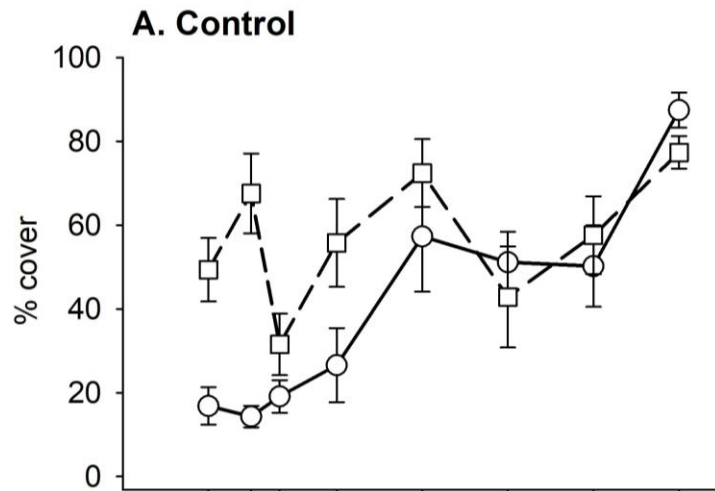
- Oaro 1
- Oaro 2
- Cape Campbell 1
- Cape Campbell 2
- ▼ Kaikoura North 2
- Kaikoura South 2
- Ward 1
- Ward 2
- ▲ Okiwi Bay
- ▼ Omihi 1
- ◆ Omihi 2
- Waipapa Bay 1
- Waipapa Bay 2
- ▲ Waipapa Bay 3

Bull kelp (*Durvillaea*) - by site



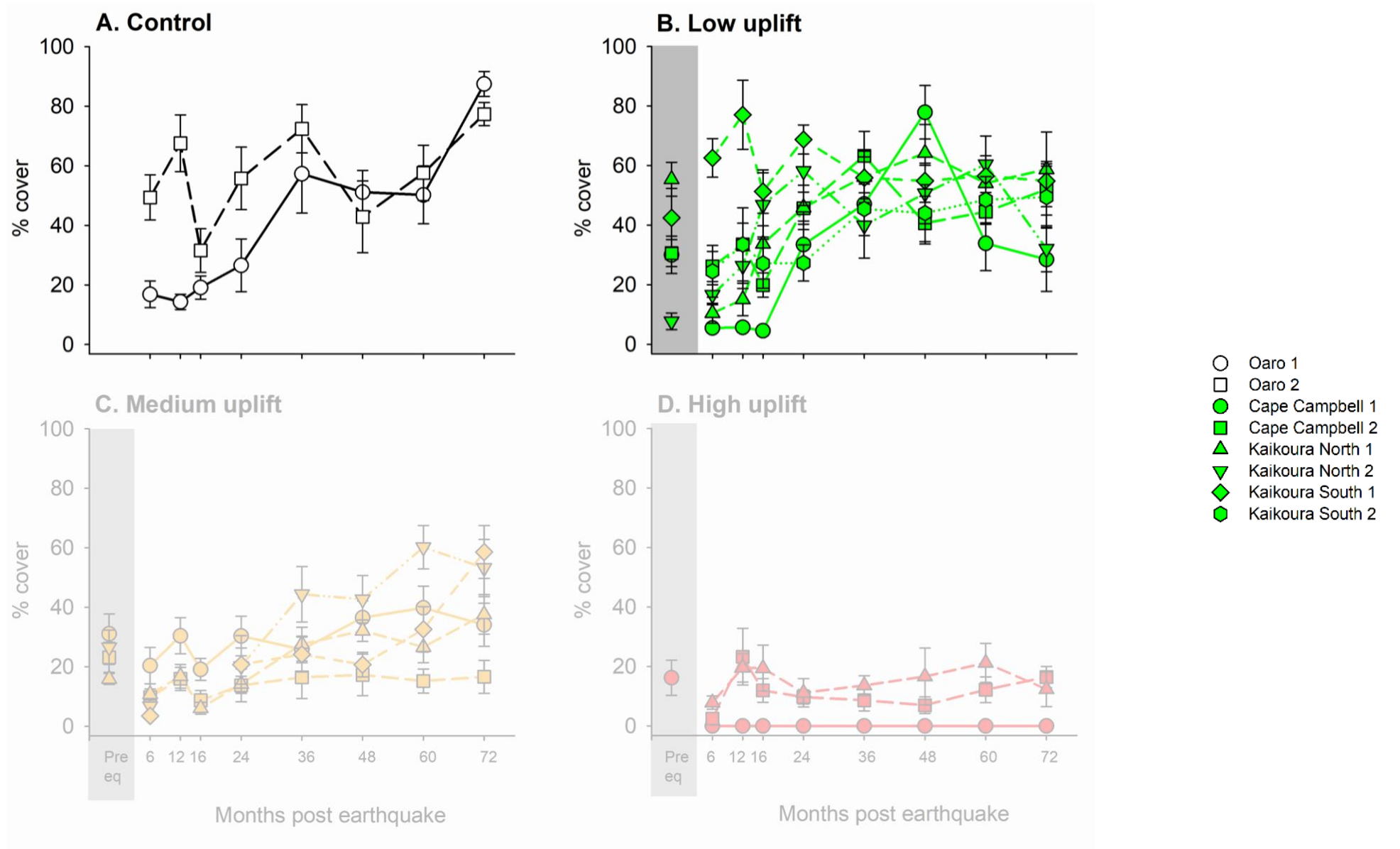
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- ▼ Omihi 1
- ◆ Omihi 2
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- Waipapa Bay 2
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Other large brown algae – by site

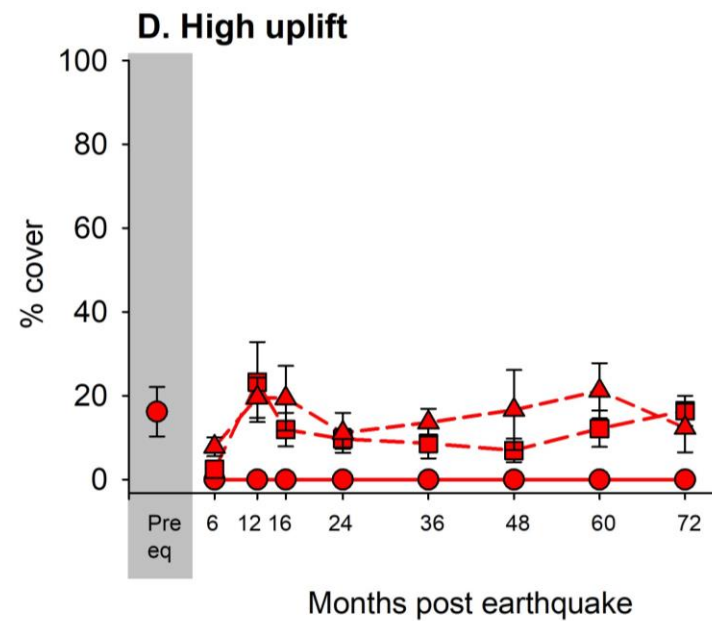
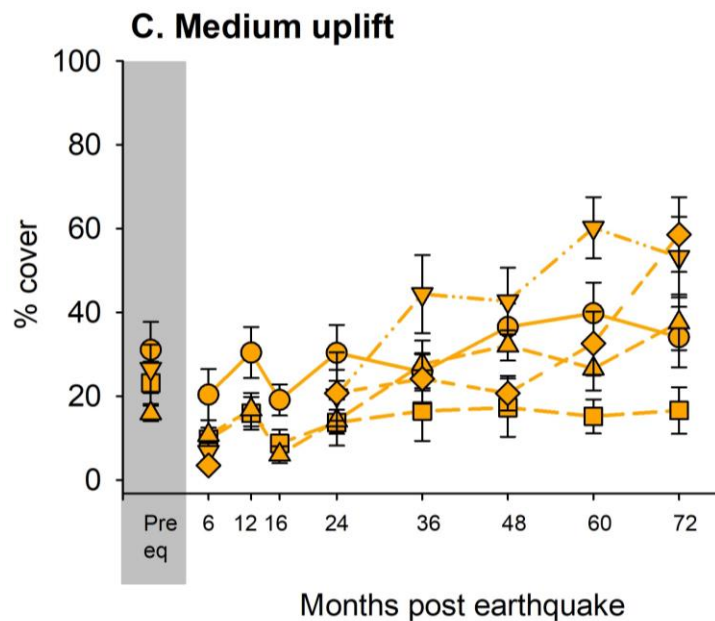
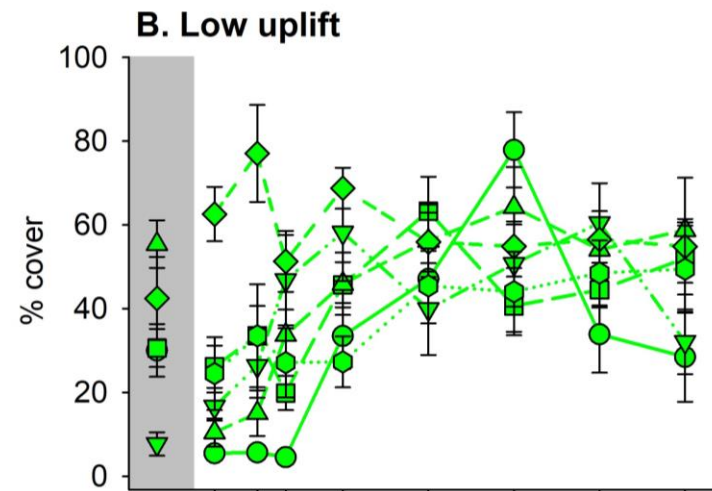
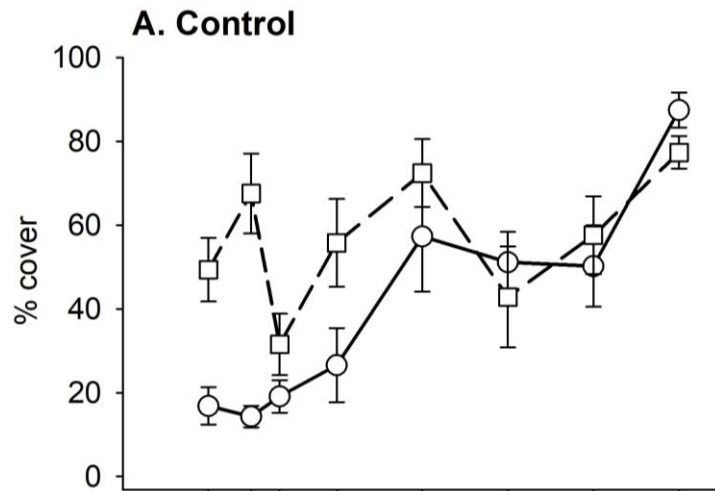


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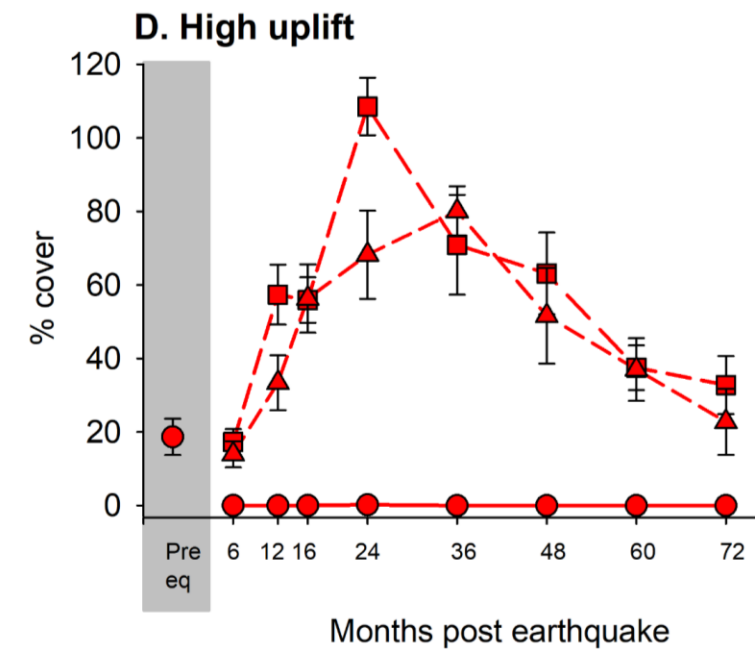
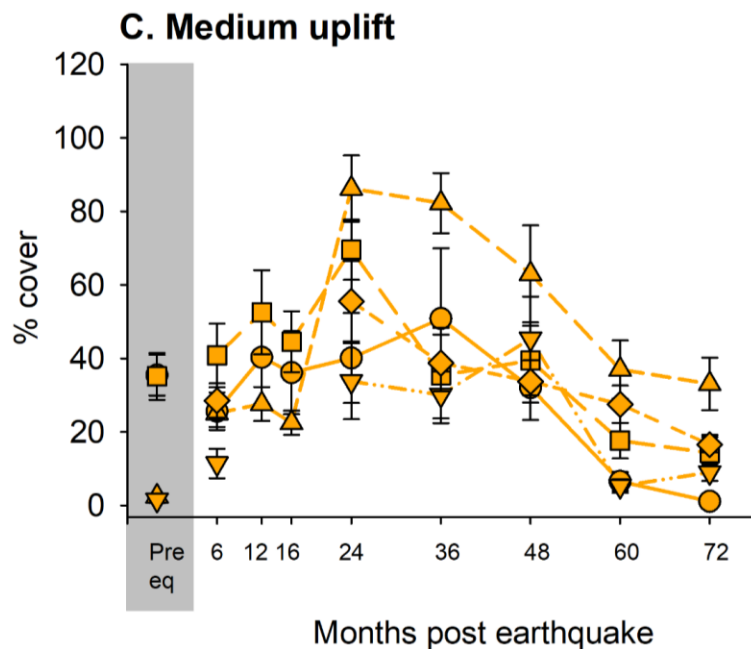
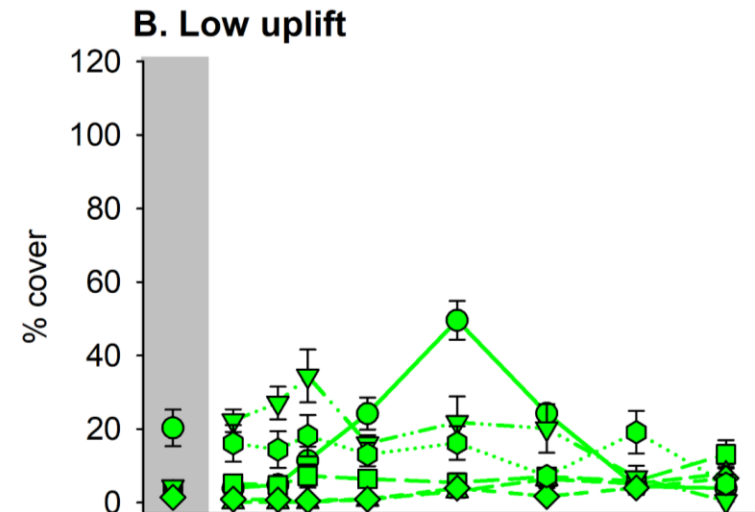
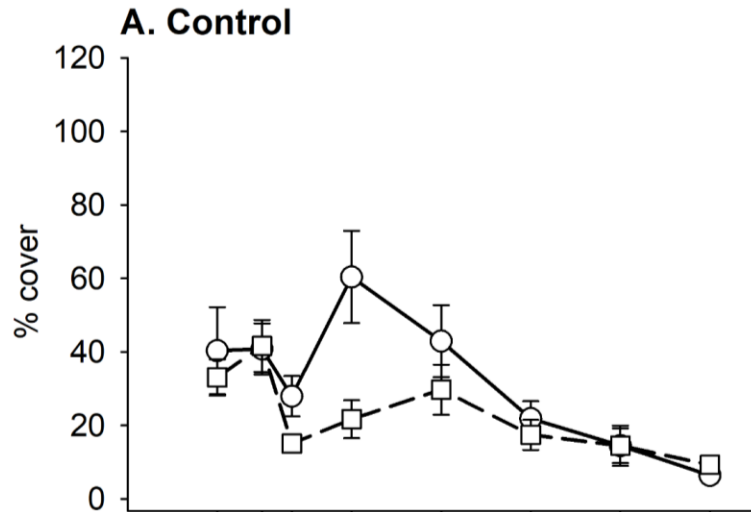


Other large brown algae – by site



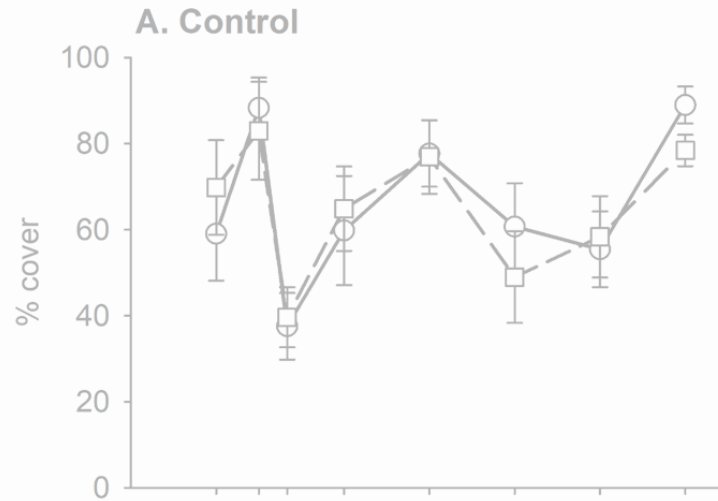
- Oaro 1
- Oaro 2
- Cape Campbell 1
- Cape Campbell 2
- ▲ Kaikoura North 1
- ▼ Kaikoura North 2
- ◆ Kaikoura South 1
- Kaikoura South 2
- Ward 1
- Ward 2
- ▲ Okiwi Bay
- ▼ Omihi 1
- ◆ Omihi 2
- Waipapa Bay 1
- Waipapa Bay 2
- ▲ Waipapa Bay 3

Red algae – by site

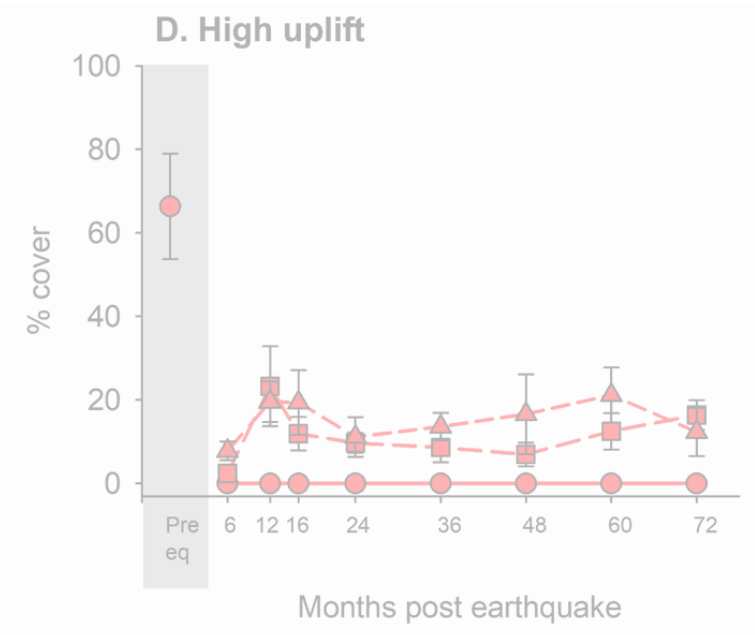
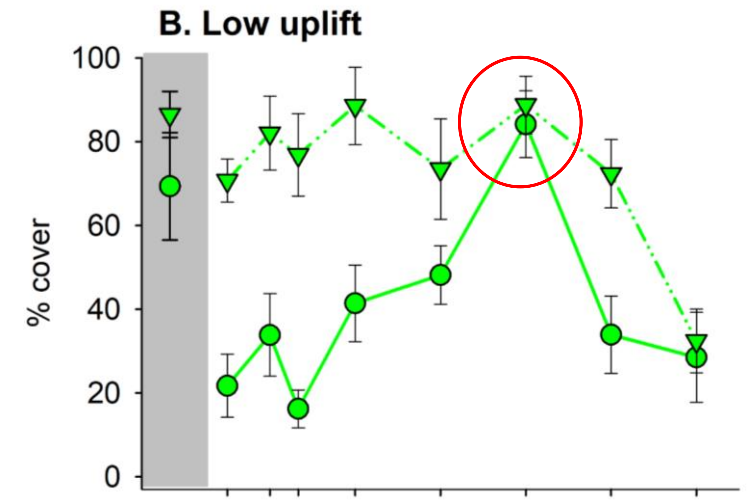


- Oaro 1
- Oaro 2
- Cape Campbell 1
- Cape Campbell 2
- ▲ Kaikoura North 1
- ▼ Kaikoura North 2
- ◆ Kaikoura South 1
- Kaikoura South 2
- Ward 1
- Ward 2
- ▲ Okiwi Bay
- ▼ Omihi 1
- ◆ Omihi 2
- Waipapa Bay 1
- Waipapa Bay 2
- ▲ Waipapa Bay 3

Large brown algae – by site

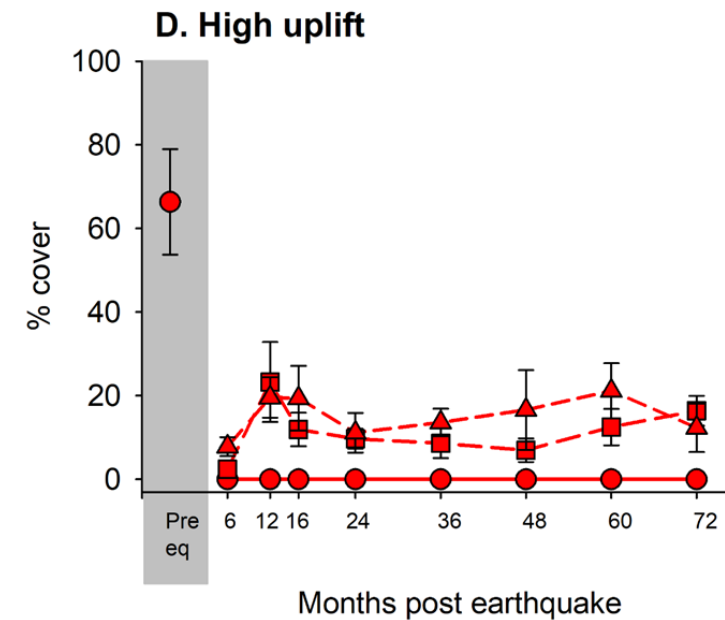
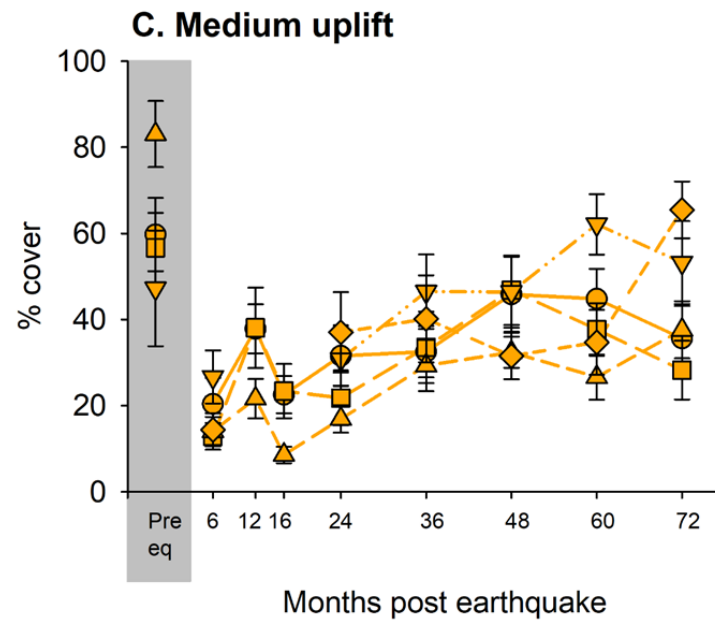
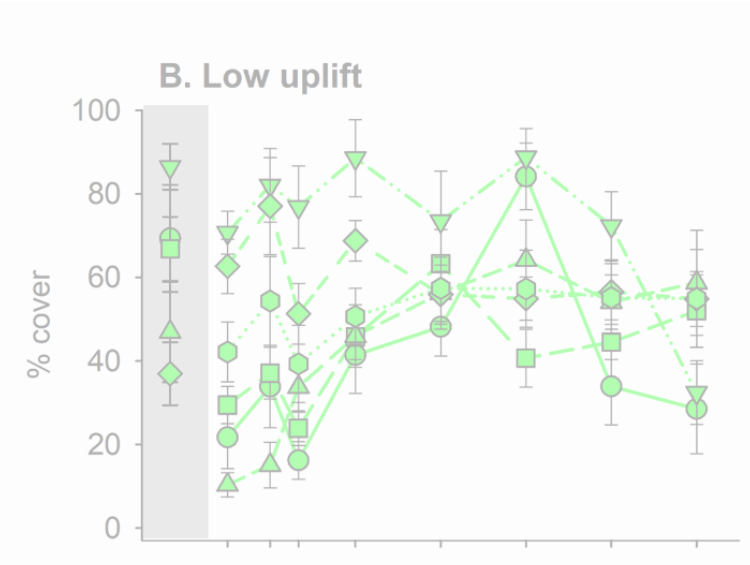
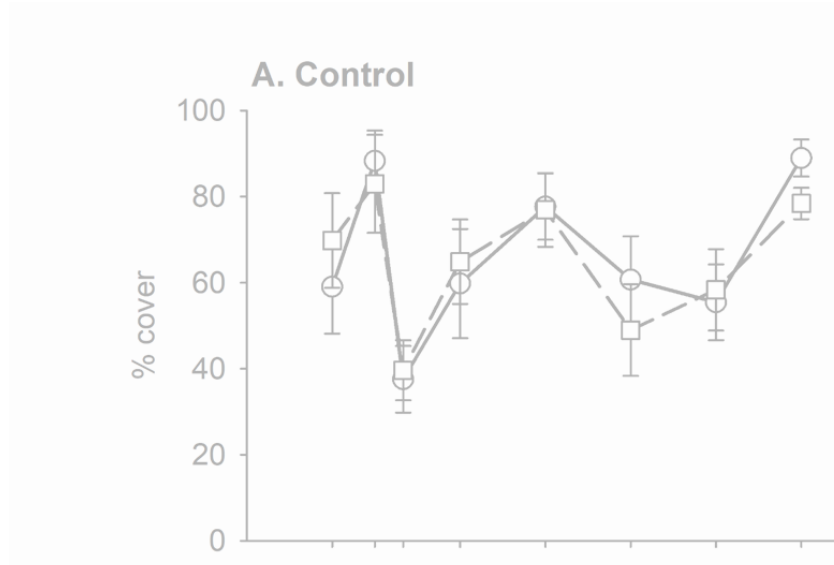


48 months



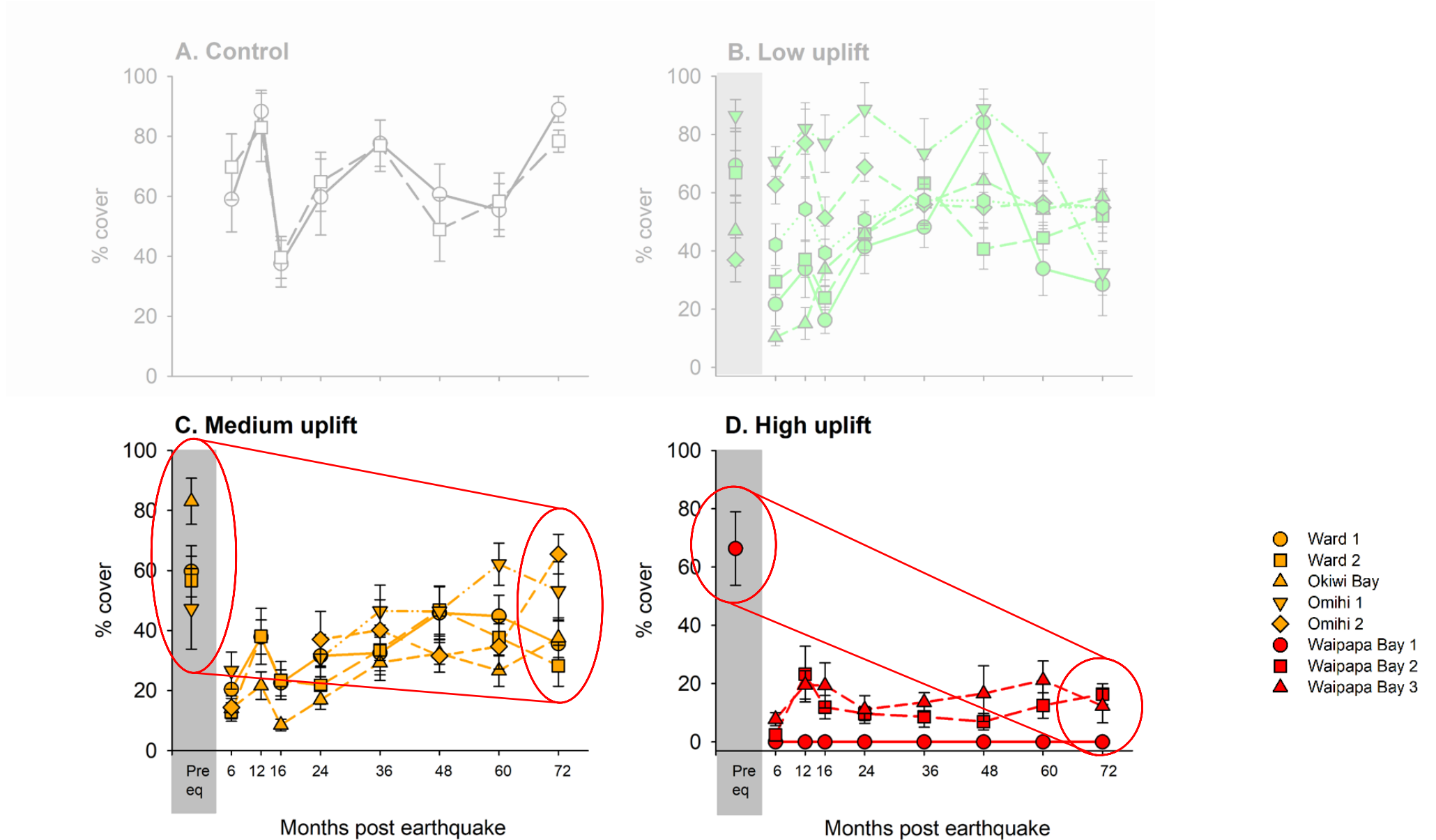
- Cape Campbell 1
- ▼ Kaikoura North 2

Large brown algae – by site

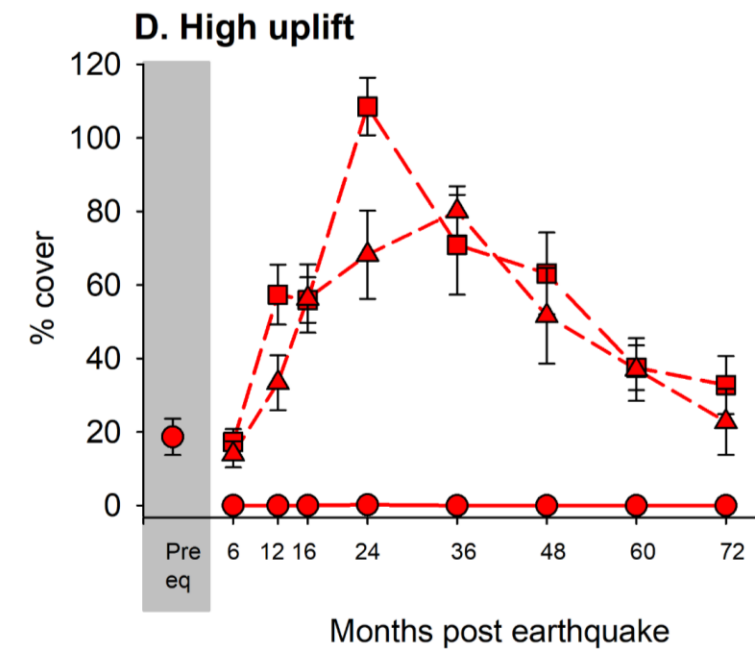
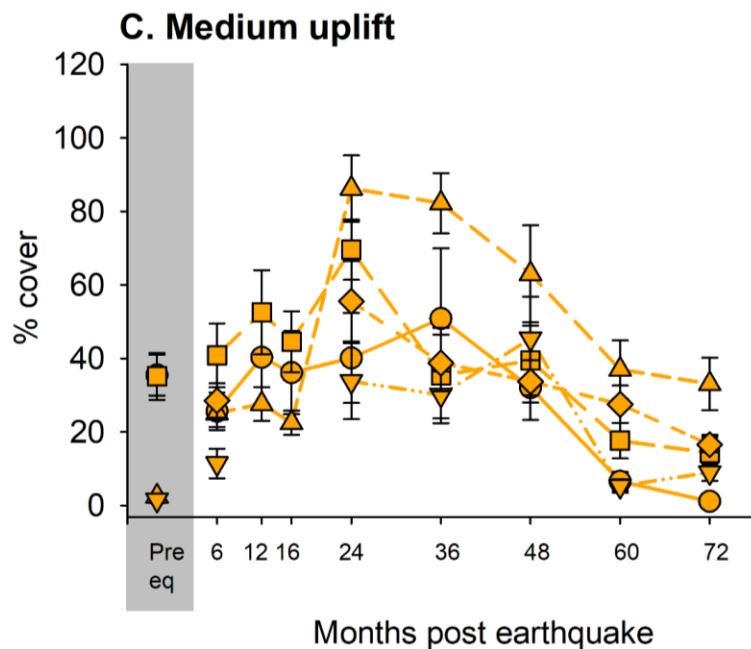
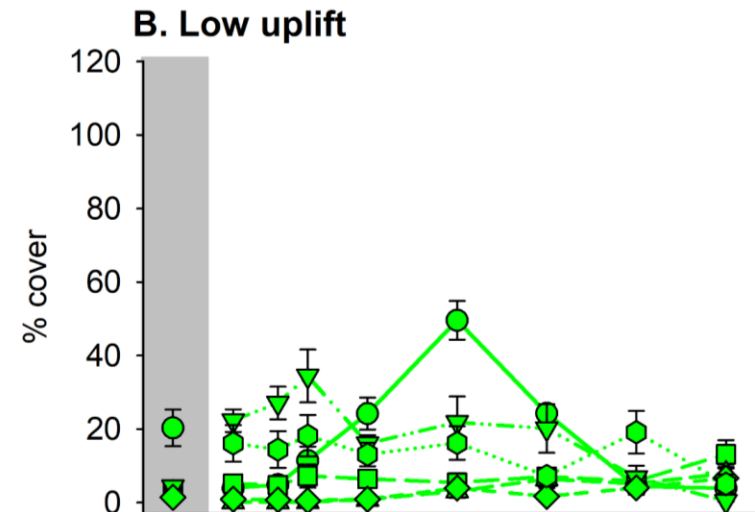
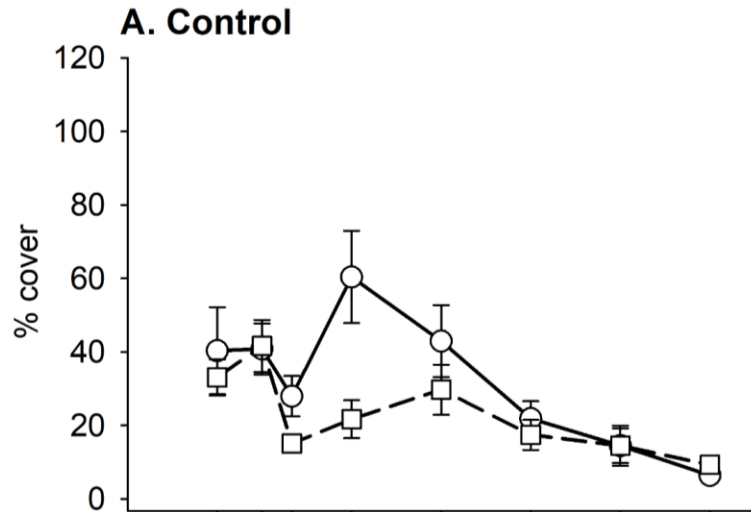


- Ward 1
- Ward 2
- ▲ Okiwi Bay
- ▼ Omihi 1
- ◆ Omihi 2
- Waipapa Bay 1
- Waipapa Bay 2
- ▲ Waipapa Bay 3

Large brown algae – by site

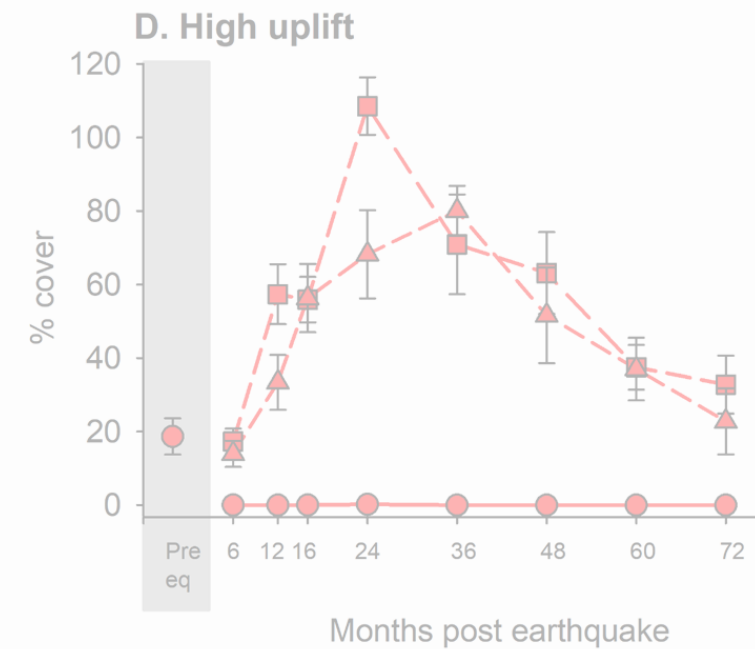
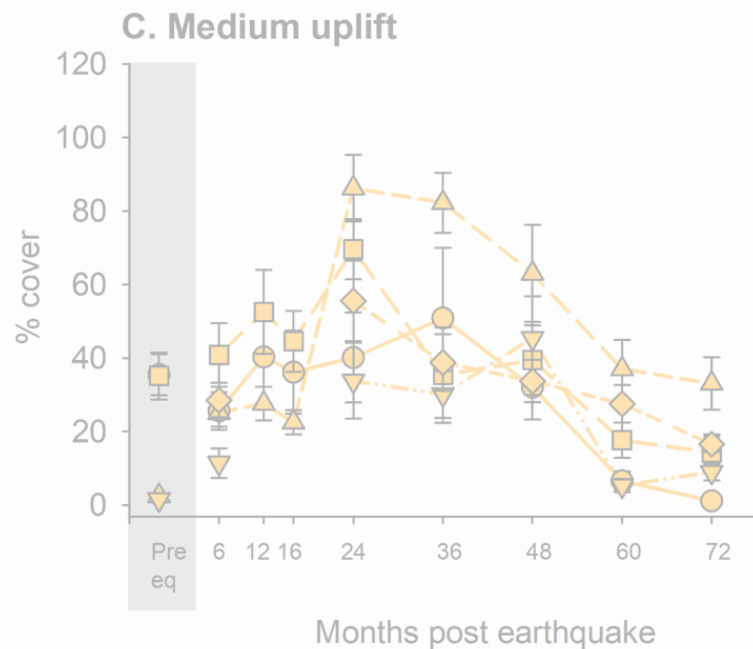
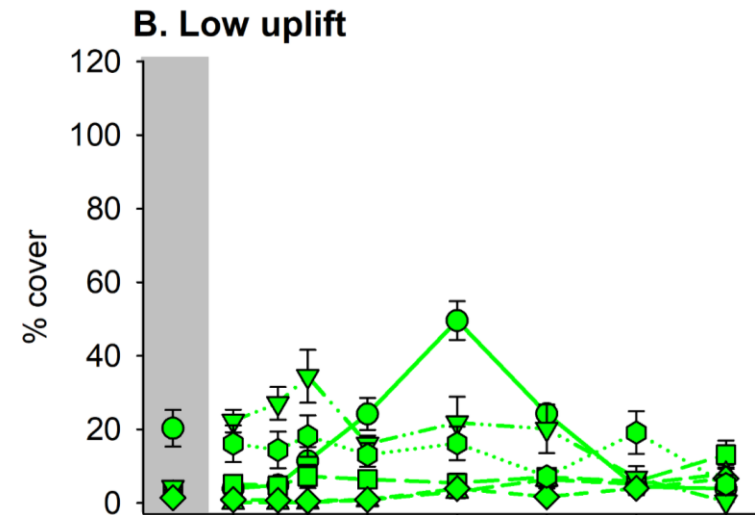
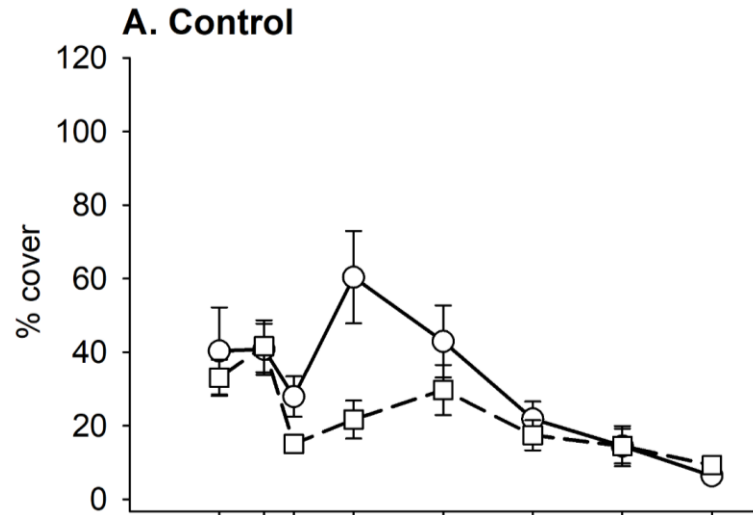


Red algae – by site



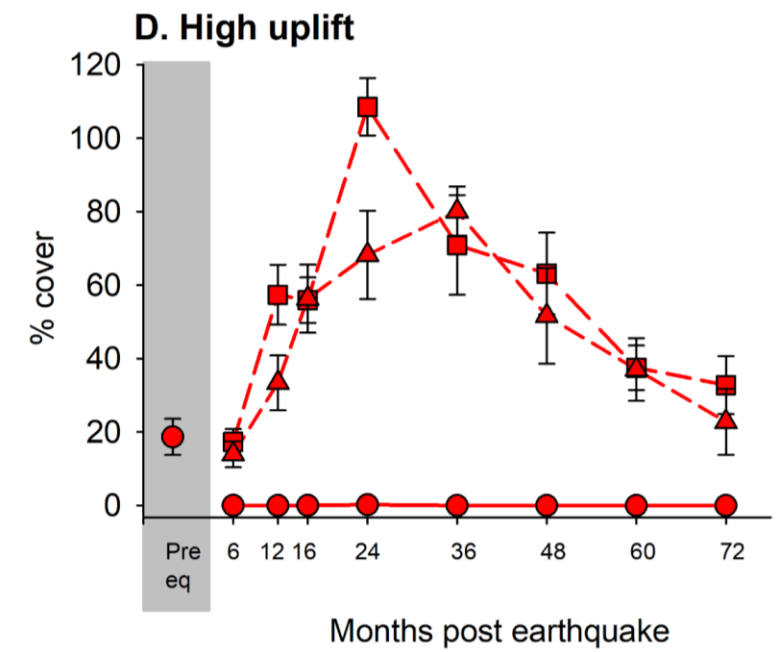
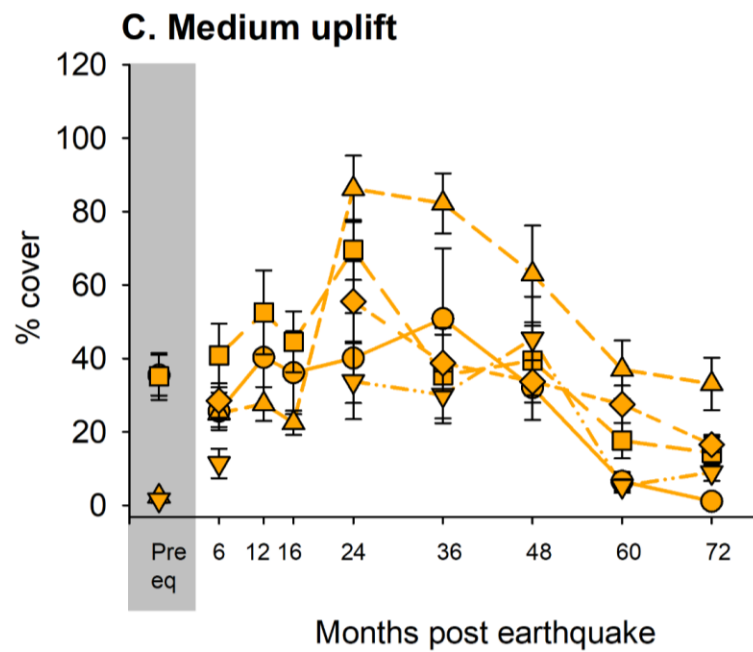
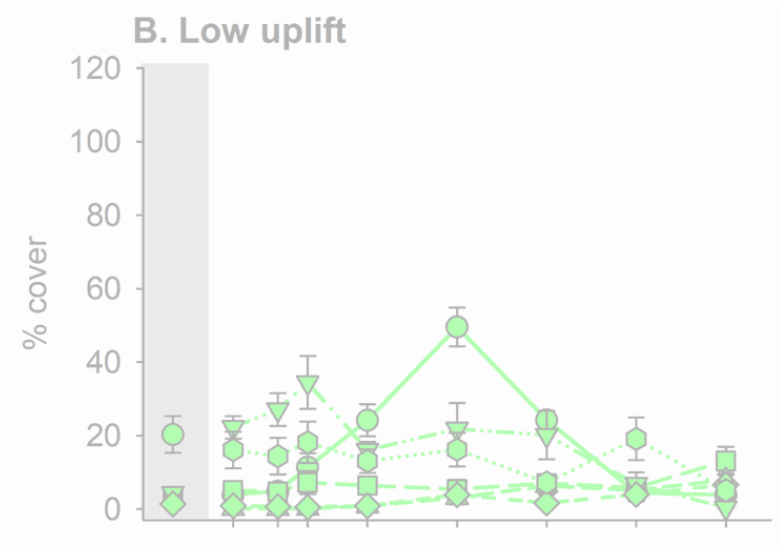
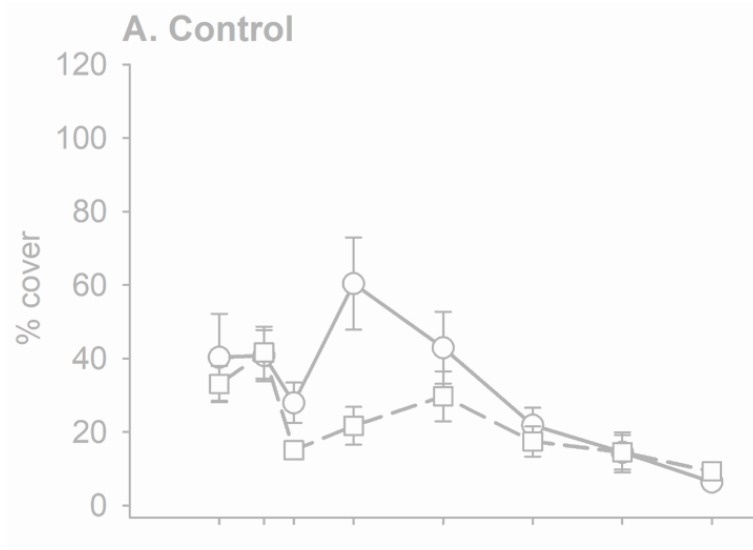
- Oaro 1
- Oaro 2
- Cape Campbell 1
- Cape Campbell 2
- ▲ Kaikoura North 1
- ▼ Kaikoura North 2
- ◆ Kaikoura South 1
- Kaikoura South 2
- Ward 1
- Ward 2
- ▲ Okiwi Bay
- ▼ Omihi 1
- ◆ Omihi 2
- Waipapa Bay 1
- Waipapa Bay 2
- ▲ Waipapa Bay 3

Red algae – by site



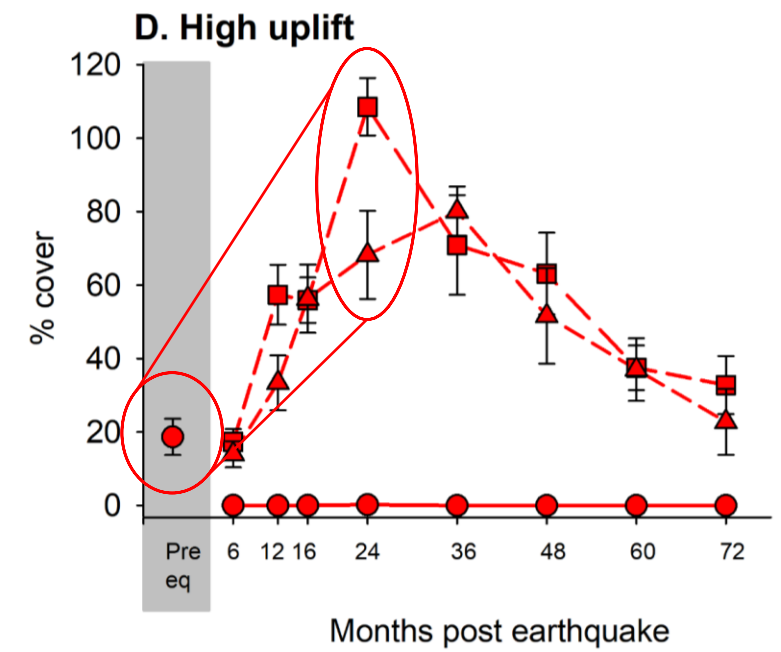
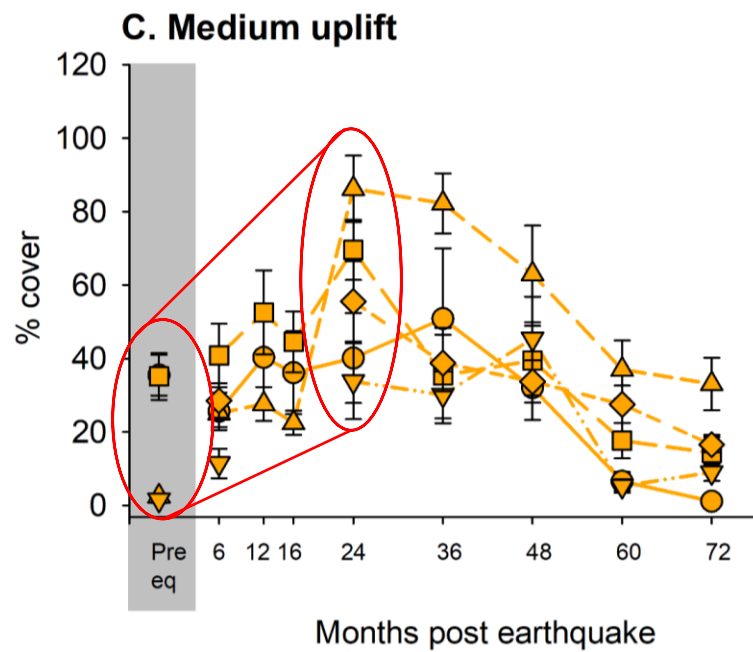
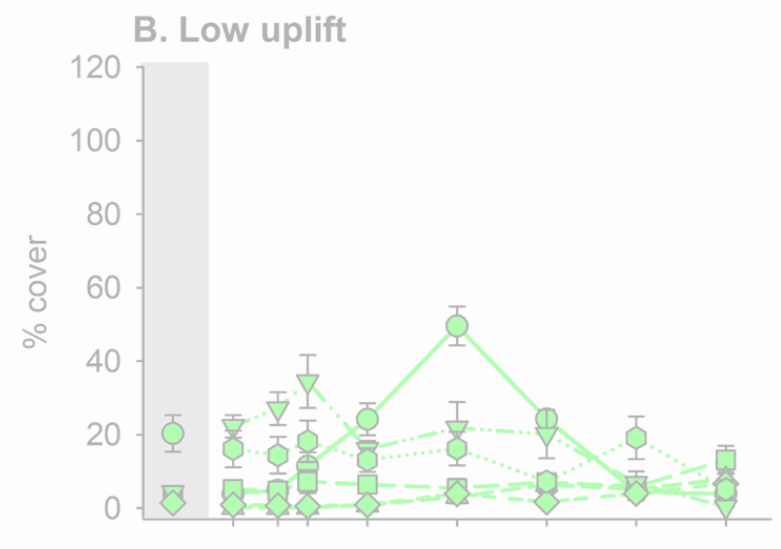
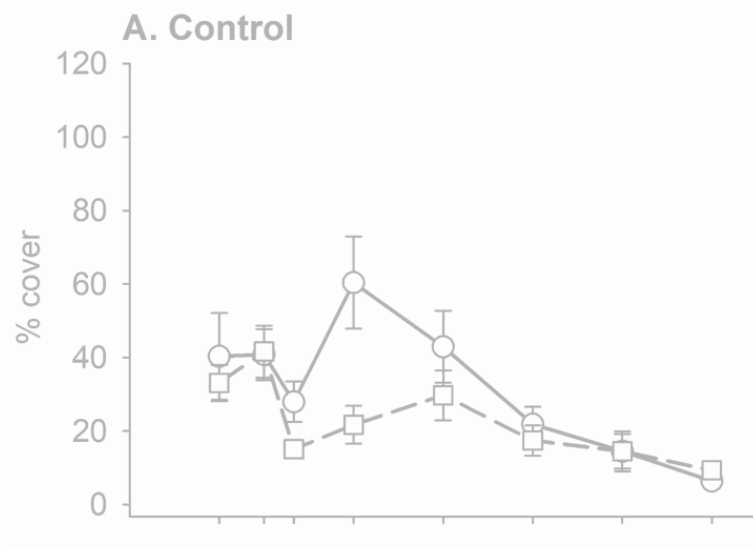
- Oaro 1
- Oaro 2
- Cape Campbell 1
- Cape Campbell 2
- ▲ Kaikoura North 1
- ▼ Kaikoura North 2
- ◆ Kaikoura South 1
- Kaikoura South 2

Red algae – by site



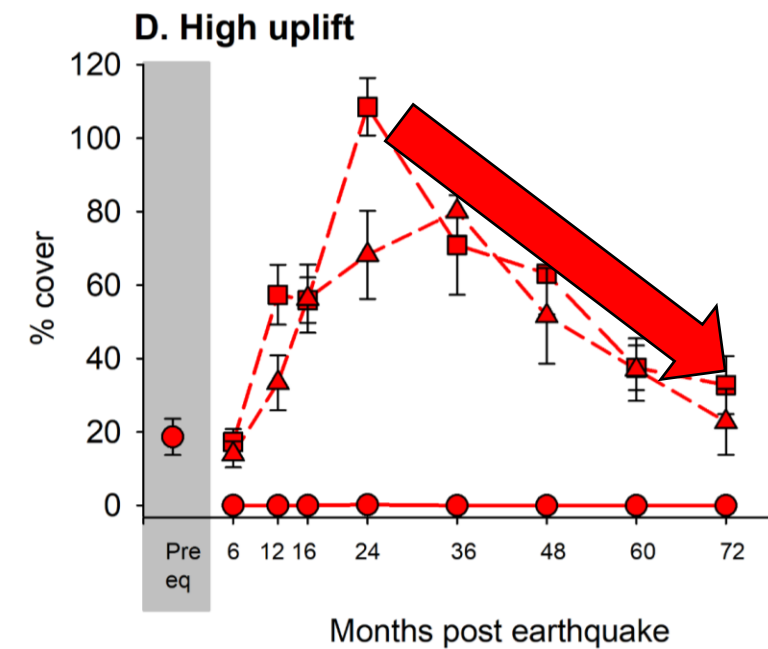
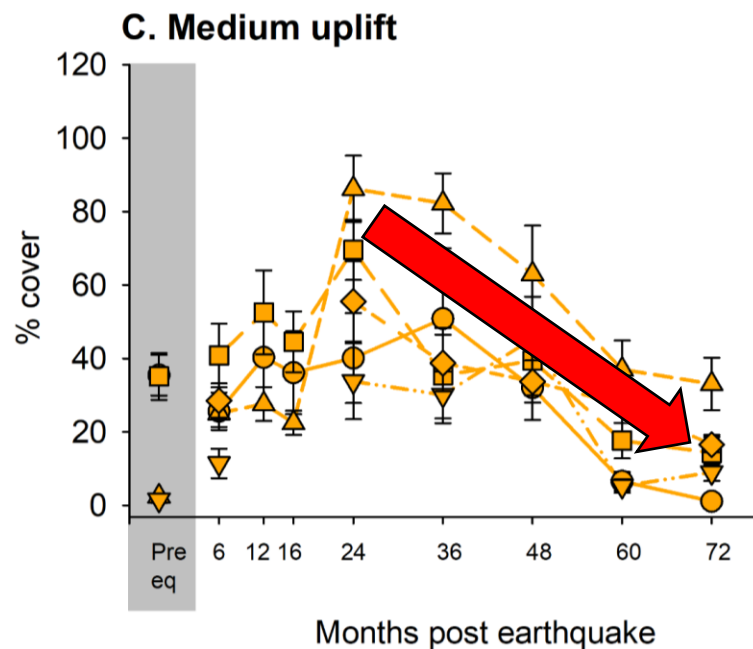
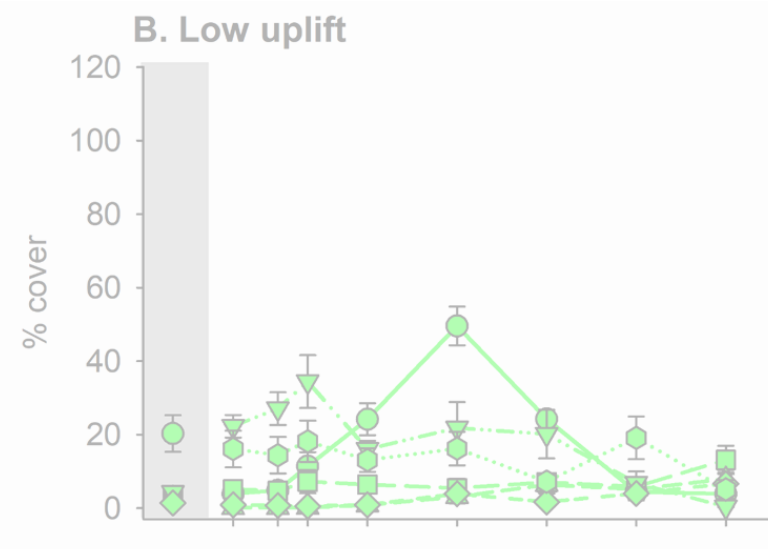
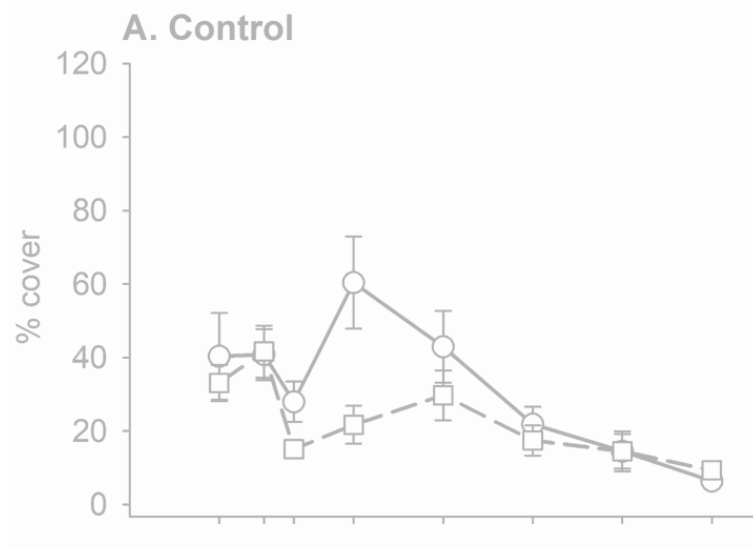
- Ward 1
- Ward 2
- ▲ Okiwi Bay
- ▼ Omihi 1
- ◆ Omihi 2
- Waipapa Bay 1
- Waipapa Bay 2
- ▲ Waipapa Bay 3

Red algae – by site



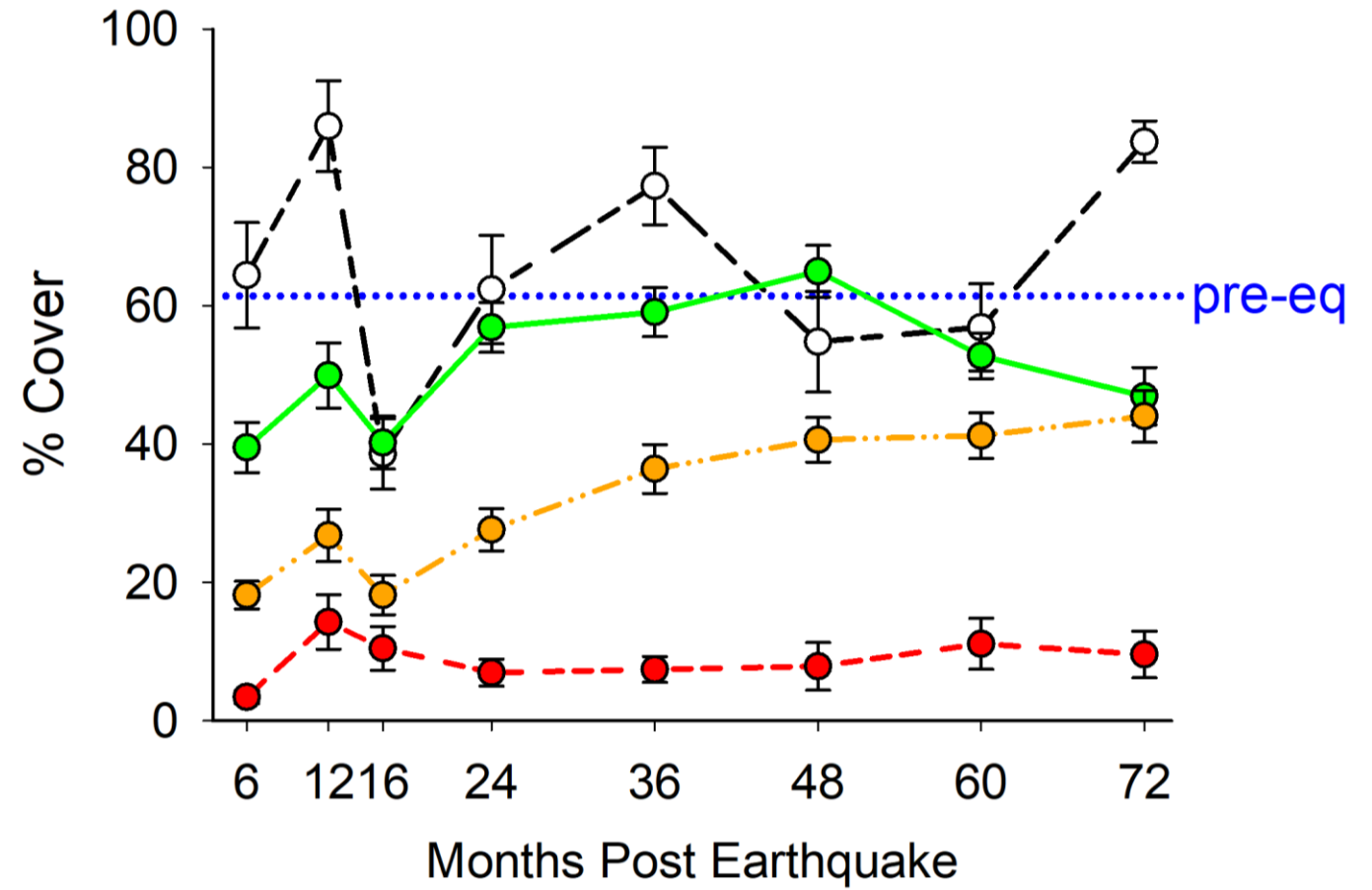
- Ward 1
- Ward 2
- ▲ Okiwi Bay
- ▼ Omihi 1
- ◆ Omihi 2
- Waipapa Bay 1
- Waipapa Bay 2
- ▲ Waipapa Bay 3

Red algae – by site



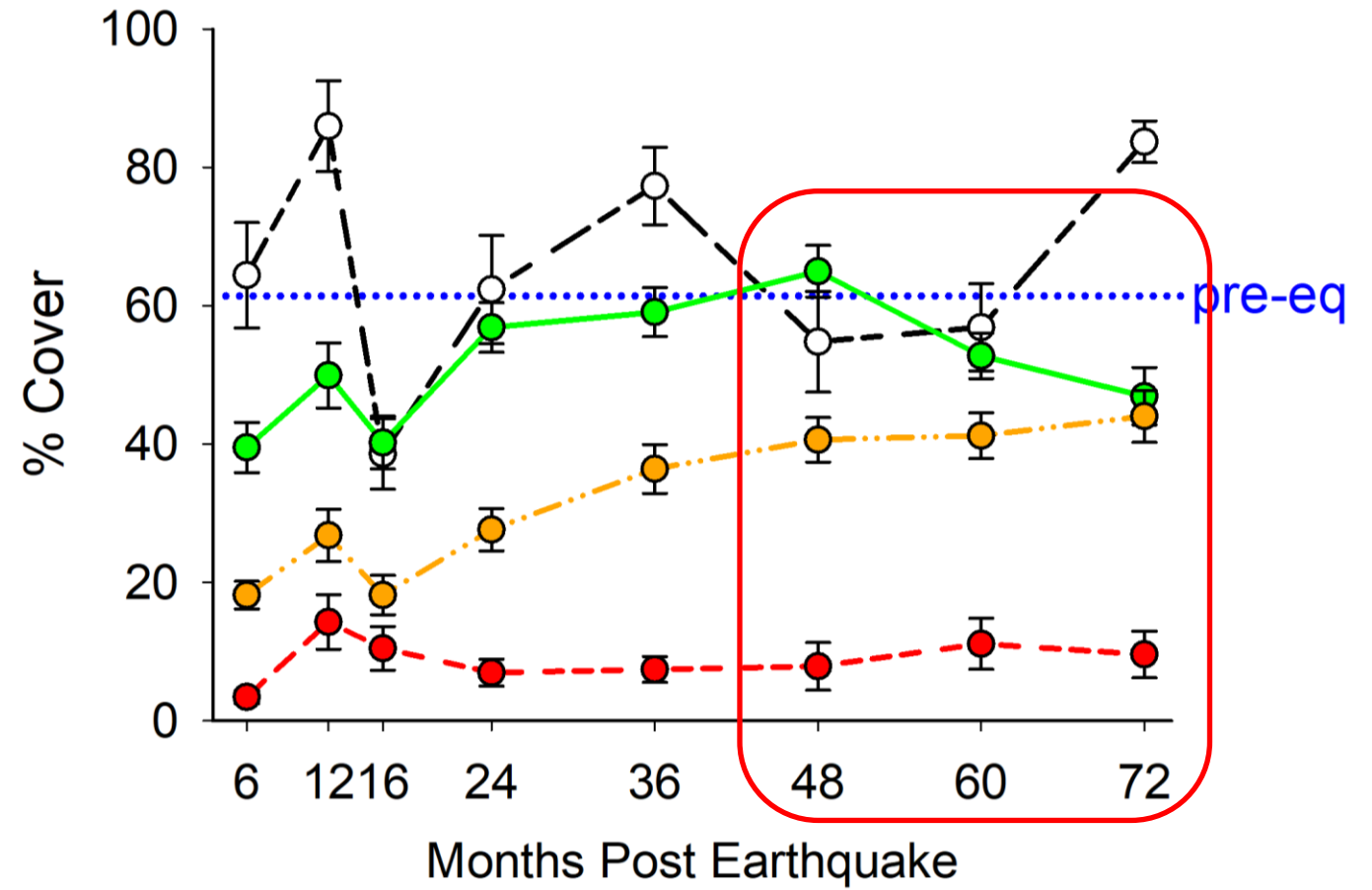
- Ward 1
- Ward 2
- ▲ Okiwi Bay
- ▼ Omihi 1
- ◆ Omihi 2
- Waipapa Bay 1
- Waipapa Bay 2
- ▲ Waipapa Bay 3

Large brown algae - low zone



- Control (n = 2)
- Low uplift (n = 6)
- Medium uplift (n = 5*)
- High uplift (n = 3)

Large brown algae - low zone



- ○ --- Control (n = 2)
- ● — Low uplift (n = 6)
- · - · - ● - · - · - Medium uplift (n = 5*)
- - - ● - - - High uplift (n = 3)

Large brown algae – by site

