Marine stressor and receptor interactions: A new approach to incorporate cumulative effects into marine spatial management

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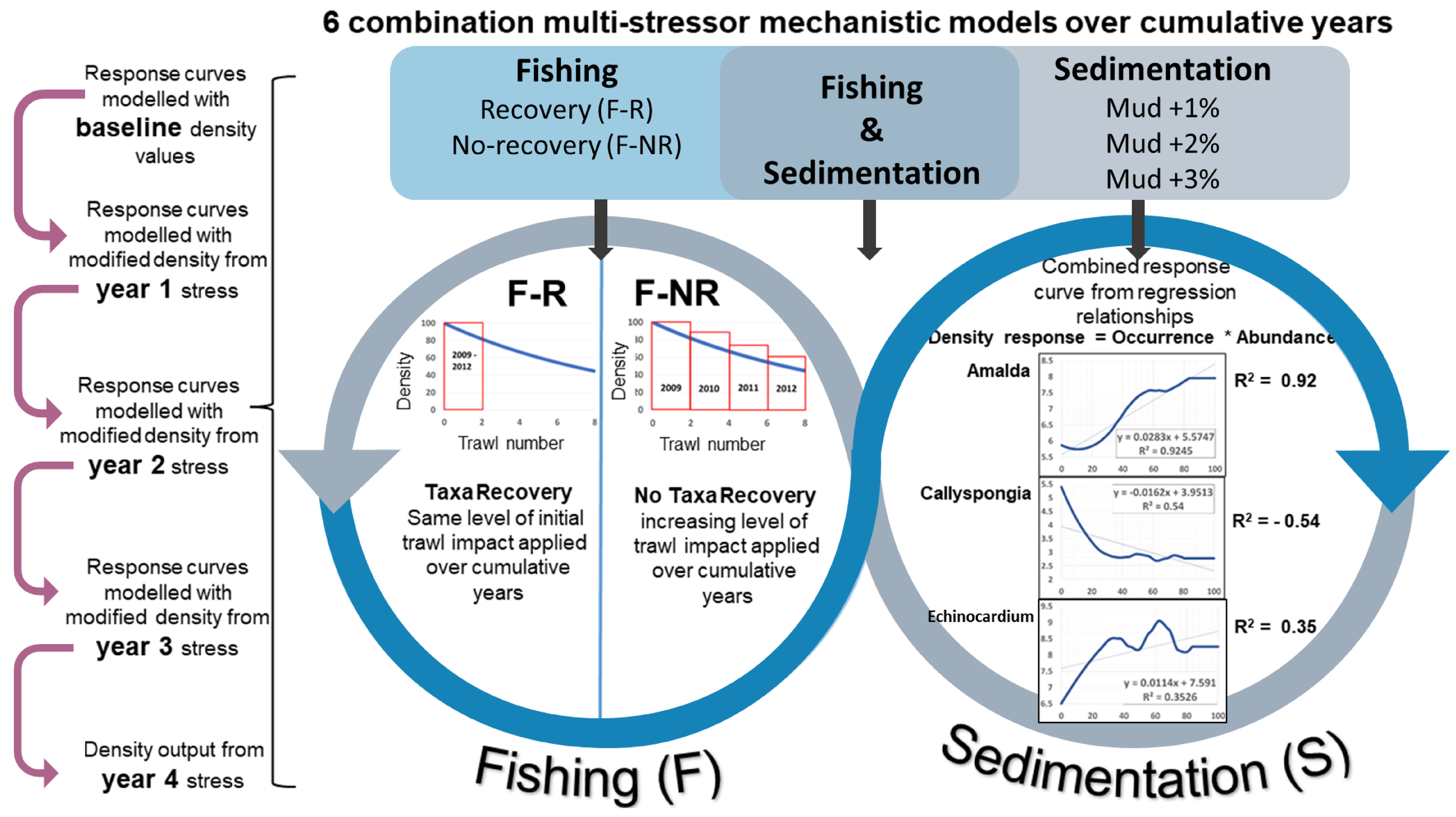
Research overview

My thesis focuses on the development of spatial tools to support the analysis of cumulative anthropogenic stressor effects in coastal marine ecosystems.

Purpose: To support the integration of ecological responses to cumulative effects into spatial management tools, with consideration of effect interactions and recovery dynamics with particular focus on benthic invertebrates.

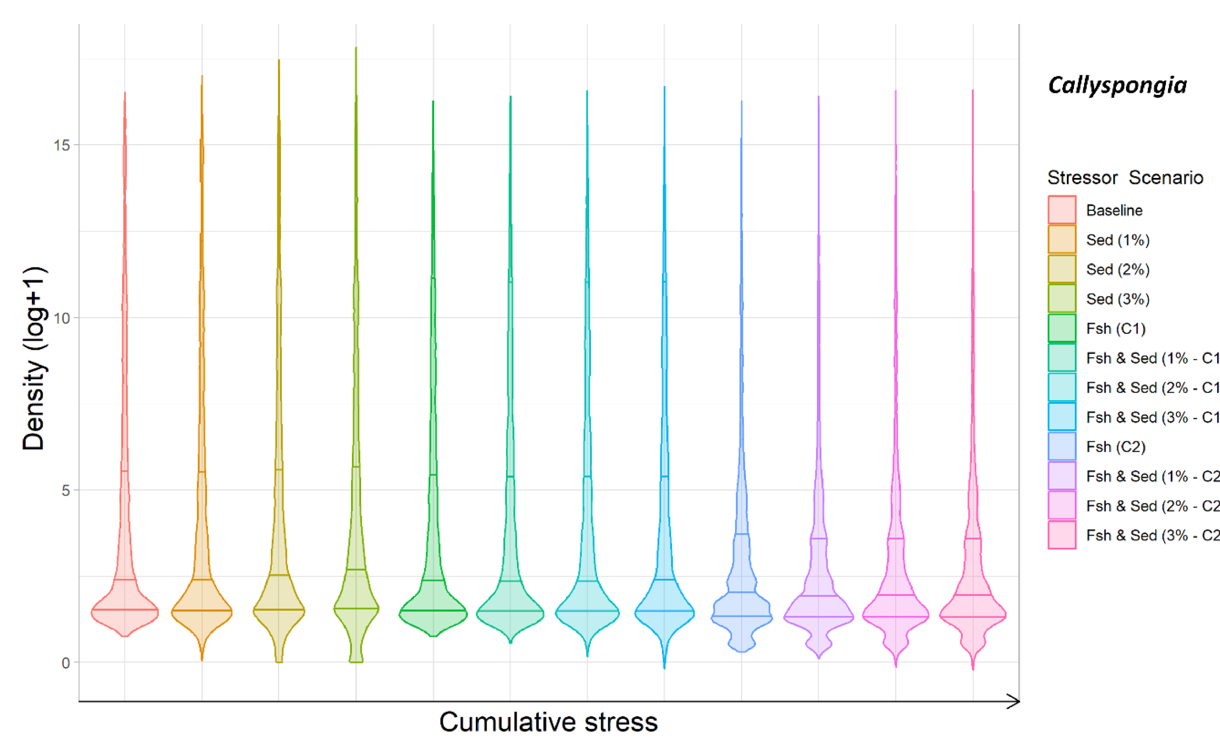
Need: For effective marine spatial management and maintenance of key biogenic environments, it is necessary to incorporate spatial tools that assess cumulative effects of stressors such as fishing and sedimentation.

Multiple stressor mechanistic model over cumulative years



- Fishing trawl stressor response curves were defined from a global meta-analysis (Sciberras et al., 2018)
- Sedimentation (in the form of % mud) stressor response curves were extracted from Boosted Regression Tree (BRT) correlative models (Watson et al., 2022)
- Spatial estimates of density from the baseline SDMs were sequentially manipulated based on the stressor response curves
- 12 stressor scenarios modelled: 4 years of cumulative fishing stress, 3 different sedimentation levels, 2 recovery scenarios (with and without recovery)

Change in mean density from cumulative stress



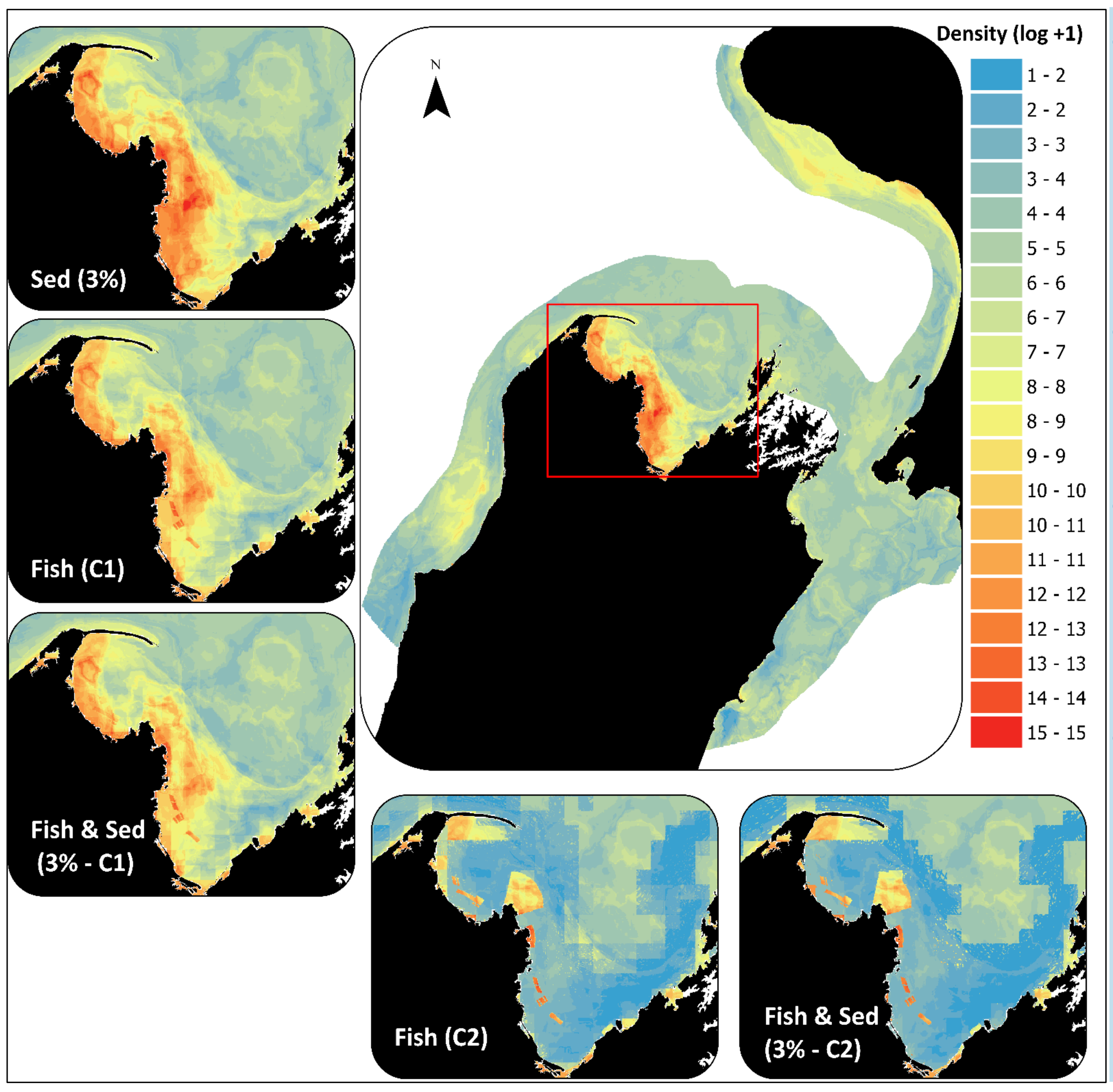
Violin diagram (ggplot2) shows increased change in the distribution and range of taxa density with increased stress

Chapter 1: Creation of baseline Species Distribution Models (SDMs) predicting probability of occurrence, abundance (count per sample unit), density (count per km²) and uncertainty for seven coastal seafloor taxa that vary in habitat usage and distribution

Chapter 2: Development of a spatial cumulative stressor mechanistic model incorporating 12 stressor scenarios and two recovery outcomes **(Chapter two findings are presented below)**

Chapter 3: Exploration of marine protection effectiveness, analysing changes in taxa distribution and density over time to perform a spatial optimisation using the decision support software – Zonation.

Spatial Stressor Maps



- Observed change in taxa distribution and density with increasing stress
- Fishing is the more pervasive stressor
- Combined stressor scenarios showed greater effect
- Greatest stressor impact observed in shallower inner coastal environments and bays

Cumulative interaction effect type from magnitude of change in density

Taxa	CAL	CAL	ECH	ECH	AMA	AMA
Stress Scenario	mean density	Change in mean density (%) from Baseline	mean density	Change in mean density (%) from Baseline	mean density	Change in mean density (%) from Baseline
With recovery (cumulative scenario 1)						
Baseline	144.04	-	59.22	-	195.37	-
Sed (1%)	139.19	-3.37	58.56	-1.11	216.02	10.57
Sed (2%)	134.64	-6.53	58.20	-1.71	238.37	22.01
Sed (3%)	130.37	-9.49	58.44	-1.31	262.22	34.22
Fish (C1)	123.71	-14.11	49.70	-16.07	215.59	10.35
Fish & Sed (1% - C1)	119.42	-17.09	48.01	-18.93	229.67	17.56
Fish & Sed (2% - C1)	117.75	-18.25	47.81	-19.26	239.33	22.50
Fish & Sed (3% - C1)	116.21	-19.32	47.62	-19.59	249.13	27.52
Without recovery (cumulative scenario 2)						
Fish (C2)	44.65	-69.00	18.85	-67.62	695.45	255.97
Fish & Sed (1% - C2)	44.06	-69.41	17.62	-69.86	859.92	340.15
Fish & Sed (2% - C2)	43.52	-69.78	17.58	-64.63	899.54	360.43
Fish & Sed (3% - C2)	43.39	-69.88	17.56	-63.42	908.60	365.06
	Additive		Synergistic		Antagonistic	

- Stressor interaction effect types were classified following definitions from (Thrush et al., 2003)

- Effects were determined by comparing the change in mean density between combined scenarios (Fishing & Sedimentation) to changes based on individual stressor scenarios (Fishing, Sedimentation)
- Cumulative interaction types varied across stressor scenarios for the same taxa and between taxa for the same level of stress applied
- The mixed outcome of stressor effects suggests that interactions can shift with increased stress which may indicate a change in a taxa's stress tolerance

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