Marine Biodiversity Hub

National Environmental Science Programme

Qualitative Models of Northern Seascapes

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Project A12 – Threatened and Migratory Marine Species in Australia's Northern Seascape

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Executive Summary

We describe the pressures, values and conceptual models for ecosystems in the Northern Marine Region. To do this, we implement the first three of five steps of the GBR Cumulative Impact Guidelines (Dunstan *et al.* 2019): 1) understanding pressures; 2) understanding values; and 3) the description of conceptual models of ecosystems. These first three steps provide a systematic hazard assessment for the Northern Marine Region, adding a consistent spatial component to earlier hazard assessments. Progressing from this hazard assessment to a cumulative impact assessment requires the subsequent or final two steps of the GBR Cumulative Impact Guidelines: 4) dose-response curves and 5) quantitative assessment.

Parks Australia has recently described a set of ecosystem complexes we spatially mapped in the Northern Marine Region using a number of different data layers generated from previous NESP work to provide the values (Step 1). The data on pressures (Step 2) was also obtained from previous work completed by the NESP Marine Biodiversity Hub. Finally (Step 3), a workshop was held in Darwin in September 2019 to describe the conceptual models for each ecosystem complex, namely the ecosystem components and the pressures that are acting on each component.

We have mapped the distribution of responses of the ecosystem complexes to the pressures that occur across a 0.1 degree grid for the entire Northern Marine Region. This shows the locations where change (both positive and negative) is expected based on the spatial distribution of values and pressures. Inshore ecosystems tend to be more impacted than offshore ecosystems. In general, where there are fewer pressures that can interact with the ecosystems there are also fewer negative changes expected. Some of the offshore systems had a larger proportion of uncertain outcomes – because the pressures did not have pathways to impact some of the ecosystem components.

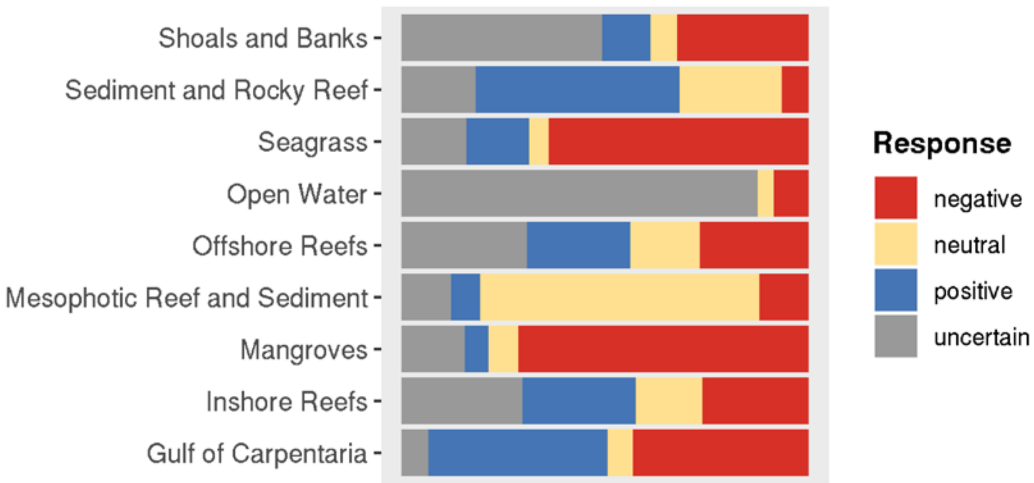

Figure 1: Total summed responses of ecosystems to the observed distribution of pressures

The outputs can be viewed as a detailed hazard assessment, similar in scope to a level 2 Productivity Susceptibility analysis for ecosystems (Hobday *et al.* 2011). It is important to note that all pressures are considered in this analysis, including those that currently have their own impact assessments (i.e. commercial fisheries) as we are progressing towards considering cumulative assessment – not just the direct impacts of individual activities.

Importantly, this analysis is designed to identify which ecosystem components should be examined in the future to assess the significance of cumulative impacts (i.e. through a formal risk assessment). The outputs from this first stage have identified the key natural values in the ecosystem complexes that may be at risk of unsustainable impacts. These outputs will also be useful in identifying potential indicators for the ecosystem complexes described by Parks Australia.

1. Introduction

Identifying the cumulative impacts of multiple activities on Key Natural Values is an important aspect of Ecologically Sustainable Development[1]. Even regions where there is relatively little activity still contain sufficient activities to potentially impact the marine environment (Dunstan *et al.* 2018, Kyne *et al.* 2018). In the Northern Marine Region, historically see as having low pressure on the marine environment (Dunstan *et al.* 2018), a significant number of activities have been mapped and their potential impacts to Threatened, Endangered or Protected Species (TEPS) identified (Kyne *et al.* 2018).

Typically, impact assessments focus on single species but this makes estimating cumulative impacts difficult. A significant problem with a species-specific approach (e.g. focusing on each individual TEPS) is that it requires information on each species and their potential interaction with each pressure. When the list of species is long there is a significant amount of information required for every single species of concern, often limiting what can be assessed.

An alternative approach is to use an understanding of the ecosystem that these species are part of to describe both the hazards and risk to those species and the locations where they might be found. Dunstan *et al.* (2019) suggest a similar approach in the guidelines for cumulative impact assessment the Great Barrier Reef Marine Park Authority. The guidelines (Dunstan *et al.* 2019), provide a 5 step process to assessing the cumulative risks and impacts of human activities on the environment.

These steps are (from Dunstan *et al.* 2019):

Step 1: Understanding Pressures

For the area under consideration for the plan of management, the intensity and distribution of pressures should be mapped. This should include consideration of both the spatial intensity and the temporal pattern.

Step 2: Understanding Values

Environmental values are listed as a Matter of National Environmental Significance (MNES) under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). There are potentially a large number of values that can be identified and the values of any can be ecological, social, economic or cultural. All these values have a spatial component; thus, a practical approach to systematically assess cumulative impacts is to use habitats as a proxy for the values they contain. Environmental, social, cultural and economic values can be identified within these habitats as being derived from components (i.e., species, habitats, processes) of ecosystems, and should be identifiable with conceptual system models.

Step 3: Conceptual Models of Key Habitats

Conceptual models need to portray the ecological system at a level of resolution that is useful to the purposes of the risk assessment, striking a balance between what can be achieved by the science and data and what is desired by managers. The level of resolution should be checked against the pressure and values identified to ensure that values that

[1] http://www.environment.gov.au/about-us/esd

occur in the habitats can be included in the conceptual models and that the pressures acting on those values, can also be included.

Step 4: Zone of Influence

The zones of influence that define the spatial extent over which a pressure influences a value need to be mapped spatially but can also be presented in tabular format. Iterative steps between identifying the zone of influence and defining the conceptual models may be required to ensure that derived assessment and measurement end-points are meaningful and measurable.

Step 5: Risk Assessment and Uncertainty

The existing impacts and potential risks of new activities or development projects that can potentially affect values need to be calculated. Cause-effect models can be used to identify measurement end-points for each of the assessment end-points associated with the values. The cumulative impact of existing and potential pressures should be calculated for each measurement endpoint. Risks of each new activity can be compared against the desired environmental condition.

This project worked through steps 1-3 of the guidelines to develop conceptual models for habitats that can be identified within the Northern Marine Region and describe how different TEPS interact with those habitats. It identifies the pressures that are occurring on those habitats and which parts of the ecosystem they are acting on. The outputs should be viewed as a detailed hazards assessment, similar in scope to a level 2 PSA analysis for ecosystems (Hobday *et al.* 2011). It is important to note that all pressures are considered in this analysis, including those that currently have impact assessments (i.e. commercial fisheries). This is because we are looking at the cumulative impacts of activities and while the direct impacts of fisheries are managed through harvest strategies, the indirect impacts may propagate through the rest of the ecosystem. Thus, this analysis is designed to identify which ecosystem components should be examined in the future to assess the sustainability of cumulative impact (i.e. through a formal risk assessment – step 5 in this framework and the equivalent of a level 3 stock assessments).

Data on pressures and species distribution has been previous collated in the Seascape Scoping project (Kyne *et al.* 2018) and form the basis for the work in this project. We will map the ecosystem complexes described in the Parks Australia Natural Values Hierarchy to areas identified in Seamap Australia, with additional input from experts to define the spatial boundaries for ecosystem complexes.

Conceptual models for each ecosystem complex, including the identification of new models where required, were developed in a workshop held in Darwin in September 2019. For each ecosystem complex we identified the key values and pressures in the system and how these interacted with each other.

2. Conceptual models

Conceptual models represent a working hypothesis about how an ecosystem works. They should: a) identify the important components and processes in the system; b) document assumptions about how these components and processes are related; c) identify the linkages between these components/processes and anthropogenic pressures; and d) identify knowledge gaps or other sources of uncertainty.

Conceptual models come in many different forms including simple narrative descriptions, schematic diagrams, box-and-arrow flowcharts, or even cartoons that pictorially illustrate physical and biological processes and the effects of anthropogenic pressures. Even though there are many forms of conceptual models, they all hold common elements and can be constructed using a common set of steps.

Steps or tasks in constructing conceptual models:

1. Identify bounds of the system of interest
2. Identify key model components, subsystems, and interactions
3. Identify natural and anthropogenic stressors (pressures)
4. Describe relationships of stressors, ecological factors, and responses

Conceptual models need to portray the ecological system at a level of resolution that is useful to the purposes of the risk assessment, striking a balance between simplicity and complexity. They should not seek to represent the entire system with myriad components and processes; rather the goal should be to encompass the relevant subsystem, which includes the components of the system that are the focus of the risk assessment, the associated processes and variables that act to maintain and regulate the ecosystem components, and the natural and anthropogenic pressures of concern.

3. Methods

In preparing this analysis we have used the steps outlined in Dunstan *et al.* (2019) to calculate the hazards assessment for the cumulative impacts of pressures on ecosystems and ecosystem components. Specifically, we have identified the pressures, values, conceptual models for the pressures interacting with the potential values within Ecosystem complexes – steps 1-3 of the GBR Cumulative Impact guidelines.

3.1 Pressures

Pressures acting in the Northern Marine Region have been described by Kyne *et al.* (2018) and are a systematic compilation of all pressure information available. The data sets used in this report were sourced from this work. We characterised a pressure as present whenever intensity exceed the 25% quantile of the distribution of pressure intensities across the Northern Marine Region. The 25% quantile was chosen to distinguish areas where activity was more frequent, in the absence of dose response relationships, altering this value could change some results.

3.2 Values

We used the draft ecosystem complexes as defined by the Parks Australia MERI framework to identify ecosystems in the Northern Marine Region. For each ecosystem complex we used an existing data source (Table 1) to identify the spatial boundary. Finally, all the complexes were merged so that there were no overlaps between complexes.

Table 1: Ecosystem Complexes and data source to map those complexes

Ecosystem Complex	Data Source
1. Mangroves	SeamapAus_NT_mangroves_100Polygon.shp
2. Seagrass	seagrass_camris.shp
3. Oceanic shoals	SeamapAus_NAT_Aus_margin_geomorph_2006_DATAPolygon.shp select feature = banks/shoals & feature = pinnacle
4. Offshore coral reefs <30 m	SeamapAus_NAT_Aus_margin_geomorph_2006_DATAPolygon.shp select feature = reef
5. Inshore coral reefs <30	WCMC-reefs/WCMC-008-CoralReefs2010.shp
6. Mesophotic reef and sediment > 30	Contour from 30m to 150m, minus gulf, oceanic shoals and all other features
7. Sediment and rocky reef < 30m	Contour from 30m to coast minus mangroves, seagrass and reef and all other features
8. Gulf of Carpentaria	SeamapAus_NAT_Aus_margin_geomorph_2006_DATAPolygon.shp select feature id 96, basin

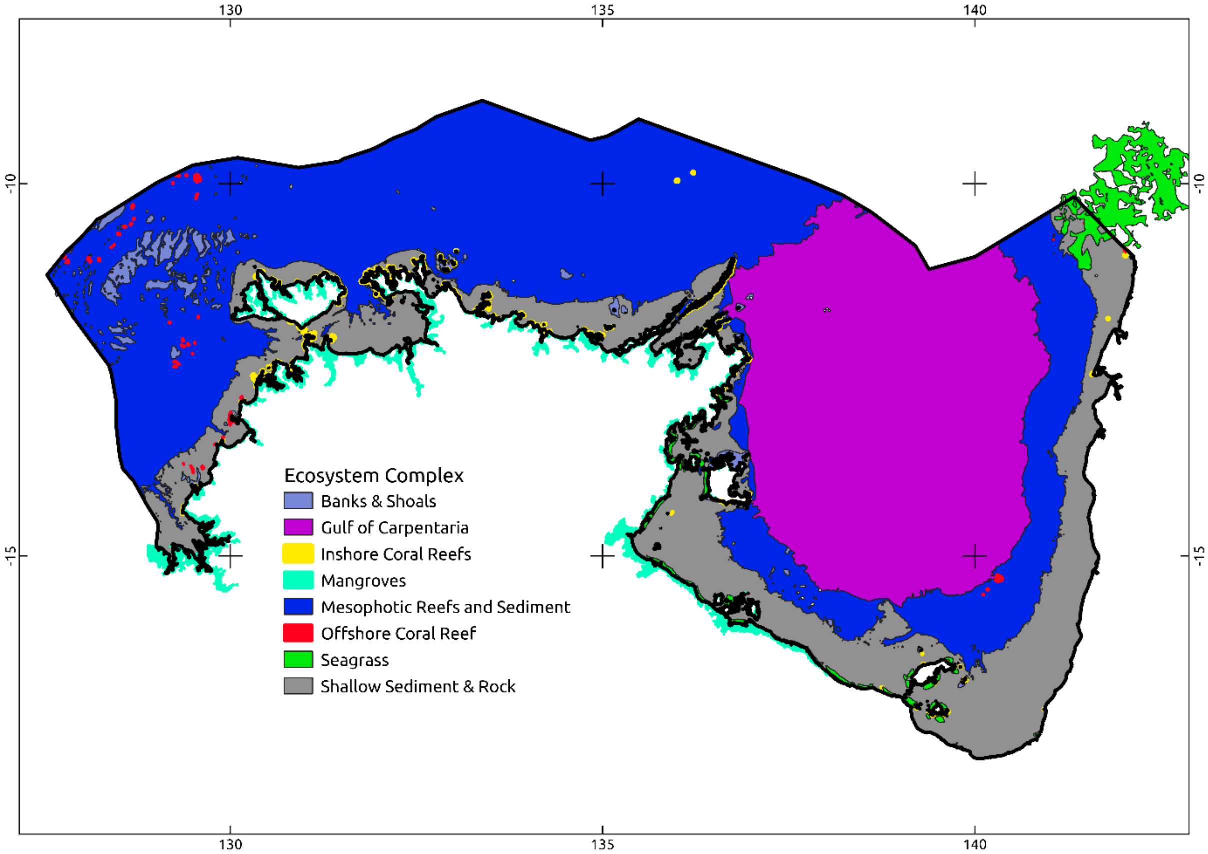

Figure 2: Ecosystem Complexes found in the Northern Marine Region

Within each ecosystem complex, we identified the key natural values that were part of each ecosystem complex and described the conceptual model of the ecosystem complex.

The natural values identified through the workshops are listed in Table 2, derived from the Parks Australia Natural Values Hierarchy.

Table 2: Natural Values in each ecosystem complex

1. Mangroves	Mangroves, Terrestrial Predators, Large Vertebrate Predators
2. Seagrass	Dugong, Large Apex Predators (Sharks & Crocodiles), Turtles
3. Shoals and Banks	Benthic/Pelagic Piscivores, High Relief Filter Feeders, Reef Invertebrates, Herbivorous Fishes
4. Offshore coral reefs <30 m	Turtles, Corals, Invertebrates, Apex Predators, Meso Predators
5. Inshore coral reefs <30	Turtles, Corals, Invertebrates, Apex Predators, Meso Predators
6. Mesophotic reef and sediment > 30m	Turtles, Corals, Benthic Fish, Heterotrophic Corals, Meso Predators, Apex Predators
7. Sediment and rocky reef < 30m	Demersal Fish, Prawns, Sessile Filter Feeders, Invertebrates
8. Gulf of Carpentaria	Seabirds, Cetaceans and Large Piscivorous Fish, Turtles, Sharks
9. Open Water	Small Pelagics, Marnie Mammals, Turtles, Seabirds, Billfish Mackerel, Tuna

3.3 Conceptual Models

A workshop was organised in Darwin in September 2020 to build conceptual models for each of the ecosystem complexes. The qualitative model is represented by functional groups (nodes in the diagrams) and relationships between the nodes, indicated by lines terminating in either a solid circle or an arrow. A line terminating in a circle indicates that there is a negative relationship between the functional groups (e.g. Predatory Fish (PF) consume and impact Deposit Feeders (DF); -1). A line terminating in an arrow indicates a positive relationship between the two functional groups (e.g. Sessile Filter Feeders (SFF) consume Phytoplankton (PP); +1). A predatory relationship is indicated by a solid circle and an arrow going in opposite directions. A competitive relationship is indicated by two solid circles. A symbiotic relationship is indicated by two arrows. The response of the ecosystem to pressures (e.g. fishing gears, temperature and shipping) can be analytically calculated from this system using the numerical values of the links between the ecosystem components. The response from a qualitative model can be viewed only as a directional change in the abundance (count, occurrence or presence) of each functional group. A negative value indicates a decline in that functional group, a positive value indicates an increase in that group, while values between -0.25 and 0.25 are deemed ambiguous and the direction of response is not known (but thought to be small).

The qualitative models for the Gulf of Carpentaria were obtained from Hosack *et al.* (2012)

Spatial response to pressures

In the analysis presented here, the pressures were overlayed the ecosystem complexes on a 0.1 degree grid. The analytical outcome of the qualitative model with the pressures present at each grid cell is calculated and the results for selected ecosystem components are presented.

The intersection of each pressure with each ecosystem complex was mapped based on the pressures that were identified as interacting with that complex in the qualitative model. The list of pressures that intersect with each complex is provided below.

Table 3: Pressures acting on each ecosystem complex

Pressure	Mangroves	Seagrass	Shelf Soft Sediment	Pelagic	Coral Reefs	Mesophotic Reefs & Soft Sed	Shoals & Banks	Gulf of Carpentaria
Temperature	x	x			x			
Salinity	x							
Cyclones	x	x			x		x	
Rainfall trend	x		x					
Sediment	x							
Nutrients	x	x	x				x	
Toxicants	x	x						
Oil and gas			x			x	x	x
Trawl Impacts			x					x
Illegal fishing				x	x	x	x	x
Ship strike				x	x			
Ship noise				x				
Ghost nets				x	x			x
Plastics				x				
Commercial fishing					x	x		
Recreational fishing					x	x		
pH					x		x	

4. Results

For each ecosystem complex we have produced 3 figures:

1. The conceptual model for the ecosystem complex, identifying each ecosystem component and key natural value that occurs, and the pressures acting on that system.
2. The scenario response of the ecosystem (as described in the conceptual model) to different combinations of pressures that may occur. For example, cyclones may occur by themselves, or in combination with increased temperature. Different combinations of pressures will change the analytical response of the system and the potential cumulative change.
3. The spatial response of each ecosystem complex to the combination of pressures that occur in the Northern Marine Region. The response of each key natural value is mapped based on the combination of pressures that occur within each 0.1 degree grid cell. For example, in one 0.1 degree cell, fishing and increase in temperature may occur and the response of the system to that pressure combination is mapped. In the adjacent cell, only increase in temperature may occur so only that is mapped.

4.1 Mangroves

Mangrove ecosystem complexes (Figure 2) are impacted significantly by increased temperature, cyclones, increased sediments, nutrients and toxicants (Figure 3). These pressures singly, or in combination with other pressures, affect all components of the ecosystem. The key natural value of mangrove ecosystem complex is the mangroves themselves, which provide habitat, structure and food for many of the species that occur there. Other key natural values (terrestrial predators - birds and large vertebrate predators - crocodiles) are equally impacted by any loss of mangroves. All natural values are likely to be impacted across the range of mangrove ecosystem complexes (Figure 4).

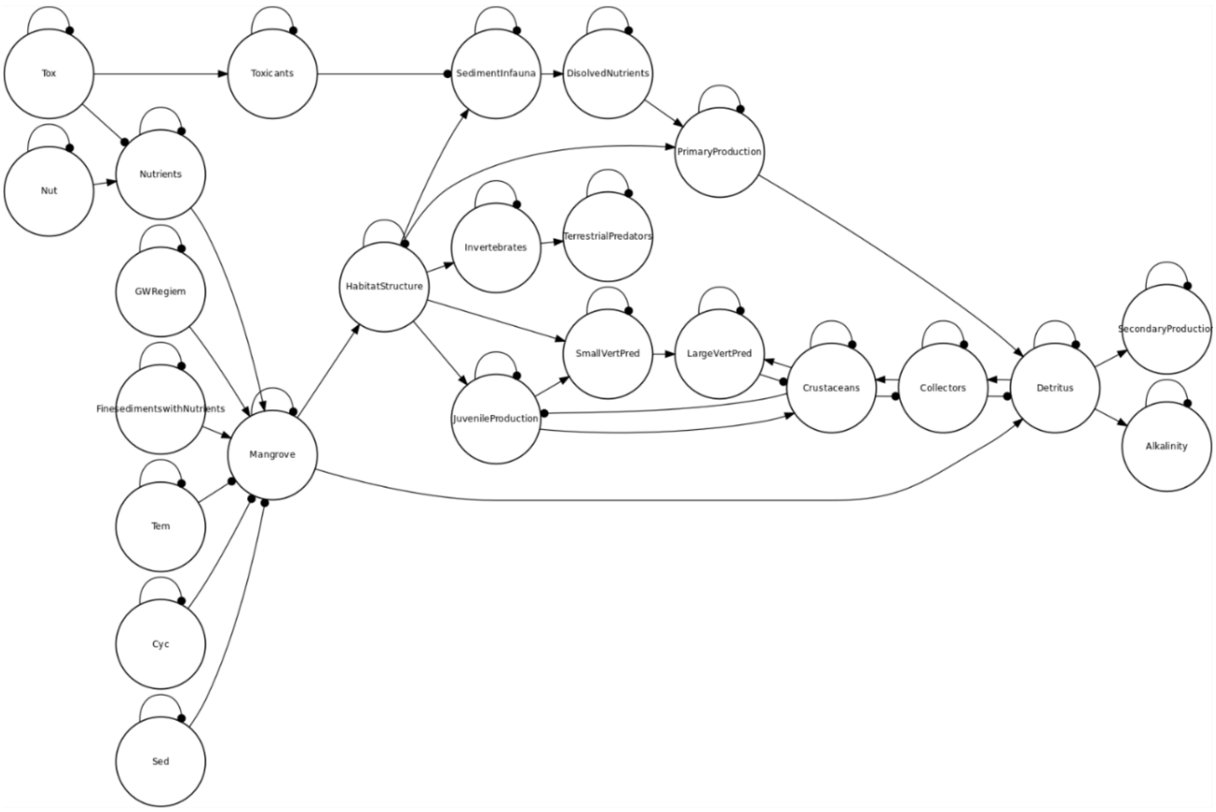

Figure 3: Qualitative Models for Mangrove Ecosystem Complexes. Pressures are Increased Temperature (Temp), Cyclones (Cyc), Excess Nutrients (Nut), Increased Sediments (Sed), Toxicants (Tox)

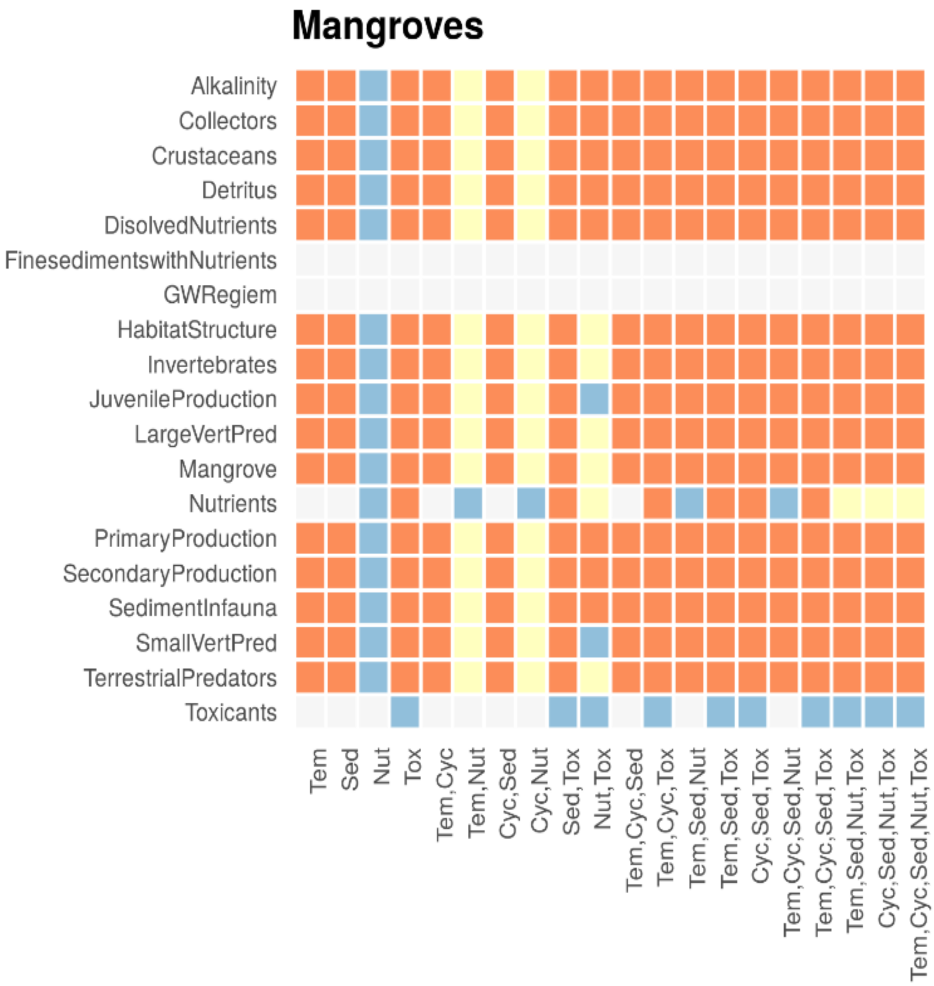

Figure 4: Scenario response for the change under different combinations of pressures. Pressures are as above. Blue shows positive change, red negative change and yellow no change. Grey nodes represent uncertain outcomes

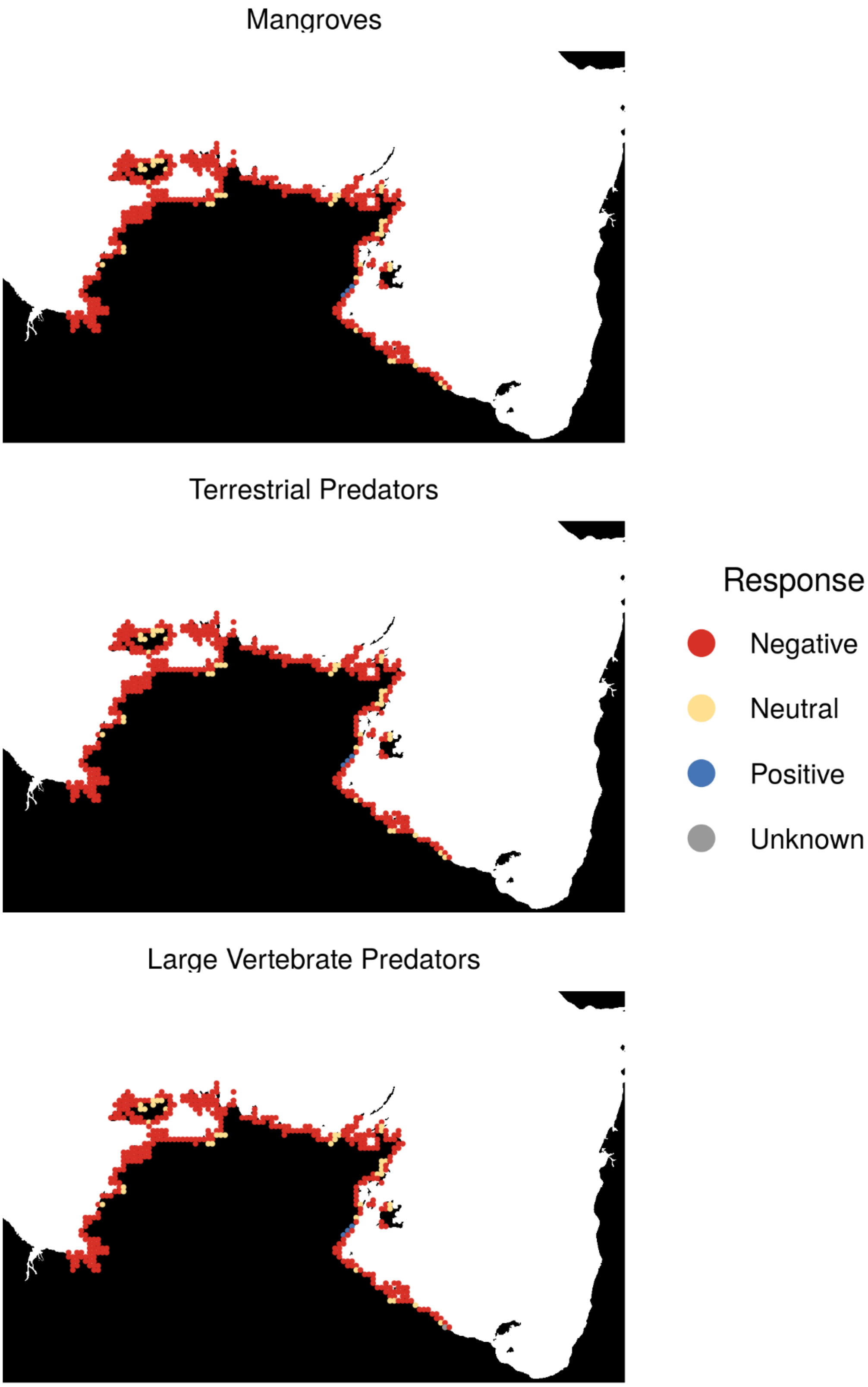

Figure 5: Spatial response to pressures for Key Natural Values in Mangroves

4.2 Seagrass

Seagrass ecosystem complexes (Figure 5) are impacted significantly by increased temperature, toxicants, excess nutrients and cyclones (Figure 6). These pressures singly, or in combination with other pressures affect all components of the ecosystem. The key natural value of the seagrass ecosystem complex is the seagrasses themselves, which provide habitat, structure and food for many of the species that occur there. Other key natural values (turtles, dugongs, large apex predators - sharks) are equally impacted by any loss of seagrass. All natural values are likely to be impacted across the range of seagrass ecosystem complexes (Figure 7).

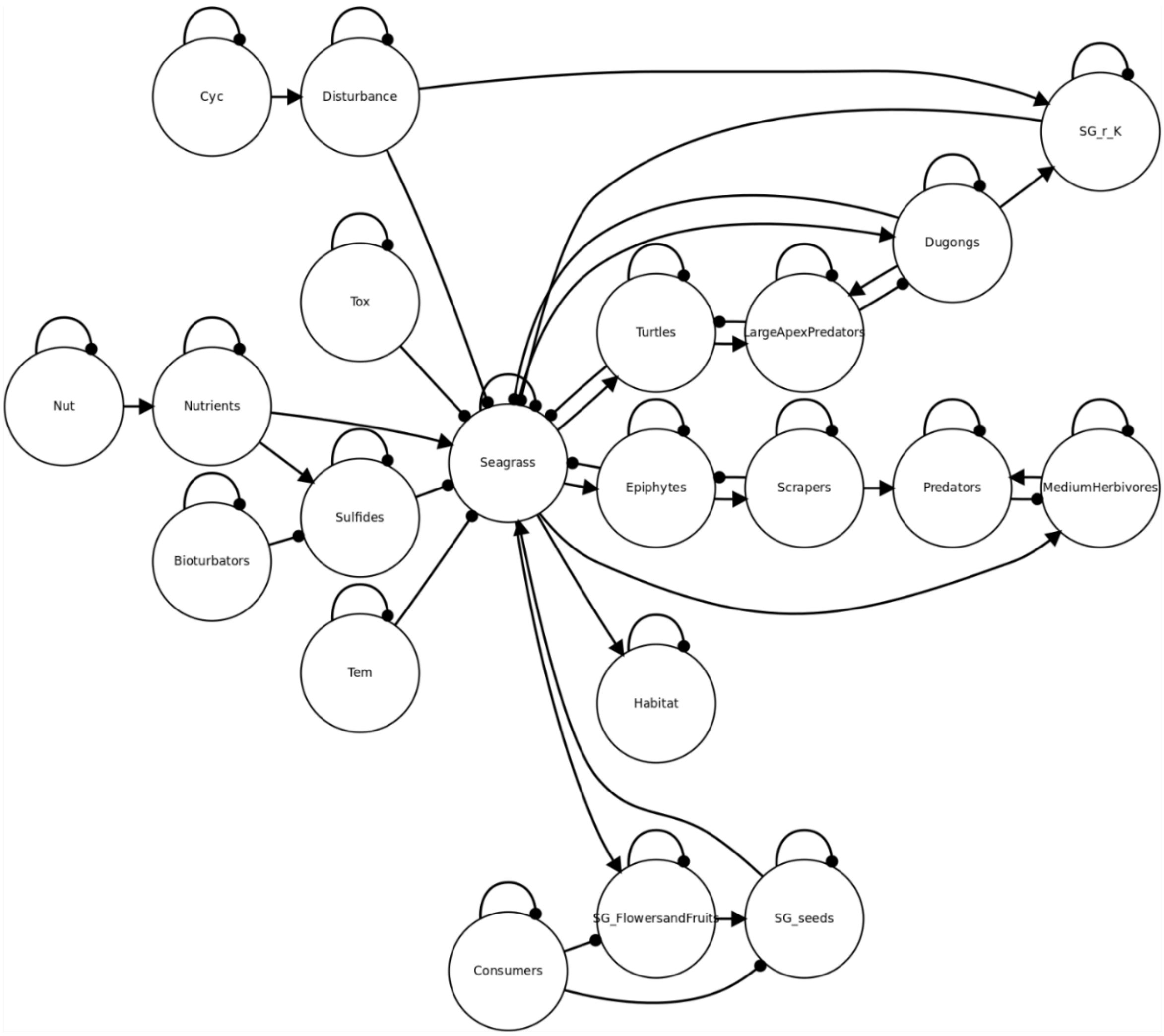

Figure 6: Qualitative Model for Seagrass. Pressures are Increased Temperature (Temp), Toxicants (Tox), Excess Nutrients (Nut) and Cyclones (Cyc).

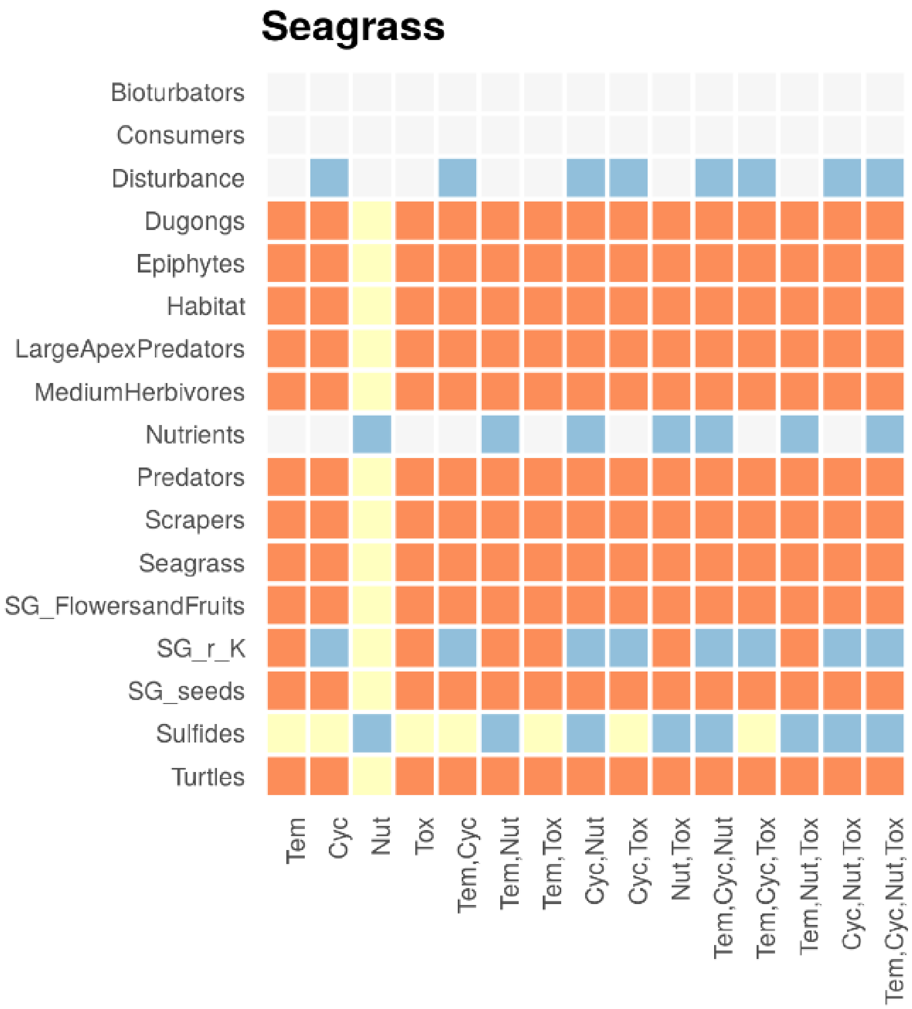

Figure 7: Scenario response for the change under different combinations of pressures. Pressures are as above. Blue shows positive change, red negative change and yellow no change. Grey nodes represent uncertain outcomes

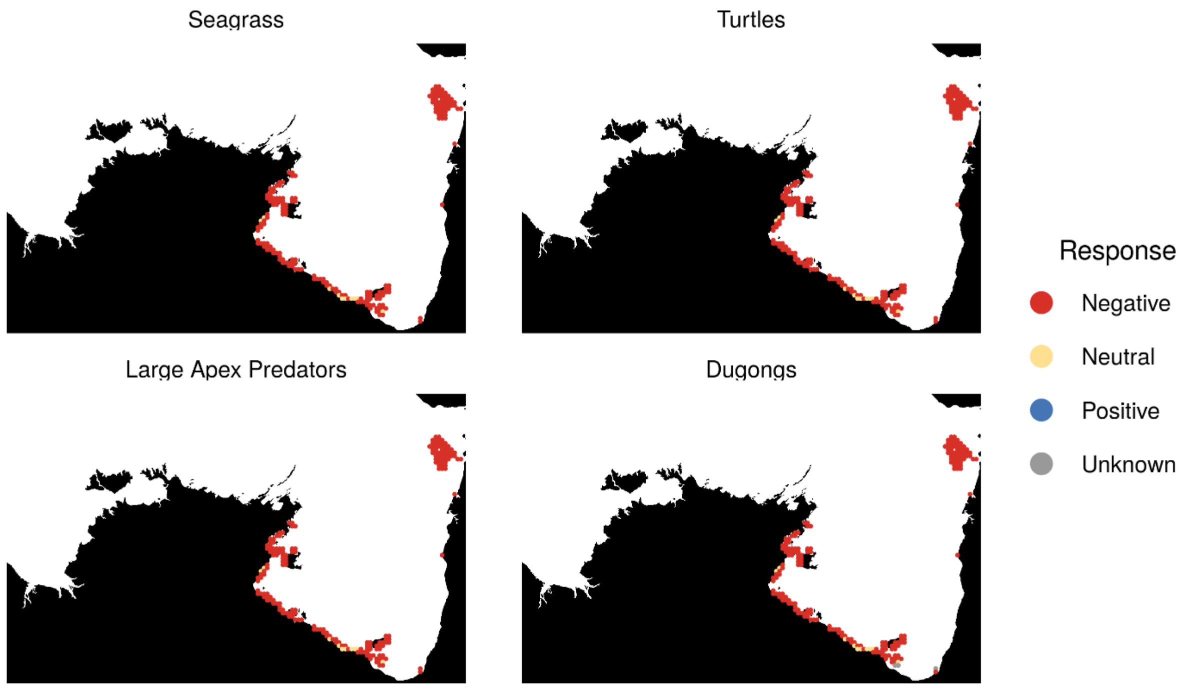

Figure 8: Spatial response of Key Natural Values in seagrass to pressures

4.3 Shoals and Banks

The qualitative model for Offshore Shoals and Banks was developed as a result of the NESP Marine Biodiversity Hub surveys of the Oceanic Shoals (Caley *et al.* 2015 – Figure 8). The pressures acting on shoals and banks are increased temperature, oil & gas spills, cyclones and increased nutrients. Increases in temperature and oil & gas spills both directly affect high relief algae and increased nutrient indirectly affects high relief algae. Cyclones indirectly affect both high relief algae and high relief filter feeders. Consequently, high relief is impacted under all scenarios (Figure 9) but high relief filter feeders are only impacted by cyclones. Ecosystem components that rely on algae are also impacted under many scenarios, but those linked to filter feeders are not. This is reflected in the spatial distribution of impacts on key natural values. Benthic and pelagic piscivores and reef invertebrates are impacted throughout the shoals' extent, but filter feeders and herbivorous fish are not impacted in the same way and may actually increase under some scenarios (Figure 10).

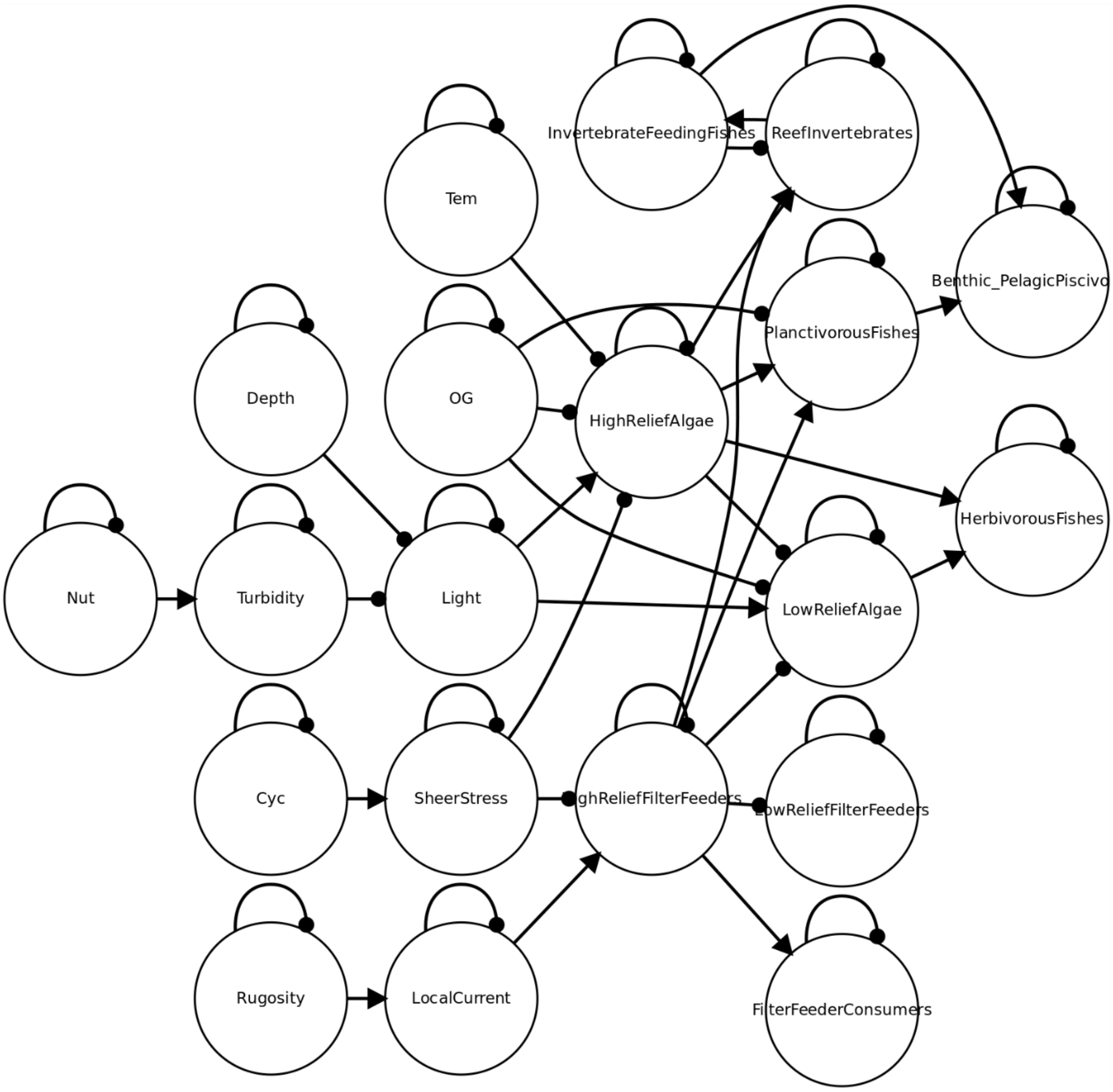

Figure 9: Qualitative Model for Shoals and Banks. Pressures are Increased Temperature (Temp), Oil & Gas Spills (OG), Cyclones (Cyc) and Increased Nutrients (Nut).

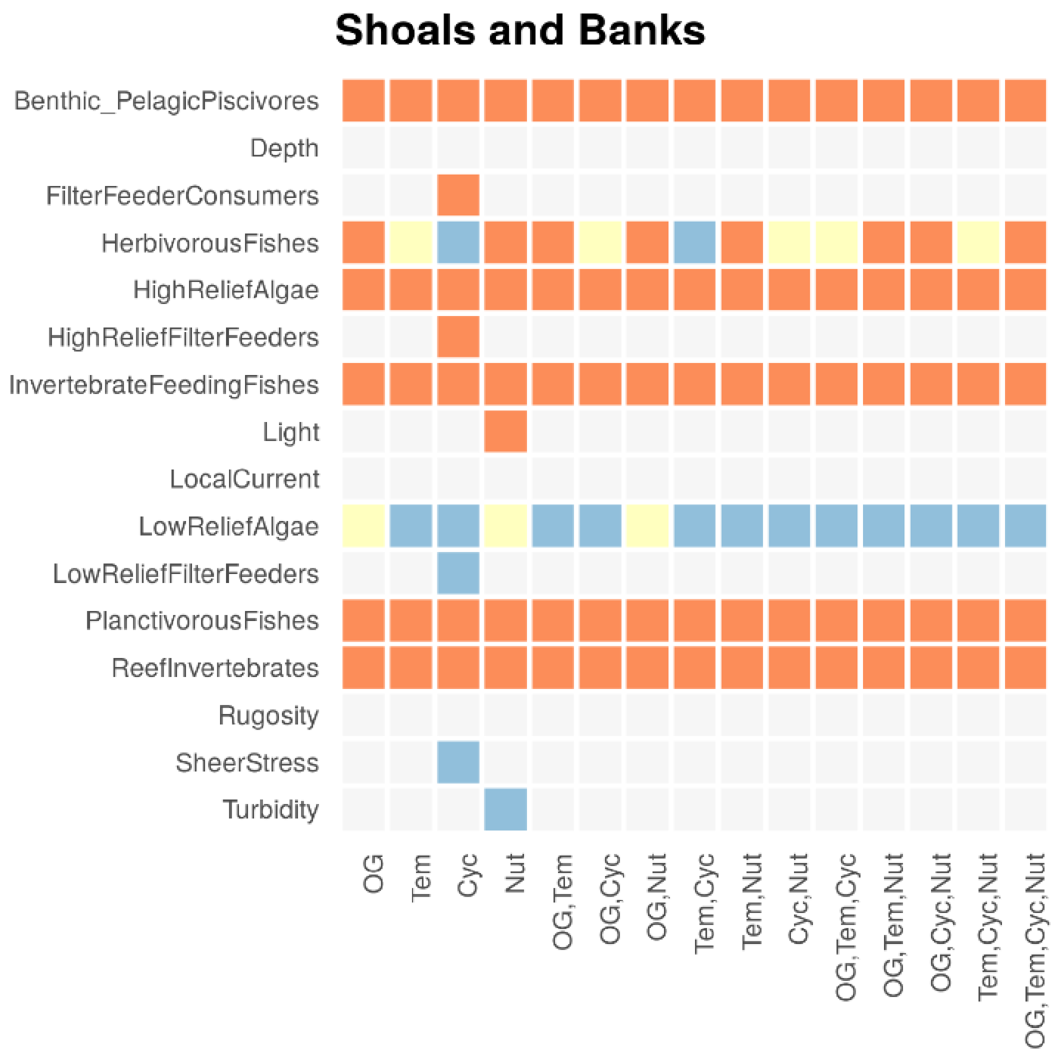

Figure 10: Scenario response for the change under different combinations of pressures. Pressures are as above. Blue shows positive change, red negative change and yellow no change. Grey nodes represent uncertain outcomes

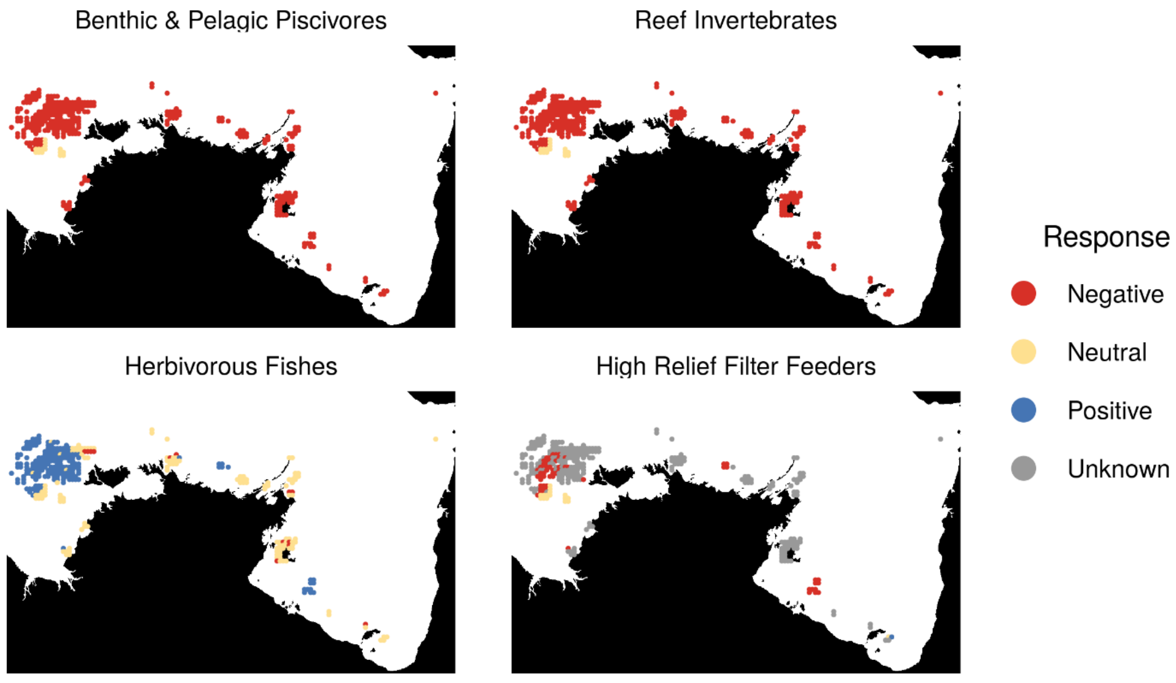

Figure 11: Spatial response of Key Natural Values in Shoals and Banks to pressures.

4.4 Offshore coral reefs <30 m

The qualitative models for inshore and offshore coral reefs are identical. The pressures on these ecosystem complexes are cyclones, ship strike, increasing temperature, ghost nets and commercial fisheries (Figure 11). The ecosystem components of offshore and inshore reefs respond in different ways to pressures. Many components are only slightly affected but apex predators, corals, coral consumers, meso predators and small fish are impacted under most scenarios (Figure 12). Turtles are only affected by ghost nets. The spatial distribution of likely impacts for offshore reefs shows that corals, apex predators and meso predators will have a negative change across the ecosystem complex, but invertebrates will show little change and turtles are only impacted where ghost nets are likely to be present (Figure 13).

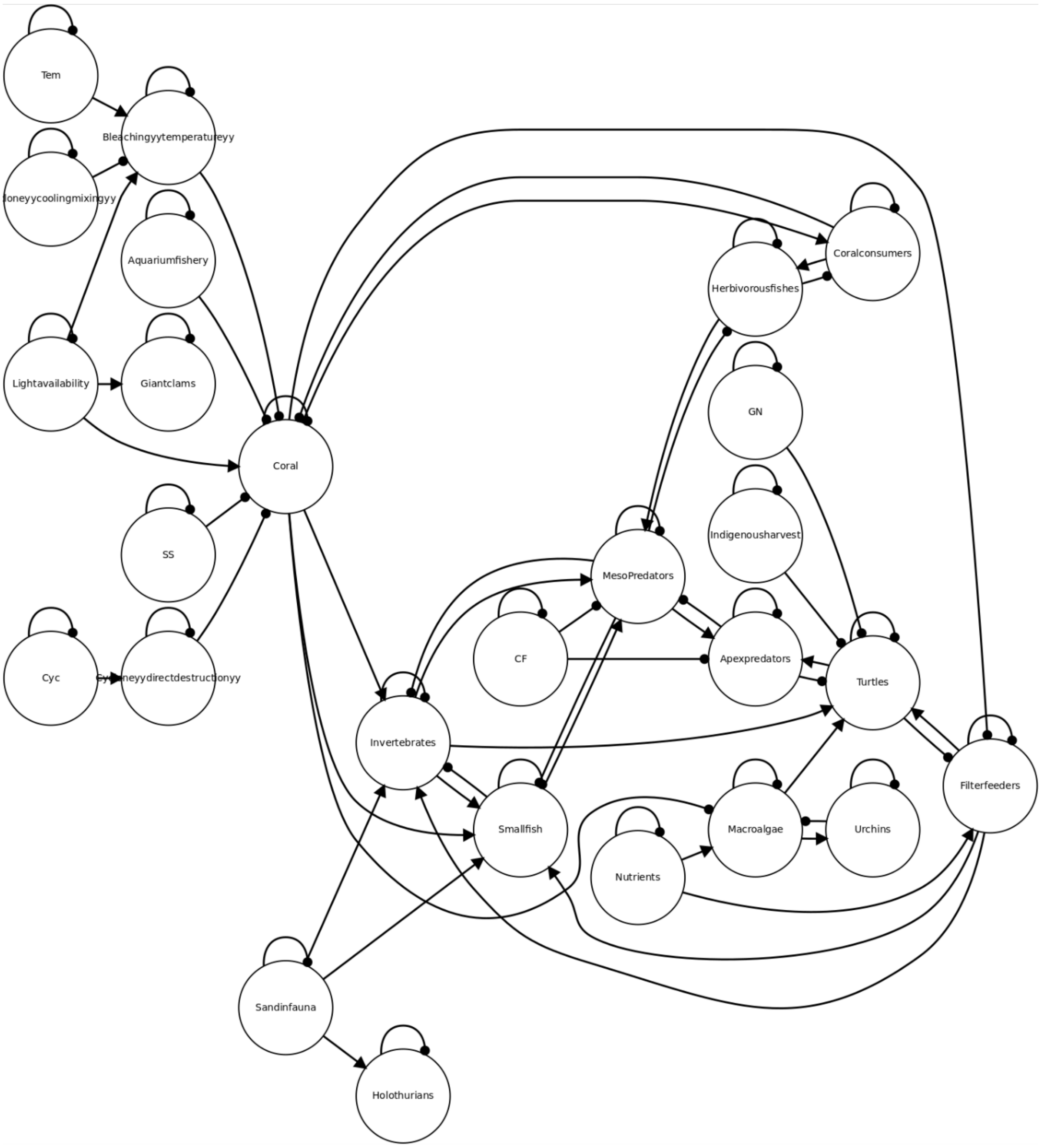

Figure 12: Qualitative Model for both Inshore and Offshore Coral Reefs. Pressures are Cyclones (Cyc), Ship Strike (SS), Increasing Temperature (Temp), Ghost Nets (GN) and Commercial Fisheries (CF)

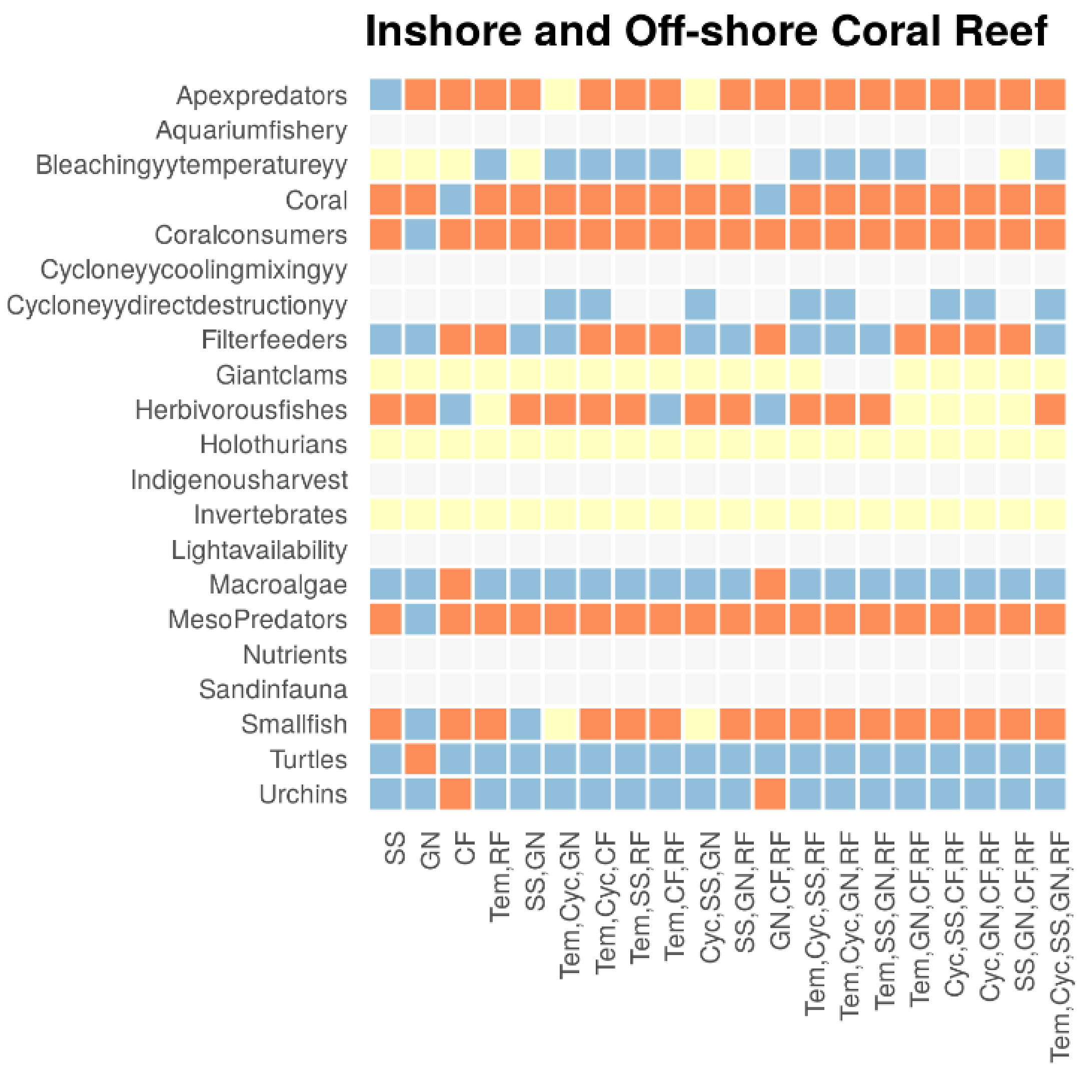

Figure 13: Scenario response for the change under different combinations of pressures. Pressures are as above. Blue shows positive change, red negative change and yellow no change. Grey nodes represent uncertain outcomes

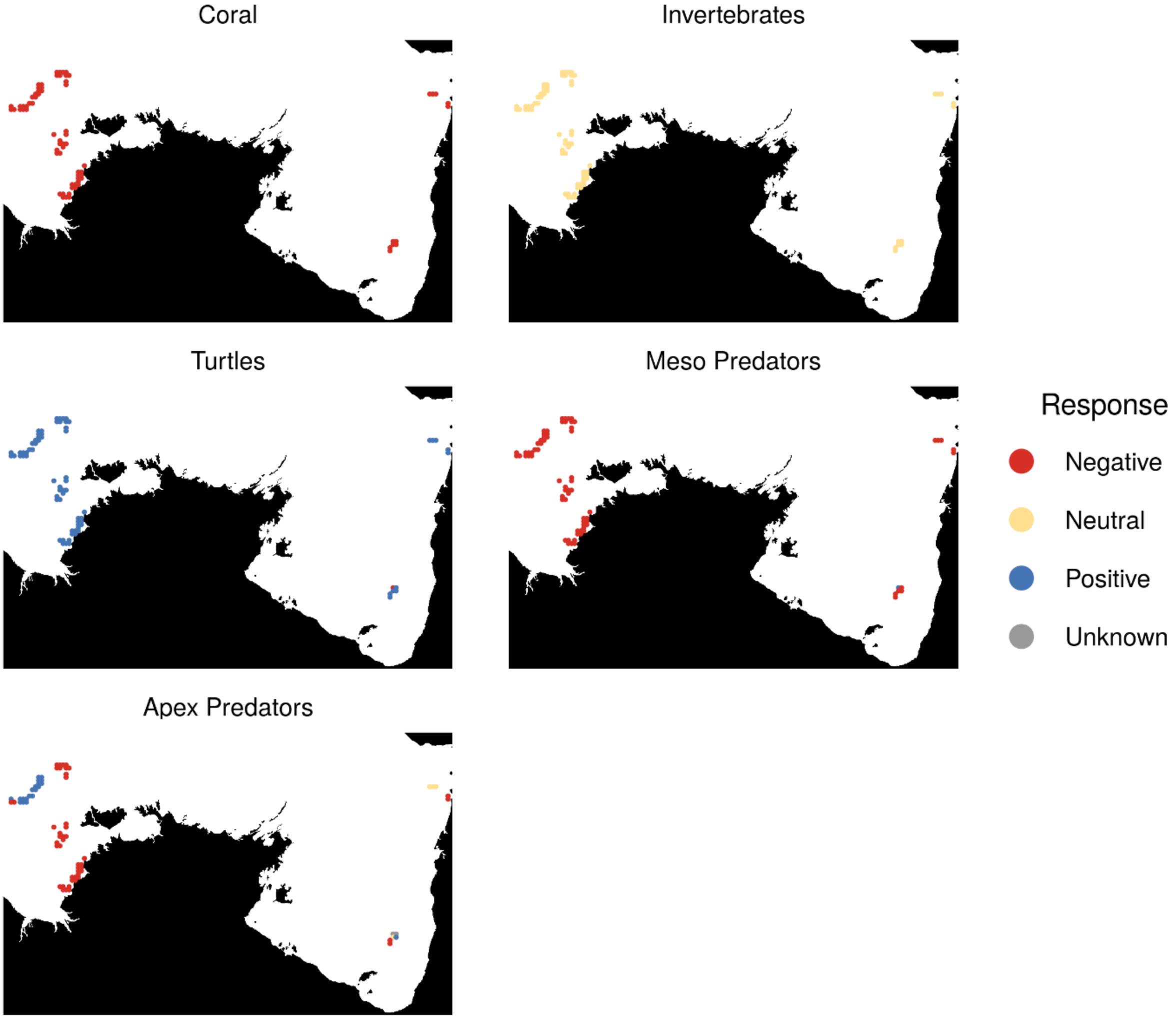

Figure 14: The spatial response of Key Natural Values in Offshore Coral Reefs to pressures.

4.5 Inshore coral reefs <30

The qualitative model for inshore reefs and scenario responses is identical to offshore reefs and is shown in Figures 11&12. The spatial distribution of impacts for inshore reefs is restricted to the coastal areas. Corals, meso predators and apex predators are impacted, and turtles and invertebrates show positive changes or no change respectively (Figure 14).

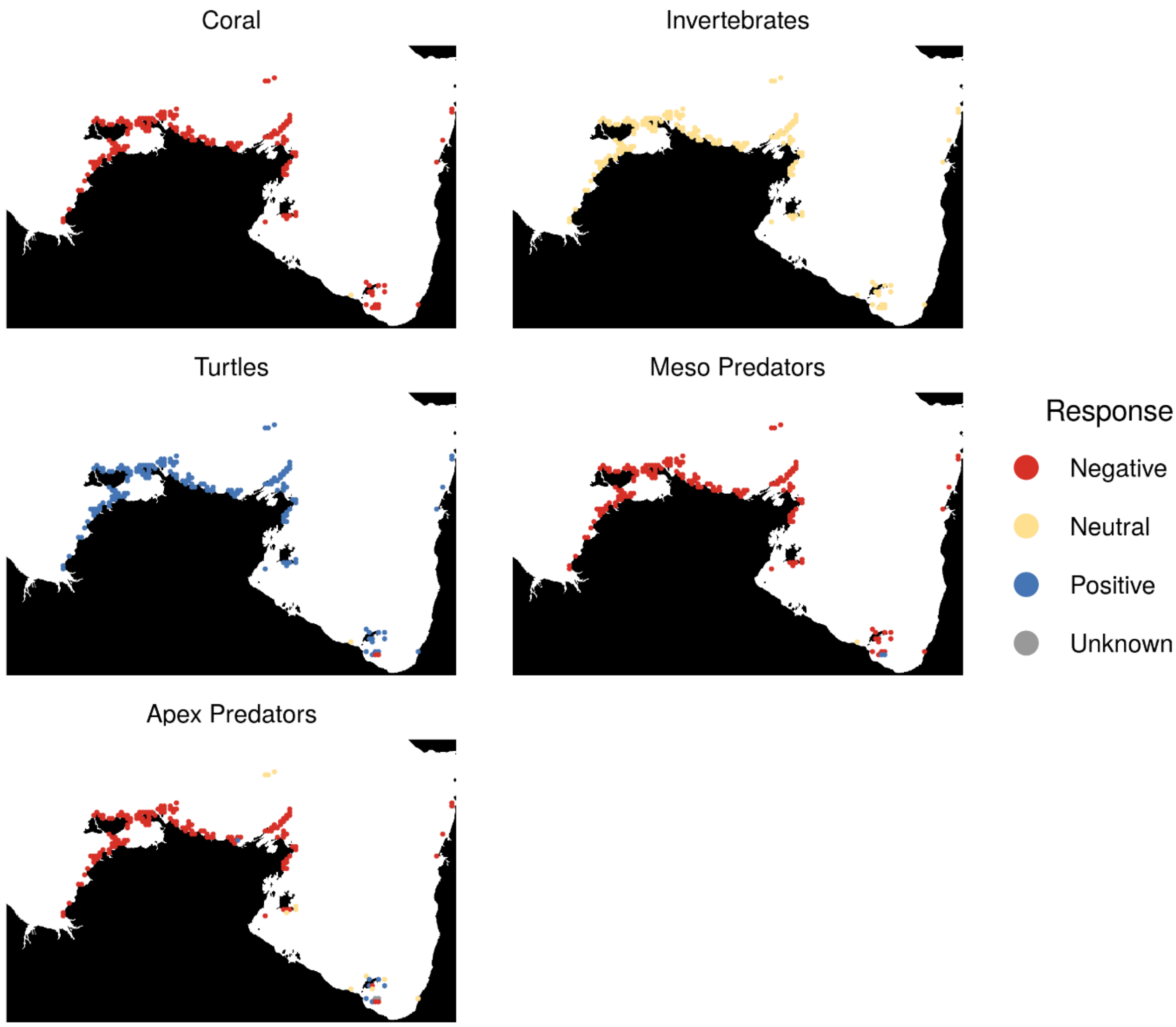

Figure 15: The spatial response of Key Natural Values in Inshore Coral Reefs to pressures.

4.6 Mesophotic reef and sediment > 30

Mesophotic reef and sediment is a complex system that encompasses both hard and soft substrates in depths between 30m and 150m. It includes the deepest areas considered in this work. This ecosystem complex is both deep and offshore and the pressures on it are limited to oil and gas spills, commercial fisheries and recreational fisheries (Figure 15). The two fisheries pressures impact apex and meso predators and the system associated with them while oil and gas spills impact corals (both phototrophic and heterotrophic) and the benthic system associated with them (Figure 16). The benthic associated systems show no likely change except in locations where oil and gas spill have been recorded (Figure 17). However, due to both the extensive footprint of recreational and commercial fisheries, apex and meso predators are likely to have decreased (Figure 17).

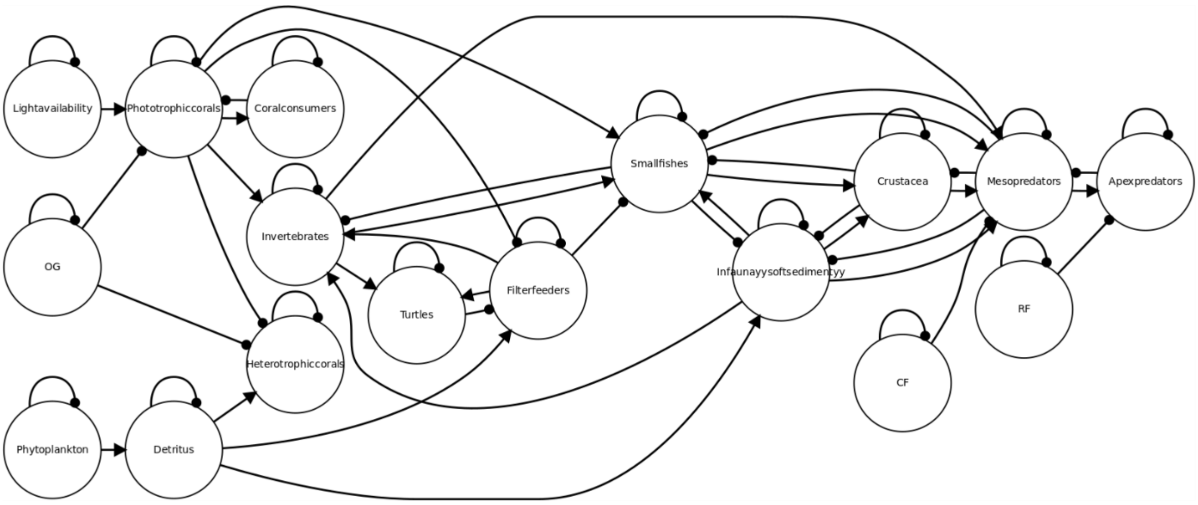

Figure 16: Qualitative model for Mesophotic reefs and sediments between 30m and 150m. Pressures are Oil & Gas (OG), Commercial Fisheries (CF) and Recreational Fisheries (RF)

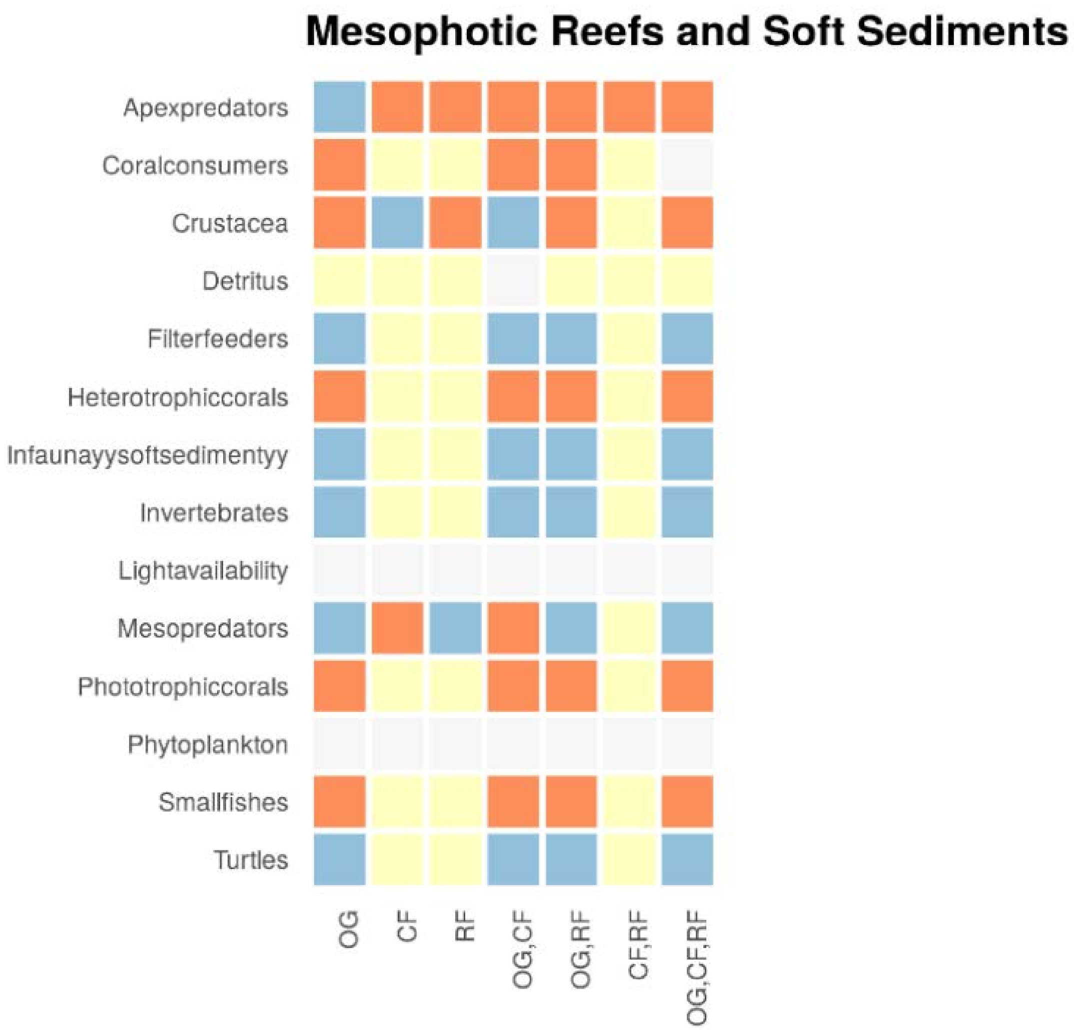

Figure 17: Scenario response for the change under different combinations of pressures. Pressures are as above. Blue shows positive change, red negative change and yellow no change. Grey nodes represent uncertain outcomes

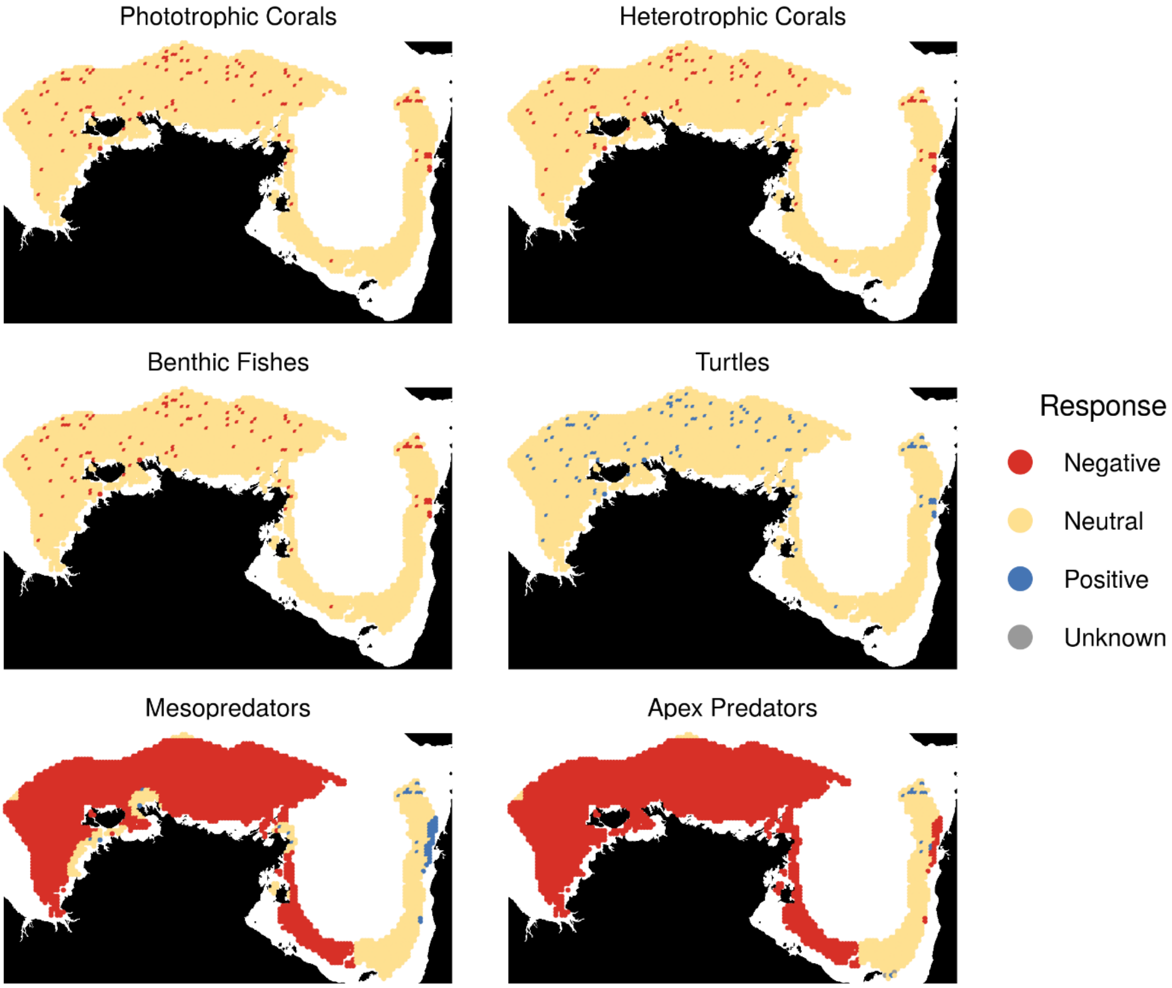

Figure 18: The spatial response of Key Natural Values in Mesophotic Reefs and Sediment to pressures.

4.7 Sediment and rocky reef < 30m

The shallow sediment and ecosystem complex is restricted to depths less and 30m that are not seagrass, coral reef or mangroves. The pressures identified on this complex are excess nutrients, oil and gas spills and trawl fisheries (Figure 19). The structure of the ecosystem complex has several feedback loops and combinations of each pressure produces different outcomes for the ecosystem components (Figure 20). Increasing nutrients tends to cause a positive change to the many components, whereas increasing trawl and oil spills decrease many components. Consequently, the spatial distribution of expected changes in the key natural values is complex, showing areas with both positive and negative change for all the key natural values (Figure 21).

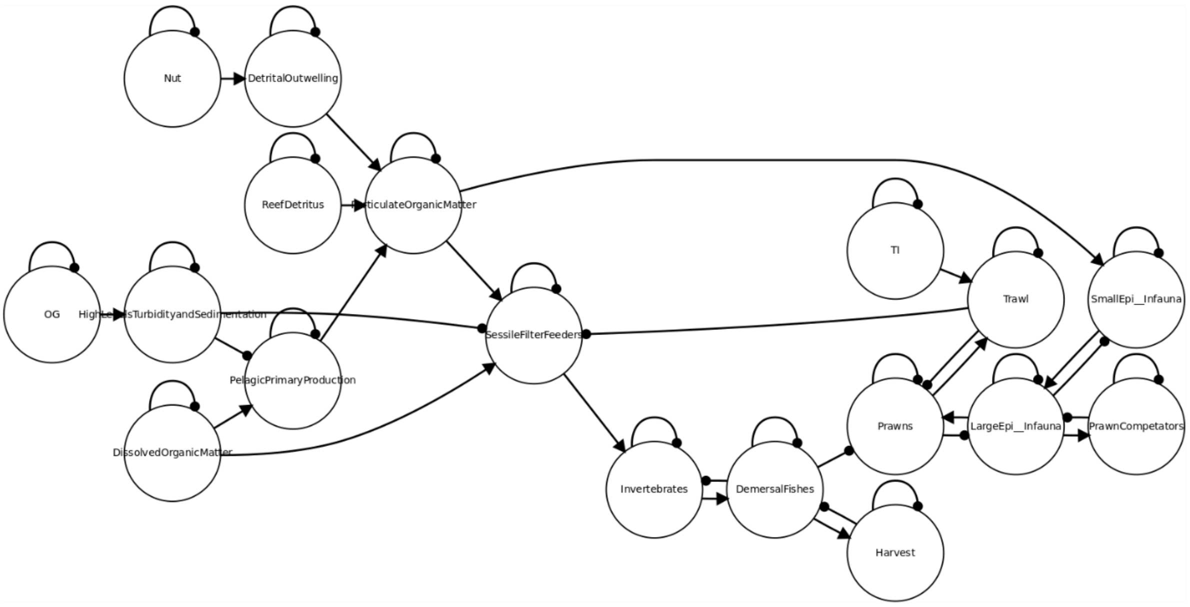

Figure 19: Qualitative Model for shallow soft sediment and reef less than 30m. Pressures are Excess Nutrients (Nut), Oil and Gas (OG), Excess Trawl Fisheries (Ti)

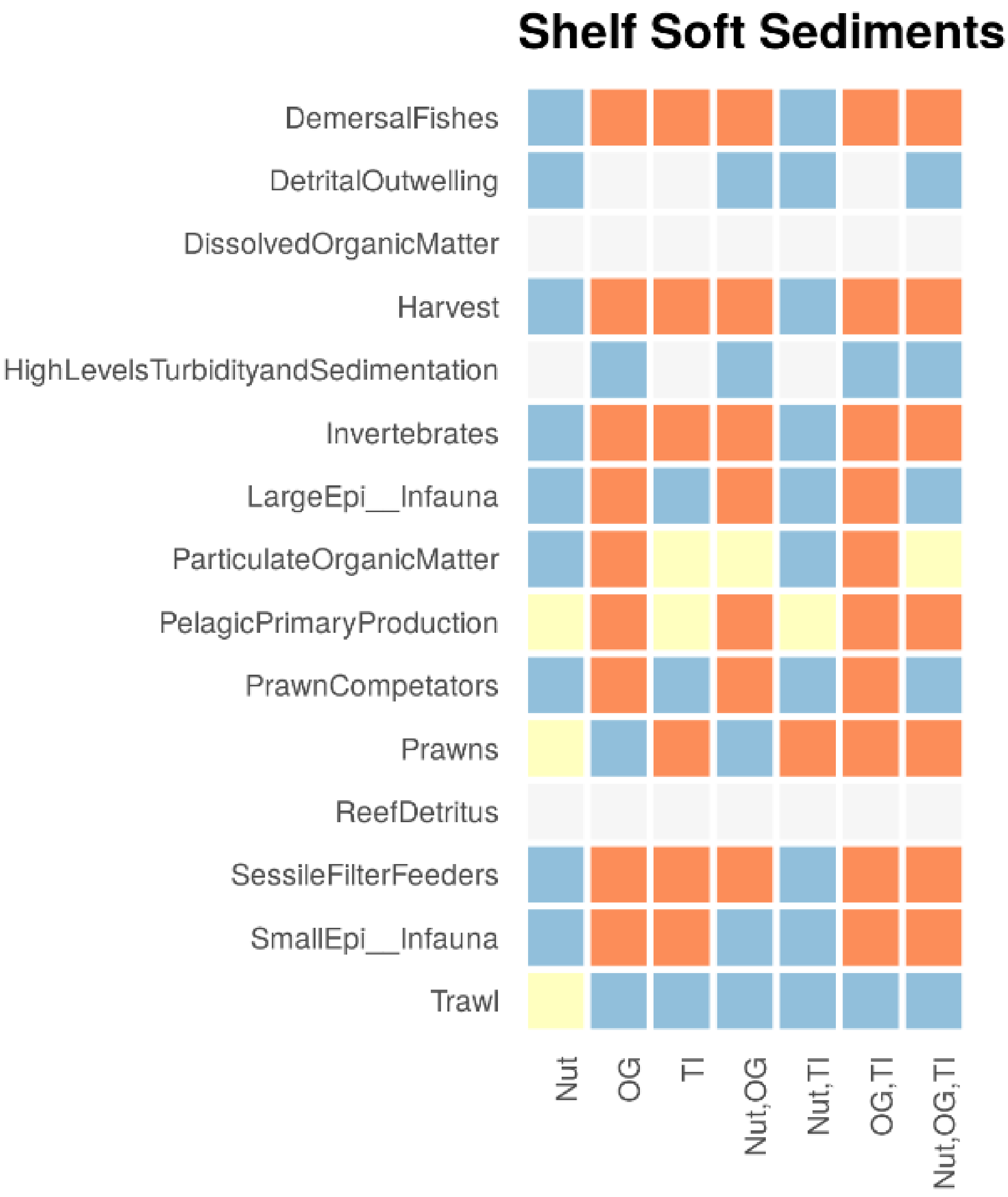

Figure 20: Scenario response for the change under different combinations of pressures. Pressures are as above. Blue shows positive change, red negative change and yellow no change. Grey nodes represent uncertain outcomes

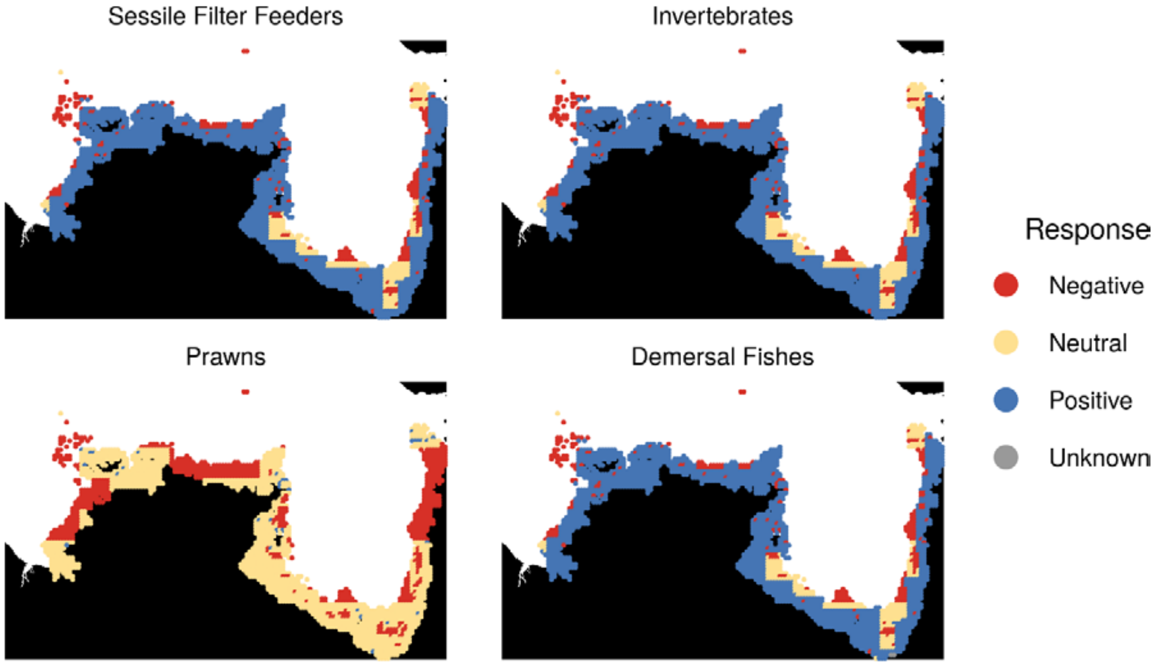

Figure 21: Spatial response of Key Natural Values to pressures for shallow sediments and rocky reefs

4.8 Gulf of Carpentaria

The qualitative model for the Gulf of Carpentaria is documented in Hosack et al. (2012) and described in detail there. It is a Key Ecological Feature (KEF). Pressures acting on this KEF are commercial and recreational fisheries, oil and gas spills and ghost nets (Figure 22). The Gulf is a large complex system with pressures that act on multiple ecosystem components. Consequently, the expected impacts of the system are complex (Figure 23). Small pelagics show a positive response to all the combinations of pressures but sharks show consistently negative responses – with all other ecosystem components varying between these extremes. The spatial distribution of the key natural values (Figure 24) shows a consistently negative response for sharks, turtles, cetaceans & large piscivorous fish show negative responses but seabirds are consistently positive.

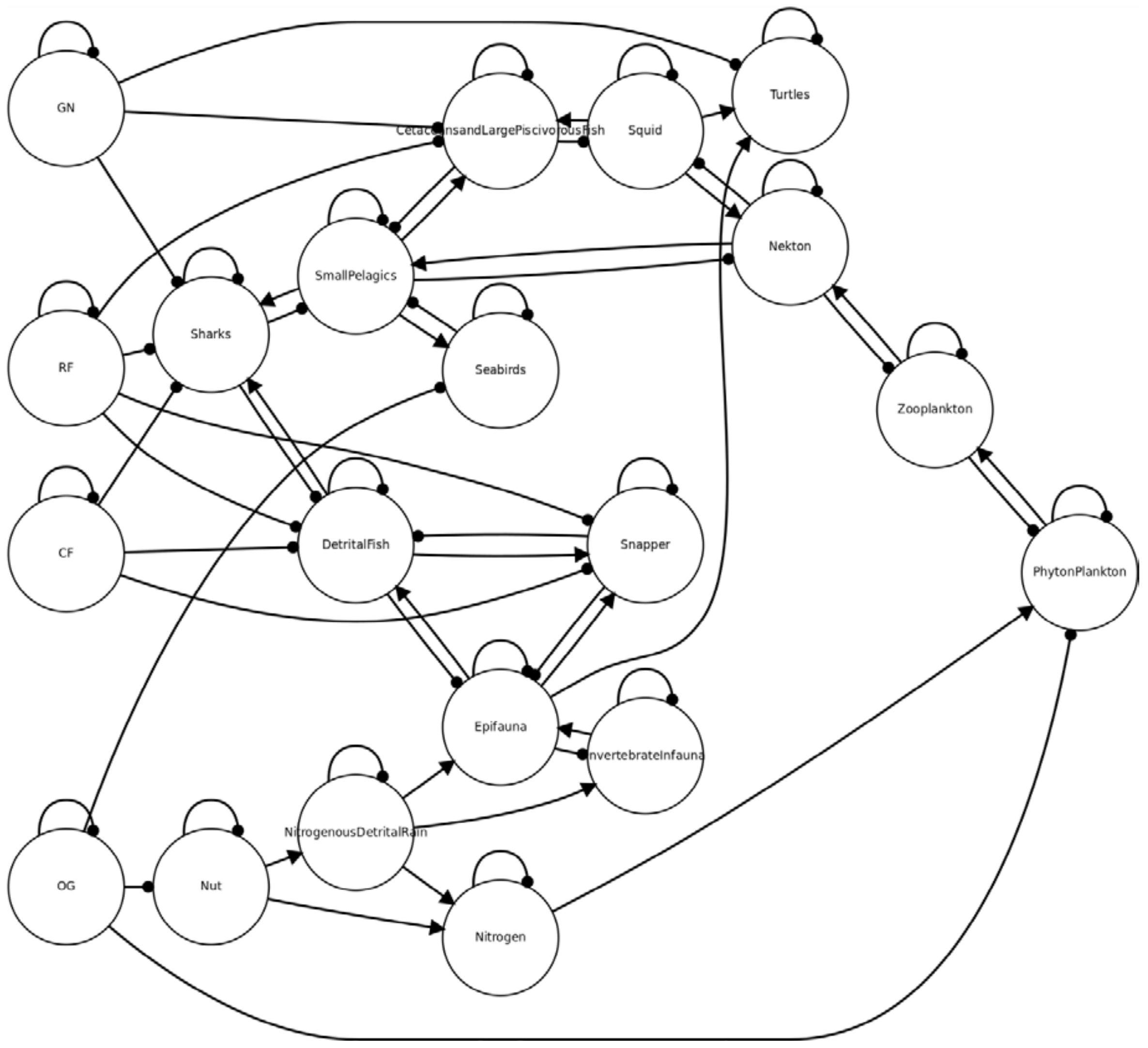

Figure 22: Qualitative model for Gulf of Carpentaria KEF. Pressures are Commercial Fisheries (CF), Recreational Fisheries (RF), Ghost Nets (GN) and Oil Spills (OG)

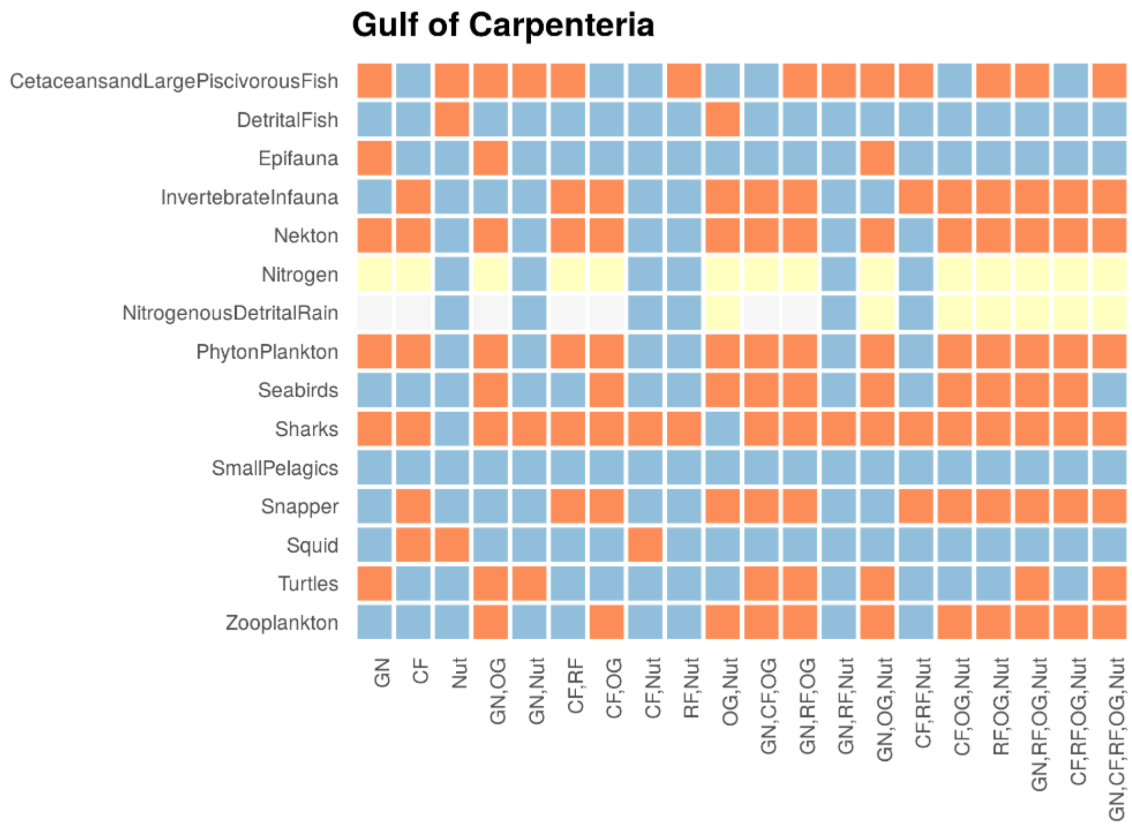

Figure 23: Scenario Responses for ecosystem components in the Gulf of Carpentaria. Pressures acting on the system are described above. Blue shows positive change, red negative change and yellow no change.

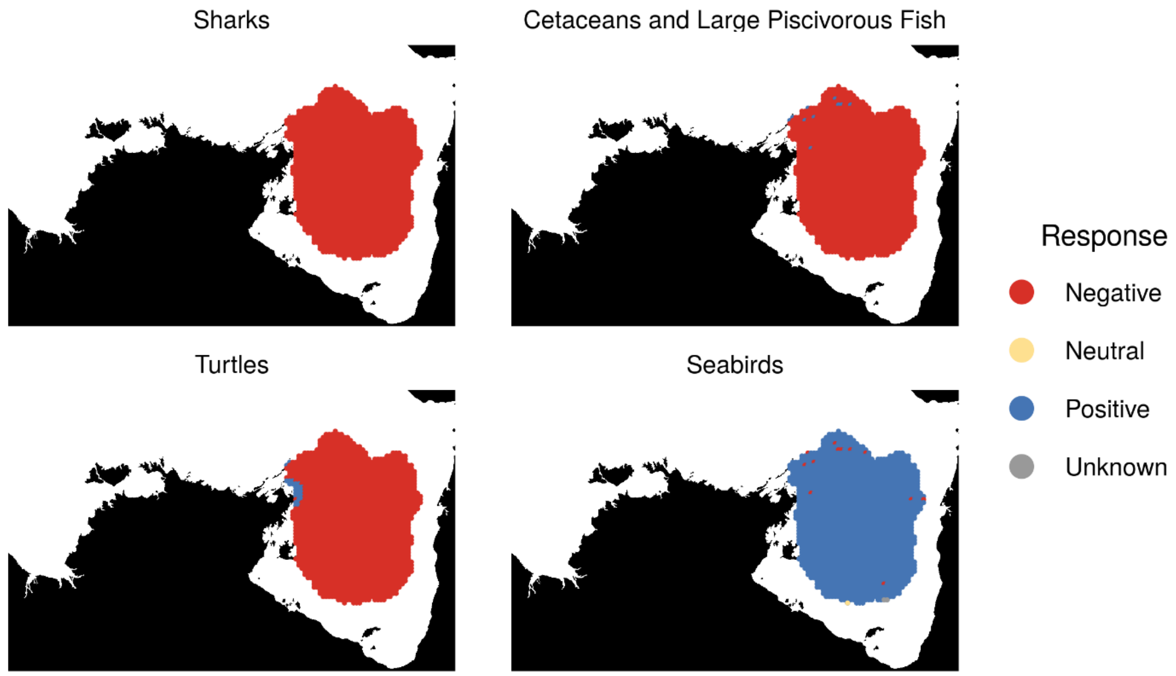

Figure 24: Spatial response of Key Natural Values in the Gulf of Carpentaria

4.9 Open Water

Open Water Ecosystem Complexes in the Northern Marine Region are potentially impacted by plastics, commercial and recreational fisheries, ghost nets, noise and shipping (Figure 25). For this analysis we assumed that fisheries impacts were small and only considered the cumulative effects of the other pressures. This limits the impacts to only the large key natural values such as turtles, seabirds and sharks and rays (Figure 26). Key natural values under this scenario are mostly unchanged, with the exception of turtles and marine mammals (Figure 27).

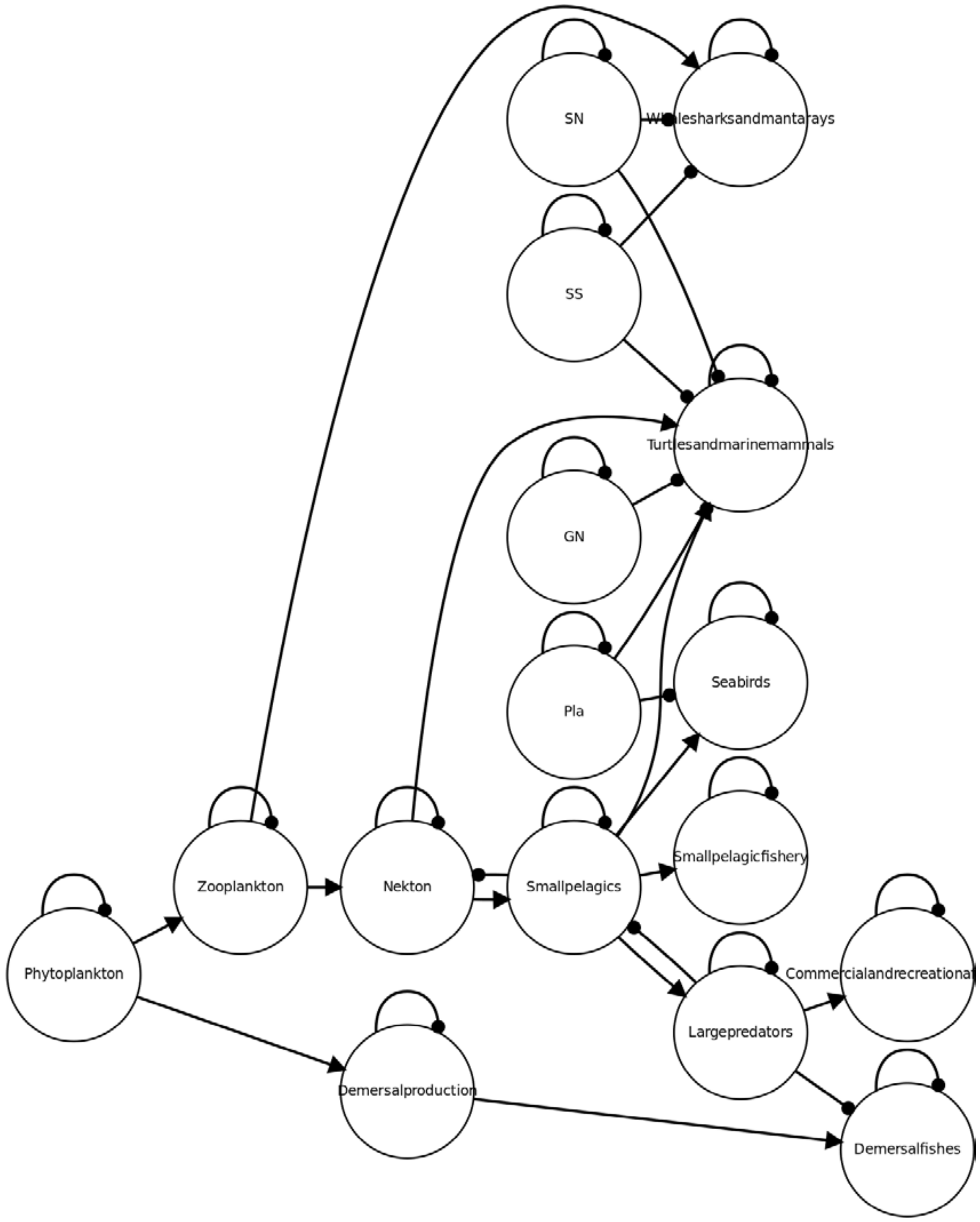

Figure 25: Qualitative Model for Open Water Ecosystem Complex. Pressures are Plastics (Pla), Commercial and Recreational Fisheries, Ghost Nets (GN), Noise (SN) and Shipping (SS).

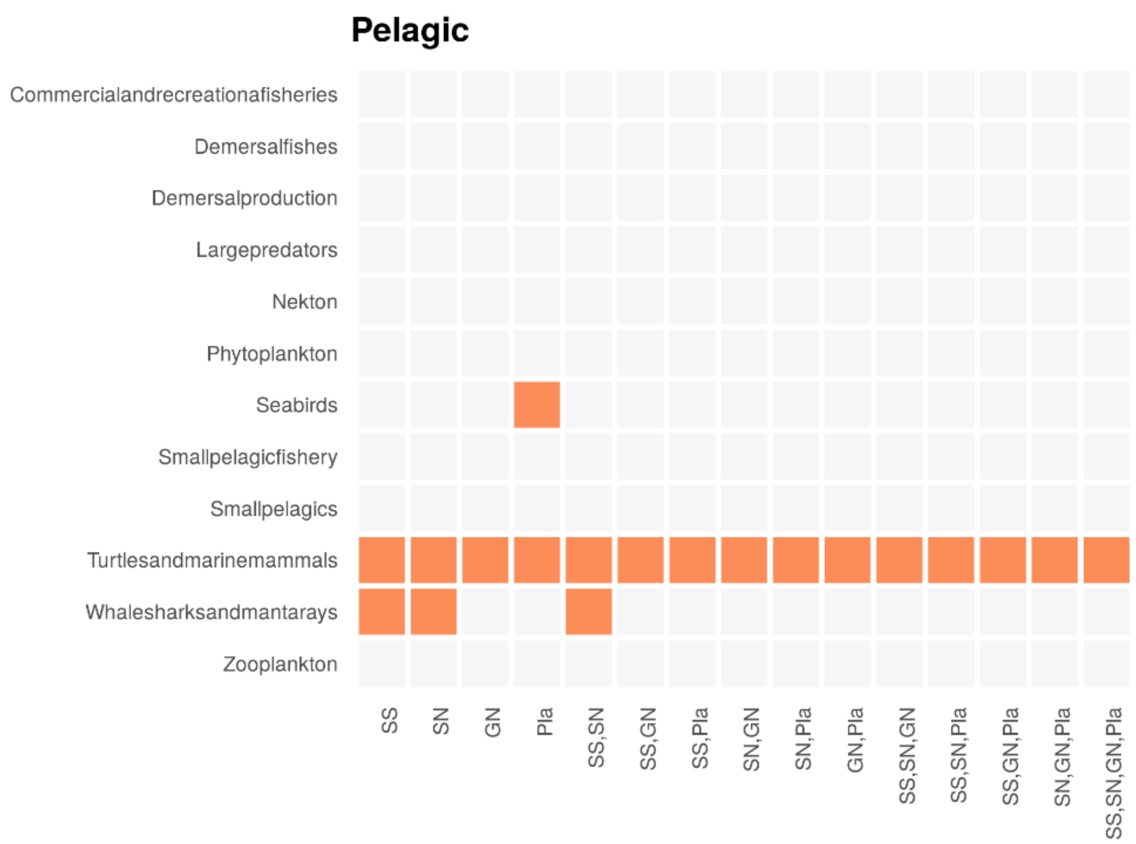

Figure 26: Scenario response for the change under different combinations of pressures. Pressures are as above. Grey nodes represent uncertain outcomes

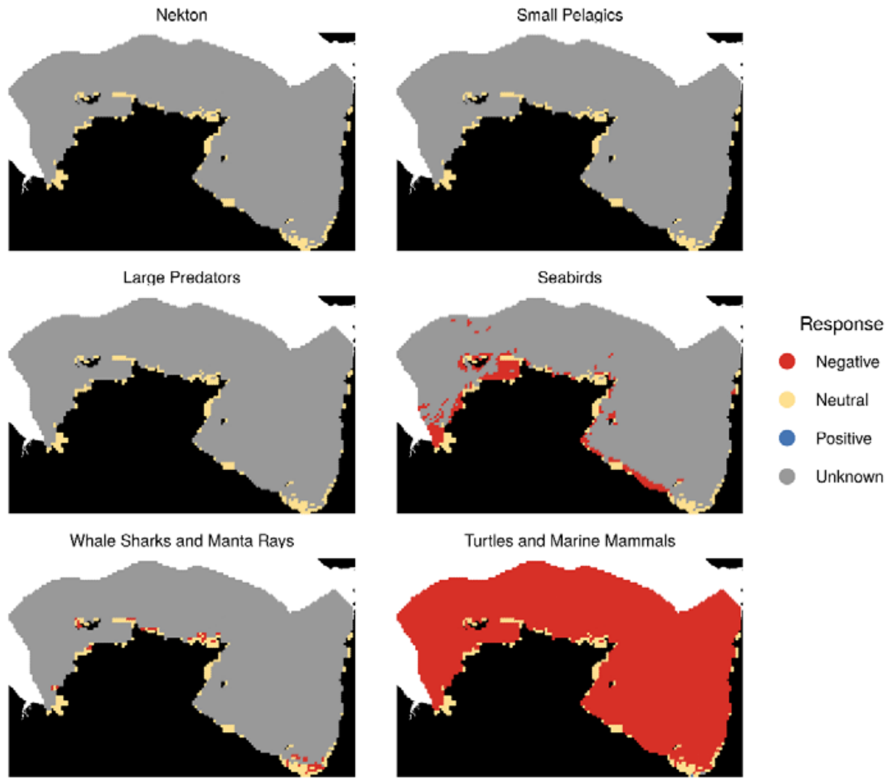

Figure 27: Spatial Response of Key Natural Values in Open Water

5. Discussion

This report details a hazards assessment for ecosystem complexes as defined under the Parks Australia MERI framework. The results show that even in an area with low use, there is a significant number of key natural values that may be impacted in many of the ecosystem complexes. The ecosystem complexes showing the highest number of hazards are those found close to shore (i.e. mangroves and seagrass) (Figure 28). Areas offshore such as the Mesophotic reefs, offshore reefs and the Gulf of Carpentaria (Figure 28) show fewer hazards of concern, but large megafauna remain at risk from a variety of activities, especially in Open water (Figures 26 & 27). In some of the ecosystems there were a large number of uncertain outcomes, such as Shoals and Banks and Open Water ecosystems. This indicated that there was uncertainty in how the system would change with the pressures that were observed across the Northern Marine Region

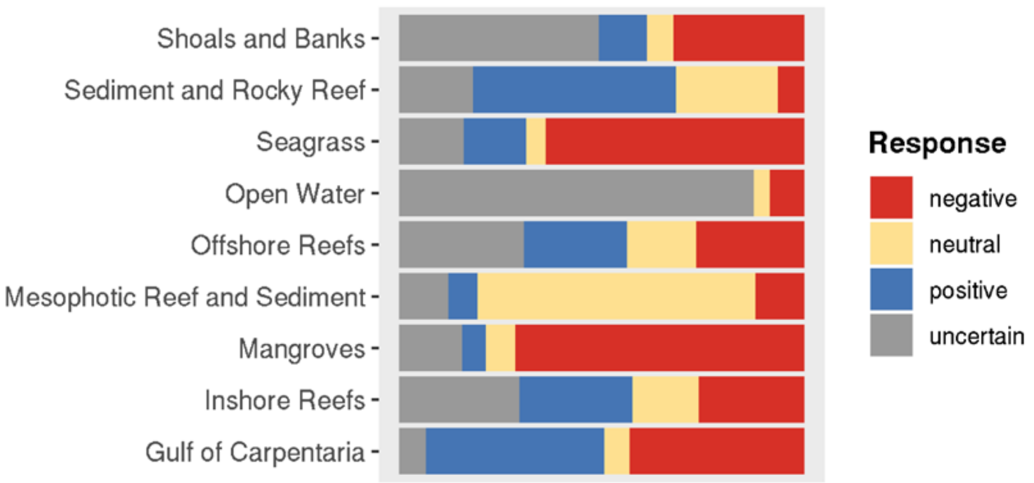

Figure 28: Total summed responses of ecosystems to the observed distribution of pressures

The next step, as identified in the GBR Guidelines, would be the description of dose response relationships between species and the pressures that act on them. This would allow for the quantification of direct impacts and a better understanding of which pressures would be of concern and where this might occur. The hazards assessment shown here can then be used to prioritise a more formal risk assessment process, either through expert elicitation or through a quantitative risk assessment process.

Where data is not available, the outputs from this work can be used to inform monitoring programs to collect the spatial and temporal data necessary to estimate impacts and the effectiveness of existing management actions.

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Appendix A – Workshop Attendees

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