

Bioregions of the South West Pacific Ocean

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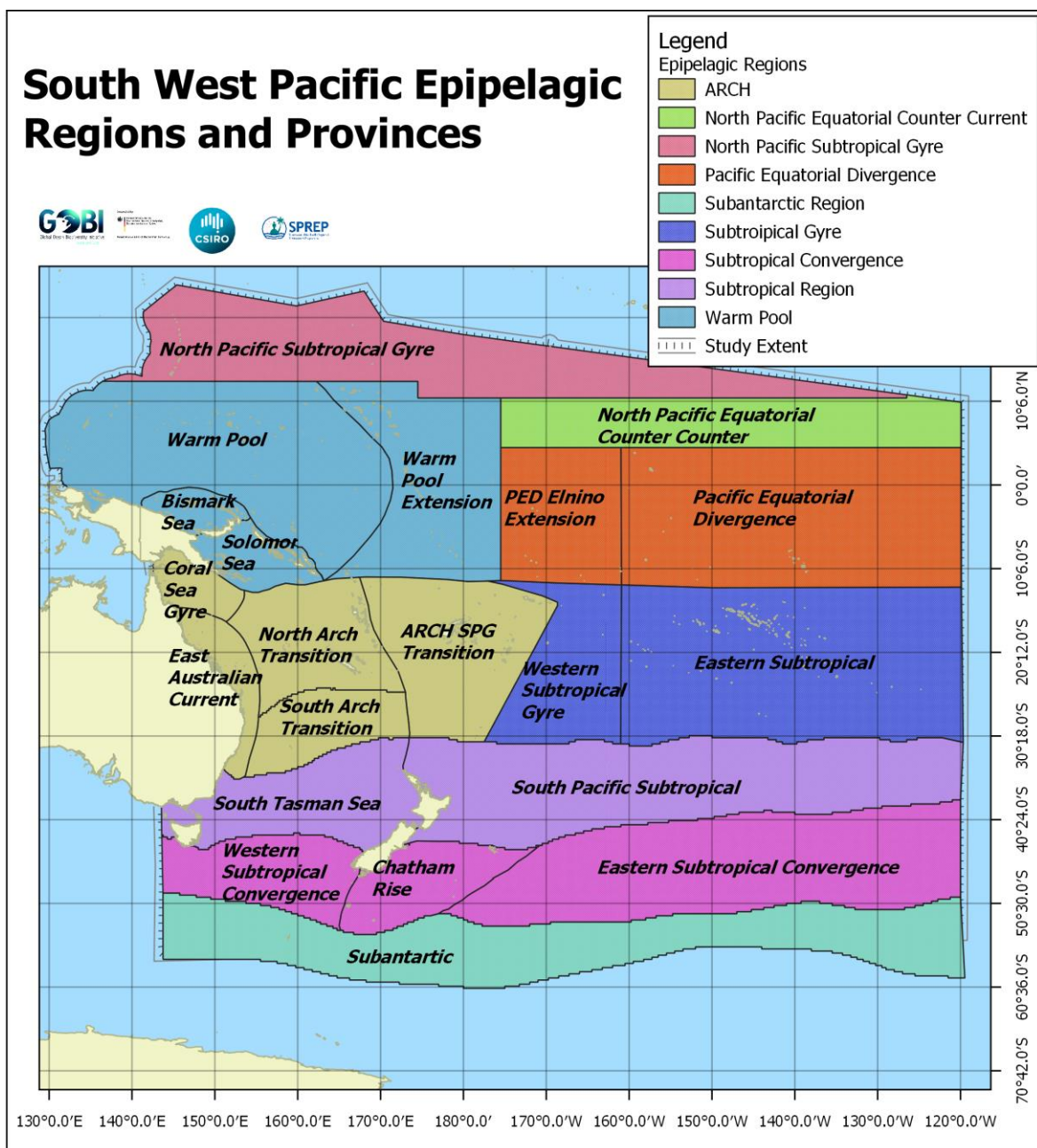
Bioregions of the South West Pacific Ocean

This project has developed sub-regional bioregionalisations for the western-south Pacific Ocean and the Indian Ocean. This combines approaches CSIRO developed in Australia, used in the Bay of Bengal (in collaboration with BOBLME) with similar approaches that have been used throughout the Indian and Pacific Oceans to derive a single combined bioregionalisation. The project has developed an expert derived bioregionalisation in the Indian and Pacific Oceans through expert workshops and novel statistical analysis of physical and biological data.

The project draws on experience in CSIRO, GOBI partners, and other collaborators, using approaches currently being trialled in Australia and around the Antarctic margins, and has collaborated with regional and national stakeholders to ensure a consistent approach. This Appendix contains the descriptions of each marine region and each province with the region. Where sufficient information exists it includes a description, a qualitative ecosystem model of the system and the pressures on it and a scenario analysis that explores the way the ecosystem changes with different pressures.

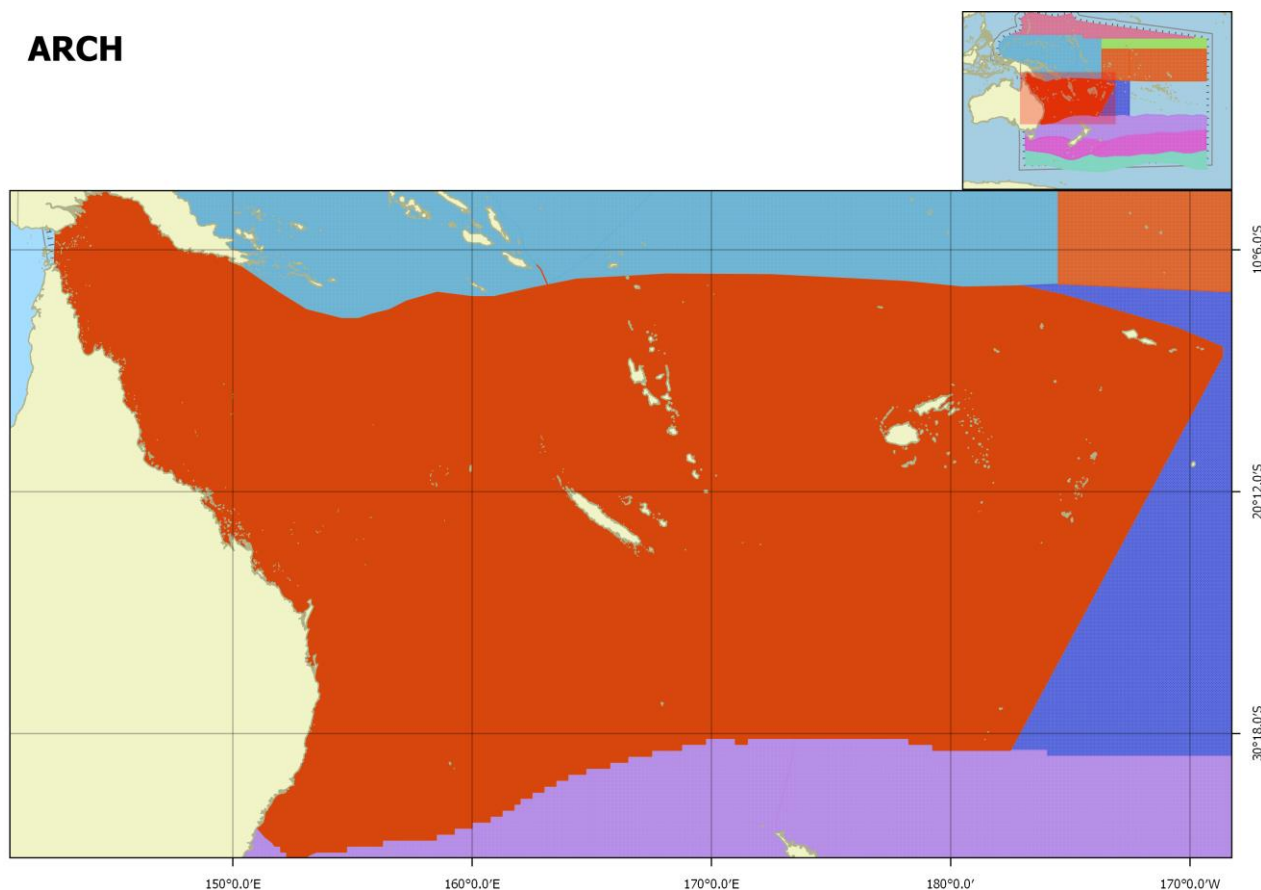
1 Pelagic Bioregions

The distributions of the Large Marine Areas – the highest level of classification for the South West Pacific Ocean are shown below.



1.1 Western Pacific Archipelagic Deep Basins (ARCHm)

ARCH



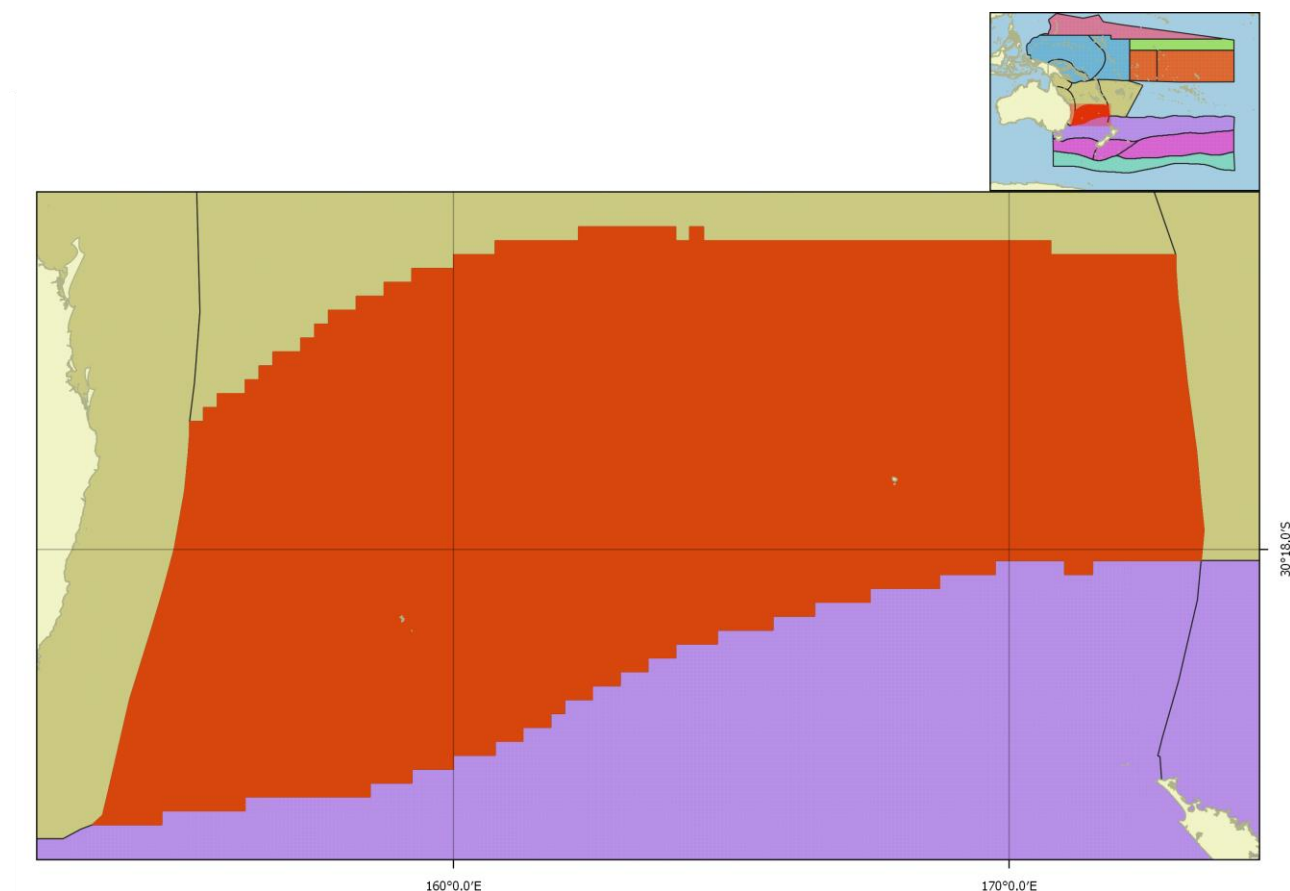
The Western Pacific Archipelagic Deep Basin is characterised by low Particulate Organic Matter (POM) and $\delta^{15}\text{N}$ ($1.9 \pm 3.0\text{‰}$). Minimum $\delta^{15}\text{N}$ values were recorded in the south-west off New Caledonia, Fiji and Tonga ($12.5 \pm 1.8\text{‰}$ and $10.9 \pm 2.0\text{‰}$ for Bigeye and Yellowfin tuna, respectively)

Mean Trophic Position (MTP) estimates were the highest in ARCHm province compared with other Provinces (5.6 ± 0.8 for Bigeye Tuna, and 4.8 ± 0.9 for yellowfin Tuna). Bigeye Tuna are found deeper than in WARM province and PEQD province during daytime (300–450m) but shallower than in WARMm and PEQD during night time; ARCHm biochemical region is characterised by low POM $\delta^{15}\text{N}$ values (2‰) characteristic of high nitrogen (N_2) fixation rates (Shiozaki et al., 2014). Additionally, nitrogen (N_2) fixation results in the production of organic matter with a $\delta^{15}\text{N}$ value of 0‰ as diazotrophs fix the atmospheric nitrogen gas ($\delta^{15}\text{N} = 0\text{‰}$) (Minagawa and Wada, 1984; Altabet, 2006).

The influence of nitrogen fixation is not only observed in New Caledonia but also in Fiji and up to longitudinal boundary of 160 West. This observation extends the ARCHm frontier towards the east compared to the Longhurst ARCH biogeographical province. The presence of picophytoplankton (such as diazotrophs) favours mesozooplankton as an extra step in the food chain (Sommer et al., 2002; Gutiérrez-Rodríguez et al., 2014).

For Bigeye Tuna, a deeper habitat in the southern regions (ARCHm) was supported by archival tag data, where the mean diving depth of bigeye was higher in New Caledonia (ARCHm) than in the western equatorial Pacific (WARMm), depth difference of 50–90 m according to distribution of Bigeye Tuna (Houssard et al., 2017)

1.1.1 South ARCH transition



The South ARCH Transition zone extends from the South of New Caledonia ($\sim 19^{\circ}\text{S}$) to approximately latitude 32°S . To the south of New Caledonia, the surface flow returns from the East Australian Current (EAC) back into the central south Pacific as the South Tropical Counter Current (STCC) (Marchesiello et al., 2010). In this region, the structures of the ocean currents are prone to shear instabilities and high eddy kinetic energy is observed (Qiu et al., 2009). The region is characterised by winter enrichment, resulting in increase winter ChlA concentrations (Ceccarelli et al., 2013; Dandonneau and Gohin, 1984). South of $\sim 19^{\circ}\text{S}$ latitudinal boundary, waters are characterized by colder temperature, higher salinity, a shallower nitracline, higher nitrate content in the surface layer, higher primary production and higher micronekton biomass estimates (Marchesiello et al., 2010). This region is also under the influence of the South Tropical Counter Current branches (Marchesiello et al., 2010).

Within New Caledonia (19°S - 22°S), the region is characterised by with surface salinity, higher concentrations of nitrate ($0.13 \pm 0.12 \mu\text{M}$) and chlorophyll content occurred with more frequent maxima at the surface in the cooler seasons. Phosphate concentrations varied with an average of $0.067 \pm 0.038 \mu\text{M}$ from the surface to 100 m depth and were occasionally lower than $0.05 \mu\text{M}$ at the surface layer. The mixed layer depth was shallower during the hot season, located at approximately 25 meters, denoting stronger surface stratification in the water column than during the cool season. The Deep Chlorophyll Maxima (DCM) (0.25 – 0.3 mg m^{-3}) and the nutricline were

located at 90 m depth. During the hot season surface waters were low in nitrate ($0.03 \pm 0.02 \mu\text{M}$) and the DCM was often centred at around 100 m with mean values of $0.41 \pm 0.16 \text{ mg m}^{-3}$. In general, above the DCM in the top 50 meters, chlorophyll concentrations were typically lower than during the cool season, particularly in the 19°S – 22°S area. Phosphate tended to be lower ($0.05 \pm 0.03 \mu\text{M}$) than in the northern part of this region.

As a consequence of these physical patterns, during the cool season the Net Primary Production is higher ($350 \text{ mgC m}^{-2}\text{d}$) in New Caledonia in the 20°S – 22°S area compared to the northern region of New Caledonia. During the hot season the entire region was more oligotrophic, with a weaker north–south gradient, and average values of $200 \text{ mgC m}^{-2}\text{d}$. During the cool season, chlorophyll was dominated by picophytoplankton ($<3 \mu\text{m}$) (mean= $75.9\% \pm \text{SD}=17.2\%$ in biomass); nanoplankton and microphytoplankton represented $12.8\% \pm 9.6\%$ and $11.3\% \pm 12.6\%$ of chlorophyll biomass, respectively. The cyanobacteria *Prochlorococcus* were the dominant species of the picophytoplankton group ($91.9\% \pm 6.3\%$ in abundance) with cell abundances of up to $250 \times 10^3 \text{ mL}^{-1}$. Remaining abundances of picophytoplankton were comprised of *Synechococcus* ($6.3\% \pm 6.2\%$) and picoeukaryotes ($1.8\% \pm 0.8\%$). The fractionated chlorophyll and community structure during the hot season were similar; however, cell abundance was much lower during the hot season, with maximum cell counts of *Prochlorococcus* of $160 \times 10^3 \text{ mL}^{-1}$.

South of New Caledonia, in the 20°S – 30°S latitudinal band, eddy features were generated due to baroclinic instability of the Sub Tropical Counter Current (STCC). The STCC was generated by the meeting of two opposite current flows: the eastward STCC and the westward South Caledonian Jet (Qiu et al., 2008; Couvelard et al., 2008). The mesoscale eddy field in the south western Pacific and especially in the STCC region is characterized by an eddy life cycle with three dynamic phases depending on the period of the year: growing (August–October), maturing (November–January) and decaying (March–June) phases (Qiu et al., 2008).

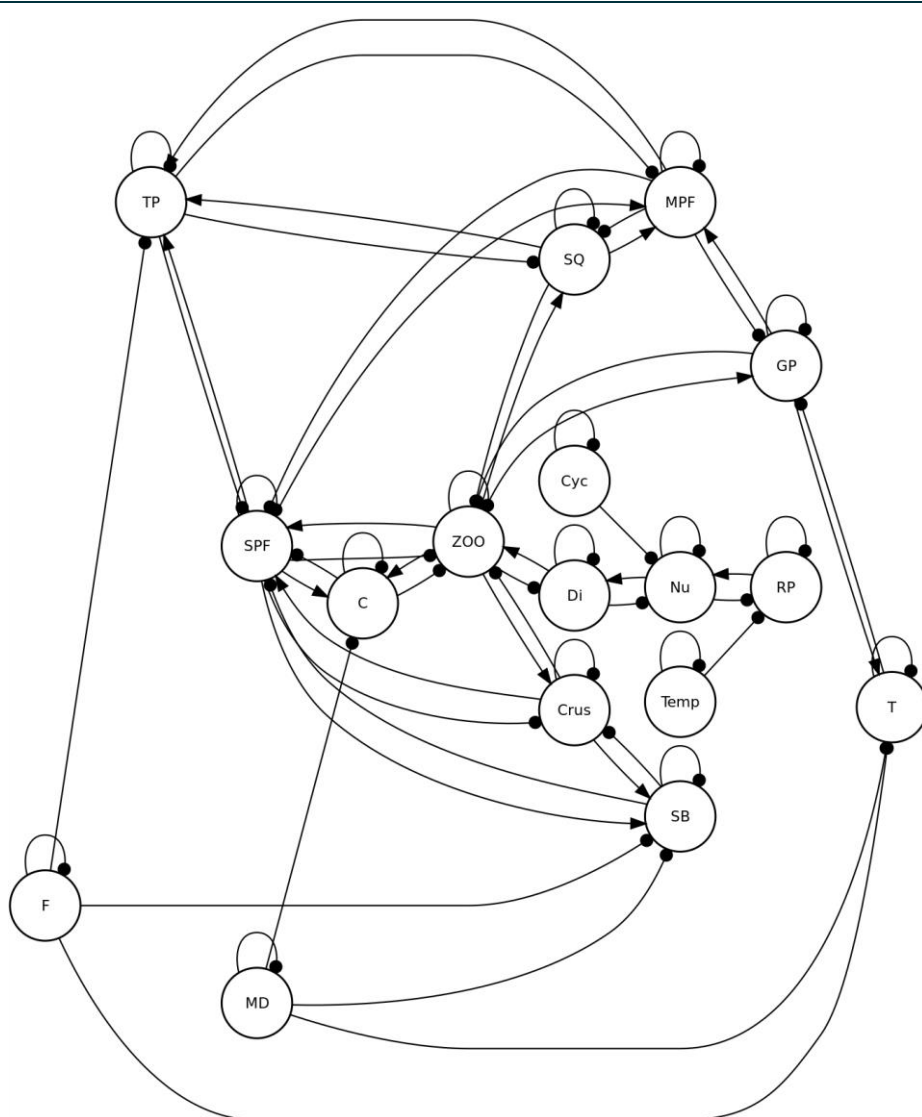


Figure 1: Ecosystem components in the qualitative model are: Top Predators ((TP)), Sea Birds ((SB)), Crustaceans ((Crus)), Small Pelagic Fish ((SPF)), Medium Pelagic Fish ((MPF)), Squid ((SQ)), Turtles ((T)), Cetaceans ((C)), Diatoms ((Di)), Nutrients (Nu)), Regenerated Production ((RP)), Zooplankton ((ZOO)), Gelatinous Plankton ((GP)). Pressures acting on the system are: Fisheries ((F)), Marine Debris ((MD)), Cyclone ((Cyc)), Temperature ((Temp)). Circle arrow heads represent a negative effect from one component to another, normal arrow heads represent a positive influence and circle arrow heads back onto the same node represent a self-regulation effect (e.g. density dependence).

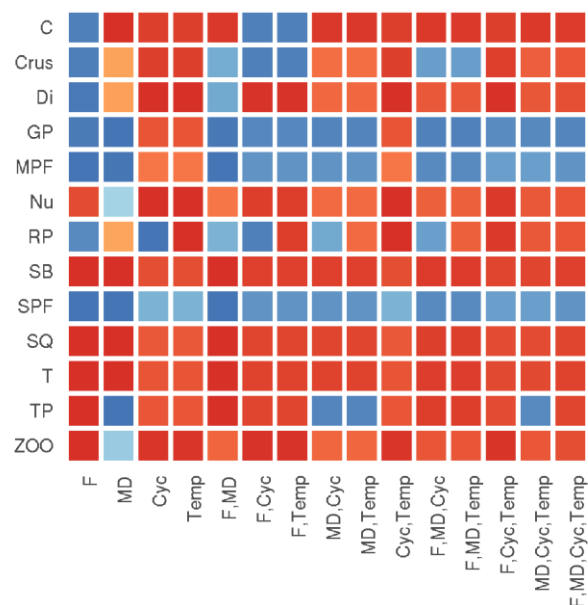
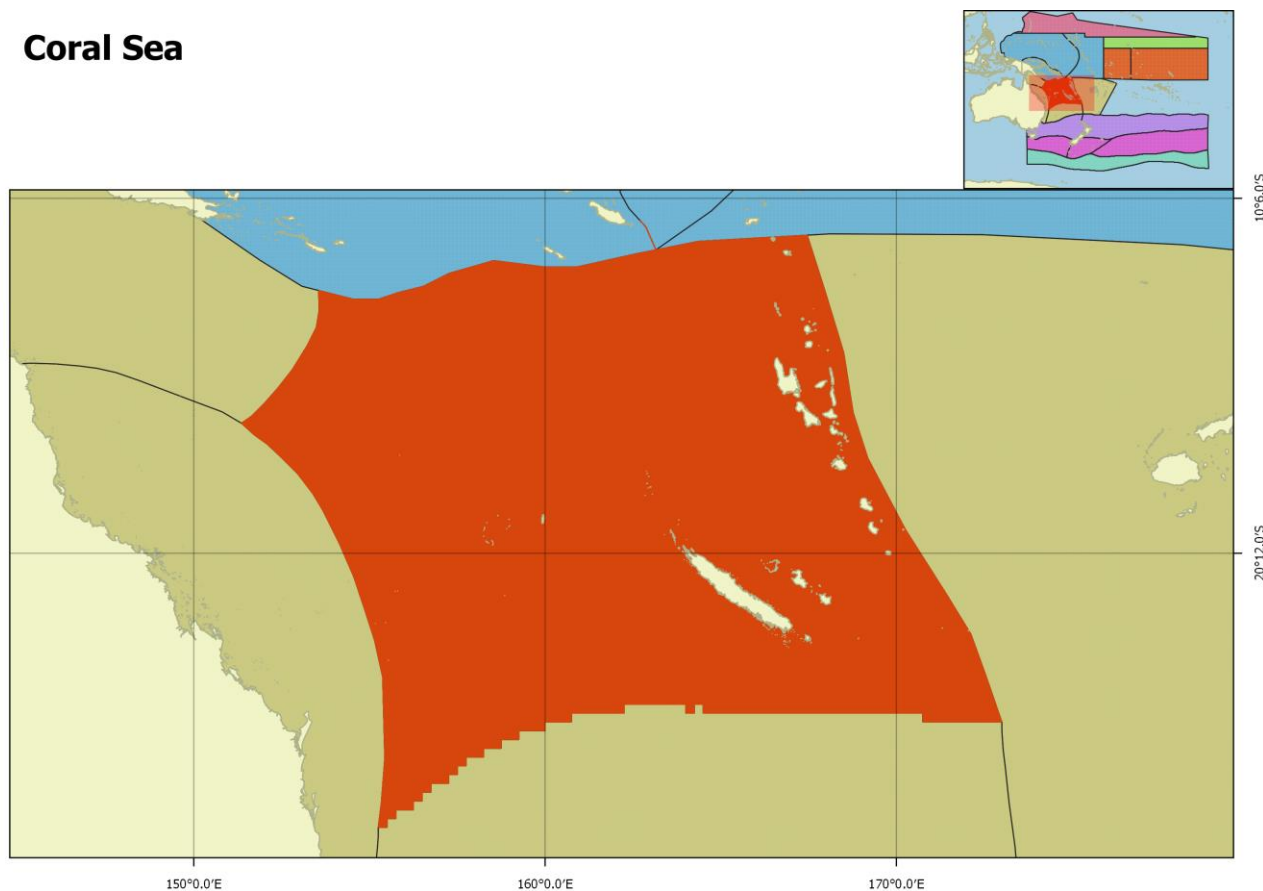


Figure 2: Ecosystem scenario responses to combinations of pressures. Red indicates a negative change and blue indicates a positive change. Labels are described above. Ecosystem components in the qualitative model are: Top Predators (TP), Sea Birds ((SB), Crustaceans ((Crus), Small Pelagic Fish ((SPF), Medium Pelagic Fish ((MPF), Squid ((SQ), Turtles ((T), Cetaceans ((C), Diatoms ((Di), Nutrients ((Nu), Regenerated Production ((RP), Zooplankton ((ZOO), Gelatinous Plankton ((GP). Pressures acting on the system are: Fisheries (F), Marine Debris ((MD), Cyclone ((Cyc), Temperature ((Temp).

1.1.2 Coral Sea & Coral Sea gyre Provinces

Coral Sea



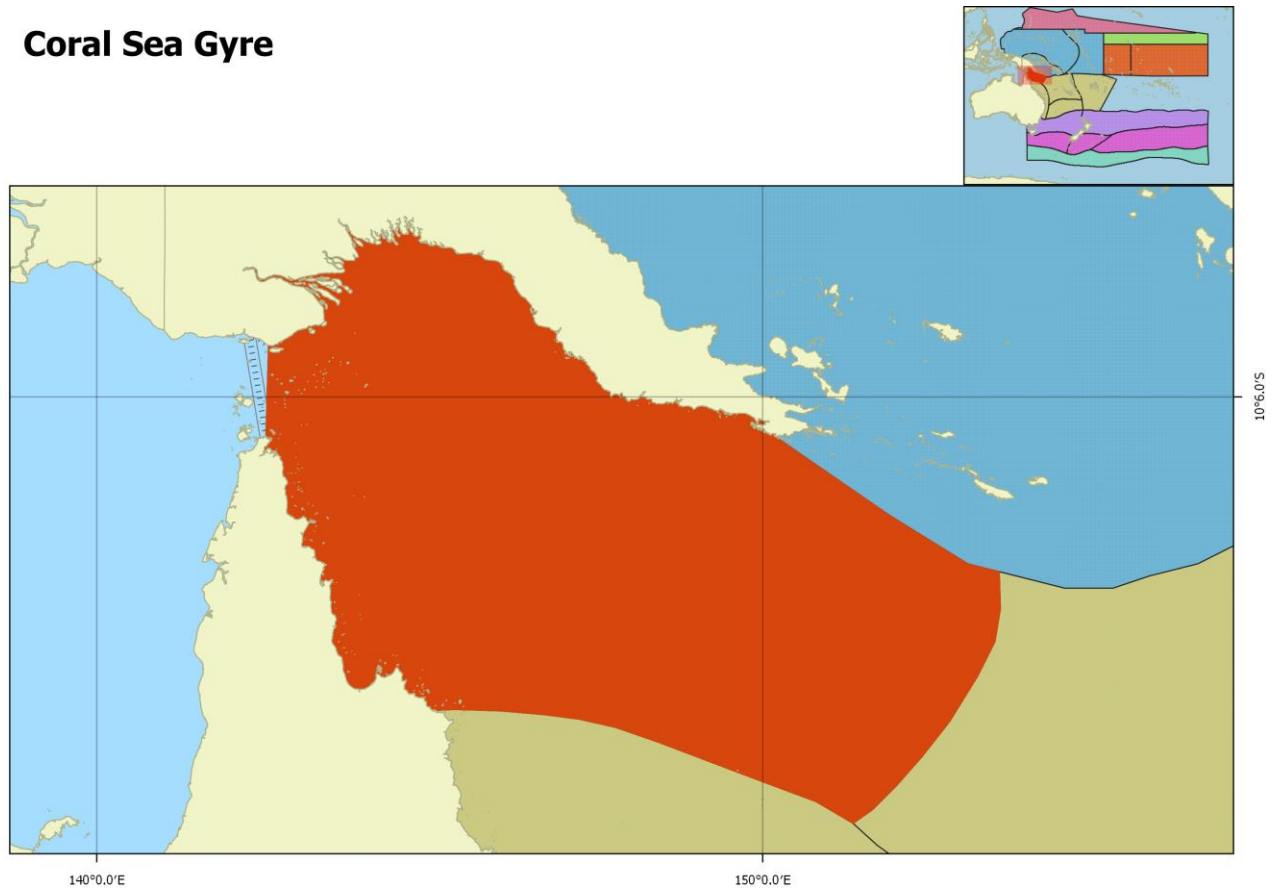
The Coral Sea Province is bounded by the East Australia Current Province, the Bismarck Solomon Sea Province and the Northern and Southern ARCH transition provinces. The eddy features within the province are ubiquitous and are generated to the north of New Caledonia, in the Coral Sea, by barotropic instability generated by the north Caledonian and Vanuatu Jets. Eddies in the Coral Sea have a radius between 25 and 300 km (Couvelard et al., 2008) and they are generated by a complex topography dominated by several islands and reefs initiating nonlinear currents (Gourdeau et al., 2008; Marchesiello et al., 2010).

North of 19°S–20°S latitudinal line the waters were characterized by warm temperature, low salinity, low nitrate and lower primary production, representative of the Coral Sea oligotrophic regime and largely influenced by the warmer and fresher waters of the South Pacific Convergence Zone; lower overall acoustic doppler current profile (ADCP) derived zooplankton biomass and clear attenuation of the diel migration in the upper layer (0–100 m) (Smeti et al 2015).

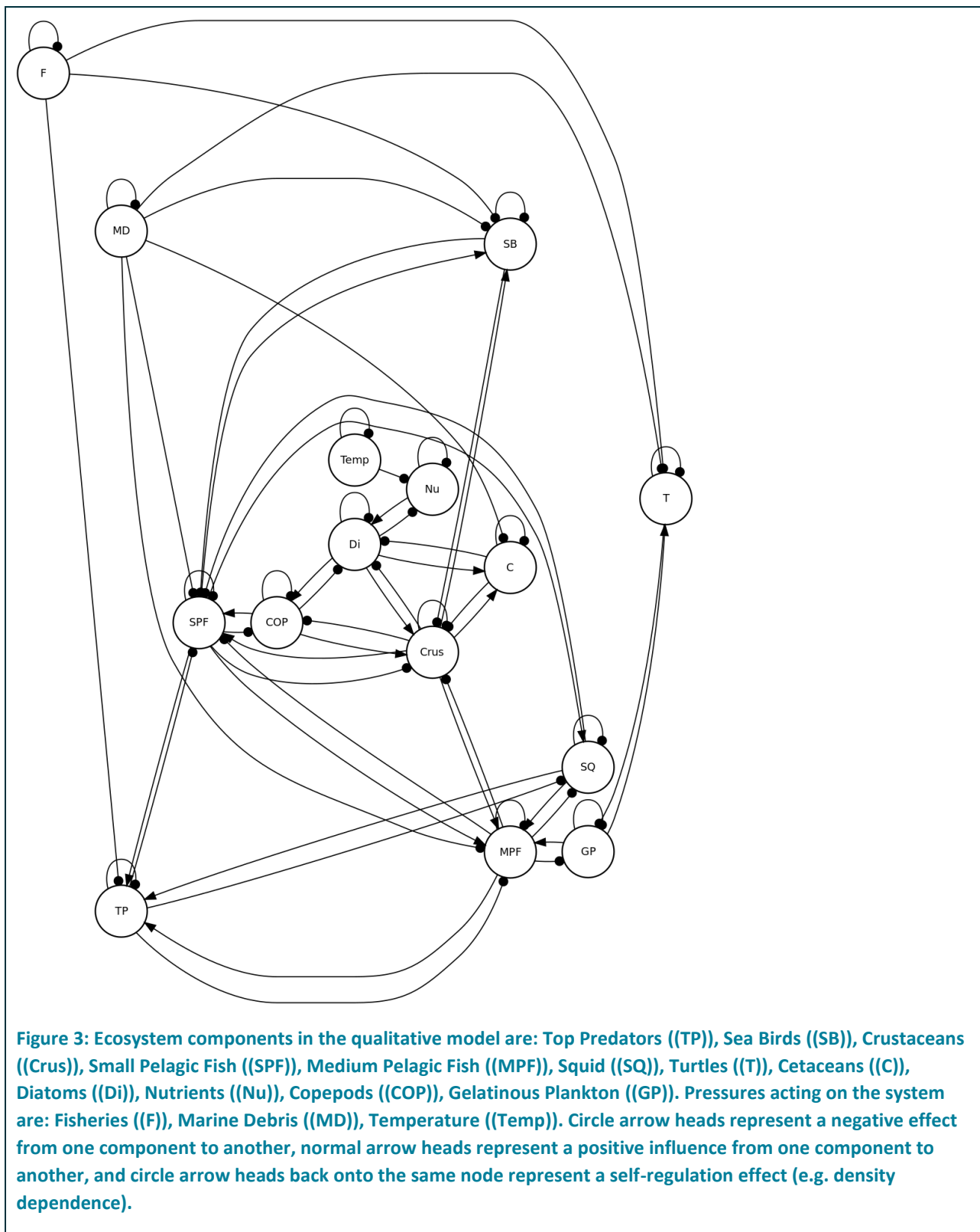
The dominant feature of circulation across 0–150 m is the westward-flowing South Equatorial Current (SEC) from 25°S to the equator. The SEC flow bifurcates at the Australian continental margin (Ridgway and Dunn, 2003) at 15°S, with one branch connecting with the southward flowing East Australian Current (EAC) (Qu and Lindstrom, 2002) and the other forming the Gulf of Papua Current which flows northward along the coast of Queensland, Australia. Within the Coral Sea, the

SEC comprises narrow filaments and jets created by the complex island, reef, seamounts and ridge topography (Gourdeau et al., 2008) namely the North Vanuatu Jet at around 13–15°S, and the North Caledonian Jet at around 17–18°S (Couvelard et al., 2008; Marchesiello et al., 2010)

Coral Sea Gyre



In New Caledonia, tuna catches are dominated by Albacore Tuna (*Thunnus alalunga*) and exhibit two seasonal peaks in July–August and December, and the highest catch rates occur in the north-western part of New Caledonia's EEZ (Briand et al., 2011). The influence of temperature, primary production and micronekton density has been demonstrated as important drivers of higher tuna catch rates in New Caledonia (Briand et al., 2011)



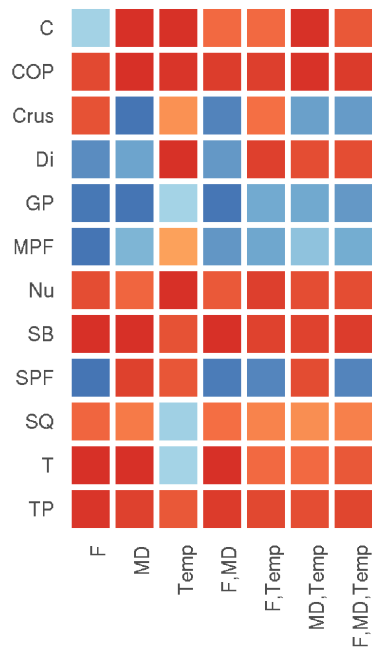
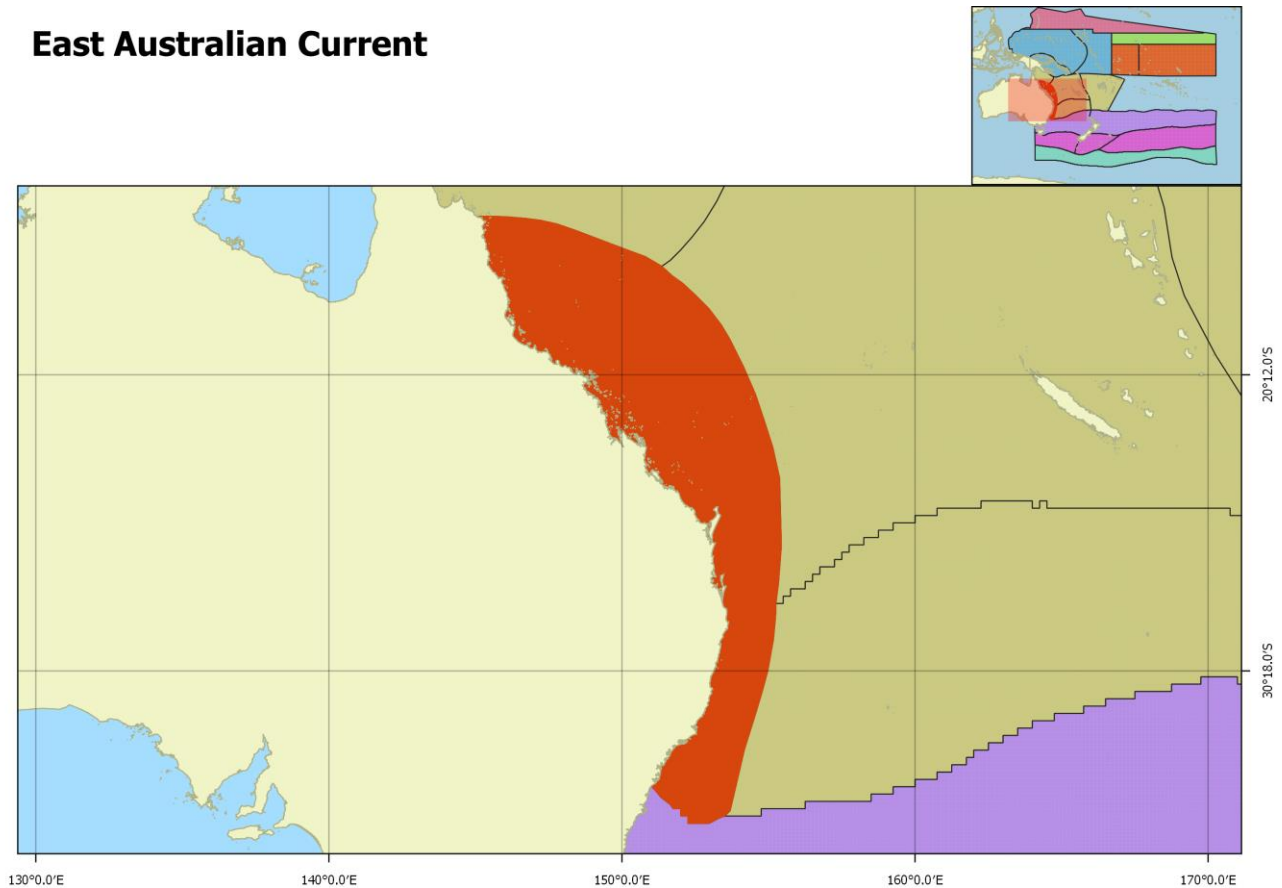


Figure 4: Ecosystem scenario responses to combinations of pressures. Red indicates a negative change and blue indicates a positive change. Labels are described above. Ecosystem components in the qualitative model are: Top Predators (TP), Sea Birds (SB), Crustaceans (Crus), Small Pelagic Fish (SPF), Medium Pelagic Fish (MPF), Squid (SQ), Turtles (T), Cetaceans (C), Diatoms (Di), Nutrients (Nu), Copepods (COP), Gelatinous Plankton (GP). Pressures acting on the system are: Fisheries (F), Marine Debris (MD), Temperature (Temp).

1.1.3 East Australia Current Province

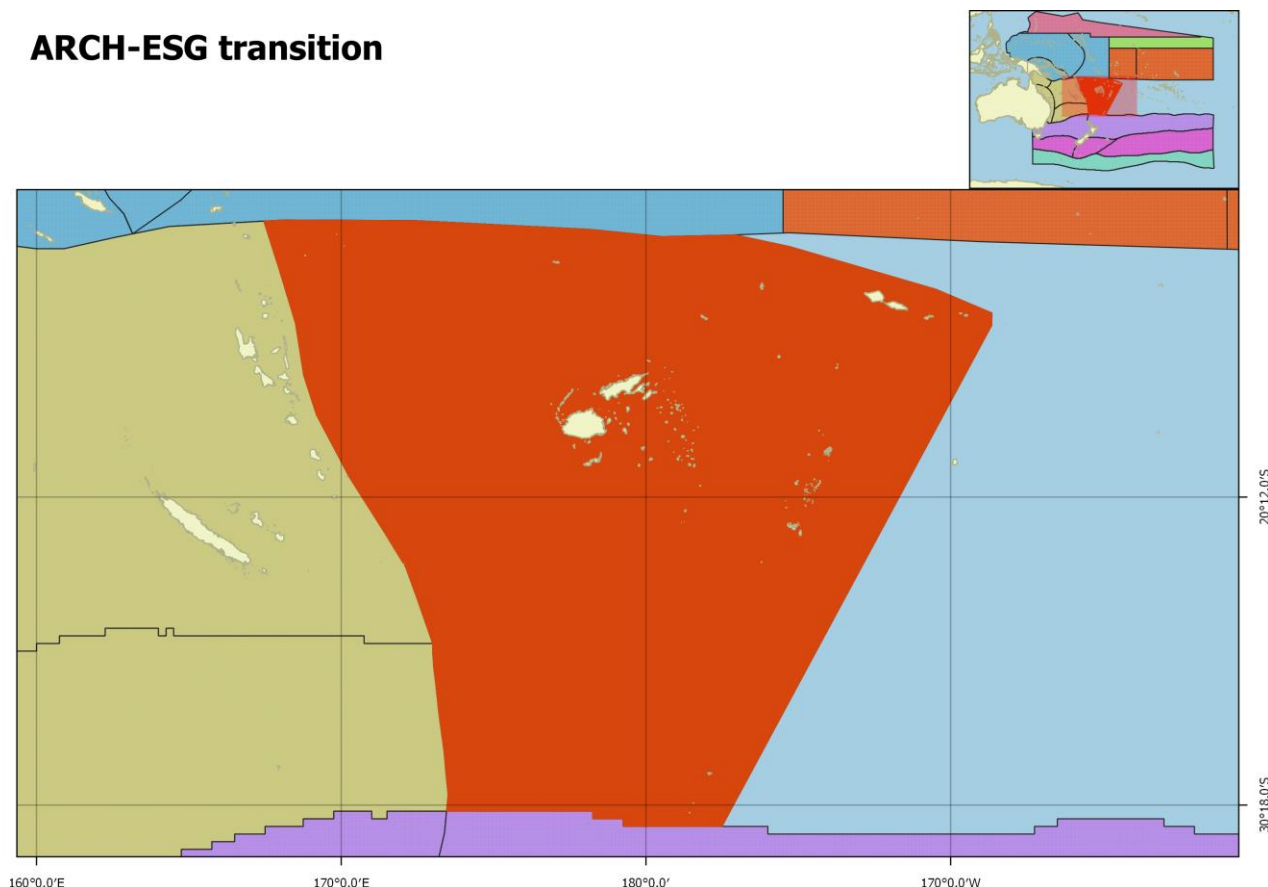
East Australian Current



The East Australia Current Province (AUSE in Longhurst 2010) is the southward boundary current that moves along the east coast of Australia. It is driven by the Subtropical Gyre and is primarily responsible for warm water transportation down the east coast of Australia to the Tasman Sea. This in turn supports a large fishery and significant biodiversity in the southern extent of the province. Qualitative models and responses to pressures for this province can be found in Dambacher et al., (2012).

1.1.4 ARCH-ESG Transition Province

ARCH-ESG transition



In contrast to the South West ARCH Province, the ocean around New Caledonia (17°S-19°S) were characterised by relatively warm, low salinity waters with a mixed layer depth of 60 meters and low values of nitrate ($0.05 \pm 0.07 \mu\text{M}$) to a depth of 90 meters. This province extends eastwards from the Coral Sea Province and includes New Caledonia, Fiji, Tonga and Samoa.

The stable nitrogen isotope ratio $\delta^{15}\text{N}$ in the mesozooplankton from the upper 100m of the water column were 1.5‰ lower to the east of New Caledonia (Northern ARCH) compared to the Coral Sea in the west, with a separation around 163.5°E. There was evidence that the east–west difference in mesozooplankton $\delta^{15}\text{N}$ values was transferred into the macrozooplankton and micronekton communities (Hunt et al., 2015). The $\delta^{15}\text{N}$ values of the primary consumer zooplankton were consistently lower east of New Caledonia (middle ARCH) (average = $3.79\text{‰} \pm 0.52$) than to the west (coral sea) (average = $5.62\text{‰} \pm 0.26$). A similar pattern was observed in the microzooplankton and micronekton composition (Hunt et al 2015). Amongst the nekton species a significant (negative) relationship between $\delta^{15}\text{N}$ and longitude was only detected for *T. alalunga*. For the species of micronekton with significant longitudinal correlations, there was a mean increase in $\delta^{15}\text{N}$ of 2.9‰ between 157°E and 170°E.

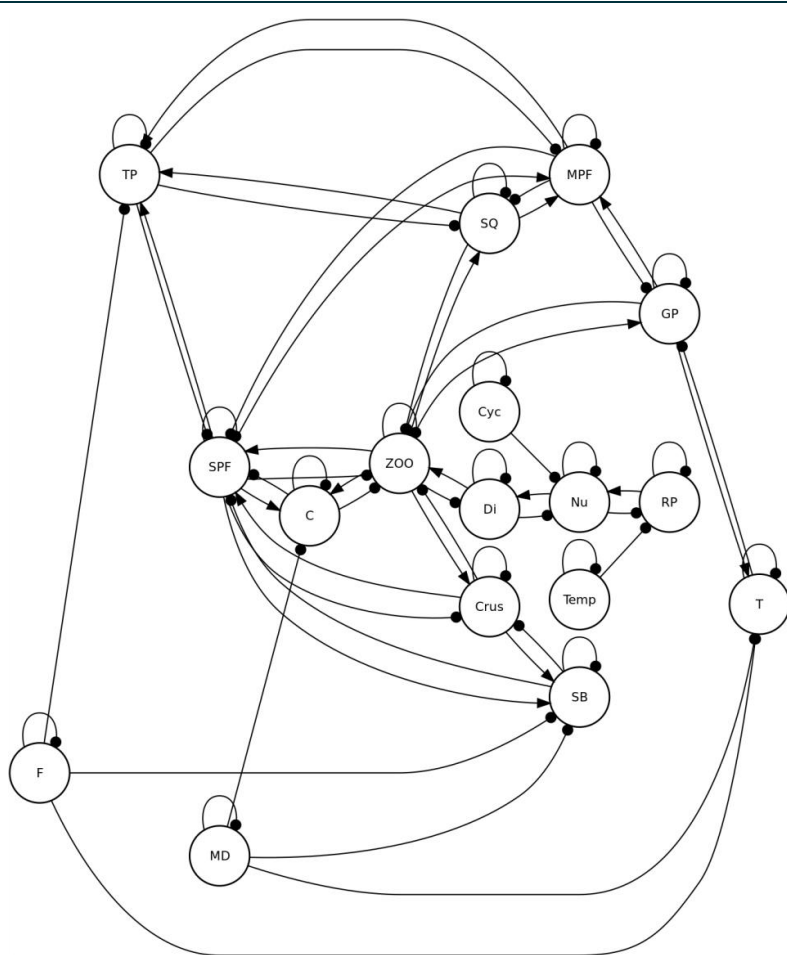


Figure 5: Ecosystem components in the qualitative model are: Top Predators ((TP)), Sea Birds ((SB)), Crustaceans ((Crus)), Small Pelagic Fish ((SPF)), Medium Pelagic Fish ((MPF)), Squid ((SQ)), Turtles ((T)), Cetaceans ((C)), Diatoms ((Di)), Nutrients ((Nu)), Regenerated Production ((RP)), Zooplankton ((ZOO)), Gelatinous Plankton ((GP)). Pressures acting on the system are: Fisheries ((F)), Marine Debris ((MD)), Cyclone ((Cyc)), Temperature ((Temp)). Circle arrow heads represent a negative effect from one component to another, normal arrow heads represent a positive influence from one component to another, and circle arrow heads back onto the same node represent a self-regulation effect (e.g. density dependence).

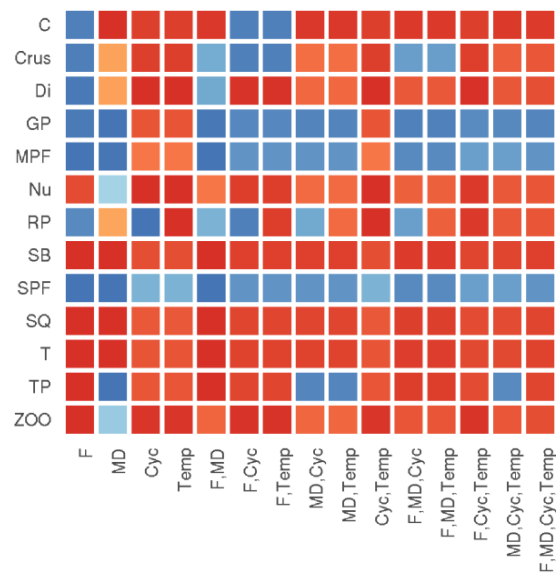
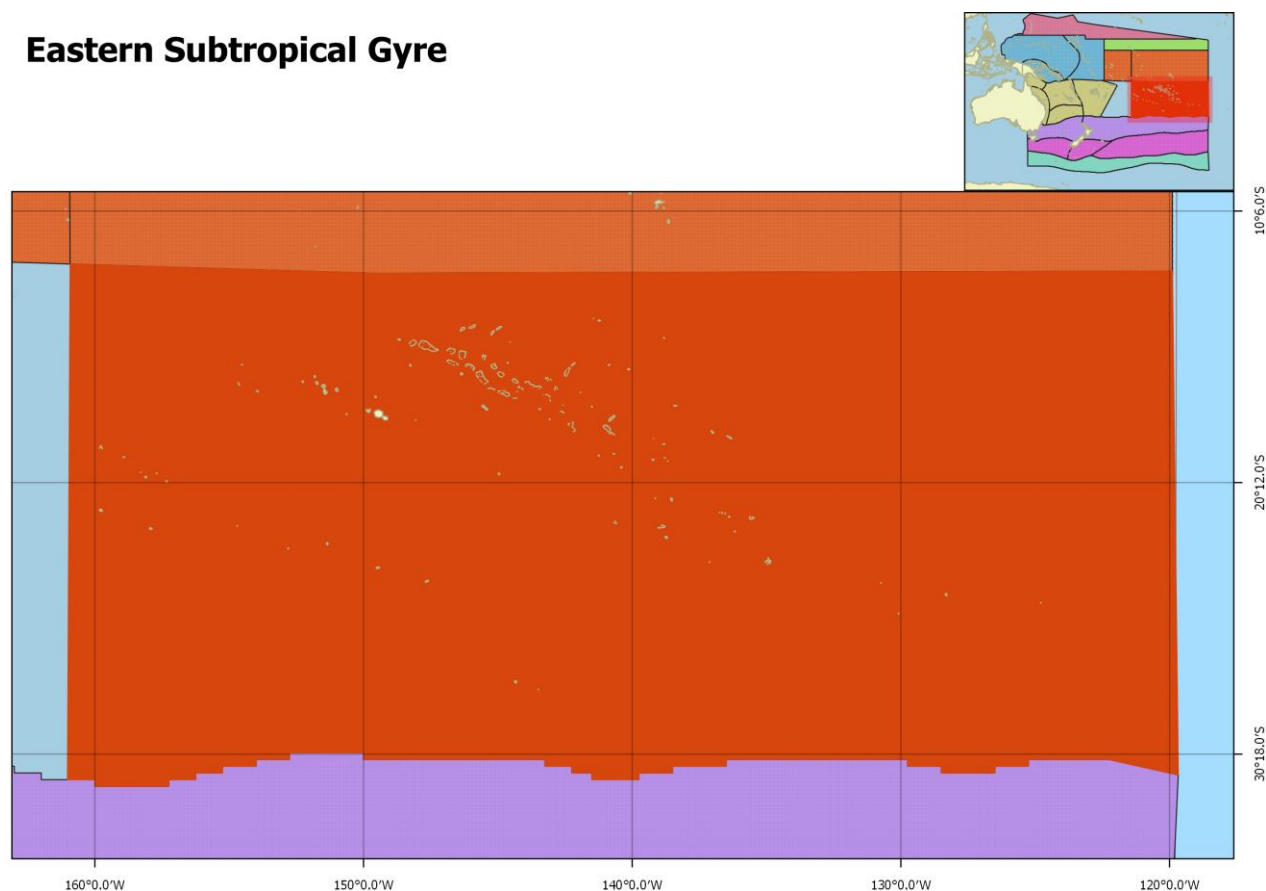


Figure 6: Ecosystem scenario responses to combinations of pressures. Red indicates a negative change and blue indicates a positive change. Ecosystem components in the qualitative model are: Top Predators (TP), Sea Birds (SB), Crustaceans (Crus), Small Pelagic Fish (SPF), Medium Pelagic Fish (MPF), Squid (SQ), Turtles (T), Cetaceans (C), Diatoms (Di), Nutrients (Nu), Regenerated Production (RP), Zooplankton (ZOO), Gelatinous Plankton (GP). Pressures acting on the system are: Fisheries (F), Marine Debris (MD), Cyclone (Cyc), Temperature (Temp).

1.2 Subtropical Gyre

1.2.1 Eastern Subtropical Gyre

Eastern Subtropical Gyre



The Eastern Subtropical Gyre (can be found south of 10-14°S (down to 20°S) in French Polynesia and northern boundaries of this region is the South Equatorial Counter Current (SECC) around 8-14°S. The waters in this region are influenced by the Great Southern Gyre and have oligotrophic characteristics less favourable for micronekton development. The waters of the south pacific central gyre south of 13°S are oligotrophic (Rougerie & Rancher 1994). The region is characterised by high POM $\delta^{15}\text{N}$ ($11.1 \pm 2.9\text{‰}$). Maximum $\delta^{15}\text{N}$ values were found in the south-east in SPSGm ($19.4 \pm 2.5\text{‰}$ and $17.2 \pm 2.6\text{‰}$ for bigeye and yellowfin tuna, respectively). The mean trophic position estimates were high in SPSG (5.4 ± 1.1 for Bigeye Tuna, and 4.6 ± 1.1 for yellowfin). In regions of SPSG that exhibited the highest POM $\delta^{15}\text{N}$ values (11‰), the nitrate pool would be completely utilized resulting in no isotope fractionation effect (Rafter et al., 2013).

Nitrogen fixation is low (Deutsch et al., 2001; Shiozaki et al., 2014) in regions where new primary production is fuelled by nitrate, large phytoplankton such as diatoms are directly grazed by macrozooplankton, leading to a shorter food chain (Le Borgne et al., 2011).

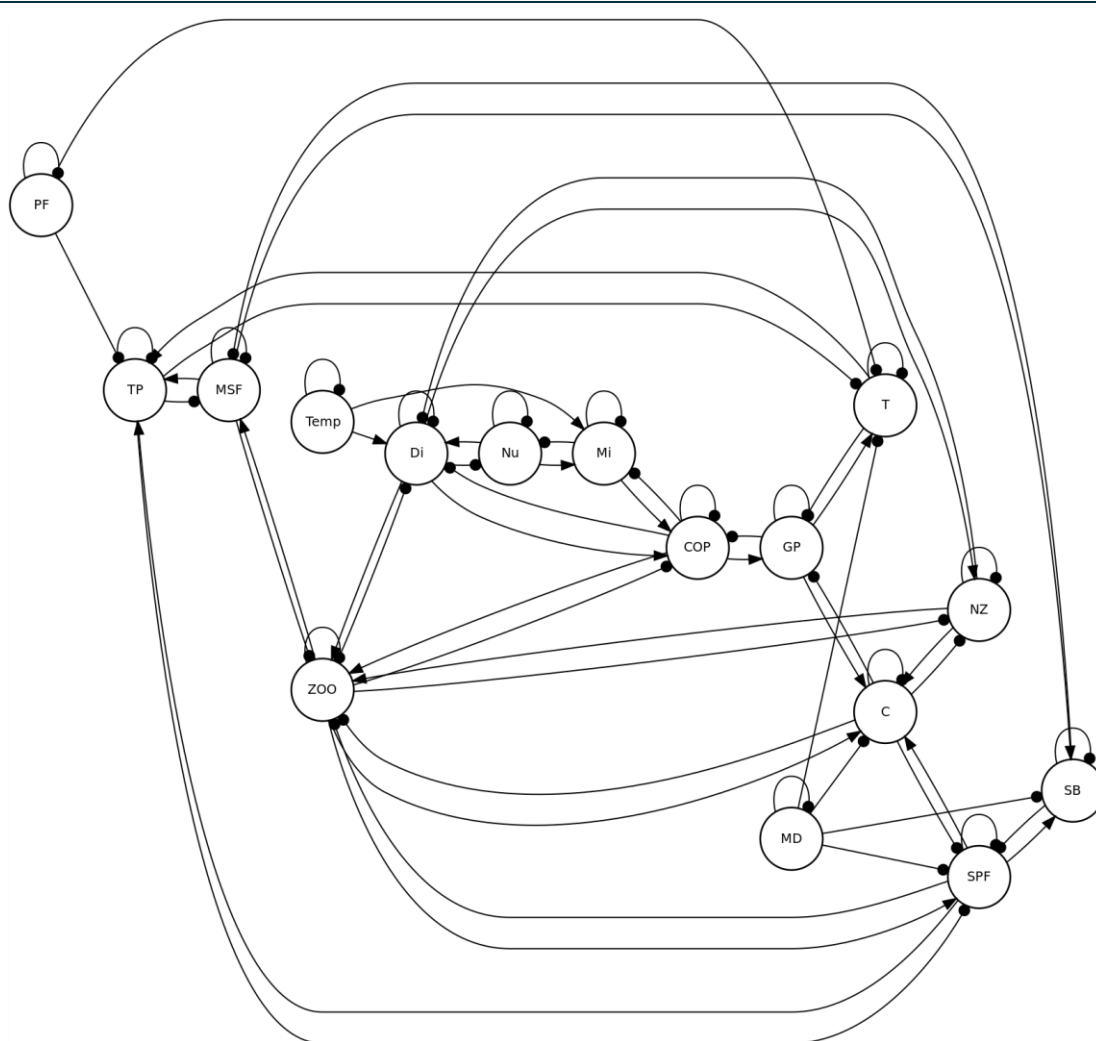


Figure 7: Ecosystem components in the qualitative model are: Top Predator (TP), Mid Size Fish and Squid (MSF), Small Pelagic Fish (SPF), Sea Birds (SB), Turtles (T), Meso-Macro Zooplankton (ZOO), Gelatinous Plankton (GP), Cetaceans (C), Copepods (COP), NanoZooplankton (NZ), Diatoms ((Di), Microbes (Mi) and Nutrients (Nu). Pressures acting on the system are: Marine Debris (MD), Pelagic Fisheries (PF) and Temperature (Temp). Circle arrow heads represent a negative effect from one component to another, normal arrow heads represent a positive influence from one component to another, and circle arrow heads back onto the same node represent a self-regulation effect (e.g. density dependence).

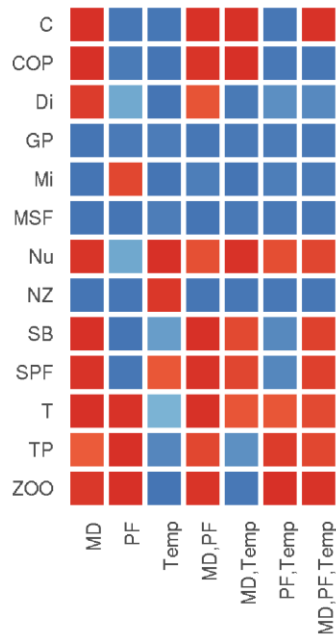
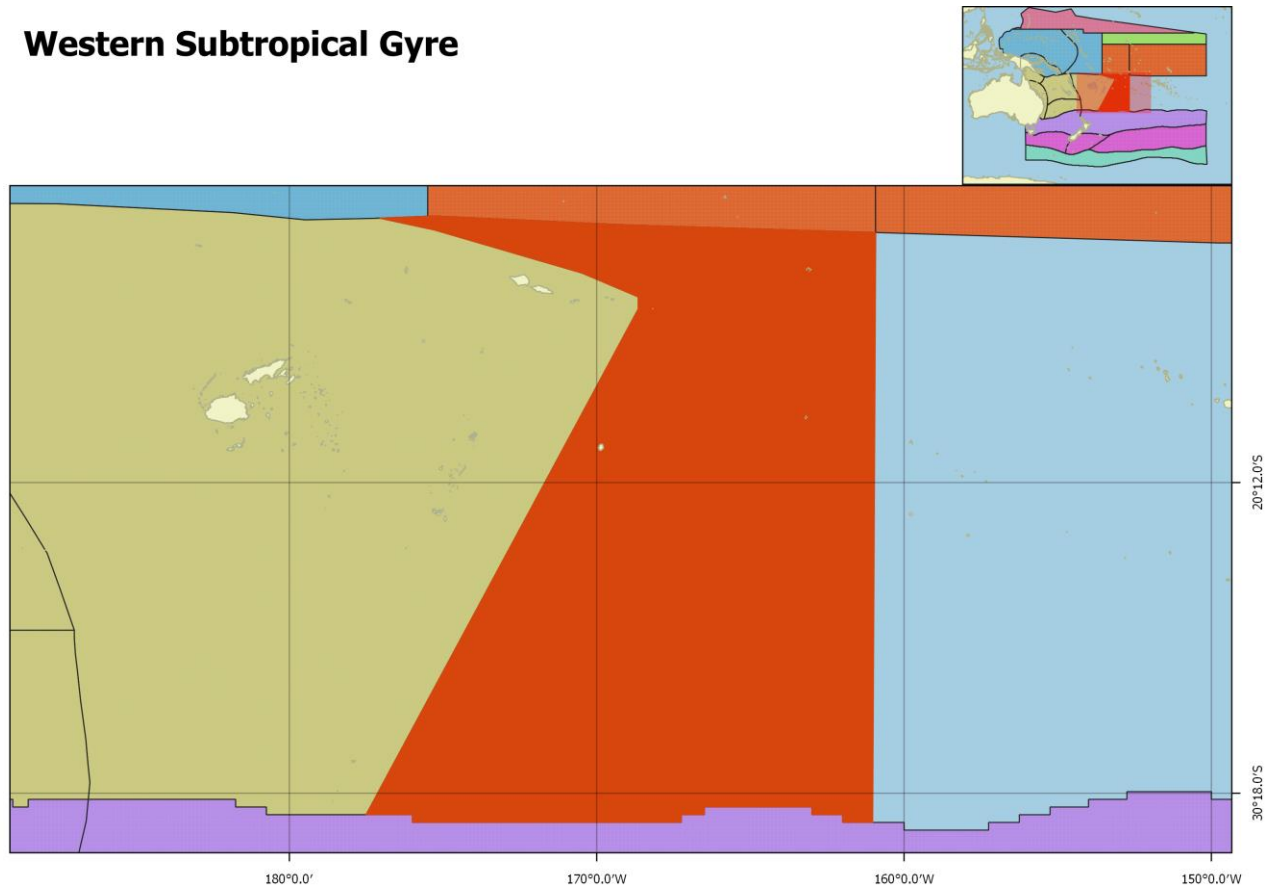


Figure 8: Ecosystem scenario responses to combinations of pressures. Red indicates a negative change and blue indicates a positive change. Ecosystem components in the qualitative model are: Top Predator (TP), Mid Size Fish and Squid (MSF), Small Pelagic Fish (SPF), Sea Birds (SB), Turtles (T), Meso-Macro Zooplankton (ZOO), Gelatinous Plankton (GP), Cetaceans (C), Copepods (COP), NanoZooplankton (NZ), Diatoms ((Di), Microbes (Mi) and Nutrients (Nu). Pressures acting on the system are: Marine Debris (MD), Pelagic Fisheries (PF) and Temperature (Temp)

1.2.2 Western Subtropical Gyre

Western Subtropical Gyre



Pelagic species in the Western Subtropical Gyre (ARCH-SPG Longhurst et al. 2010) transition zone show a noticeable transition from the POM $\delta^{15}\text{N}$ seen the ARCH provinces to the lower values seen in the SPSG province. In this region the values are between 3-6% (Houssard et al. 2017).

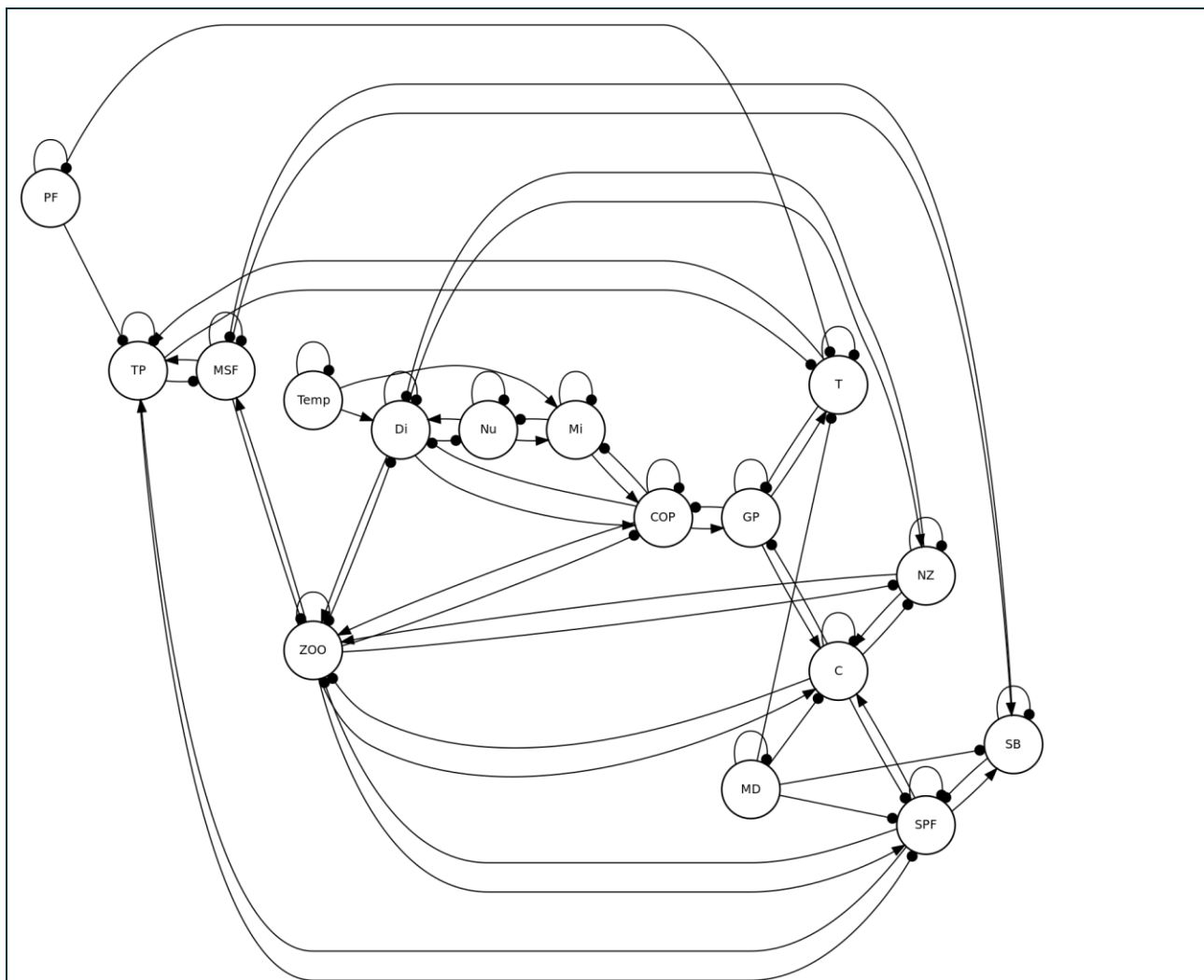


Figure 9: Ecosystem components in the qualitative model are: Top Predator (TP), Mid Size Fish and Squid (MSF), Small Pelagic Fish (SPF), Sea Birds (SB), Turtles (T), Meso-Macro Zooplankton (ZOO), Gelatinous Plankton (GP), Cetaceans (C), Copepods (COP), NanoZooplankton (NZ), Diatoms ((Di), Microbes (Mi) and Nutrients (Nu). Pressures acting on the system are: Marine Debris (MD), Pelagic Fisheries (PF) and Temperature (Temp). Circle arrow heads represent a negative effect from one component to another, normal arrow heads represent a positive influence from one component to another, and circle arrow heads back onto the same node represent a self-regulation effect (e.g. density dependence).

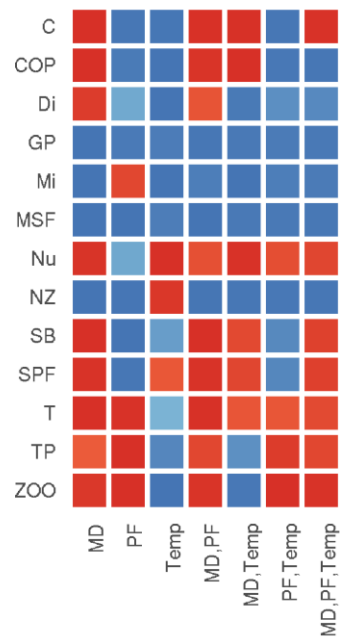
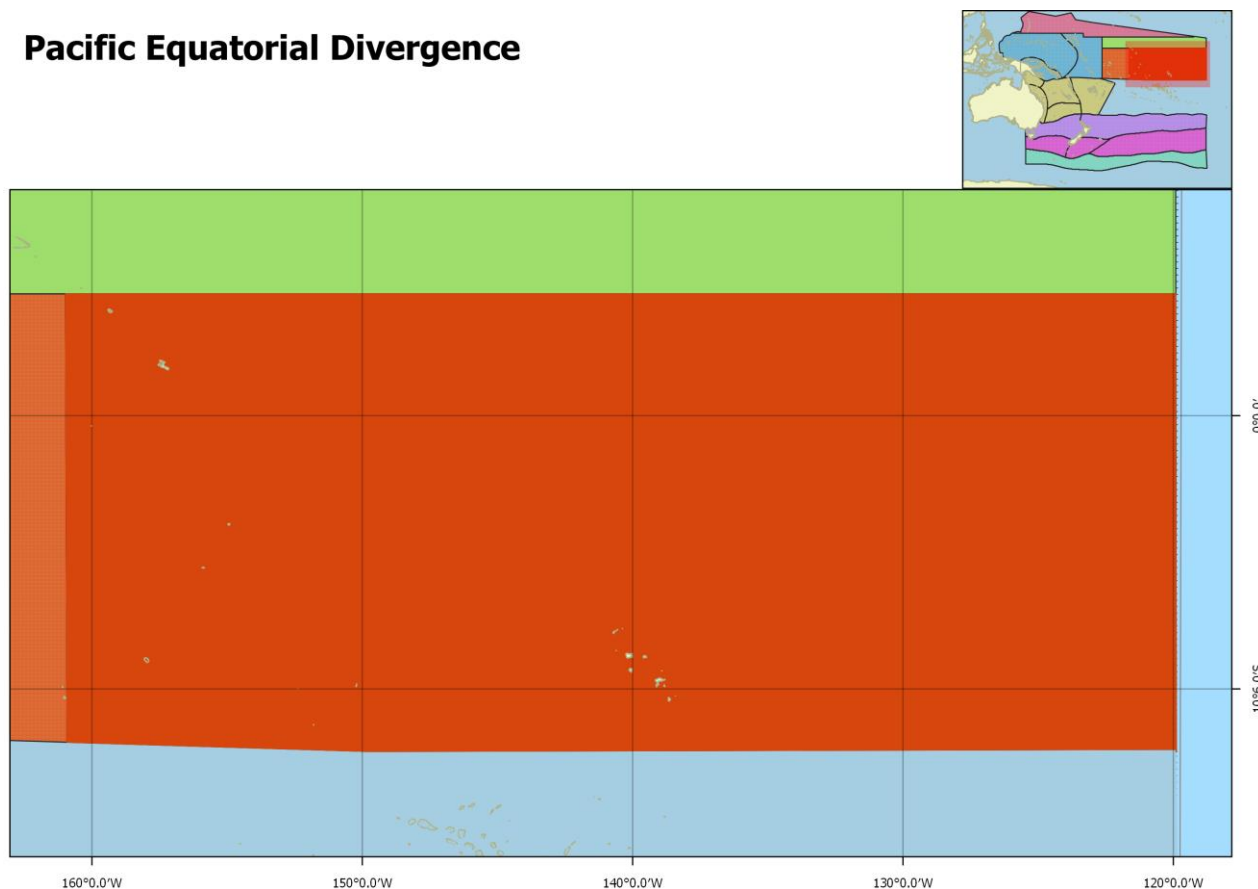


Figure 10: Ecosystem scenario responses to combinations of pressures. Red indicates a negative change and blue indicates a positive change. Ecosystem components in the qualitative model are: Top Predator (TP), Mid Size Fish and Squid (MSF), Small Pelagic Fish (SPF), Sea Birds (SB), Turtles (T), Meso-Macro Zooplankton (ZOO), Gelatinous Plankton (GP), Cetaceans (C), Copepods (COP), NanoZooplankton (NZ), Diatoms ((Di), Microbes (Mi) and Nutrients (Nu). Pressures acting on the system are: Marine Debris (MD), Pelagic Fisheries (PF) and Temperature (Temp)

1.3 Pacific Equatorial Divergence (PEQD)

1.3.1 Pacific Equatorial Divergence

Pacific Equatorial Divergence



The Pacific Equatorial Divergence (PEQD) is similar to the region describe by Longhurst (2010) but extends further south based on information from migratory fish species. Both Bigeye and Yellowfin tuna showed low $\delta^{15}\text{N}$ values in PEQD ($12.1 \pm 1.6\%$ and $13.0 \pm 2.6\%$, respectively) and the mean trophic position estimates were the lowest in PEQD compared with other regions (3.7 ± 0.8 for Bigeye Tuna, and 3.7 ± 0.9 for Yellowfin Tuna). Bigeye Tuna are shallower than in ARCHm during the day (250-350 meters depth) but deeper than in ARCHm during the night. The $\delta^{15}\text{N}$ values could occur due to incomplete and low levels of nutrient utilization driven by Rayleigh fractionation (Altabet, 2001; Yoshikawa et al., 2006; Graham et al., 2010).

Within the PEQD micronekton abundance was higher (than in regions to the north and south) in an area between Marquesas Archipelagos (8-10°S) and a west-northwest/east-southeast oriented line stretching between 11°S and 14°S, in a weak convergence, favourable to micronekton development due to the concentration of lower trophic levels with no oxygen limitation in the deep layers (Houssard et al., 2017).

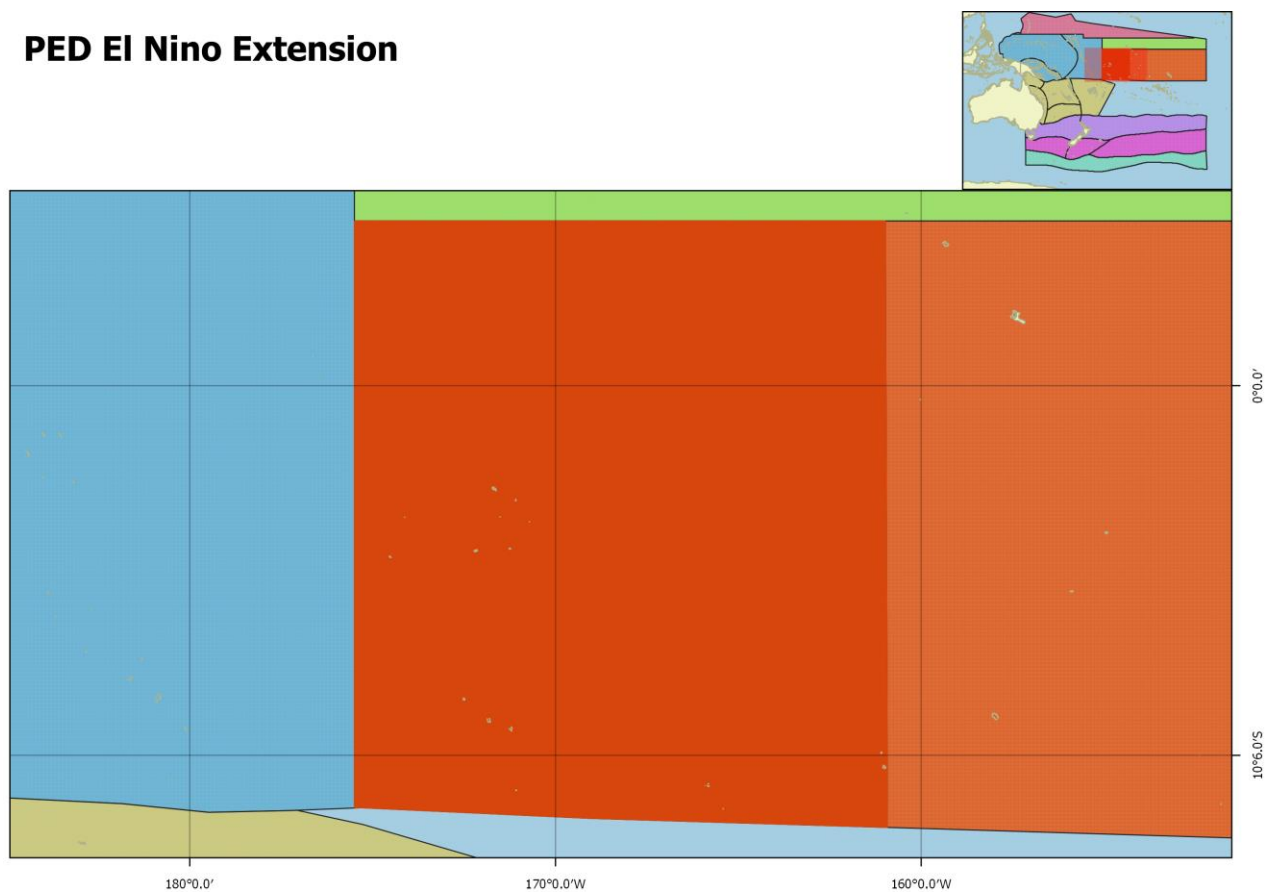
To the north (up to 4°S), waters are enriched by the equatorial upwelling, but intense organic matter remineralisation limits oxygen availability under the thermocline.

The equatorial upwelling north of the Marquesas supports high biomass and biomass is known to decrease as latitude increases (Vinogradov 1981). The same patterns emerge for primary productivity which is maximal between 2°N and 2°S (Lindley et al., 1995, Barber et al., 1996, Chavez et al., 1996). However, the mesozooplankton maximum is shifted several degrees south to

between 2°S and 5°S at 140°W (Vinogradov 1981, White et al., 1995). Although Vinogradov (1981) and Lehodey et al., (1997) predict a tuna forage biomass maximum at the same latitude as that of the zooplankton, ECOTAP¹ program results locate it more to the south. In the equatorial upwelling, occurrence of macronutrients (such as nitrate or orthophosphate) in the photic layer allows production of larger phytoplanktonic cells than in oligotrophic areas which are nutrient-limited (Le Bouteiller et al. 1992). As a result, mesozooplankton diet consists of a greater proportion of phytoplankton, leading to a closer relationship between phytoplankton and mesozooplankton.

1.3.2 PED El Nino Extension

PED El Nino Extension



The PED El Nino extension is the extension of the PED during El Nino phases. During the these phases it is similar to the PED. During La Nina phases it is similar to the Warm Pool La-Nina Extension Province.

¹ <https://spccfpstore1.blob.core.windows.net/digitallibrary-docs/files/d8/d843f67bb9d60726271069186b1b315c.pdf?sv=2015-12-11&sr=b&sig=bqnDFMfy9Ewdtqpmw3SNQ10095vm9vuEwPrFdSlzB58%3D&se=2020-09-19T00%3A08%3A20Z&sp=r&rsc=public%2C%20max-age%3D864000%2C%20max-stale%3D86400&rsct=application%2Fpdf&rscd=inline%3B%20filename%3D%22WP9.pdf%22>

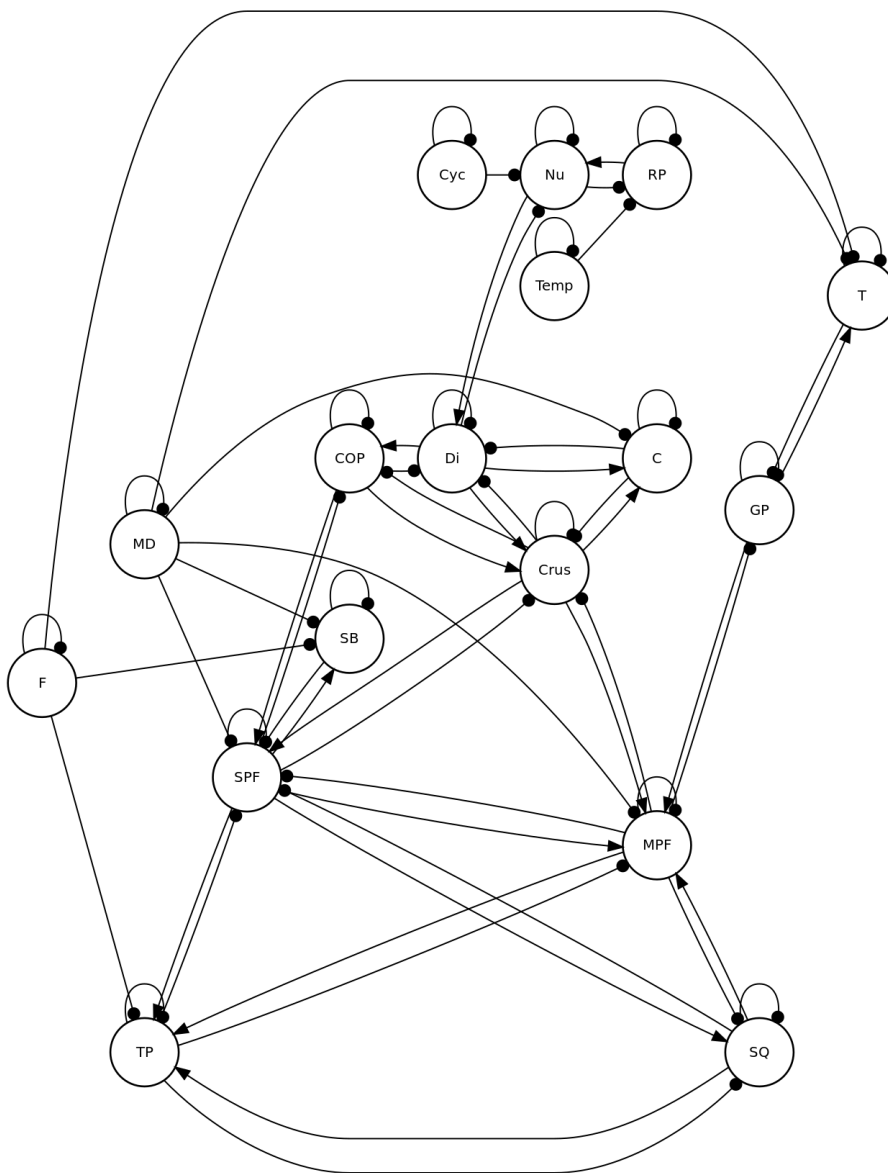


Figure 11. Ecosystem components in the qualitative model are: Top Predators (TP), Sea Birds (SB), Crustaceans (Crus), Small Pelagic Fish (SPF), Medium Pelagic Fish (MPF), Squid (SQ), Turtles (T), Cetaceans (C), Diatoms (Di), Nutrients (Nu), Regenerated Production (RP), Copepods (COP) and Gelatinous Plankton (GP) . Pressures acting on the system are: Fisheries (F), Marine Debris (MD), Cyclone (Cyc) and Temperature (Temp). Circle arrow heads represent a negative effect from one component to another, normal arrow heads represent a positive influence from one component to another, and circle arrow heads back onto the same node represent a self-regulation effect (e.g. density dependence).

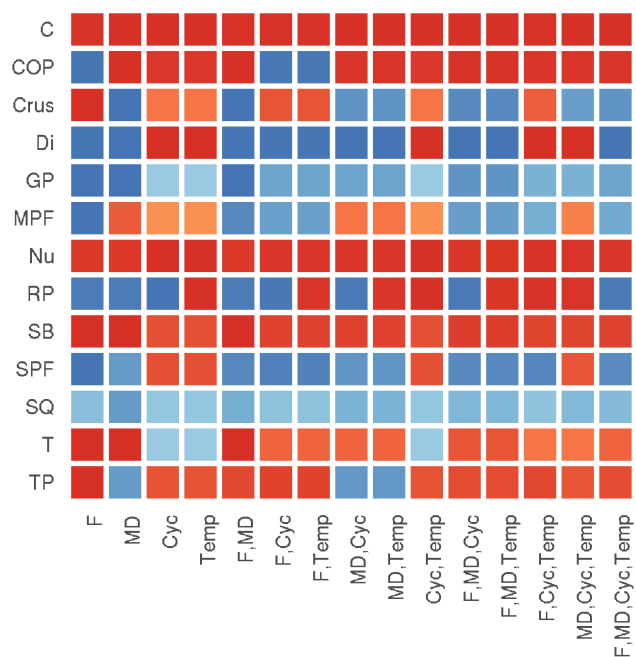
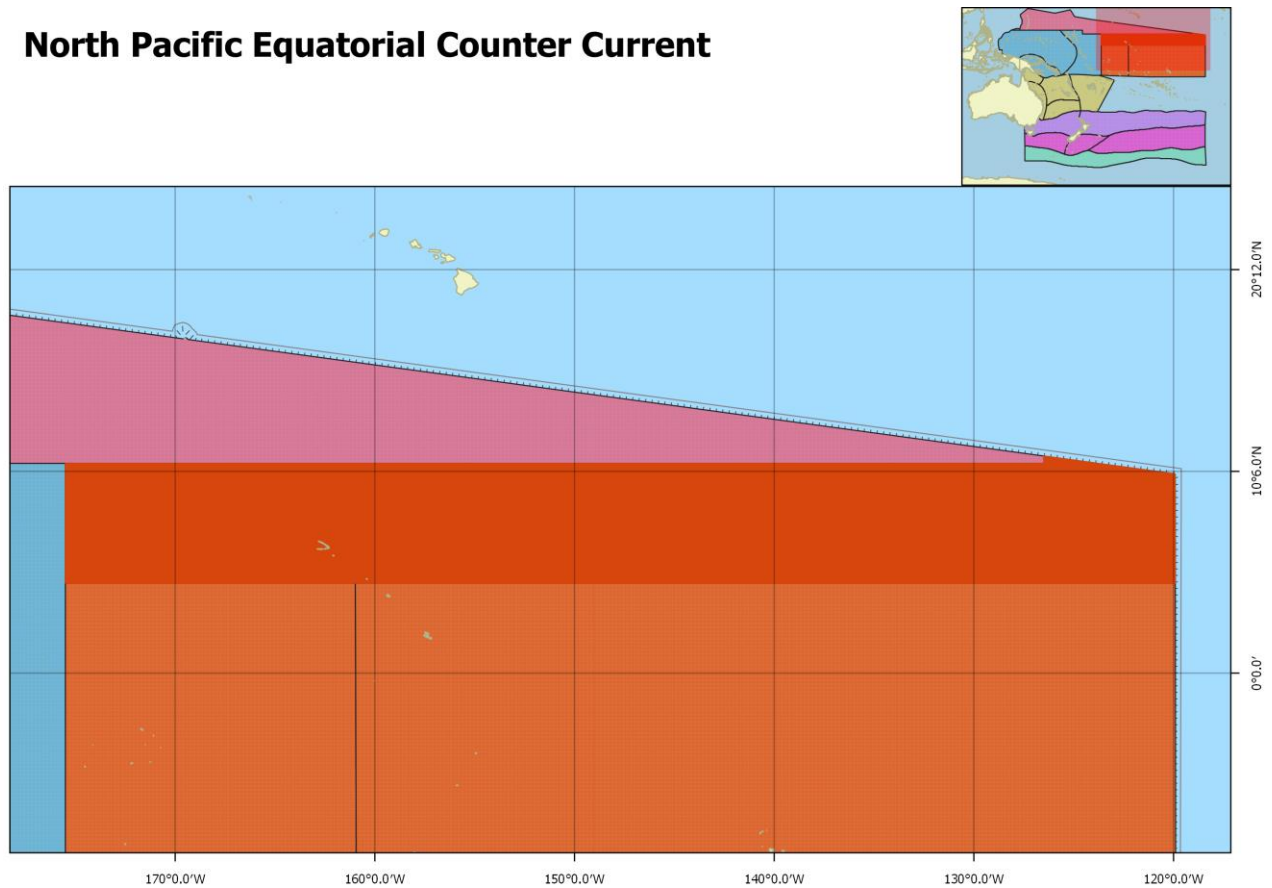


Figure 12. Ecosystem scenario responses to combinations of pressures. Red indicates a negative change and blue indicates a positive change. Ecosystem components in the qualitative model are: Top Predators (TP), Sea Birds (SB), Crustaceans (Crus), Small Pelagic Fish (SPF), Medium Pelagic Fish (MPF), Squid (SQ), Turtles (T), Cetaceans (C), Diatoms (Di), Nutrients (Nu), Regenerated Production (RP), Copepods (COP) and Gelatinous Plankton (GP) . Pressures acting on the system are: Fisheries (F), Marine Debris (MD), Cyclone (Cyc) and Temperature (Temp).

1.4 North Pacific Equatorial Counter-current (PNEC)

North Pacific Equatorial Counter Current



This North Pacific Equatorial Counter-current (NPEC) region is identical to the area described in Longhurst (2010). Houssard et al., (2017) found medium-high POM $\delta^{15}\text{N}$ ($7.7 \pm 1.6\%$), however no tuna were sampled in the NPEC.

influence from one component to another, and circle arrow heads back onto the same node represent a self-regulation effect (e.g. density dependence).

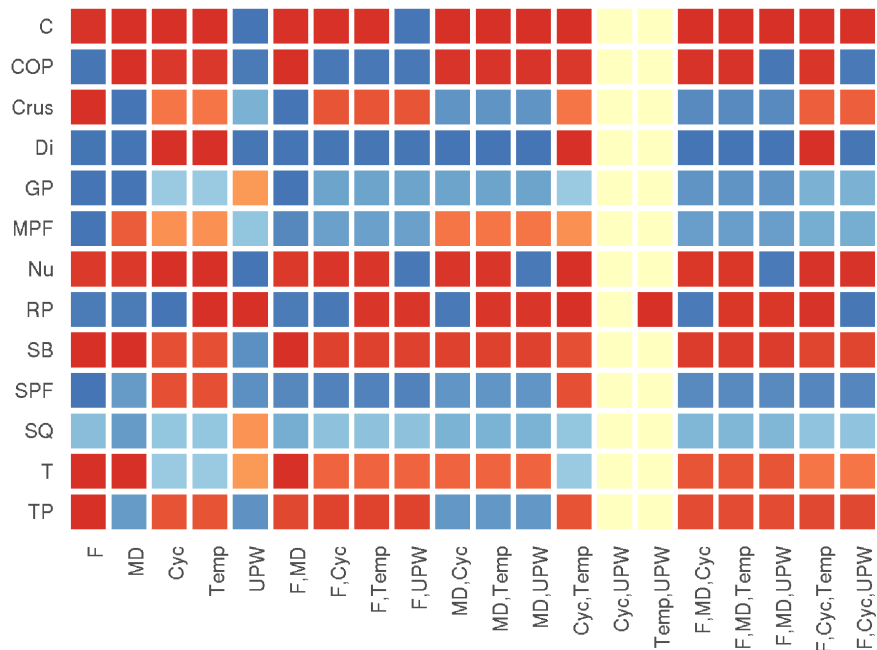
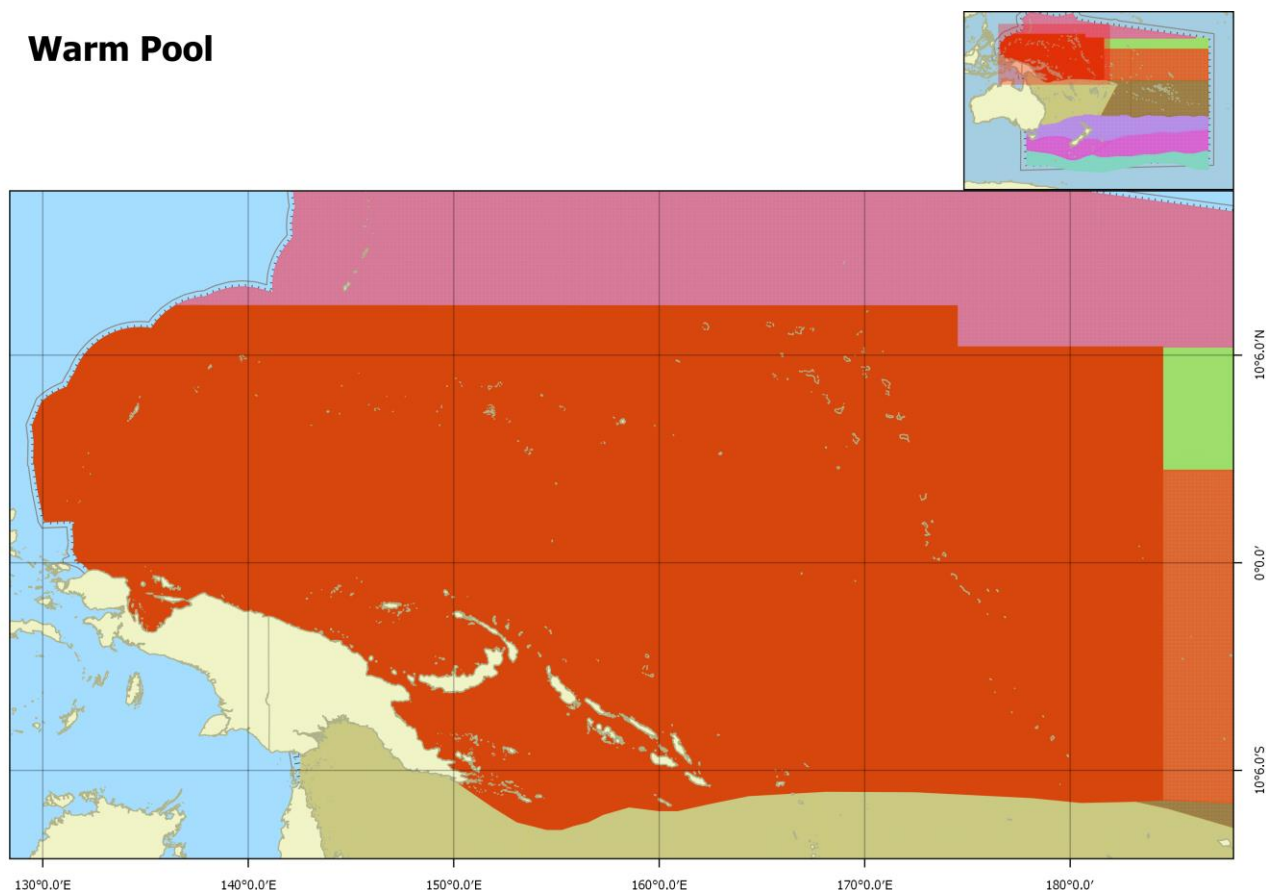


Figure 14. Ecosystem scenario responses to combinations of pressures. Red indicates a negative change and blue indicates a positive change. Ecosystem components in the qualitative model are: Top Predators (TP), Sea Birds (SB), Crustaceans (Crus), Small Pelagic Fish (SPF), Medium Pelagic Fish (MPF), Squid (SQ), Turtles (T), Cetaceans (C), Diatoms (Di), Nutrients (Nu), Regenerated Production (RP), Copepods (COP) and Gelatinous Plankton (GP). Pressures acting on the system are: Fisheries (F), Marine Debris (MD), Cyclone (Cyc), Temperature (Temp) and Upwelling (UPW).

1.5 Western Pacific Warm Pool (WARM)

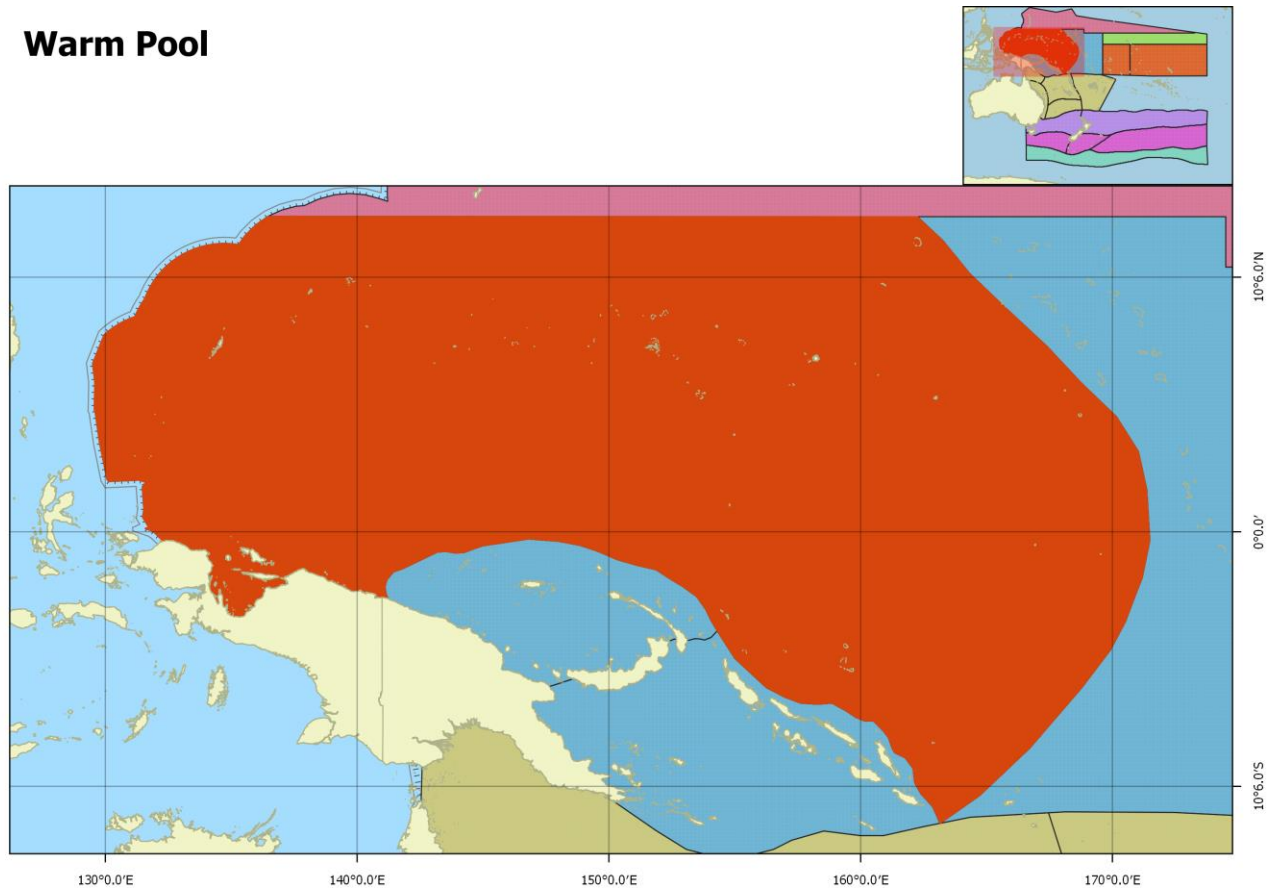
Warm Pool



Large migratory fish species in the Western Pacific Warm Pool (WARMm) have medium-high POM $\delta^{15}\text{N}$ ($7.5 \pm 2.7\%$) and moderate $\delta^{15}\text{N}$ values were found at the equator in WARMm ($15.5 \pm 1.7\%$ and $14.1 \pm 2.5\%$ for Bigeye and Yellowfin tuna) since new primary production is maintained by nitrate (Yoshikawa et al., 2006; Rafter and Sigman, 2016). The mean trophic position estimates were low to intermediate in WARMm (4.1 ± 0.8 for Bigeye and 3.6 ± 1.1 for Yellowfin). Bigeye tuna have a shallower distribution in the WARMm in the day (250-350m) compared to the ARCHm, but this distribution is deeper than the ARCHm during the night. The depth of the 20°C isotherm is approximately 140 meters depth in the western equatorial Pacific (WARMm). For Bigeye tuna, a deeper preferred habitat in the southern regions (ARCHm) was indicated by archival tag data, where the mean diving depth of bigeye was deeper in New Caledonia (ARCHm) than in the western equatorial Pacific (WARMm, depth difference of 50–90 m according to individuals) (Houssard et al 2017)

1.5.1 Pacific Warm Pool

Warm Pool



The Pacific Warm Pool is well described in Longhurst (2010) and is strongly influenced by the North Equatorial Counter Current (From the Equator to 10°N) with micronekton composition different from micronekton composition of other northern areas to the east (Hidaka et al., 2001)

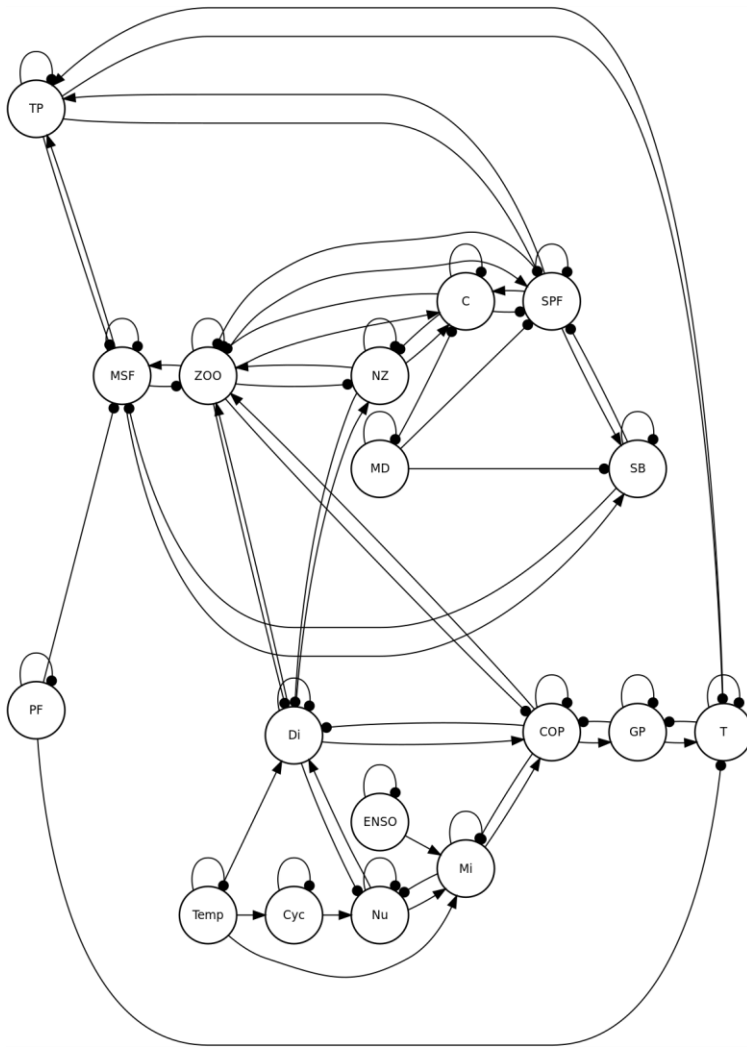


Figure 15. Ecosystem components in the qualitative model are: Top Predators (TP), Mid-size Fish and Squid (MSF), Small Pelagic Fish (SPF), Sea Birds (SB), Turtles (T), Meso-Macro Zooplankton (ZOO), Gelatinous Plankton (GP), Cetaceans (C), Copepods (COP), Nano-Zooplankton (NZ), Diatoms (Di), Microbes (Mi) & Nutrients (Nu). Pressures acting on the system are: Marine Debris (MD), Pelagic Fisheries (PF), Cyclones (Cyc), El Nino Southern Oscillation (ENSO) & Temperature (Temp). Circle arrow heads represent a negative effect from one component to another, normal arrow heads represent a positive influence from one component to another, and circle arrow heads back onto the same node represent a self-regulation effect (e.g. density dependence).

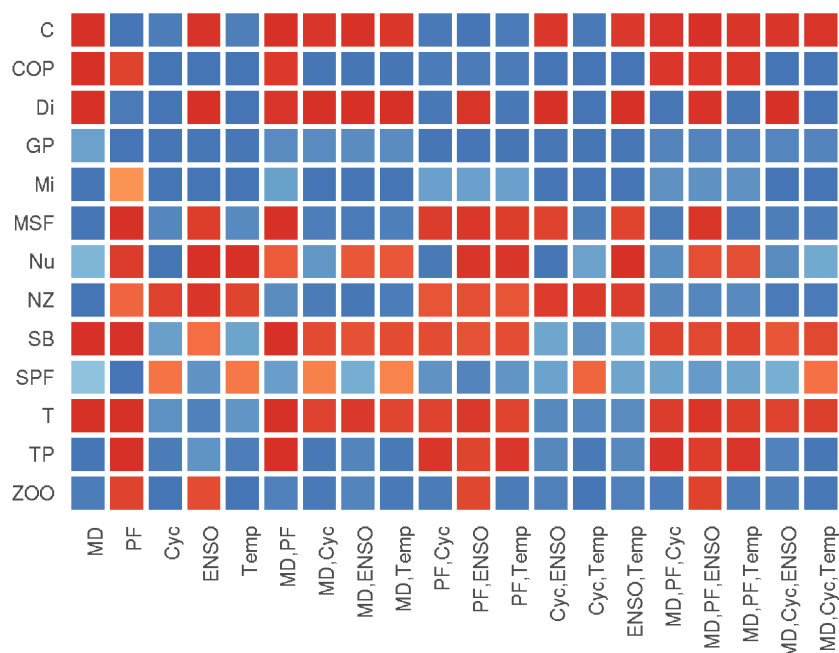
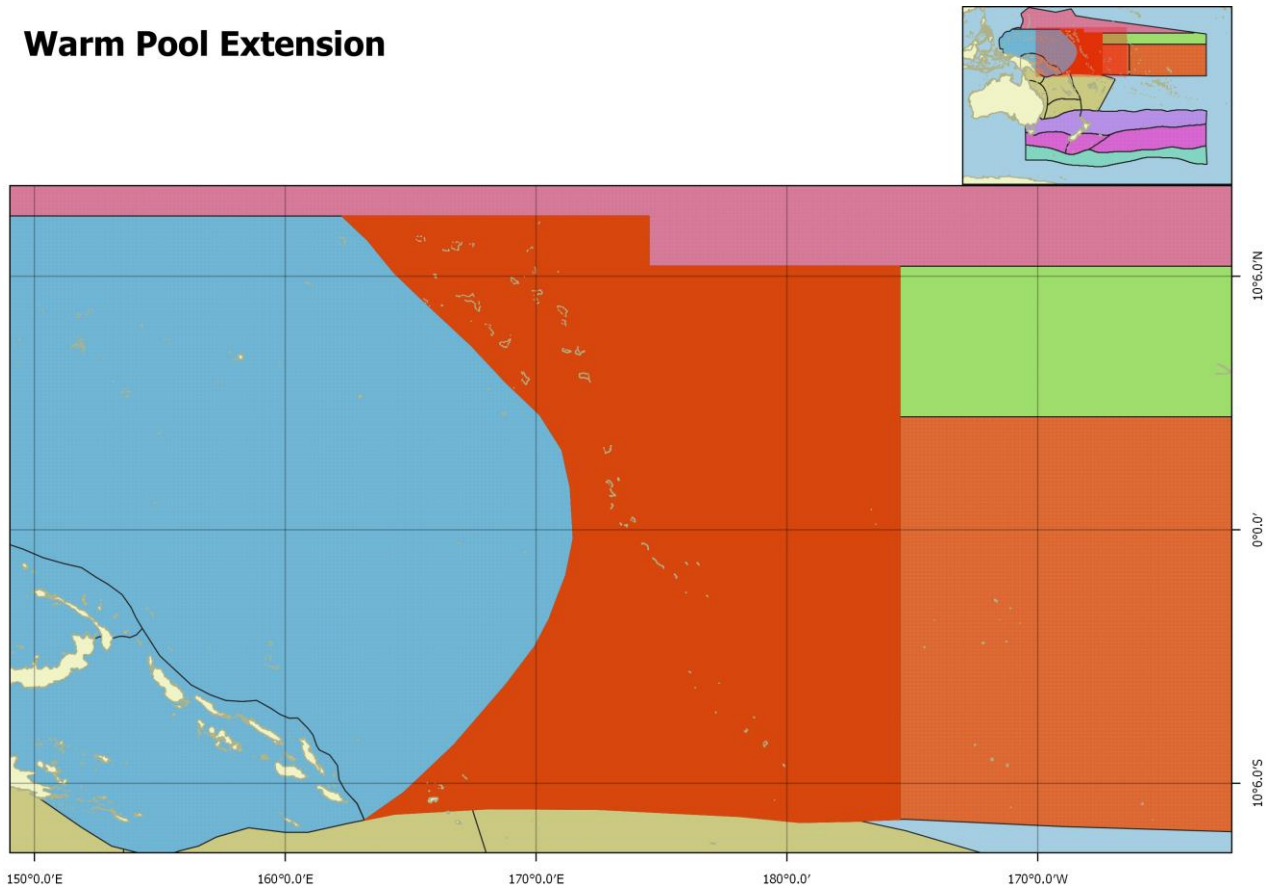


Figure 16. Ecosystem scenario responses to combinations of pressures. Red indicates a negative change and blue indicates a positive change. Ecosystem components in the qualitative model are: Top Predators (TP), Mid-size Fish and Squid (MSF), Small Pelagic Fish (SPF), Sea Birds (SB), Turtles (T), Meso-Macro Zooplankton (ZOO), Gelatinous Plankton (GP), Cetaceans (C), Copepods (COP), Nano-Zooplankton (NZ), Diatoms (Di), Microbes (Mi) & Nutrients (Nu). Pressures acting on the system are: Marine Debris (MD), Pelagic Fisheries (PF), Cyclones (Cyc), ENSO (ENSO) & Temperature (Temp).

1.5.2 Warm Pool La-Nina Extension Province

Warm Pool Extension



The Warm Pool La-Nina Extension Province encompasses the transition region where the Pacific Warm pool extend to in La-Nina years. When the Pacific is in a La-Nina phase, surface temperatures in this region rise and large migratory fish (e.g. Tunas) move eastwards from the Pacific Warm Pool province to this region. In an El-Nino phase, the reverse is true and there are much fewer Tunas and similar species in this Province.

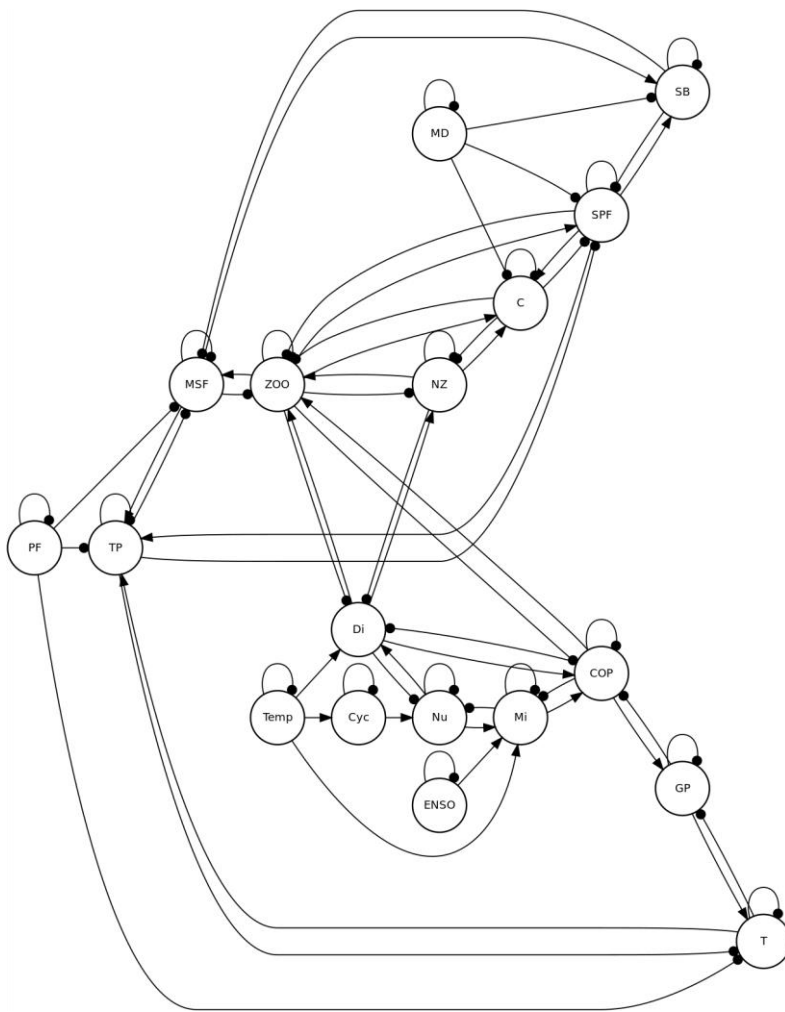


Figure 17. Ecosystem components in the qualitative model are: Top Predator (TP), Mid-Size Fish and Squid (MSF), Small Pelagic Fish (SPF), Sea Birds (SB), Turtles (T), Meso-Macro Zooplankton (ZOO), Gelatinous Plankton (GP), Cetaceans (C), Copepods (COP), NanoZooplankton (NZ), Diatoms (Di), Microbes (Mi) and Nutrients (Nu). Pressures acting on the system are: Marine Debris (MD), Pelagic Fisheries (PF), Cyclones (Cyc), ENSO (ENSO), Temperature (Temp). Circle arrow heads represent a negative effect from one component to another, normal arrow heads represent a positive influence from one component to another, and circle arrow heads back onto the same node represent a self-regulation effect (e.g. density dependence).

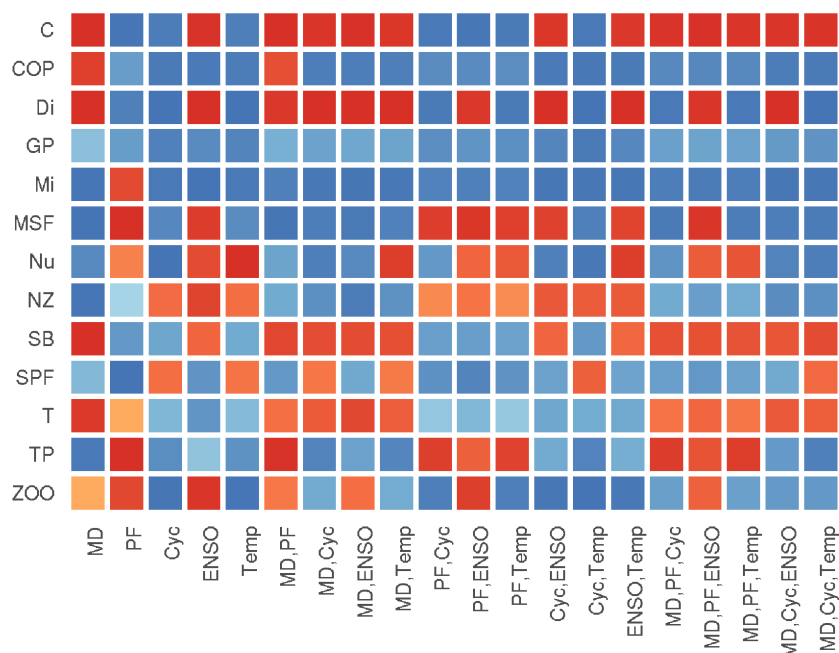
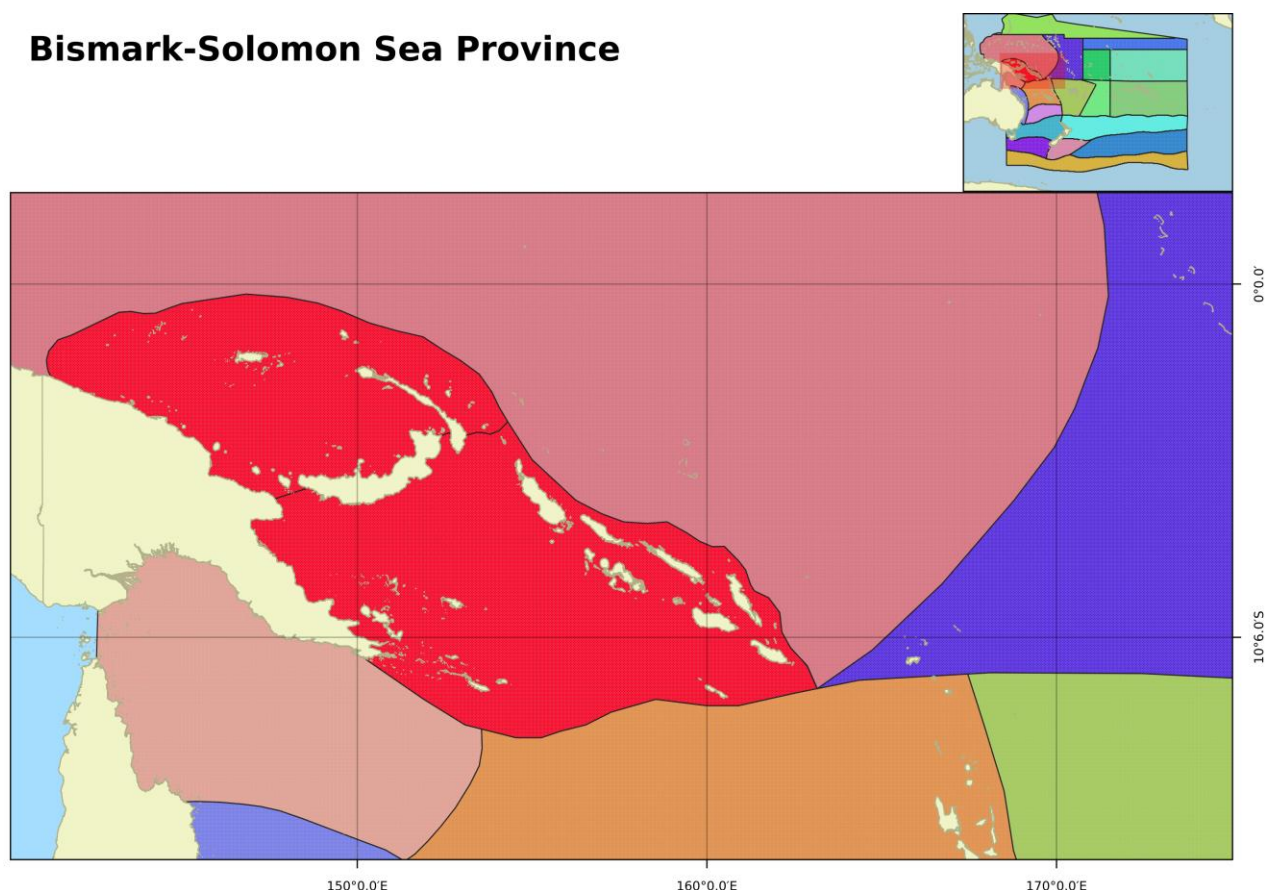


Figure 18: Ecosystem scenario responses to combinations of pressures. Red indicates a negative change and blue indicates a positive change. Ecosystem components in the qualitative model are: Top Predator (TP), Mid-Size Fish and Squid (MSF), Small Pelagic Fish (SPF), Sea Birds (SB), Turtles (T), Meso-Macro Zooplankton (ZOO), Gelatinous Plankton (GP), Cetaceans (C), Copepods (COP), NanoZooplankton (NZ), Diatoms (Di), Microbes (Mi) and Nutrients (Nu). Pressures acting on the system are: Marine Debris (MD), Pelagic Fisheries (PF), Cyclones (Cyc), ENSO (ENSO), Temperature (Temp).

1.5.3 Bismarck-Solomon Sea Province

Bismarck-Solomon Sea Province



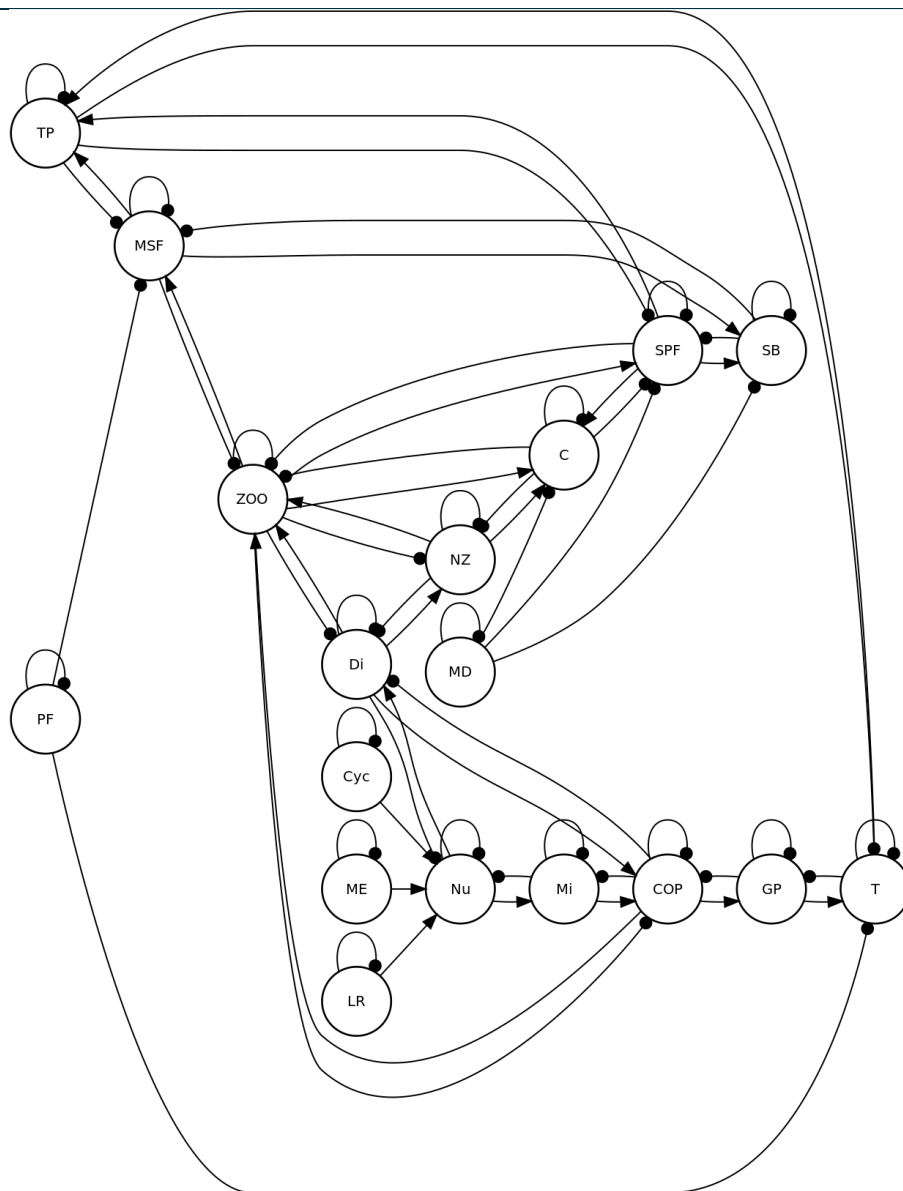
The dominant biogeographic forcing agents defining this ecoregions vary from location to location but generally include isolation, upwelling, nutrient inputs, freshwater influx, temperature regimes, exposure, sediments, currents, and bathymetric or coastal complexity. In ecological terms, these are strongly cohesive units, large enough to encompass ecological or life history processes for most sedentary species (Green et al 2014).

The Bismarck-Solomon Sea Province is two semi-enclosed tropical marginal seas with associated reefs and islands (McKinnon et al., 2013). The ecoregion includes important deep-sea features such as the New Britain Trench, which is just south of the island of New Britain, south west of Solomon Archipelago. These seas are in the western part of the so-called warm pool region and, as such, have some of the warmest waters in the global ocean comprising predominately of oligotrophic seas (McKinnon et al., 2014). It is around annual mean Sea Surface Temperature (SST) ranges within 28 °C–29.5°C.

Analysis of mean and seasonal change of Sea Surface Temperature (SST) and Salinity (SSS) in the Solomon and Bismarck Seas (Delcroix et al., 2014) shows large annual oscillations in the Solomon Sea, with the coldest and saltiest waters occurring in July/August mainly due to horizontal advection.

The mean ocean surface circulation flow is known to enter the Solomon Sea from both its northern and southern parts. From the north, the flow is southward through Solomon Strait; one-part flows along the New Britain coast and exits northward through Vitiaz Strait; the other part flows southward into the Solomon Sea, exiting through its southern limit.

With western current and upwelling generally contribute to richness of nutrient and species in the region apart coral (within the CTI). McKinnon et al (2014) indicated the region as part of the global centre of marine biodiversity primarily defined by high species diversity of corals (almost 600) and reef fish (>2,000) (Veron et al., 2011), and it contains 76% of the world's coral species and a number of endemics of various coral reef taxa.



At pelagic level, the occurrence of species such as tuna and charismatic species has been a focus for conservation in region (BSSE initiative). Bismarck Solomon sea region characterised with deep water habitats, offshore reef with low pressure, unique land and reef types. It is rich reproduction and aggregation sites for Tuna compare to east, whale passage, dolphins, Leatherback nesting, turtle migratory path, feeding habitats for green and hawksbill turtle has certainly characterised the region.

Figure 19: Ecosystem components in the qualitative model are: Top Predator (TP), Mid-Size Fish and Squid (MSF), Small Pelagic Fish (SPF), Sea Birds (SB), Turtles (T), Meso-Macro Zooplankton (ZOO), Gelatinous Plankton (GP), Cetaceans (C), Copepods (COP), NanoZooplankton (NZ), Diatoms (Di), Microbes (Mi) & Nutrients (Nu). Pressures acting on the system are: Marine Debris (MD), Pelagic Fisheries (PF), Mesoscale Eddies (ME), Land Runoff (LR) & Cyclones (Cyc). Circle arrow heads represent a negative effect from one component to another, normal arrow heads represent a positive influence from one component to another, and circle arrow heads back onto the same node represent a self-regulation effect (e.g. density dependence).

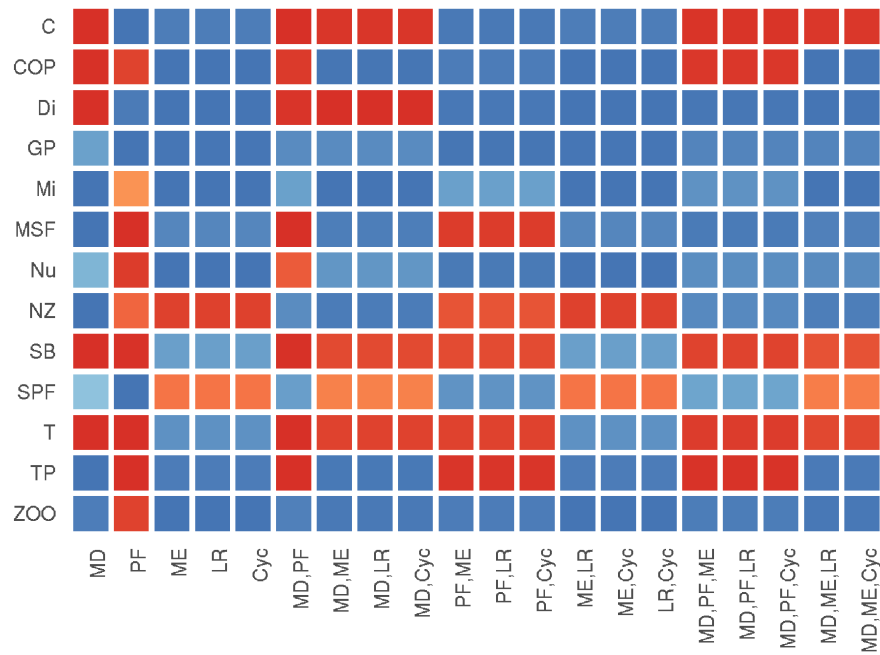
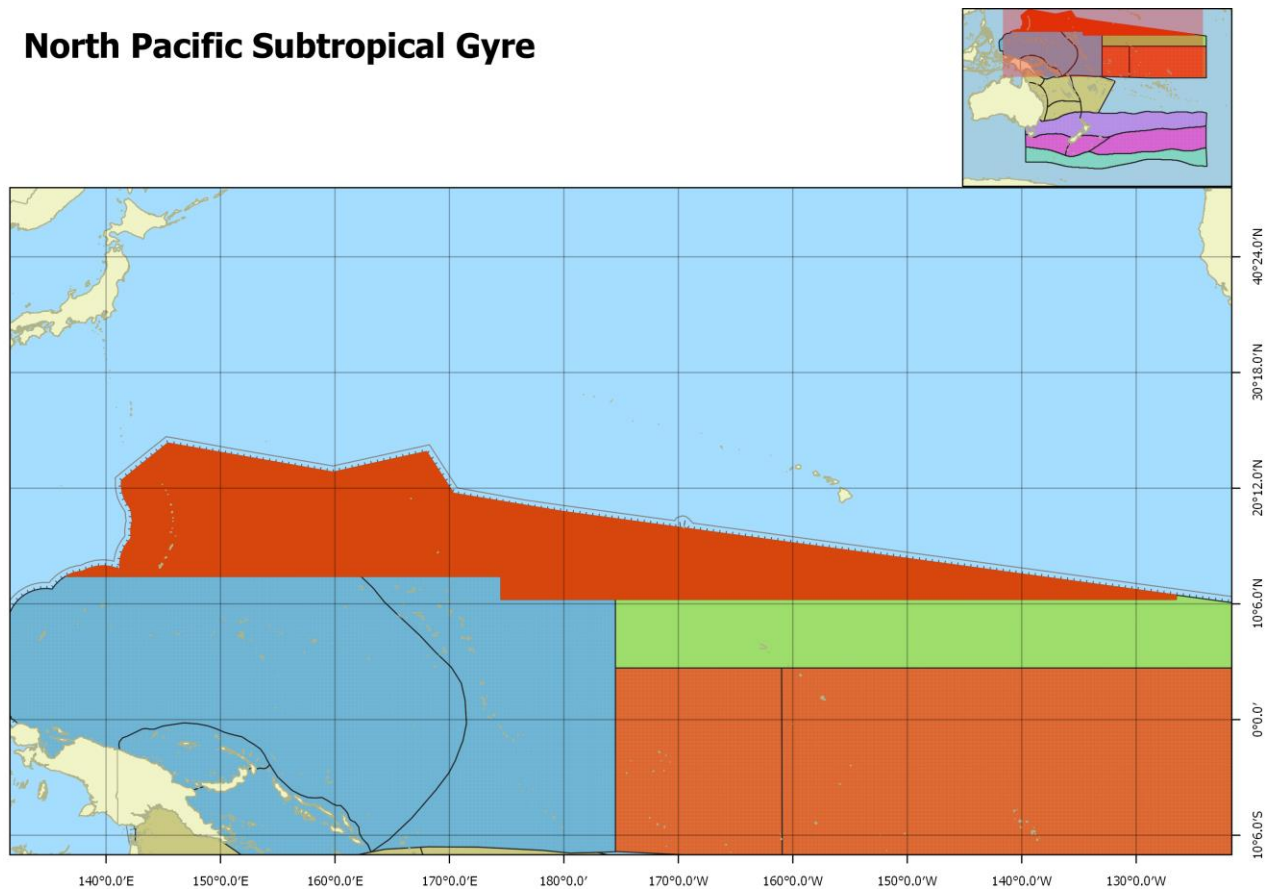


Figure 20: Ecosystem scenario responses to combinations of pressures. Red indicates a negative change and blue indicates a positive change. Ecosystem components in the qualitative model are: Top Predator (TP), Mid-Size Fish and Squid (MSF), Small Pelagic Fish (SPF), Sea Birds (SB), Turtles (T), Meso-Macro Zooplankton (ZOO), Gelatinous Plankton (GP), Cetaceans (C), Copepods (COP), NanoZooplankton (NZ), Diatoms (Di), Microbes (Mi) & Nutrients (Nu). Pressures acting on the system are: Marine Debris (MD), Pelagic Fisheries (PF), Mesoscale Eddies (ME), Land Runoff (LR) & Cyclones (Cyc).

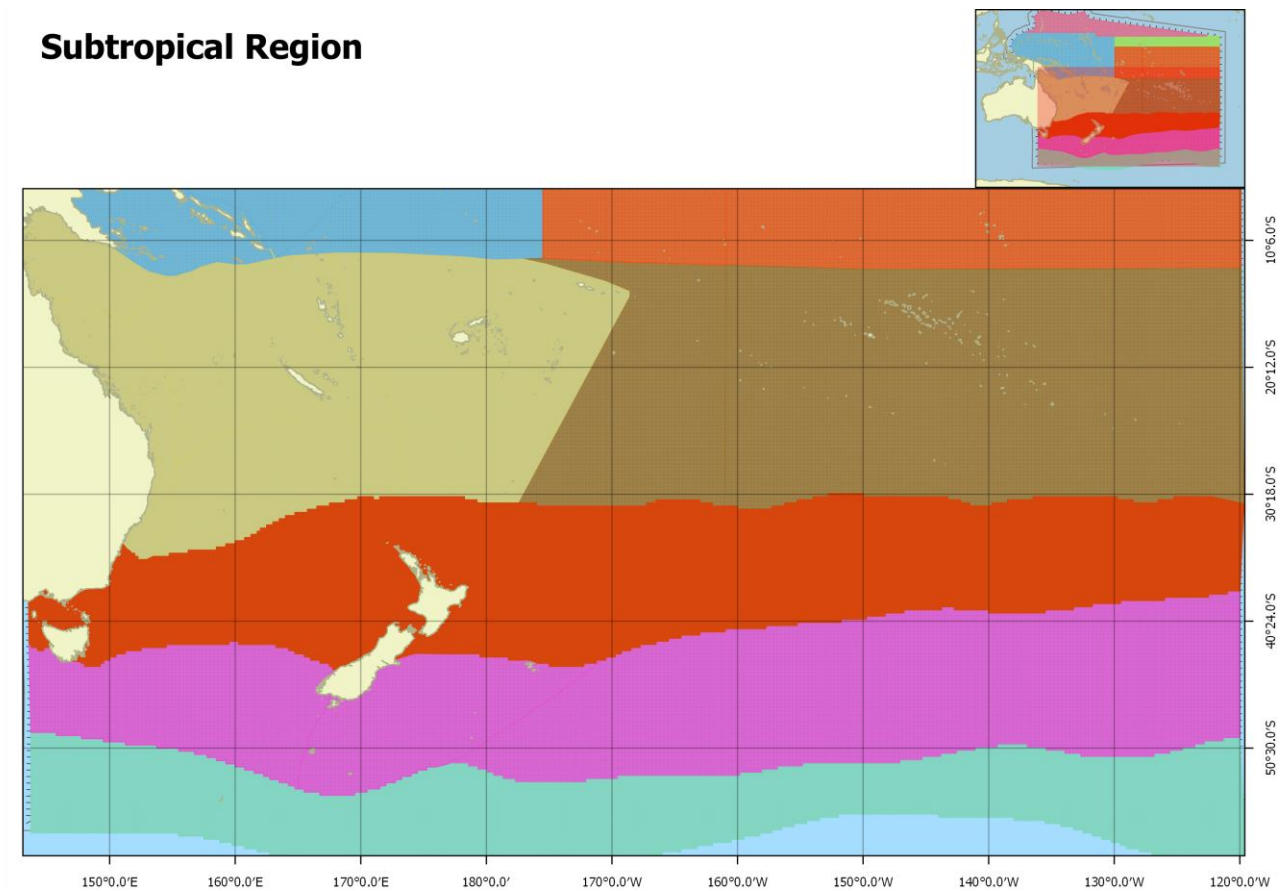
1.6 North Subtropical Gyre

North Pacific Subtropical Gyre



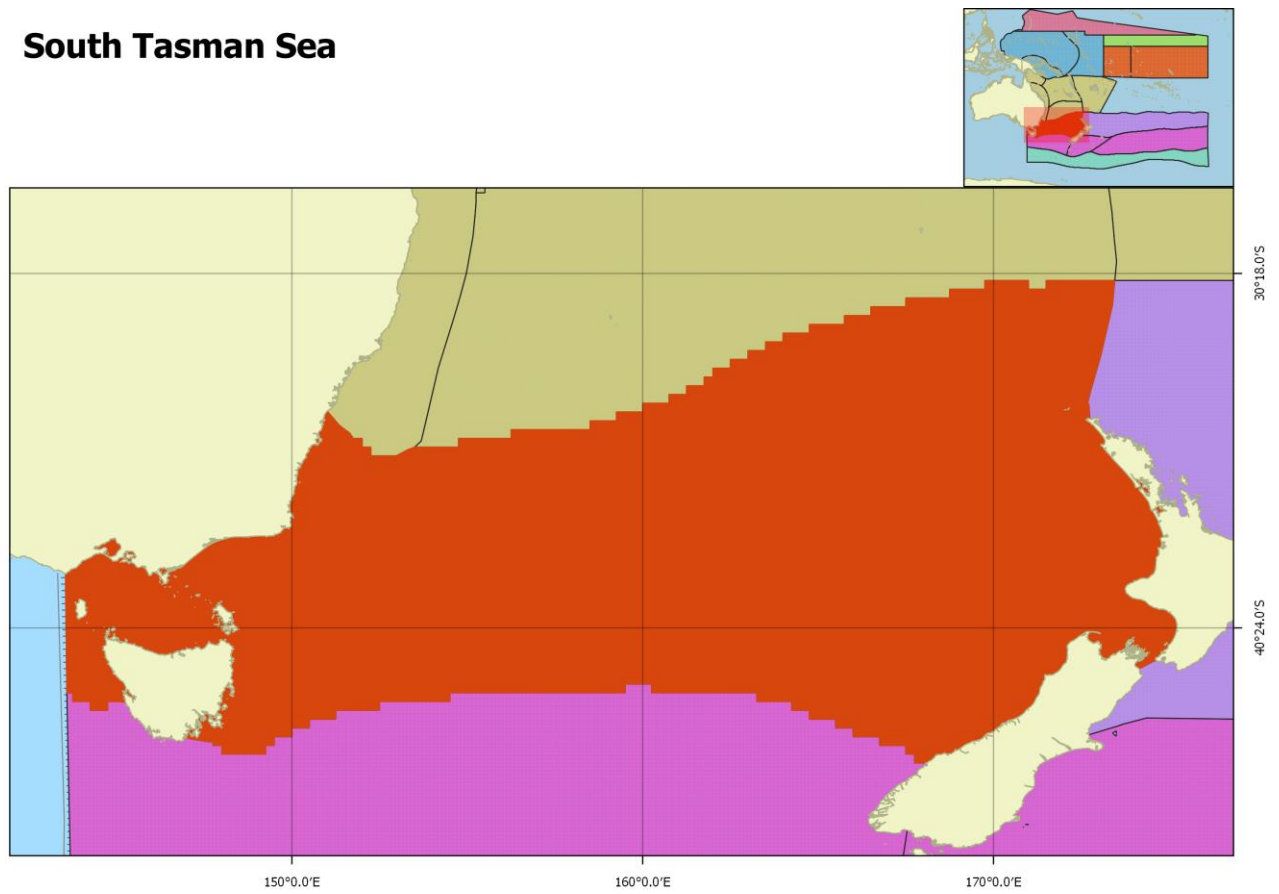
This is part of a large province north of the Equator, as identified by Longhurst et al. 2010.

1.7 Subtropical Region



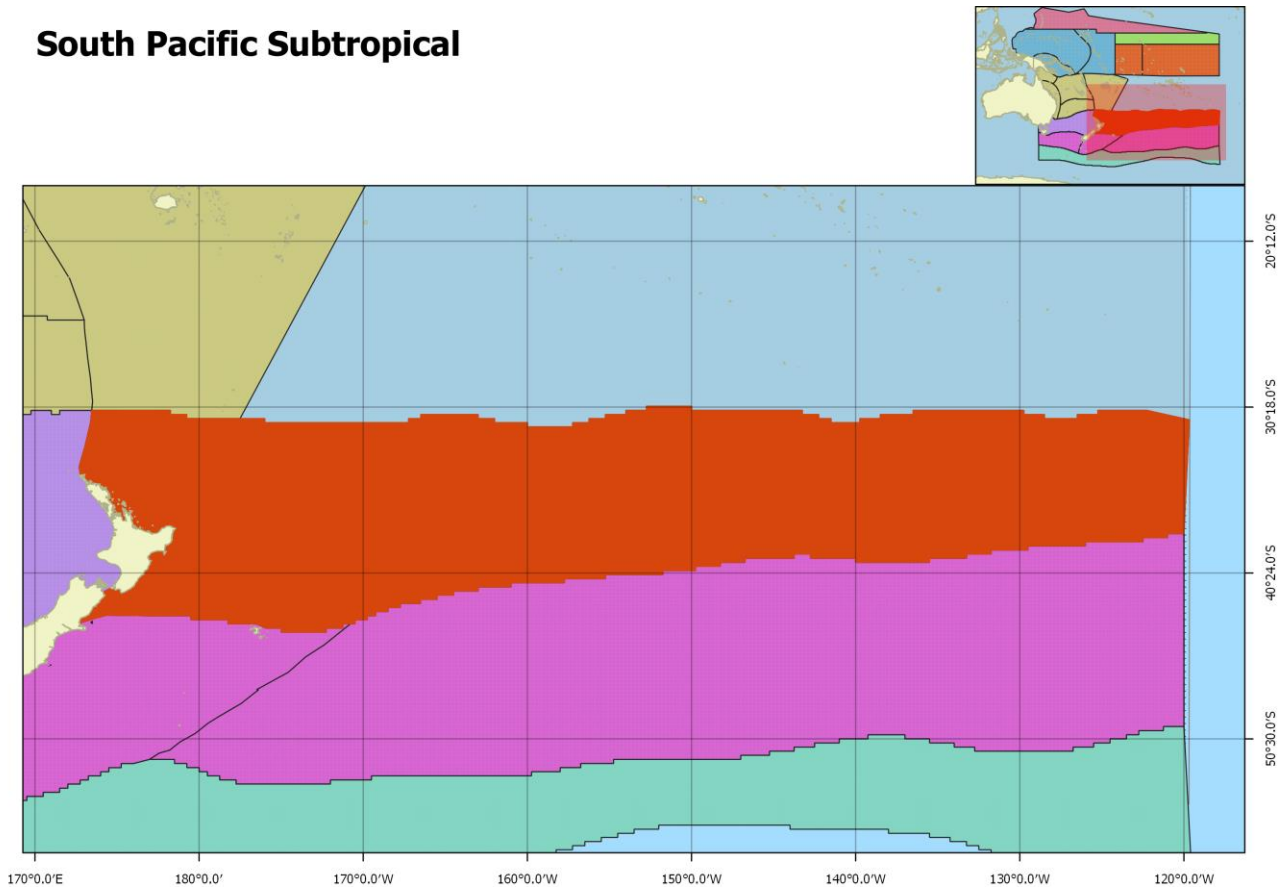
1.7.1 South Tasman Sea

South Tasman Sea



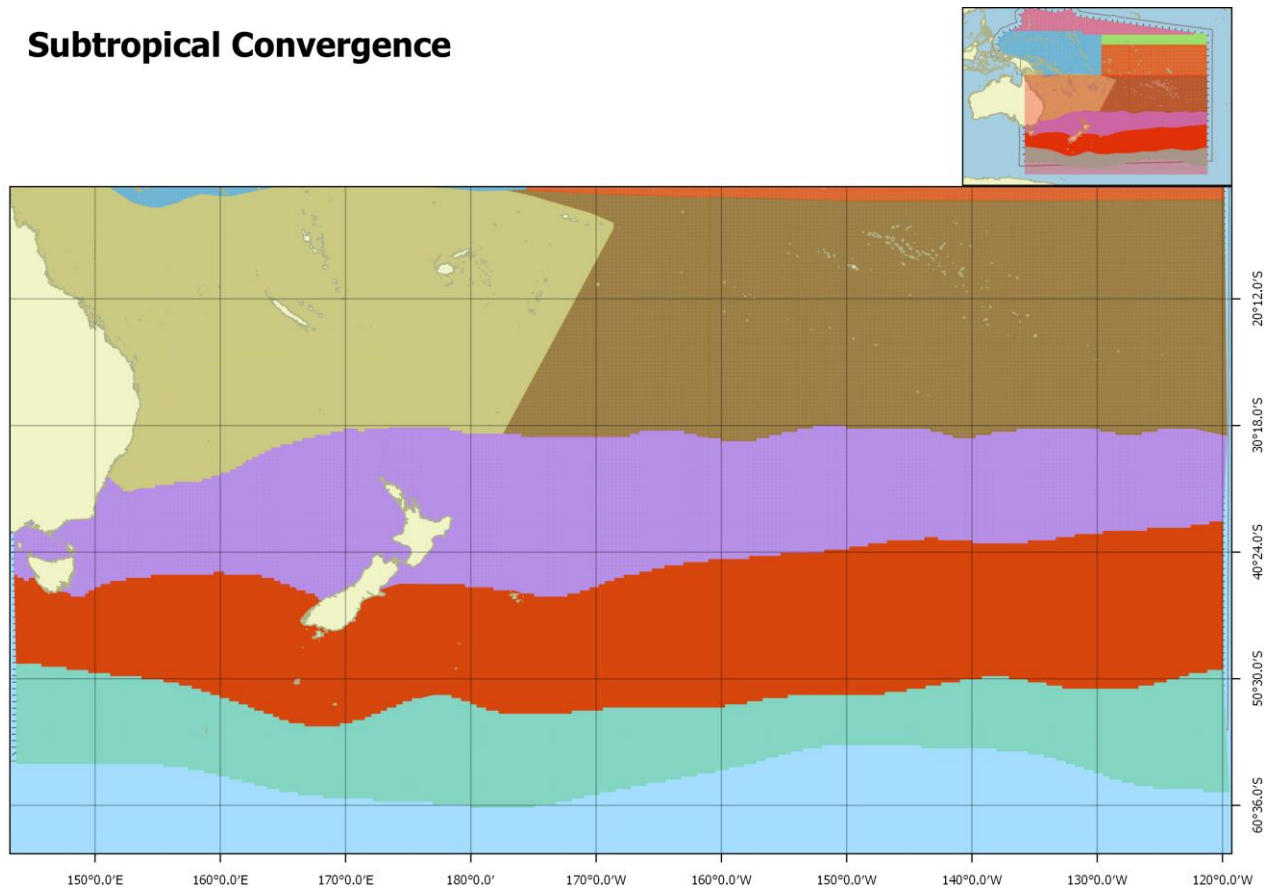
1.7.2 South Pacific Subtropical

South Pacific Subtropical



1.8 South Subtropical Convergence

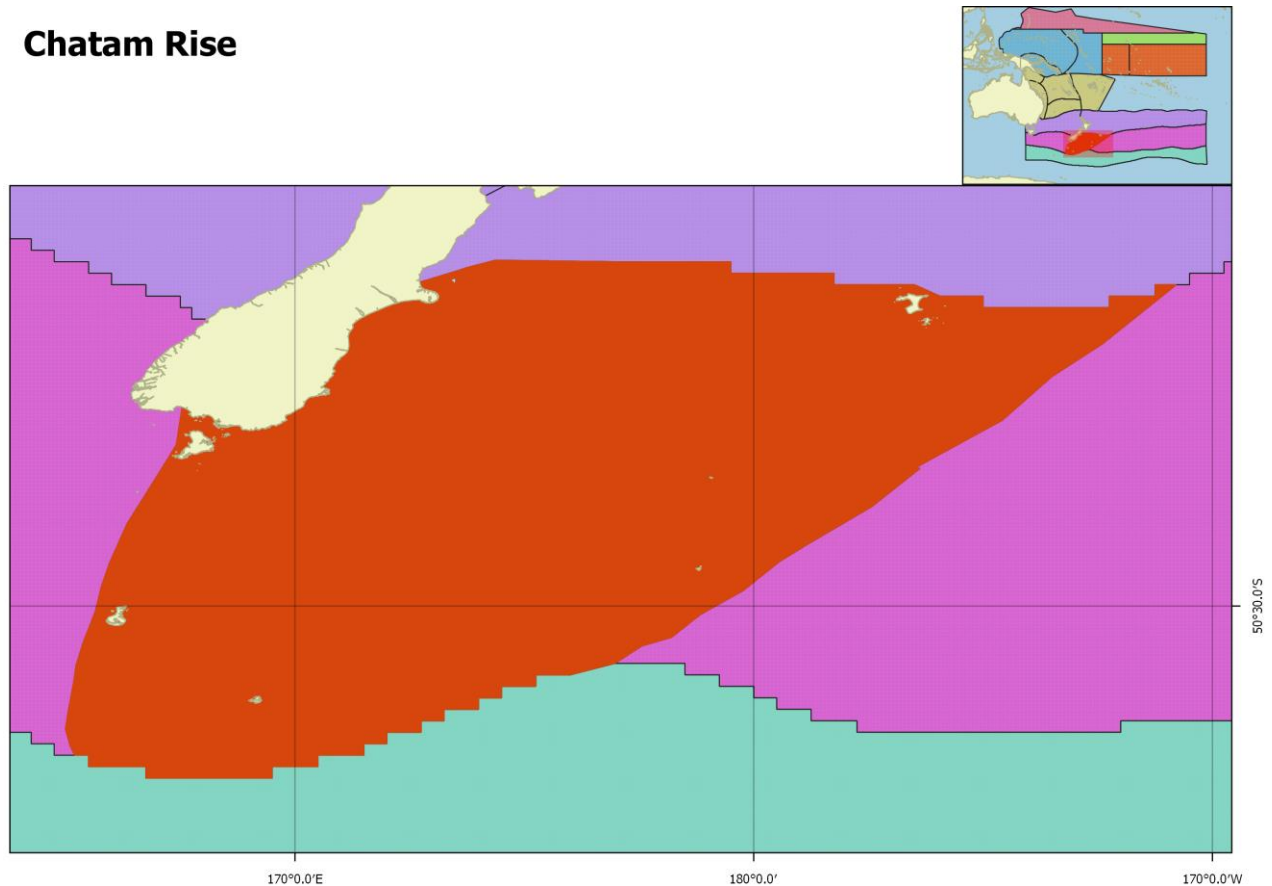
Subtropical Convergence



The South Subtropical Convergence is very similar to the region identified in Longhurst (2010). This is the frontal zone that marks the intersection of colder sub Antarctic waters with warmer tropical waters and is a region that supports substantial fisheries.

1.8.1 Chatham Rise (NEWZ)

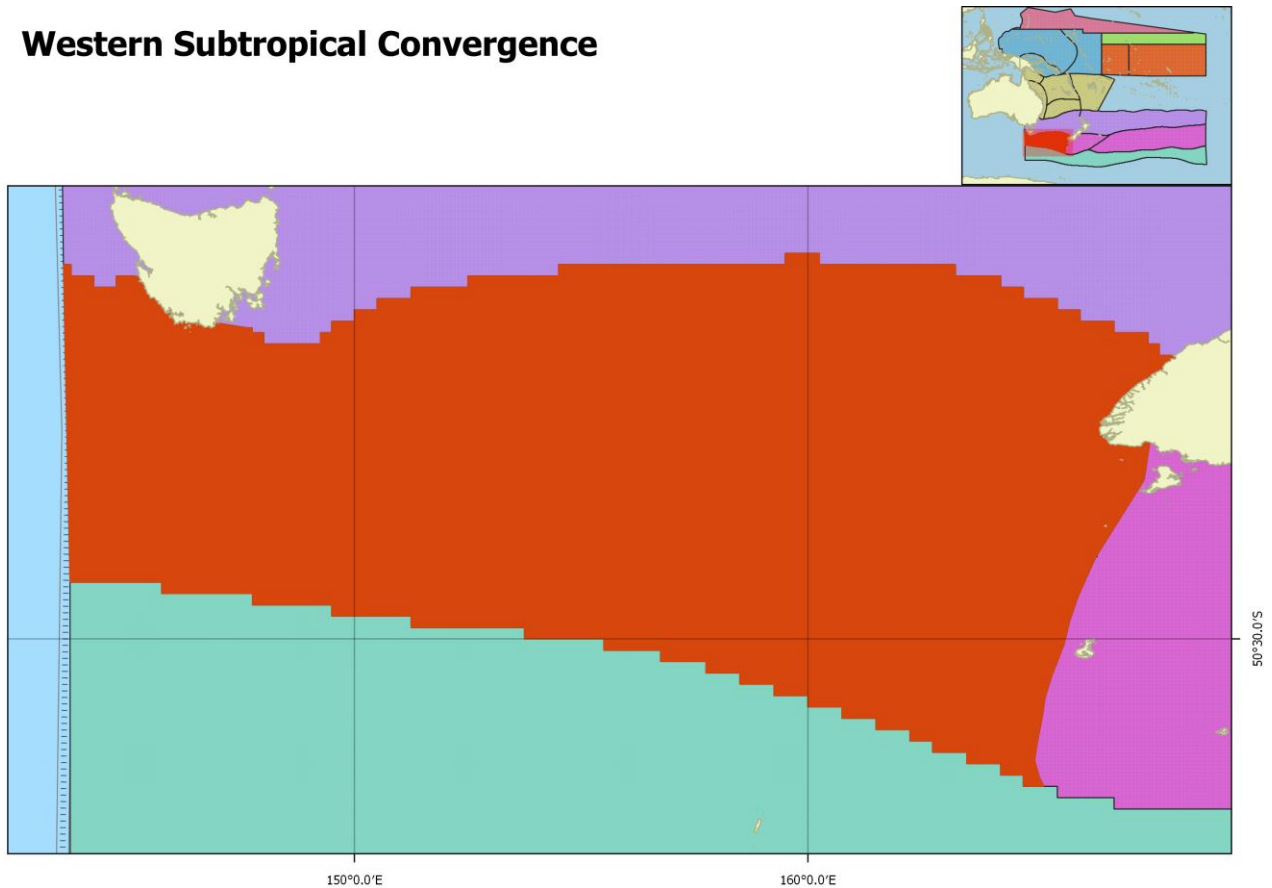
Chatam Rise



This region is like the region identified in Longhurst (2010) as New Zealand Coastal (NEWZ). However, it does not include the western or norther coastal areas. The Antarctic circumpolar current wraps around the southern extend of New Zealand and rises over the Campbell Plateau and Chatham Rise. This water mass intersects with warmer waters from the Subtropical convergence to generate a series of fronts over the rise (Hadfield et al. 2007). This area supports a highly productive fishery.

1.8.2 Western Subtropical Convergence

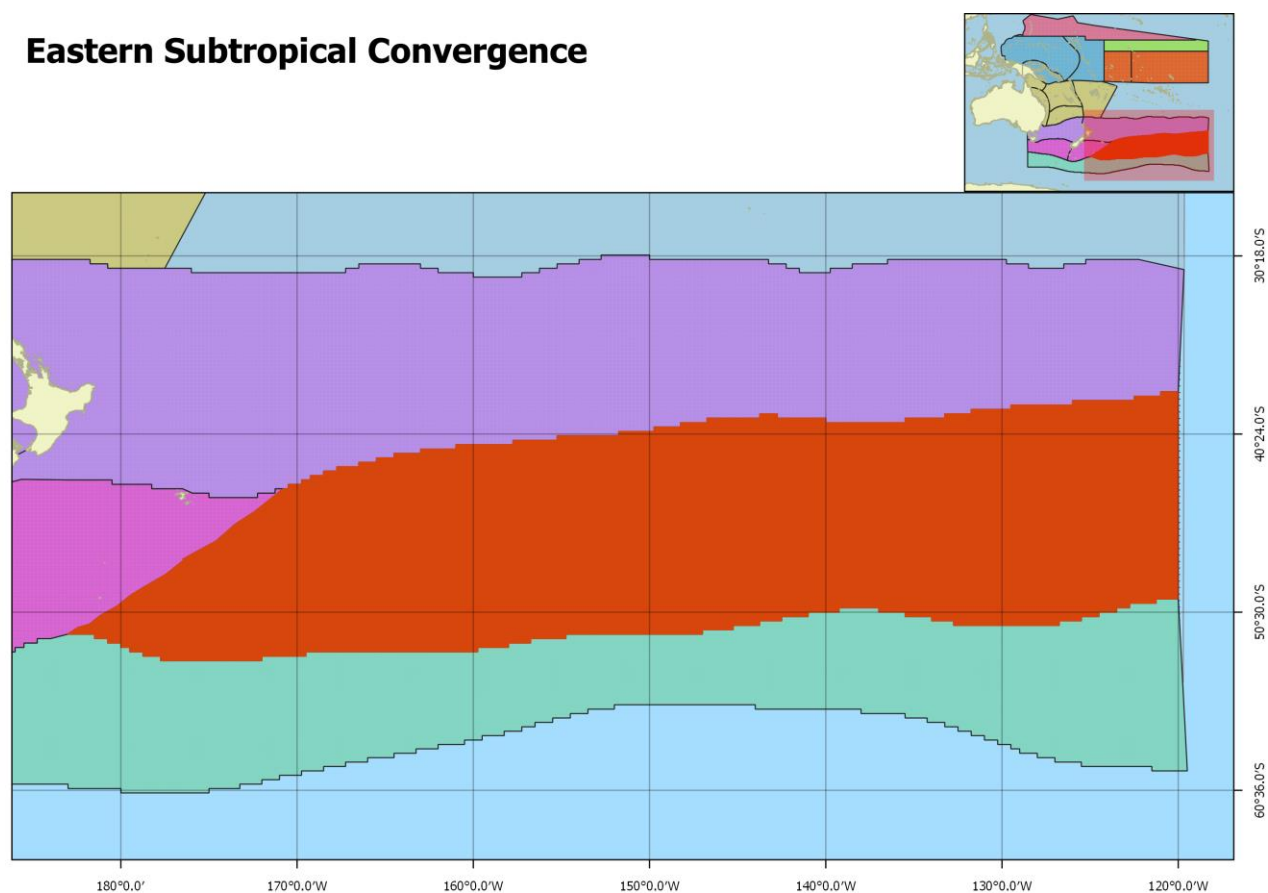
Western Subtropical Convergence



This region extends from the Subtropical region south to the Antarctic Polar Front. It is an extension of a similar region identified in the Indian Ocean and is strongly influenced by Antarctic waters. It joins into the South Tasman Sea in the north.

1.8.3 Eastern Subtropical Convergence

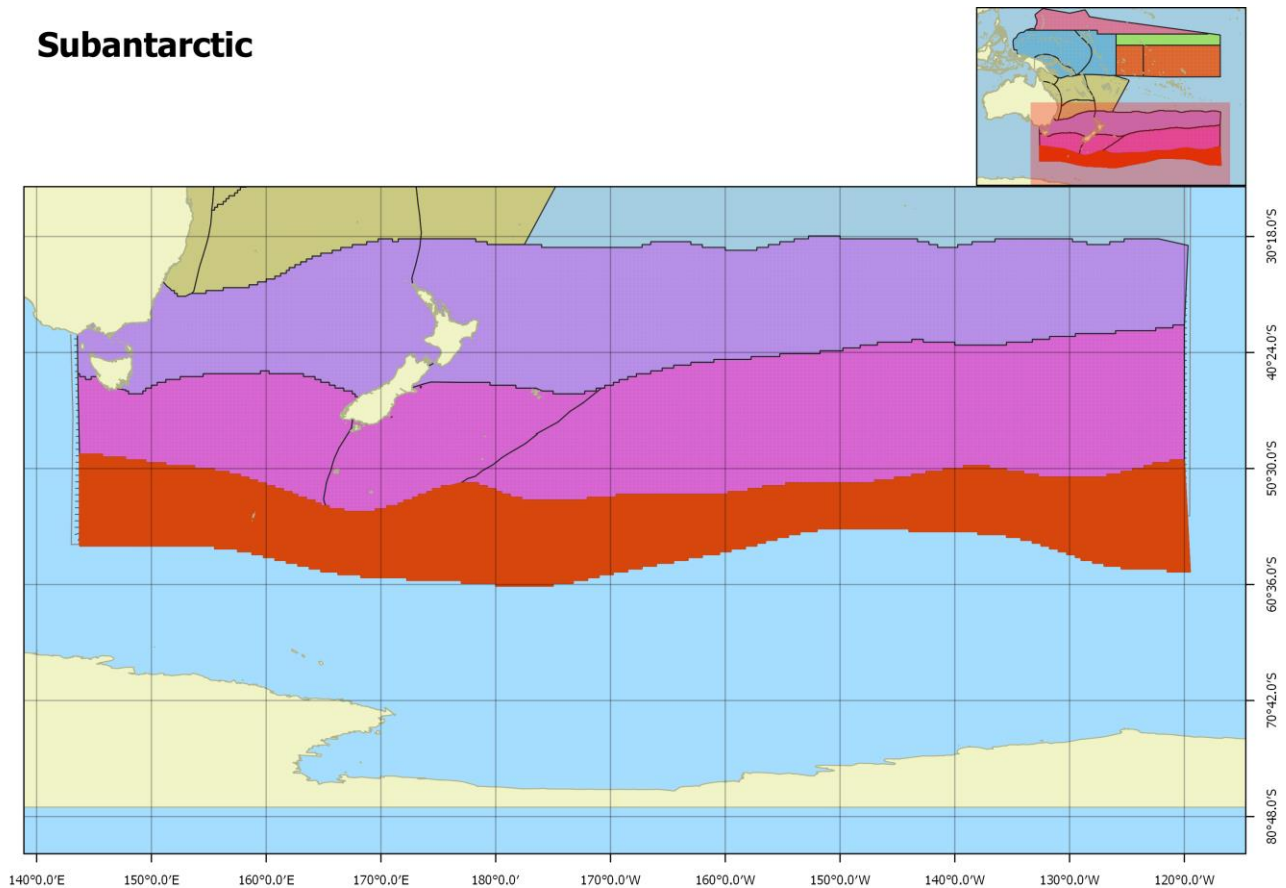
Eastern Subtropical Convergence



This region extends from the Subtropical region south to the Antarctic Polar Front. It extends from the Chatham Rise through to the coast of South America. It is strongly influenced by Antarctic waters.

1.9 Subantarctic Province

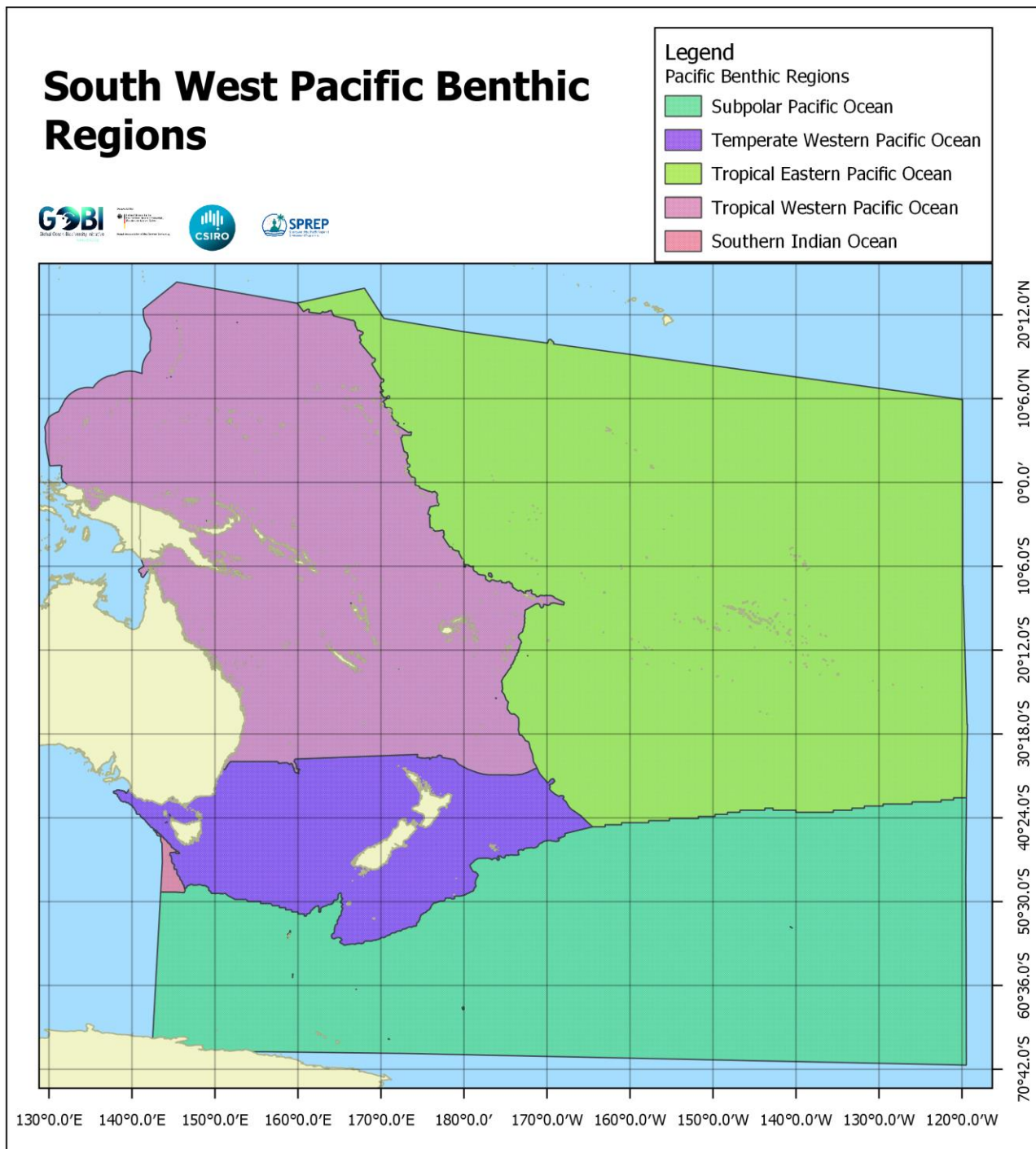
Subantarctic



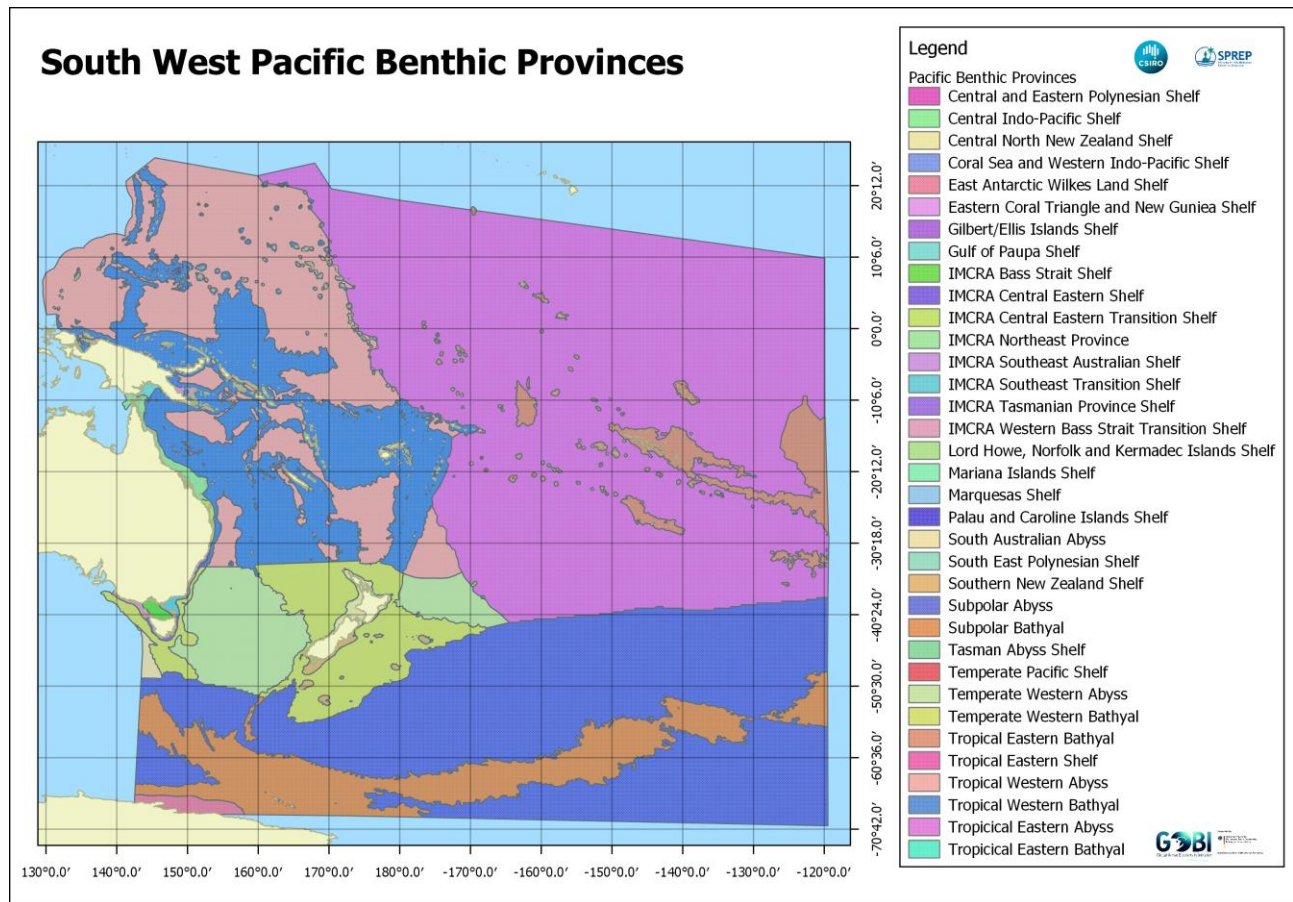
The Subantarctic Province contains the Antarctic Circumpolar Current which flows clockwise from west to east around Antarctica. The current is circumpolar due to the lack of any landmass connecting with Antarctica and this keeps warm ocean waters away from Antarctica, enabling that continent to maintain its huge ice sheet. The colder water temperatures of the Subantarctic Province results in a different fauna, as the region transitions into a polar fauna.

2 South Western Pacific Benthic Bioregions

The distribution of the Large Marine Areas – the highest level of classification for the South West Pacific Ocean is shown below.

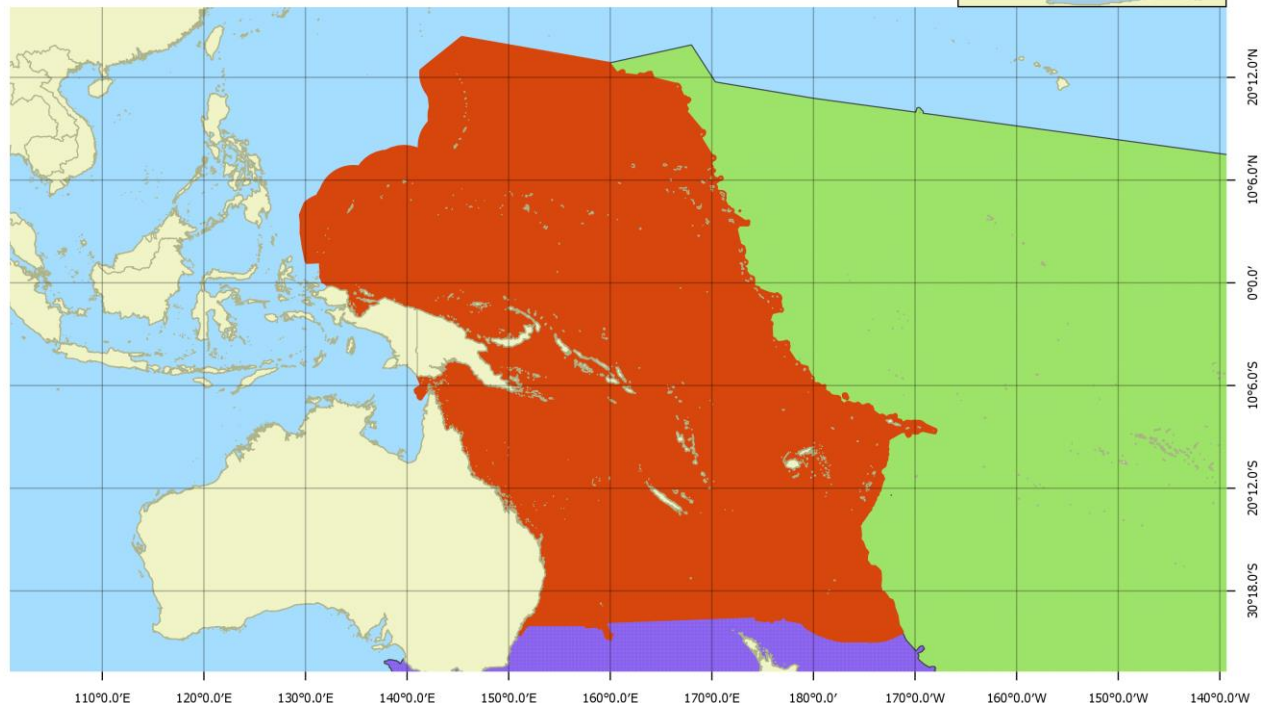


The distribution of the provinces within the Large Regions is shown below. More detailed descriptions of each of the provinces to given below.



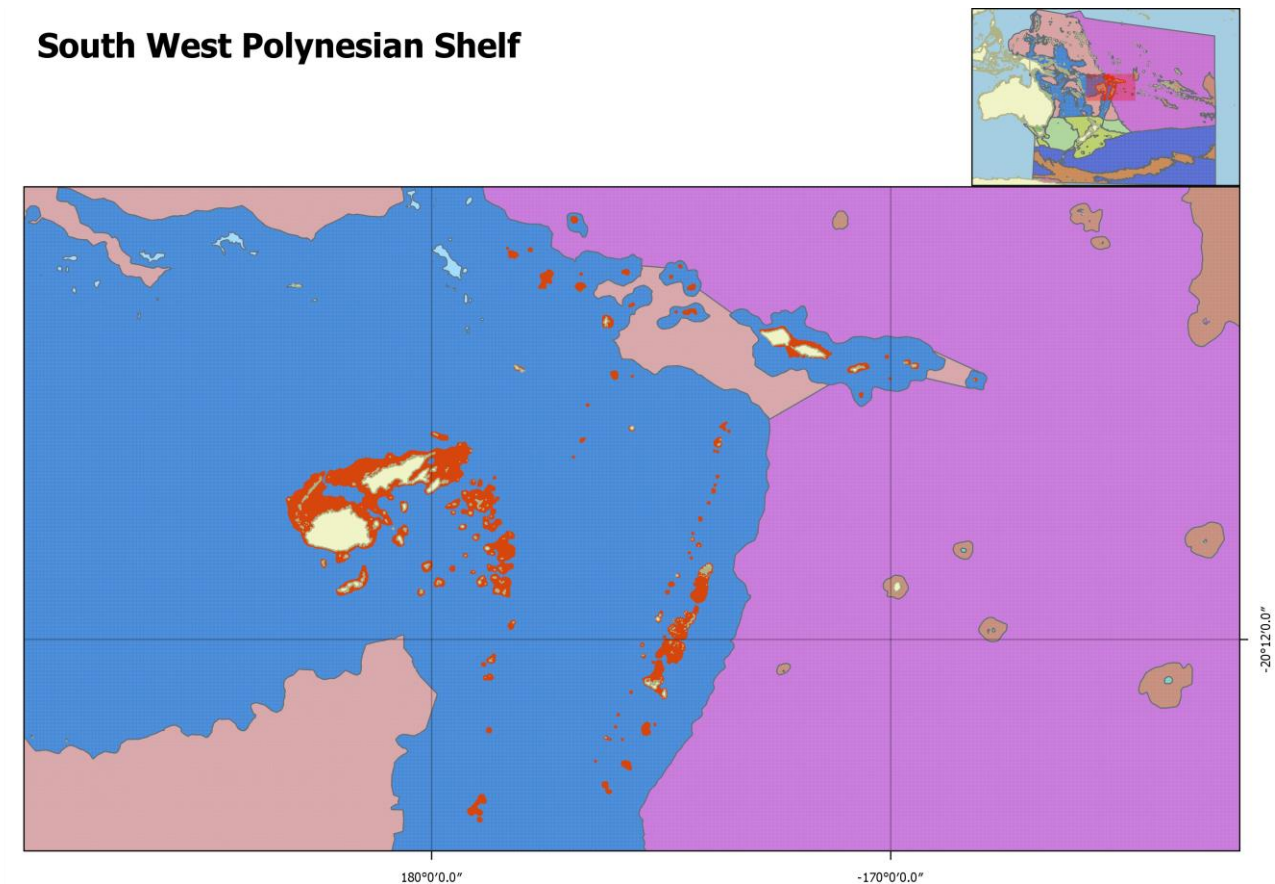
2.1 SW Pacific Tropic Western Region

Tropical Western Pacific Ocean



Large encompassing bioregion for the western tropic shelf, slope and abyssal fauna/flora, bounded to the east of the Marshall Islands and Kiribati. The southern latitudinal boundary which sits below Lord Howe, New Caledonia and Kermedecs and cuts slightly north up the eastern coast of Australia to match the distribution of Australia's IMCRA regions. On the Australian coastline the southern boundary reflects the latitudinal break in the middle of the Central Eastern IMCRA transition province (IMCRA 4). The eastern boundary is defined by a decrease in coral diversity and turnover of both shallow water coral and fish species (Kulbicki et al., 2013, Veron et al., 2015). The eastern boundary is also bounded by the abyssal Kermedec trench to the east of the Kermedec archipelago. The eastern boundary also kinks around the eastern side of American Samoa and Tonga, but remains west of Niue, this reflects the distribution of fishes in this area, which has a dramatic change across this region (Kulbicki et al., 2013). Western and northern extents are bounded by the distribution of the bioregional project, but they reflect the edge of the Coral-Triangle on the west the central Pacific towards the north.

2.1.1 South West Polynesian Shelf



The South West Polynesian Shelf province contains the islands of Tonga, Samoa, American Samoa and Fiji. This region has been differentiated from surrounding areas for both corals and fishes (Kulbicki et al., 2013, Veron et al., 2015). The species seen in this area are similar to the species seen in New Caledonia and Vanuatu. We have grouped Fiji and the other islands based on the distribution of fishes (Kulbicki et al., 2013), rather than the split seen in the coral ecoregions (Veron et al., 2015). The shelf region is constrained to shelf areas as defined by Harris *et al.*, (2014), which equates to depth approximately less than 200 meters.

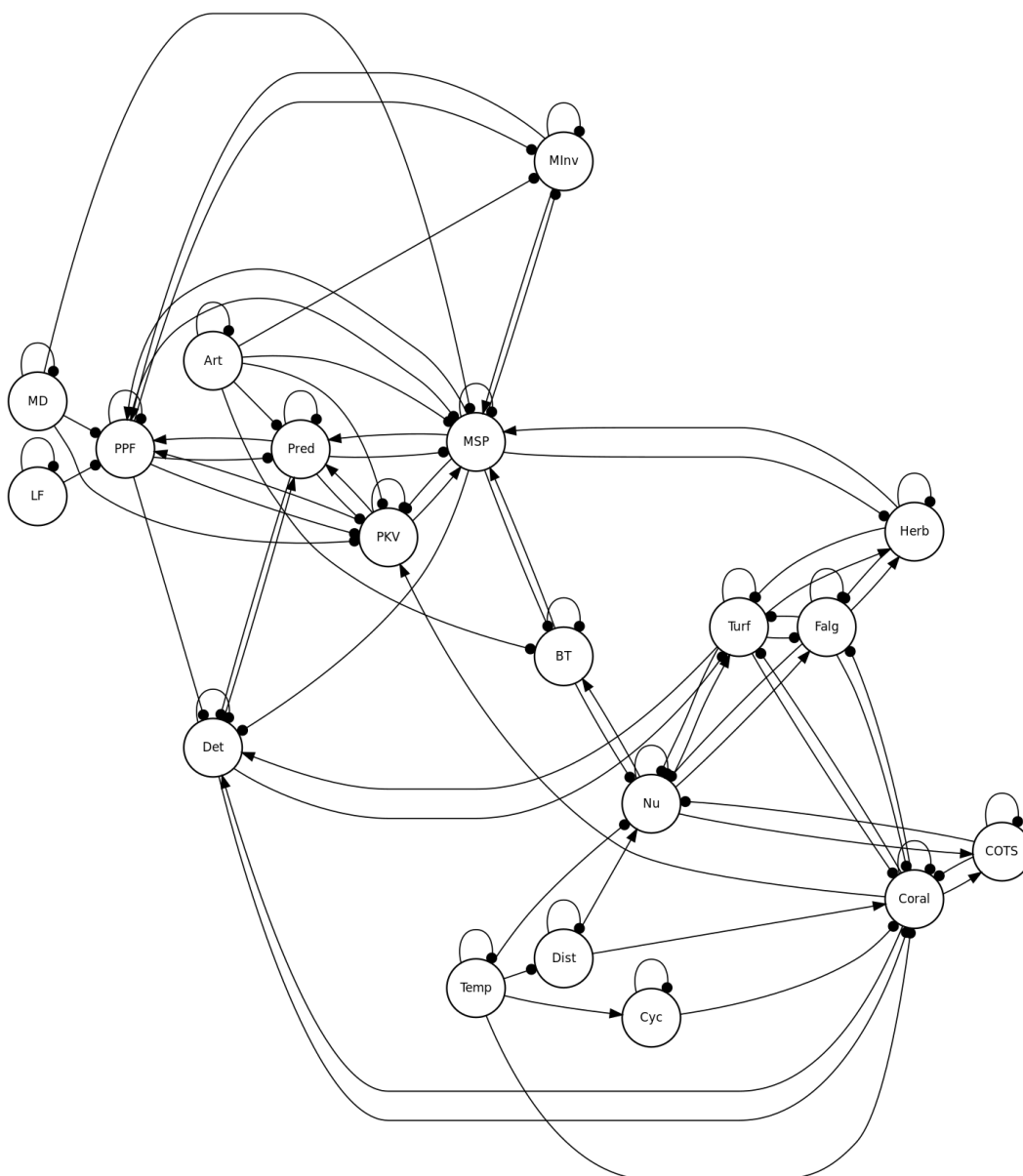


Figure 21. Ecosystem components in the qualitative model are: Pelagic Predatory Fish (PPF), Detritivore (Det), Predatory Fish (Pred), Medium Sized Predators (MSP), Mobile Invertebrates (MInv), Herbivorous Fish (Herb), Coral (Coral), Planktivores (PKV), Bio-Turbators (BT), Nutrients (Nu), Fleshy Algae (Falg), Turf Algae (Turf), Coral Predators (COTS) and Distance to deep water (Dist) . Pressures acting on the system are: Temperature (Temp), Artisanal Fisheries (Art), Line Fishing (LF), Marine Debris (MD) and Cyclones (Cyc). Circle arrow heads represent a negative effect from one component to another, normal arrow heads represent a positive influence from one component to another, and circle arrow heads back onto the same node represent a self-regulation effect (e.g. density dependence).

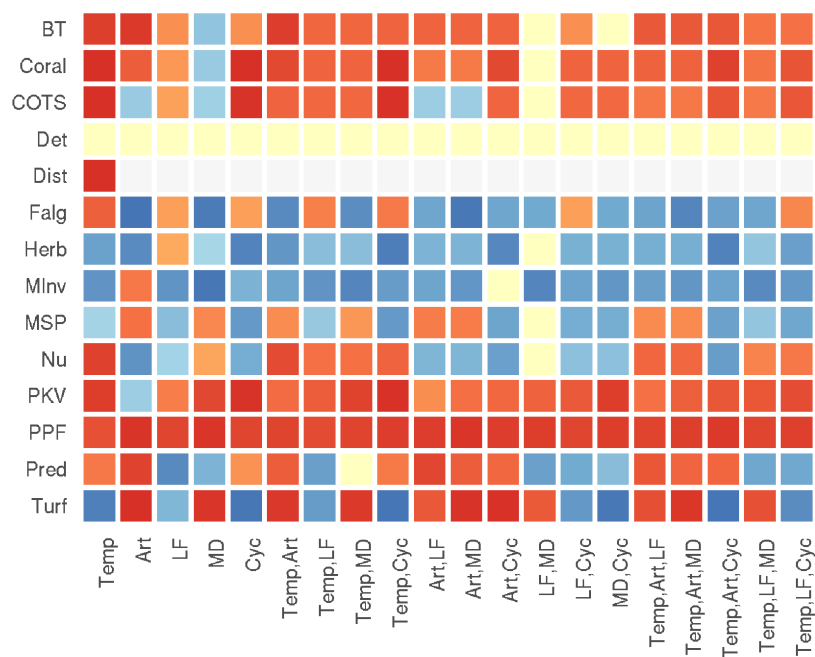
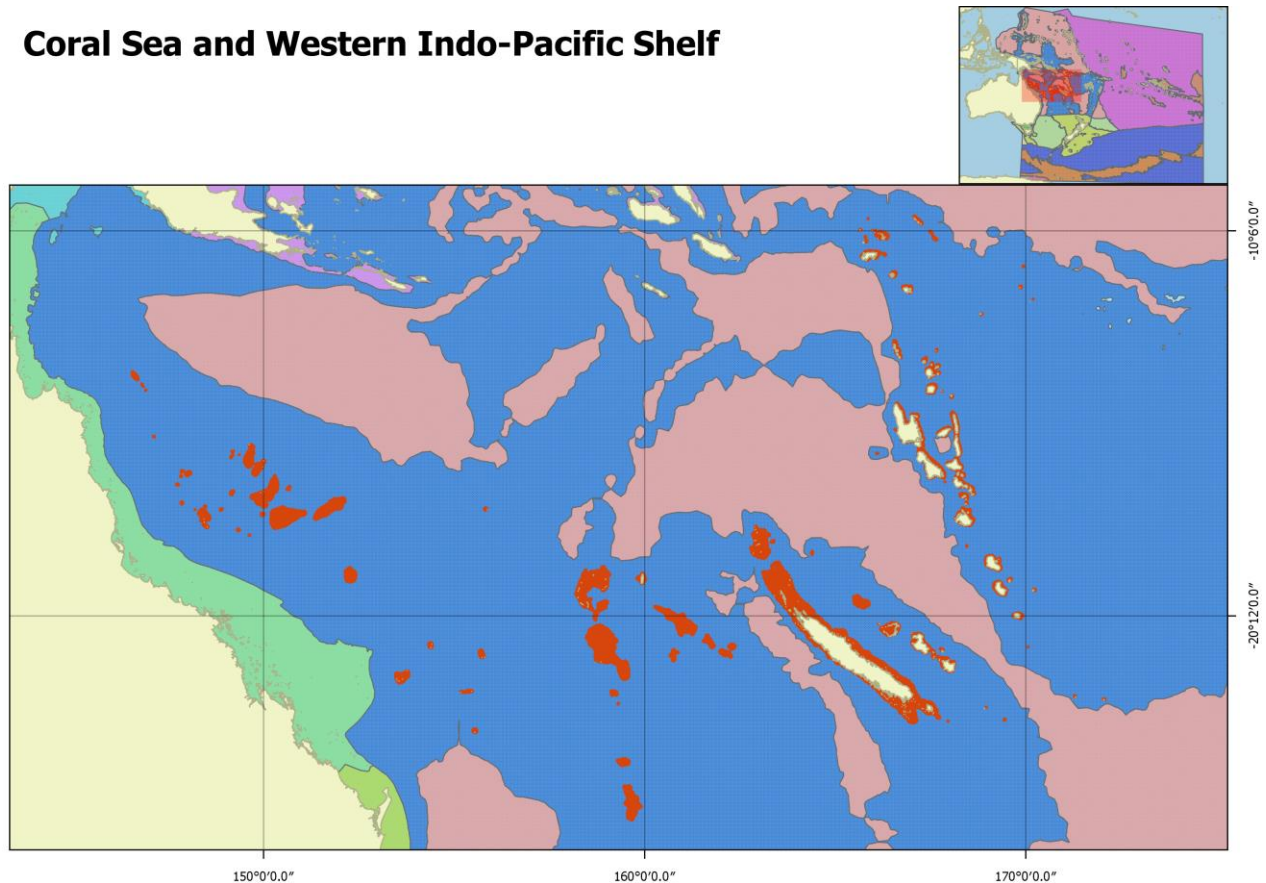


Figure 22. Ecosystem scenario responses to combinations of pressures. Red indicates a negative change and blue indicates a positive change. Ecosystem components in the qualitative model are: Pelagic Predatory Fish (PPF), Detritivore (Det), Predatory Fish (Pred), Medium Sized Predators (MSP), Mobile Invertebrates (MInv), Herbivorous Fish (Herb), Coral (Coral), Planktivores (PKV), Bio-Turbators (BT), Nutrients (Nu), Fleshy Algae (Falg), Turf Algae (Turf), Coral Predators (COTS) and Distance to deep water (Dist) . Pressures acting on the system are: Temperature (Temp), Artisanal Fisheries (Art), Line Fishing (LF), Marine Debris (MD) and Cyclones (Cyc).

2.1.2 Coral Sea and Western Indo-Pacific Shelf

Coral Sea and Western Indo-Pacific Shelf



The Coral Sea and Western Indo-Pacific Shelf Province includes the Coral Sea, New Caledonia and Vanuatu Shelf region. The regionalisation is based on the ecoregionalisations of reef fish and corals (Kulbicki et al., 2013, Veron et al., 2015). This area is a geographically distinct region, but it shares similar species to Vanuatu, which is geographically separated to the north by the New Hebrides Trench. The coral species also share an affinity with the species found around Fiji. Like other ecoregions based on shallow water fauna, we constrained the Coral Sea and Western Indo-Pacific Shelf Province to shelf habitats (approximately 200 meters depth) to reflect the biogeographic distribution of these shallower water species.

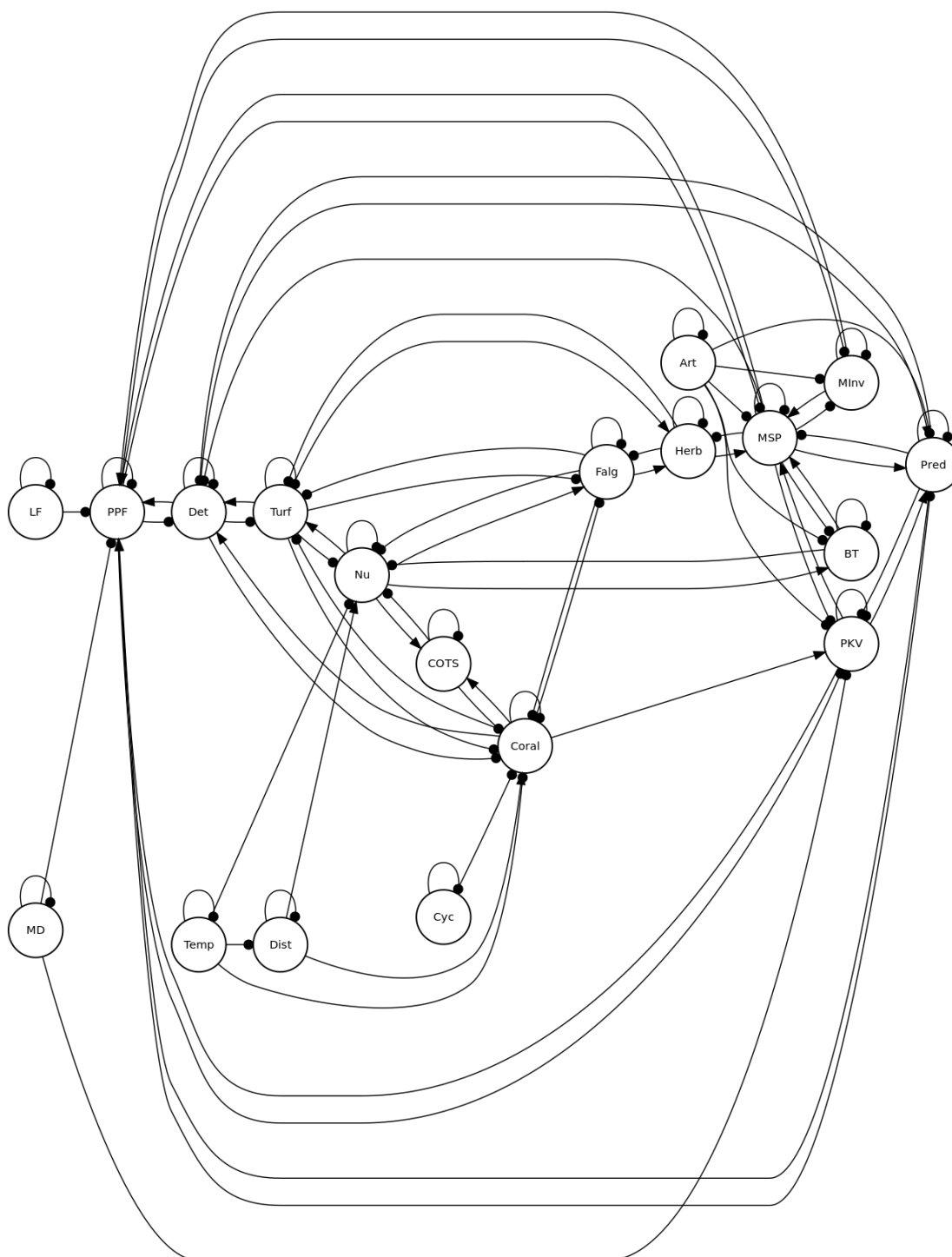


Figure 23. Ecosystem components in the qualitative model are: Pelagic Predatory Fish (PPF), Detritivore (Det), Predatory Fish (Pred), Medium Sized Predators (MSP), Mobile Invertebrates (MInv), Herbivorous Fish (Herb), Coral (Coral), Planktivores (PKV), BioTurbators (BT), Nutrients (Nu), Fleshy Algae (Falg), Turf Algae (Turf), Coral Predators (COTS) and Distance to deep water (Dist). Pressures acting on the system are: Temperature (Temp), Artesinal Fisheries (Art), Line Fishing (LF), MarineDebris (MD) and Cyclones (Cyc). Circle arrow heads represent a negative effect from one component to another, normal arrow heads represent a positive influence from one component to another, and circle arrow heads back onto the same node represent a self-regulation effect (e.g. density dependence).

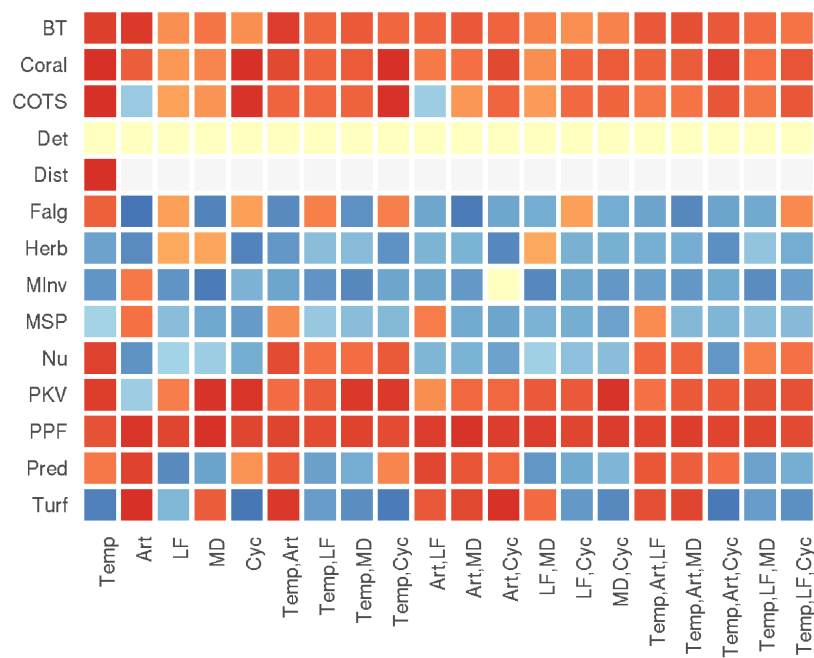
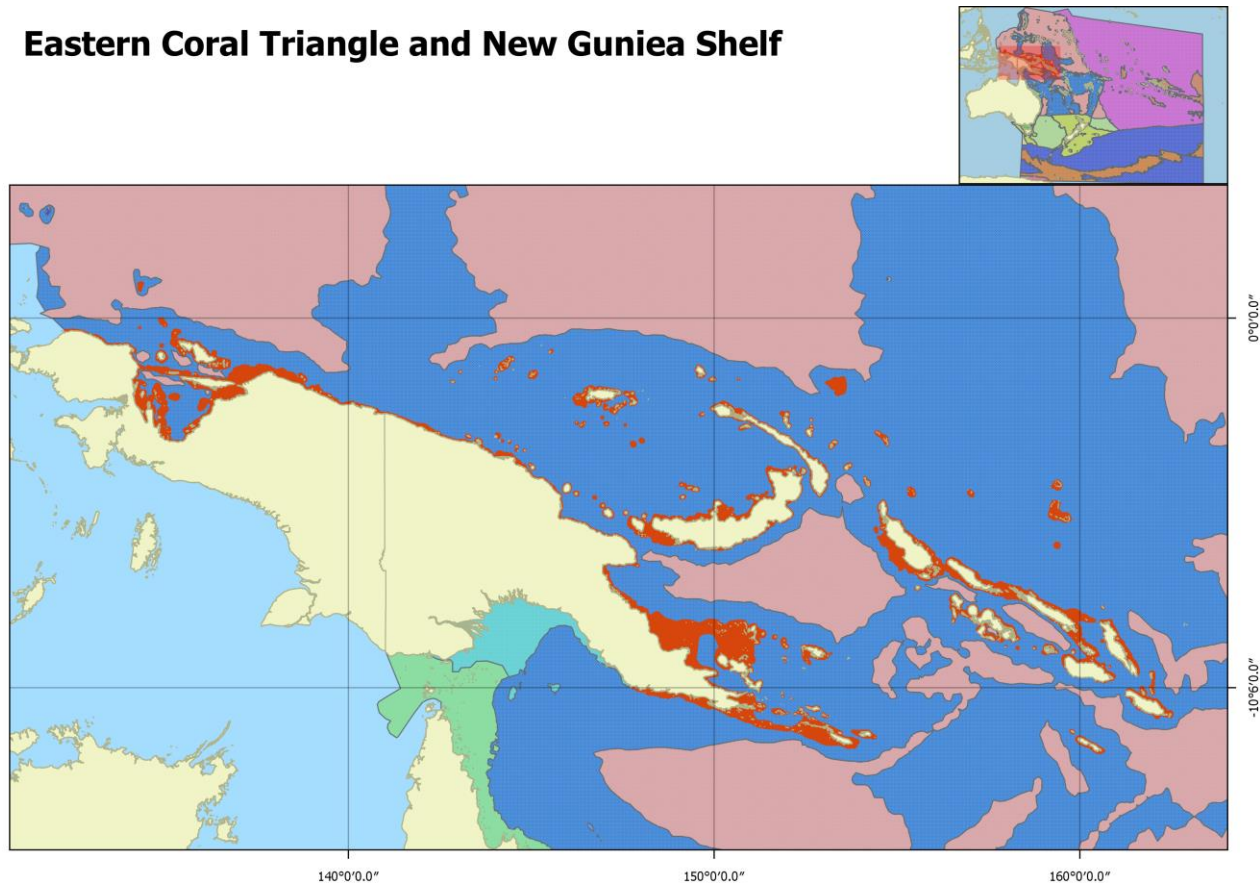


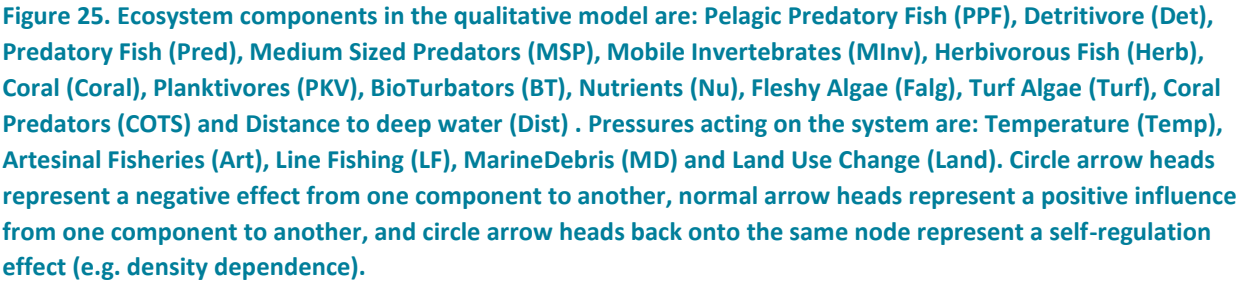
Figure 24. Ecosystem scenario responses to combinations of pressures. Red indicates a negative change and blue indicates a positive change. Ecosystem components in the qualitative model are: Pelagic Predatory Fish (PPF), Detritivore (Det), Predatory Fish (Pred), Medium Sized Predators (MSP), Mobile Invertebrates (MInv), Herbivorous Fish (Herb), Coral (Coral), Planktivores (PKV), BioTurbators (BT), Nutrients (Nu), Fleshy Algae (Falg), Turf Algae (Turf), Coral Predators (COTS) and Distance to deep water (Dist). Pressures acting on the system are: Temperature (Temp), Artesinal Fisheries (Art), Line Fishing (LF), MarineDebris (MD) and Cyclones (Cyc).

2.1.3 Eastern Coral Triangle and New Guinea Shelf

Eastern Coral Triangle and New Guinea Shelf



The Eastern Coral Triangle and New Papua New Guinea Shelf is an important area for corals and reef fish (Kulbicki et al., 2013; Veron et al., 2015). The delineation of this region was based on existing coral (Veron et al., 2015) and reef fishes (Kulbicki et al., 2013) ecoregional classifications. We merged multiple smaller, but biologically similar ecoregions into province size region. Our Eastern Coral Triangle and New Guinea Shelf contains the Solomon Archipelago, the Solomon Shelf and the Bismarck Sea Shelf ecoregions. We did this because the corals found in the Solomon Archipelago, Bismarck Sea Shelf, Solomon Sea and Milne Bay areas all shared a close compositional and diversity affinity. This bioregion formed a coherent group with only distant affinity to other western Pacific ecoregions (Veron et al., 2015). We constrained the Eastern Coral Triangle and New Guinea Shelf region to shelf habitats (approximately 200 meters depth) to reflect the biogeographic distribution of these shallower water species.



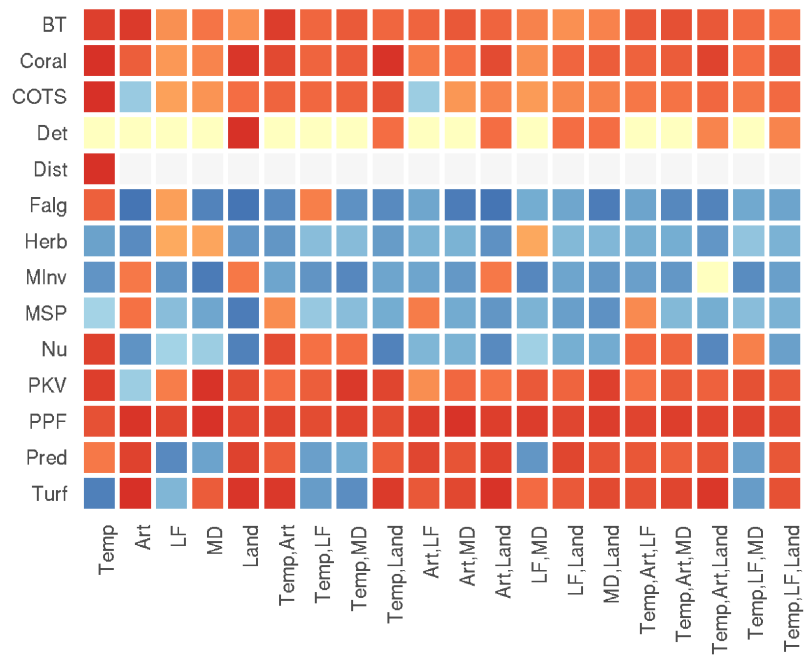
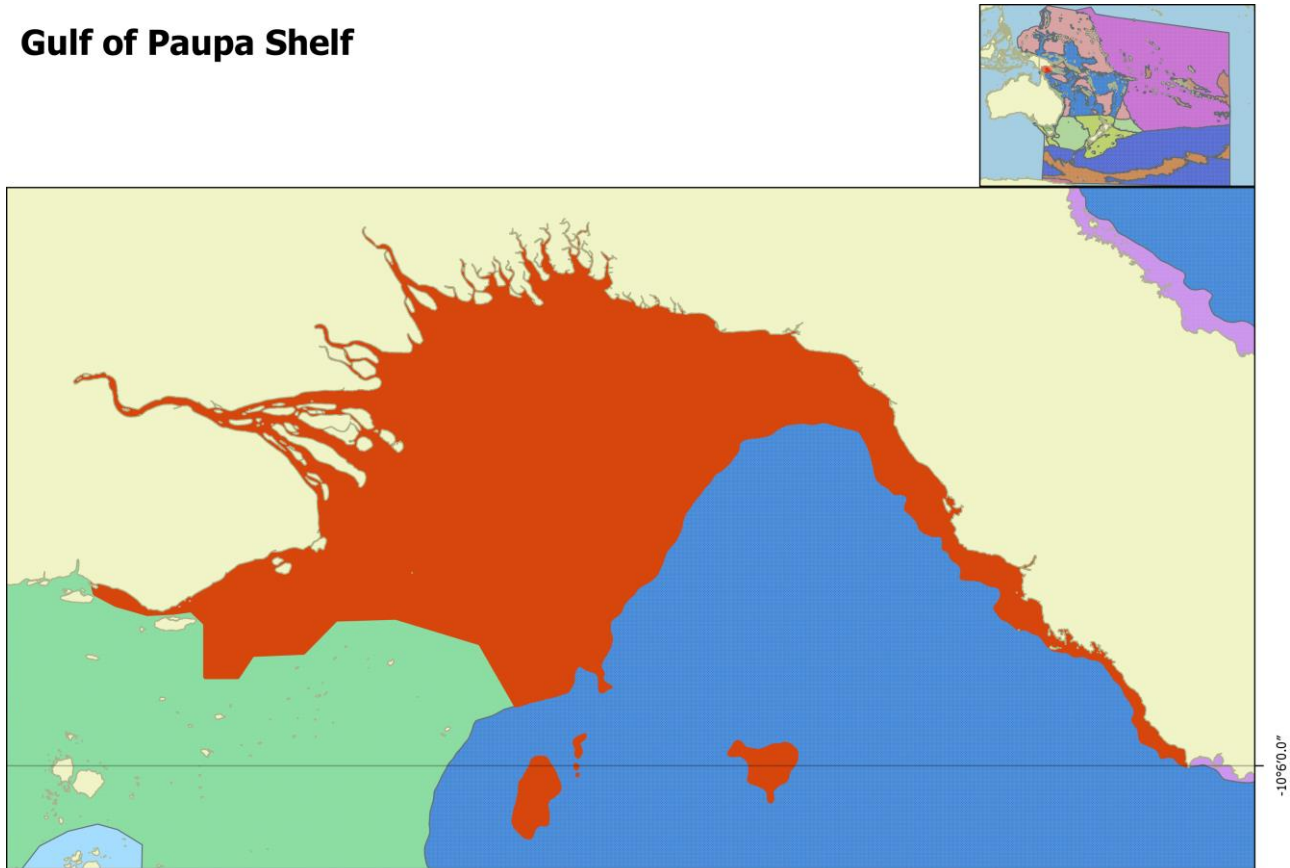


Figure 26. Ecosystem scenario responses to combinations of pressures. Red indicates a negative change and blue indicates a positive change. Ecosystem components in the qualitative model are: Pelagic Predatory Fish (PPF), Detritivore (Det), Predatory Fish (Pred), Medium Sized Predators (MSP), Mobile Invertebrates (MInv), Herbivorous Fish (Herb), Coral (Coral), Planktivores (PKV), BioTurbators (BT), Nutrients (Nu), Fleshy Algae (Falg), Turf Algae (Turf), Coral Predators (COTS) and Distance to deep water (Dist) . Pressures acting on the system are: Temperature (Temp), Artesinal Fisheries (Art), Line Fishing (LF), MarineDebris (MD) and Land Use Change (Land).

2.1.4 Gulf of Papua Shelf

Gulf of Paupa Shelf



The Gulf of Papua Shelf is just north of Australia's IMCRA Northeast Province. It is separated out from the IMCRA region to the south and the Easter Coral and New Guinea Shelf to the east and north, due to a decline in coral and fish diversity driven by the proximity to Port Moresby and the increase in mangrove habitat and sedimentation (Veron *et al.*, 2015; Kulbicki *et al.*, 2013). This is a shelf province and contains habitats which are approximately less than 200 meters deep.

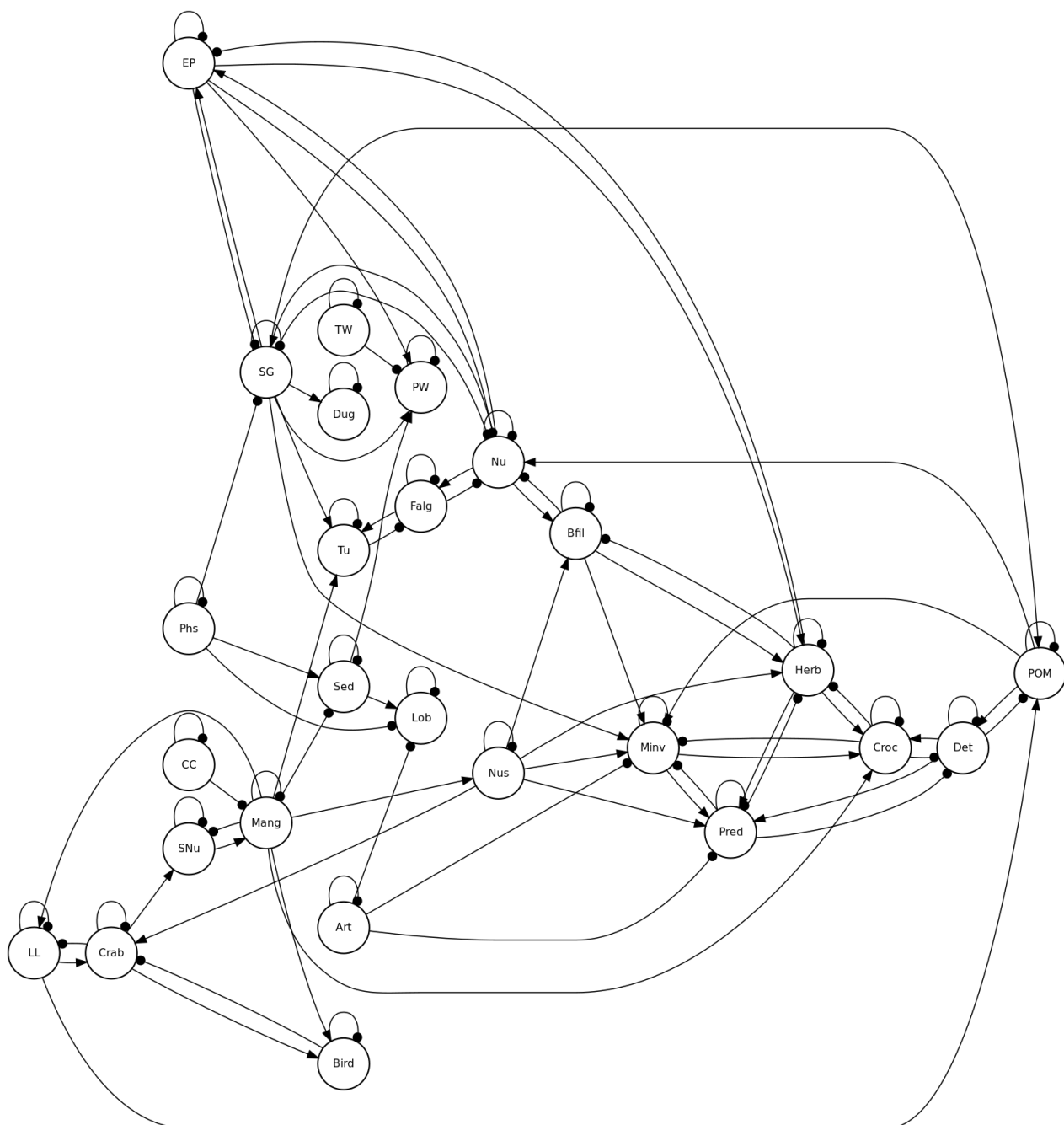


Figure 27. Ecosystem components in the qualitative model are: Prawns (PW), Dugongs (Dug), Epiphytes (EP), seagrass (SG), BioFilm (Bfil), Predatory Fish (Pred), SoilNutrients (SNU), Birds (Bird), Crabs (Crab), Particulate Organic Matter (POM), Detritivores (Det), Mobile Invertebrates (MInv), Fleshy Algae (Falg), Mangrove (Mang), Turtle (Tu), Nutrients (Nu), LeafLitter (LL), Herbivorous Fish (Herb), RootStructureNursury (Nus), Crocodiles (Croc), Climate Change (CC), Lobster (Lob). Pressures acting on the system are: Trawl (TW), Physical Disturbance (Phs), Sediment (Sed) and Artisanal Fisheries (Art).

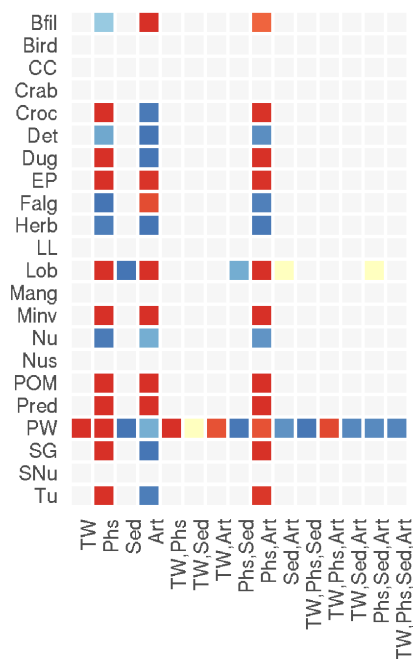
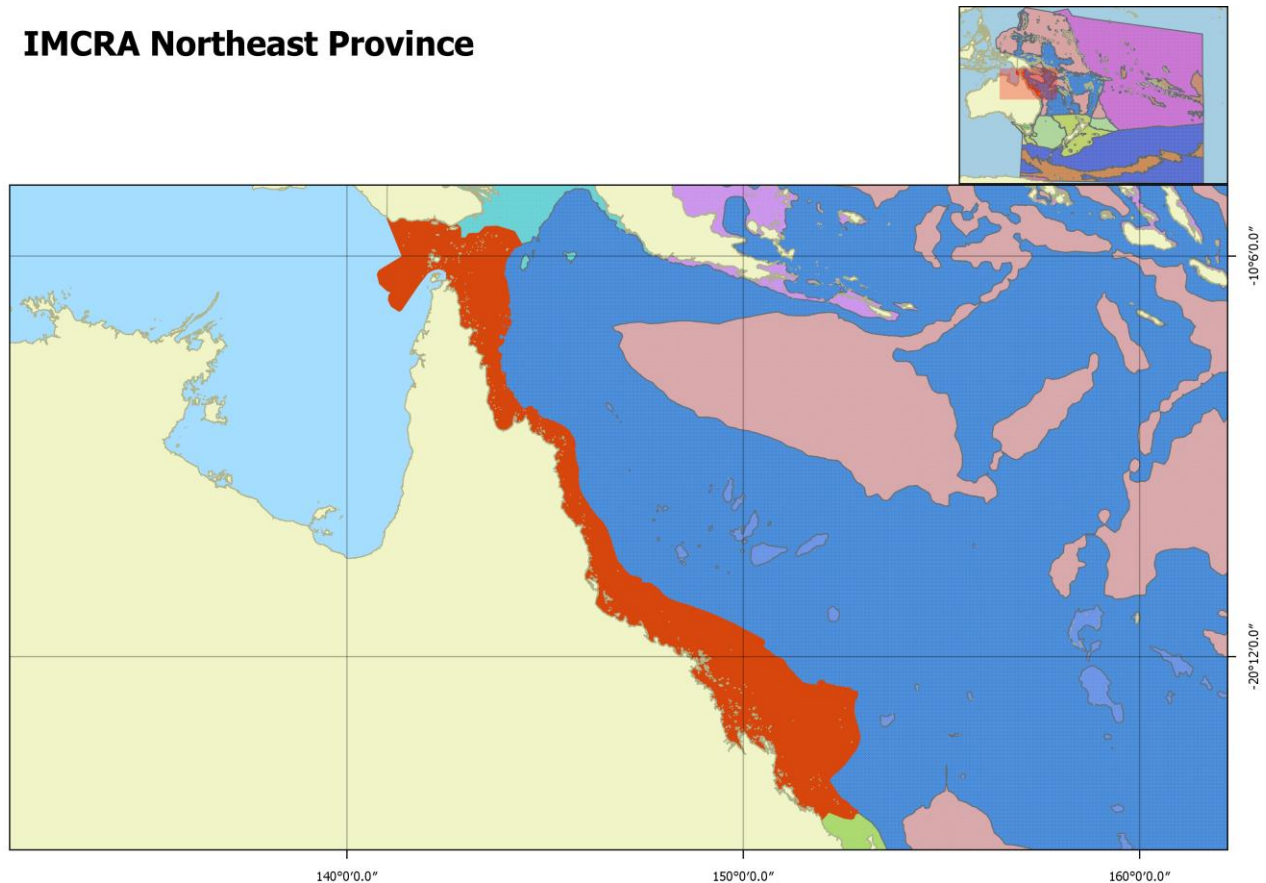


Figure 28. Ecosystem scenario responses to combinations of pressures. Red indicates a negative change and blue indicates a positive change. Ecosystem components in the qualitative model are: Prawns (PW), Dugongs (Dug), Epiphytes (EP), seagrass (SG), BioFilm (Bfil), Predatory Fish (Pred), SoilNutrients (SNU), Birds (Bird), Crabs (Crab), Particulate Organic Matter (POM), Detritivores (Det), Mobile Invertebrates (Minv), Fleshy Algae (Falg), Mangrove (Mang), Turtle (Tu), Nutrients (Nu), LeafLitter (LL), Herbivourous Fish (Herb), RootStructureNursury (Nus), Crocodiles (Croc), Climate Change (CC) and Lobster (Lob). Pressures acting on the system are: Trawl (TW), Physical Disturbance (Phs), Sediment (Sed) and Artisanal Fisheries (Art).

2.1.5 IMCRA Northeast Shelf

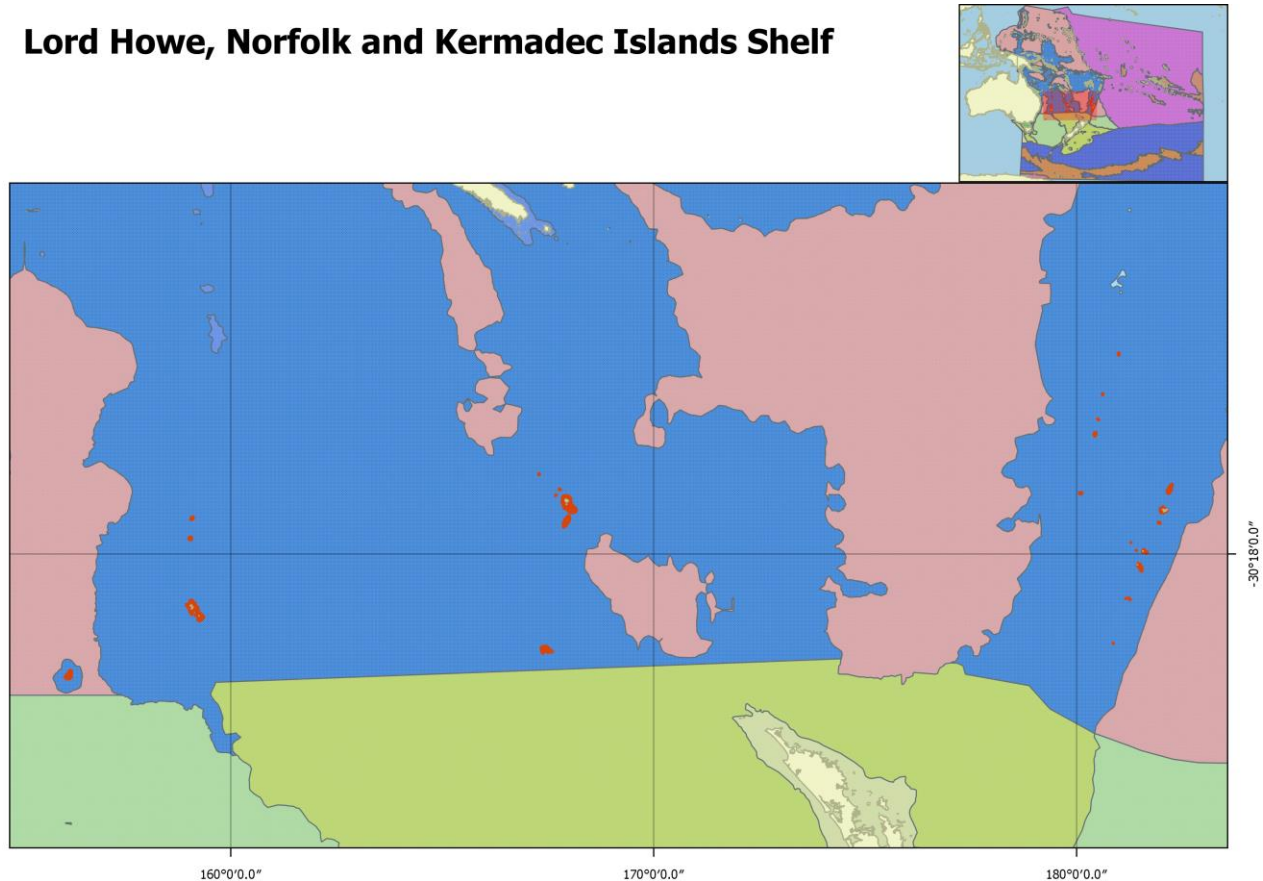
IMCRA Northeast Province



The IMCRA Northeast Province contains the Great Barrier Reef shelf is based on Australia's IMCRA bioregionalisation. It is separated out due to the unique nature of the GBR and the fauna within. This classification is also supported by corals, fish and other groups (Veron *et al.*, 2015; Kulbicki *et al.*, 2013). This is a shelf province and contains habitats which are approximately less than 200 meters deep. Models for this region can be seen in Anthony *et al.*, 2013.

2.1.6 Lord Howe, Norfolk and Kermadec Islands Shelf

Lord Howe, Norfolk and Kermadec Islands Shelf



This region is based on a band of similar species of coral, fish and other invertebrates distributed across this narrow band of islands, which are approximately at the same latitude (O'Hara *et al.*, 2011; Veron *et al.*, 2015; Kulbicki *et al.*, 2013). They represent the southern boundary of the tropical western shelf fauna. But are also unique and need to differentiate from the New Caledonia (Coral Sea and Western Indo-Pacific Shelf province) and the Central Indo-Pacific Shelf fauna to the north. This region is a shelf province and is constrained depths less than approximately 200 meters.

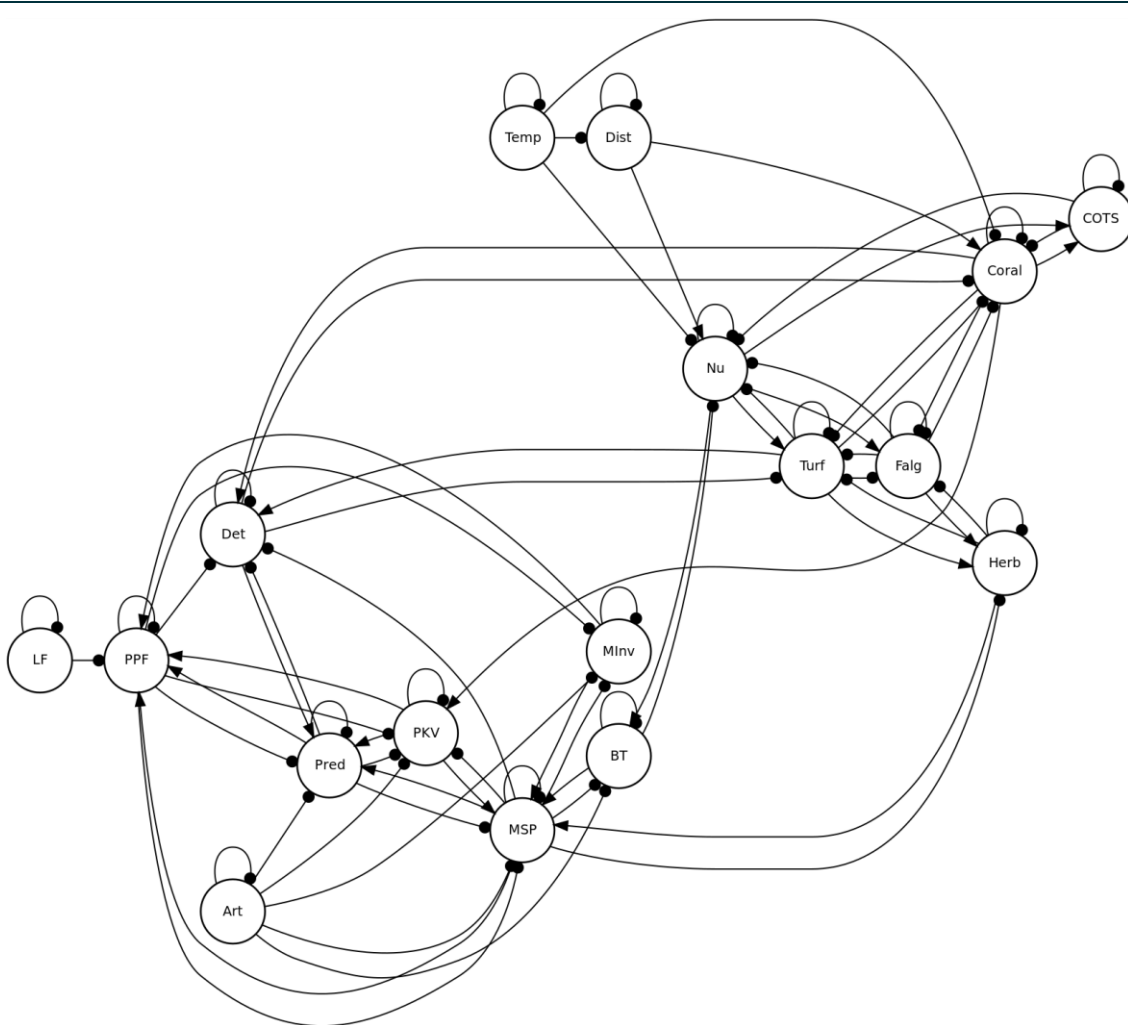


Figure 29. Ecosystem components in the qualitative model are: Pelagic Predatory Fish (PPF), Detritivore (Det), Predatory Fish (Pred), Medium Sized Predators (MSP), Mobile Invertebrates (Minv), Herbivorous Fish (Herb), Coral (Coral), Planktivores (PKV), BioTurbators (BT), Nutrients (Nu), Fleshy Algae (Falg), Turf Algae (Turf), Coral Predators (COTS) and Distance to deep water (Dist). Pressures acting on the system are: Temperature (Temp), Artisanal Fisheries (Art) and Line Fishing (LF).

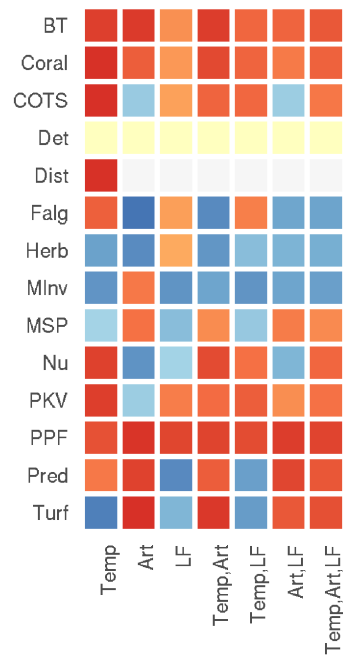
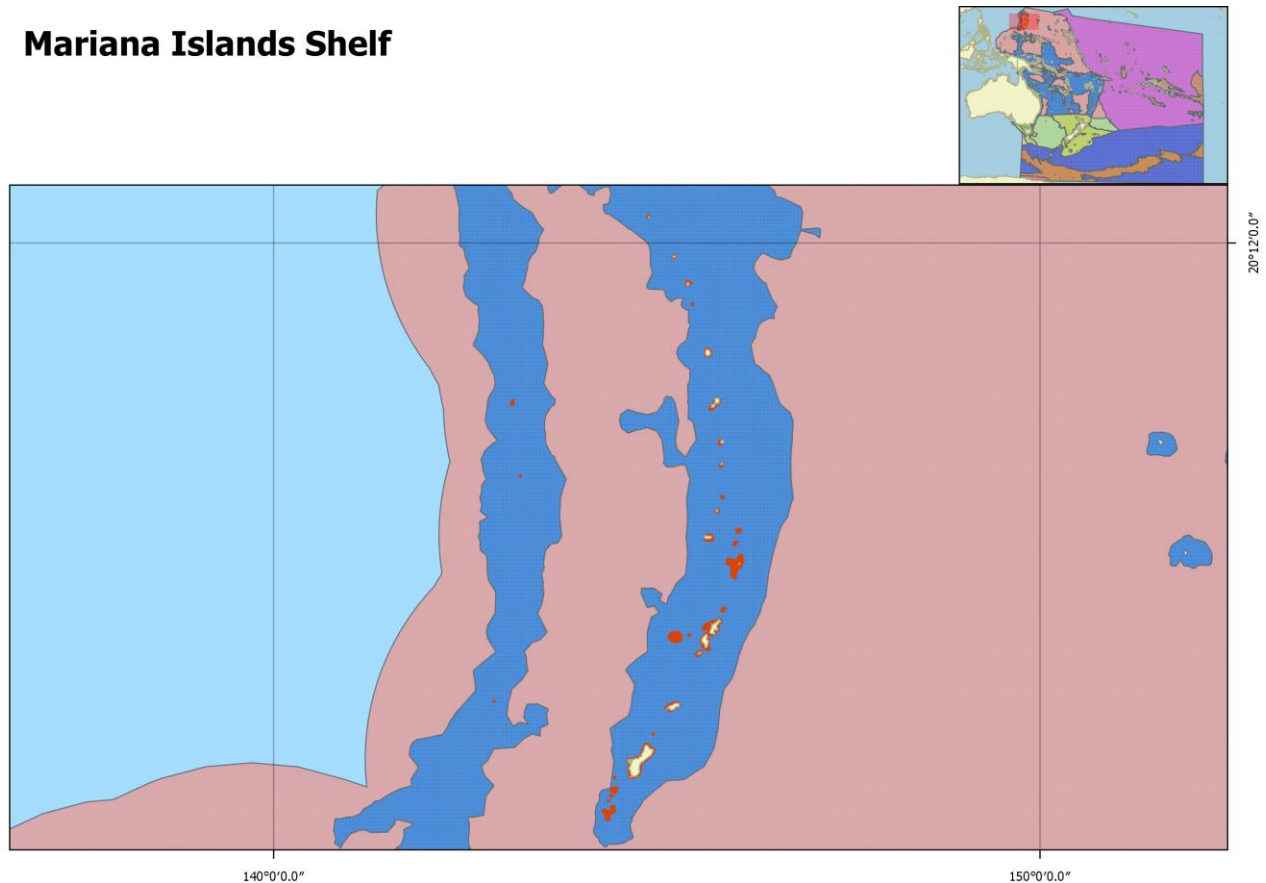


Figure 30: Ecosystem scenario responses to combinations of pressures. Red indicates a negative change and blue indicates a positive change. Ecosystem components in the qualitative model are: Pelagic Predatory Fish (PPF), Detritivore (Det), Predatory Fish (Pred), Medium Sized Predators (MSP), Mobile Invertebrates (MInv), Herbivorous Fish (Herb), Coral (Coral), Planktivores (PKV), BioTurbators (BT), Nutrients (Nu), Fleshy Algae (Falg), Turf Algae (Turf), Coral Predators (COTS) and Distance to deep water (Dist). Pressures acting on the system are: Temperature (Temp), Artisanal Fisheries (Art) and Line Fishing (LF).

2.1.7 Marianas Islands Shelf

Mariana Islands Shelf



The Marianas Province is delineated to the East by the Marianas Trench, and to the south by the Northern Equatorial Current and Equatorial Counter Current. The southern boundary separates Guam and the Northern Mariana Islands from the Caroline Islands, and is supported by the decline in coral diversity (Randall, 1995). The lower coral diversity is partially due to the Northern Equatorial current, which isolates the Marianas and limits larval dispersal (Kendall and Poti, 2014). In addition the islands north of Anatahan to Uracas in the Northern Marianas are volcanically active, and have limited reef development (Riegl, 2011). The northern and western boundaries of the province are delineated by the study extent and are not representative of an ecological boundary or change.

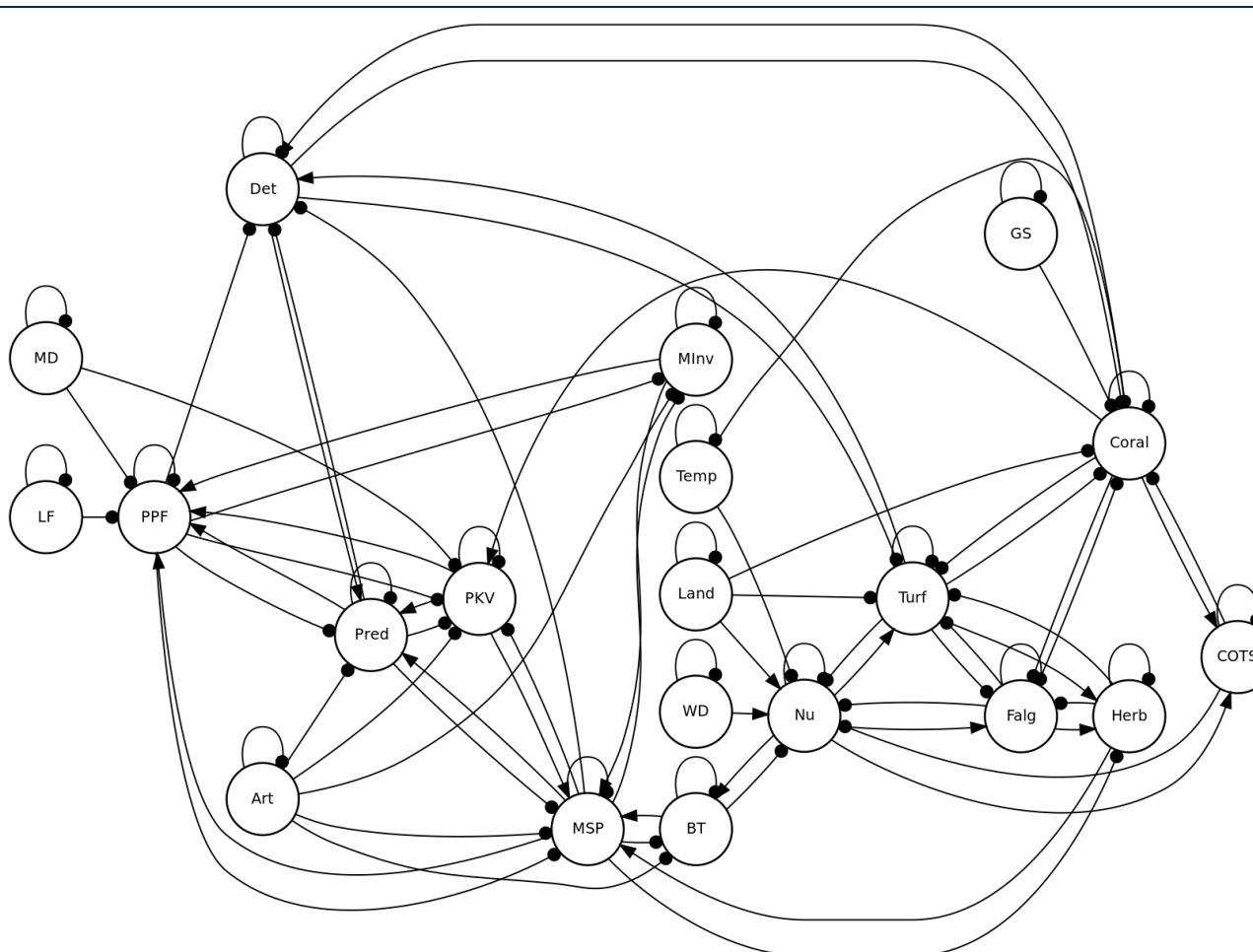


Figure 31. Ecosystem components in the qualitative model are: Pelagic Predatory Fish (PPF), Detritivore (Det), Predatory Fish (Pred), Medium Sized Predators (MSP), Mobile Invertebrates (MInv), Herbivorous Fish (Herb), Coral (Coral), Planktivores (PKV), BioTurbators (BT), Nutrients (Nu), Fleshy Algae (Falg), Turf Algae (Turf), Coral Predators (COTS). Pressures acting on the system are: Temperature (Temp), Artisanal Fisheries (Art), Line Fishing (LF), Marine Debris (MD), Land Use Change (Land), Grounding Ships (GS) and Waste Discharge (WD).

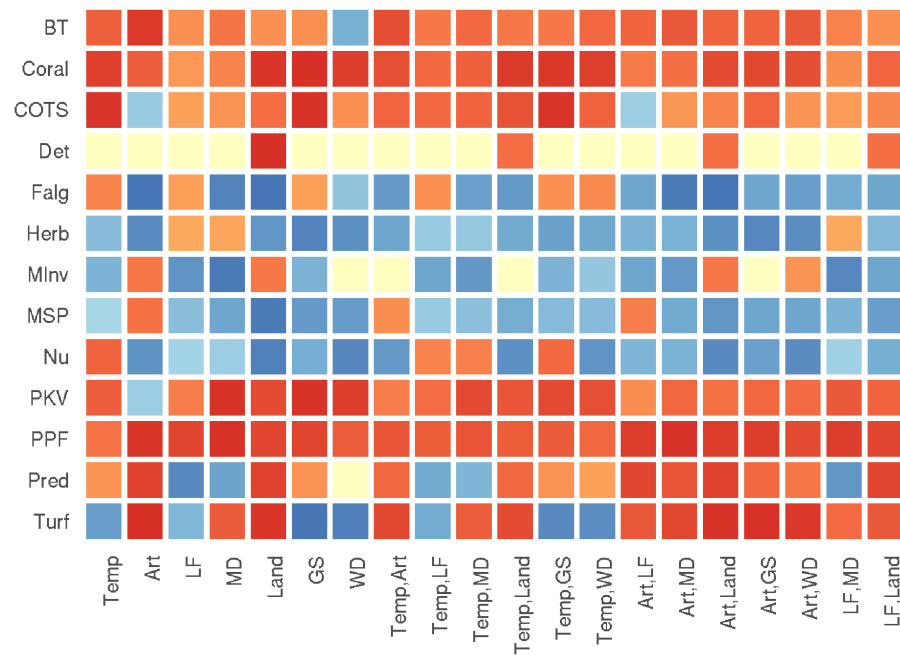
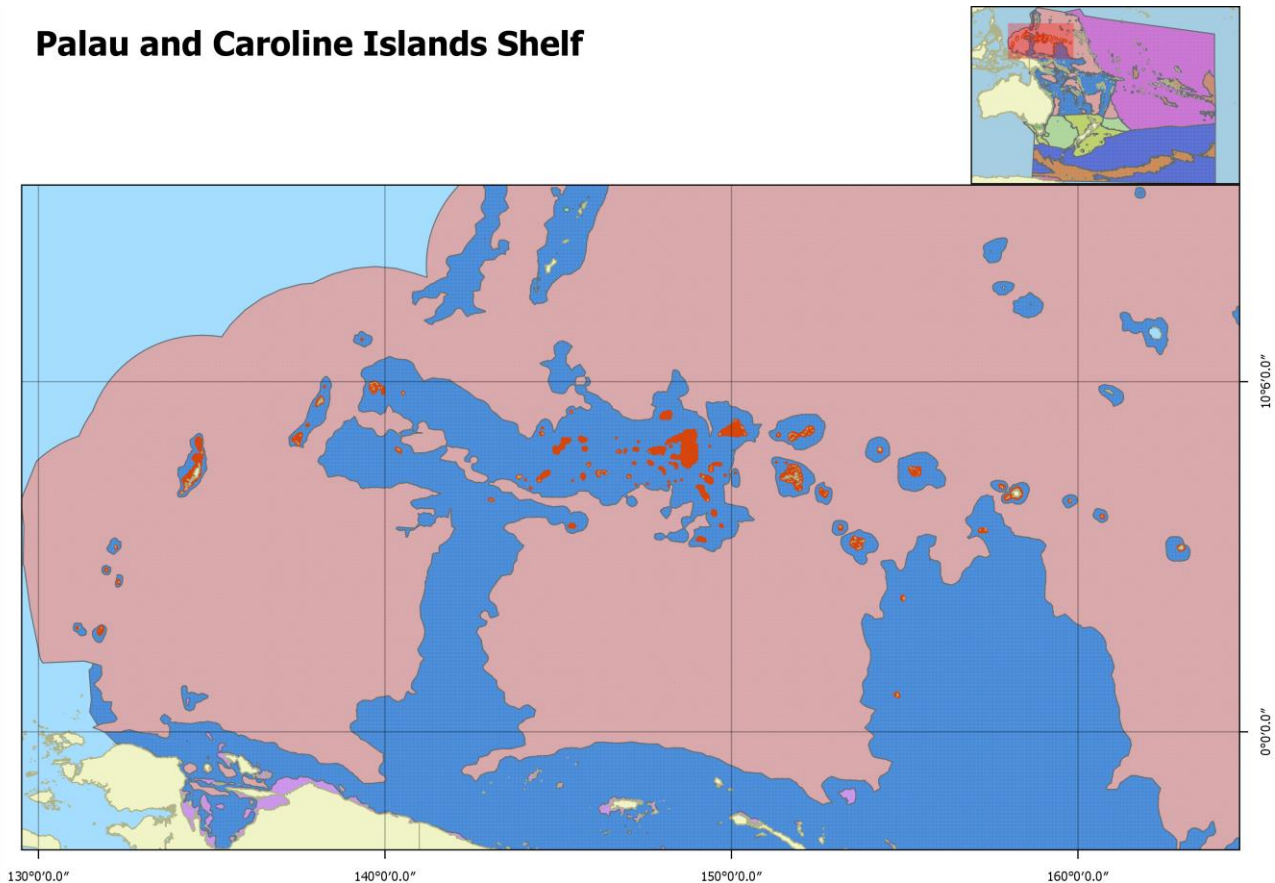


Figure 32: Ecosystem scenario responses to combinations of pressures. Red indicates a negative change and blue indicates a positive change. Ecosystem components in the qualitative model are: Pelagic Predatory Fish (PPF), Detritivore (Det), Predatory Fish (Pred), Medium Sized Predators (MSP), Mobile Invertebrates (MInv), Herbivorous Fish (Herb), Coral (Coral), Planktivores (PKV), BioTurbators (BT), Nutrients (Nu), Fleshy Algae (Falg), Turf Algae (Turf), Coral Predators (COTS). Pressures acting on the system are: Temperature (Temp), Artisanal Fisheries (Art), Line Fishing (LF), Marine Debris (MD), Land Use Change (Land), Grounding Ships (GS) and Waste Discharge (WD).

2.1.8 Palau and Caroline Islands Shelf

Palau and Caroline Islands Shelf



The Palau and Caroline Islands Shelf region are a large group of volcanic islands and seamounts. The Marianas and Caroline Islands are separated from neighbouring region by deep oceanic waters. The Palau and Caroline Island Shelf region is based on the Caroline coral ecoregions (Veron *et al.*, 2015), but also, the distribution of reef fish species which appear to have a close affinity across these islands (Kulbicki *et al.*, 2013). Like other provinces based on shallow water fauna we constrained the Palau and Caroline Islands province to shelf habitats (approximately 200 meters depth) to reflect the biogeographic distribution of these shallower water species.

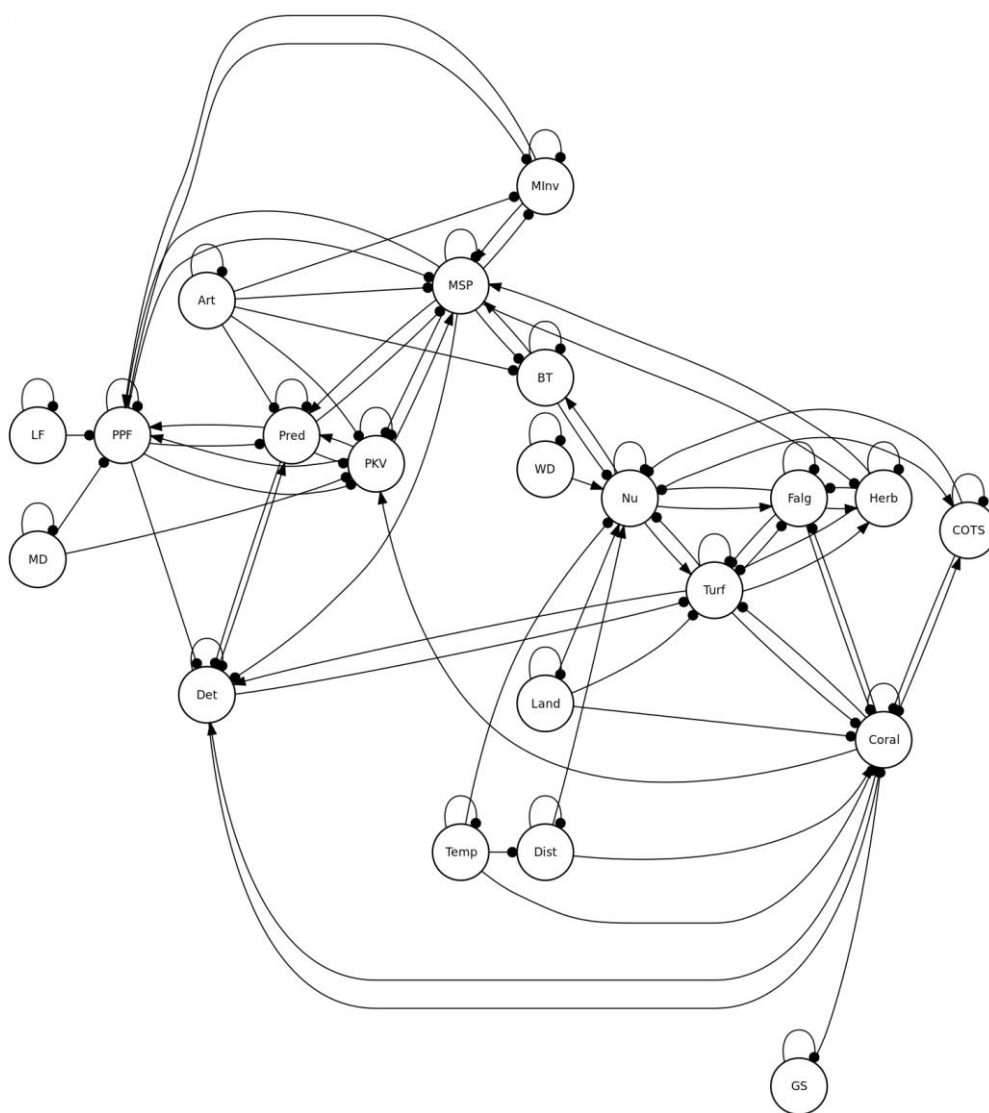


Figure 33. Ecosystem components in the qualitative model are: Pelagic Predatory Fish (PPF), Detritivore (Det), Predatory Fish (Pred), Medium Sized Predators (MSP), Mobile Invertebrates (MInv), Herbivorous Fish (Herb), Coral (Coral), Planktivores (PKV), BioTurbators (BT), Nutrients (Nu), Fleshy Algae (Falg), Turf Algae (Turf), Coral Predators (COTS) and Distance to deep water (Dist). Pressures acting on the system are: Temperature (Temp), Artesinal Fisheries (Art), Line Fishing (LF), Marine Debris (MD), Land Use Change (Land), Grounding Ships (GS) and Waste Discharge (WD).

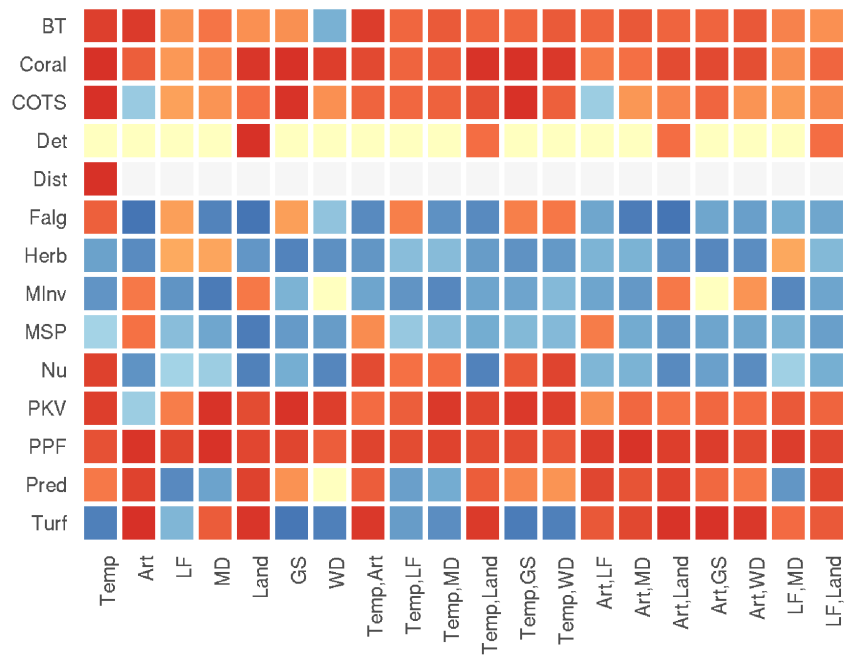
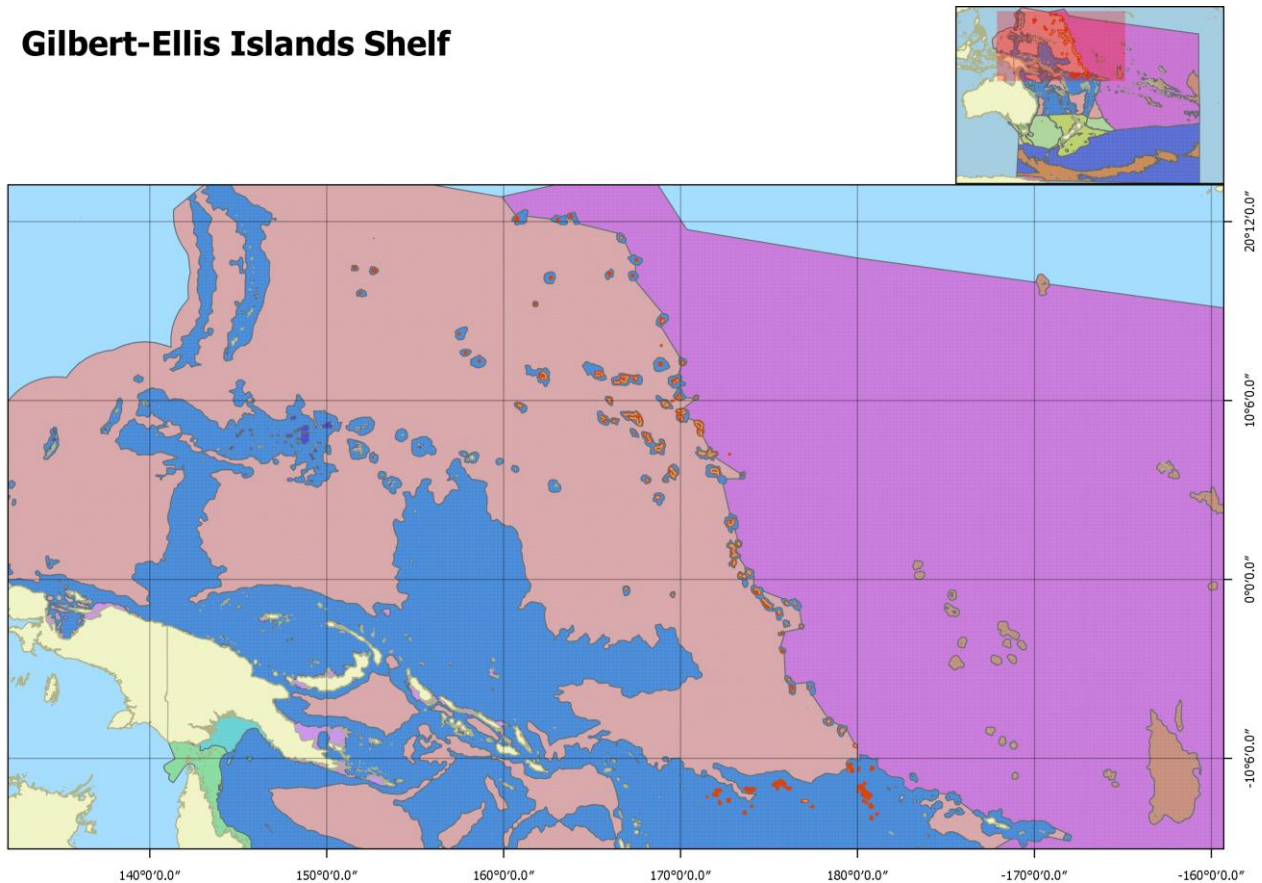


Figure 34. Ecosystem scenario responses to combinations of pressures. Red indicates a negative change and blue indicates a positive change. Ecosystem components in the qualitative model are: Pelagic Predatory Fish (PPF), Detritivore (Det), Predatory Fish (Pred), Medium Sized Predators (MSP), Mobile Invertebrates (MInv), Herbivorous Fish (Herb), Coral (Coral), Planktivores (PKV), BioTurbators (BT), Nutrients (Nu), Fleshy Algae (Falg), Turf Algae (Turf), Coral Predators (COTS) and Distance to deep water (Dist). Pressures acting on the system are: Temperature (Temp), Artesinal Fisheries (Art), Line Fishing (LF), MarineDebris (MD), Land Use Change (Land), Grounding Ships (GS) and Waste Discharge (WD).

2.1.9 Gilbert-Ellis Islands Shelf

Gilbert-Ellis Islands Shelf



The Gilbert and Ellis Islands Shelf region is based on the ecoregionalisations of reef fish and corals (Kulbicki et al., 2013, Veron et al., 2015). This region is separated from the neighbouring Micronesia islands to the west by deep oceanic waters. The Gilbert and Ellis islands are combined into a single large province because of the distribution of reef fish in this area, and the close affinity between the composition of corals Gilbert Islands of West Kiribati (Veron et al., 2015). Like other provinces based on shallow water fauna we constrained Gilbert and Ellis Islands Shelf province to shelf habitats (approximately 200 meters depth) to reflect the biogeographic distribution of these shallower water species.

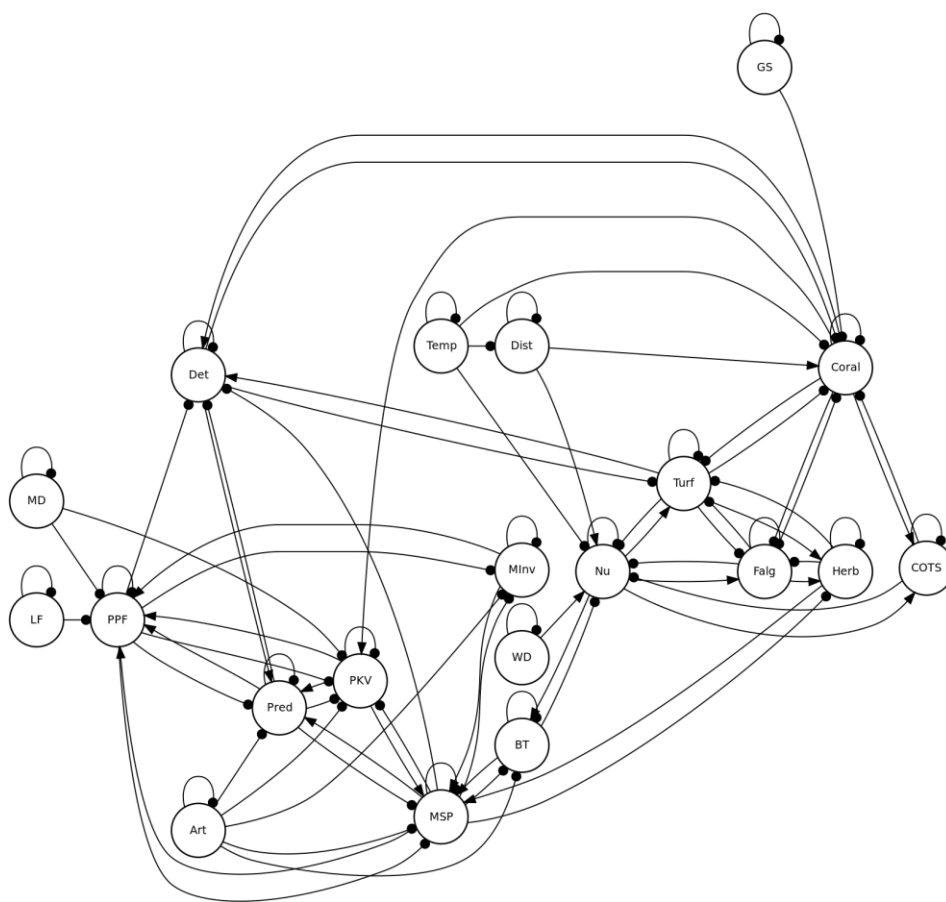


Figure 35. Ecosystem components in the qualitative model are: Pelagic Predatory Fish (PPF), Detritivore (Det), Predatory Fish (Pred), Medium Sized Predators (MSP), Mobile Invertebrates (MInv), Herbivorous Fish (Herb), Coral (Coral), Planktivores (PKV), Bio-Turbators (BT), Nutrients (Nu), Fleshy Algae (Falg), Turf Algae (Turf), Coral Predators (COTS) and Distance to deep water (Dist). Pressures acting on the system are: Temperature (Temp), Artesinal Fisheries (Art), Line Fishing (LF), Marine Debris (MD), Grounding Ships (GS) and Waste Discharge (WD).

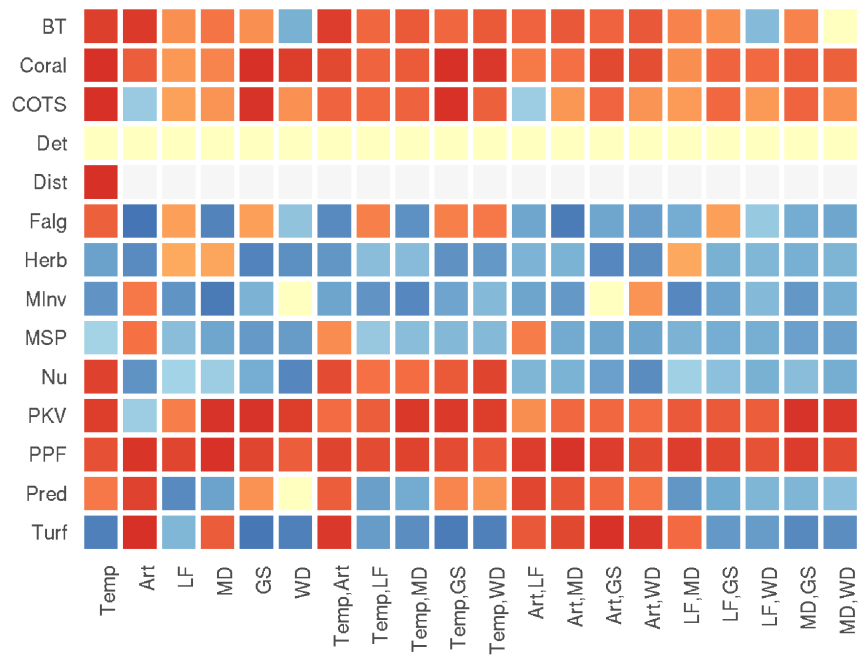
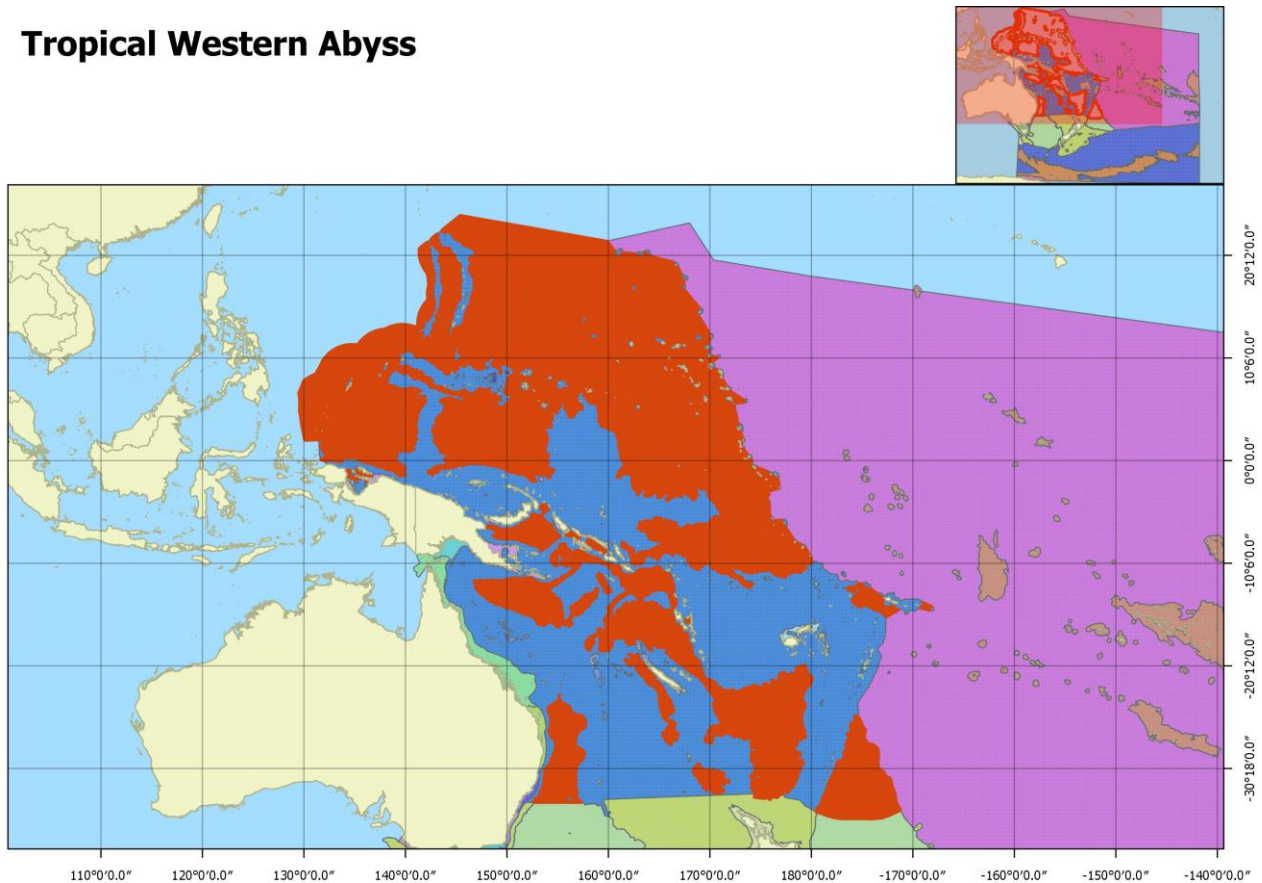


Figure 36. Ecosystem scenario responses to combinations of pressures. Red indicates a negative change and blue indicates a positive change. Ecosystem components in the qualitative model are: Pelagic Predatory Fish (PPF), Detritivore (Det), Predatory Fish (Pred), Medium Sized Predators (MSP), Mobile Invertebrates (MInv), Herbivorous Fish (Herb), Coral (Coral), Planktivores (PKV), BioTurbators (BT), Nutrients (Nu), Fleshy Algae (Falg), Turf Algae (Turf), Coral Predators (COTS) and Distance to deep water (Dist). Pressures acting on the system are: Temperature (Temp), Artesinal Fisheries (Art), Line Fishing (LF), Marine Debris (MD), Grounding Ships (GS) and Waste Discharge (WD).

2.1.10 Tropic Western Abyss

Tropical Western Abyss



The Tropical Abyssal Province is based on the modelled distribution of ophiuroids and squat lobsters using the Regions of Common Profile Method (Foster *et al.*, 2013), see the Appendix ‘Statistical Bioregionalisations’ for details. This approach separated out the abyssal province at about 3500 meters deep and beyond. This is slightly different from other regionalisation’s which made this boundary at 2000 meters (O’Hara *et al.*, 2011). But it does conform to other benthic classifications which draw this boundary at 3500 meters (e.g. GOODS classification and Watling *et al.*, 2013).

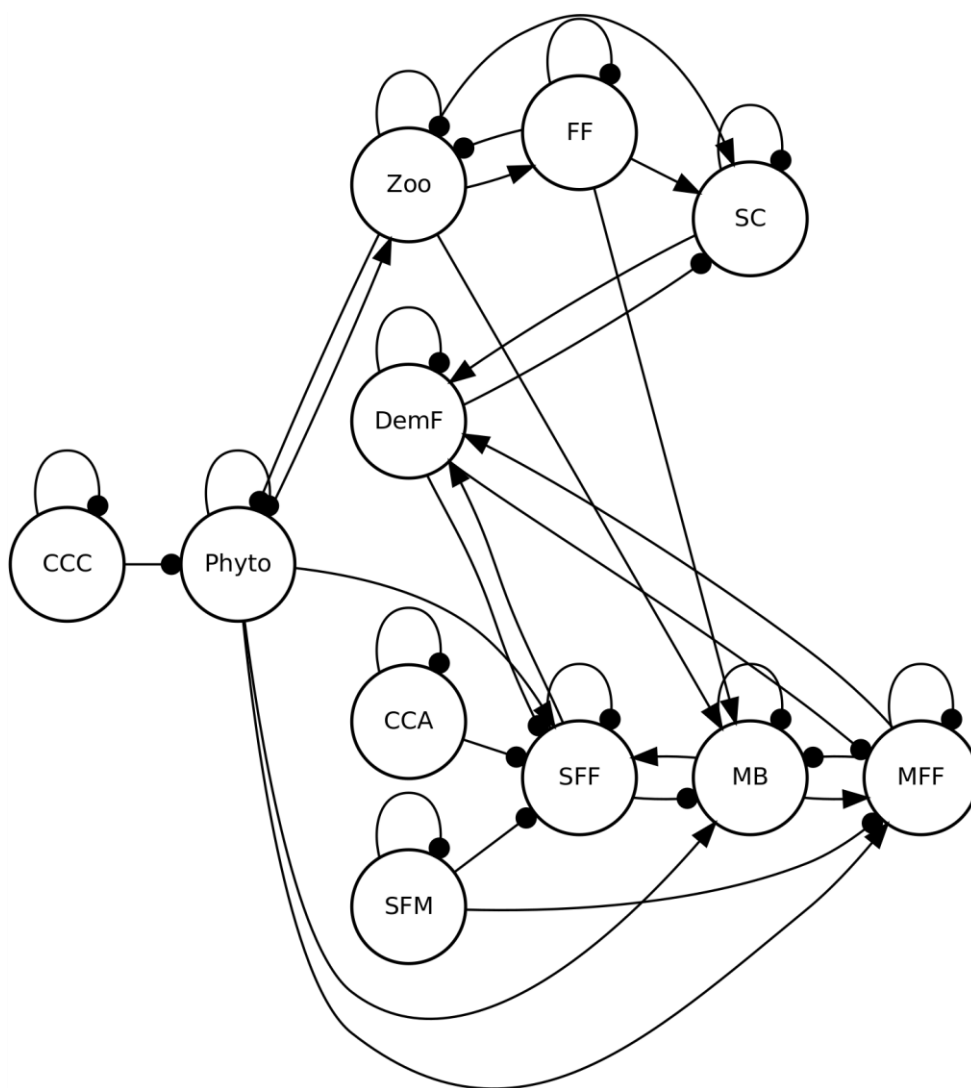


Figure 37. Ecosystem components in the qualitative model are: Demersal Fishes (DemF), Sessile Filter Feeders (SFF), Mobile Filter Feeders (MFF), Food Falls (FF), Scavengers (SC), Microbes (MB), Phytoplankton (Phyto) and Zooplankton (Zoo). Pressures acting on the system are: Seafloor Mining (SFM), Climate Change Chlorophyll (CCC) and Climate Change Acidification (CCA).

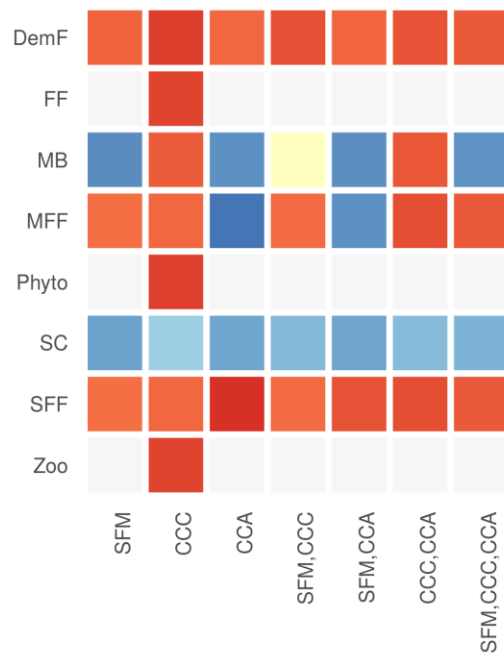
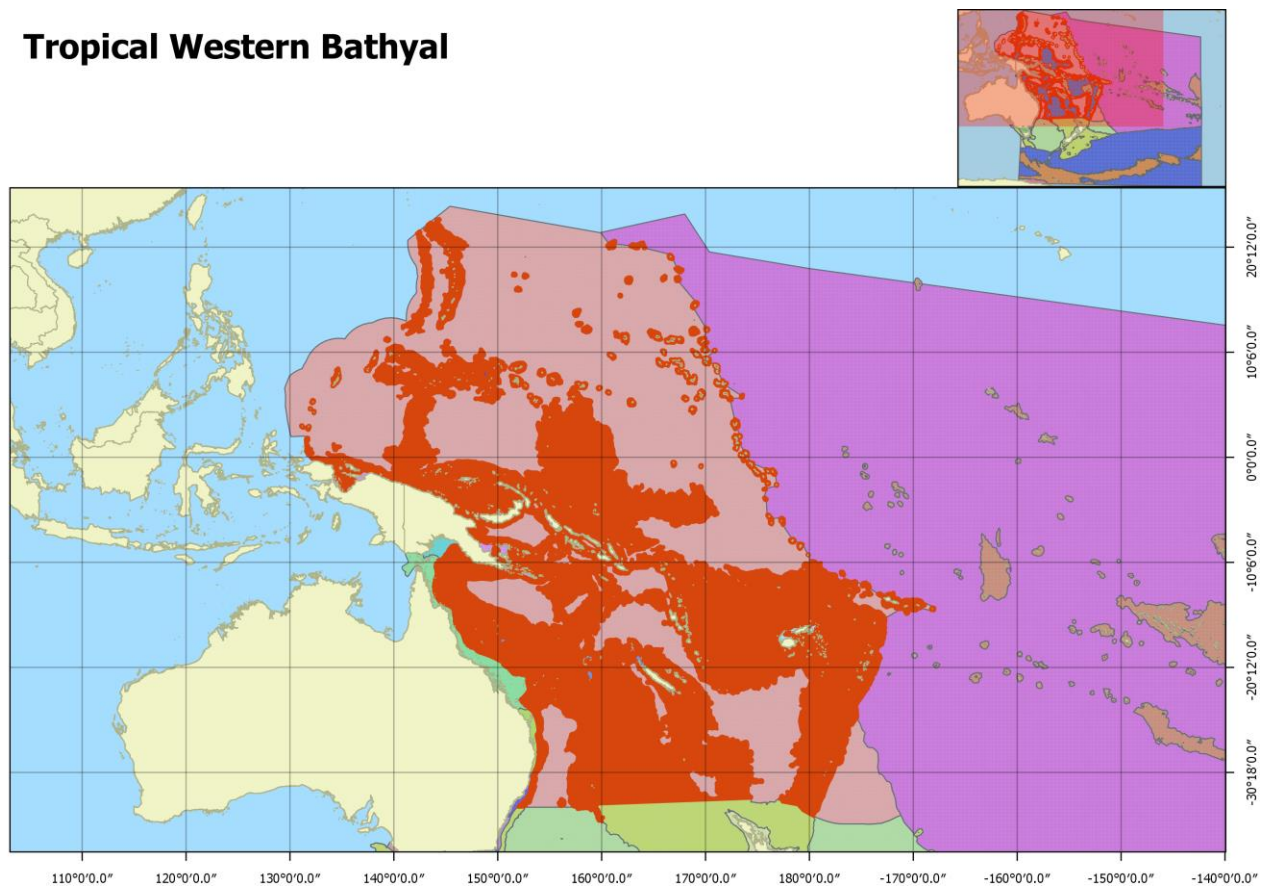


Figure 38. Ecosystem scenario responses to combinations of pressures. Red indicates a negative change and blue indicates a positive change. Ecosystem components in the qualitative model are: Demersal Fishes (DemF), Sessile Filter Feeders (SFF), Mobile Filter Feeders (MFF), Food Falls (FF), Scavengers (SC), Microbes (MB), Phytoplankton

(Phyto) and Zooplankton (Zoo). Pressures acting on the system are: Seafloor Mining (SFM), Climate Change Chlorophyll (CCC) and Climate Change Acidification (CCA).

2.1.11 Tropic Western Bathyal

Tropical Western Bathyal



The Tropical Bathyal Province is based on the modelled distribution of ophiuroids and squat lobsters using the Region of Common Profile Method (Foster *et al.*, 2013), see the Appendix 'Statistical Bioregionalisations' for details.. This approach separated out the bathyal province between 200 and 3500 meters depth. This is slightly different from other regionalisation's which made this boundary at 2000 meters (O'Hara *et al.*, 2011). The 2000 to 3500 meter region could be viewed as the lower bathyal and a more reduced subset of the shallower bathyal region. We however, do not define an upper and lower bathyal region, but recognise that there will be an affinity between these two bathomes (e.g. GOODS classification and Watling *et al.*, 2013).

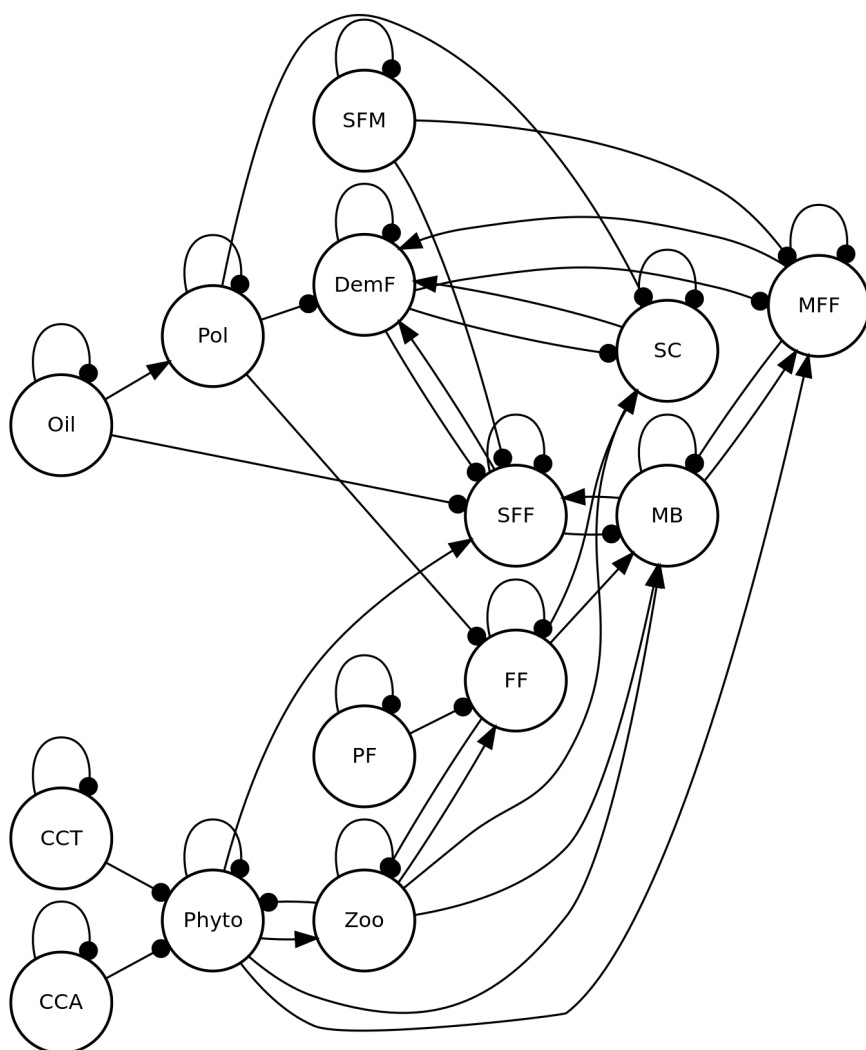


Figure 39. Ecosystem components in the qualitative model are: Demersal Fishes (DemF), Sessile Filter Feeders (SFF), Mobile Filter Feeders (MFF), Food Falls (FF), Scavengers (SC), Microbes (MB), Phytoplankton (Phyto) and Zooplankton (Zoo). Pressures acting on the system are: Climate Change Temperature (CCT), Pelagic Fisheries (PF), Pollution (Pol), Climate Change Acidification (CCA), Oil Spills (Oil) and Seafloor Mining (SFM).

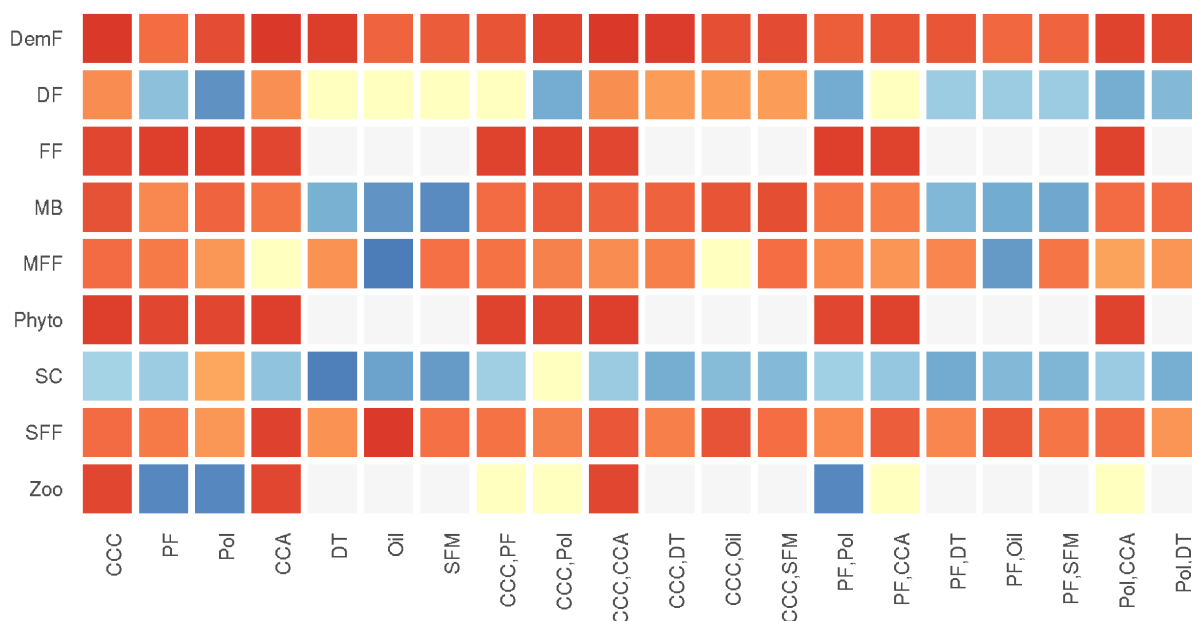
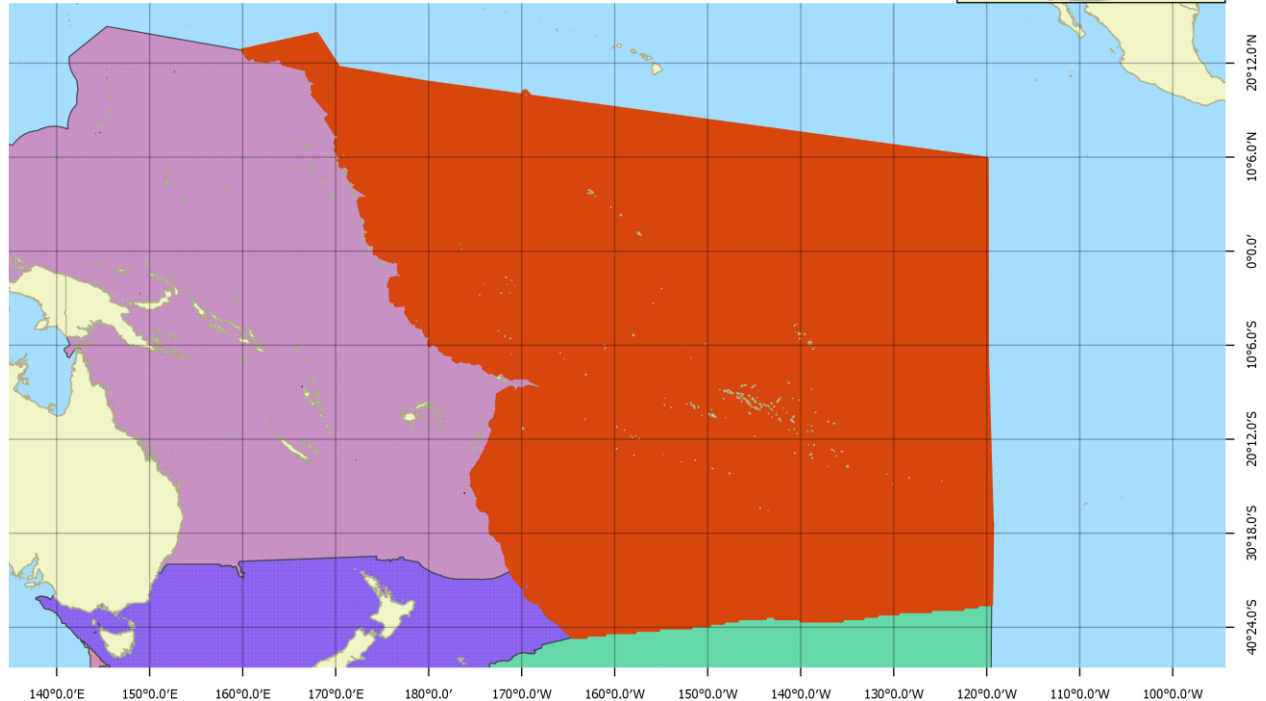


Figure 40. Ecosystem scenario responses to combinations of pressures. Red indicates a negative change and blue indicates a positive change. Ecosystem components in the qualitative model are: Demersal Fishes (DemF), Sessile Filter Feeders (SFF), Mobile Filter Feeders (MFF), Food Falls (FF), Scavengers (SC), Microbes (MB), Phytoplankton (Phyto), Zooplankton (Zoo). Pressures acting on the system are: Climate Change Temperature (CCT), Pelagic Fisheries (PF), Pollution (Pol), Climate Change Acidification (CCA), Oil Spills (Oil) and Seafloor Mining (SFM).

2.2 Tropic Eastern Region

Tropical Eastern Pacific Ocean

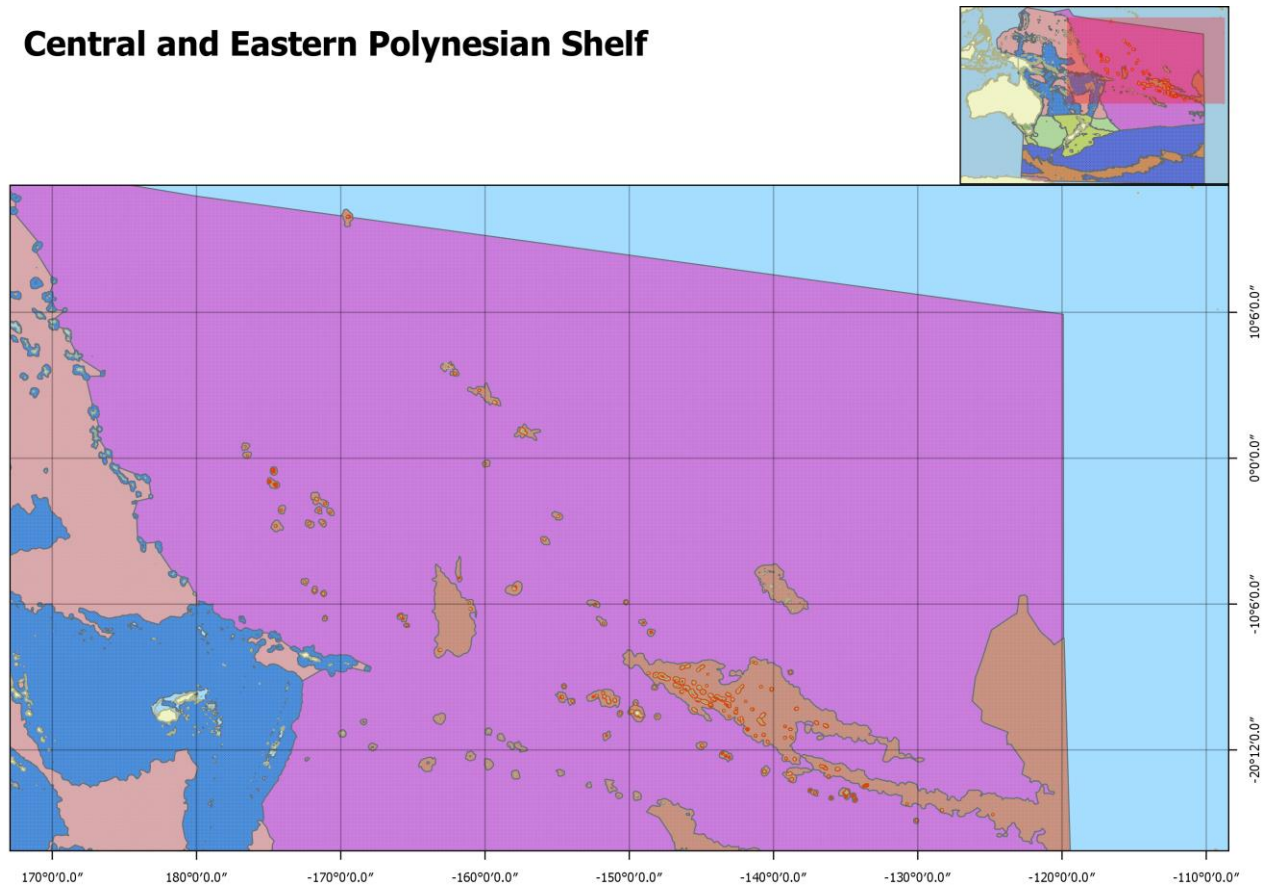


Map 1 Tropical Eastern Pacific Ocean Benthic Region

Large bioregional province for eastern tropic shelf, slope and abyssal depth regions. Bounded to the west by Marshall Islands, Gilbert Islands and Kiribati. The western boundary is also bounded by the Kermadec archipelago and abyssal trench and wraps around American Samoa. The eastern boundary ends at approximately at the longitudinal location of the Pitcairn Islands. The southern boundary sits at a higher latitude than the Tropic Western Pacific southern boundary, and reflects southern boundary of the tropical coral, fishes and other tropical species.

2.2.1 Central and Eastern Polynesia Shelf

Central and Eastern Polynesian Shelf



The broad longitudinal province contains the Phoenix, Central Kiribati, South Line Islands, Society, Tuamotu, Pitcairn Islands and French Polynesia. This region is based on the broad group of coral ecoregions (Veron *et al.*, 2015) and the distribution of fishes (Kulbicki *et al.*, 2013). Although this province is an amalgamation of a few coral and fish ecoregions, there was consensus at the workshop that all these ecoregions shared a close affinity. This province is constrained to approximately 200 meters deep.

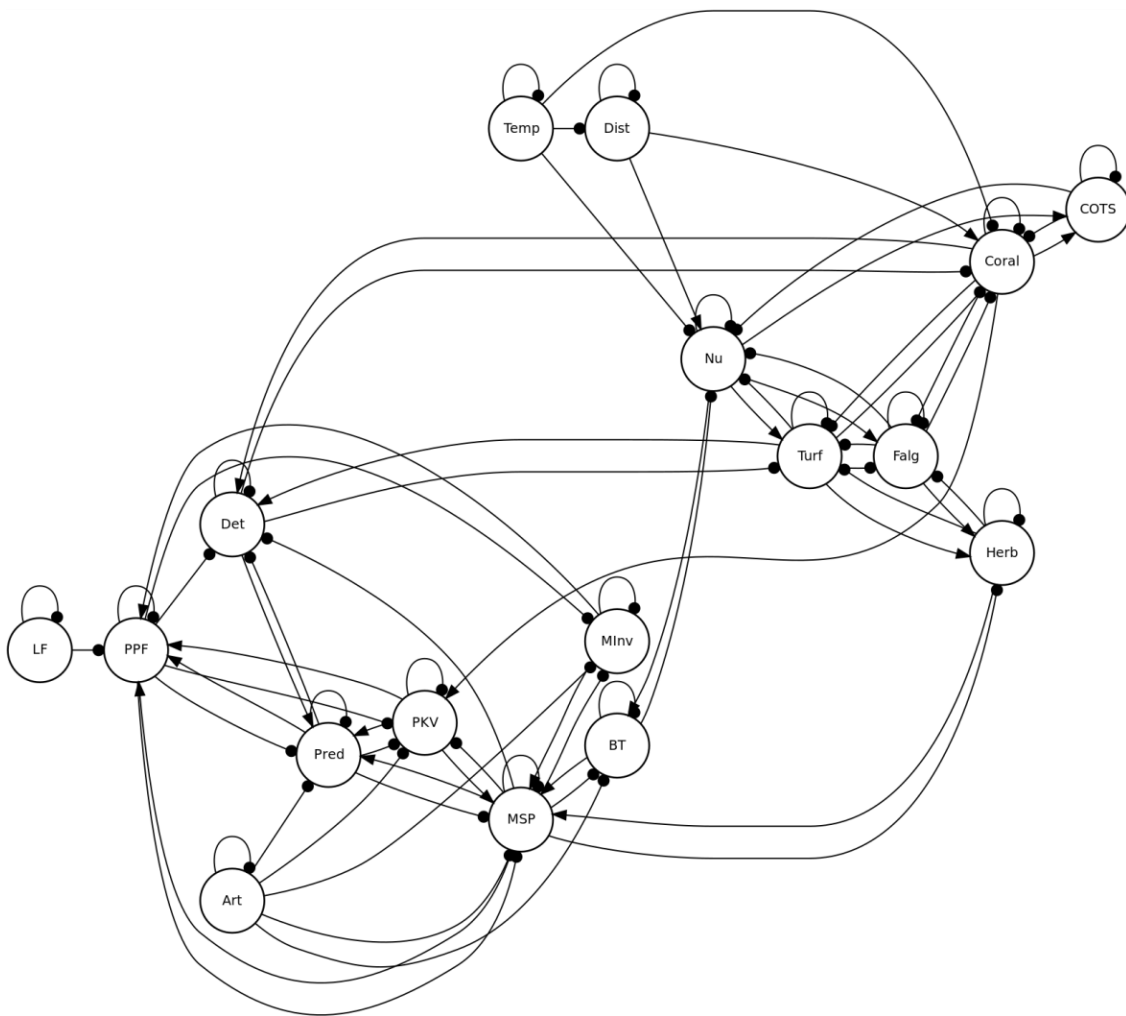


Figure 41: Ecosystem components in the qualitative model are: Pelagic Predatory Fish (PPF), Detritivore (Det), Predatory Fish (Pred), Medium Sized Predators (MSP), Mobile Invertebrates (Minv), Herbivorous Fish (Herb), Coral (Coral), Planktivores (PKV), BioTurbators (BT), Nutrients (Nu), Fleshy Algae (Falg), Turf Algae (Turf), Coral Predators (COTS) and Distance to deep water (Dist). Pressures acting on the system are: Temperature (Temp), Artisanal Fisheries (Art) and Line Fishing (LF).

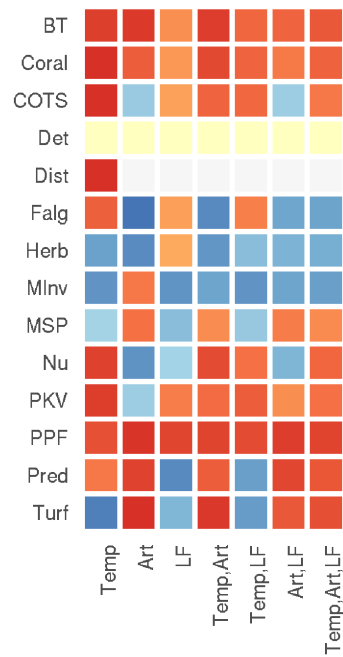
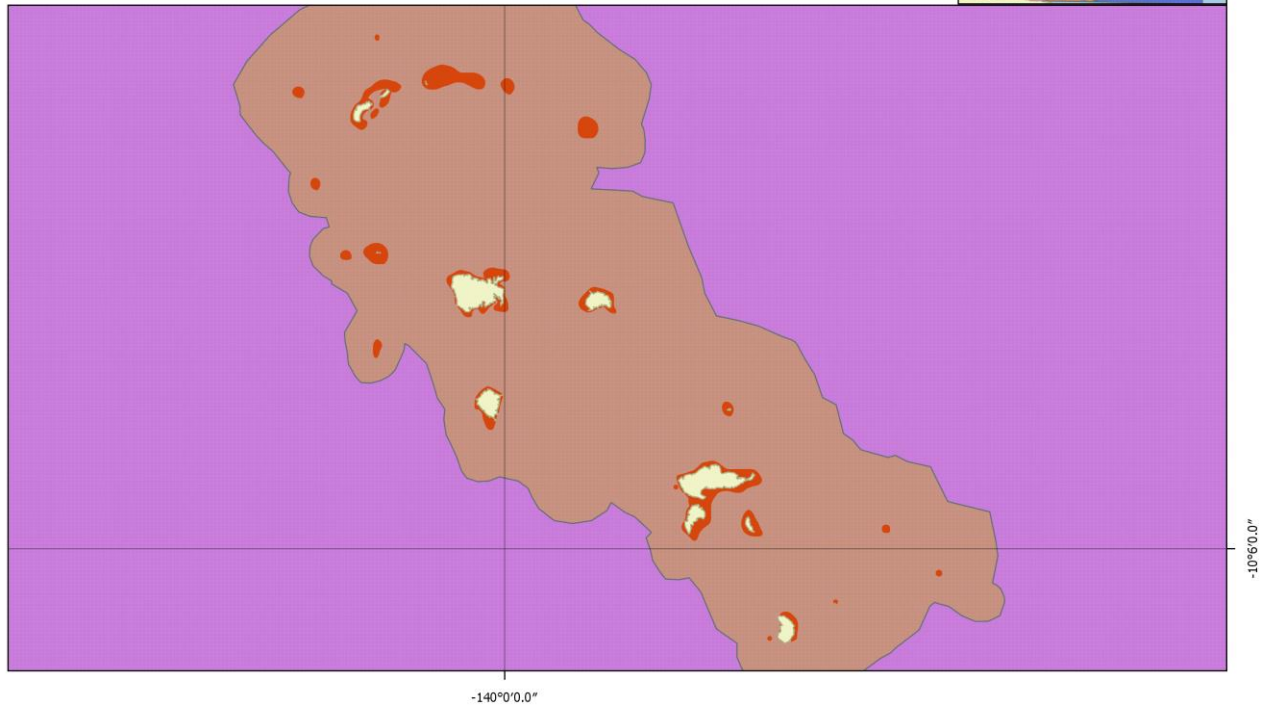


Figure 42. Ecosystem scenario responses to combinations of pressures. Red indicates a negative change and blue indicates a positive change. Ecosystem components in the qualitative model are: Pelagic Predatory Fish (PPF), Detritivore (Det), Predatory Fish (Pred), Medium Sized Predators (MSP), Mobile Invertebrates (MInv), Herbivorous Fish (Herb), Coral (Coral), Planktivores (PKV), BioTurbators (BT), Nutrients (Nu), Fleshy Algae (Falg), Turf Algae (Turf), Coral Predators (COTS) and Distance to deep water (Dist). Pressures acting on the system are: Temperature (Temp), Artisanal Fisheries (Art) and Line Fishing (LF).

2.2.2 Marquesas Shelf

Marquesas Shelf



The Marquesas Islands are a unique and geographically distinct region. These islands are the most eastern extent of coral distributions and many reef fishes in the Pacific. They share no close affinity to any neighbouring regions. The classification of the Marquesas Shelf Province is based on corals and fishes (Kulbicki et al., 2013, Veron et al., 2015). This province is constrained

to approximately 200 meters depth.

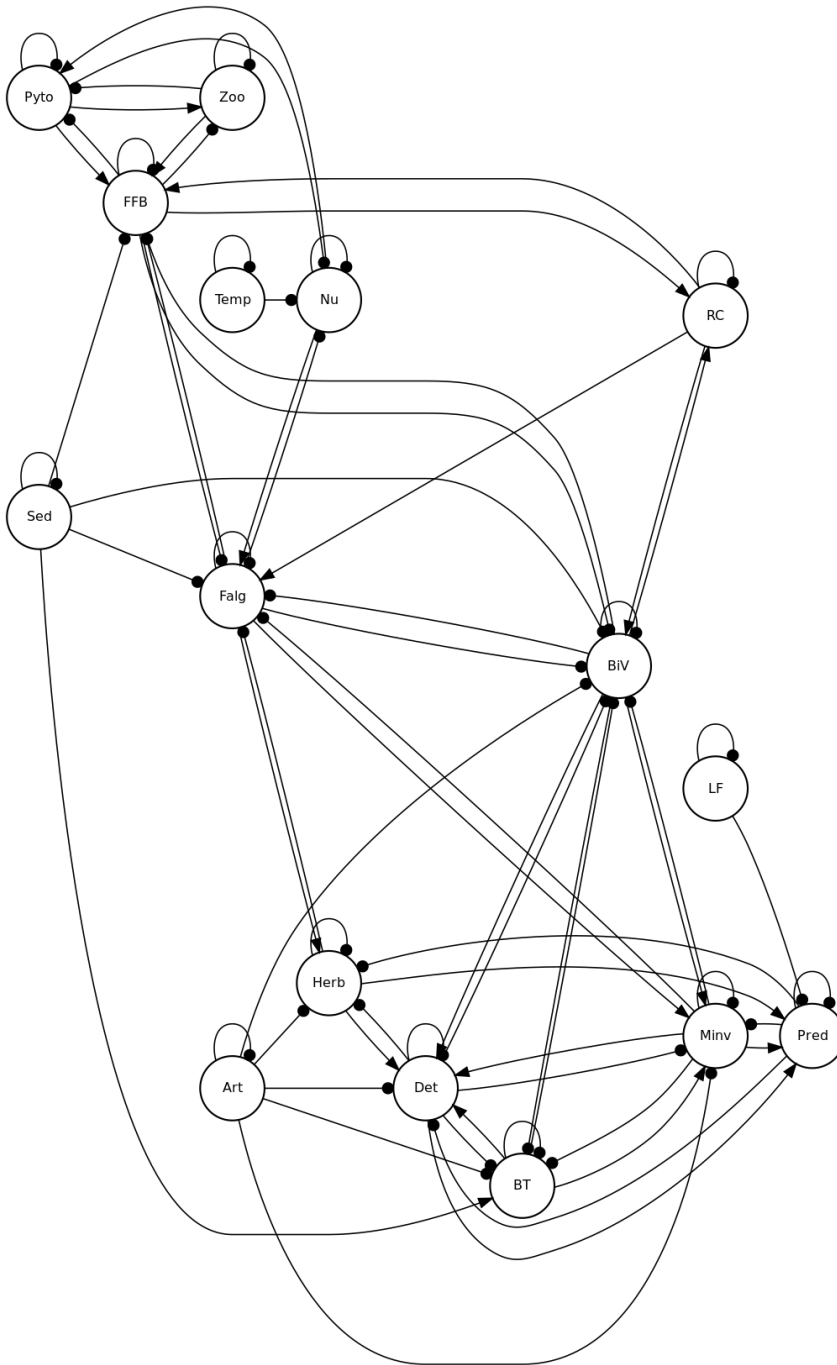


Figure 43. Ecosystem components in the qualitative model are: Phytoplankton (Pyto), Bioturbators (BT), Reef Complexity (RC), Detritivores (Det), Fleshy Algae (Falg), Filter Feeding Benthic (FFB), Predatory Fish (Pred), Herbivorous Fish (Herb), Mobile Invertebrates (Minv), Bivalves (BiV), Nutrient (Nu) and Zooplankton (Zoo). Pressures acting on the system are: Sediment (Sed), Artisanal Fisheries (Art), Line Fishing (LF) and Temperature (Temp).

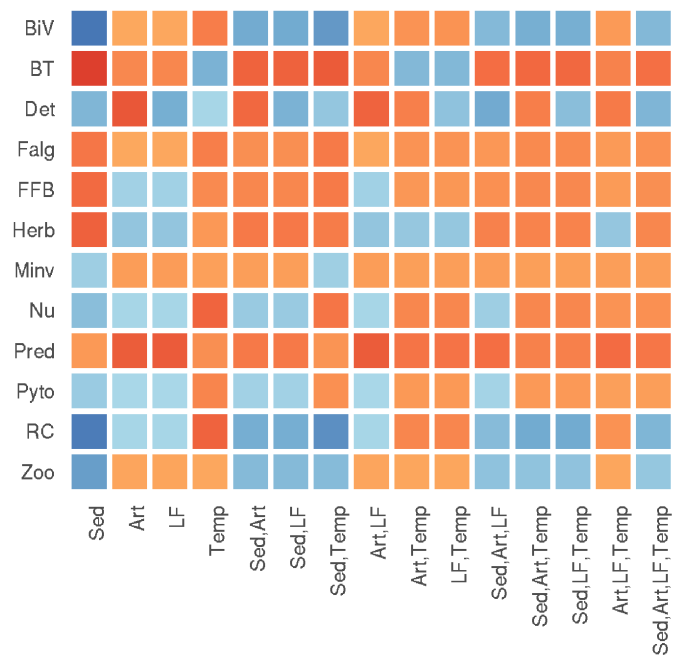
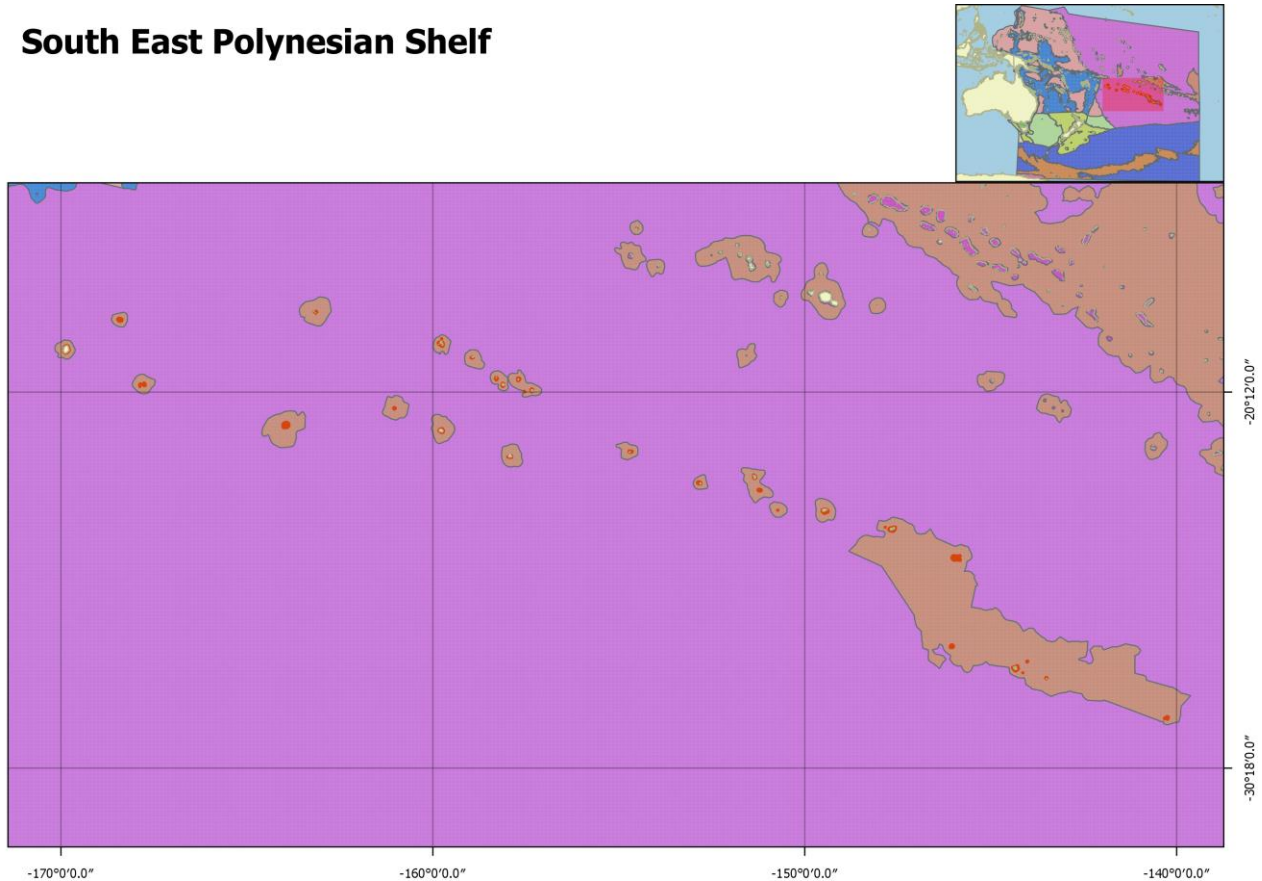


Figure 44. Ecosystem scenario responses to combinations of pressures. Red indicates a negative change and blue indicates a positive change. Ecosystem components in the qualitative model are: Phytoplankton (Pyto), Bioturbators (BT), Reef Complexity (RC), Detritivores (Det), Fleshy Algae (Falg), Filter Feeding Benthic (FFB), Predatory Fish (Pred), Herbivorous Fish (Herb), Mobile Invertebrates (Minv), Bivalves (BiV), Nutrient (Nu) and Zooplankton (Zoo). Pressures acting on the system are: Sediment (Sed), Artisanal Fisheries (Art), Line Fishing (LF) and Temperature (Temp).

2.2.3 South East Polynesian Shelf

South East Polynesian Shelf



The South East Polynesia Shelf Province includes the Cook and Austral Islands. This province is based on a merger of two coral ecoregions (Cooks and Austral) and the distribution of fishes (Kulbicki et al., 2013, Veron et al., 2015). This region is distinct from the Central and Eastern Polynesian Shelf Province to the north and Niue to the west. This province is constrained to approximately 200 meters depth.

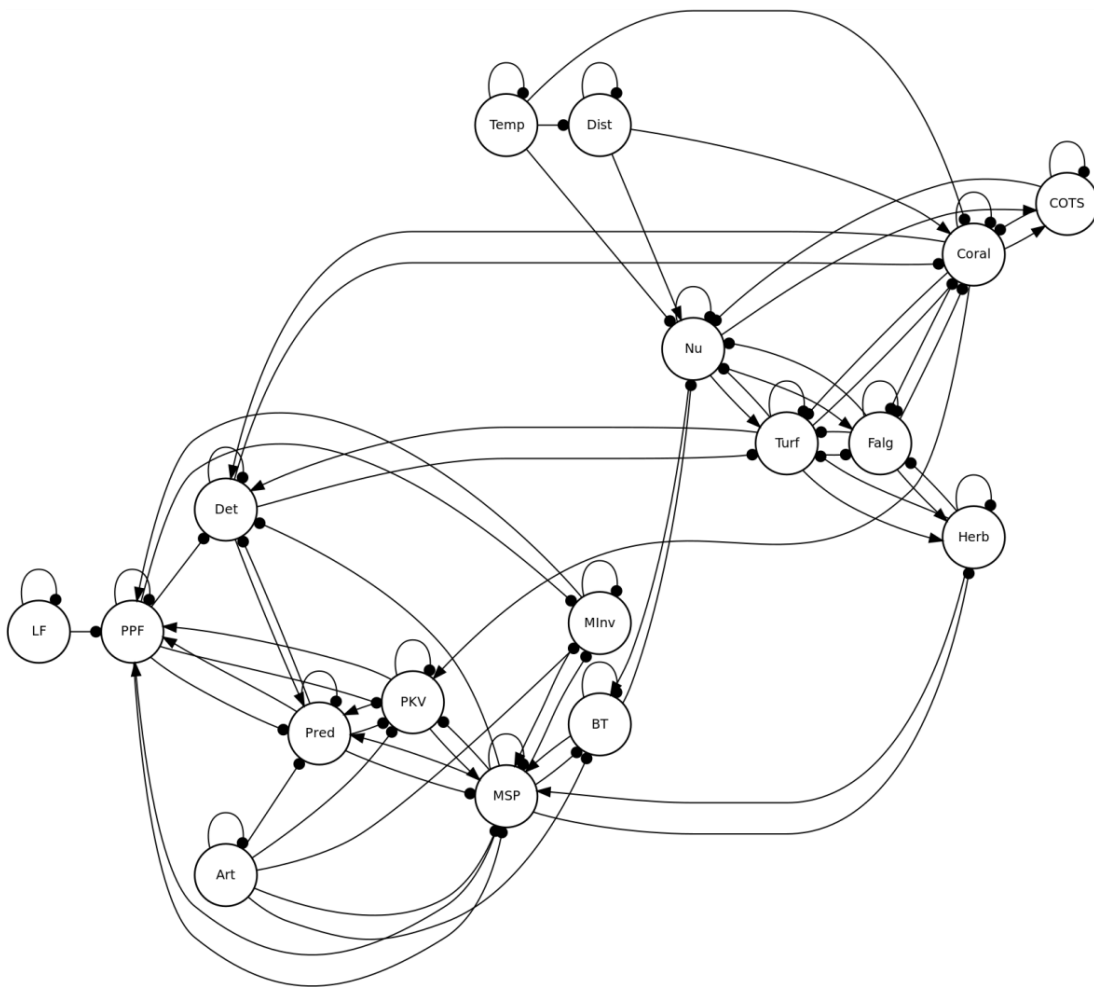


Figure 45. Ecosystem components in the qualitative model are: Pelagic Predatory Fish (PPF), Detritivore (Det), Predatory Fish (Pred), Medium Sized Predators (MSP), Mobile Invertebrates (Minv), Herbivorous Fish (Herb), Coral (Coral), Planktivores (PKV), BioTurbators (BT), Nutrients (Nu), Fleshy Algae (Falg), Turf Algae (Turf), Coral Predators (COTS) and Distance to deep water (Dist) . Pressures acting on the system are: Temperature (Temp), Artisanal Fisheries (Art) and Line Fishing (LF)"

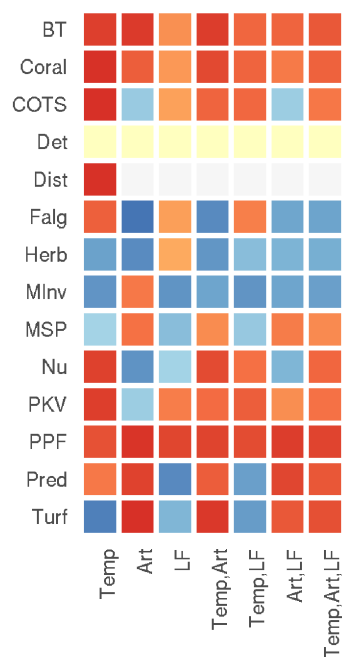
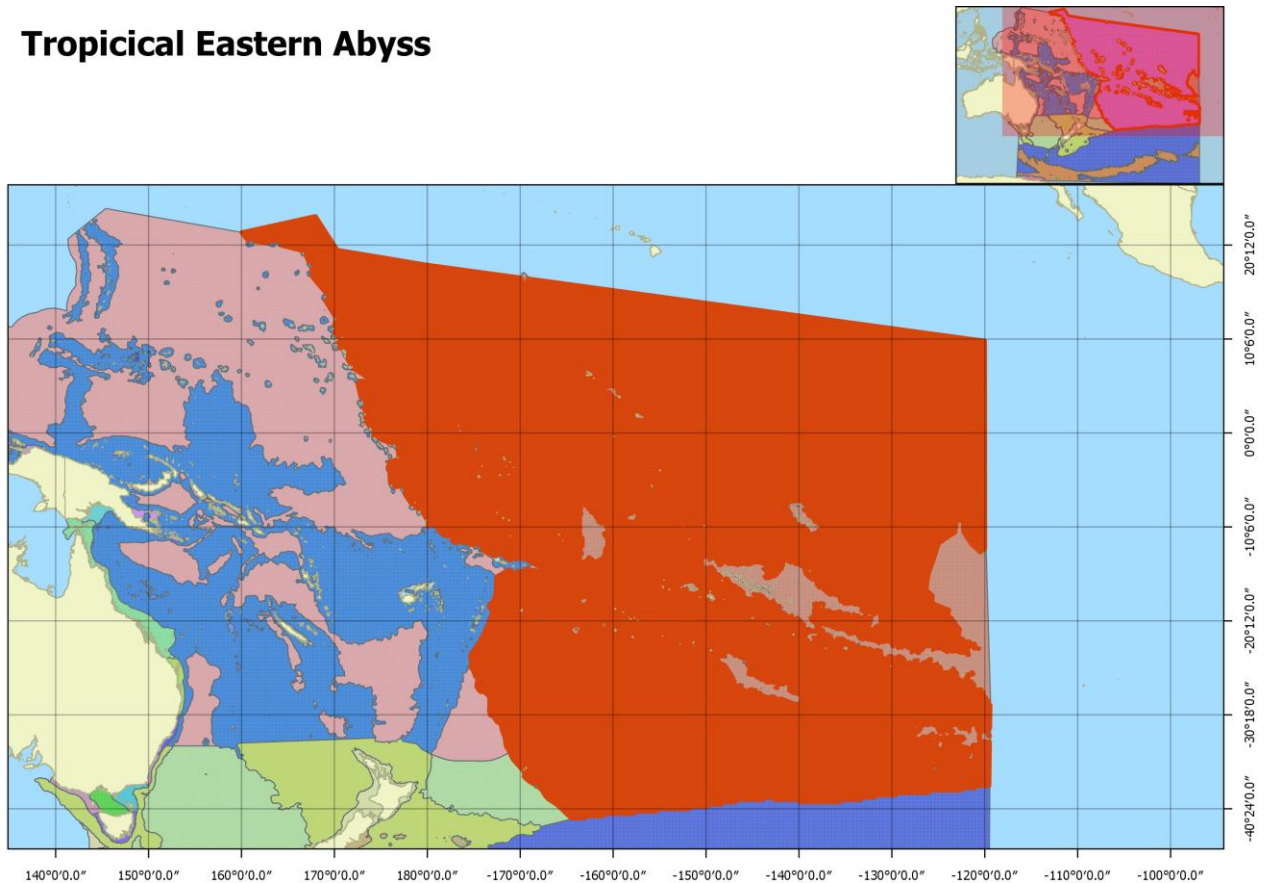


Figure 46: Ecosystem scenario responses to combinations of pressures. Red indicates a negative change and blue indicates a positive change. Ecosystem components in the qualitative model are: Pelagic Predatory Fish (PPF), Detritivore (Det), Predatory Fish (Pred), Medium Sized Predators (MSP), Mobile Invertebrates (MInv), Herbivorous Fish (Herb), Coral (Coral), Planktivores (PKV), BioTurbators (BT), Nutrients (Nu), Fleshy Algae (Falg), Turf Algae (Turf), Coral Predators (COTS) and Distance to deep water (Dist) . Pressures acting on the system are: Temperature (Temp), Artisanal Fisheries (Art) and Line Fishing (LF).

2.2.4 Tropical Eastern Abyss

Tropical Eastern Abyss



The Tropical Eastern Abyssal Province is based on the modelled distribution of ophiuroids and squat lobsters using the Regions of Common Profile method (Foster *et al.*, 2013), see the Appendix 'Statistical Bioregions' for details. This approach separated out the abyssal province at about 3500 meters deep and beyond. This is slightly different from other regionalisation's which made this boundary at 2000 meters (O'Hara *et al.*, 2011). But it does conform to other benthic classifications which draw this boundary at 3500 meters (e.g. GOODS classification and Watling *et al.*, 2013).

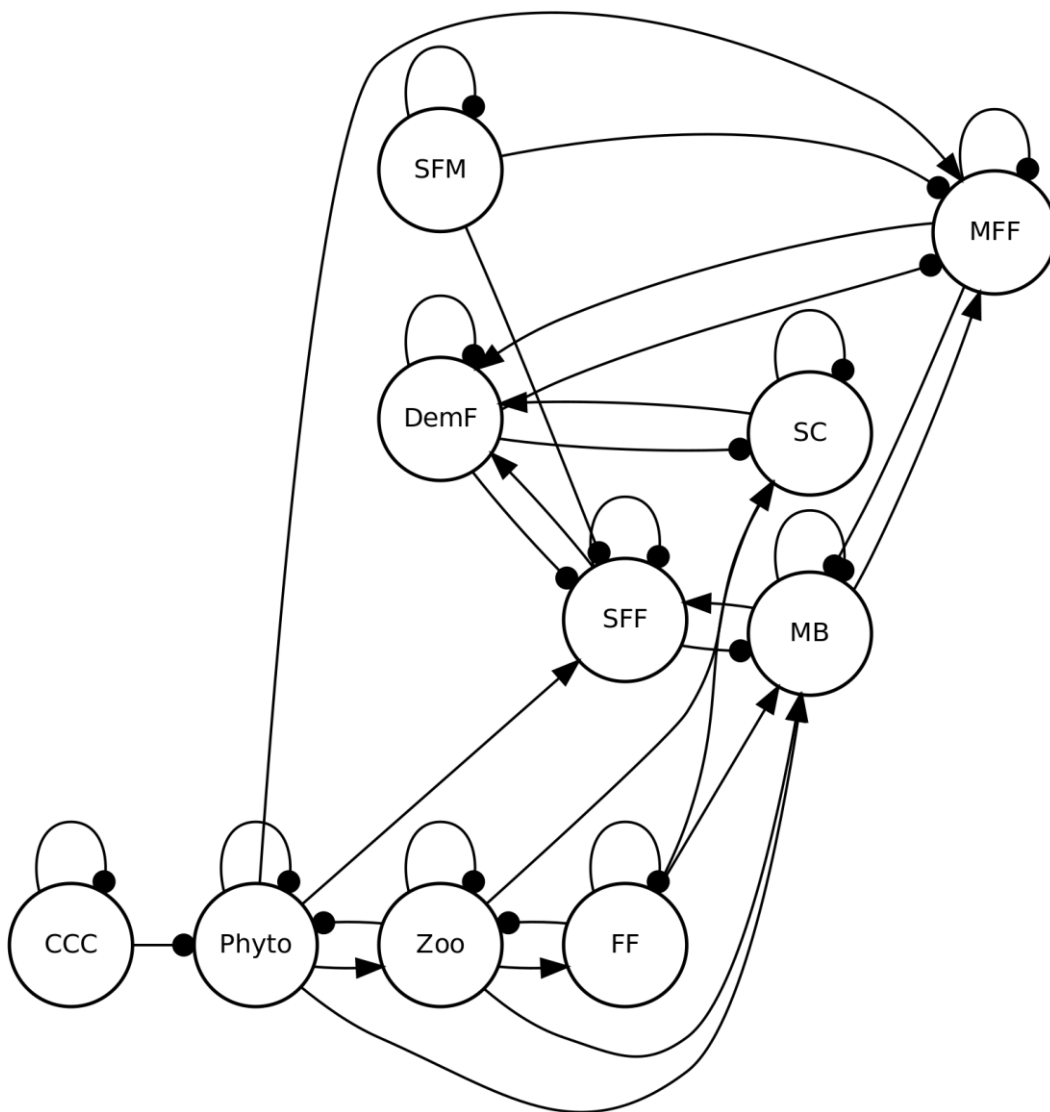


Figure 47. Ecosystem components in the qualitative model are: Demersal Fishes (DemF), Sessile Filter Feeders (SFF), Mobile Filter Feeders (MFF), Food Falls (FF), Scavengers (SC), Microbes (MB), Phytoplankton (Phyto) and Zooplankton (Zoo). Pressures acting on the system are: Seafloor Mining (SFM) and Climate Change Chlorophyll (CCC).

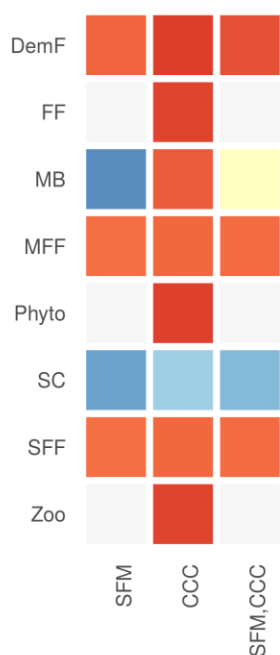
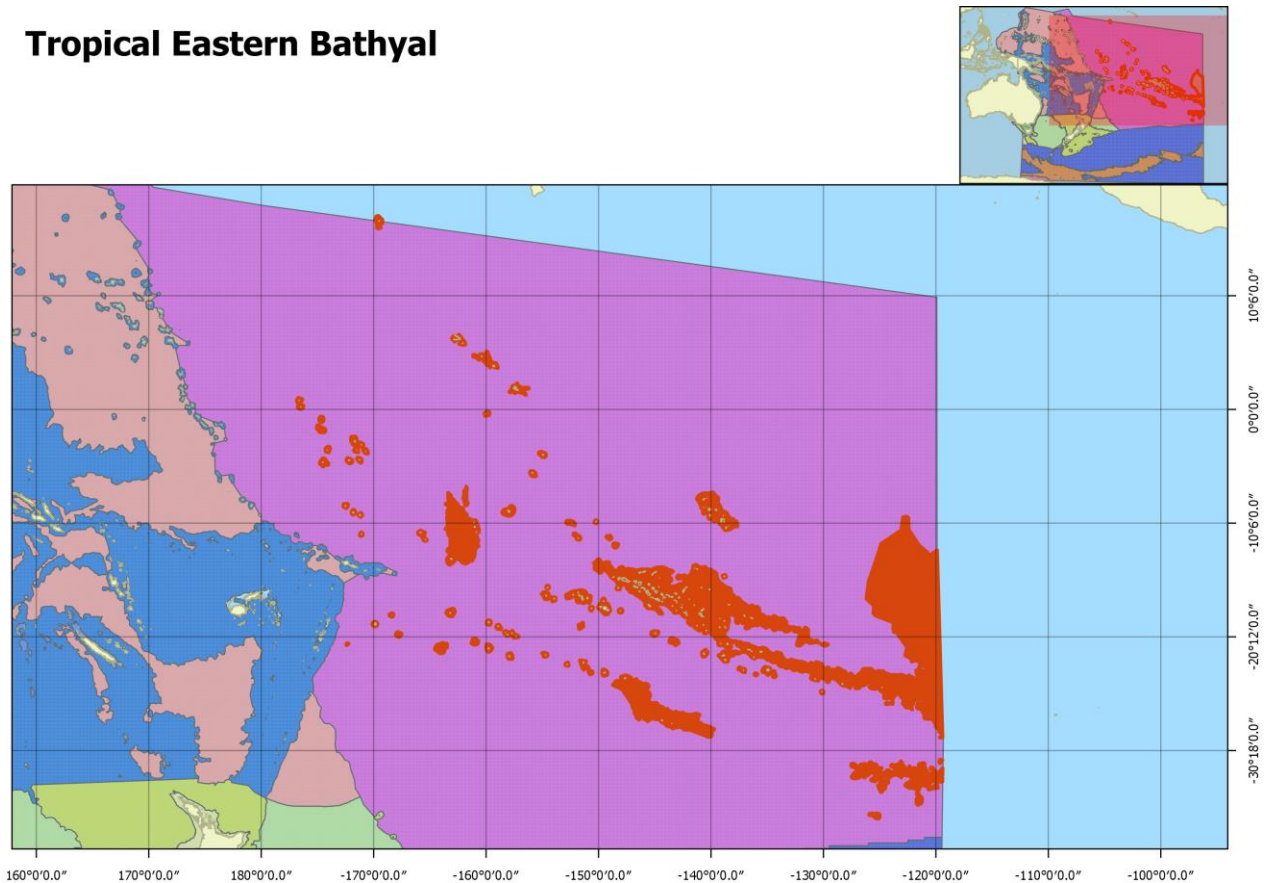


Figure 48. Ecosystem scenario responses to combinations of pressures. Red indicates a negative change and blue indicates a positive change. Ecosystem components in the qualitative model are: Demersal Fishes (DemF), Sessile Filter Feeders (SFF), Mobile Filter Feeders (MFF), Food Falls (FF), Scavengers (SC), Microbes (MB), Phytoplankton (Phyto) and Zooplankton (Zoo). Pressures acting on the system are: Seafloor Mining (SFM) and Climate Change Chlorophyll (CCC).

2.2.5 Tropic Eastern Bathyal

Tropical Eastern Bathyal



The Tropic Eastern Bathyal province is based on the modelled distribution of ophiuroids and squat lobsters using the Regions of Common Profile Method (Foster *et al.*, 2013), see the Appendix ‘Statistical Bioregions’ for details. This approach separated out the bathyal province between 200 and 3500 meters depth. This is slightly different from other regionalisation’s which made this boundary at 2000 meters (O’Hara *et al.*, 2011). The 2000 to 3500 meter region could be viewed as the lower bathyal and a more depauperate subset of the shallower bathyal region. We however, do not define an upper and lower bathyal region, but recognise that there will be an affinity between these two bathomes (e.g. GOODS classification and Watling *et al.*, 2013).

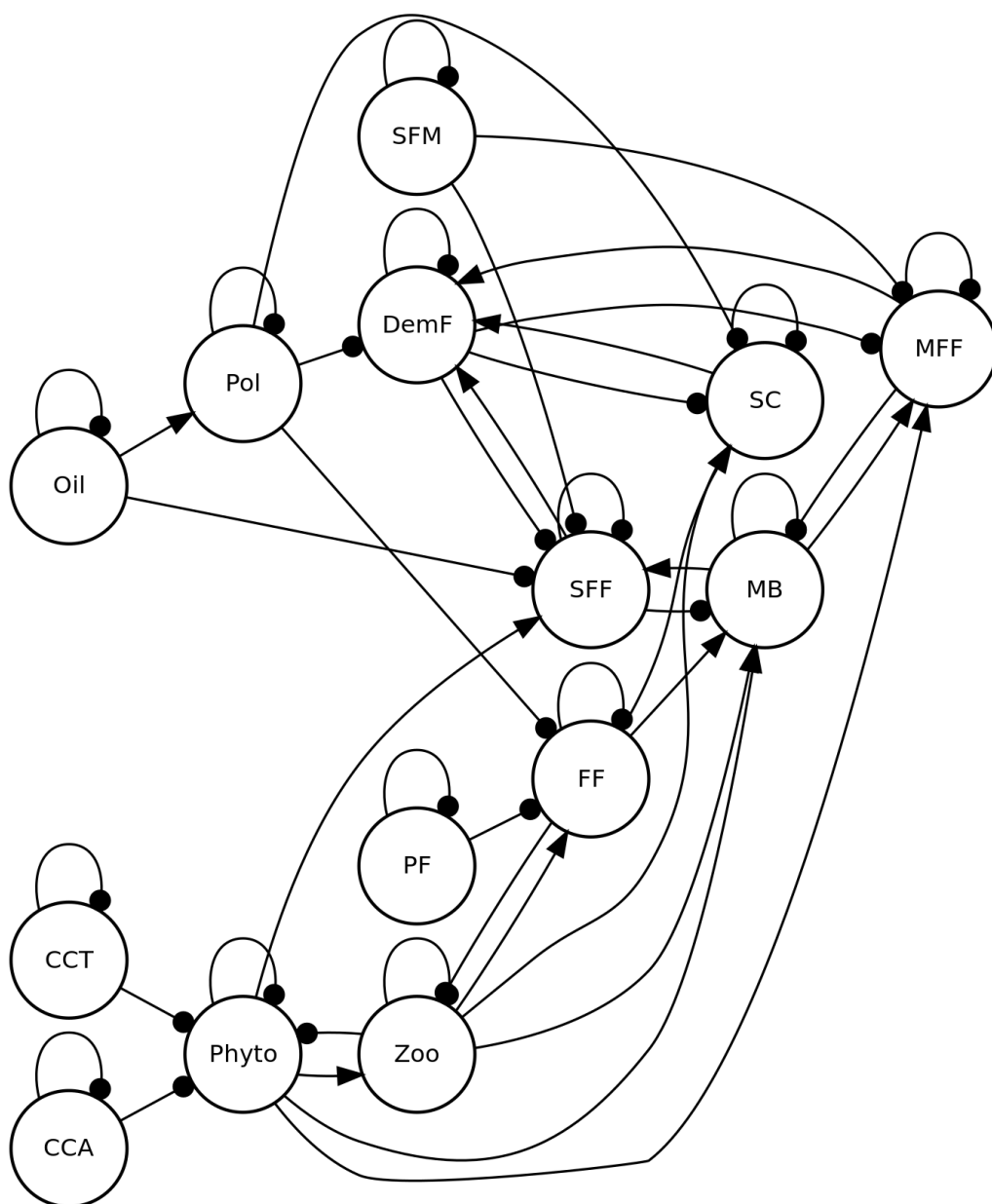


Figure 49. Ecosystem components in the qualitative model are: Demersal Fishes (DemF), Sessile Filter Feeders (SFF), Mobile Filter Feeders (MFF), Food Falls (FF), Scavengers (SC), Microbes (MB), Phytoplankton (Phyto) and Zooplankton (Zoo). Pressures acting on the system are: Climate Change Temperature (CCT), Pelagic Fisheries (PF), Pollution (Pol), Climate Change Acidification (CCA), Oil Spills (Oil) and Seafloor Mining (SFM).

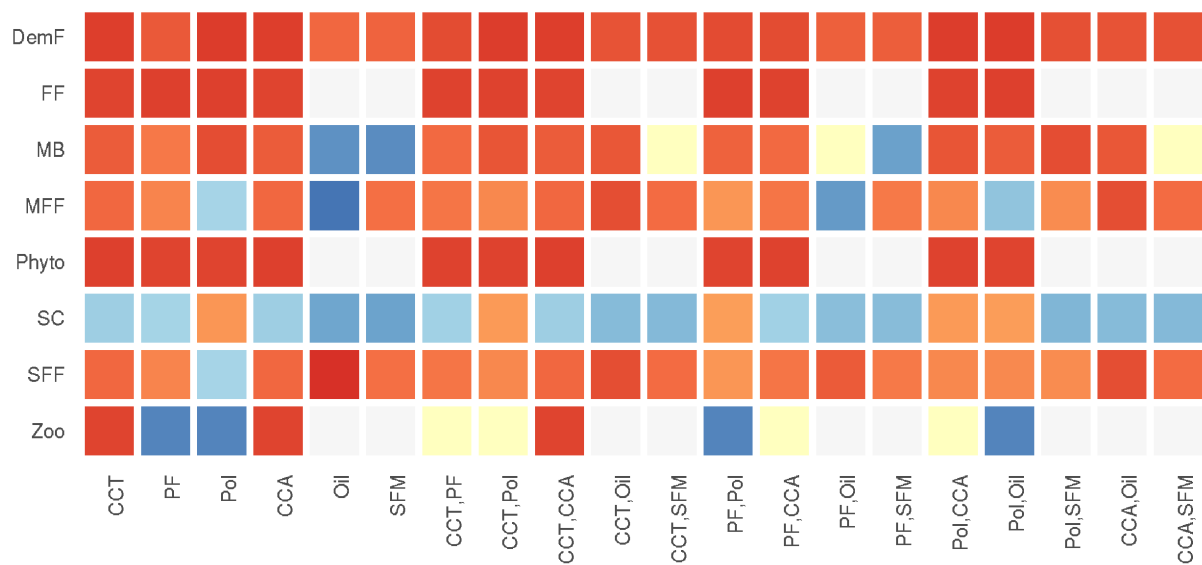
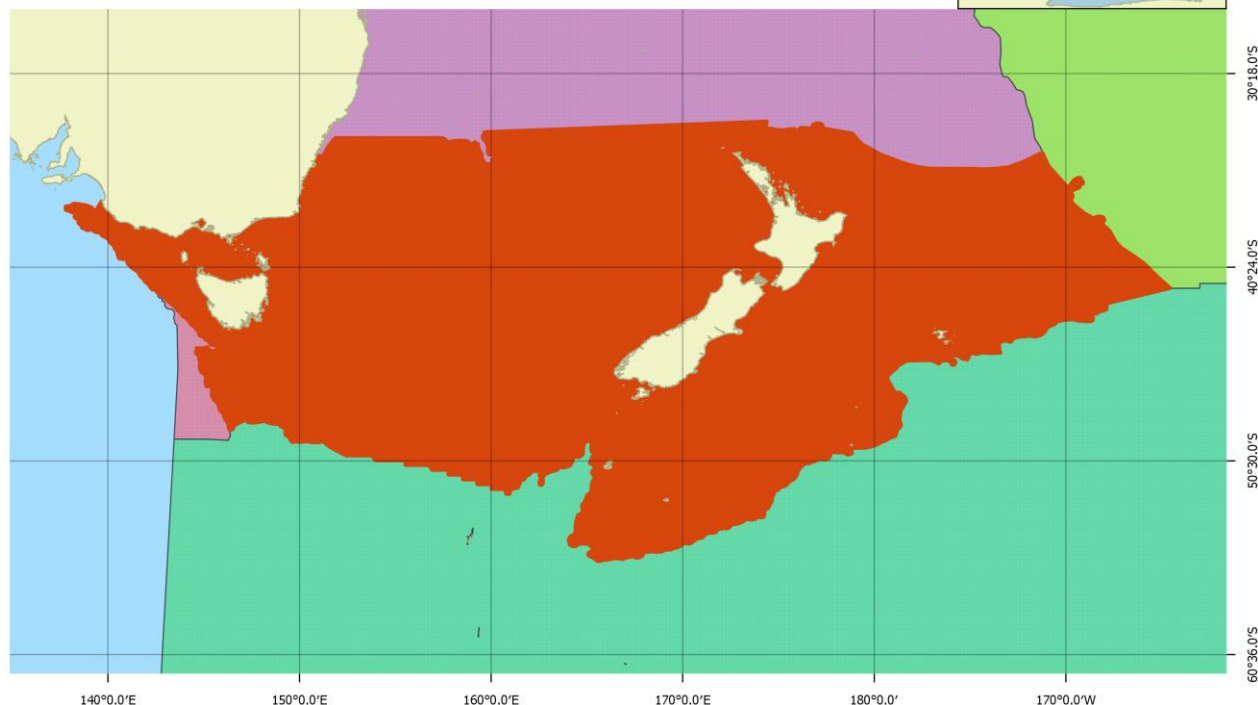


Figure 50. Ecosystem scenario responses to combinations of pressures. Red indicates a negative change and blue indicates a positive change. Ecosystem components in the qualitative model are: Demersal Fishes (DemF), Sessile Filter Feeders (SFF), Mobile Filter Feeders (MFF), Food Falls (FF), Scavengers (SC), Microbes (MB), Phytoplankton (Phyto) and Zooplankton (Zoo). Pressures acting on the system are: Climate Change Temperature (CCT), Pelagic Fisheries (PF), Pollution (Pol), Climate Change Acidification (CCA), Oil Spills (Oil) and Seafloor Mining (SFM).

2.3 Temperate Western Region

Temperate Western Pacific Ocean



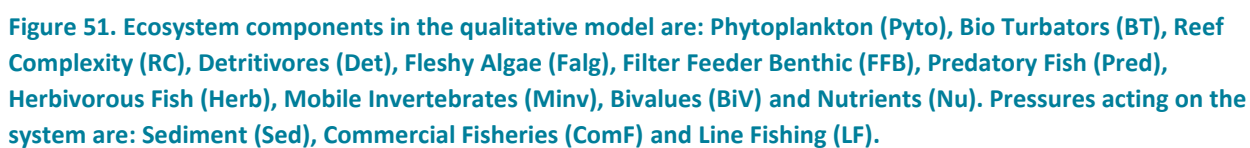
The Temperate Western Pacific Region is a large bioregional province which includes temperate regions of Australia and much of New Zealand's economic exclusive zone (EEZ). The northern latitudinal boundary which sits below Lord Howe, New Caledonia and Kermedecs and cuts slightly north up the eastern coast of Australia to match the distribution of Australia's IMCRA regions. On the Australian coastline the southern boundary reflects the latitudinal break in the middle of the Central Eastern IMCRA transition province (IMCRA 4). The eastern boundary follows New Zealand's EEZ bathyal boundary (~3500 meters) and reflects the partitioning of this region as seen in the GOOD biogeographic classification (GOODS report). This reflects the distribution of benthic fauna across this region, which largely ends at this boundary due to much deeper seafloor areas to the east and a lack of island which can support these species. The southern boundary is driven by the extent of the sub-polar front and the sub-antarctic front. This boundary is slightly shifted to adhere to follow the bathyal depth contour that runs at 3500 meters across this Southern Indian and Pacific Antarctic mid-ocean ridges.

2.3.1 Central North New Zealand Shelf

Central North New Zealand Shelf



The Central North New Zealand shelf regionalisation is shallower shelf areas that encompass the top of New Zealand's south island and the north island. This classification is based on the work of classification of demersal fishers, the physical environment and ophiuroids (O'Hara *et al.*, 2011; Stephenson *et al.*, 2018). This region came directly from Stephenson *et al.* (2018) 'ten groups' output, which a more generalised classification for this region. The Central North New Zealand Shelf Province was constrained to shelf habitats.



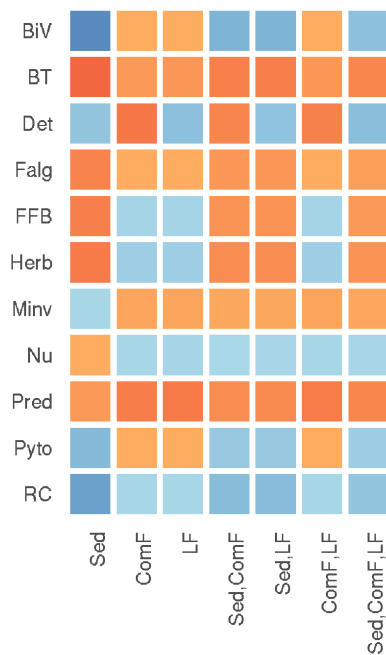
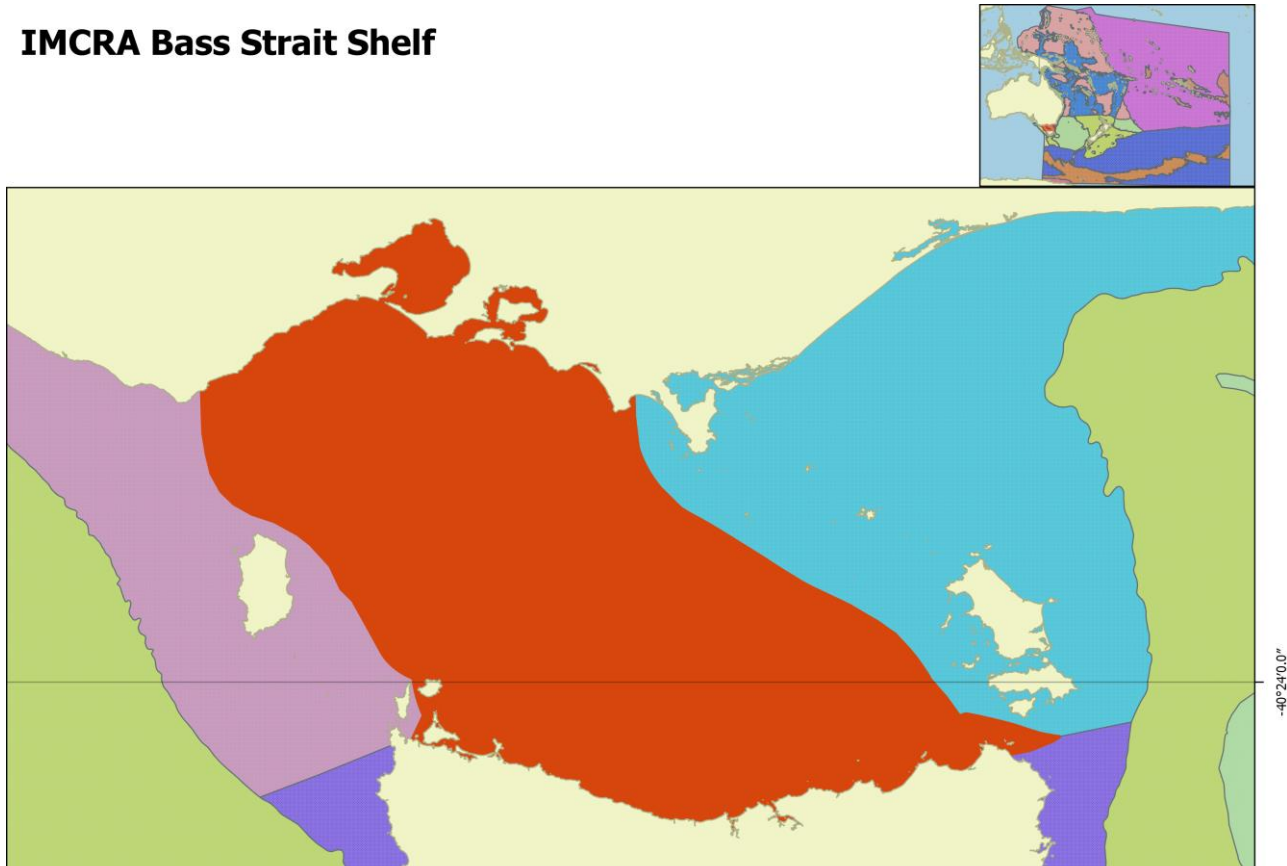


Figure 52. Ecosystem scenario responses to combinations of pressures. Red indicates a negative change and blue indicates a positive change. Ecosystem components in the qualitative model are: Phytoplankton (Pyto), Bio Turbators (BT), Reef Complexity (RC), Detritivores (Det), Fleshy Algae (Falg), Filter Feeder Benthic (FFB), Predatory Fish (Pred), Herbivorous Fish (Herb), Mobile Invertebrates (Minv), Bivalves (BiV) and Nutrients (Nu). Pressures acting on the system are: Sediment (Sed), Commercial Fisheries (ComF) and Line Fishing (LF).

2.3.2 IMCRA Bass Strait Shelf

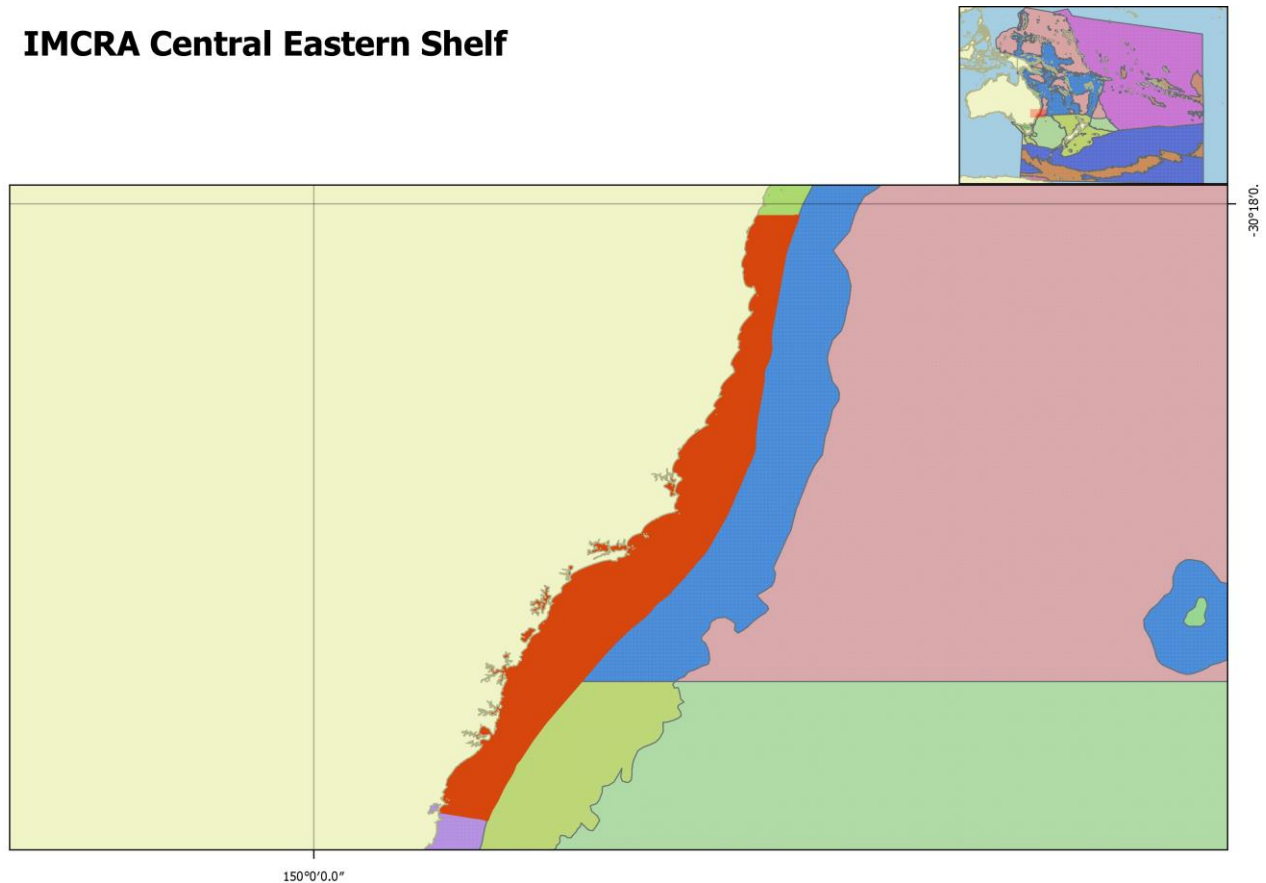
IMCRA Bass Strait Shelf



The IMCRA Bass Strait Shelf province is taken directly from Australia's national marine bioregionalisation. This is a shallow strait between Victoria and Tasmania. Within the IMCRA framework it is based on the distribution of demersal fishes and geomorphic features. See the IMCRA report for details (Heap *et al.*, 2005). Qualitative models for this province can be found in Hosack and Dambacher (2012).

2.3.3 IMCRA Central Eastern Shelf

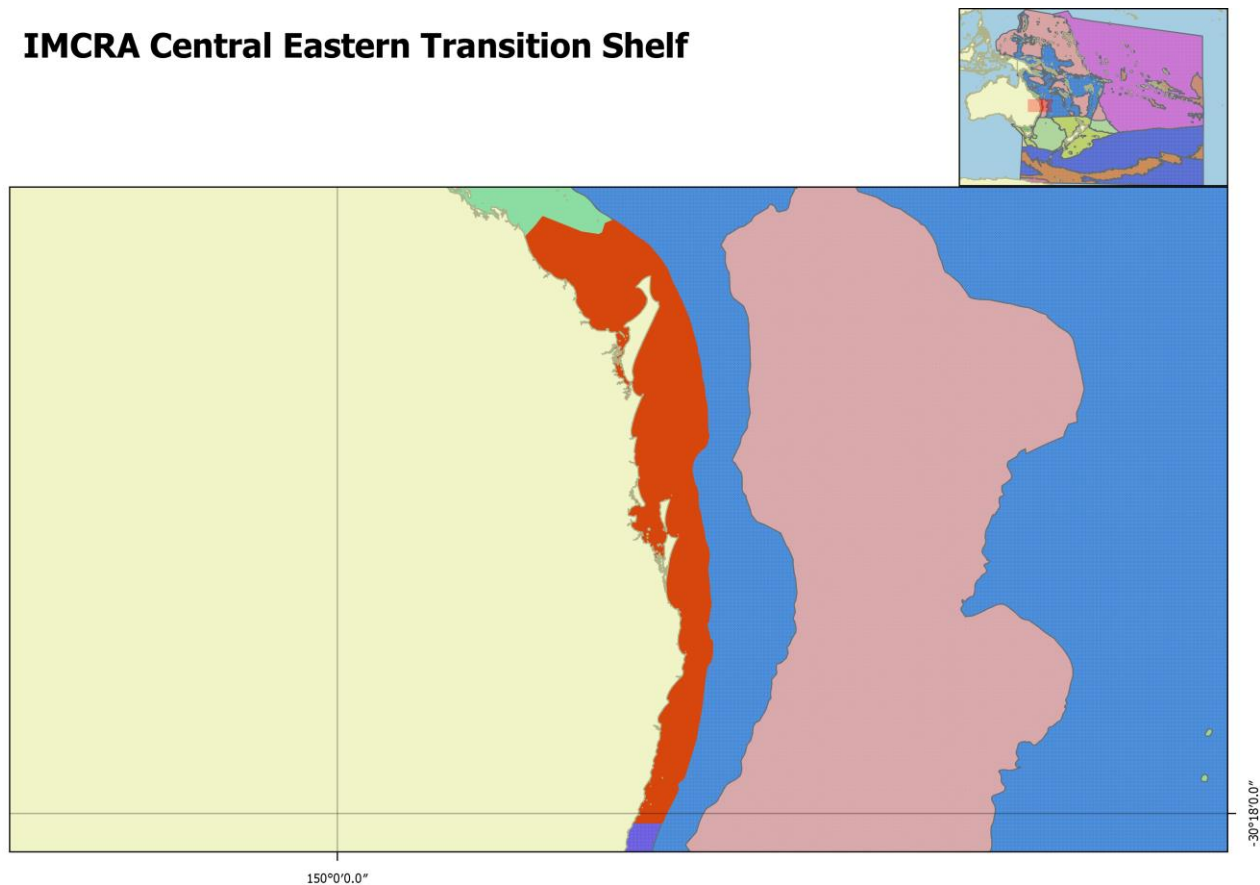
IMCRA Central Eastern Shelf



The IMCRA Central Eastern Shelf province is taken directly from Australia's national marine bioregionalisation. This province is located on the east margin shelf of Australia. Within the IMCRA framework it is based on the distribution of demersal fishes and geomorphic features. See the IMCRA report for details (Heap *et al.*, 2005). This area is constrained to the shelf and was originally derived based on the depth wise structure of demersal fish. Qualitative models for this province can be found in Dambacher *et al.* (2012).

2.3.4 IMCRA Central Eastern Transition Shelf

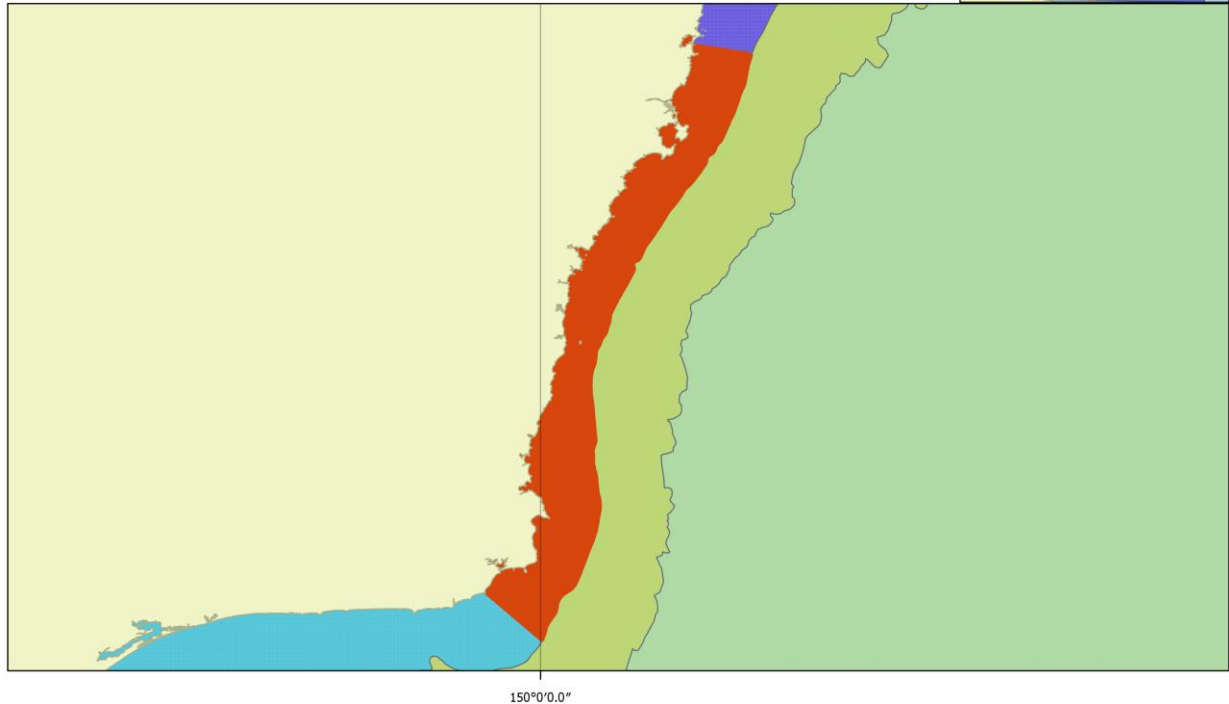
IMCRA Central Eastern Transition Shelf



The IMCRA Central Eastern Transition Shelf province is taken directly from Australia's national marine bioregionalisation. This province is located on the east margin shelf of Australia. Within the IMCRA framework it is based on the distribution of demersal fishes and geomorphic features. See the IMCRA report for details (Heap et al., 2005). This area is constrained to the shelf and was originally derived based on the depth wise structure of demersal fish. This region also reflects where tropical species are transition into a sub-tropical and temperate fauna. Qualitative models for this province can be found in Dambacher et al. (2012).

2.3.5 IMCRA Southeast Australian Shelf

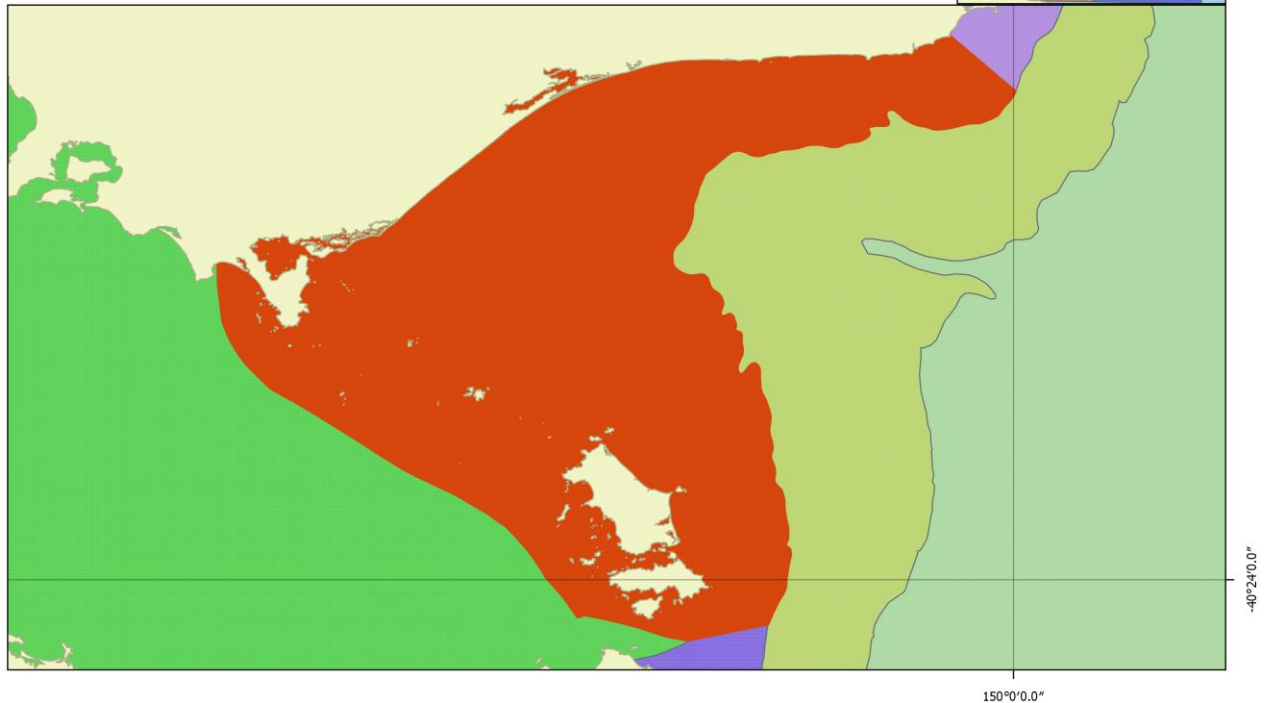
IMCRA Southeast Australian Shelf



The IMCRA Southeast Australian Shelf province is taken directly from Australia's national marine bioregionalisation. This province is located on the southeast shelf of Australia. Within the IMCRA framework it is based on the distribution of demersal fishes and geomorphic features. See the IMCRA report for details (Heap et al., 2005). This area is constrained to the shelf and was originally derived based on the depth wise structure of demersal fish. This region also reflects where sub-tropical fauna transitions into a temperate fauna, but also where the east coast shelf starts to wrap into the Bass Strait. Qualitative models for this province can be found in Dambacher et al. (2012).

2.3.6 IMCRA Southeast Transition Shelf

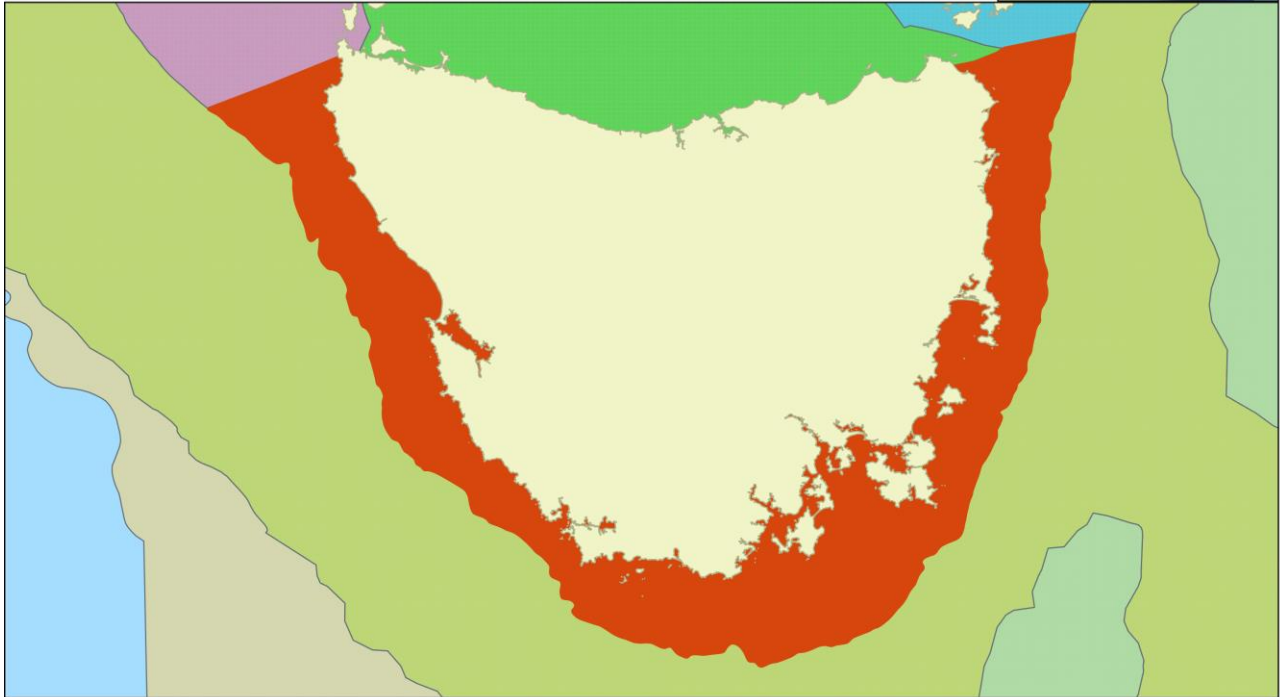
IMCRA Southeast Transition Shelf



The IMCRA Southeast Transition Shelf province is taken directly from Australia's national marine bioregionalisation. This province is located on the southeast shelf of Australia. Within the IMCRA framework it is based on the distribution of demersal fishes and geomorphic features. See the IMCRA report for details (Heap et al., 2005). This region where the east coast shelf starts to wrap into the Bass Strait. Qualitative models for this province can be found in Hosack and Dambacher (2012).

2.3.7 IMCRA Tasmanian Province Shelf

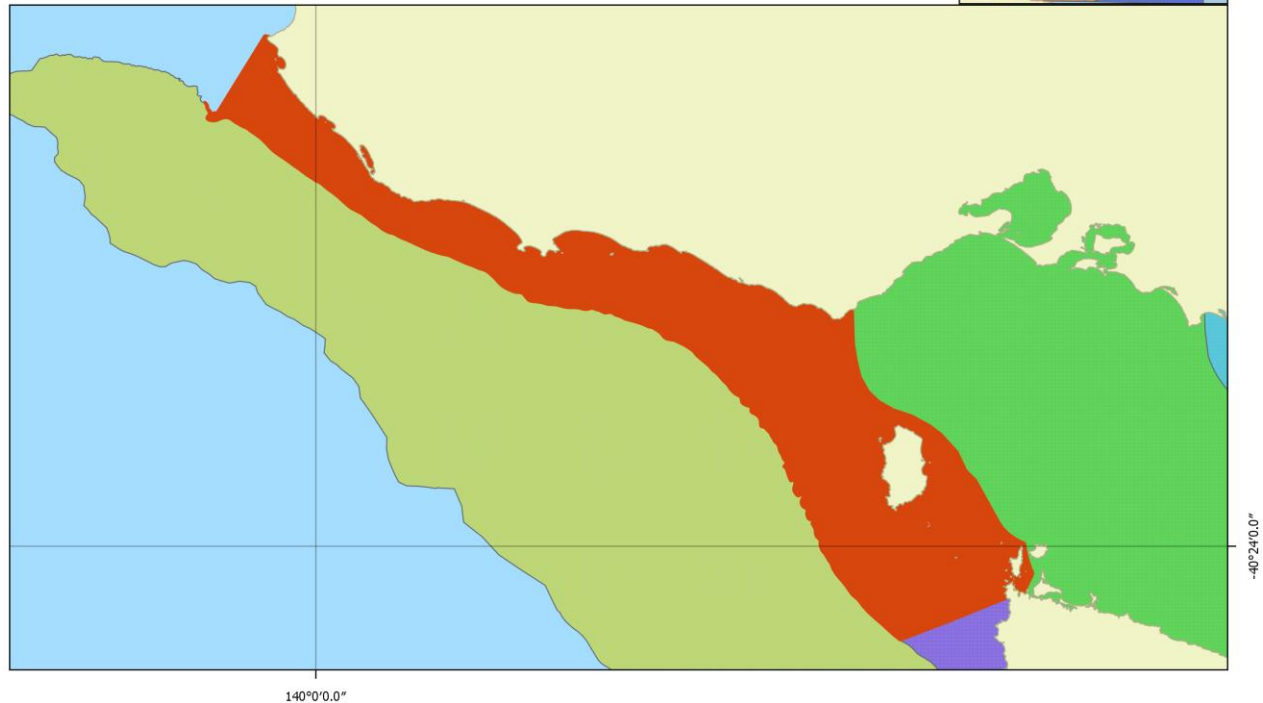
IMCRA Tasmanian Province Shelf



The IMCRA Tasmanian Shelf province is taken directly from Australia's national marine bioregionalisation. This province is located around Tasmania shelf (excluding Bass Strait). Within the IMCRA framework it is based on the distribution of demersal fishes and geomorphic features. See the IMCRA report for details (Heap et al., 2005). Qualitative models for this province can be found in Hosack and Dambacher (2012).

2.3.8 IMCRA Western Bass Strait Transition Shelf

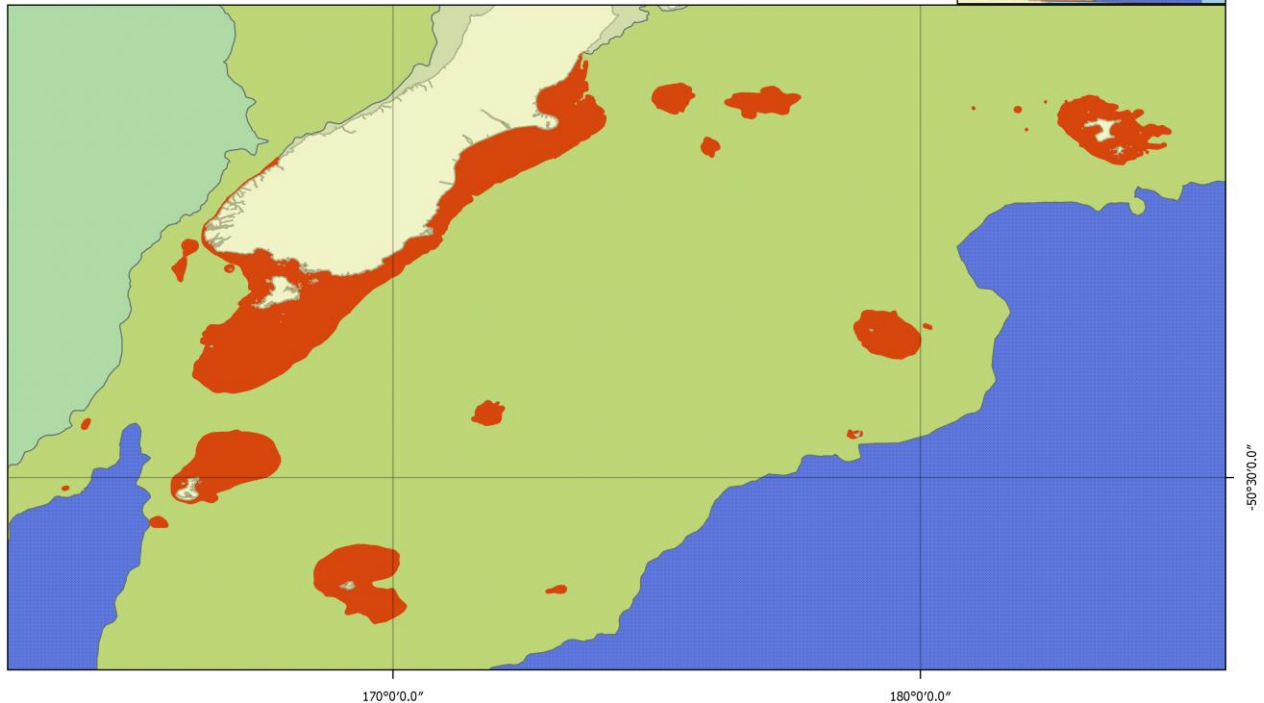
IMCRA Western Bass Strait Transition Shelf



The IMCRA West Bass Strait Transition Shelf province is taken directly from Australia's national marine bioregionalisation. This province is located west of Bass Strait. Within the IMCRA framework it is based on the distribution of demersal fishes and geomorphic features. See the IMCRA report for details (Heap et al., 2005). It also reflects the start of the longitudinal change in fauna from the east coast to the west coast of Australia. Qualitative models for this province can be found in Hosack and Dambacher (2012).

2.3.9 Southern New Zealand Shelf

Southern New Zealand Shelf



The Southern New Zealand shelf regionalisation is shallower shelf areas that encompass the southern shelf areas of New Zealand's EEZ and the shallower shelf areas that represent the subpolar islands in the south of New Zealand's EEZ. This classification is based on the work of classification of demersal fishers, the physical environment and ophiuroids (O'Hara *et al.*, 2011; Stephenson *et al.*, 2018). This region came directly from Stephenson *et al.*, 2018 'ten groups' output, which a more generalised classification for this region. Subantarctic New Zealand Shelf

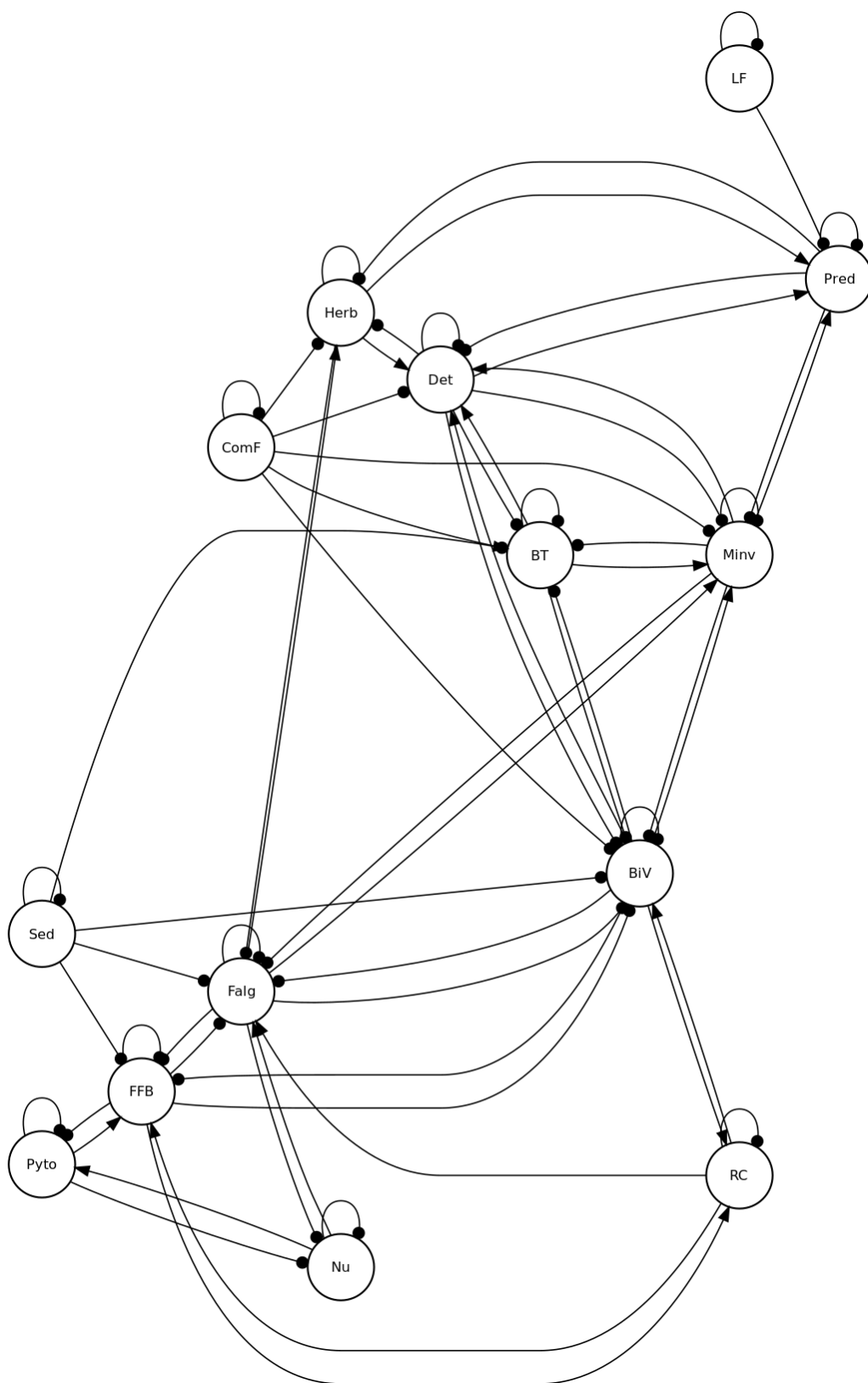


Figure 53 Ecosystem components in the qualitative model are: Phytoplankton (Pyto), Bio Turbators (BT), Reef Complexity (RC), Detritivores (Det), Fleshy Algae (Falg), Filter Feeder Benthic (FFB), Predatory Fish (Pred), Herbivorous Fish (Herb), Mobile Invertebrates (Minv), Bivalves (BiV) and Nutrients (Nu). Pressures acting on the system are: Sediment (Sed), Commercial Fisheries (ComF) and Line Fishing (LF).

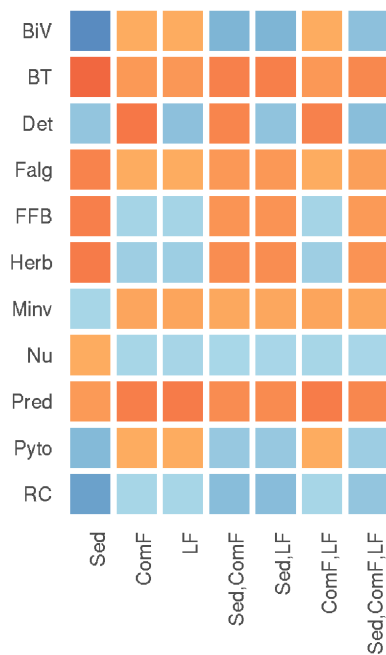
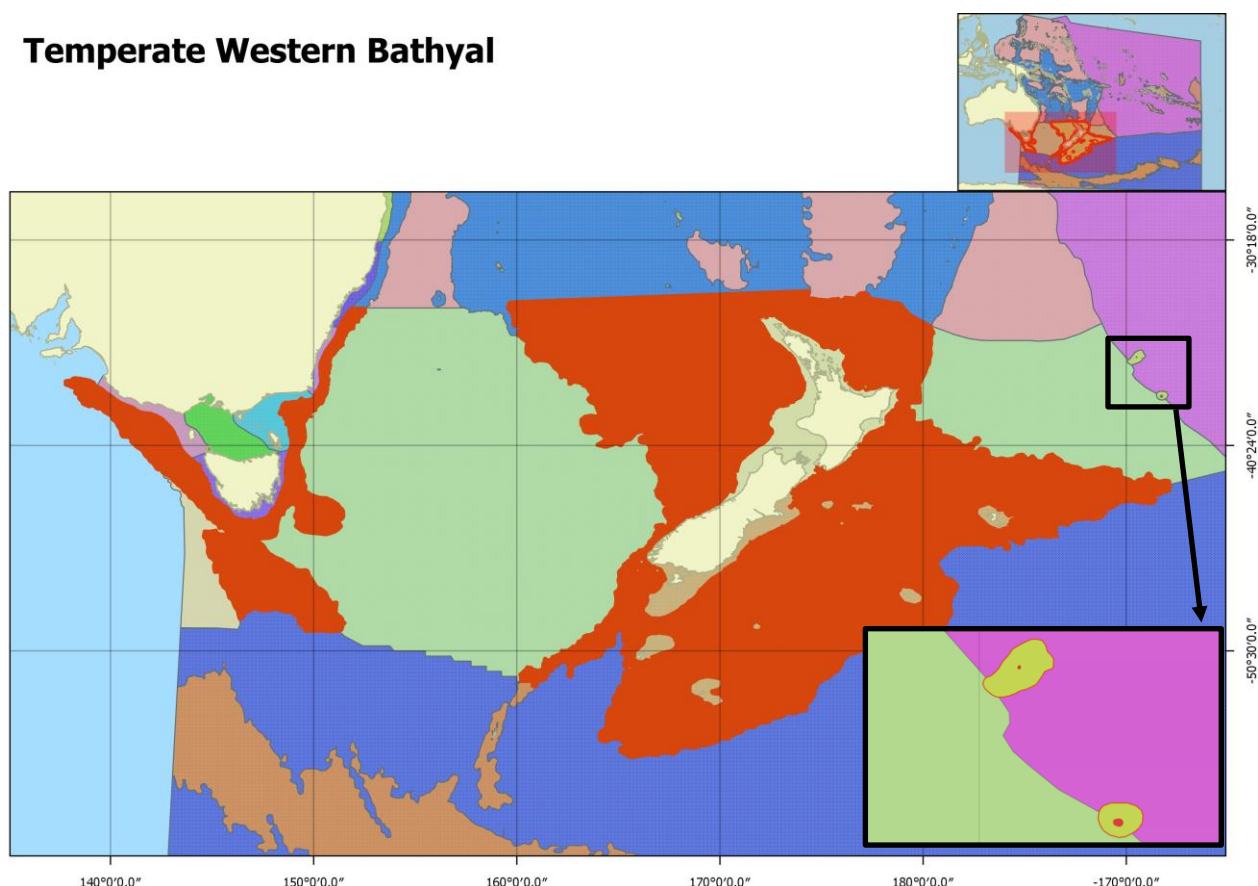


Figure 54. Ecosystem scenario responses to combinations of pressures. Red indicates a negative change and blue indicates a positive change. Ecosystem components in the qualitative model are: Phytoplankton (Pyto), Bio Turbators (BT), Reef Complexity (RC), Detritivores (Det), Fleshy Algae (Falg), Filter Feeder Benthic (FFB), Predatory Fish (Pred), Herbivorous Fish (Herb), Mobile Invertebrates (Minv), Bivalves (BiV) and Nutrients (Nu). Pressures acting on the system are: Sediment (Sed), Commercial Fisheries (ComF) and Line Fishing (LF).

2.3.10 Temperate Western Bathyal

Temperate Western Bathyal



Map 2 Temperate Western Bathyal Province in the Temperate western Region. Note the two shallow areas on the Louisville ridge (insert) included in this province.

The Temperate Western Bathyal Province is based on the modelled distribution of ophiuroids and squat lobsters using the Region of Common Profile Method (Foster *et al.*, 2013), see the Appendix ‘Statistical Bioregionalisations’ for details. This approach separated out the bathyal province between 200 and 3500 meters depth. This is slightly different from other regionalisations which made this boundary at 2000 meters (O’Hara *et al.*, 2011). The 2000 to 3500 meter region could be viewed as the lower bathyal and a more depauperate subset of the shallower bathyal region. We however, do not define an upper and lower bathyal region, but recognise that there will be an affinity between these two bathomes (e.g. GOODS classification and Watling *et al.*, 2013).

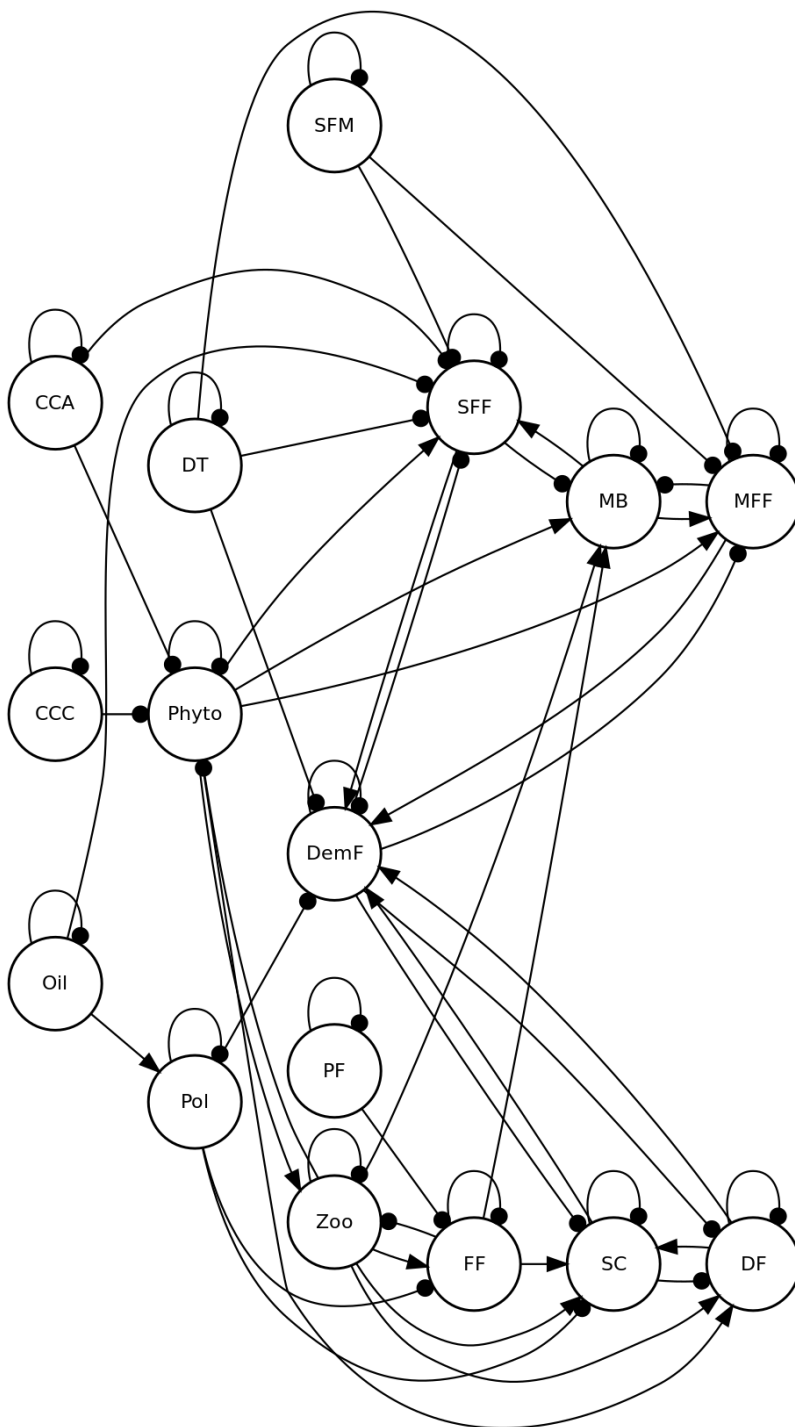


Figure 55. Ecosystem components in the qualitative model are: Demersal Fishes (DemF), Sessile Filter Feeders (SFF), Mobile Filter Feeders (MFF), Food Falls (FF), Scavengers (SC), Microbes (MB), Phytoplankton (Phyto), Zooplankton (Zoo) and Deposit Feeders (DF). Pressures acting on the system are: Climate Change Chlorophyll (CCC), Pelagic Fisheries (PF), Pollution (Pol), Climate Change Acidification (CCA), Demersal Trawling (DT), Oil Spills (Oil) and Seafloor Mining (SFM).

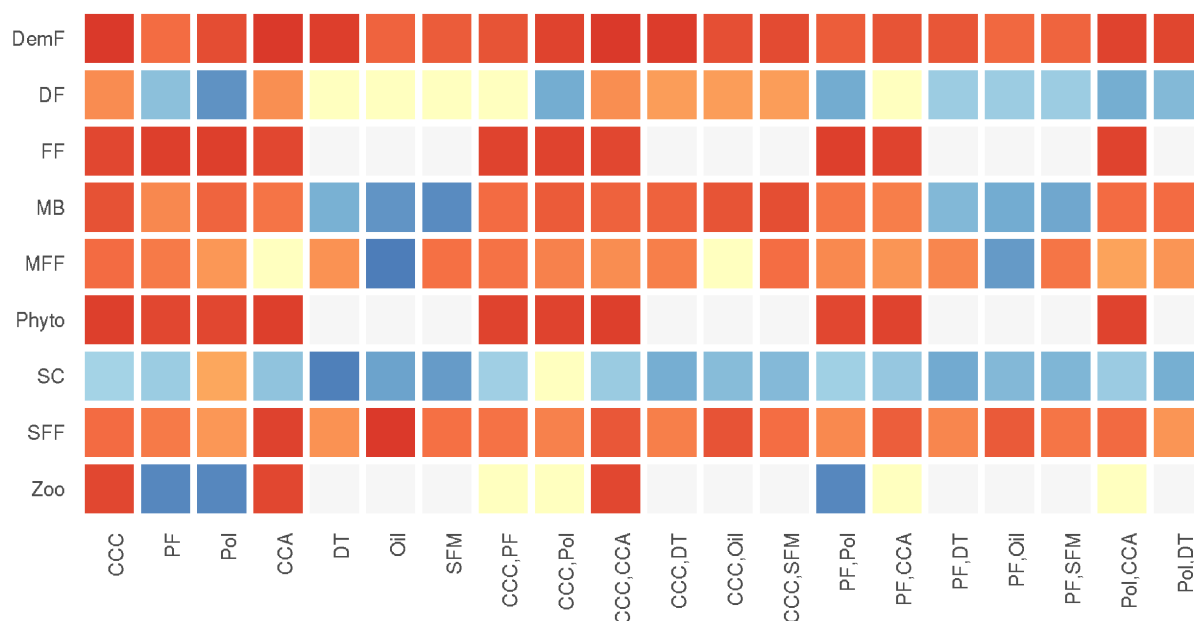
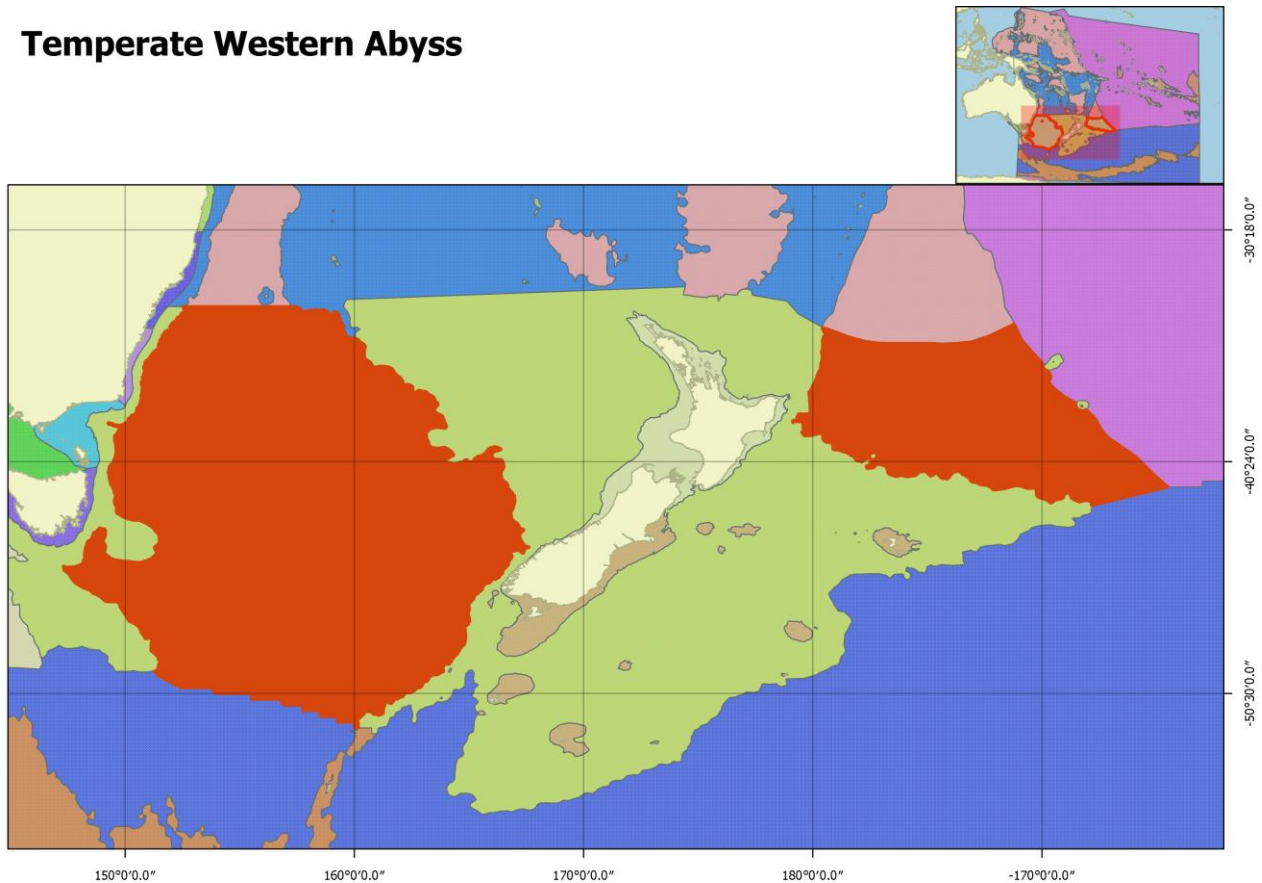


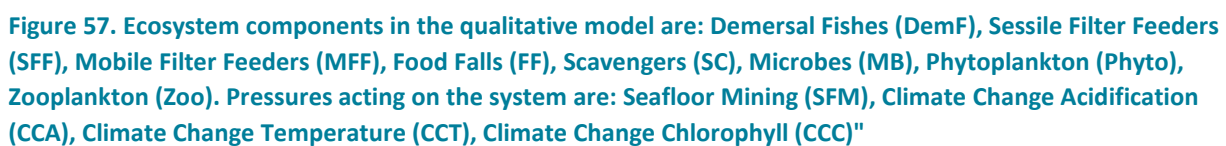
Figure 56. Ecosystem scenario responses to combinations of pressures. Red indicates a negative change and blue indicates a positive change. Ecosystem components in the qualitative model are: Demersal Fishes (DemF), Sessile Filter Feeders (SFF), Mobile Filter Feeders (MFF), Food Falls (FF), Scavengers (SC), Microbes (MB), Phytoplankton (Phyto), Zooplankton (Zoo) and Deposit Feeders (DF). Pressures acting on the system are: Climate Change Chlorophyll (CCC), Pelagic Fisheries (PF), Pollution (Pol), Climate Change Acidification (CCA), Demersal Trawling (DT), Oil Spills (Oil) and Seafloor Mining (SFM).

2.3.11 Temperate Western Abyss

Temperate Western Abyss



The Temperate Western Abyssal Province is based on the modelled distribution of ophiuroids and squat lobsters using the Regions of Common Profile Method (Foster *et al.*, 2013), see the Appendix 'Statistical Bioregionalisations' for details. This approach separated out the abyssal province at about 3500 meters deep and beyond. This is slightly different from other regionalisations which made this boundary at 2000 meters (O'Hara *et al.*, 2011). But it does conform to other benthic classifications which draw this boundary at 3500 meters (e.g. GOODS classification and Watling *et al.*, 2013).



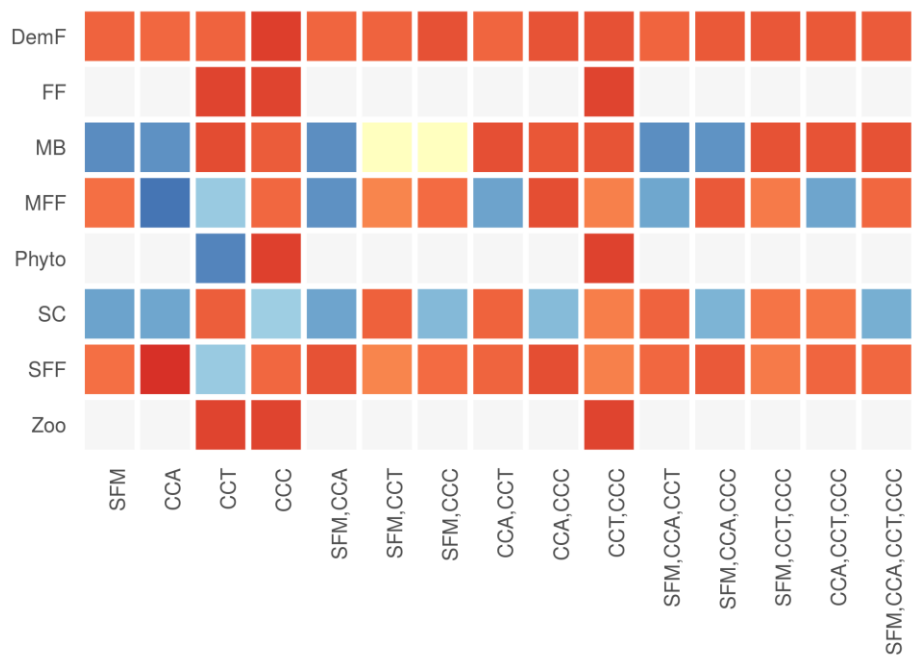
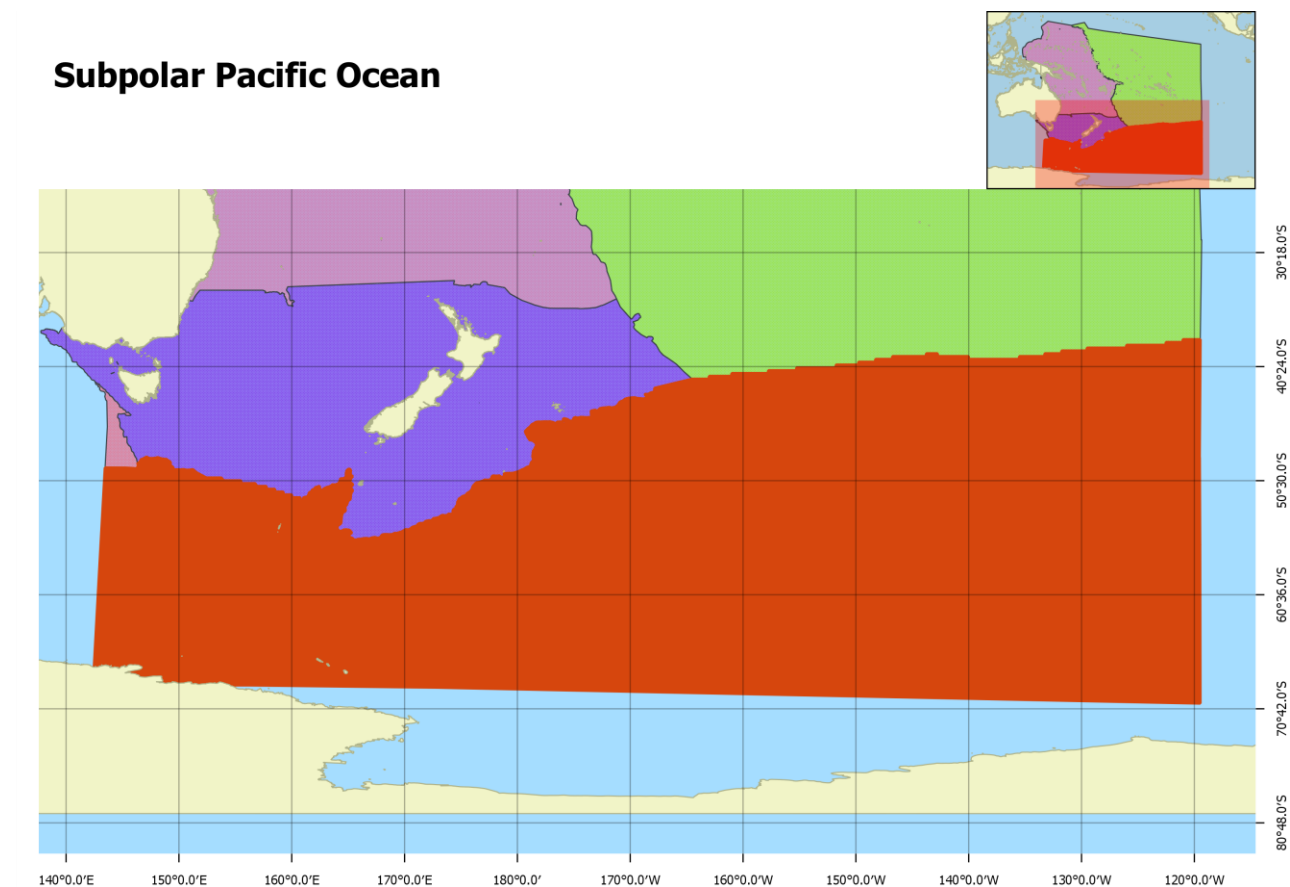


Figure 58. Ecosystem scenario responses to combinations of pressures. Red indicates a negative change and blue indicates a positive change. Ecosystem components in the qualitative model are: Demersal Fishes (DemF), Mobile Filter Feeders (MFF), Food Falls (FF), Scavengers (SC), Microbes (MB), Phytoplankton (Phyto) and Zooplankton (Zoo). Pressures acting on the system are: Seafloor Mining (SFM).

2.4 SW Pacific Subpolar Region

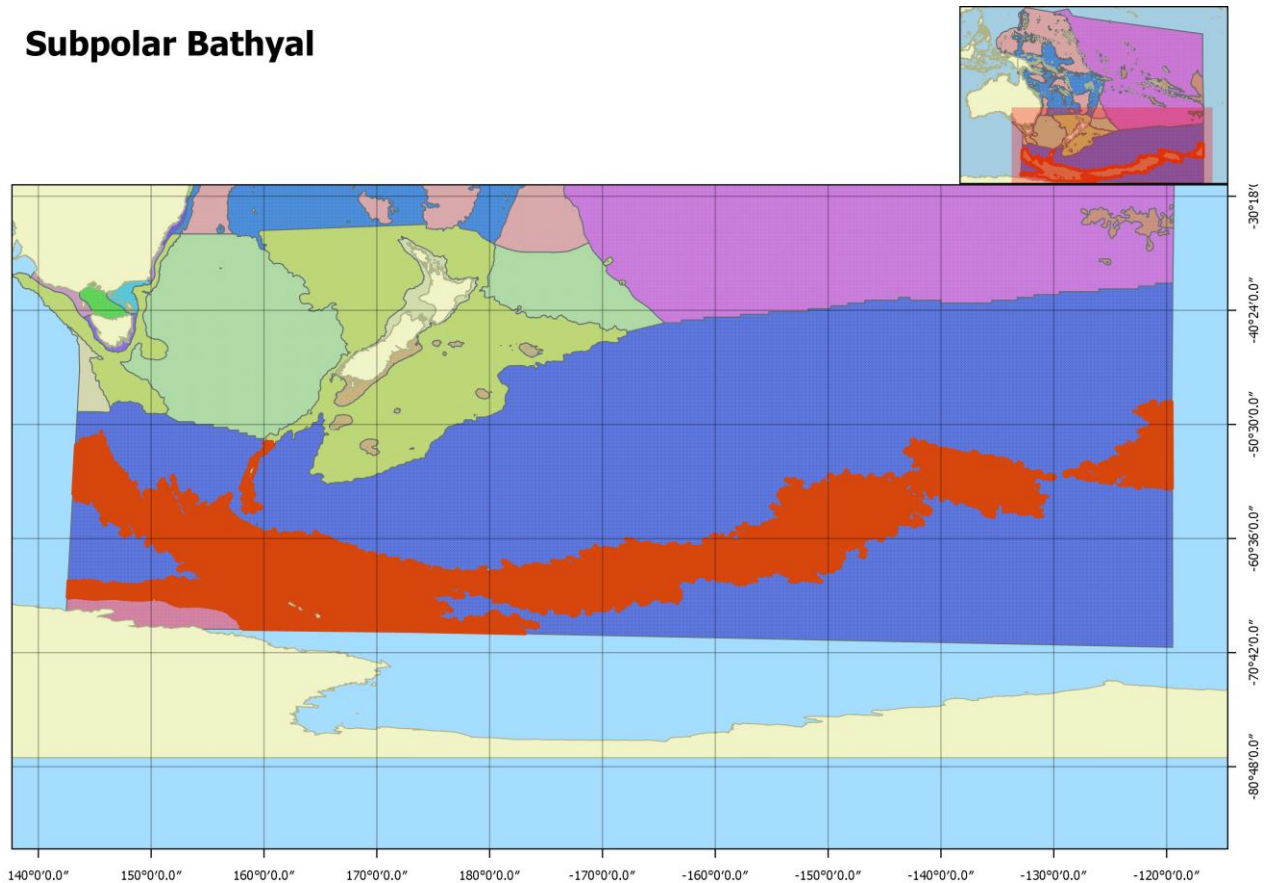


Map 3 Pacific Subpolar Benthic Region

The northern boundary is driven by the extent of the subantarctic front and the bathyal depth contour that runs at 3500 meters across this Southern Indian and Pacific Antarctic mid-ocean ridges. The southern boundary follows the CCAMLR boundary. This area is comprised of temperate and subpolar species which are restricted to subpolar archipelagos and other subpolar islands and seamounts.

2.4.1 Sub-polar Bathyal

Subpolar Bathyal



The subpolar bathyal province is defined by the bathymetry differentiation that emerged from our model-based bioregionalisation models for ophiuroids, squat lobsters and corals. They also are complemented by other existing schemes such as the GOODS benthic classification. However, the GOODS classification is restricted to ~800m depth, where our analysis shows that the major biogeographic break is along the shelf edge (at approximately 200m). We used the Harris *et al.*, 2008 geomorphic classification as our boundary for defining the start of the bathymetry province. The deepest boundary of the bathymetric province was set at 3500m, which agreed with both the model-based bioregionalisations and the GOODS classification. The Subpolar Bathyal Province follows the Southern Indian and Pacific Antarctic mid-ocean ridges.

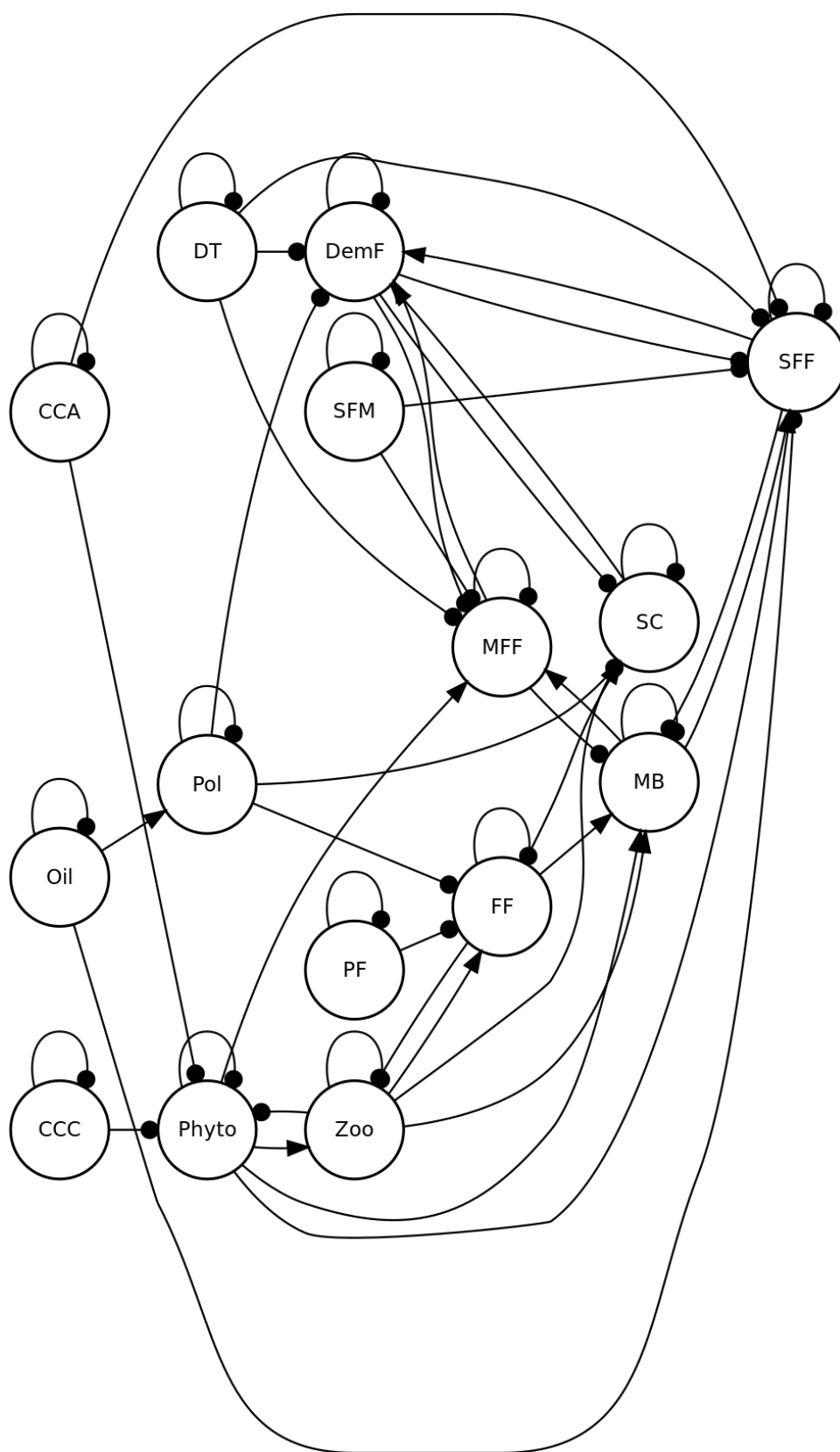


Figure 59. Ecosystem components in the qualitative model are: Demersal Fishes (DemF), Mobile Filter Feeders (MFF), Food Falls (FF), Scavengers (SC), Microbes (MB), Phytoplankton (Phyto), Zooplankton (Zoo). Pressures acting on the system are: Sessile Filter Feeders (SFF), Climate Change Chlorophyll (CCC), Pelagic Fishing (PF), Pollution (Pol), Climate Change Acidification (CCA), Demersal Trawling (DT), Oil Spills (Oil) and Seafloor Mining (SFM).

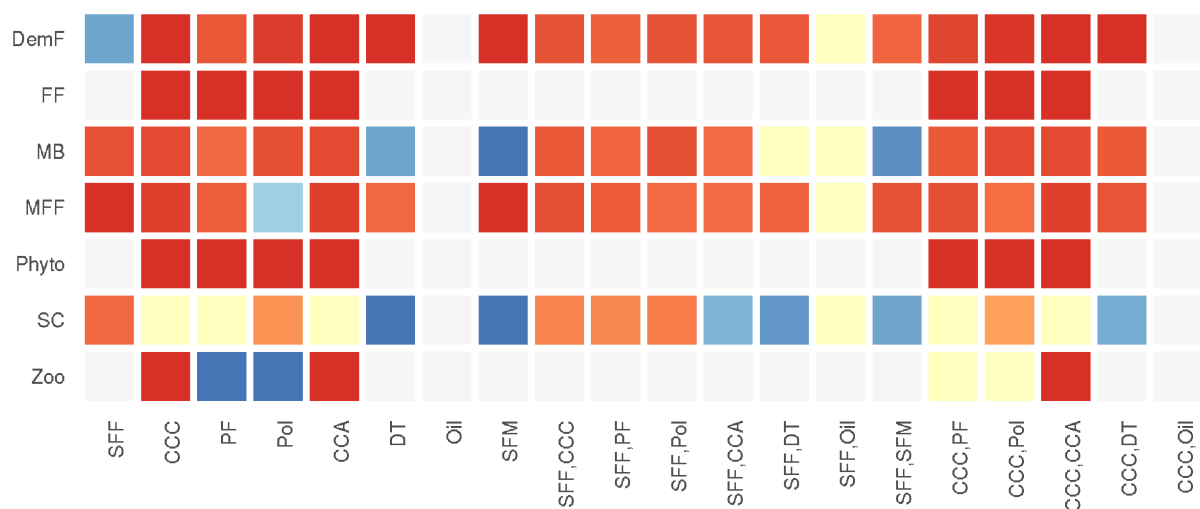
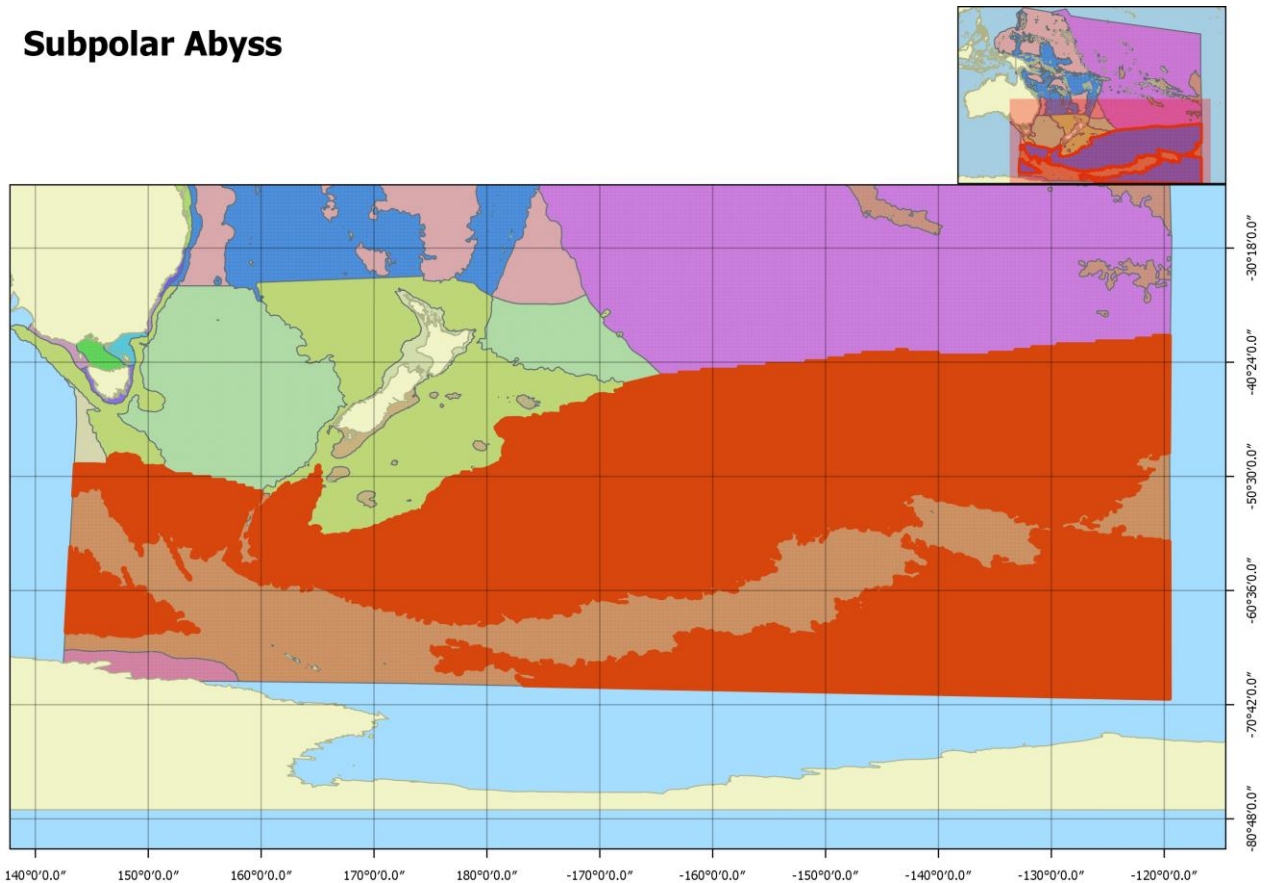


Figure 60. Ecosystem scenario responses to combinations of pressures. Red indicates a negative change and blue indicates a positive change. Ecosystem components in the qualitative model are: Demersal Fishes (DemF), Mobile Filter Feeders (MFF), Food Falls (FF), Scavengers (SC), Microbes (MB), Phytoplankton (Phyto), Zooplankton (Zoo). Pressures acting on the system are: Sessile Filter Feeders (SFF), Climate Change Chlorophyll (CCC), Pelagic Fishing (PF), Pollution (Pol), Climate Change Acidification (CCA), Demersal Trawling (DT), Oil Spills (Oil) and Seafloor Mining (SFM).

2.4.2 Sub-polar Abyss

Subpolar Abyss



The Subpolar Abyssal Province sits within the Subpolar Bioregion and is defined by the abyssal regions that emerged from the model-based classification for ophiuroids and the agreed with the GOODS classification. Subpolar Abyssal Province is the deep seafloor (>3500 meters) that is on the southern side of the Southern Indian and Pacific Antarctic mid-ocean ridges.

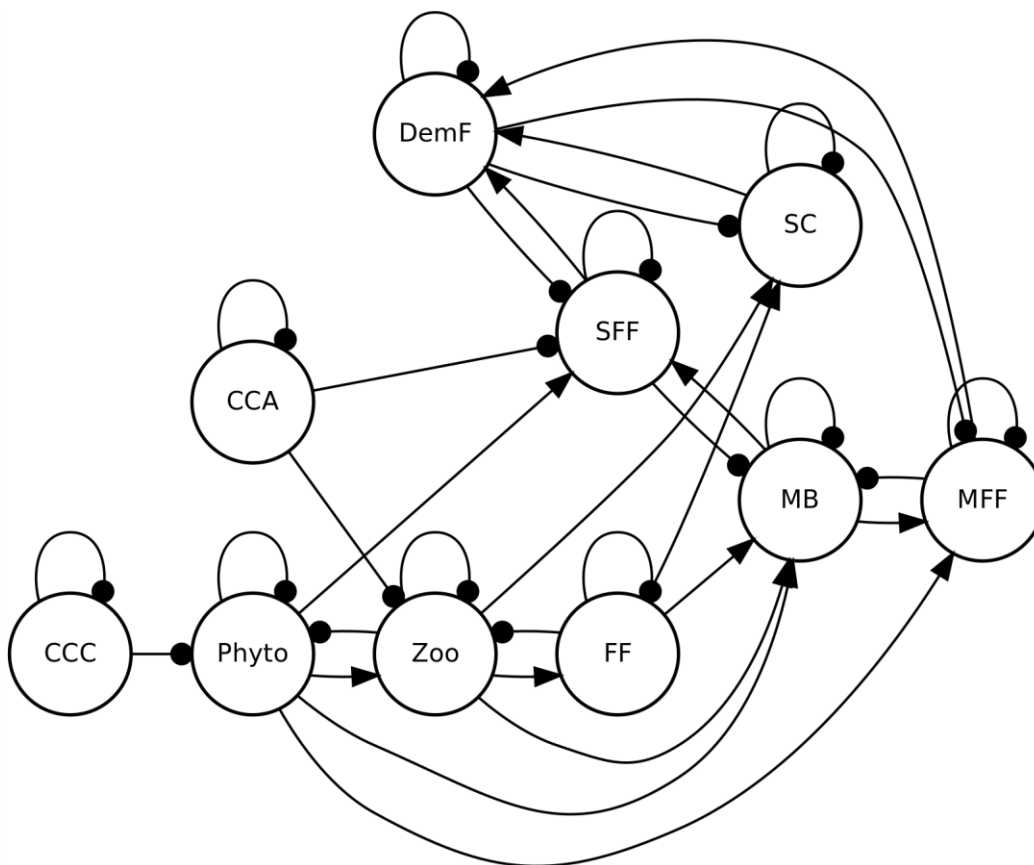


Figure 61. Ecosystem scenario responses to combinations of pressures. Red indicates a negative change and blue indicates a positive change. Ecosystem components in the qualitative model are: Demersal Fishes (DemF), Sessile Filter Feeders (SFF), Mobile Filter Feeders (MFF), Food Falls (FF), Scavengers (SC), Microbes (MB), Phytoplankton (Phyto) and Zooplankton (Zoo). Pressures acting on the system are: Climate Change Chlorophyll (CCC) and Climate Change Acidification (CCA).



Figure 62. Ecosystem components in the qualitative model are: Demersal Fishes (DemF), Sessile Filter Feeders (SFF), Mobile Filter Feeders (MFF), Food Falls (FF), Scavengers (SC), Microbes (MB), Phytoplankton (Phyto) and Zooplankton (Zoo). Pressures acting on the system are: Climate Change Chlorophyll (CCC) and Climate Change Acidification (CCA).

Appendix 1. Statistical Bioregionalisations

We developed and implemented a series of models which extended on a Regions of Common Profile (RCP) models (Foster *et al.*, 2013) to generate biologically data driven bioregions for the Southwest Pacific and the Southwestern Pacific Ocean regions. The RCP approach is a 'Mixture-of-Experts' finite mixture model. This model characterizes a bioregion as a spatial region, where the probability of observing a species, at a randomly chosen location falling within that bioregion, should be approximately constant. Additionally, the chances of observing that species at random sites in different bioregions should be unequal. This model-based notion was formally introduced by Foster *et al.*, (2013).

However, at regional scales the availability of broad scale biological datasets tends to decrease, instead, ad-hoc datasets which are an amalgamation of smaller scientific surveys and ad-hoc collections. These records are often kept in natural history collections and in online repositories. These *ad-hoc* data often come with the unfortunate problem of missing information on where species were not observed (absences). As a consequence we can never truly estimate the probability of occupancy from these data as we are missing key information (absences). This also means that the models (built for presence-absence and abundance data) are ill equipped to deal with these data, without some modifications.

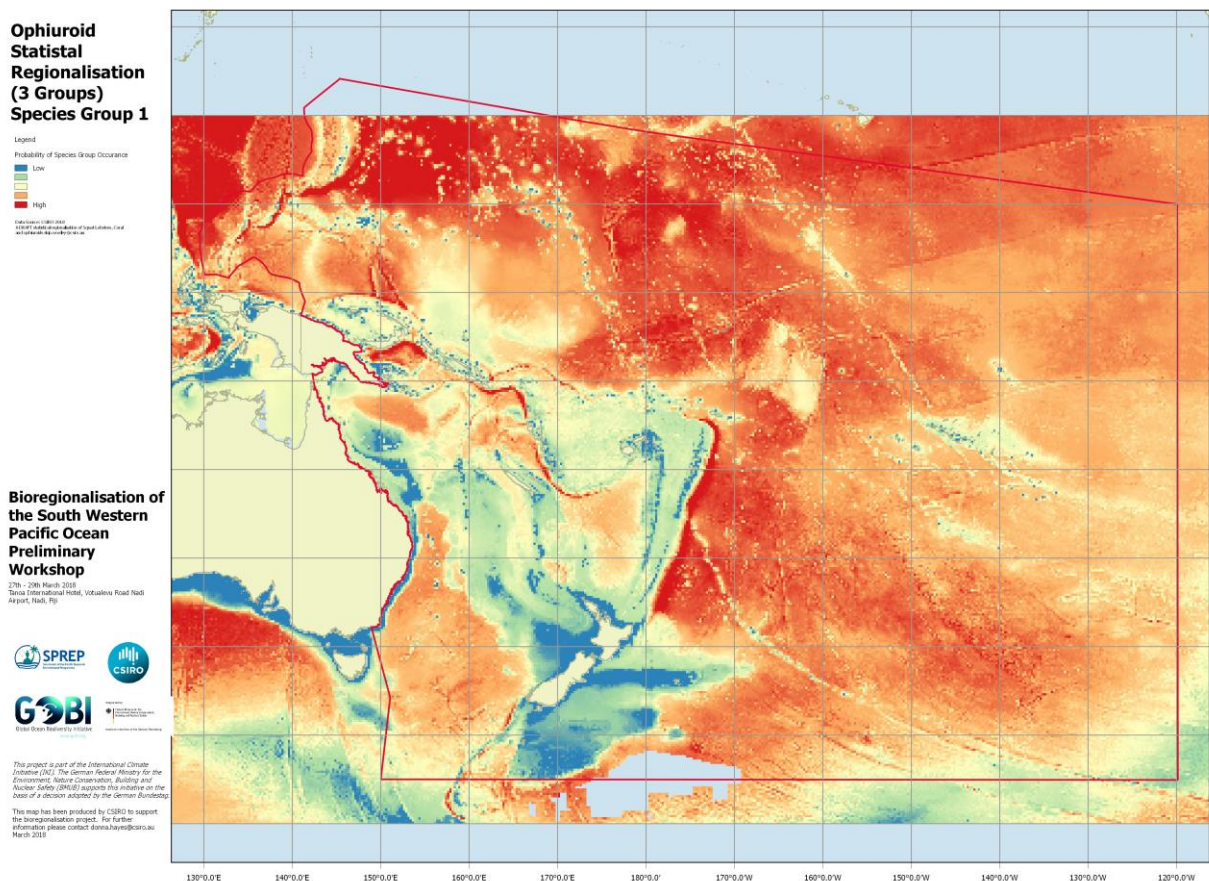
We do this by extending the RCP model to be a spatial point process (Cressie 1993). Based on the current implementation of the RCP models, we can do this simply by generating a spatial Poisson model, which is often done for single species models (Fithian & Hastie, 2014). The inhomogeneous Poisson point process RCP (IPPM-RCP) was fitted as a Poisson model. This was achieved by fitting the model to a grid of environmental predictors, where individual species occurrences are summed to reflect a count (Poisson), the exception being that cells with no species records in them are not excluded from model fitting, but rather are given a value of zero (akin to a background point). This model then produces a bioregions similar to the definition above, but rather than a probability of occurrence of a species within a bioregion, we generate a probability of sighting a species within a bioregion (a density based on the presence points).

We used the IPPM-RCP method to generate bioregions from benthic regions of the southwest Pacific Ocean we developed three seafloor taxonomic groups, brittle stars (Ophiuroidea), squat lobsters (Galatheaidea and Chirostyloidea) and cold-water corals (Octocorallia). Three biological datasets were used that included 363 brittle star, 160 squat lobster and 14 coral species with greater than 10 observations across the southwest Pacific Ocean region. These biological data were fitted to a set of environmental and spatial data, including latitude, longitude, depth, nitrate, oxygen, silicate and temperature as linear and quadratic terms. The environmental covariates were derived from the World Ocean Atlas datasets and were tri-

linearly interpolated to the seafloor using the GEBCO bathymetry layer. The log area of each cell is also included as an offset to account for any latitudinal bias in cell size.

Based on model fitting, taking a parsimonious approach, we found three broad regions for the ophiuroid and coral species, and four for the squat lobster dataset. The number of groups was derived based on Bayesian Information Criteria. Spatial predictions were made across the Southwest Pacific Ocean seafloor for each taxon, which contained mean (point) and standard errors in the prediction of each archetype (group).

These model predictions were then taken to the first Southwest Pacific Ocean expert elicitation workshop for generating bioregions across the Southwest Pacific Ocean. After consultation among experts with reference to these models and local knowledge of the region three broad scale bioregional provinces were agreed upon which represented broad scale biological and physical classifications which strongly reflected predicted distribution from the IPPM-RCP models. The large regions were then used at the top of hierarchical scheme which then classified finer scale region within each of the broad provinces.



Ophiroid Statistical Regionalisation (3 Groups) Species Group 2

Legend
Probability of Species Group Occurrence
Low
Medium
High

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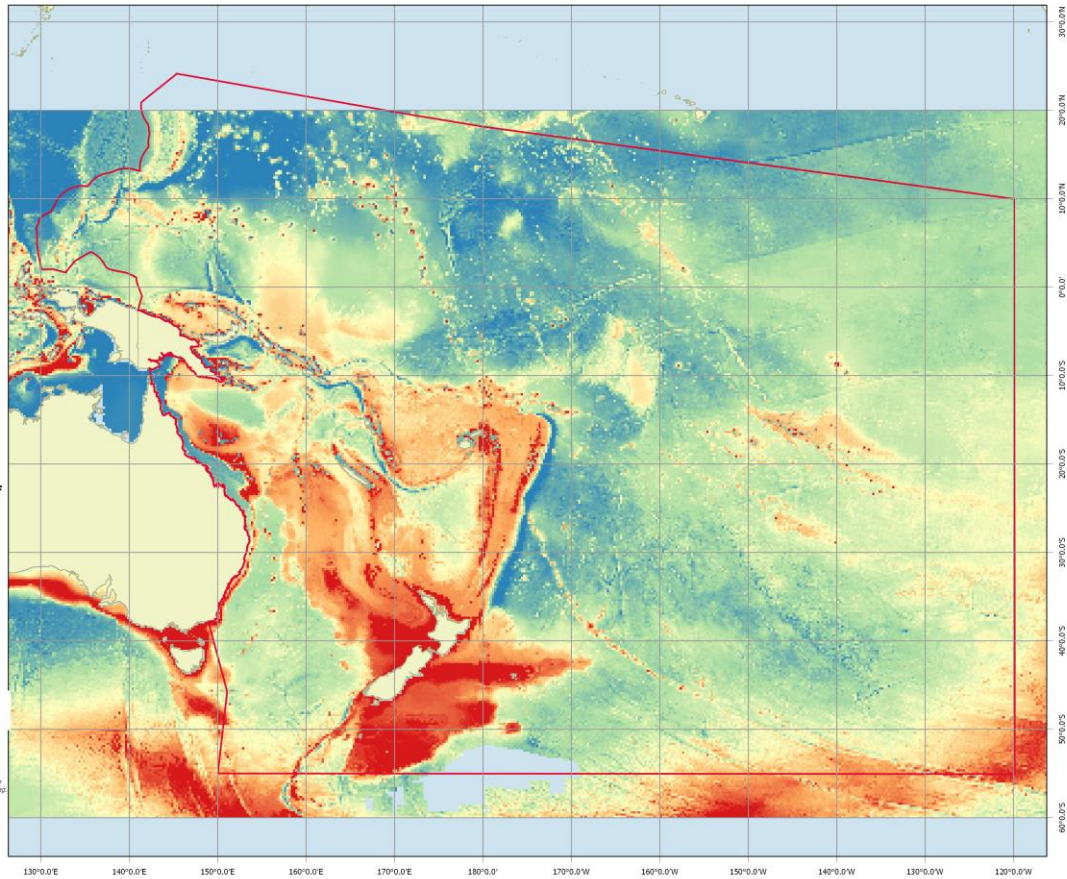
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Coral Statistical Regionalisation (3 Groups) Species Group 1

Legend
Probability of Species Group Occurrence
Low
Medium
High

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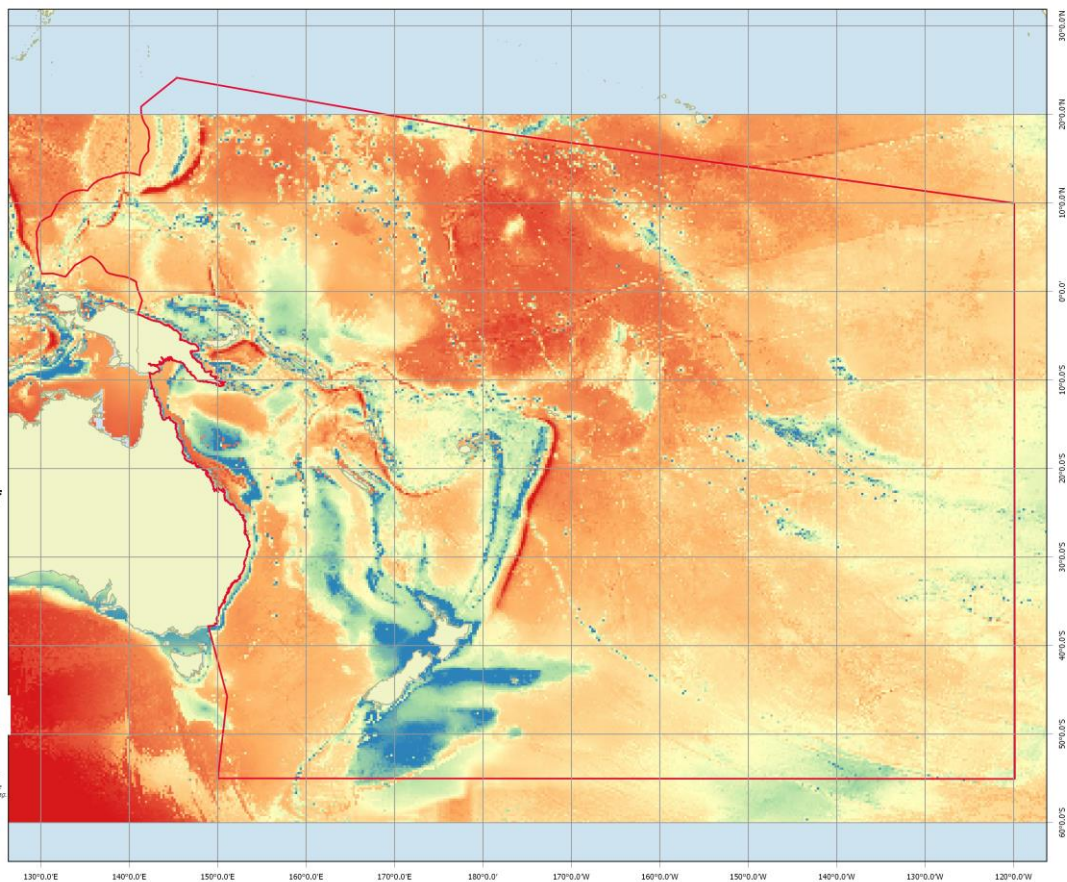
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Coral Statistal Regionalisation (3 Groups) Species Group 2

Legend
Probability of Species Group Occurrence
Low
High

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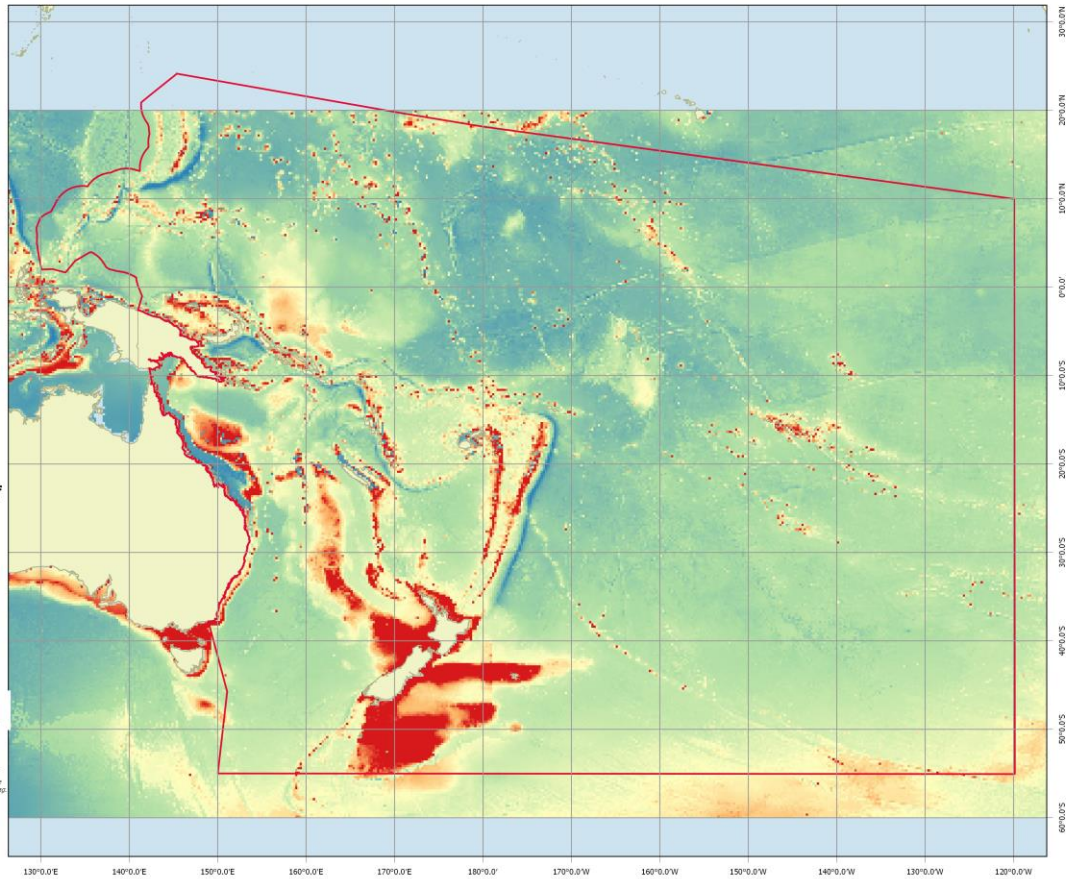
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Coral Statistal Regionalisation (3 Groups) Species Group 3

Legend
Probability of Species Group Occurrence
Low
High

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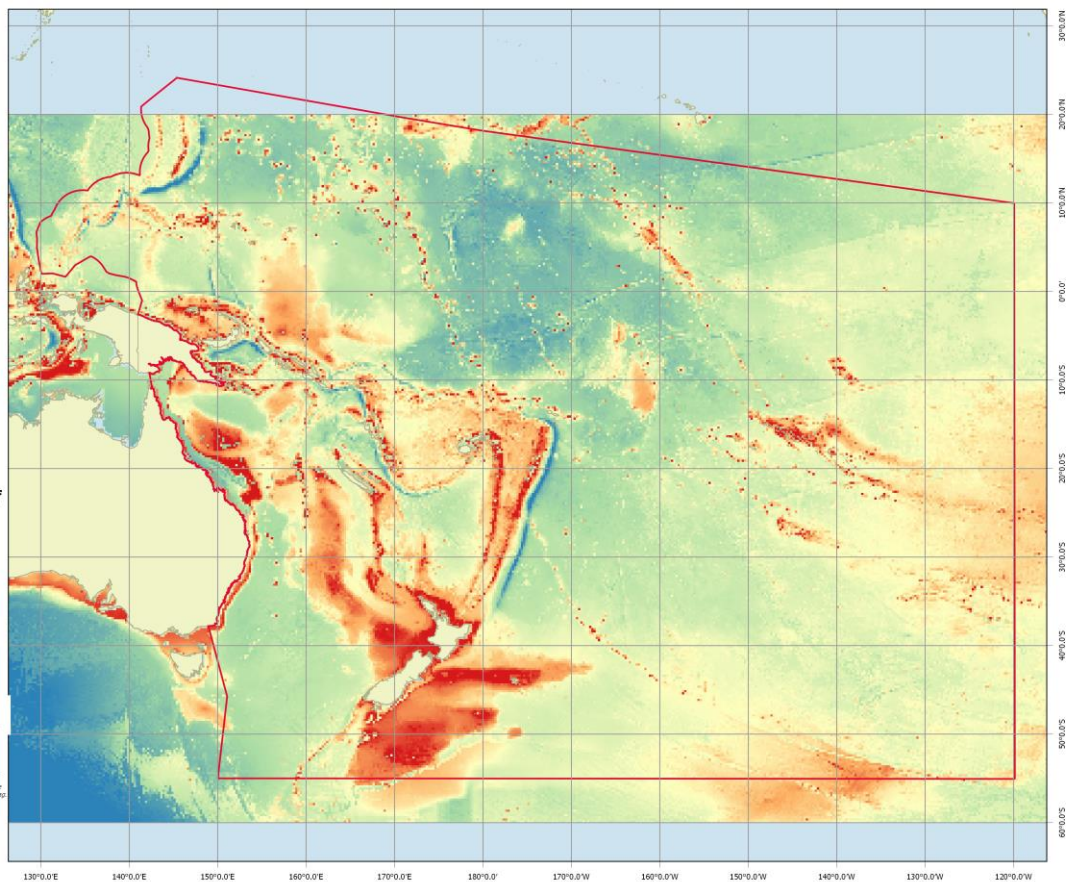
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Squat Lobster Statistical Regionalisation (4 Groups) Species Group 1

Legend
Probability of Species Group Occurrence
Low
Medium
High

Validation CSIRO 2018
A CSIRO statistical analysis of Squat Lobster, based on the data of the International Climate Initiative (ICI)

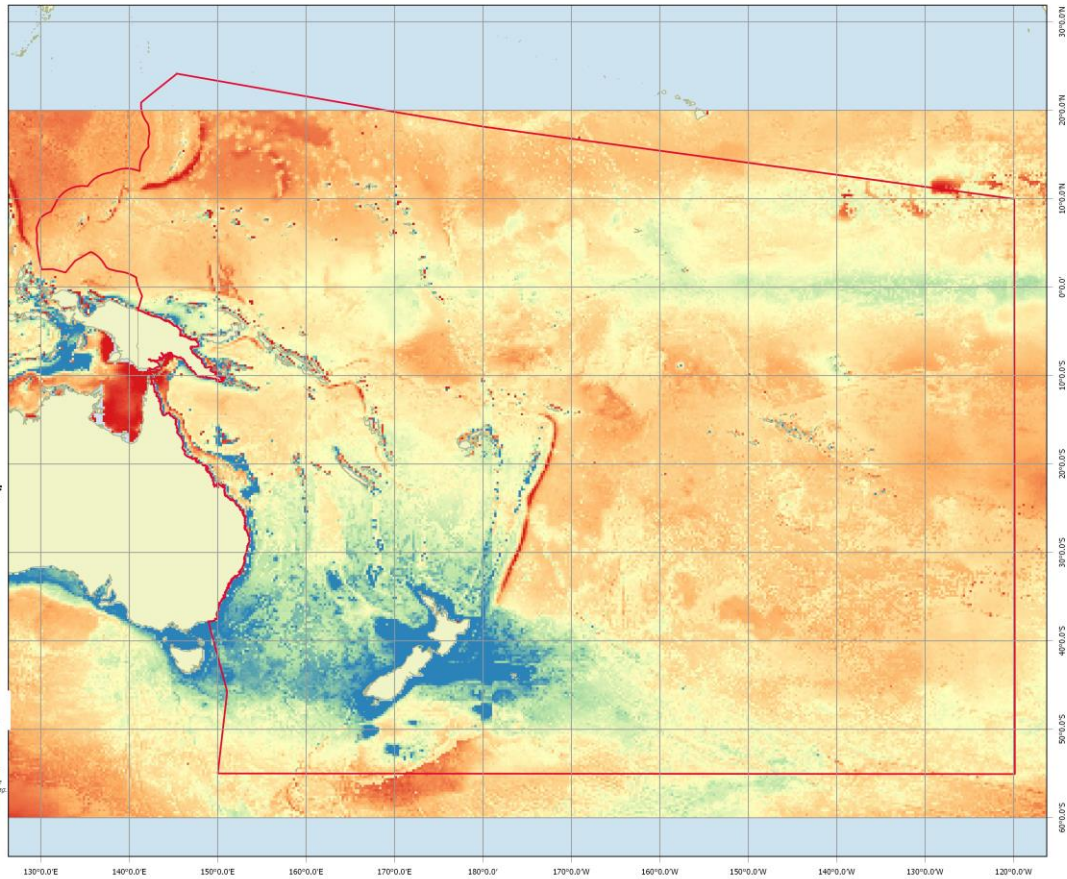
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Squat Lobster Statistical Regionalisation (4 Groups) Species Group 2

Legend
Probability of Species Group Occurrence
Low
Medium
High

Validation CSIRO 2018
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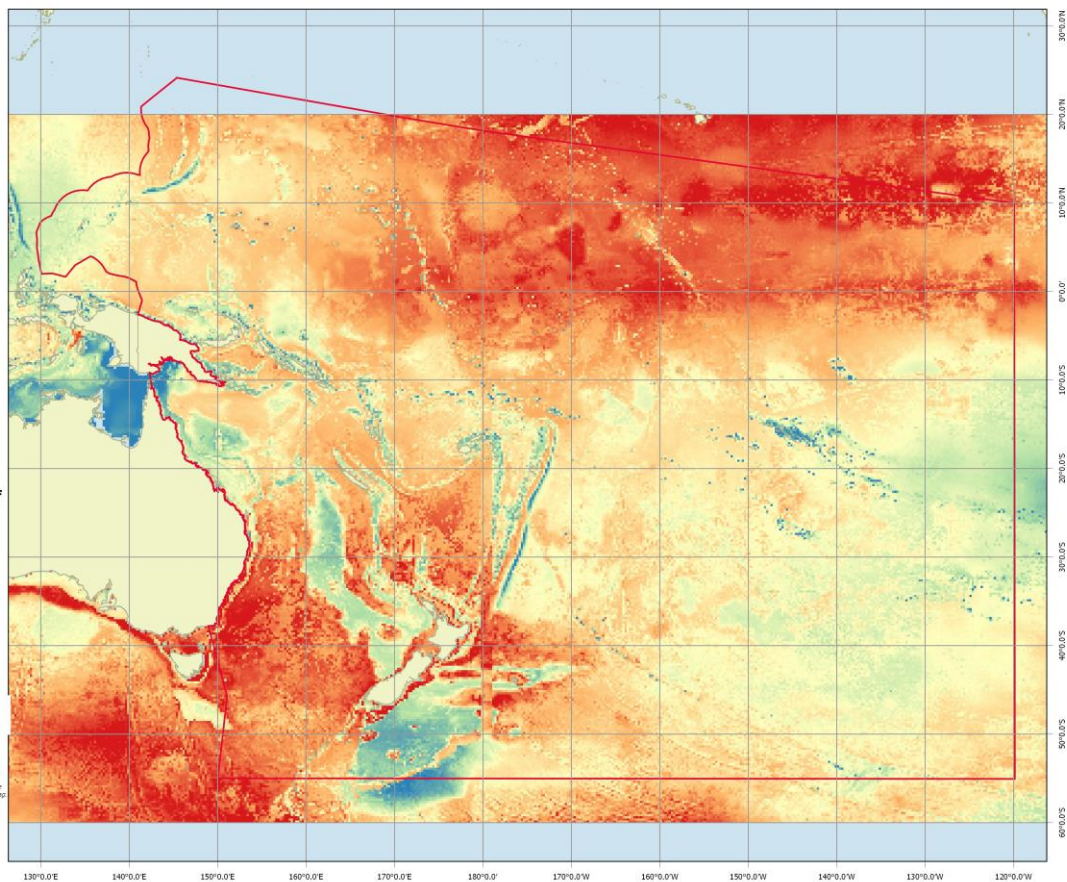
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Squat Lobster Statistical Regionalisation (4 Groups) Species Group 3

Legend
Probability of Species Group Occurrence
Low
Medium
High

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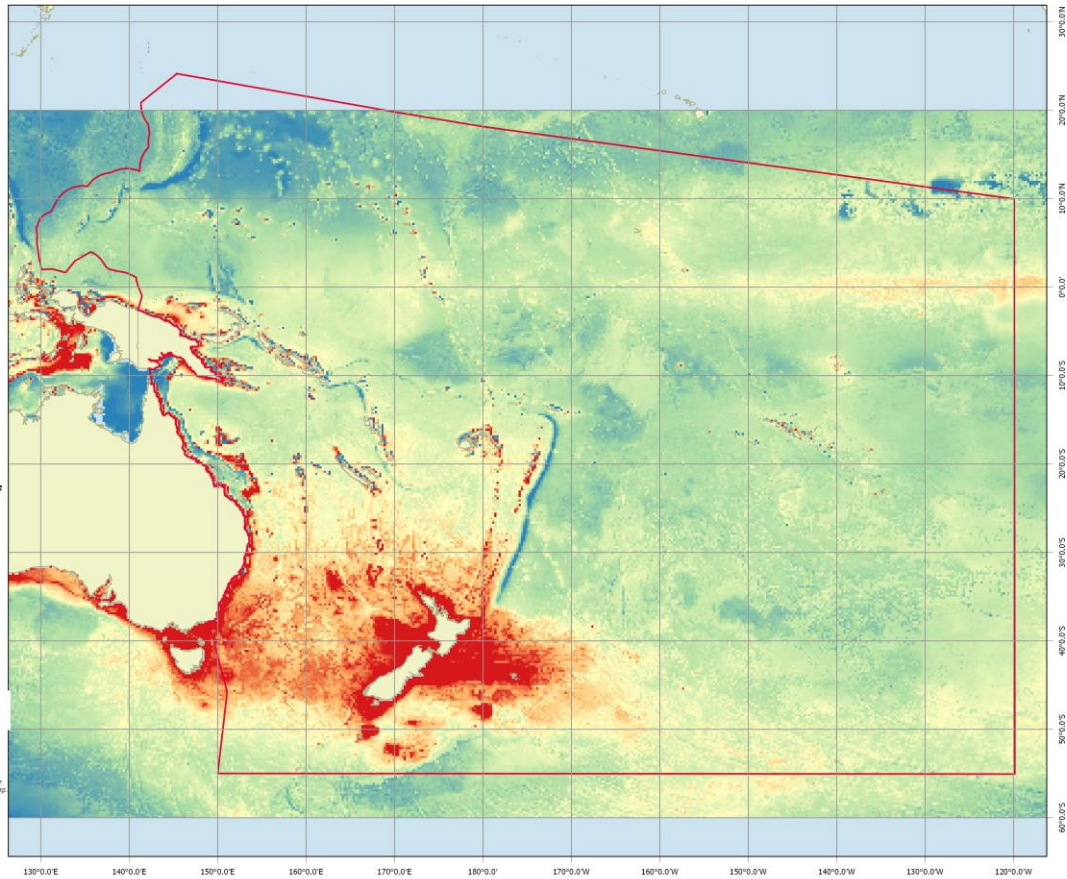
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Squat Lobster Statistical Regionalisation (4 Groups) Species Group 4

Legend
Probability of Species Group Occurrence
Low
Medium
High

Information CSIRO 2018
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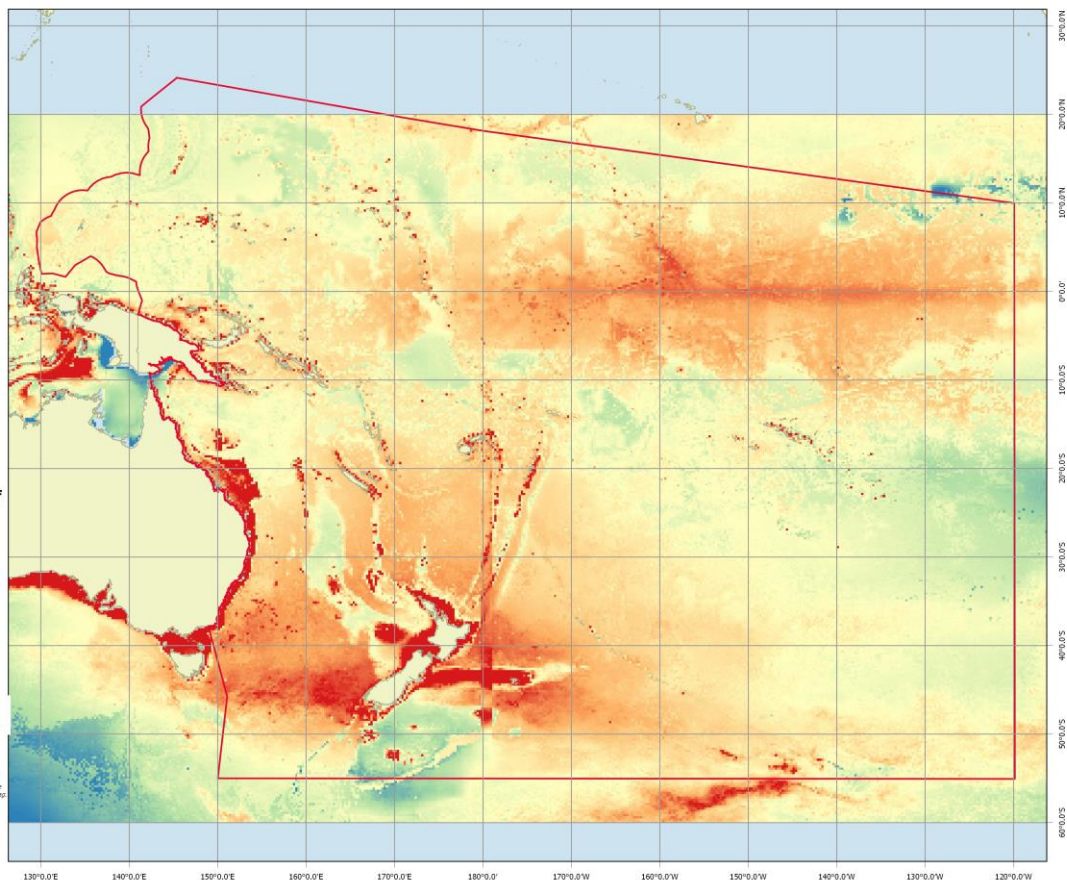
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Appendix 1: Qualitative Models

Table 1 Functional Groups used in the qualitative modelling.

Name	Acronym	Pressure
Acidification	Acid	p
Artisanal Fisheries	Art	p
Bacteria Graziers	Bgraz	
Biofilm	Bfil	
BioTurbators	BT	
Birds	Bird	
Bivalves	BiV	
CCA	CCA	
Chemosynthetic Bacteria	ChemB	
Chemosynthetic Symbionts	ChSym	
Climate Change Acidification	CCA	p
Climate Change Chlorophyll	CCC	p
Climate Change Temperature	CCT	p
Climate Change	CC	p
Commercial Fisheries	ComF	p
Coral	Coral	
Coral Predators	COTS	
Crabs	Crab	
Crocodile	Croc	
Crustacean Fishery	CrF	
Cyclones	cyc	p
Detritivores	Det	
Distance to Deep water	Dist	
Deposit Feeders	DepF	
Demersal Fishes	DemF	
Demersal Trawling	DT	p
Dugong	DG	
Encrusting Invertebrates	Enclnv	
Epiphytes	EP	
Filter Feeding Benthic	FFB	
Fleshy Algae	Falg	
Food Falls	FF	
Grounding Ships	GS	
Hake Fishery	HF	
Herbivorous Fish	Herb	
Land Use Change	Land	p
Large Sediment	Lsed	p
Leaf Litter	LL	
Line Fishing	LF	p
Lobster	Lob	
Longline Fishing	LLF	p

Low Saline Water	LSW	p
Mangrove	Mang	
Marine Debris	MD	p
Medium Sized Predators	MSP	
Mining Prospecting	MinP	p
Mining Tailings	MinT	p
Microbes	MB	
Mobile Filter Feeders	MFF	
Mobile Invertebrates	Minv	
Net Fishing	Net	p
Non-Vent Predators	NVP	
Nitrification	Nuf	p
Nutrients	Nu	
Oil Spills	Oil	p
Particulate Organic Matter	POM	
Pelagic Fishing	PF	p
Physical Disturbance	Phs	p
Phytoplankton	Phyto	
Planktivores	PKV	
Pollution	Pol	p
Prawns	PW	
Predatory Fish	Pred	
Reef Complexity	RC	
Seafloor Mining	SFM	p
Sea Urchins	SU	
Seagrass	SG	
Scavengers	SC	
Sediment	Sed	p
Sessile Filter Feeders	SFF	
Soft Corals	Soft	
Soil Nutrients	Snu	
Squid	SQ	
Targeted Fishing	TT	p
Temperature	Temp	p
Trawl	TW	p
Turf Algae	Turf	
Turbidity Increase	Tur	p
Turtle	Tu	
Upwelling	UW	p
Vent Mining	VM	p
Zooplankton	Zoo	
RootStructureNursury	Nus	

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