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The Peel-Harvey Estuarine Ecosystem – system analysis and management implications

Project 4.3.2 ‚Ecosystem modelling'
Western Australian Marine Science Institution (WAMSI)

Final Report by Sarah Fretzer, Murdoch University 2011

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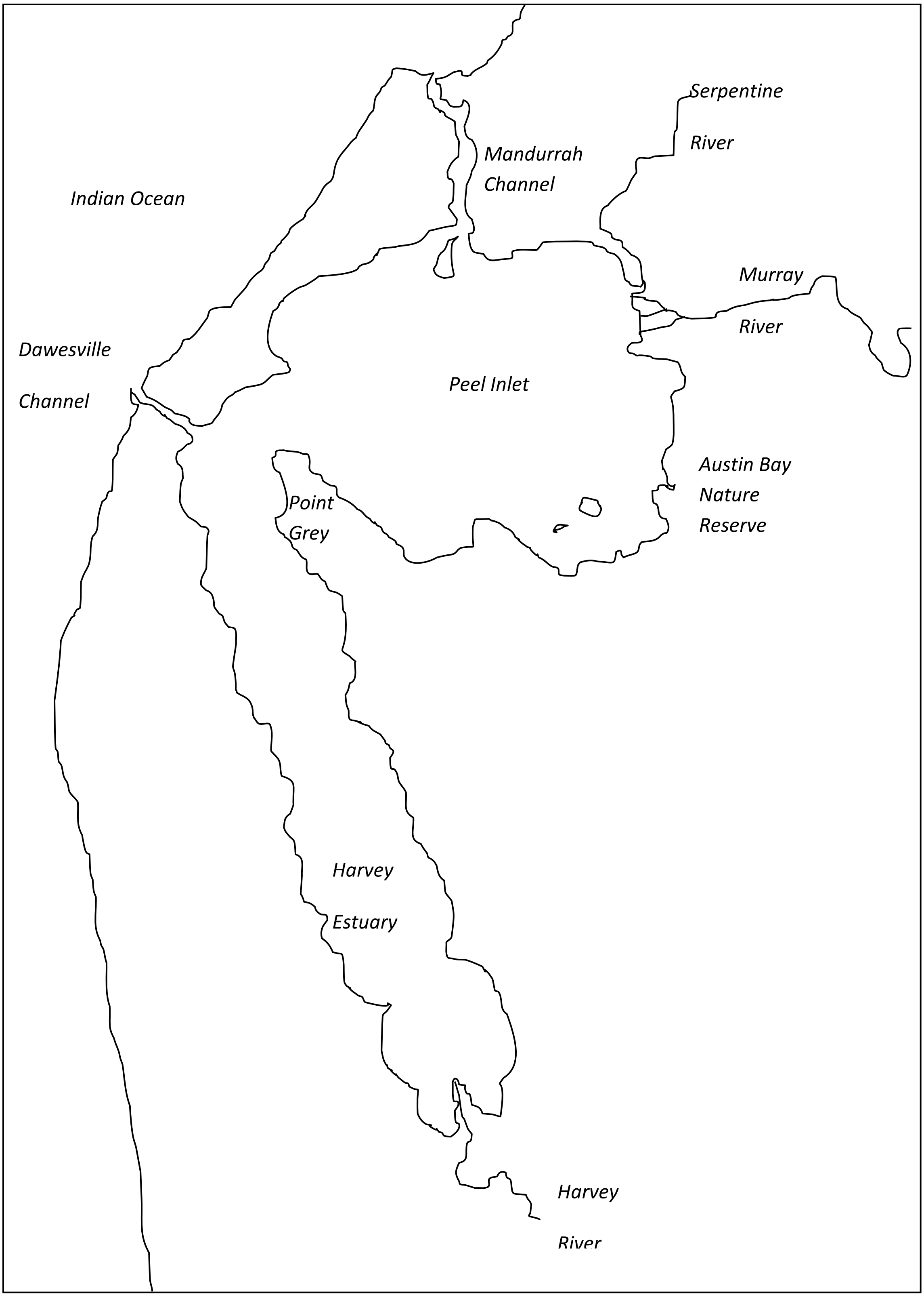
Thesis entitled: Analysing the effects of anthropogenic activities on two aquatic ecosystems in Western Australia and identifying sustainable policies for ecosystem-based management

By Sarah Fretzer

The Western Australian Science Institution funded my studies on the Peel-Harvey estuarine ecosystem, which are part of project 4.3.2 'Ecosystem modelling'. My studies were focusing on system analysis of the Peel-Harvey Estuary and implications for ecosystem-based management.

1. Introduction

The Peel-Harvey Estuary is located 80 km south of Perth, Western Australia and has an area of 131 km^2. The estuarine system consists of the round Peel Inlet with an area of approximately 75 km^2 and the elongated Harvey Estuary that has an area of approximately 56 km^2. The Peel Inlet and Harvey Estuary are joined by a narrow channel through Point Grey Sill. The Peel-Harvey Estuary has a maximum depth of 2.5 m and an average depth of 0.5 m. The estuary is connected to the Indian Ocean via a natural entrance channel in the northern Peel Inlet and an artificial entrance channel, the Dawesville Channel, which is located in the northern part of the Harvey Estuary. The catchment of the Peel-Harvey Estuary has a cumulative area of 11 930 km^2 and three rivers discharge into the estuary, i.e. the Serpentine River, Murray and Harvey Rivers. The soils of the catchment are mostly of sand, loams and clays and approximately 75% of the area is cleared of natural vegetation for agricultural purposes. In addition to clearing, the catchment of the Peel-Harvey Estuary has been modified extensively through the construction of drains that made the land suitable for agricultural use such as dairying, beef farming, as well as orchards and vegetable farming. Due to the characteristics of the soil types in the catchment, which are rather infertile and have low nutrient binding capacity, the application of fertilizers was essential for agriculture. However, a large fraction of the nutrients were flushed into the estuary and caused extensive macrophyte growth and algal blooms. Drifting macrophytes, in particular *Cladophora montagneana*, accumulated on beaches and caused an unpleasant smell, which affected surrounding neighbourhoods to the extend that the macrophytes needed to be removed. Toxic blooms of the green algae *Nodularia spumigena* caused fish kills and also affected human health. The algal blooms and extensive macrophyte growth became a nuisance to the commercial fishing sector, which was of great economical importance to the region during the 1970s and 1980s.



Map of the Peel-Harvey Estuary in Western Australia

The condition of the estuary became of such public concern that an extensive study of the estuary was initiated, the “Peel - Harvey estuarine system study (1976-1980)”. This study investigated different aspects of the ecosystem, for example nutrient input, important macrophyte and phytoplankton species, invertebrates and also environmental factors, such as hydrology. The fish fauna was also studied extensively at the same time. Based on this science, authorities developed a management action plan which aimed at reducing the nutrient input and increasing the flushing of the estuary to reduce the nutrient levels in the water body and thereby to decrease the primary production. The quantities of fertilizer applied needed to be reduced and the importance of natural vegetation for reducing nutrient input became evident. To increase the flushing, an artificial entrance channel was planned and opened in 1994, the Dawesville Channel. It was expected that the Dawesville Channel would flush about 10% of the estuaries’ volume per day. The channel was also expected to increase the salinity in the estuary and reduce its range between wet and dry seasons. Water quality was expected to improve, in particular through an increase in dissolved oxygen, a reduction of the duration of stratification and a decrease of turbidity. Furthermore, scientific investigations by applying hydrodynamic models had revealed that an increase in water levels and an increase in the tidal effects needed to be considered for management.

The Dawesville Channel was opened in 1994. It has delivered the predicted changes in water quality and a reduction in primary production. The artificial entrance channel has had a major impact on the ecosystem of the Peel-Harvey Estuary and its surrounding natural vegetation. The species composition and dominance have changed in many communities exhibiting that many marine species that had not previously been recorded entering the estuary, for example in the communities of macrophytes, fish and invertebrates. The surrounding vegetation has been affected by the increased penetration of salt water in the lower Harvey River, which has led to the decline of riverine trees in the area.

The Peel-Harvey Estuary is of great importance to waterbirds, as it is considered an important breeding site and it is part of the Peel-Yalgorup wetland system, which ‘comprises the most important area for waterbirds in south-western Australia’. Since June 1990, The Peel-Yalgorup wetland system has been recognised as ‘Wetland of International Importance’ by the Ramsar Convention on Wetlands. Due to a lack of data and great variations in bird abundances, the impact of the Dawesville Channel on the different waterbird species around the Peel-Harvey Estuary remains unknown.

In contrast to the opening of the artificial entrance channel, other proposed management tools appear to have been less effective, as the nutrient input from the catchment in 2007 was still as high as in the 1980s. Furthermore, urban nutrient run- off also needs to be considered, as urban groundwater contributes to the nitrogen compounds in the estuary. With increasing urbanisation and canal development around the estuary, this nutrient source cannot be ignored. Increasing urbanisation is only one challenge that the ecosystem faces. Another major factor is climate change, which, with predicted decreasing rainfall and also rising temperature, will affect the catchment of the estuary as well as its water body. Fishing also causes pressure on the estuarine ecosystem with recreational fishing pressure slowly replacing the commercial fishing sector, which has decreased substantially due to political pressure over the last decades. The recreational fishing sector heavily impacts the estuary since the opening of the Dawesville Channel and the recreational catch of blue swimmer crabs in 1998 exceeded the commercial catch by factor four. With increasing urbanisation in the area of the Peel-Harvey Estuary, an ecosystem based management of both fishing sectors is important for the sustainability of the estuary in the future.

To maintain the diversity and the health of the estuarine ecosystem, management policies need to be identified that ensure long-term sustainability. In the past, the Dawesville Channel has been the management tool that has led to the most marked changes in and around the estuarine water body.

In this study, a quantitative modelling technique, Ecopath with Ecosim and Ecospace, is applied to identify the impacts of

1. an artificial entrance channel,
2. fishing,
3. reduction in plant (seagrass, algae, macrophytes, etc.) habitat through dredging and
4. a Marine Protected Area

on the ecosystem of the Peel-Harvey Estuary.

2. Research results

Ecopath is a quantitative modelling technique that describes the biomass flows between functional groups. A functional group can consist of s single species, a taxonomic family or taxa. Two Ecopath models that are identical in design have been developed for the Peel-Harvey Estuary consisting of 30 living functional groups and describing the state of the ecosystem before ('pre DC') and after ('post DC') the opening of the Dawesville Channel. The functional groups of the Ecopath models describe dolphins, sharks, waterbirds (2 groups), teleost fish (13 groups), invertebrates (7 groups) and primary producers (6 groups). Since the opening of the Dawesville Channel, the ecosystem of the Peel-Harvey Estuary has declined drastically in total biomass, as well as in biomass at each trophic level and in the size of flows between the functional groups.

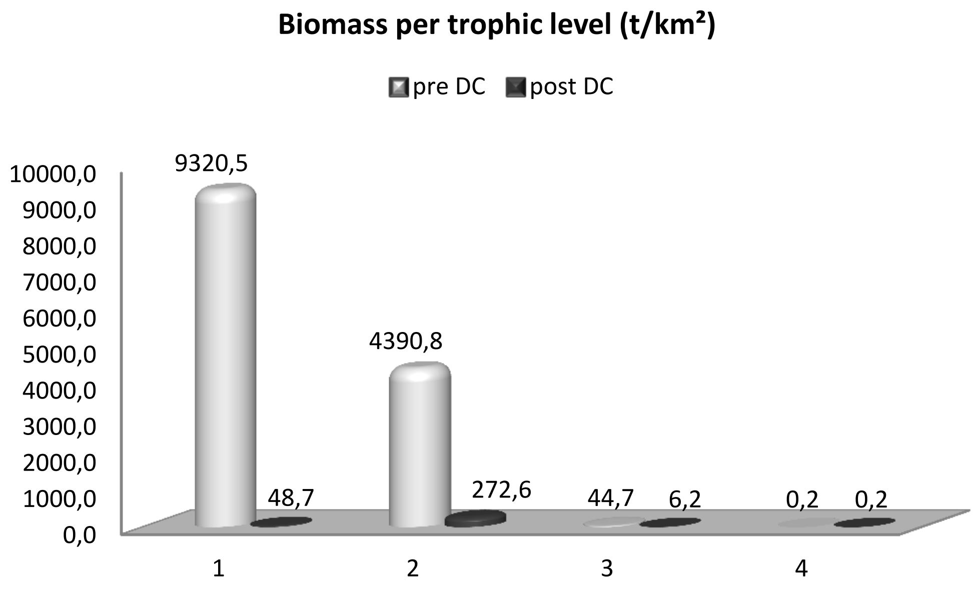
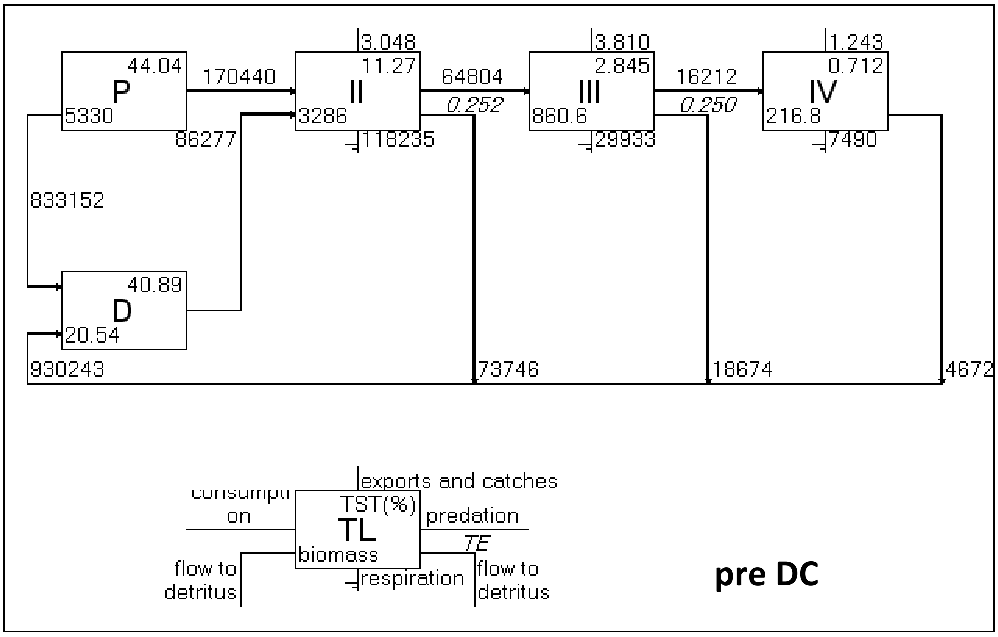


Figure 1: Biomass estimates in t km^{-2} per trophic level before (pre DC) and after (post DC) the opening of the Dawesville Channel in the Peel-Harvey Estuary



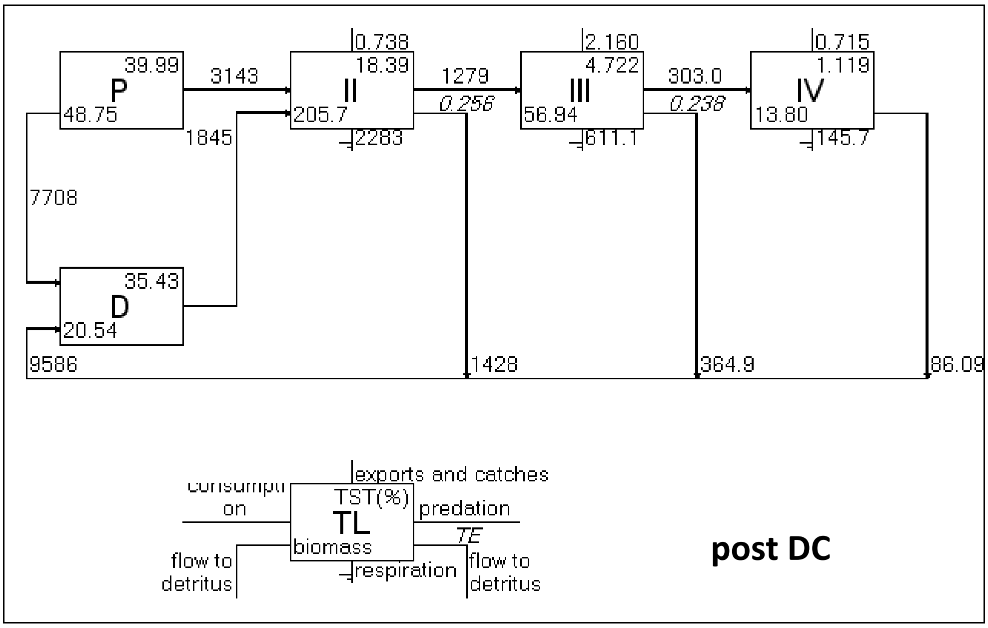


Figure 2: Flows per trophic level in t km^{-2} before (pre DC) and after (post DC) the opening of the Dawesville Channel,   P: Primary producers, first trophic level, D: detritus pool

Changes in flows and transfer efficiencies illustrate a change in the functioning of the ecosystem, where consumption has become a more important and more efficient flow since the opening of the entrance channel.

The results of the Ecopath model indicate that Dawesville Channel has markedly impacted species composition and dominance in faunal and floral communities. Estuarine fish species have decreased and marine species have become more dominant in the Peel-Harvey Estuary.

To support the reliability of the Ecopath and Ecosim predictions, model uncertainty and the sensitivity of the parameter settings were assessed in detail. Overall, the results of this analysis indicate that the parameter settings for the ‘pre DC and ‘post DC’ models are robust and do not lead to uncertainties regarding modelling results and predictions.

Ecosim allows dynamical simulations of the mass-balanced Ecopath model over a defined time period to investigate alternative fishing policies. Ecosim was applied in this modelling exercise to identify the impact of primary producers on functional groups of the estuary and the impacts of fishing on target and non-target species.

The results of this analysis indicate that role of primary producers should be considered for ecosystem-based fisheries management and habitat conservation, for example the management and conservation of seagrass beds. A decline in this habitat should be of concern for fisheries managers, as it leads to a decrease in the biomass of target species.

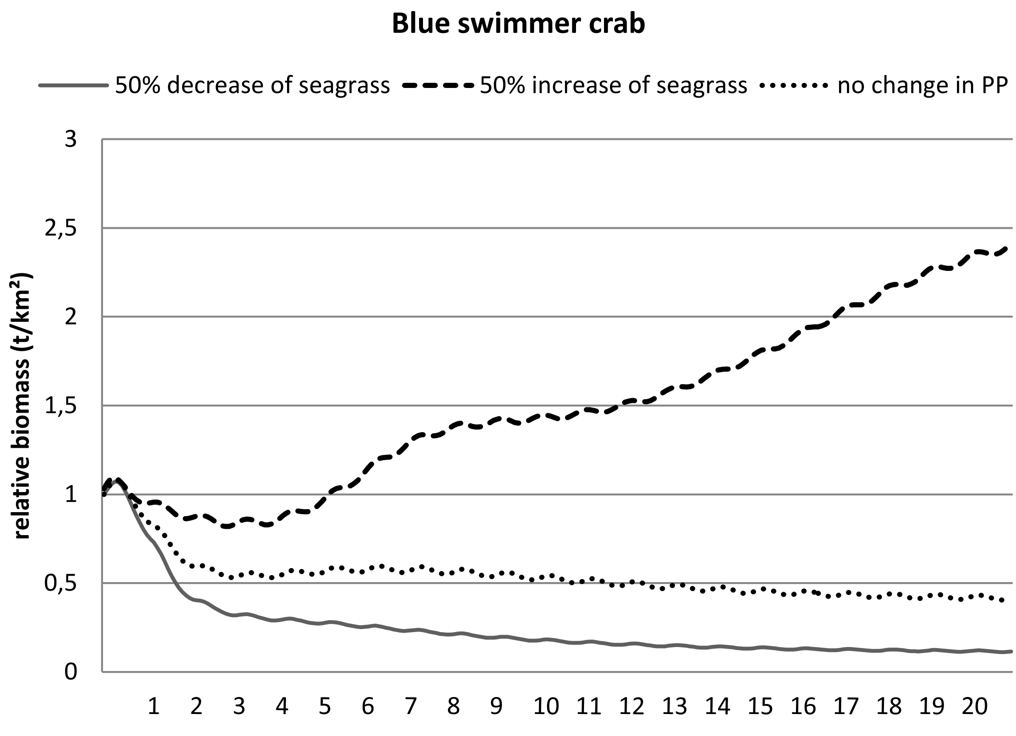


Figure 3: Effect of 50% increase and decrease of seagrass biomass on the relative biomass of Blue Swimmer Crabs

With high nutrient concentrations still being present in the estuarine water body, phytoplankton blooms in the future will lead to the collapse of some fish stocks, such as the target species *Aldrichetta forsteri* and *Mugil cephalus*, whereas *Arripis georgianus* will increase in biomass, as this species is able to profit from high phytoplankton biomasses as food source.

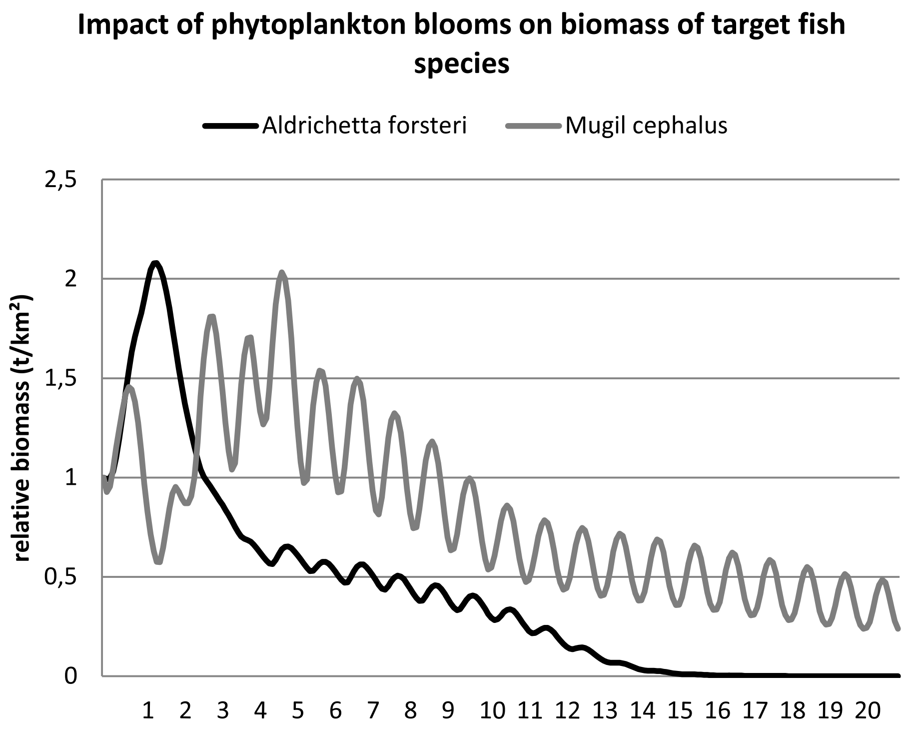


Figure 4: Effect of phytoplankton blooms, simulating an increase of the biomass of microscopic algae by factor 10, on the target fish species *Aldrichetta forsteri* and *Mugil cephalus*

The results of the Ecosim scenarios indicate that adjustments of fishing regulations should be considered for example, regarding the marked fishing pressure on the main target species, the Blue Swimmer Crab (*Portunus pelagicus*). The recreational fishing sector impacts the biomasses of the crab populations more than the commercial fishing sector using crab traps. An increase in the relative recreational fishing rate will lead to a depletion in crab biomasses, which indicates the extent of the recreational fishery, compared to a rather sustainable status of commercial fishery. Fish species are also targeted in the Peel-Harvey Estuary, but not to the same magnitude as the Blue Swimmer Crab and a change in the relative fishing rate has no severe long-term impacts on the biomasses of any target fish species.

The Peel-Harvey Estuary is of great importance to waterbirds, as it is considered an important breeding site and it is part of the Peel-Yalgorup wetland system, which ‘comprises the most important area for waterbirds in south-western Australia’. The Peel-Yalgorup wetland system has been recognised as ‘Wetland of International Importance’ by the Ramsar Convention on Wetlands.

Ecospace represents biomass dynamics over two-dimensional space and time. By applying Ecospace, three different aspects were explored with regard to the ecosystem-based management of the Peel-Harvey Estuary: 1. the role of waterbirds and measures for waterbird conservation, 2. the impact of plant removal through dredging on the ecosystem and 3. identification of an effective Marine Protected Area (MPA). The results indicate that piscivorous waterbirds are the main predator group in the estuarine ecosystem causing 76% of total predation mortality on all prey groups of the food web.

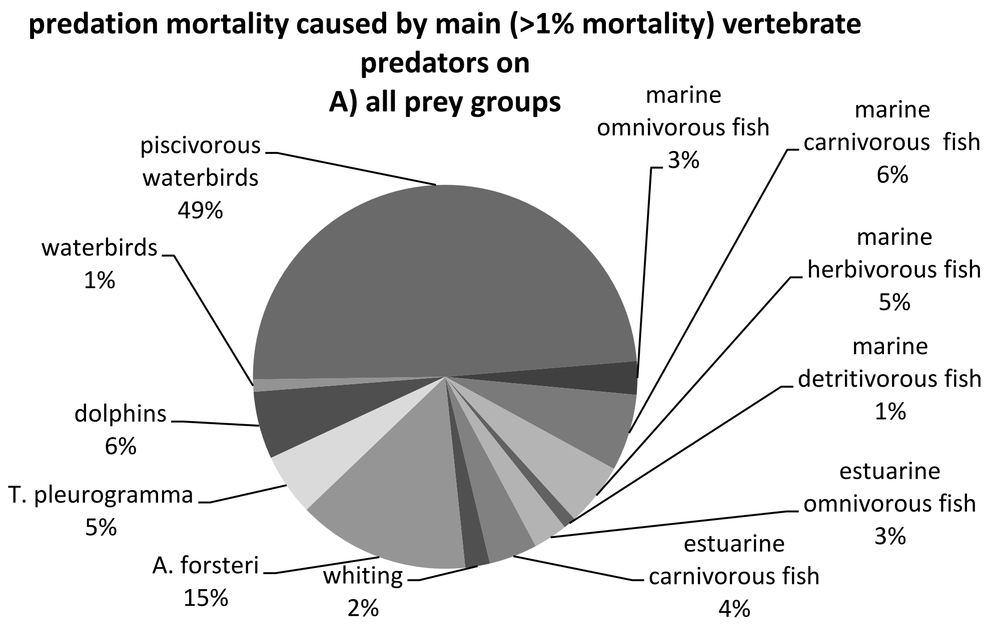


Figure 5: Predation mortality of main vertebrate predators on all prey groups

Waterbirds are slightly impacted by fishing, as a reduction in fishing effort will lead to a small increase in bird biomass. Waterbird biomasses will benefit from an introduction of a Marine Protected Area (MPA), and the highest benefit will result from the MPA at the eastern Peel Inlet. The MPA at the Peel Inlet is more effective than a MPA at Point Grey, as MPA Peel produces higher total biomasses and higher biomass of many functional groups, such as bivalves, crustaceans, Blue Swimmer Crabs and most marine fish groups. The MPA at Point Grey can only be effective, if the fishing pressure is reduced or managed sustainable for the different target fish species, as the Ecospace predictions indicate that the fishing pressure apparently piles up at the boundary of the MPA Point Grey.

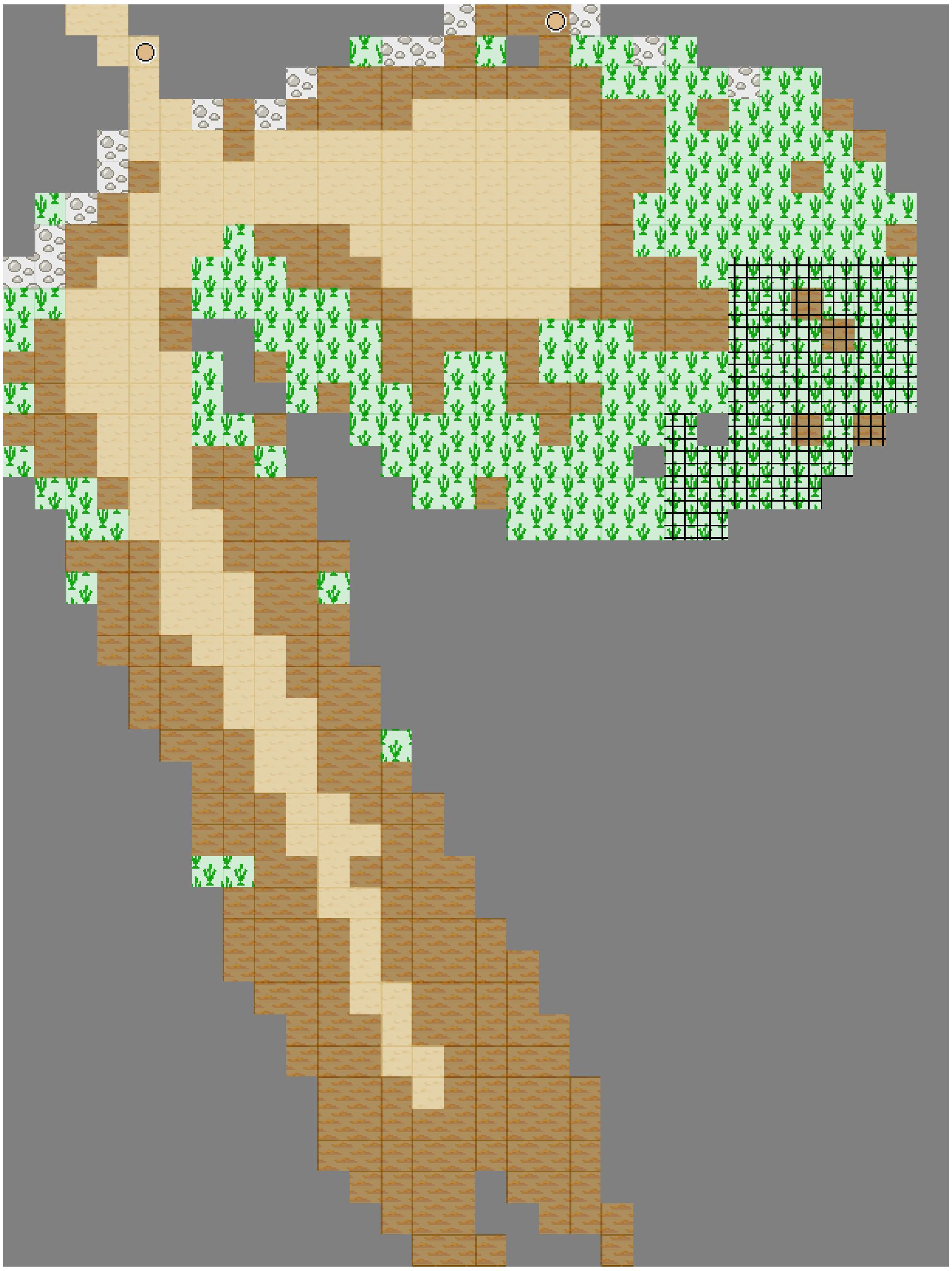


Figure 6: Basemap of the Peel-Harvey Estuary showing the hypothesized Marine Protected Area

(MPA) at the eastern part of Peel Inlet covering plant habitat with very high primary production (black grid); the hypothesized MPA is adjacent to the Austin Bay Nature Reserve; habitats: shallow mud (brown), deep sand (sand), rock (grey rocks) and plant cover (green); land cells are coloured in dark grey; two central points for boating in the estuary were defined as ports (brown circles) and these are located at the Dawesville Channel and at Mandurah, in the North of the Peel Inlet

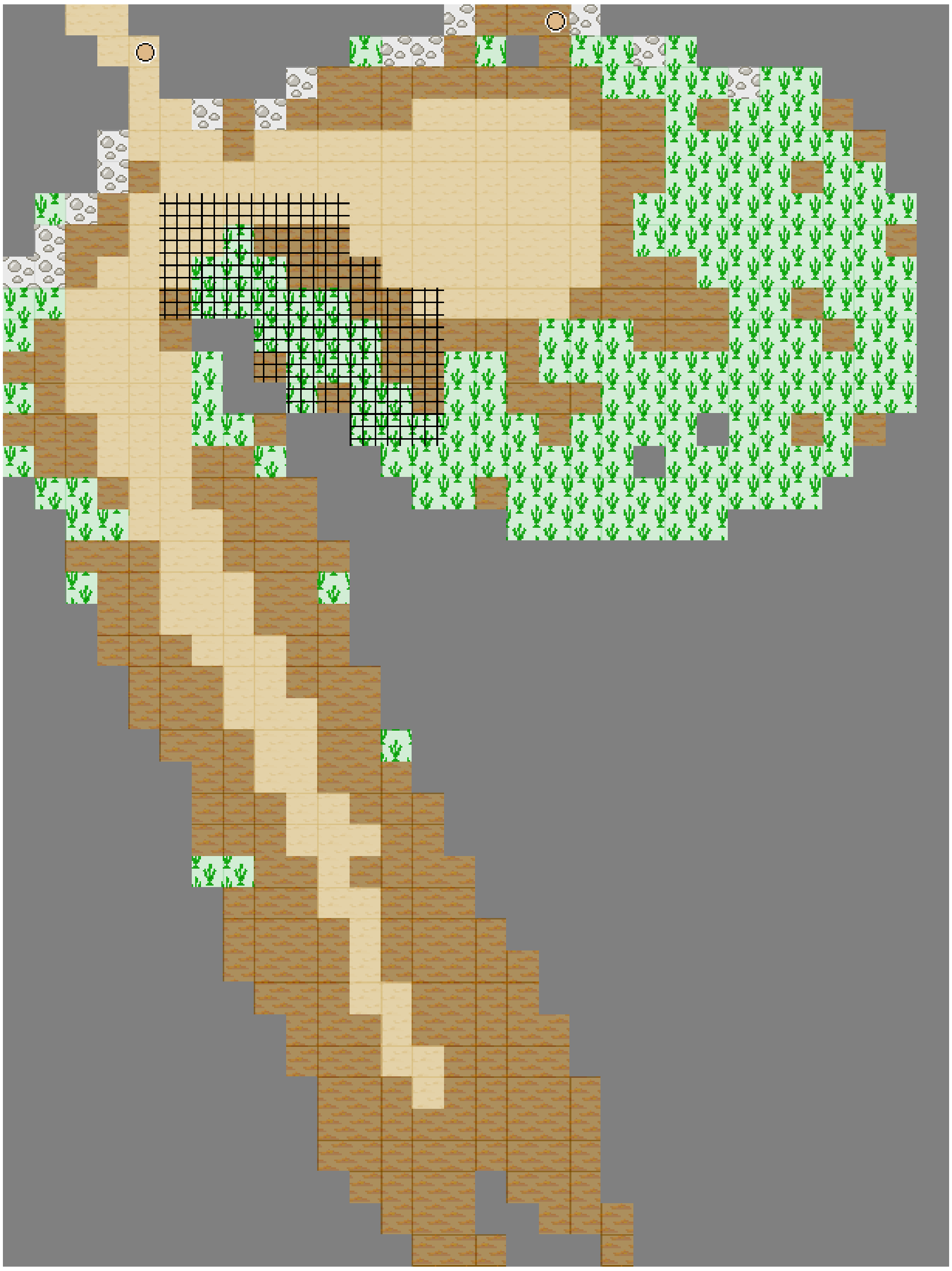


Figure 7: Basemap of the Peel-Harvey Estuary showing the hypothesized Marine Protected Area

(MPA) at the Point Grey peninsula with the MPA covering three different habitat types (black grid) and having the same dimension as the MPA at the eastern Peel Inlet (Fig. 7.3); habitats: shallow mud (brown), deep sand (sand), rock (grey rocks) and plant cover (green); land cells are coloured in dark grey; two central points for boating in the estuary were defined as ports (brown circles) and these are located at the Dawesville Channel and at Mandurah, in the North of the Peel Inlet

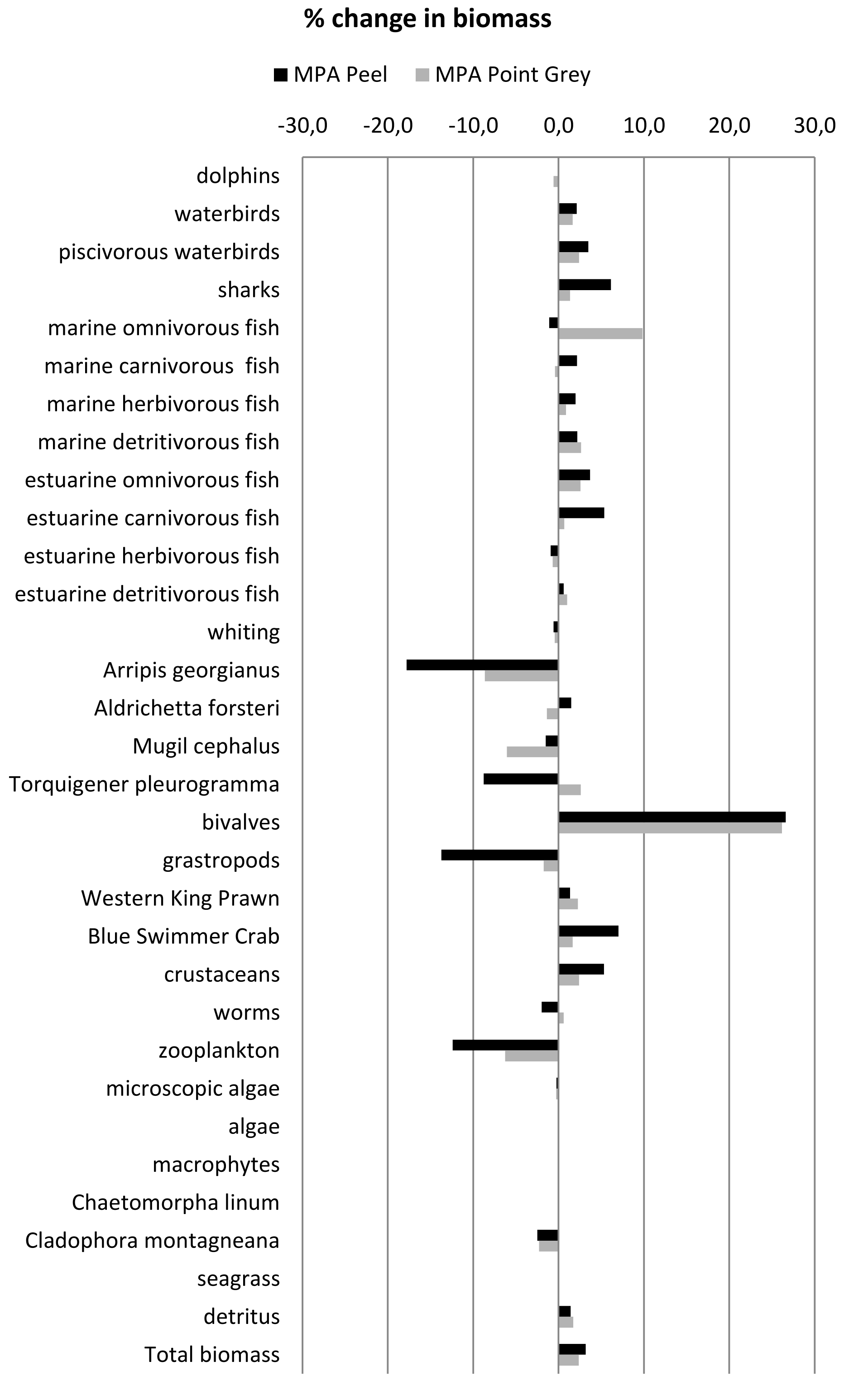


Figure 8: % change in biomass for each functional group after introduction of a MPA, such as a MPA at the eastern Peel Inlet (black bars) and at Point Grey (grey bars), biomass changes are compared to the trends in biomass under the current fishing scenario and current habitat distribution

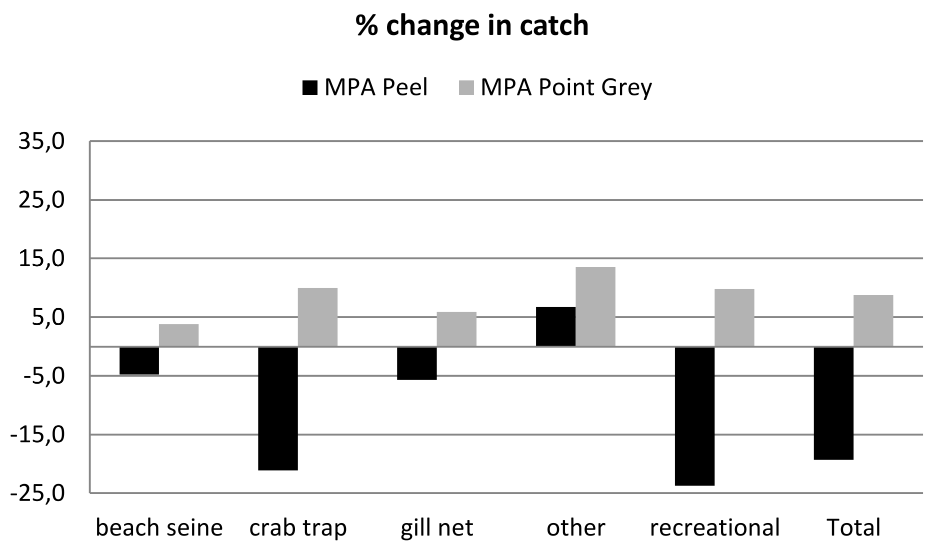


Figure 9: % change in catch exhibited for the different commercial fishing gears and the recreational fishing sector after introduction of a MPA, such as a MPA at the eastern Peel Inlet (black bars) and at Point Grey (grey bars), catch changes are compared to the catches under the current fishing scenario and current habitat distribution

The results of the Ecospace scenario indicate that waterbirds would not be affected by the removal of submerged plants through dredging, as their assigned feeding habitats are not markedly reduced. Even if a decline in submerged plants might affect a fraction of the waterbird group, this is compensated by an increase in other major prey groups, such as crustaceans. The removal of plant biomass through dredging at the northern Peel Inlet does not show drastic effects on the ecosystem, but it seems to affect the fish community, as some groups will show a marked increase in biomass, such as omnivorous fish.

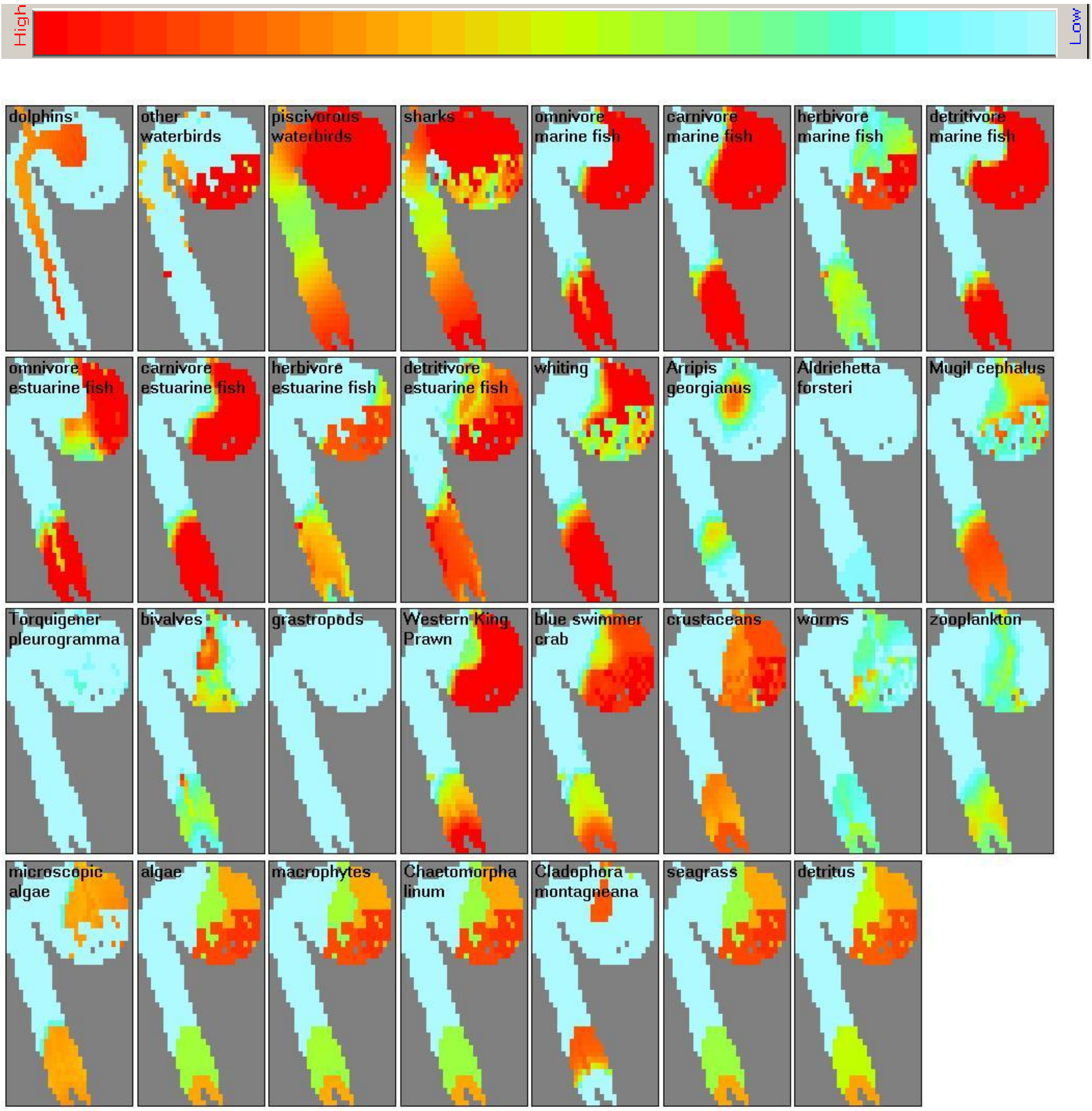


Figure 10: Biomass distributions predicted by Ecospace for the Peel-Harvey Estuary exhibiting the biomasses for a scenario where aquatic plants in the Peel Inlet are removed through dredging (Fig. 7.3), with red indicating high and blue indicating low deviations from the Ecopath baseline for each functional group, Color scale linear in biomass, shading from red (high) to blue (low)

3. Discussion

The Dawesville Chanel was designed and constructed to decrease the nutrient concentrations and correlating primary production in the Peel-Harvey Estuary. The results of the Ecopath modelling exercise demonstrate clearly that the primary production has declined. In consideration of ecosystem-based management, however, the construction of an artificial entrance channel should be considered with caution. The Peel-Harvey Estuary has almost become a marine environment and marine species are immigrating into the water body, which affects the species communities and species composition with negative consequences for local estuarine species. In regard to the conservation of biodiversity, it needs to be investigated if local populations might be threatened by an increase in competition for food and habitat caused by immigrating species and by a changing environment after the opening of an entrance channel.

The Dawesville Channel reduced the primary production in the estuary, but it was not able to reduce the nutrient input. The persisting high nutrient concentrations in the estuary have caused major problems in the past and have the potential to cause problems in the future by nourishing phytoplankton blooms of toxic marine species that just immigrated. These plankton blooms might alter the existing species composition in the estuary.

The settings for the Ecosim scenarios are based on a historical data set that was derived from linking the recreational catch to the population living in the area of the Peel-Harvey Estuary. The model was not able to reproduce the time series of commercial catch or CPUE data and so, this tuning process failed due to bad trend data. In 1998, the commercial catch was only a small fraction of the total catch, which indicates that the CPUE data set might not represent properly the changes in biomass over the last decades. However, more data is needed on the recreational catch and thus, on the total catch in the estuary, to improve the model predictions investigated here. It is advisable to repeat the tuning process with an appropriate long-term data set to confirm that the high vulnerability values are realistic. If these vulnerability settings are realistic values, they will persist in a different tuning process.

For the Peel-Harvey Estuary, the Marine Protected Area at Peel Inlet is more effective than the MPA Point Grey, as MPA Peel produces higher total biomasses and higher biomass of many functional groups. The MPA Point Grey can only be effective, if the fishing pressure is reduced or managed sustainable for the different target fish species.

Ecospace is an ideal tool to investigate the efficacy of a planned Marine Protected Area and should be considered for ecosystem-based management.