

Problem statement

The reintroduction of sea otters to British Columbia has caused changes in ecosystem dynamics and the provision of the benefits humans derived from the ecosystem. As sea otters continue their expansion, an integrated understanding of the potential impacts might be useful for decision-making.

Introduction

Sea otters were extirpated in British Columbia around 1930 after conservation efforts failed to recover the population from intense hunting in the 17th and 18th centuries.

Reintroduced to the west coast of Vancouver Island in the 70's, sea otters re-established themselves, and the population continues to grow and expand (Fig. 1).

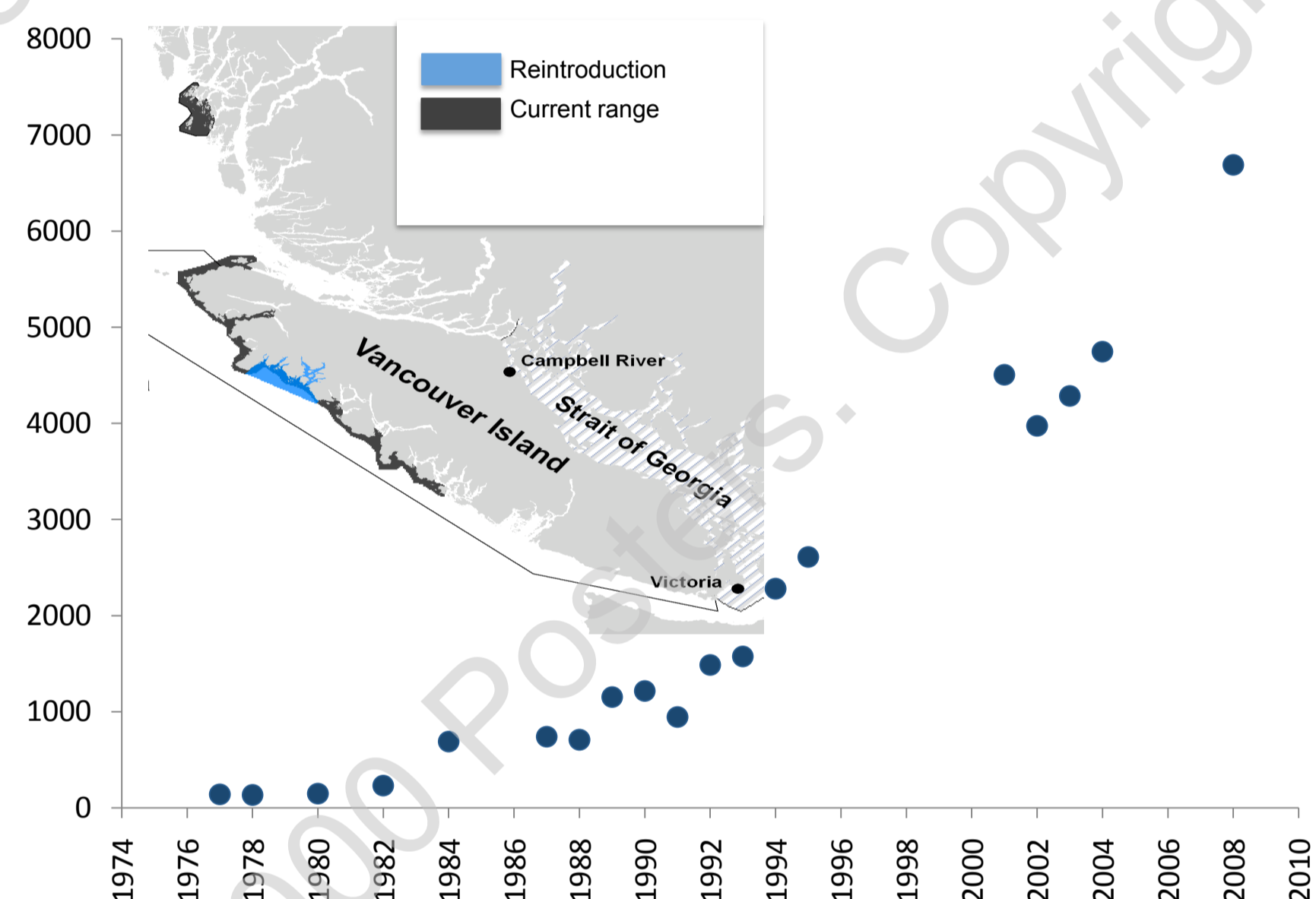


Figure 1: Historical counts of sea otters (Nichol *et al.* 2009) and the areas of reintroduction and expansion from (Gregr *et al.* 2008).

Sea otters are recognized as a keystone species, able to shift nearshore marine ecosystems from a sea urchin dominated to a macro-algae dominated state by reducing grazing pressure (Fig. 2).

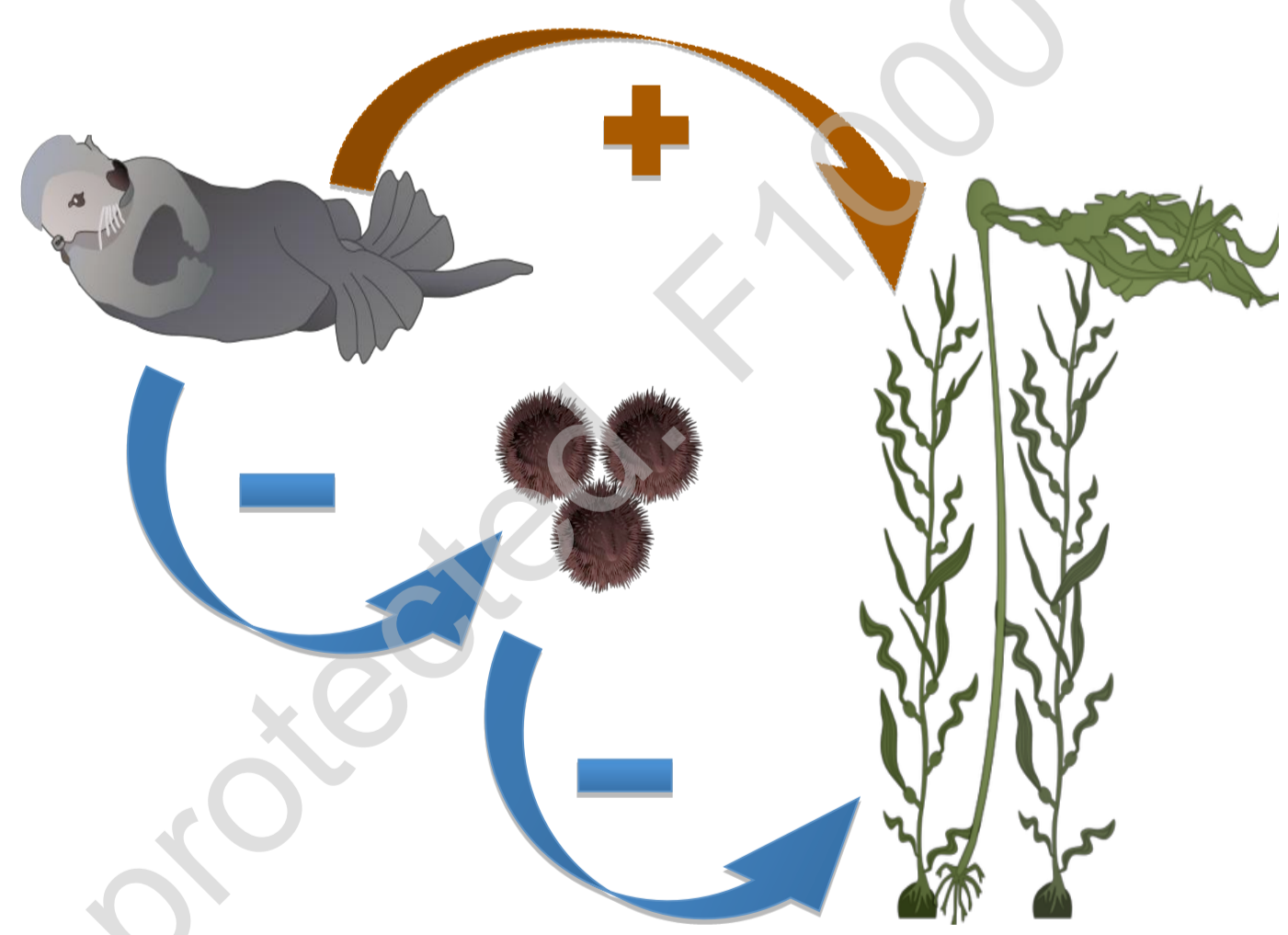


Figure 2: Influence diagram showing how otters can change nearshore ecosystems through the removal of macroalgae grazers.

The sea otters-urchins-kelp forest dynamic has captured the attention of the researchers. However, little attention has been paid to the broader ecosystem level impacts.

Research objectives

- To build an ecosystem model that represents:
 - The reintroduction and expansion of sea otters
 - Indirect benefits provided by kelp forests.

Methods

We built an Ecopath with Ecosim (EwE) model. We used a food web and parameters from existing models and databases in British Columbia (Fig. 3).

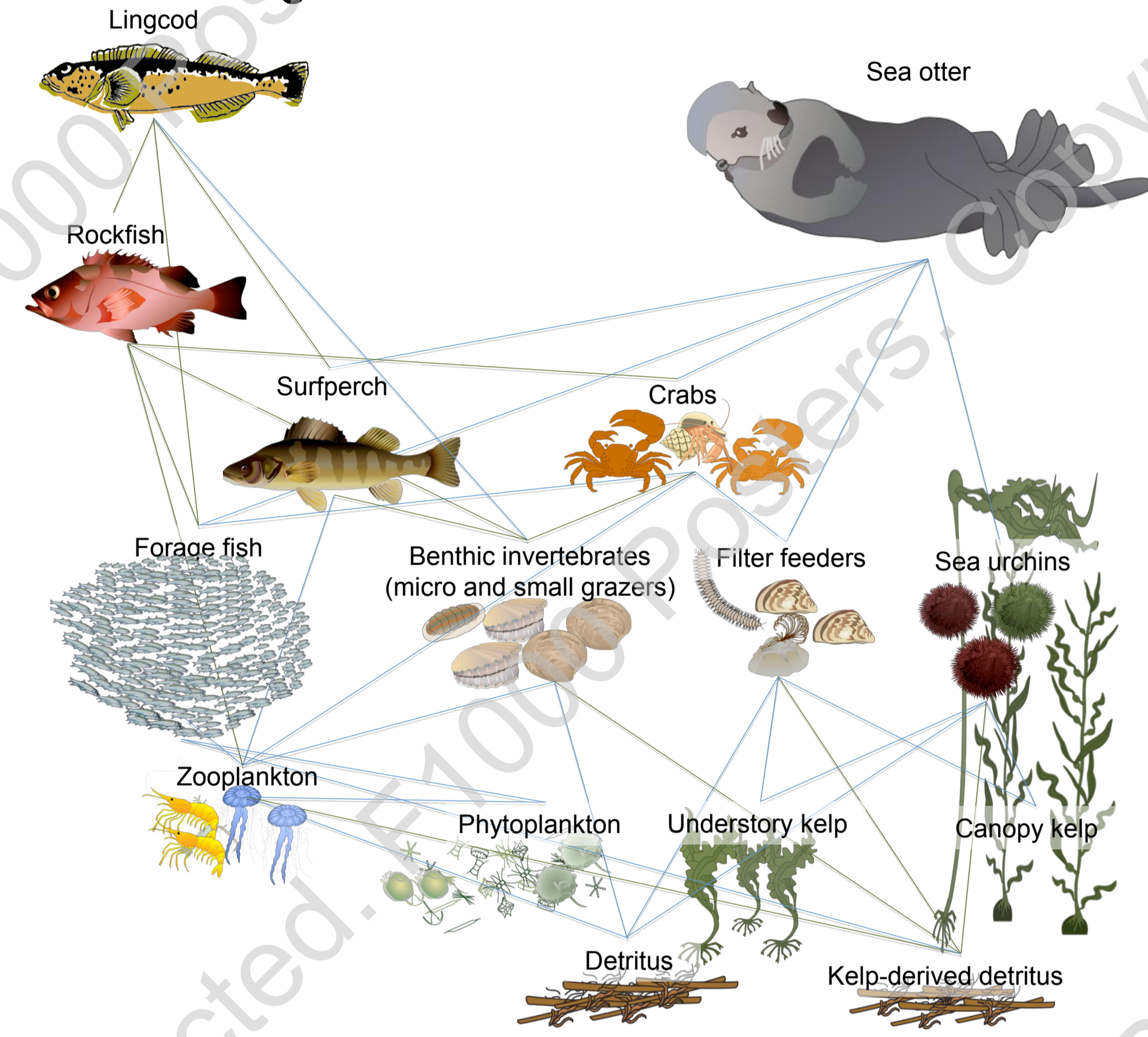


Figure 3. Food web adapted from Simenstad *et al.* (1978), Halpern *et al.* (2006), Markel (2006), Markel and Martone (pers. comm.) Ainsworth *et al.* (2002), Preikshot *et al.* (2005), and Maschner *et al.* (2009). Green links represent the indirect benefits from kelp through increased feeding areas and prey retention.

Indirect benefits provided by kelp

Contribution of kelp to primary and secondary production.

Represented in EwE by including kelp detritus in the food web.

Increased feeding areas and prey retention.

Represented using mediation, where the abundance of one species/group affects the predator-prey relationship of other species/groups. It is a scaled multiplier (0-1) that can affect three parameters:

1. Effective search rate of predators for prey,
2. Foraging areas,
3. Prey vulnerable biomass.

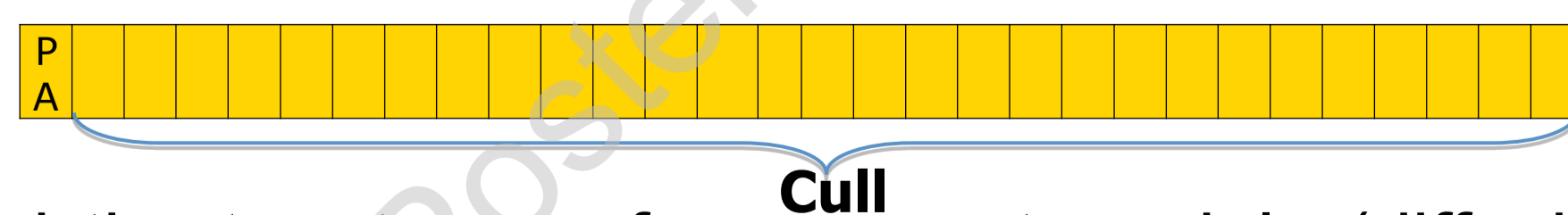
We applied parameters (2) and (3) to the relationships showed in Fig. 3.

Sea otter reintroduction in Ecospace

There is no direct way to represent species reintroduction in Ecospace. EwE assumes that all species are initially distributed in suitable habitats defined by the modeler. To model the reintroduction we :

1. Built a linear map of 30 cells,
2. Assigned sea otter biomass to all cells,
3. Set a protected area (PA) in the first cell,
4. Culled otters with high effort for the first 10 years in the non PA cells.

The intention was to concentrate sea otter biomass in one cell and drive the population down to 0 in the remaining cells.



5. Explored the two types of movement models (diffusion and Individual based model) available in EcoSpace.

Results and discussion

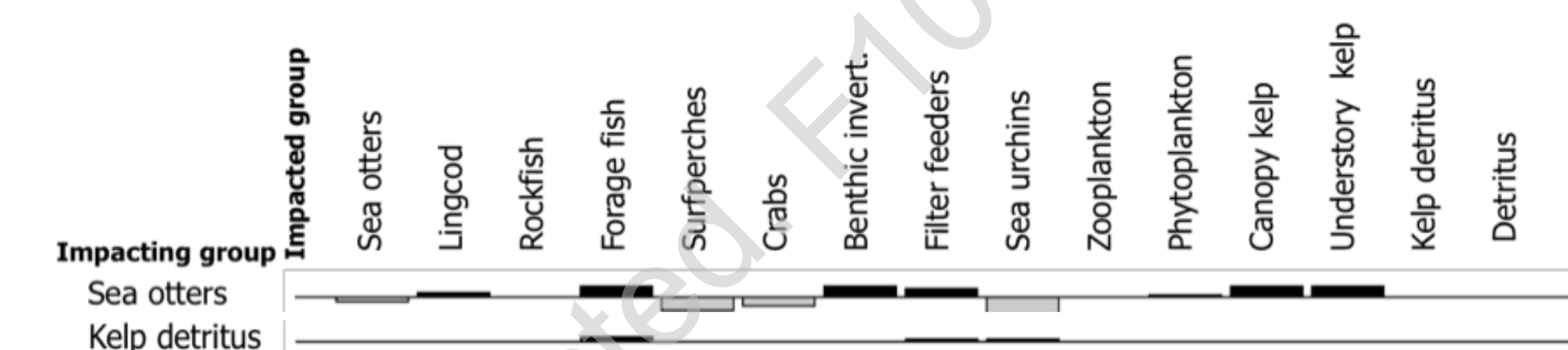


Figure 4: Impact diagram showing role of sea otters and kelp detritus in the modelled ecosystem. Black bars above a line indicate positive effects while grey bars below a line negative effects.

Our model showed important known ecosystem dynamics such as the negative impacts of sea otters on crabs and sea urchins. A positive effect on kelp forests, lingcod, forage fish, benthic invertebrates and filter feeders, as well as the contribution of kelp detritus, are also evident (Fig. 4).

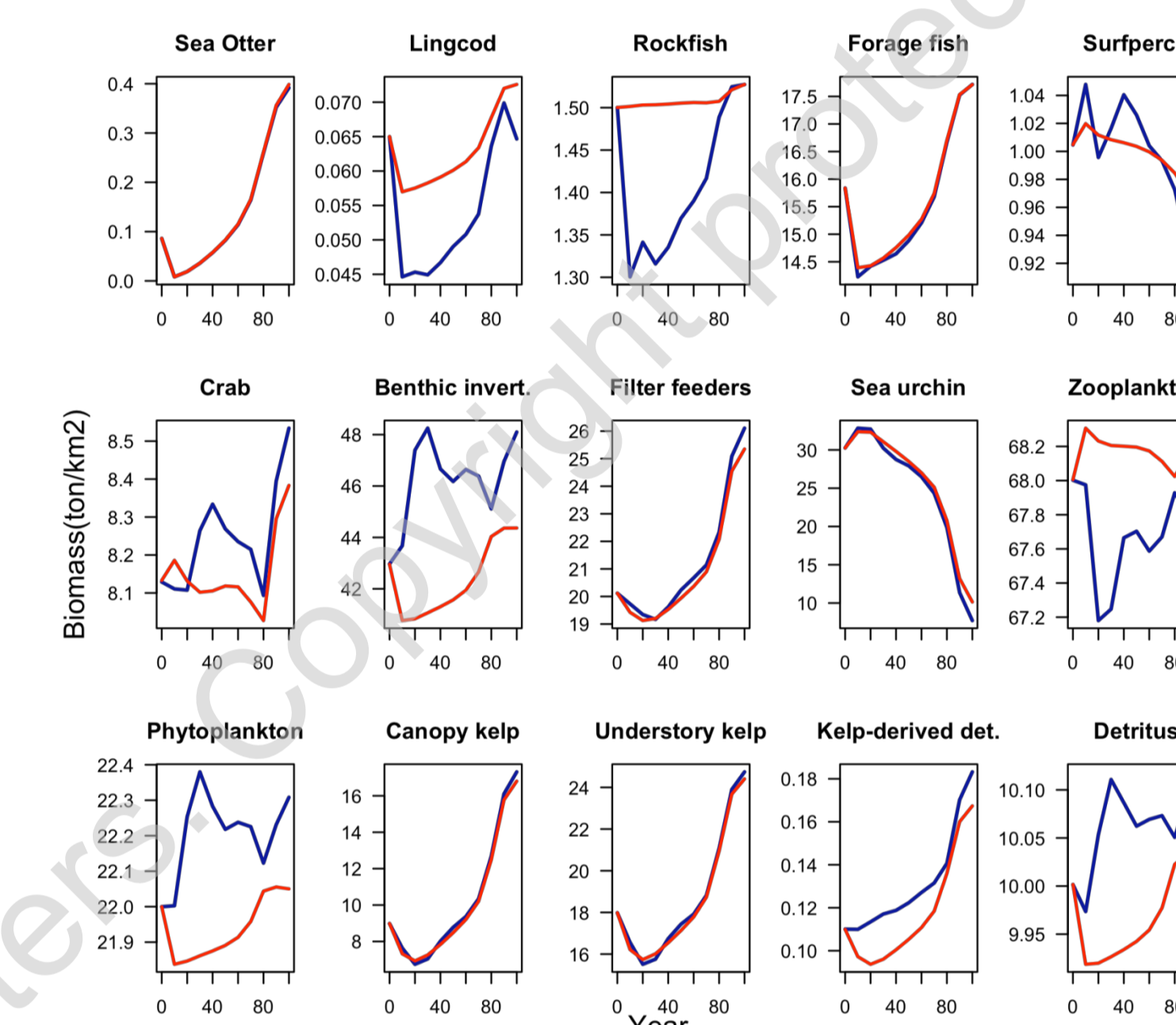


Figure 5: Biomass change over time for food web groups. Red lines show results without mediation, blue lines results with mediation.

Mediation changed some species dynamics (Fig. 5). When kelp forest increases, lingcod, rockfish, and benthic invertebrates also increased. Slight changes were observed in zooplankton, phytoplankton and detritus.

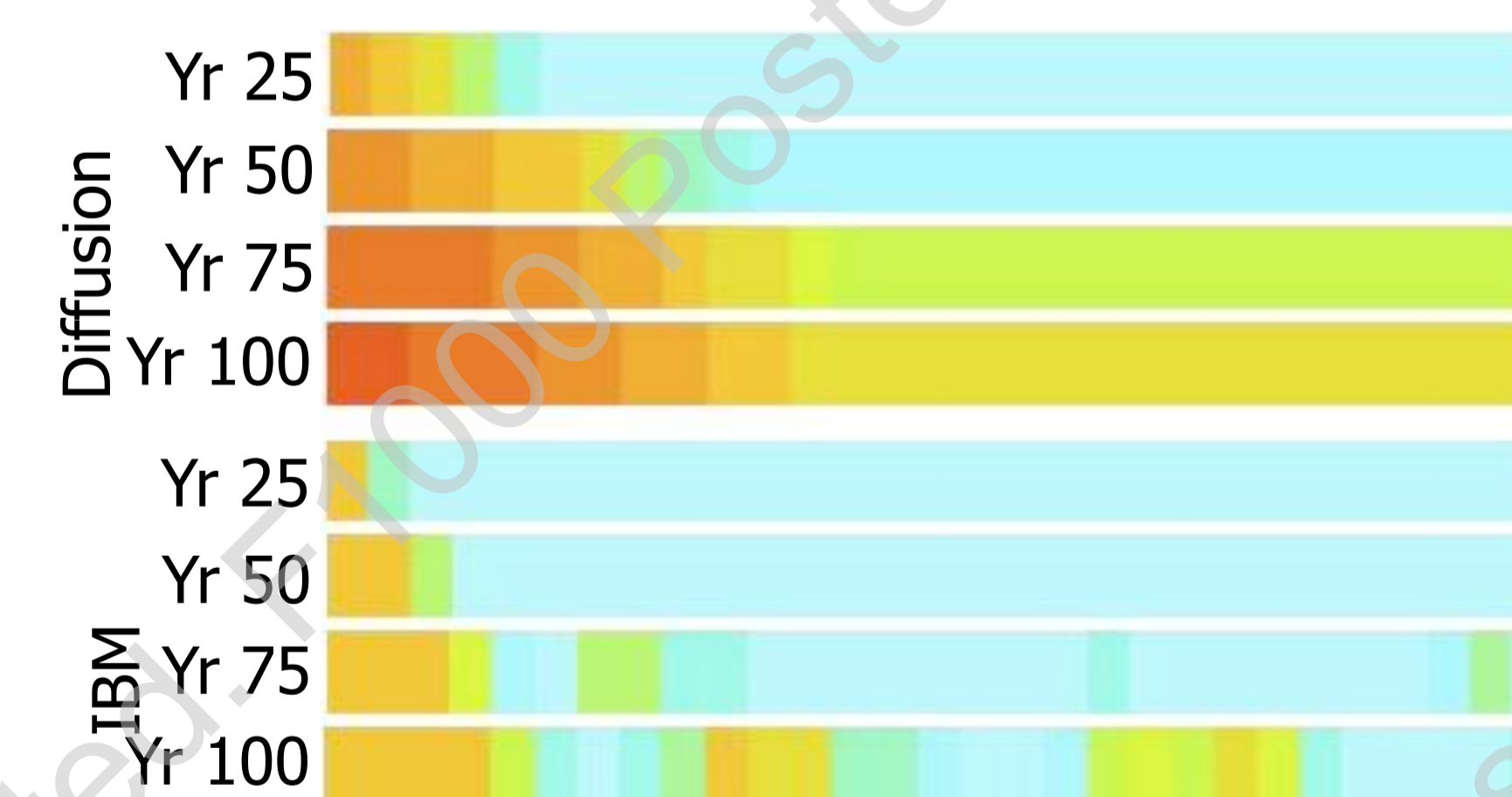


Figure 6: Spatial distribution of sea otter biomass for the two movement models in Ecospace (red is high, and blue is low biomass).

The diffusion model showed more uniform expansion while the IBM a more random distribution (Fig. 6). The IBM also produced more conservative biomass estimates.

Conclusions

- EwE can be used to represent species reintroductions.
- The contribution of sea otters to ecosystem dynamics can be captured using a kelp detritus group and mediation.
- A model incorporating the impacts of fisheries, and habitat information is needed to confirm these theoretical results.

Acknowledgments



We also thank Russ Markel, Becca Martone and Tomas Tomascik for their contributions to this work.