Kelp & Complexity:

Fig.1 : Kelp Forest

Kelp Forests, the importance of their integral complexity, their optimal vs. sub-optimal conditions & what can be done to help

Kelp forests are highly complex ecosystems found in temperate to cold shallow oceans and seas, they consist of a variety of large and often densely packed macroalgae – this large brown/green subspecies of seaweed support many marine, costal, eco, financial and aquacultural systems. I will present the importance of the complexity and intertwined elements of kelp forests, the factors which cause kelp forests to thrive or decline and look to provide a deeper understanding of the complexities surrounding kelp forests and what needs to change in order to improve the health of kelp forests and the surrounding systems.

Complexity of kelp forests exists in nearly every element of their existence; structurally these near-fractal systems are made of intricate and scalable combinations of a wide variety of seaweeds and sea-life. Ecologically these systems are integral to the health of the oceans, providing a diverse habitat and feeding ground for sea life of all sizes prompting Charles Darwin to say "I do not believe nearly so many species of animals would perish as would here, from the destruction of the kelp" [1]. Kelp forests are exceptional at sequestering carbon, contributing to local and wider societies / economies, protecting coastlines. Kelp is one of the most promising options for sustainable materials and foods, aquaculturally easily scalable, and is fast growing without land, fresh water, fertilizer, feed or medicine.

As with most complex systems seemingly small changes can cumulate and hugely shift the entire system. While rich, diverse systems such as kelp forests seem resistant to change, they are susceptible to the compounding effects explained under chaos theory and the sensitive dependency of the butterfly effect. Studied by Ed Lorenz, complex and chaotic systems (such as kelp forests) are difficult to model classically due to the inaccessibility of sufficient input data.

The theory of determinism, explored by Pierre-Simon Laplace brought about a hypothetical all-knowing being or 'demon' (Laplace's Demon) for whom "the future, just like the past would be present before our eyes" [2]. Hypothetically arguing if you collect enough data, that you can see the outcome of changes to complex systems (such as kelp forests). Enacting change and predicting the outcome (in the medium or long term) is frivolous due to the vast range of variables which can radically shift the possible outcomes, so in practice these chaotic systems are understood through embracing the complexity and approaching the system non-linearly.

Kelp forests have existed for somewhere between 10 - 140 [3] million years – since then, there has been fluctuation in their state and abundance. Suggesting kelp forests are 'regular' and not 'chaotic' - however, kelp forests, alongside many other complex ecosystems can be seen to be 'chaotic' as they respond predictably to controlled inputs in the short term but remain impossible to predict in the longer term.

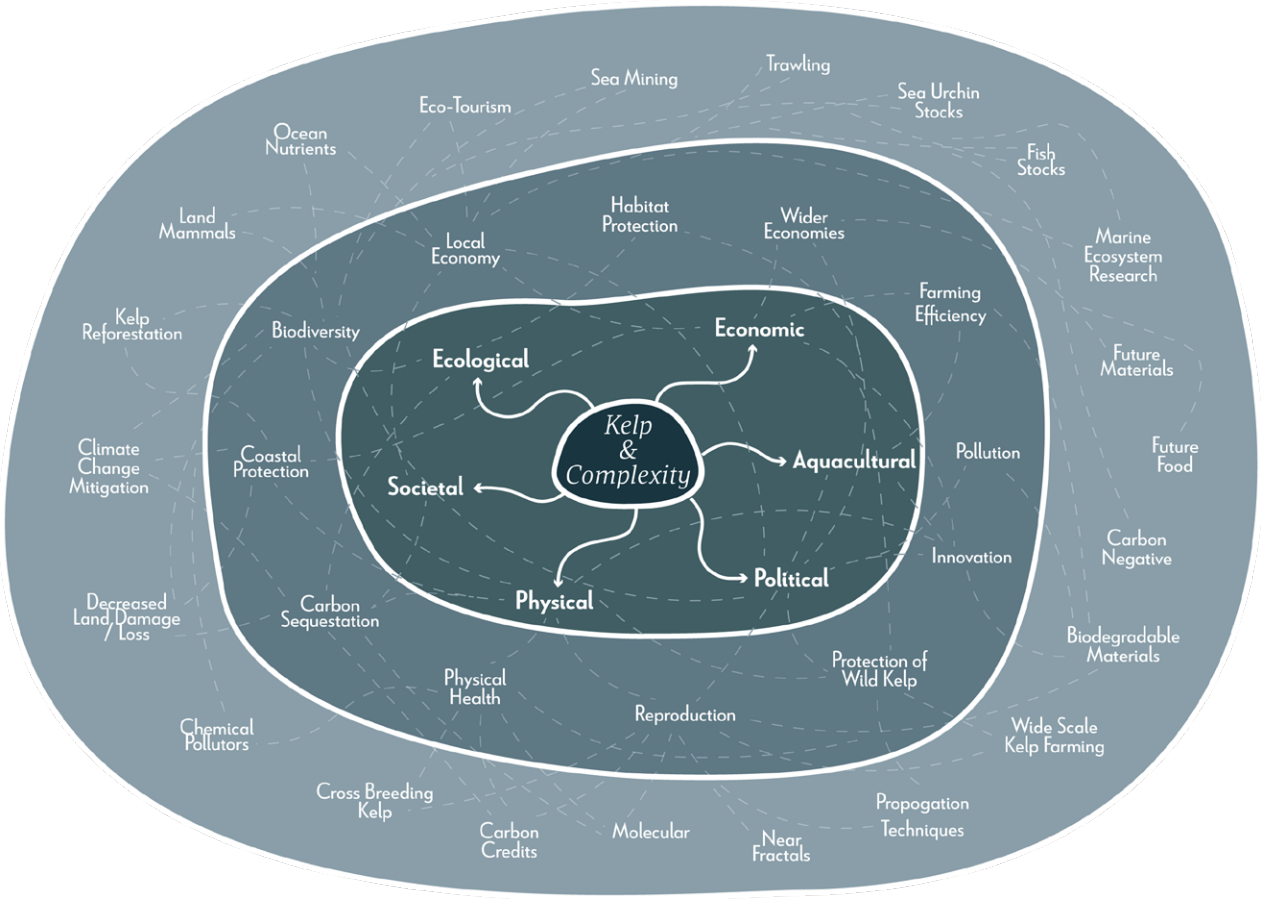


Fig.2 : This diagram shows how quickly kelp forests intertwine with the vast amount of elements and other systems

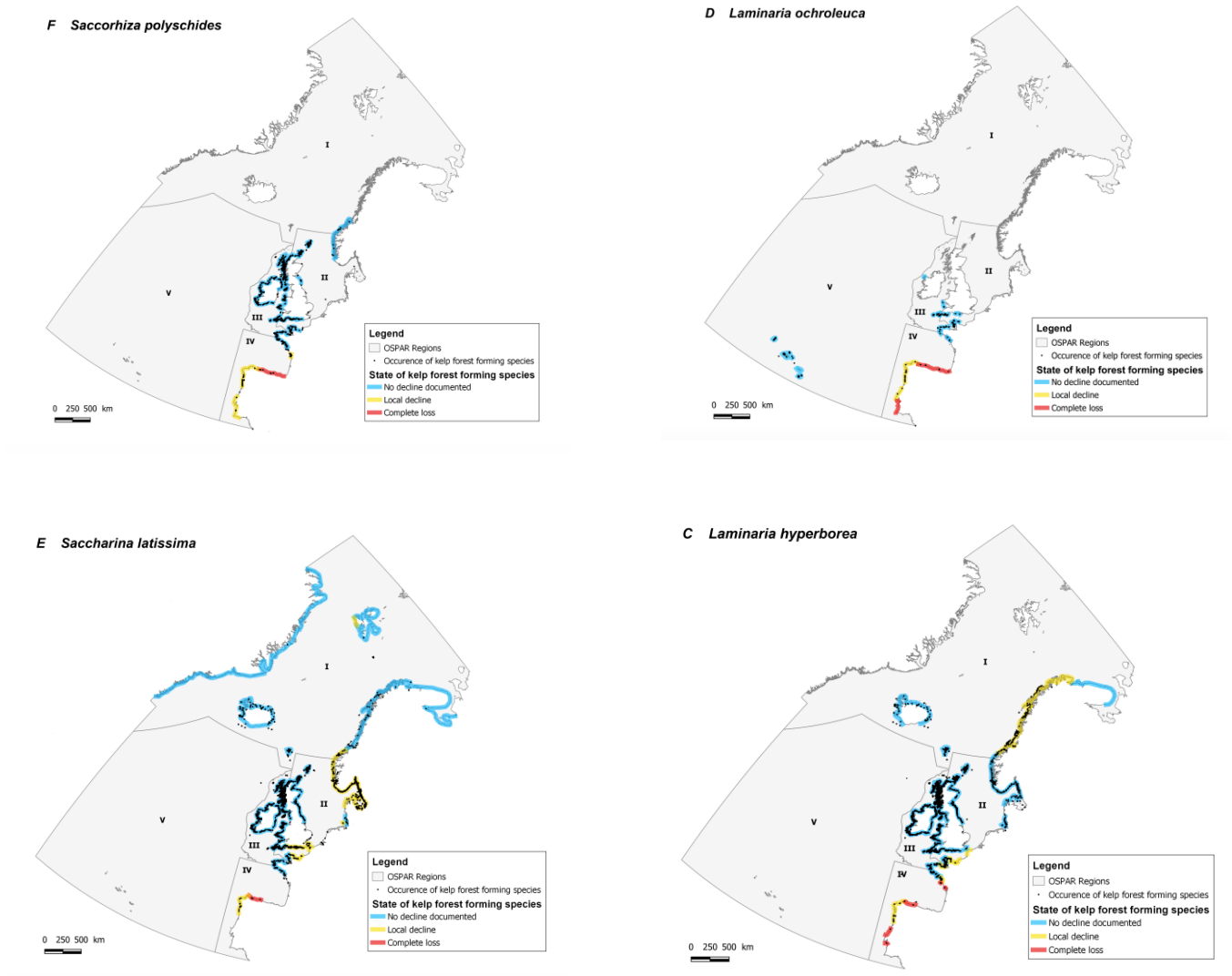
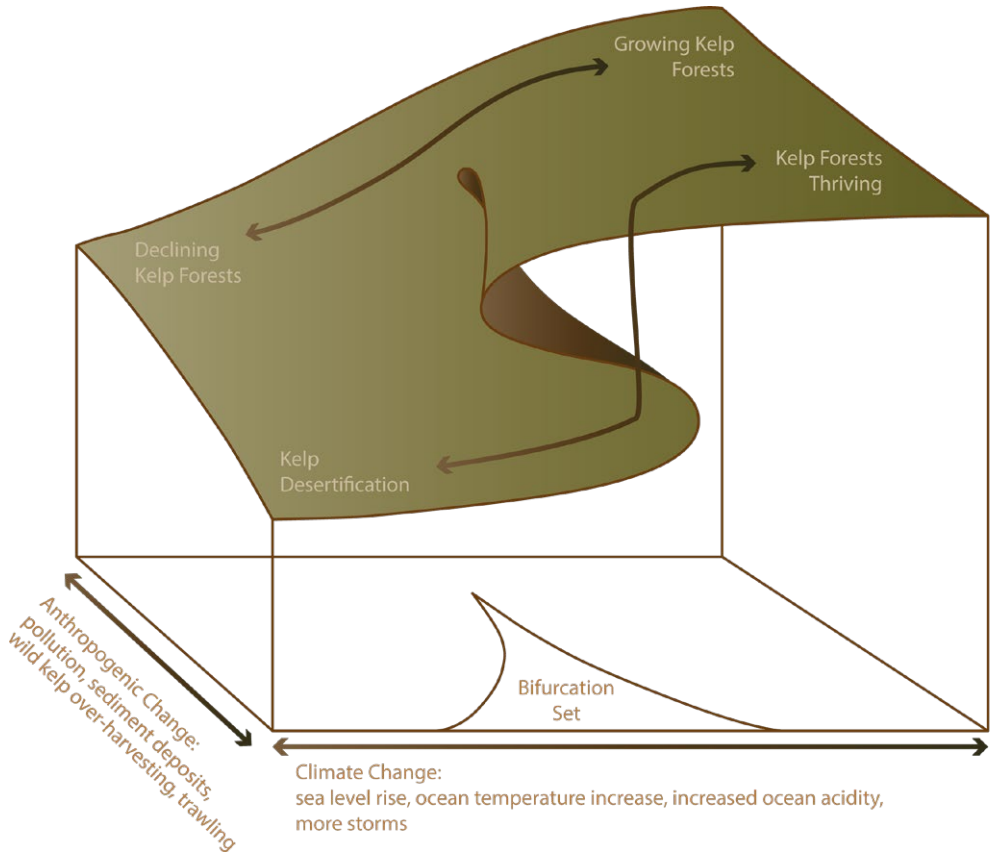


Fig.3 : These diagrams show different species of kelp / seaweeds and their state of declines in the OSPAR region

Fig.4 : Chilean wild kelp harvesting

Despite the efficiency of farming kelp, over-harvesting wild kelp is still an issue. Chile holds some of the largest kelp forests in the world and "accounts for nearly 40% of global harvesting of wild kelp"[4] while "only 5% of total seaweed production in the country comes from aquaculture"[5]. Kelp is a very efficient crop, and can grow at a rate of 2-3ft (60-90cm) per day[6], and is packed with nutrients, for example "1 hectare of a seaweed farm can produce more protein than the same amount of land used for cattle"[7]

Fig.5 : Catastrophe curve diagram, depicting kelp forest growth/decline



Kelp forest systems follow the curve catastrophe pattern by René Thom. Kelp Forest systems can change slowly, over a longer period in a sustained and consistent manner, however when certain parameters shift, the systems can radically jump to a large-scale loss as outlined in the diagram above.

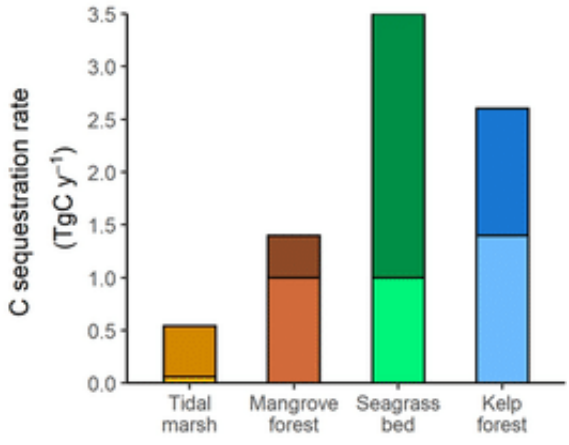


Fig.6 : Chart showing estimates for Kelp forest sequestration for vegetated coastal ecosystems in Australia

Kelp forests grow consistently in cool and nutrient rich waters near coastal areas which are (ideally) undeveloped or protected, allowing the symbiotic relationship between coastal/ marine plants and animals with the kelp forests. Sustainable and managed harvest of wild kelp is possible, farming is more efficient and sustainable; Kelp can be farmed where it would not naturally grow, it does not pollute or detriment local ecosystems and the process can clean the water, provide habitat for small wildlife all while sequestering CO_2e.

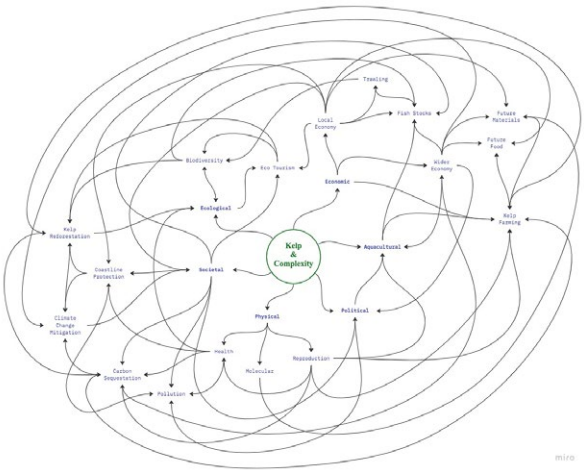


Fig.7 : Diagram showing interconnectedness of kelp systems

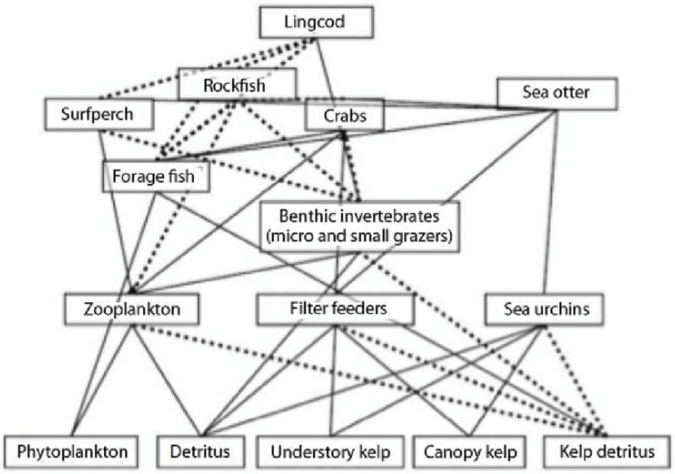


Fig.8 : Diagram showing interconnectedness of kelp ecosystems

Natural systems which degenerate kelp stocks, such as changing water temperatures, an influx of natural predators and water acidification are generally more manageable for forests, occurring slowly enough for adaption. Physical, biological and chemical issues caused by humans, such as anthropogenic climate change leading to rapid change in water temperatures, depths and acidification; poor fishing and coastline management systems (fewer predators of animals which eat the kelp); over pollution, sediment deposits, unsustainable coastline management, unsustainable / destructive fishing practices and the over-harvesting of wild kelp forests all detriment kelp forests too quickly for adaptation.

As Friedrich A. von Hayek wrote about in his paper 'The Theory of Complex Phenomena' there are both simple and complex phenomena, and while Karl Popper's falsification theory has merit, there are systems for which it is not an accurate or effective way to test, explore or derive answers, treating individual elements "as 'black boxes' which are presumed to be of the same kind but about whose identifying characteristics it has nothing to say"[8]. Due to Kelp forests complexity, they fail to garner as much support and research from scientists or the public as simpler phenomena.

To understand kelp forest systems, you must understand the integral interdependency of the elements which make them beneficial and difficult to predict. The immense diversity, complexity and deterministic chaotic nature of the system means there is no simple way to fully explain kelp forest systems, how they work or what they will do next. However, creating models, diagrams and looking at patterns of behaviour help us grasp what kelp forests really are without brutally trivialising the subject. The main issues causing the catastrophic level of kelp forest decline are predominantly anthropogenic; these challenges are the easiest to tackle, but for action to take effect many more people must embrace the complex nature and look for a deeper understanding of the importance of this vital ecosystem.

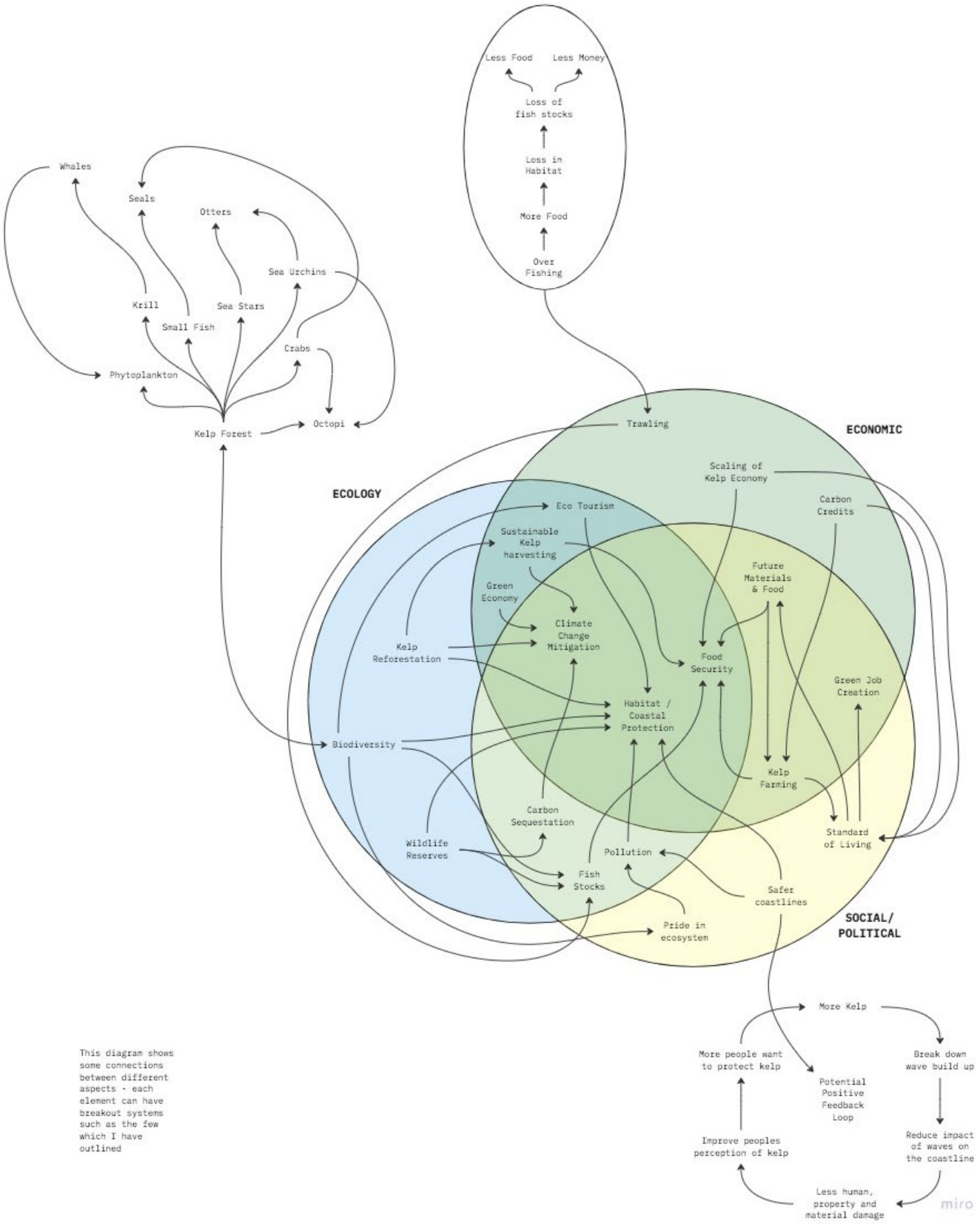


Fig.9 : Diagram showing interconnectedness of kelp systems

This Work Contains [999] Words (excluding captions & words in diagrams)

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3. J. Boyer, 'Miocene Epoch', Plant Evolution & Paleobotany, 14/11/22 < https://sites.google.com/site/paleoplant/geologic/phanerozoic/cenozoic/neogene/miocene>

4. Philip Hamilton Production, 'The Blue Forest', Minute 11', Waterbear, < https://www.waterbear.com/watch/mini-doc/61fa4e5ec9242e82f2c238c9>

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Figures:

Fig. 1 : Olivia Box, 'Turf Algae and Kelp Forests', JSTOR, 14/11/22, <https://daily.jstor.org/turf-algae-and-kelp-forests/>

Fig. 2 : Made by myself 13/11/22

Fig. 3 : Marie La Rivière, 'Case report for kelp forest habitat', OSPAR Commission, Page 8, 11/11/22, <https://www.ospar.org/documents?v=46871>

Fig. 4 : Raúl Súnico, 'Un paso adelante para seguir potenciando el interés comercial y productivo del recurso algal en Chile', PRENSA SUBPESCA, 15/11/22 < https://www.subpesca.cl/sitioprensa/614/w3-article-93443.html>

Fig. 5 : Made by myself 09/11/22

Fig. 6 : Karen Filbee-dexter / Thomas Wernberg, 'Kelp forest contribution to organic carbon standing stocks and sequestration', Research Gate, 15/11/22, < https://www.researchgate.net/figure/Kelp-forest-contribution-to-organic-carbon-standing-stocks-and-sequestration-rates-for_fig1_343161408>

Fig. 7 : Made by myself 09/11/22

Fig. 8 : Espinosa-Romero, 'Food web diagram of the kelp forest ecosystems on the west coast of Vancouver Island', ResearchGate, < https://www.researchgate.net/figure/Food-web-diagram-of-the-kelp-forest-ecosystems-on-the-west-coast-of-Vancouver-Island-by_fig11_233870619>

Fig. 9 : Made by myself 17/11/22