Depletion of Kelp Ecosystems on the East Coast of Tasmania – Impacts of Treatment Methods

Research Question: How do treatment methods such as lobster translocation and abalone smashing affect populations of Golden kelp (*E.radiata),* Long-spined sea urchins (*C.rodgersii)* and Southern Rock lobsters (*J.edwardsii)* populations along the East Coast of Tasmania over a period of two years?

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Word Count: 3821

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1. Introduction

Organisms are said to live in communities. A community can be described based on the dominant plant species present (kelp forests, for example). A community's organisms are dependent on other existing organisms present as well as by non-living, abiotic factors such as climate (Cambridge, IB Biology).

In alignment with the 14th Sustainable Development Goal (SDG), Life Below Water, the conservation of marine ecosystems, particularly kelp forest ecosystems, is imperative especially in the face of climate change. Kelp forests can store 20 times more carbon per acre than forests on land, serving as key defense against ocean acidification—an alarming consequence of climate change. However, recent surveys utilizing satellite, drone, and piloted aircraft imagery have revealed an alarming truth: over the past decade, 96% of kelp forests in the region have disappeared replaced by barrens of sea urchins (nature.org).

Climate change, marked by the relentless rise in global temperatures in many places across the globe, threatens these remarkable ecosystems. Giant kelp forests once covered Tasmania's entire east coast. But now, they're disappearing really quickly. In some places, only 5% of the original kelp forests are left (BBC news).

As with plants, animal enzymes are affected by temperature. The advantage of animals is that they can move to escape adverse conditions. (Cambridge, IB Biology).

Centrostephanus rodgersii, also known as the long-spined sea urchin, has undergone a range expansion caused by long-term oceanic warming and the poleward migration of its habitat from the coast of Australia's mainland to Tasmania, where it was historically absent. Due to overfishing, its primary predator – the spiny lobster *Jasus edwardsii*, has greatly decreased in population, facilitating the overgrazing of kelp species such as *Ecklonia radiata*. Globally, this has resulted in the formation of "urchin barrens," following kelp-deficient reefs with diminished productivity, biodiversity, and ecosystem function. These urchin barrens are sustained by feedback mechanisms that persist for extended periods and prove challenging to reverse as they are exacerbated by climate change. Thus, it circles back to adversely affecting the settlement and early survival of southern rock lobster; only to further reduce predation on *C.rodgersii*.

2. Background Information:

2.1 Tasmanian Ecosystem Overview

Fig.1. Schematic of main ocean currents
off eastern Australia and Tasmania | *Research Gate https://rb.gy/8csuos*

Every organism has its own specific ecological niche. Tasmania hosting many diverse marine species, each well suited to their niches suggests that it has a unique ecosystem. This can be attributed to environmental conditions shaped by the convergence of ocean currents surrounding Tasmania's coast.

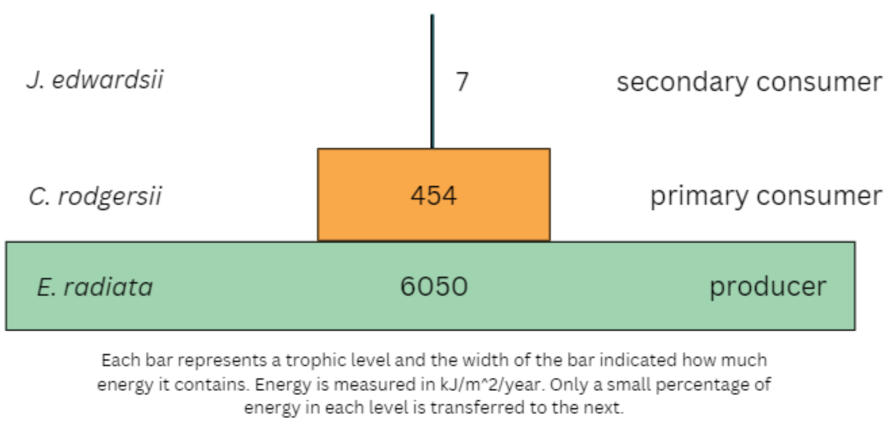

Fig.2. Pyramid of energy for a kelp ecosystem at Trumpeter Bay, Tasmania | *Diagram manually created*

As macroalgae, *E. radiata* carries out photosynthesize however, not all of energy emitted from the sun is use. Some is reflected back from the surface of its blades, some goes right through without being used and some is lost while respiration. Approximately 10% of the energy in producers is passed to herbivores such as *C. rodgersii*, and a similar percentage is passed from herbivores to carnivores like *J. edwardsii* (Cambridge, IB Biology). Gross primary production is represented by the lowest bar, which shows the amount of energy flowing through the producers.

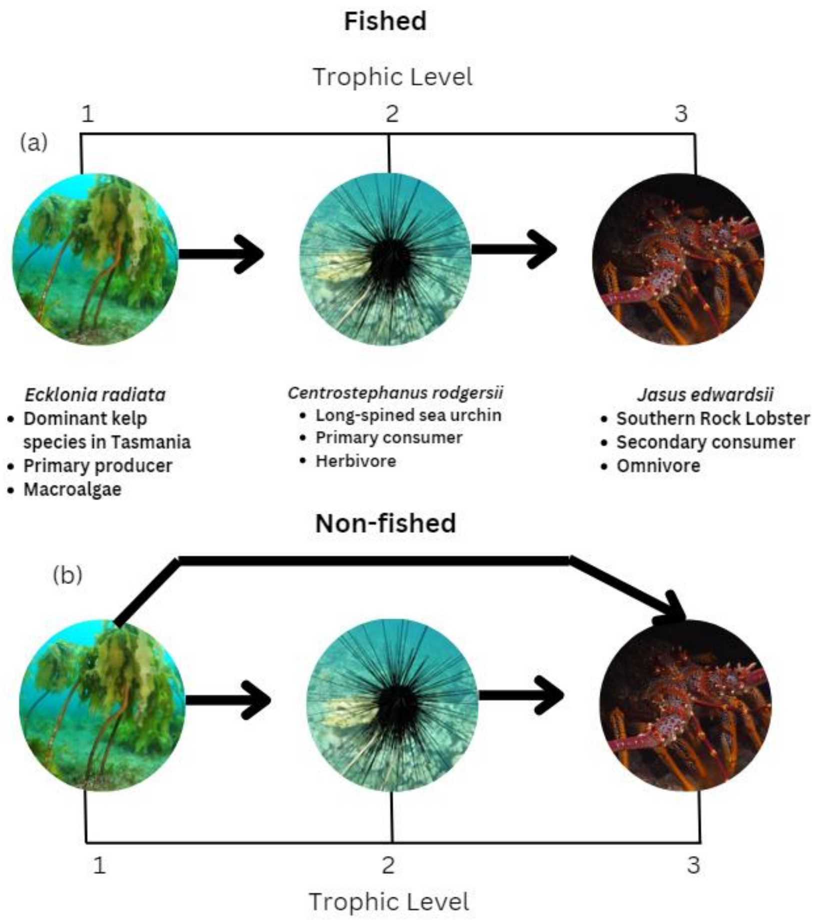

Fig.3. Food Chain | *Diagram manually created*

Fig. 1(a) illustrates the impact of fishing in kelp ecosystems. In these areas, lobster populations have decreased significantly under fishing pressure, leading to elevated sea urchin densities, the formation of urchin barrens, and a decline in kelp production.

(b) Conversely, in regions where lobster populations have rebounded due to protection, sea urchins that have not been consumed by these recovering predators hide in crevices. As a result, kelp forests, particularly those dominated by Ecklonia radiata, thrive in these protected areas, allowing lobsters to rely on them as well.

2.2 Tasmanian Coastal Threats

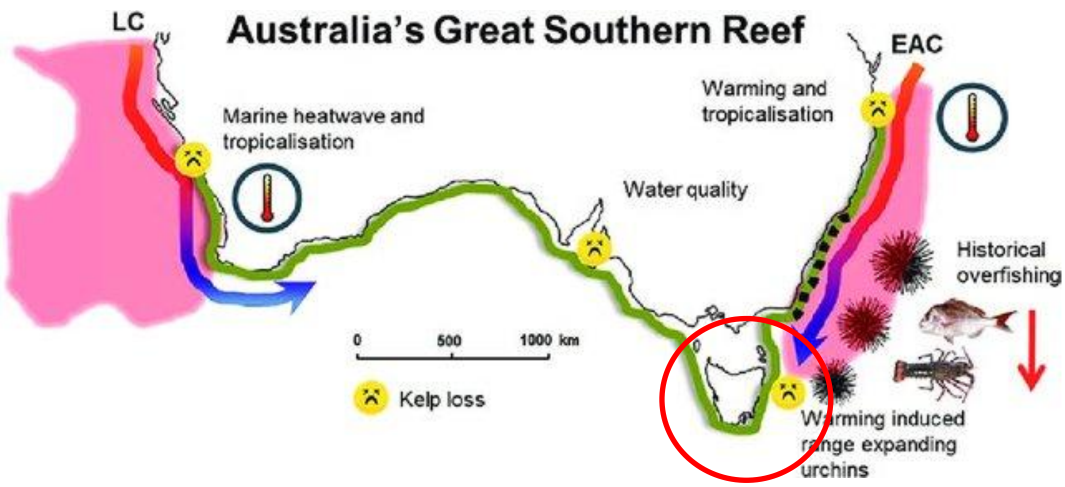

Fig.4. Regional drivers of *Ecklonia radiata* loss in Tasmania | *Research Gate https://rb.gy/vnqlb8*

The challenges of climate change and overfishing stand as significant threats to marine ecosystems across the world. The Tasmanian east coast experiences warming at a rate approximately four times higher than the global ocean average (ABC news). Annually, the climate change-intensified East Australian Current (EAC), warmed over the Pacific Ocean, carries a destructive, spiky species from New South Wales to the rocky reefs of eastern Tasmania (refer to Fig. 4).

As the atmosphere warms, it induces an increase in wind strength, compelling the current to extend further down the coast with greater force. This heightened warming trend has led to the migration of approximately 100 species into Tasmanian waters, southward along the Tasmanian east coast. Since the 1970s, there has been a surge in the population of *Centrostephanus rodgersii* (long-spined sea urchin) typically found in the temperate waters of the north. These urchins, known for sea floor grazing, pose a threat to kelp forests when congregated in large groups, referred to as barrens.

At the same time, intensive fishing practices of reef-based predators, including the spiny lobster *Jasus edwardsii* has heightened the vulnerability of kelp beds to the climate-driven proliferation of sea urchins.

Battling this catastrophical shift is challenging, given that the East Australian Current consistently brings new batches of urchin larvae down each year.

2.3 Relevance of Reproductive Biology

Understanding mating systems, breeding behaviors, and reproductive cycles allows researchers to predict when and where reproduction occurs, evaluate reproductive health, identify limitations in population growth, predict responses to environmental changes, and develop targeted conservation measures.

2.4 Importance of Kelp Forests in Marine Ecosystems

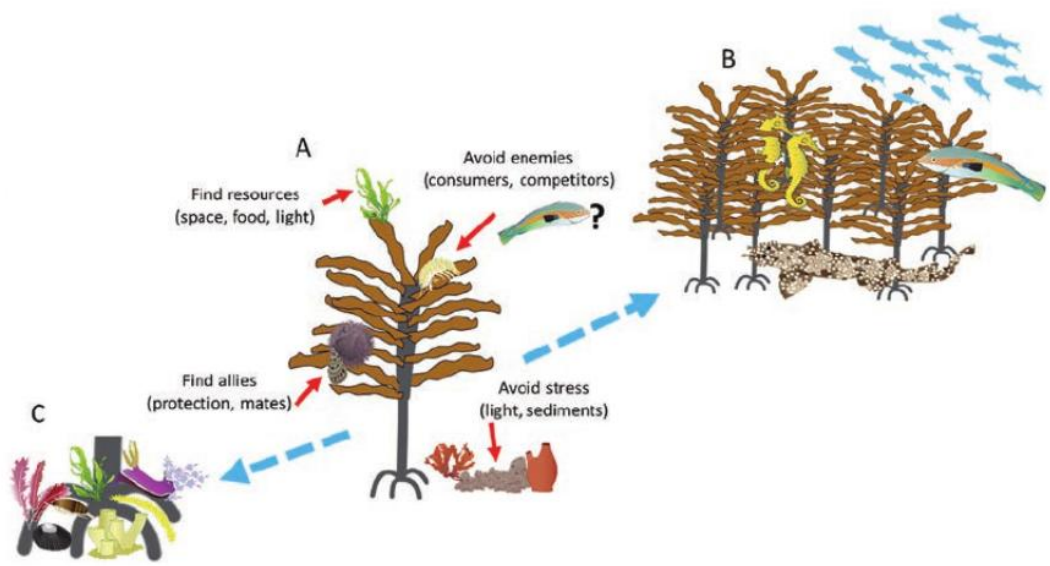

Fig.5. | *Integration and Application Network, University of Maryland Center for Environmental Science https://rb.gy/ee1y09*

Provides benefits like stress relief, protection from enemies to other species, scaling from (A) individuals up to (B) patch and landscape scales and (C) sub-individual structures

Kelp belongs to the group of Brown algae (*phaeophyta*) from the plant kingdom. Unlike other plants, kelp forests can grow on rocky reefs because of their distinct holdfast system. Rather than roots extending into the soil, kelp holdfasts attach to submerged rocks. The current speed inside a kelp forest is reduced by a drag created by the kelp plants, for a calmer environment, providing shelter for many invertebrates, fish, and marine mammals (NOAA fisheries). Being primary producers in most environmental food chains and webs of the ecosystem, kelp are known as foundational species. As it provides support to the whole ecosystem and species within it, it is known as a keystone species. As kelp is often accompanied by rapid growth rates, to limit their distribution, marine grazers such as urchins, fish, and snails often feed on them. However, in recent times, the overpopulation by some invasive species has threatened their populations severely.

2.4.1 Ecklonia radiata

Fig.6. *Ecklonia radiata* | Taxonomy derived from *WORMS (marinespecies.org)*

Globally one of the most widespread kelps, this Laminarian species dominates temperate reefs throughout Australasia and southeastern Africa. They form monospecific forests and are the only Laminarian kelp throughout their range. Warmer conditions have led to increased grazing pressure from herbivorous fish and sea urchins leading to deforestation. As a result, this species is becoming increasingly sparse and patchy in many locations across its range.

2.4.2 Life Cycle, Reproduction and Settlement

Ecklonia radiata undergoes a typical Laminarian life cycle, explained below in Fig. 7.

The species utilizes three modes of dispersal: zoospores, sperm, and the release of fertile drift material.

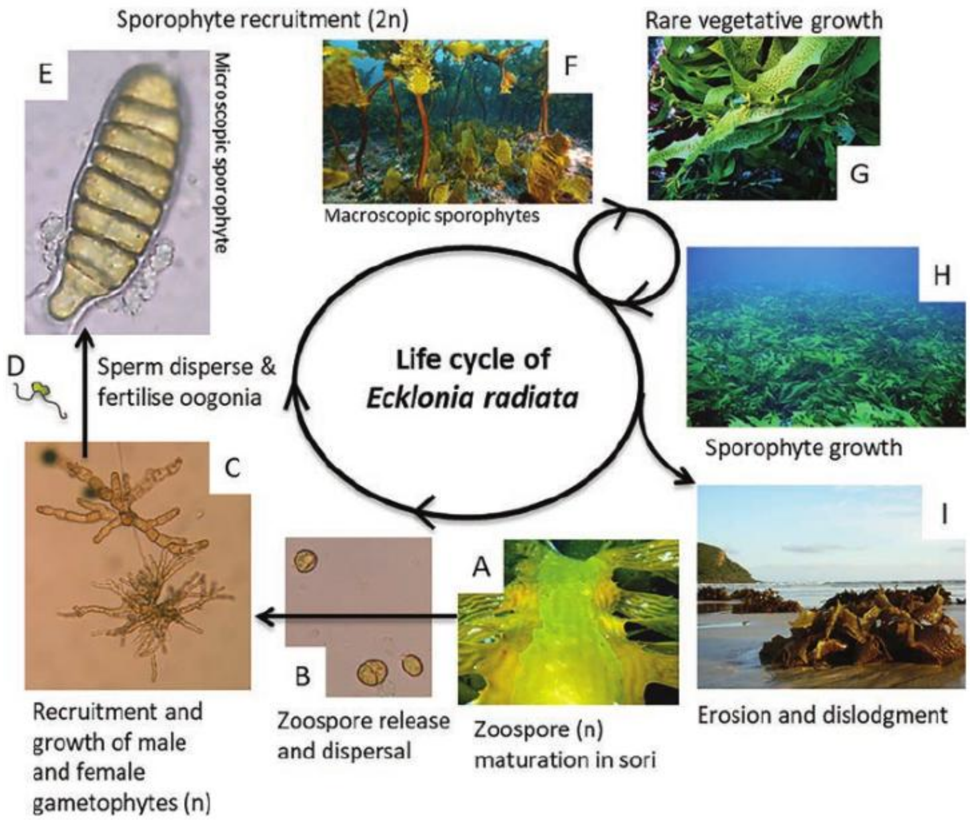

Fig.7. Life Cycle of *Ecklonia radiata* | *Biology and Ecology of the Globally Significant Kelp Ecklonia radiata (2009) https://rb.gy/ee1y09*

The life cycle of Ecklonia radiata: (A) Sporophytes bear reproductive sori releasing zoospores (B), which settle and develop into male and female gametophytes (C). (D) Fertilization of oogonia leads to juvenile sporophytes (E, F). Stages 1, 2, and 3 form dense forests (H). Some populations in Western Australia reproduce vegetatively (G). Sporophytes are often dislocated during storms, transporting detritus (I) to other habitats, providing spatial subsidies.

2.5 Importance of Sea Urchins in Marine Ecosystems

Being grazers (herbivores), sea urchins control the population of algae in a given area. However, their ability to reproduce in mass numbers serves as a disadvantage to many environments and these mass numbers often lead to overgrazing, which affects the whole ecosystem as reefs depend on algae as a main source of food, protection and habitat.

2.5.1 Centrostephanus rodgersii

Fig.8. *Centrostephanus Rodgersii | Red Map https://www.redmap.org.au/species/2/34/*

Taxonomy derived from *WORMS (marinespecies.org)*

A genus of the *Diadematidae* family, *Centrostephanus rodgersii*, commonly known as the long-spined sea urchin or black sea urchin, is a marine invertebrate echinoderm species found in the coastal waters of southern Australia, including Tasmania.

It is characterized by its large size, dark purple color, and long, slender spines that sometimes exhibit a green tinge when reflected in light. Their presence has led to the creation of 'white rock' areas due to the removal of kelp and other large macroalgae.

2.5.2 Life Cycle, Reproduction and Settlement

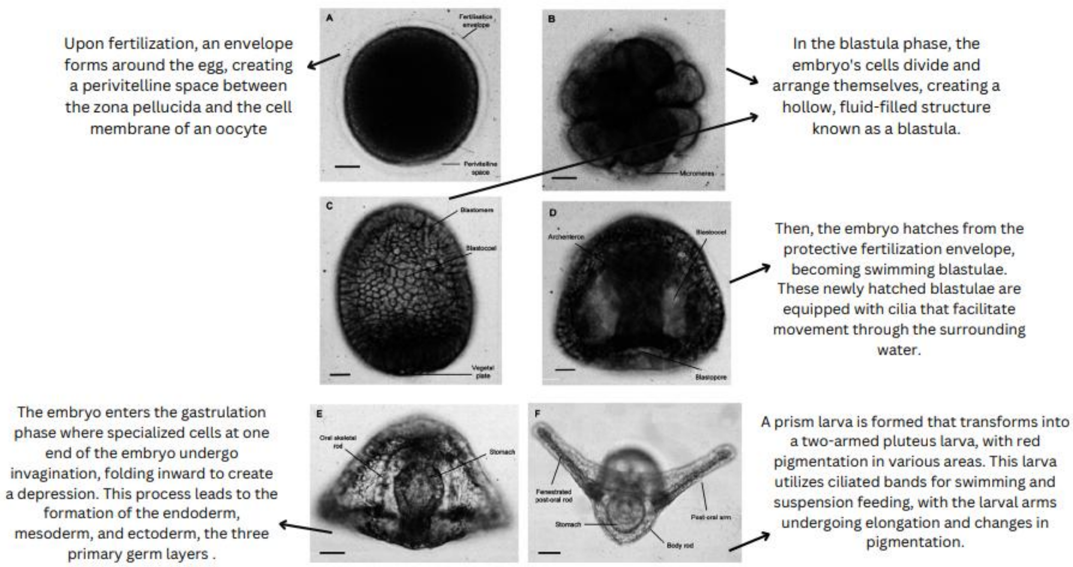

Fig.9. Larval Development of Sea Urchin *Centrostephanus Rodgersii | Personal Annotations, Fig. on Research Gate Invertebrate Reproduction & Development (2005) https://rb.gy/b2ce85*

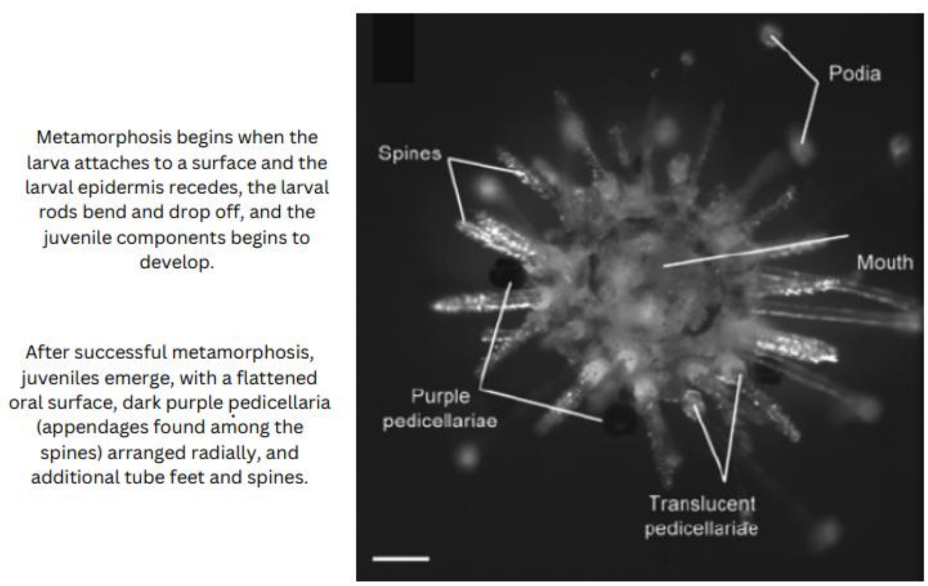

Fig.10. Metamorphosis of Sea Urchin *Centrostephanus rodgersii | Personal annotations, Fig. on Research Gate https://rb.gy/jjkz94*

2.6 Importance of Lobsters in Marine Ecosystems

Lobsters, as key predators, help control populations of invertebrates such as sea urchins, preventing overgrazing. Beyond their ecological significance, lobsters have economic importance as they support commercial fisheries and provide livelihoods for coastal communities.

2.6.1 Jasus edwardsii

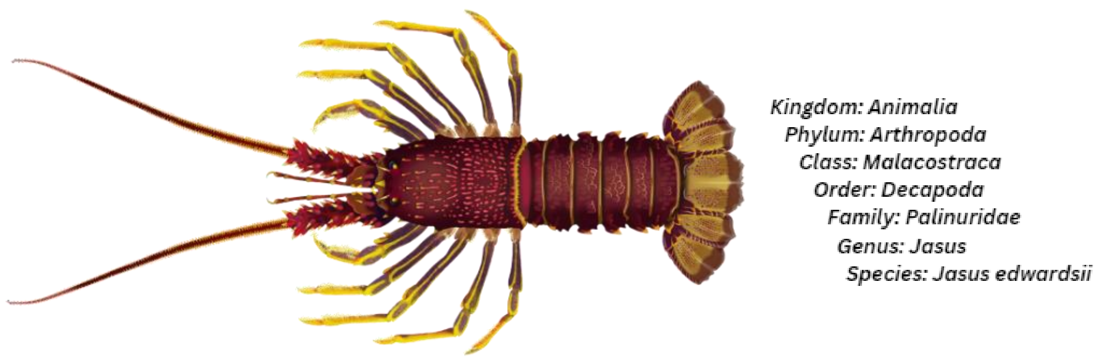

Fig.11. Vertical view of *Jasus edwardsii* | *Marinewise*

Taxonomy derived from *WORMS (marinespecies.org)*

Jasus edwardsii, or the southern rock lobster, spiny rock lobster, or red rock lobster is a species of spiny lobster that has an orange-red color in shallow water and two long spines projecting forward from the front of the carapace beside the eyes. The intensive fishing of *J. edwardsii*, especially targeting large individuals, has raised concerns on the impacts on kelp ecosystems. The removal of these predatory lobsters can compromises populations of kelp beds, as these predators regulate the populations of grazers like sea urchins.

2.6.2 Life Cycle, Reproduction and Settlement

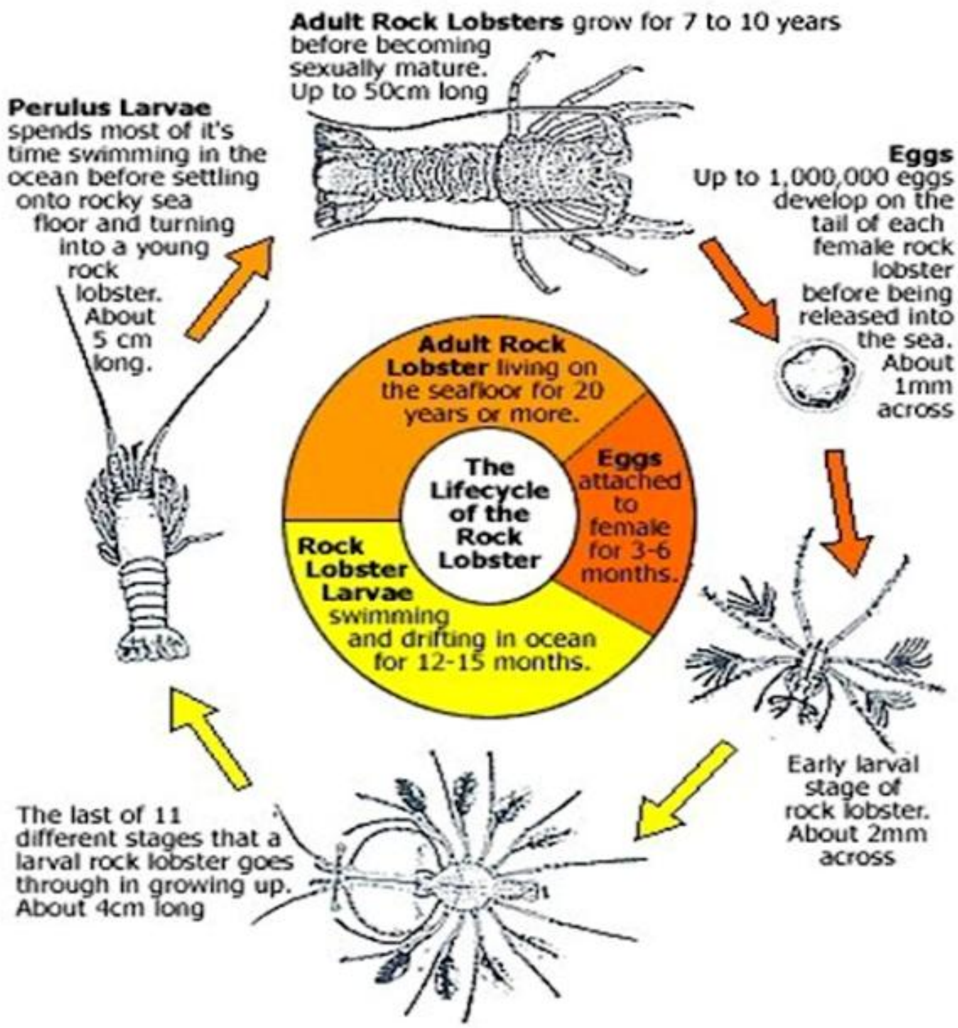

Fig.12. Stages of *Jasus edwardsii* from egg to adult | *New Zealand Rock Lobster Industry Council https://nzrocklobster.co.nz/lobster-facts/life-cycle/*

2.7 Overview of Treatment methods

1. **Abalone Smash (Urchin Culling) –** At initial stages when barrens occur as small patches in seaweed beds, divers can reduce *C. rodgersii* densities at local scales by culling or reaping to prevent barren habitat formation.
2. **Lobster Translocation –** Experiments (CR. Johnson, SD. Linghave) have shown clearly that populations of large lobsters prey heavily on invading urchins, thus attracting large rock lobsters to areas supporting established barrens and seaweed beds supporting *C. rodgersii,* would prevent their populations from increasing to the point where overgrazing occurs at a meso-scale.

3. Research question

Detailed research led me to formulate the research question to gain an in depth understanding of population dynamics between *C.rodgersii, E.radiata* and *J.edwardsii* and changes in their populations driven by factors such as climate change and overfishing.

How do treatment methods such as lobster translocation and abalone smashing affect populations of C.rodgersii, E.radiata and J.edwardsii populations along the East Coast of Tasmania over a period of two years?

3.1 Independent Variable: Treatment method: 1) Lobster Translocation 2) Abalone Smash

3.2 Dependent Variable*:* *E. radiata* (kelp) population, *C.rodgersii* (sea urchin) population, *J. edwardsii* (lobster) population over 2 years at yearly intervals.

East Tasmania was chosen as the location of study because it had the most extensive expanse of all three dependent variables.

3.3 Control Variables:

Table 1. Control Variables (Inclusion Criteria)

Control Variable	Method of control	Impact if not controlled
Sampling Methodology	Belt transect surveys were standardized for all sites to ensure consistency in sampling effort and data collection across sites.	Inconsistent survey techniques could have introduced bias into the results, leading to varying organism abundance numbers, causing discrepancies in the comparability of data between sites.
Time of Sampling	For a treated site and its corresponding control site, surveys were conducted at the same time of year with a nearly equal duration (1 year) between each sample collection.	If surveys were not conducted consistently, seasonal variations in biological activity could have biased the results. Longer duration between sample collections for one site will cause discrepancies in data collection when comparing numbers to that of its corresponding site.
Location of all control and treated sites	Similarity in water temperature, salinity, depth, substrate type, exposure to wave action was ensured between treated and control sites.	Variations in these conditions may lead to differences in habitat suitability, affecting the distribution and abundance of organisms independently of the treatment.

3.4 Exclusion Criteria:

- Human activities such as fishing pressure, pollution, or recreational activities may directly or indirectly alter benthic habitats, making it difficult to isolate the effects of the treatment from other environmental stressors.
- Unaccounted species interactions could have influenced the abundance of target organisms, potentially masking or confounding the effects of the treatment. Interactions with other species, not included in the study, may lead to misinterpretation of the results.

3.5 Hypothesis:

In response to the research question, I believe that in response to abalone smashing or lobster translocation there will be a revival of kelp forests and populations. Supporting this is the fact that there will be an increase in lobster populations, which will help control and decrease urchin populations that prey on kelp, in turn increasing kelp populations.

The cascading effect of fewer urchins within the food chain will likely cause kelp populations to rebound. This is known as a trophic cascade, where reciprocal changes occur in species abundances and ecosystem structures due to shifts in predation pressures.

4. Methodology

A commonly used sampling method in ecology is transects. Transects show distributions of species based on abiotic factors or changes in communities across habitats (*Cambridge, IB Biology*).

Depending upon the terrain and the organisms present, the most adequate type of transect is chosen. To answer the research question, it may be better to carry out a continuous 'belt' transect where all species in a 1 m zone are recorded to provide a detailed picture of the area as it is focused on the East Coast Tasmania.

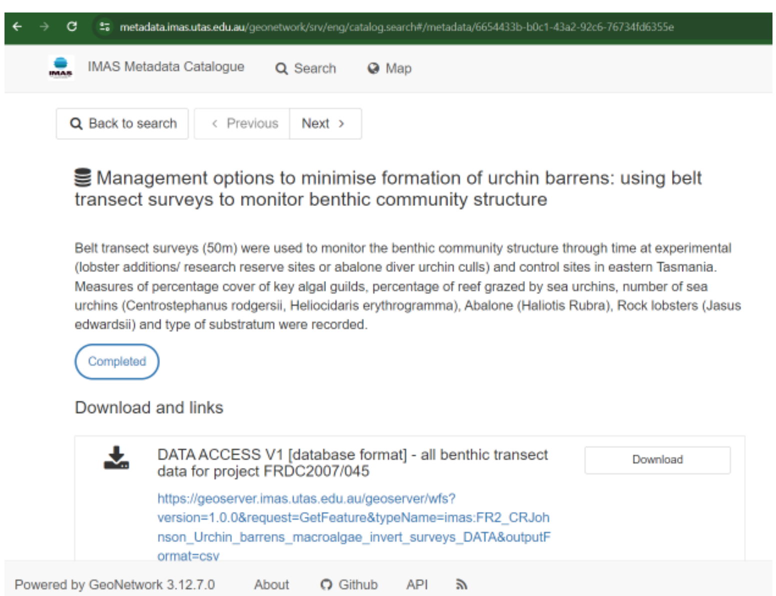

Fig.13. Screenshot of data acquired from *IMAS Catalogue that was sourced from GBIF*

Secondary data was used due to lack of time and expertise in field work for this particular study. It was challenging to collect data through experimentation or find a simulation that could test my hypothesis.

Thus, for the purpose of data collection, the Global Biodiversity Information Facility (GBIF) website was used to explore raw data provided by various sources. Most sources had a comparatively smaller amount of data or had too many discrepancies over the years. After careful consideration, it was deduced that the data based on belt transect surveys at selected research and control sites on the east coast Tasmania, Australia published by CSIRO National Collections ad Marine Infrastructure (NCMI) Information and Data Centre (IDC), would be best suited to explore this research question.

These surveys covered a distance of 50 meters, providing a standardized approach for sampling benthic communities. Such a method ensures reliability of the dataset, thus providing substantial data for the analysis of the topic being addressed in this essay.

The data extracted was based on *Centrostephanus rodgerii* numbers, *Jasus edwardsii* and *Ecklonia radiata* numbers of twelve sites over two years ranging from 2008-2011; the kelp and barren habitats in Bunker Bay, St. Helen's Island, and Trumpeter Bay treated with urchin culling and their respective control sites in Mistaken Cape, Sloop Rock, and Wineglass Bay and the kelp and barren habitats in Elephant Rock and North Bay treated with lobster translocation and their respective control sites in Sloop Rock and Cape PL.

The file downloaded from the link shown in Fig. 13 depicted raw data that was filtered year wise and species wise to be extracted from over 7500 rows and 70 columns of data. From the data collected transect wise; the total sum of each of the three species from each site at each period with its specific treatment was calculated. Reorganization and compression of all data was done in tables that were classified period, treatment and site wise to come to a total of 45 rows 6 columns.

Fig.14. Spatial Extent of study and data collected | University of Tasmania through the Institute for Marine and Antarctic Studies
https://metadata.imas.utas.edu.au/geonetwork/srv/eng/catalog.search#/metadata/6654433b-b0c1-43a2-92c6-76734fd6355e

5. Processing Data & Analysis

Treatment 1: Lobster Translocation

Lobster Translocation 1 (a)				Lobster Control 1 (b)			
No. of years	**E.radiata**	**C.rodgersii**	**J.edwardsii**	**No. of years**	**E.radiata**	**C.rodgersii**	**J.edwardsii**
0	6460	1064	2	0	6058	1130	3
1	4820	769	5	1	4764	1197	1
2	4473	822	3	2	5053	931	0

Table 2 (a) Lobster Translocation at Elephant Rock (kelp region) and (b) Control at Sloop Rock (kelp region)

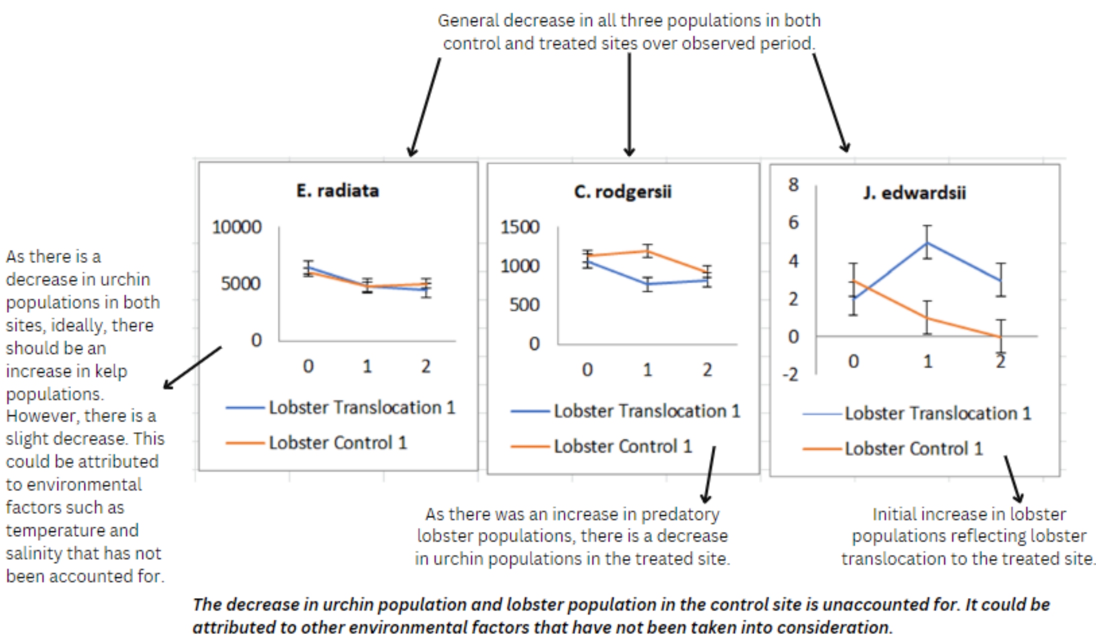

Figure 14 Kelp, urchin and lobster populations against time as a result of Lobster Translocation (Trial 1)

Lobster Translocation 2 (a)				Lobster Control 2 (b)			
No. of years	**E.radiata**	**C.rodgersii**	**J.edwardsii**	**No. of years**	**E.radiata**	**C.rodgersii**	**J.edwardsii**
0	1381	45	0	0	1342	394	0
1	1176	1044	2	1	1378	6	0
2	1219	483	3	2	1208	688	0

Table 3 (a) Lobster Translocation at Elephant Rock (barren region) and (b) Control at Sloop Rock (barren region)

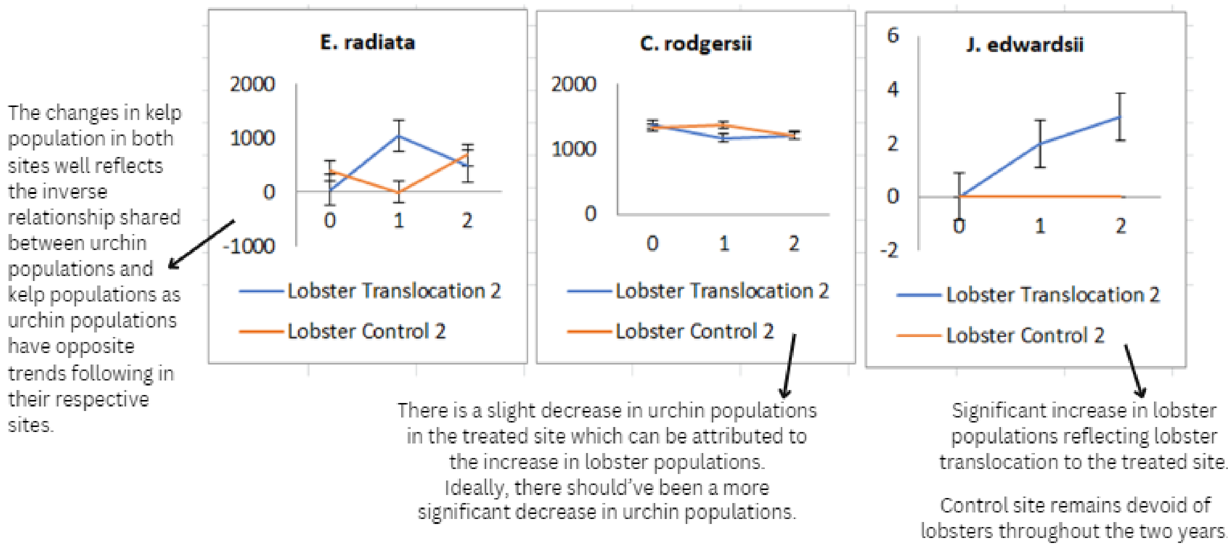

Fig.15. Kelp, urchin and lobster populations against time as a result of Lobster Translocation (Trial 2)

Lobster Translocation 3 (a)				Lobster Control 3 (b)			
No. of years	**E.radiata**	**C.rodgersii**	**J.edwardsii**	**No. of years**	**E.radiata**	**C.rodgersii**	**J.edwardsii**
0	3274	70	7	0	5043	57	15
1	3455	29	11	1	4020	64	11
2	2861	27	12	2	4845	64	19

Table 4 (a) Lobster Translocation at North Bay and (b) Control at Cape Pillar

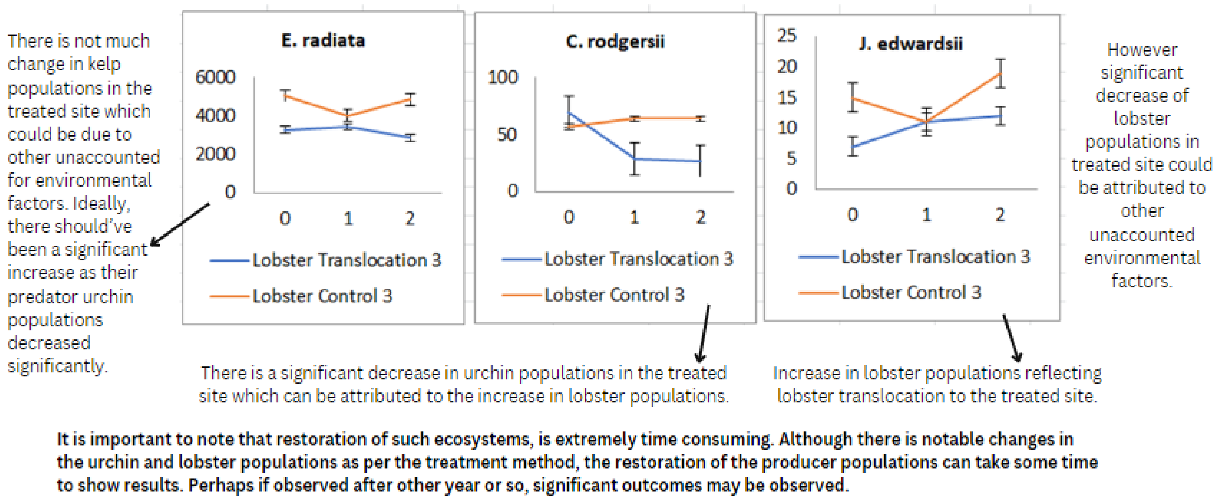

Fig.16. Kelp, urchin and lobster populations against time as a result of Lobster Translocation (Trial 3)

While the lobster translocation method demonstrates initial positive outcomes, such as an increase in *Jasus edwardsii* populations and short-term control of *Centrostephanus rodgersii* in certain scenarios, concerns arise regarding the sustainability of these effects over time. The success of lobster translocation is not very clear, necessitating a better understanding of species interactions, habitat suitability, and the potential of indirect effects.

Treatment 2: Abalone Smash

Abalone Smash 1 (a)				Abalone Control 1 (b)			
No. of years	**E.radiata**	**C.rodgersii**	**J.edwardsii**	**No. of years**	**E.radiata**	**C.rodgersii**	**J.edwardsii**
0	6625	657	0	0	4764	1197	1
1	6163	448	6	1	5053	931	0
2	6067	395	2	2	4925	1006	1

Table 5 (a) Abalone Smash at St. Helen's Island and (b) Control at Sloop Rock

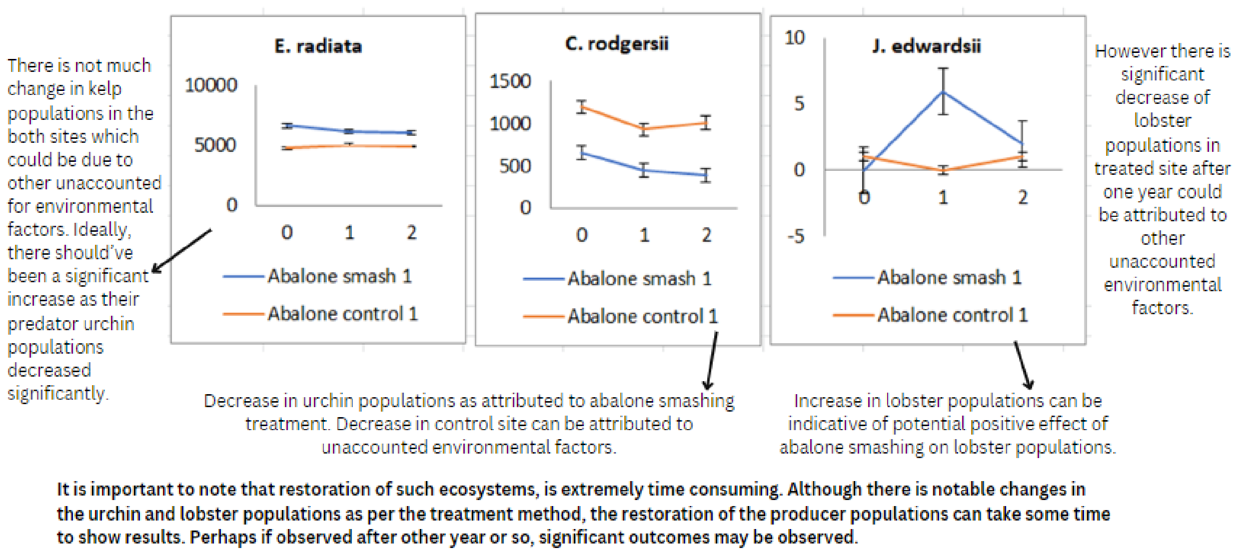

Fig.17. Kelp, urchin and lobster populations against time as a result of Abalone Smash (Trial 1)

Abalone Smash 2 (a)				Abalone Control 2 (b)			
No. of years	**E.radiata**	**C.rodgersii**	**J.edwardsii**	**No. of years**	**E.radiata**	**C.rodgersii**	**J.edwardsii**
0	6269	415	1	0	5925	311	20
1	5305	423	5	1	4585	245	28
2	6050	454	7	2	5215	161	1

Table 6 (a) Abalone Smash at Trumpeter Bay and (b) Control at Wineglass Bay

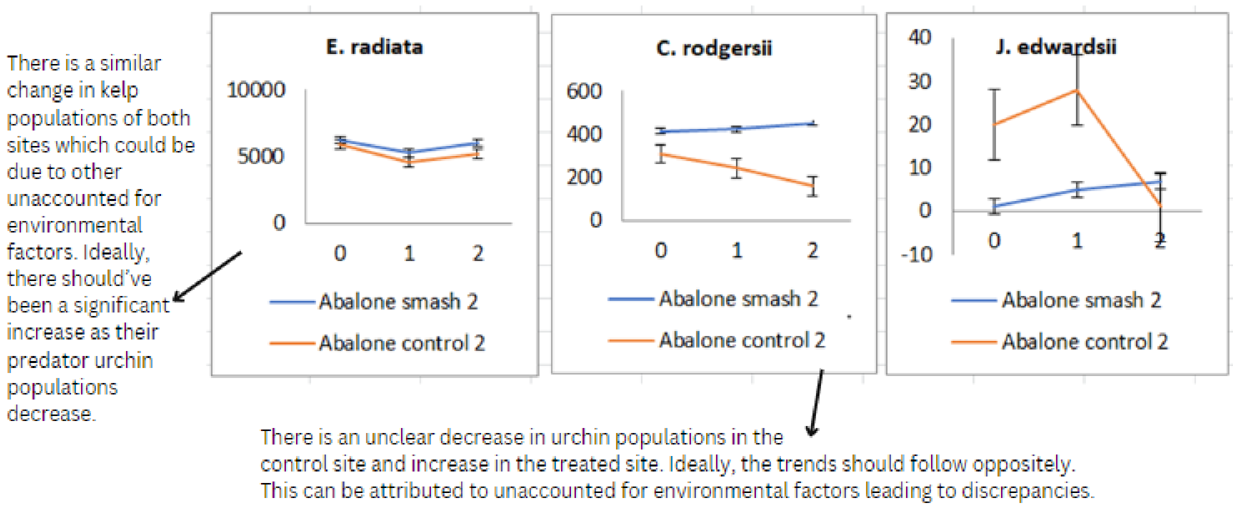

Fig.18. Kelp, urchin and lobster populations against time as a result of Abalone Smash (Trial 2)

Abalone Smash 3 (a)				Abalone Control 3 (b)			
No. of years	E.radiata	C.rodgersii	J.edwardsii	No. of years	E.radiata	C.rodgersii	J.edwardsii
0	8155	315	2	0	7300	430	2
1	5490	228	5	1	4958	409	1
2	7615	229	6	2	6685	422	4

Table 7 (a) Abalone Smash at Bunker Bay and (b) Control at Mistaken Cape

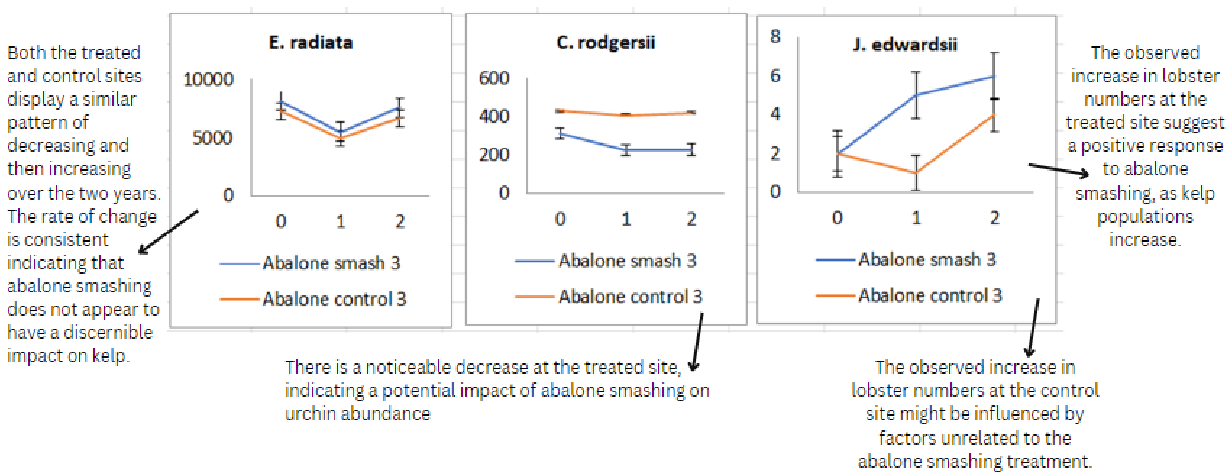

Fig.19. Kelp, urchin and lobster populations against time as a result of Abalone Smash (Trial 3)

The treatment method demonstrates a significant impact on reducing *Centrostephanus rodgersii* abundance, particularly evident in the treated sites. The initial positive response of *Jasus edwardsii* in some instances suggests potential benefits for lobster populations, but the sustained effects over time raise concerns. The consistent patterns in *Ecklonia radiata* numbers across treated and control sites indicate that abalone smashing may have a less pronounced impact on kelp abundance.

6. Analysis

Cumulating all data from each of the six sites, with one column being *Centrostephanus rodgersii* numbers and another being *Ecklonia radiata* numbers, a Pearson correlation coefficient test is applied to confirm the nature of correlation and the relationship between the two variables. The same is repeated in terms of *Centrostephanus rodgersii* numbers and *Jasus edwardsii* numbers, and *Jasus edwardsii* numbers and *Ecklonia radiata* numbers to gain an understanding of their relationships.

6.1 Hypotheses for Statistical Calculation:

There are three sets of hypotheses that are to be considered to evaluate the relationship between all three species and their dependence on each other.

Centrostephanus rodgersii and Ecklonia radiata:

Null Hypothesis (H0): There is no significant correlation between *Centrostephanus rodgersii* populations and *Ecklonia radiata* populations.

Alternative Hypothesis (H1): There is a significant negative correlation between *Centrostephanus rodgersii* populations and *Ecklonia radiata* populations.

Centrostephanus rodgersii and Jasus edwardsii:

Null Hypothesis (H0): There is no significant correlation between *Centrostephanus rodgersii* populations and *Jasus edwardsii* populations.

Alternative Hypothesis (H1): There is a significant negative correlation between *Centrostephanus rodgersii* populations and *Jasus edwardsii* populations.

Jasus edwardsii and Ecklonia radiata:

Null Hypothesis (H0): There is no significant correlation between *Jasus edwardsii* populations and *Ecklonia radiata* populations.

Alternative Hypothesis (H1): There is a significant positive correlation between *Jasus edwardsii* populations and *Ecklonia radiata* populations.

6.2 Calculations:

Pearson's Correlation Coefficient – Centrostephanus rodgersii (X) & Ecklonia radiata (Y)

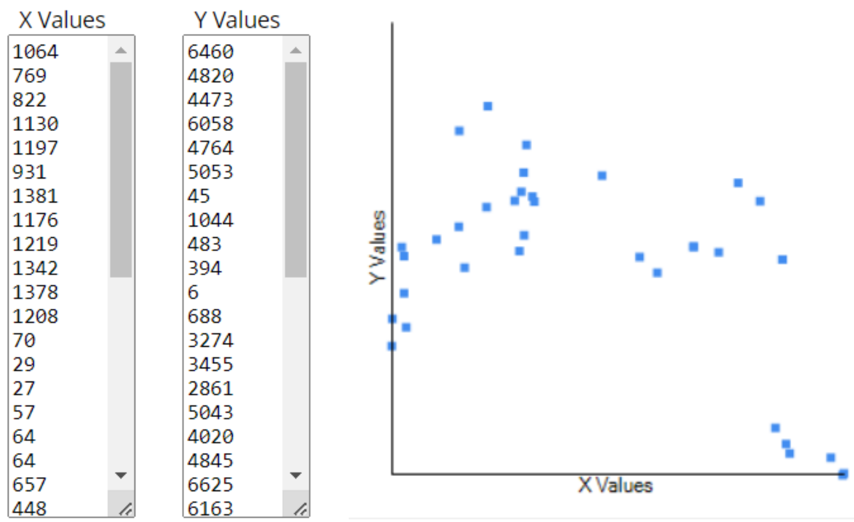

Fig.20. C.rodgersii (X) & E.radiata (Y) data input

Calculations & Result

X Values
∑ = 22604
Mean = 627.889
∑(X - Mx)2 = SSx = 7309767.556

Y Values
∑ = 164935
Mean = 4581.528
∑(Y - My)2 = SSy = 167835988.972

X and Y Combined
N = 36
∑(X - Mx)(Y - My) = -17721665.889

R Calculation
r = ∑((X - My)(Y - Mx)) / √((SSx)(SSy))
r = -17721665.889 / √((7309767.556)(167835988.972)) = **-0.506**

Key

X: X Values
Y: Y Values
M_x: Mean of X Values
M_y: Mean of Y Values
$X - M_x$ & $Y - M_y$: Deviation scores
$(X - M_x)^2$ & $(Y - M_y)^2$: Deviation Squared
$(X - M_x)(Y - M_y)$: Product of Deviation Scores

Although the relationship between the variables is moderate, there is a negative correlation. The negative sign indicates an inverse relationship, while how close the coefficient is to 0 helps deduce the strength of the relationship.

Pearson's Correlation Coefficient – Centrostephanus rodgersii (X) & Jasus edwardsii (Y)

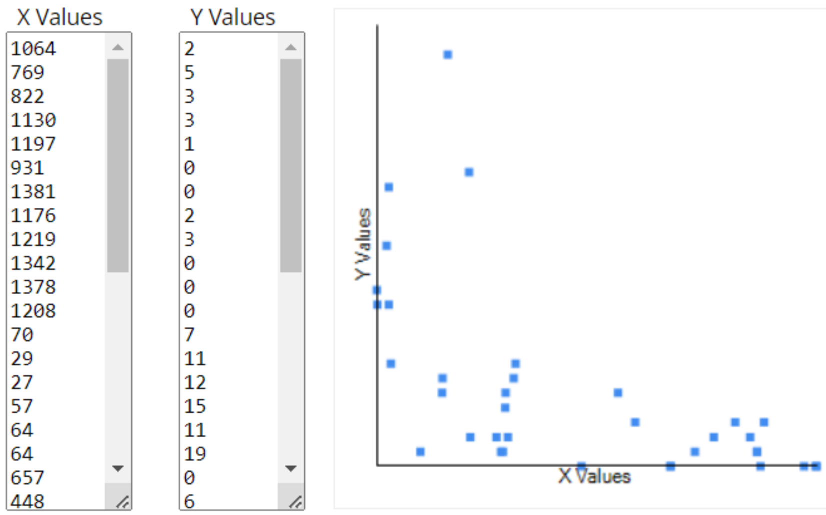

Fig.21. C.rodgersii (X) & J.edwardsii (Y) data input

Calculations & Result

Key

X: X Values
Y: Y Values
M_x: Mean of X Values
M_y: Mean of Y Values
$X - M_x$ & $Y - M_y$: Deviation scores
$(X - M_x)^2$ & $(Y - M_y)^2$: Deviation Squared
$(X - M_x)(Y - M_y)$: Product of Deviation Scores

X Values
∑ = 22604
Mean = 627.889
∑(X - Mx)2 = SSx = 7309767.556

Y Values
∑ = 186
Mean = 5.167
∑(Y - My)2 = SSy = 1509

X and Y Combined
N = 36
∑(X - Mx)(Y - My) = -63113.333

R Calculation
r = ∑((X - My)(Y - Mx)) / √((SSx)(SSy))
r = -63113.333 / √((7309767.556)(1509)) = **-0.6009**

Although the relationship between the variables is moderately strong, there is a negative correlation.

Pearson's Correlation Coefficient – Jasus edwardsii (X) & Ecklonia radiata (Y)

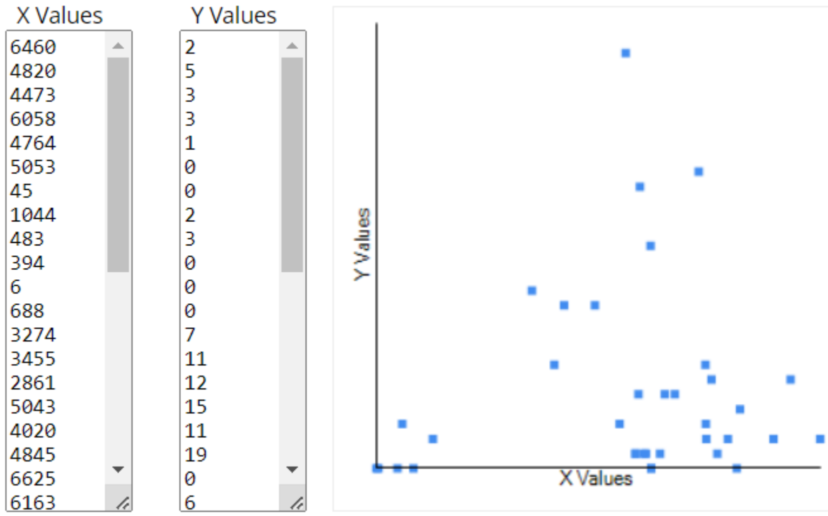

Fig.22. J.edwardsii (X) & E.radiata (Y) data input

Calculations & Result

Key

X: X Values
Y: Y Values
M_x: Mean of X Values
M_y: Mean of Y Values
$X - M_x$ & $Y - M_y$: Deviation scores
$(X - M_x)^2$ & $(Y - M_y)^2$: Deviation Squared
$(X - M_x)(Y - M_y)$: Product of Deviation Scores

X Values
∑ = 164935
Mean = 4581.528
∑(X - Mx)2 = SSx = 167835988.972

Y Values
∑ = 186
Mean = 5.167
∑(Y - My)2 = SSy = 1509

X and Y Combined
N = 36
∑(X - Mx)(Y - My) = 53712.833

R Calculation
r = ∑((X - My)(Y - Mx)) / √((SSx)(SSy))
r = 53712.833 / √((167835988.972)(1509)) = **0.1067**

Although the relationship between the variables is weak, there is a positive correlation. The positive value indicates a direct relationship.

7. Conclusion

Observing the data tables and the data processing methods, it is clear that the data collected and processed could help answer the research question and define a relationship between dependent and independent variables.

The analysis utilized the Pearson correlation coefficient to assess the strength and direction of the relationship between these two ecological variables.

The Pearson correlation coefficient (r) calculated for the combined data of *Centrostephanus rodgersii* numbers and *Ecklonia radiata* numbers from the selected sites was deduced to a value of approximately -0.506.

The calculated Pearson correlation coefficient of approximately -0.506 implies a moderate, negative correlation between *Centrostephanus rodgersii* populations and *Ecklonia radiata* populations at the selected sites. While the negative correlation indicates that as sea urchin populations decrease, kelp abundance increases, the magnitude of the coefficient (closer to zero) helps us deduce that this relationship is moderately strong.

Hence, the null hypothesis is rejected and the alternative hypothesis is accepted.

The Pearson correlation coefficient (r) calculated for the combined data of *Centrostephanus rodgersii* numbers and *Jasus edwardsii* numbers from the selected sites was deduced to a value of approximately -0.6009.

The calculated Pearson correlation coefficient of approximately -0.6009 implies a moderately strong, negative correlation between *Centrostephanus rodgersii* populations and *Jasus edwardsii* populations at the selected sites. While the negative correlation indicates that as sea urchin populations decrease, lobster population increases, the magnitude of the coefficient (closer to zero) helps us deduce that this relationship is also moderately strong.

Hence, the null hypothesis is rejected and the alternative hypothesis is accepted.

The Pearson correlation coefficient (r) calculated for the combined data of *Jasus edwardsii numbers* and *Ecklonia radiata* numbers from the selected sites was deduced to a value of approximately 0.1067.

The calculated Pearson correlation coefficient of approximately 0.1067 implies a weak, positive correlation between *Jasus edwardsii* populations and *Ecklonia radiata* populations at the selected sites. While the positive correlation indicates that as kelp numbers increase, lobster populations also increase, the magnitude of the coefficient (closer to zero) helps us deduce that this relationship is weak. This can be attributed to the fact that while *Jasus edwardsii* is somewhat relies on *Ecklonia radiata* for survival, it is not entirely dependent on it.

Hence, the null hypothesis is rejected and the alternative hypothesis is accepted.

Overall, my main hypothesis is proven true only to an extent; there is little effect of treatment methods on kelp populations over two years, perhaps because the time period of observation and data collection was too miniscule. However, as suggested by statistics, there is a significant relationship between all three species, thus over a longer period of time, we may be able to see stronger evidence of the effect on treatment methods on restoring kelp populations.

Supporting my hypothesis is a study by S. D. Linga, C. R. Johnsona, S. D. Frusher, and K. R. Ridgway where they used sea surface temperature data collection, remote video observation of predatory interactions on sea urchins and translocation of tagged sea urchins to discover that kelp beds are more vulnerable to overgrazing where overfishing is prominent, reducing occurrences of effective predators such as lobsters.

In response to these findings, several management strategies can be implemented to mitigate the risk of barren formations and aid in the recovery of urchin barrens.

1. Long-spined Sea Urchin Harvest Industry: Promoting the harvest of long-spined sea urchins can help control their populations and alleviate the pressure on kelp habitats.
2. Autonomous Underwater Vehicles: These specialized vehicles are capable of operating at significant depths, where manual diving becomes challenging. AUVs navigate across reefs, locating sea urchins and effectively managing their populations by urchin culling or abalone smashing as observed as a treatment method in this study.

By implementing these management measures, efficient efforts can be put towards restoring the ecological balance of kelp habitats of eastern Tasmania, and other parts of the world.

8. Evaluation

8.1 Evaluation of Methodology:

Due to lack of feasibility of experimental procedures, primary research was not possible to be conducted as a student. The use of large data bases compensated for the lack of primary research. With the reliance on secondary data, a few issues arise, such as the reliability of data provided by GBIF.org, and the discrepancy between data collection periods and the reliance on human observation.

8.2 Ethical Considerations:

No unethical objections were raised when data was derived from easily accessible websites, being an open source library of data.

8.3 Strengths:

Approximately 7000 rows of data were processed with precision and accuracy, as well as the use of various scientific sources such as IMAS and PNAS to analyze the data which hold scientific research to the highest standards, proving the reliability and ethical nature of the data set from which accurate inferences are drawn that are relevant to the research question.

The consistent use of belt transects surveys, which standardize data collection through 50-meter linear paths, provides systematic and comparable measurements across different sites and time points also improves reliability and accuracy of the dataset. The inclusion of both treated sites and control sites allows for a better comparison of increased/decreased numbers of urchins and lobsters and their effect on the kelp numbers.

8.4 Areas of Improvement:

However, there are some weaknesses and criticisms to be made with regards to such a methodology.

Area	Mitigation Strategy
The natural variability between treatment and control sites, including differences in temperature, ecology, and other environmental factors.	Select control sites in close proximity to treatment sites with similar environmental conditions.
Populations of sea urchins and lobsters, as well as kelp abundance, have seasonal fluctuations due to factors such as water temperature, nutrient availability, and reproductive cycles.	Conduct belt transect surveys at multiple sites over extended time periods to capture seasonal trends and fluctuations.
Limited availability of funding, personnel, and resources may hinder the ability to conduct extensive data collection over prolonged periods.	Secure funding and personnel resources to support extended data collection periods.
(Reliance on human observation) Variations in observer bias and inconsistencies in data collection methods may introduce errors and inaccuracies, compromising the reliability and validity of the study findings.	Implement thorough training and standardization protocols to minimize observer bias and ensure consistent data collection methods.
A limited data collection period does not help understand long-term trends resulting in a weak understanding of the study's implications over time.	Extend the data collection period over several years to detect trends.

8.5 Error Analysis:

By adding error bars to the graphs, the potential scope of errors that could occur during the data collection process can be seen. Human error may also occur during data processing due to the large volume of data being processed manually.

8.6 Extensions:

Exploring this research question in this particular essay, methods among abalone smashing and lobster translocation are evaluated in terms of their conduciveness to maintain balanced ecosystems, allowing policy makers and resource managers to implement more effective regulations and practices to protect these species and their habitats.

Further extending this topic, another aspect would be to look at the role of environmental factors such as increasing temperatures in light of climate change and factors such as salinity and depth and their effects on the populations of these species.

Another aspect would be to examine the same research question with other species of kelp, sea urchins and lobsters in other places to understand the impact of this issue on a larger global aspect.

To improve reliability and accuracy of data, a longer duration of experimentation and observation of the study would give us proper insights to the effect of treatment methods on restoring kelp populations.

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Appendix

Data compressed from main data base sheet. Full data base sheet:
https://metadata.imas.utas.edu.au/geonetwork/srv/eng/catalog.search#/metadata/6654433b-b0c1-43a2-92c6-76734fd6355e

Sub_project	Period	Date	Site	Treatment	Habitat_Type	*C.rodgersii*	*J.edwardsii*	*E.radiata*
ElephTransloc	1 (Initial)	April 2008	Elephant Rock	Lob_Translocation	Kelp Total	1064	2	6460
ElephTransloc	2 (12 months)	April 2009	Elephant Rock	Lob_Translocation	Kelp Total	769	5	4820
ElephTransloc	3 (20 months)	December 2009	Elephant Rock	Lob_Translocation	Kelp Total	681	2	4925
ElephTransloc	4 (26 months)	June 2010	Elephant Rock	Lob_Translocation	Kelp Total	822	3	4473
ElephTransloc	5	December 2010	Elephant Rock	Lob_Translocation	Kelp Total	778	7	4693
ElephTransloc	1 (Initial)	May 2008	Sloop Rock	Lob_control_1	Kelp Total	1130	3	6058
ElephTransloc	2 (13 months)	June 2009	Sloop Rock	Lob_control_1	Kelp Total	1197	1	4764
ElephTransloc	3 (19 months)	December 2009	Sloop Rock	Lob_control_1	Kelp Total	1170	0	5746
ElephTransloc	4 (24 months)	May 2010	Sloop Rock	Lob_control_1	Kelp Total	931	0	5053
ElephTransloc	5	December 2010	Sloop Rock	Lob_control_1	Kelp Total	1006	1	4925
ElephTransloc	1 (Initial)	April 2008	Elephant Rock	Lob_Translocation	Barren Total	1381	0	45
ElephTransloc	2 (12 months)	April 2009	Elephant Rock	Lob_Translocation	Barren Total	1176	2	1044
ElephTransloc	3 (19 months)	November 2009	Elephant Rock	Lob_Translocation	Barren Total	1184	4	1330
ElephTransloc	4 (25 months)	May 2010	Elephant Rock	Lob_Translocation	Barren Total	1219	3	483
ElephTransloc	5	December 2010	Elephant Rock	Lob_Translocation	Barren Total	1148	0	1055
ElephTransloc	1 (Initial)	May 2008	Sloop Rock	Lob_control_1	Barren Total	1342	0	394
ElephTransloc	2 (13 months)	June 2009	Sloop Rock	Lob_control_1	Barren Total	1378	0	6
ElephTransloc	3 (18 months)	November 2009	Sloop Rock	Lob_control_1	Barren Total	1257	1	933

ElephTranslоc	4 (24 months)	May 2010	Sloop Rock	Lob_control_1	Barren Total	1208	0	688
ElephTranslоc	5	December 2010	Sloop Rock	Lob_control_1	Barren Total	1539	0	445
NorthBayTransloc	1 (Initial)	October 2008	North Bay	Lob_Translocation	Barren Total	70	7	3274
NorthBayTransloc	2 (10 months)	August 2009	North Bay	Lob_Translocation	Barren Total	29	11	3455
NorthBayTransloc	3 (15 months)	January 2010	North Bay	Lob_Translocation	Barren Total	27	9	4145
NorthBayTransloc	4 (22 months)	July 2010	North Bay	Lob_Translocation	Barren Total	27	12	2861
NorthBayTransloc	5	January 2011	North Bay	Lob_Translocation	Barren Total	13	4	5334
NorthBayTransloc	1 (Initial)	January 2009	CapePL	Lob_control_1	Barren Total	57	15	5043
NorthBayTransloc	2 (8 months)	September 2009	CapePL	Lob_control_1	Barren Total	64	11	4020
NorthBayTransloc	3 (13 months)	February 2010	CapePL	Lob_control_1	Barren Total	68	33	6480
NorthBayTransloc	4 (18 months)	July 2010	CapePL	Lob_control_1	Barren Total	64	19	4845
NorthBayTransloc	5 (24 months)	January 2011	CapePL	Lob_control_1	Barren Total	30	19	6730
AbDivers	1 (Initial)	November 2008	St Helens Island	Ab_smash_1	Barren Total	657	0	6625
AbDivers	2 (17 months)	April 2010	St Helens Island	Ab_smash_1	Barren Total	448	6	6163
AbDivers	4 (28 months)	March 2011	St Helens Island	Lob	Kelp Total	395	2	6067
AbDivers	1 (Initial)	June 2009	Sloop Rock	Ab_control_1	Barren Total	1197	1	4764
AbDivers	2 (11 months)	May 2010	Sloop Rock	Ab_control_1	Barren Total	931	0	5053
AbDivers	3 (18 months)	December 2010	Sloop Rock	Ab_control_1	Barren Total	1006	1	4925
AbDivers	1 (Initial)	March 2009	Trumpeter Bay	Ab_smash_2	Barren Total	415	1	6269
AbDivers	2 (13 months)	April 2010	Trumpeter Bay	Ab_smash_2	Barren Total	423	5	5305
AbDivers	4 (24 months)	March 2011	Trumpeter Bay	Lob	Barren Total	454	7	6050

AbDivers	1 (Initial)	March 2009	Wineglass Bay	Ab_control_2	Barren Total	311	20	5925
AbDivers	2 (13 months)	April 2010	Wineglass Bay	Ab_control_2	Barren Total	245	28	4585
AbDivers	4 (23 months)	February 2011	Wineglass Bay	Lob	Barren Total	161	1	5215
AbDivers	1 (Initial)	November 2008	Bunker Bay	Ab_smash_3	Barren Total	315	2	8155
AbDivers	2 (17 months)	April 2010	Bunker Bay	Ab_smash_3	Kelp Total	228	5	5490
AbDivers	4 (28 months)	March 2011	Bunker Bay	Lob	Barren Total	229	6	7615
AbDivers	1 (Initial)	March 2009	Mistaken Cape	Ab_control_3	Barren Total	430	2	7300
AbDivers	2 (12 months)	March 2010	Mistaken Cape	Ab_control_3	Barren Total	409	1	4958
AbDivers	4 (23 months)	February 2011	Mistaken Cape	Lob	Barren Total	422	4	6685