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VALUTAZIONE DELL'EFFICACIA DI UN PROTOCOLLO DI MONITORAGGIO DEL KELP PER LA CITIZEN SCIENCE E IL TURISMO SCIENTIFICO: UN CASO DI STUDIO DAL SUDAFRICA

ASSESSING THE EFFICACY OF A KAYAK-BASED KELP MONITORING PROTOCOL FOR CITIZEN SCIENCE AND SCIENTIFIC TOURISM: A CASE STUDY FROM SOUTH AFRICA

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List of abbreviations

BRUV: Baited Remote Underwater Video

CS: Citizen Science

CV: Curriculum Vitae

DEMA: Diving Equipment & Marketing Association

EU: European Union

GDP: Gross Domestic Product

LB: Long Beach

MCS: Marine Citizen Science

MST: Marine Scientific Tourism

PhD: Doctor of Philosophy

RCCA: Reef Check California

SCUBA: Self-Contained Underwater Breathing Apparatus

SF: Seaforth

SST: Sea Surface Temperature

ST: Scientific Tourism

STEM: Science, technology, engineering and mathematics

TMNPMPA: Table Mountain National Park Marine Protected Area

UAE: United Arab Emirates

USA: United States of America

USD: US Dollar

UK: United Kingdom

VT: Voluntourism

ZAR: South African Rand

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Riassunto

Le foreste di kelp rappresentano un ecosistema fondamentale nelle acque temperate degli oceani del mondo e sono formate da diverse specie di Laminaria. Oltre all'importante ruolo dell'habitat che formano, queste alghe forniscono numerosi servizi ecosistemici, tra cui la produzione ittica, il riciclo dei nutrienti, il sequestro di carbonio, l'ecoturismo e prodotti che possono essere raccolti e utilizzati variamente. Questi servizi hanno un valore economico stimato in miliardi di dollari. Tuttavia, nonostante i molteplici benefici che apportano, le foreste di kelp sono soggette a pressioni antropiche e naturali. Di conseguenza, è cruciale monitorare regolarmente questi habitat per individuare tempestivamente eventuali alterazioni e adottare misure adeguate. Un'opzione efficace per il monitoraggio è l'impiego di citizen science marino e turismo scientifico marino, attività che coinvolgono volontari provenienti da vari contesti accademici e professionali in progetti di ricerca scientifica. I benefici di questi approcci al monitoraggio includono la generazione di dati scientifici, lo sviluppo di una maggiore comprensione nei confronti delle problematiche ambientali, l'apprendimento da parte dei partecipanti, benefici per la salute, la creazione di contatti tra chi usufruisce dei diversi servizi ecosistemici marini e il supporto alla formulazione di norme ambientali. Il turismo scientifico contribuisce anche ad incrementare la connessione interculturale e lo sviluppo economico dei Paesi in cui vengono svolti questi progetti, grazie alla creazione di posti di lavoro nell'ambito dei servizi per turisti.

Il presente studio si propone di valutare l'efficacia di un protocollo di monitoraggio delle foreste di kelp basato sull'uso del kayak, nell'ambito della citizen science marinoe del turismo scientifico marino. Il sito di studio si trova a False Bay, in Sudafrica. Più in particolare, il progetto è stato svolto in collaborazione con Cape RADD, un'organizzazione

con sede a Simon's Town. L'efficacia del protocollo è stata determinata valutandone la capacità di generare dati scientificamente validi e rilevanti, di favorire l'apprendimento nei partecipanti, di influenzare i loro atteggiamenti e in base alla possibilità di implementare questo progetto in un'impresa di ecoturismo. Il protocollo, che include la misurazione dell'area, della profondità e della densità dei banchi di kelp da un kayak, è stato sviluppato, testato e successivamente implementato da scienziati e non-scienziati per la raccolta di dati. Dopo ogni uscita di campionamento, i partecipanti sono stati intervistati per valutarne esperienza e la disponibilità a pagare per partecipare ad attività simili.

Sono state condotte 12 uscite in mare con un totale di 18 partecipanti, tra cui scienziati e volontari non-scienziati. Non sono state rilevate differenze significative nella qualità dei dati raccolti dai due gruppi, dimostrando che i dati ottenuti dai partecipanti non-scienziati sono comparabili a quelli raccolti dai ricercatori se si utilizza questo protocollo. Le interviste ai partecipanti hanno evidenziato un aumento delle loro conoscenze relative all'ecologia delle foreste di kelp e al campionamento scientifico. Inoltre, è stato osservato un cambiamento negli atteggiamenti dei partecipanti favorendo la comparsa di approcci maggiormente rispettosi dell'ambiente. L'analisi della disponibilità a investire in esperienze di ecoturismo ha dimostrato che le tariffe proposte da Cape RADD rispecchiano quelle che i partecipanti sarebbero disposti a pagare, confermando così la fattibilità economica del protocollo nell'ambito del turismo scientifico marino. In conclusione, il protocollo ha il potenziale per essere utilizzato in citizen science marino e nel turismo scientifico marino, con possibilità di espansione geografica e ad altre organizzazioni.

Abstract

Kelp forests are an ecosystem found in the temperate waters of the global oceans. These forests are created by several *Laminaria* species. Apart from being ecosystem builders, these algae provide several ecosystem services to humankind like fisheries production, nutrient recycling, carbon removal, habitat building, ecotourism, and direct harvest. These services are valued at millions to billions of USD. Despite all these benefits kelp forests are under pressure, human and natural ones. Thus it is crucial to monitor the kelp forests to be able to detect early changes and be able to respond to them. A cost-effective monitoring option is the use of marine citizen science and marine scientific tourism, where non-scientists participate in scientific research projects as volunteers. The benefits of marine citizen science and marine scientific tourism are many and include creating scientific data, increasing the stewardship and learning of the participants, health benefits, connecting different marine users, and providing data for policy. Benefits of scientific tourism include further the enhancement of global citizenship, connection of the participants to another culture, and economic revenue for the country and organizations, by providing employment and services to the tourists.

The primary goal of this study is to assess the efficacy of a kayak-based kelp monitoring protocol for marine citizen science and marine scientific tourism. The study site is False Bay in South Africa, specifically Simon's Town where the organization Cape RADD with whom the project was done in collaboration, has its headquarters. Efficacy means the ability of the protocol to create scientifically valid and relevant data, to increase the learning outcomes for the participants, to change participants' attitudes, and finally to represent a viable form of marine scientific tourism for a business. To reach this goal first the monitoring protocol was

developed and tested on the site. The protocol consisted of measuring the area, the depth, and the density of kelp beds, all done from a kayak. Once the protocol was usable, it was applied by non-scientists and scientists to gather data. After the sampling trips, every participant was interviewed to assess their experience and their willingness to pay for such an experience.

In total 12 trips by 18 participants, including scientists and non-scientists, were done. There were no significant differences between the data collected by scientists and non-scientists showing that the data collected by volunteers has a similar quality as the data from researchers with this protocol. Concerning the interviews of the participants, they showed an increase in learning and a change in pro-environmental attitudes of the participants. Further, the absence of a significant difference between the price the organization Cape RADD wants to charge and the willingness to pay by the participants showed the viability of the protocol for marine scientific tourism. In conclusion, the developed protocol showed its potential use in marine citizen science and marine scientific tourism with the possibility to be expanded on a larger scale.

Chapter 1: Introduction

Kelp forests are an important ecosystem in the temperate waters around the world. They can be found on the coasts of every continent, building three-dimensional habitats on rocky substrates (Wernberg *et al.*, 2019). They provide crucial ecosystem services to humans ranging from fisheries production, nutrient recycling, carbon removal, habitat building, and ecotourism to direct harvest for aquaculture (Rotmann, 1999, Teagle *et al.*, 2017, Blamey and Bolton, 2018, Wernberg *et al.*, 2019, Eger *et al.*, 2023). These services are valued in the millions to billions of USD (Blamey and Bolton, 2018, Trégarot *et al.*, 2020, Eger *et al.*, 2023).

Although playing such a crucial role in the marine environment, kelp forests are under threat, human and natural. They suffer under the effects of climate change (heatwaves and sea surface temperature (SST) warming), harvesting and fisheries, and eutrophication and pollution (Wernberg *et al.*, 2019).

To better assess the effects of those threats it is important to have baselines of the extent and status of the kelp forests today. This can be achieved by status assessments and regular monitoring programs to detect changes over time. A cost-efficient monitoring method would be the use of citizen science (CS) and scientific tourism (ST).

CS is the participation of non-scientists in the scientific research process (Bonney *et al.*, 2014). It can be used in a wide array of fields both in terrestrial and marine environments (Ambrose *et al.*, 2019, Lau *et al.*, 2019, Changeux *et al.*, 2020, Robbins *et al.*, 2020, Machado *et al.*, 2021). CS provides benefits like creating scientific data, increasing the stewardship and learning of the participants, health benefits, connecting different marine

users, and providing data for policy (Koss and Kingsley, 2010, Crall *et al.*, 2012, Hyder *et al.*, 2015, Lamine *et al.*, 2018, Kelly *et al.*, 2019, Kelly *et al.*, 2019(2), Meschini *et al.*, 2021).

ST, also called voluntourism (VT), is similar to CS with the difference that the participants or volunteers are engaged in the scientific research process as part of a vacation (Wearing, 2001, INST, 2023), often paying for the experience. The effects and benefits are like those of CS but include also the enhancement of global citizenship, connection to another culture, and economic revenue for the country and organizations, by providing employment and services to the tourists (Gray *et al.*, 2017, Schneller and Coburn, 2018, Lucrezi *et al.*, 2022, Lucrezi and Cillers, 2022).

South Africa is an ideal place to study the efficacy of CS for the monitoring of kelp forests as it is a major site for marine ST (MST) and marine CS (MCS) (e.g. volunteerworld.com, goeco.org, marinedynamics.org) and around the Cape of Good Hope peninsula and the west coast extensive kelp forests grow (Anderson *et al.*, 2007, Blamey and Bolton, 2018, Trégarot *et al.*, 2020).

The primary goal of this study is to assess the efficacy of a kayak-based kelp monitoring protocol for MCS and MST. The geographic setting is False Bay in South Africa, specifically Simon's Town. Efficacy means the ability of the protocol to create scientifically valid and relevant data, to increase the learning outcomes for the participants, to change participants' attitudes, and finally to represent a viable form of MST for a business. The following sections provide a theoretical background about MSC and MST, the benefits of kelp forests, the status and use of the kelp forests in South Africa, and the target location of False Bay.

1.1 Background

1.1.1 Kelp Forests: Ecology and Ecosystem Services

In the shallow waters of the temperate coastlines of the world (Figure 1), laminarian seaweeds, commonly known as kelp, grow and form extensive stands (Steneck *et al.*, 2002, Wernberg *et al.*, 2019, Fragkopoulou *et al*., 2022). These seaweeds reach heights of several meters thus leading to the name of kelp forests for larger patches, as they resemble terrestrial forests and have also similar functions for other marine organisms. As habitat builders and ecosystem engineers they create a three-dimensional habitat, provide food and shelter for associated organisms, and modify the abiotic conditions of the site (Steneck *et al.*, 2002, Teagle *et al.*, 2017, Wernberg *et al.*, 2019).

Kelp forests provide crucial ecosystem services. In some parts of the world, kelp is directly harvested, for example for aquaculture or consumption (Troell *et al.*, 2006, Blamey and Bolton, 2018, Wernberg *et al.*, 2019). Kelp forests are habitat and food for commercially fished organisms like abalones *(Haliotis*), lobsters (*Jasus and Panulirus*), and fish (*Pollachius, Sterolepis, Chirodactylus*) (Blamey and Bolton, 2018, Wernberg *et al.*, 2019, Eger *et al.*, 2023). Furthermore, they play a role in the regulation of the climate system by the removal of carbon and the nutrient cycle in the oceans (Wernberg *et al.*, 2019, Eger *et al.*, 2023). Lastly, kelp forests are important for the tourism industry attracting tourists from all over the world for recreational activities (Bennet *et al*., 2016, Blamey and Bolton, 2018, Wernberg *et al.*, 2019).

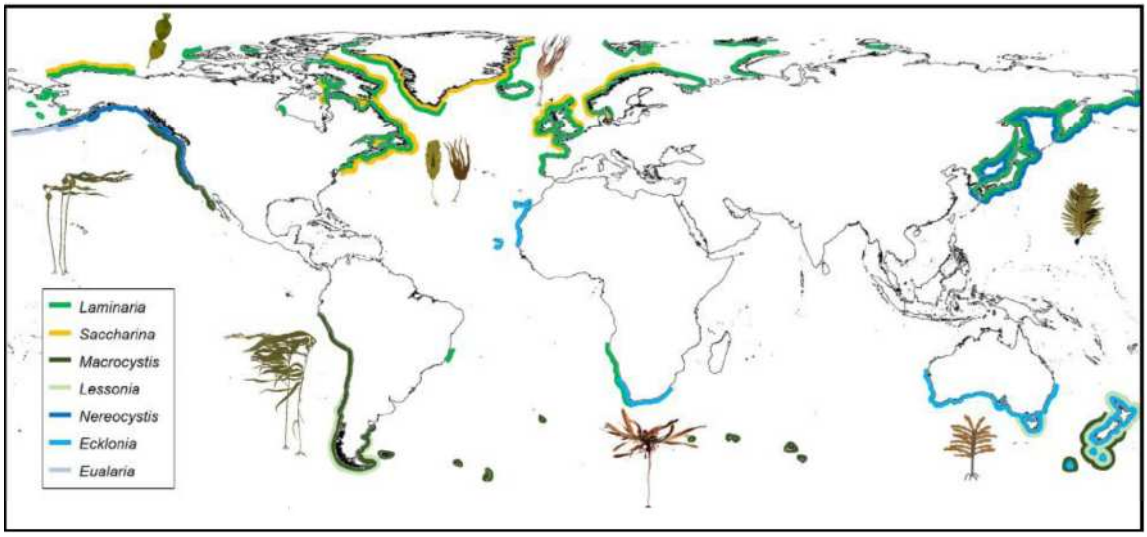

Figure 1: Distribution of the main laminarian genera globally. Each color represents a kelp genus (from Bolton, 2010). Source: Wernberg *et al.*, 2019 (modified).

The economic value of these services is in the millions to billions of USD (Blamey and Bolton, 2018, Wernberg *et al.*, 2019, Eger *et al.*, 2023). For example, the species from the genera *Ecklonia*, *Laminaria*, *Lessonia*, *Macrocystis*, *Nereocystis*, and *Saccharina*, the main forest-building species, create an average value of 500 billion USD per year worldwide (Eger *et al.*, 2023). The kelp forests in Africa alone have and provide already a value between 400-500 million USD per year (Blamey and Bolton, 2018, Trégarot *et al.*, 2020).

1.1.2 Kelp Forests in South Africa: Status and Uses

In South Africa (Figure 2), kelp forests grow in the Western Cape and Northern Cape provinces in cool and nutrient-rich waters (Anderson *et al.*, 2007, Rothman *et al.*, 2017, Blamey and Bolton, 2018, Trégarot *et al.*, 2020). These forests are dominated by two kelp species: *Ecklonia maxima* and *Laminaria pallida*, where *E. maxima* is more prominent and dominant in the southern part of the kelp forest distribution, while *L. pallida* is more

dominant in the northern part of the kelp forest range, and in the south, it forms an understory species (Anderson *et al.*, 2007, Mead *et al.*, 2013, Rothman *et al.*, 2017).

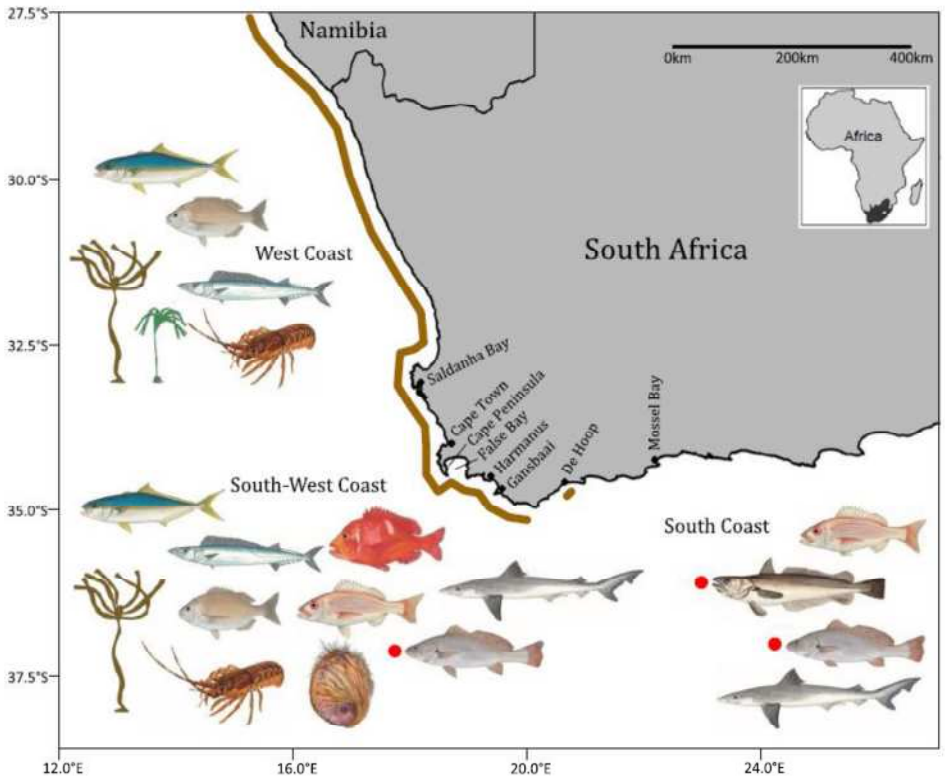

Figure 2: Distribution of South African kelp forests (brown line) and the main commercial species caught off west, south-west, and south coasts (from Blamey *et al.*, 2015). Red circles identify species not associated with reef ecosystems. Source: Blamey and Bolton, 2018.

Different from other kelp forests in the world (Krumhansl *et al*., 2016), the geographical extension of kelp forests in South Africa is increasing. In the last decade, the eastern border of the forests shifted eastwards (Bolton *et al*., 2012, Reimers *et al*., 2014, Mead *et al.*, 2013, Blamey *et al*., 2015). Now the easternmost point where *E. maxima* can be found is the De Hoop Nature Reserve east of Cape Agulhas (Bolton *et al*., 2012). This shift may be explained by oceanographical parameters. Over the last decades, there has been a cooling of the SST around the southwest and south coast of South Africa. This cooling could be related to an

increase in the upwelling in the same regions, due to changes in the wind regime (Mead *et al.*, 2013, Blamey *et al*., 2015).

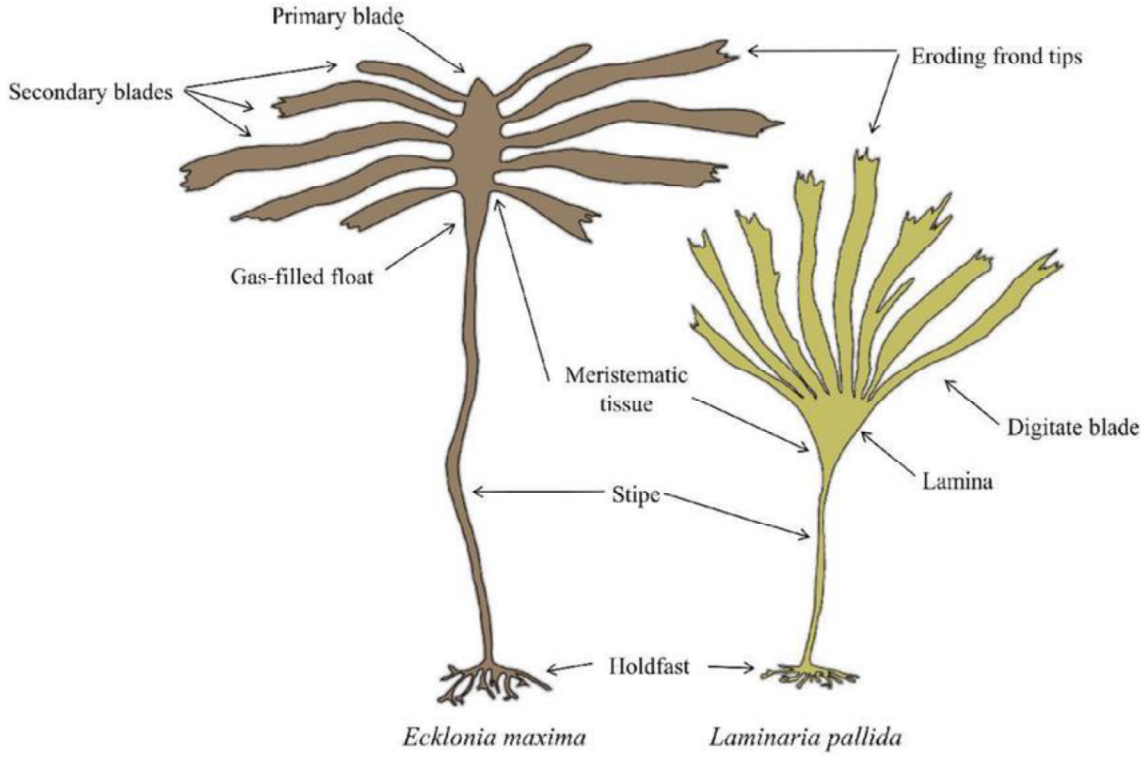

Figure 3: Schematic of *Laminaria pallida* and *Ecklonia maxima* morphology. Source: Dyer, 2018.

Kelp is harvested and used in South Africa, although mainly *E. maxima* is the targeted species. Harvested kelp is used for different purposes, but mainly as alginate raw material, agricultural stimulant, and abalone and fish feed (Rotmann 1999, Stirk *et al.*, 2004). In 2003, 5917t of fresh kelp were either harvested or collected from beach wash (Troell *et al*., 2006). Future proposals for the use of kelp include deploying it as a heavy-metal wastewater absorbent, and in the pharmaceutical industry (Stirk *et al.*, 2004).

The harvesting of kelp is regulated by concession areas; a stakeholder can purchase a harvesting permit for one concession area which has a validity of five years (Rotmann, 1999). Harvesting is mostly done by cutting the secondary blades and the primary blade

(Figure 3) during low tide from a boat. This is a lethal method, killing the kelp in the process. An alternative, non-lethal method, is to cut only the secondary blades, leaving the primary blade behind, which then can regenerate the secondary blades (Rothman *et al*., 2006, Troell *et al*., 2006).

1.1.3 False Bay: Biodiversity and Human Uses

False Bay is a large bay in the Western Cape Province of South Africa (Figure 4). The bay is part of the Atlantic Ocean, lying between the Cape Peninsula in the west and the Hottentots-Holland Mountains and Kogelberg Mountain in the east. False Bay is open to the south with the Cape of Good Hope (Cape Point) and Cape Hangklip as the southern border (Pfaff *et al*., 2019).

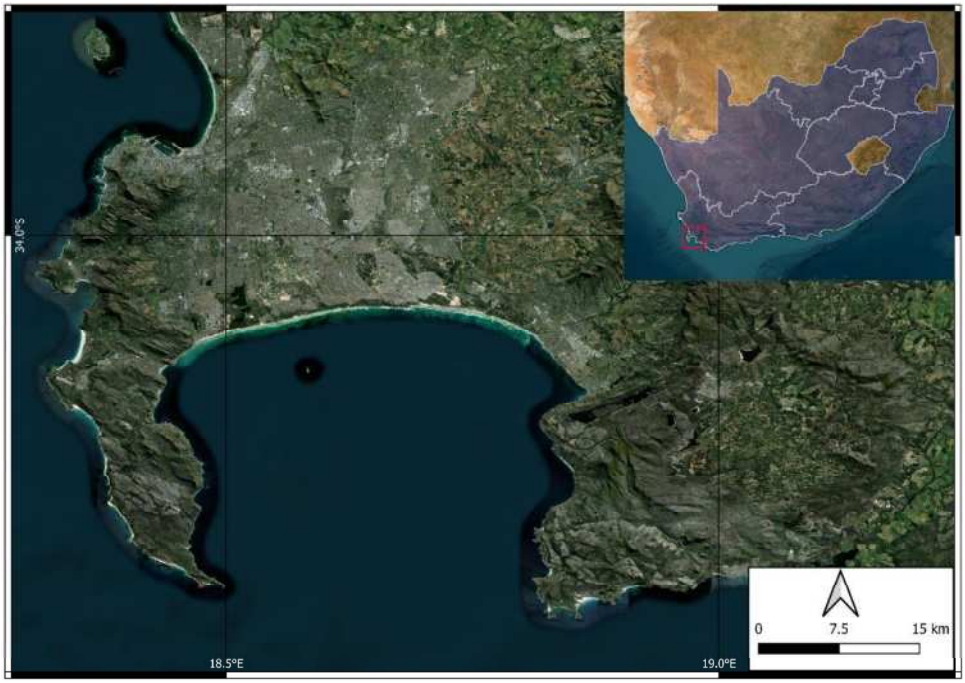

Figure 4: Map of False Bay and the location of False Bay in South Africa. Created with QGIS. Data source: Hijmans and University of California, Berkeley. Museum of Vertebrate Zoology, 2015.

False Bay is the westernmost end of the Agulhas Bioregion, which has a warm-temperate character. The proximity of this bay to the South-Western Cape Bioregion, a transition region between the warm-temperate Agulhas and cool-temperate Namaqua Bioregion, allows organisms from the cooler region to colonize False Bay (Griffiths *et al*., 2010). That is why in False Bay one can find species from cooler environments like the African penguin (*Spheniscus demersus*) to species of warmer waters like the doublesash butterflyfish (*Chaetodon marleyi*) (Global Biodiversity Information Facility, 2022a,b).

Figure 5: Marine biodiversity of False Bay, South Africa. Artwork by Rohan Chakravarty, Save Our Seas Foundation, 2022.

False Bay is a habitat for several flag species. Flag species are normally attractive organisms, which draw the attention of the broader public for conservation efforts (Stork *et al*., 1995). In False Bay, visible in Figure 5, these include cetaceans like orcas (*Orcinus orca*) and

southern right whales *(Eubalaena australis*), pinnipeds like the South African fur seals (*Arctocephalus pusillus pusillus*), birds like the African penguin (*Spheniscus demersus*) and sharks like the great white shark (*Carcharodon charcarias*), pyjama shark (*Poroderma africanum*) and puffadder shysharks (*Haplobepharus edwardsii*) (Pfaff *et al.*, 2019, Save our Seas Foundation, 2022).

The diverse coastline of False Bay, but also the proximity to Cape Town, attracts tourists from abroad, but also from South Africa. Typical activities these tourists do are beachgoing, surfing, diving, shark diving, whale watching, sailing, and hiking in the Table Mountain National Park. All of these activities plus the harvesting of local flora and fauna, provide a large revenue for the area (Pfaff *et al.*, 2019).

1.1.4 Marine Citizen Science: Uses, Benefits, and Challenges

MSC is the participation of non-scientists in the research process in marine environments (Bonney *et al.*, 2014). This participation can be in different stages of the scientific process, although the most frequent one is in the collection of data (Kelly *et al.*, 2020). Data collection can be for a wide range of topics and has the benefit of not being costly. MCS has been used successfully in collecting data about the spatial distribution of marine litter on beaches and in the sea (Ambrose *et al*., 2019, Chiu *et al*., 2020), the spreading of alien or invasive species (Machado *et al*., 2021, Mannino *et al*., 2021), the spatial distribution of flag species and habitats (Assis *et al.*, 2009, Lau *et al.*, 2019, Robbins *et al*., 2020), and monitoring of habitats (Branchini *et al*., 2014, Lamine *et al.*, 2018, Vieira *et al*., 2020, Meschini *et al*., 2021). Further to scientific data creation, MCS has other benefits. The data can be used by policymakers to manage marine spaces (Koss *et al.*, 2009, Hyder *et al.*, 2015, Lamine *et al.*, 2018). Then there are social benefits. MCS can enhance the learning and stewardship of the

participants, but also increase the understanding of the point of view of different marine users and bring them together (Crall *et al.*, 2012, Kelly *et al.*, 2019a,b). Lastly, there are the health benefits of being in touch with nature (Koss and Kingsley, 2010).

Despite all these benefits, MCS faces different challenges too. The main challenge is the validity of the collected data and scientific acceptance. As the data are not collected by educated scientists, the scientific community is reluctant to use the data collected by the volunteers for research (Bonney *et al.*, 2014, Kosmala *et al.*, 2016).

Another challenge is the recruitment and holding of volunteers for an MCS project. First, the willingness to participate in certain projects is not always given (Lucrezi and Digun-Aweto, 2020). For long-term success, an MCS project must be able to engage volunteers also in the long term. This can be archived if the motivations of the participants are maintained, but proper planning of the project is needed to achieve that (Carballo-Cárdenas and Tobi, 2016, Lotfian *et al*., 2020, Liñán *et al.*, 2022). A successful MCS project needs cooperation between all participants which can be a challenge in itself. Further, time and resources have to be allocated to the project's planning (Koss *et al.*, 2009).

1.1.5 Marine Scientific Tourism: Uses, Benefits, and Challenges

MST is the participation of tourists in the marine research process (Wearing, 2001, INST, 2023). These tourists often must pay to be allowed to participate in the projects. These projects are often conservation-oriented and focus on flag species and habitats like coral reefs, sea turtles, sharks, and cetaceans, as those attract tourists (volunteerworld.com, goeco.org, marinedynamics.org, Gray *et al.*, 2017, Lucrezi and Cillers, 2022). Many of the benefits of MST are similar to those of MCS, as the activities that the tourists do are similar to those of volunteers in MCS. Additionally, there are effects special of MCS. One of these

is the enhancement of global citizenship. Tourists participating in such projects get the chance for a cultural exchange (Gray *et al.*, 2017, Schneller and Coburn, 2018, Lucrezi and Cillers, 2022). Another benefit is that MST can bring economic benefits to the regions where they take place. They provide new job opportunities, some directly linked to the MST project, like a researcher, but also indirect like accommodations, restaurants, etc. Tourists bring capital that they spend during their time with the projects (Roques *et al.*, 2018, Schneller and Coburn, 2018, Lucrezi *et al.*, 2022a). MST can provide scientific data for the management of marine spaces, which the host countries would be unable to produce (Gray *et al.*, 2017, Roques *et al.*, 2018).

Like MCS, MST faces several challenges too. MST faces the same challenge as MCS with the validity of the scientific data and the engagement of participants (Luh Sin, 2009, Lucrezi and Cillers, 2022). Another challenge is that MST can reinforce the inequality of the world. "Rich" tourists travel to a project that helps them boost their CV (Gray *et al.*, 2017). On the other hand, these research possibilities are then not available to the local population reducing thus their development (Gray *et al.*, 2017). Lastly, MST needs the collaboration of a wide range of stakeholders, research facilities, tourist facilities, government, etc. Achieving this collaboration is a challenge, as all have different goals and communication languages (Lucrezi *et al.*, 2022a).

1.1.6 Participants in Marine Citizen Science

Participants in MCS are varied and depend a lot on the project. Some projects have target participant groups like schoolchildren (Wichmann *et al.*, 2022) or SCUBA divers (Lamine *et al.*, 2018, Lau *et al.*, 2019, Vieira *et al.*, 2020), but others are wide open to anyone who wants to participate (Assis *et al.*, 2009, Koss *et al.*, 2009, Robbins *et al.*, 2020). One thing

though, that many of the participants in MCS have in common, is that they are residents of the area where the MCS project takes place (Hammerton *et al.*, 2012, Martin *et al.*, 2016, Lucrezi and Digun-Aweto, 2020, Lucrezi, 2021, Wichmann *et al.*, 2022). The sex ratio among the participants is almost 1:1 (Hammerton *et al.*, 2012, Lucrezi and Digun-Aweto, 2020), while the age depends on the project (Hammerton *et al.*, 2012, Lucrezi and Digun-Aweto, 2020, Wichmann *et al.*, 2022).

The motivations behind the participation of the volunteers in MCS are diverse. There are ecocentric motivations, like "wanting to help", "wanting to contribute to conservation" and "wanting to contribute to science" (Koss *et al.*, 2009, Hammerton *et al.*, 2012, Carballo-Cárdenas and Tobi, 2016, Lotfian *et al*., 2020, Lucrezi 2021). Volunteers want to make a change through their participation. These are often the primary drivers of the volunteers. Then there are the personal development motivations. This means that the volunteers participate to increase their learning/knowledge and skills, such as diving skills (Koss *et al.*, 2009, Hammerton *et al.*, 2012, Carballo-Cárdenas and Tobi, 2016, Lotfian *et al*., 2020). Lastly, there are minor drivers like personal well-being and social values (Hammerton *et al.*, 2012, Carballo-Cárdenas and Tobi, 2016, Lotfian *et al*., 2020). One study clustered volunteers in MCS into four groups depending on their motivations and goals. The first group is called "activists". These volunteers align with ecocentric motivations, as they want to make a change in coastal management through their participation. The second group, the "conservationists", are motivated to contribute to science and conservation, following a personal interest in the topic. "Professionals", the third group, are motivated mostly by developing or maintaining their skills and interest in the MCS project's topic. The last group, the "hobbyists" participate in MCs because the activity of the project is enjoyable for them, which corresponds to personal well-being motivation (McAteer *et al.*, 2021).

The motivations of volunteers in MCS can change over time. Initial motivations might be replaced by new motivations or once they are fulfilled there is no interest in further participation in the MCS project. In a study conducted in the Dutch Caribbean about drivers and barriers to participation in MCS about the detection and monitoring of invasive lionfish, the first motivation for most of the participants was to "help the environment". This motivation changed over time to new motivations like commercial, social, and learning motives, as the perception of the lionfish to the participants changed. The lionfish opened new possibilities for them, for example, spearfishing as a sport or eating them as a new culinary experience (Carballo-Cárdenas and Tobi, 2016).

1.1.7 Participants in Marine Scientific Tourism

MST is mostly attractive to foreign tourists. These tourists are often young aged between 20 to 30 years (Gray *et al.*, 2017, Roques *et al*., 2018, Cilliers *et al.*, 2022, Lucrezi *et al*., 2022b, Lucrezi and Cillers, 2022, Lucrezi and Cillers, 2023), but also teens are attracted to MST (Schneller and Coburn, 2018). Furthermore, there is a prevalence of female tourists (Roques *et al*., 2018, Cilliers *et al.*, 2022, Lucrezi *et al*., 2022b, Lucrezi and Cillers, 2022, Lucrezi and Cillers, 2023). They are often doing a gap year in their careers or students (Gray *et al.*, 2017, Lucrezi *et al*., 2022b).

Diverse motivations influence tourists to participate in MST. Many of these motivations are similar to those of volunteers of MCS. An important motivation for many is the wish to contribute to conservation, research, or in general help. This would make their trip more meaningful (Luh Sin, 2009, 2020, Lucrezi *et al*., 2022b, Lucrezi and Cillers, 2023). Participants want to grow with the experience (Luh Sin, 2009, Schneller and Coburn, 2018). Like in MCS, another motivation is to learn or improve skills and knowledge. MST is a

learning experience (Luh Sin, 2009, Schneller and Coburn, 2018, Lucrezi *et al*., 2022b, Lucrezi and Cillers, 2023). Another driver for tourists is personal well-being. They enjoy the activities of MST (Lucrezi and Cillers, 2023). Lastly, social values can drive people to participate in MST. These participants want to meet other people, engage in civic engagement, and experience the culture of the destination (Schneller and Coburn, 2018, Lucrezi and Cillers, 2023). With these motivations, it is possible to cluster volunteers into "young enthusiasts", "mature voluntourists", "neutral elders" and "satisfied elders" (Lucrezi *et al*., 2022b). These four clusters can be considered an evolution of MST participants. "Young enthusiasts" are the starting group. They are young and have often a biological or environmental science background and many would enter into the category of Millenial. They experience MST for the first time."Mature voluntourists" are similar to the "young enthusiasts". The difference is that they are older and have more experience with MST. With time and more experience these "mature voluntourists" grow into the "neutral elders". They have gained more experience in MST and are more demanding concerning new MST experiences, although they have also the financial means to support these. The last cluster, the "satisfied elders" are like the "young enthusiasts". The difference is that they are older, thus suggesting that they are people who started later with MST (Lucrezi *et al*., 2022b). A study focusing on diving MST described two of these clusters for potential participants in diving MST. These are the "young enthusiasts" and the "neutral elders" (Lucrezi *et al.*, 2022a).

Different aspects influence the experience and satisfaction of participants. First, to have a satisfactory experience, the expectations of the participants must be fulfilled. These expectations include a good quality of the program, a quality destination, and detailed information for the trip (Lucrezi *et al.*, 2022b, Lucrezi and Cillers, 2022). Other aspects that

influence the satisfaction of the volunteers are the ethical conduct of the MST businesses or the experience by itself, the learning, the communication, and activities. All of these aspects influence in the end the satisfaction and the experience of volunteers and only satisfied volunteers would do MST again (Schneller and Coburn, 2018, Lucrezi *et al.*, 2022a, Lucrezi and Cillers, 2022).

1.1.8 Business Model of an MST Business

The complex business model for an MST business is visible in Figure 6. The infrastructure consists of three things: the key partners, the key activities, and the key resources. The key resources including the environment, the tourists, the staff, the equipment, etc., enable the business to offer its key activities like diving/snorkeling, research projects, teaching and courses, etc. (Forster, 2001, Debarliev and Mitrovska, 2016, Cilliers *et al.*, 2022, Kabil *et al.*, 2023). These key activities attract possible tourists to the business and a wider range of offered activities tends to lead to higher success of the business (Benson and Henderson, 2011, Cilliers *et al.*, 2022). All of these things are only possible with strong partnerships between the business and its partners (Wearing, 2001, Cilliers *et al.*, 2022, Kabil *et al.*, 2023).

An MST business has different ways to interact with its customers. Many use social media, webpages, blogs, conferences, etc. to reach out to participants and keep in contact with them (Benson and Henderson, 2011, Cilliers *et al.*, 2022, Kabil *et al.*, 2023). These customers, as described in the sub-chapter 1.1.7, are mostly young people with interests in marine biology and conservation.

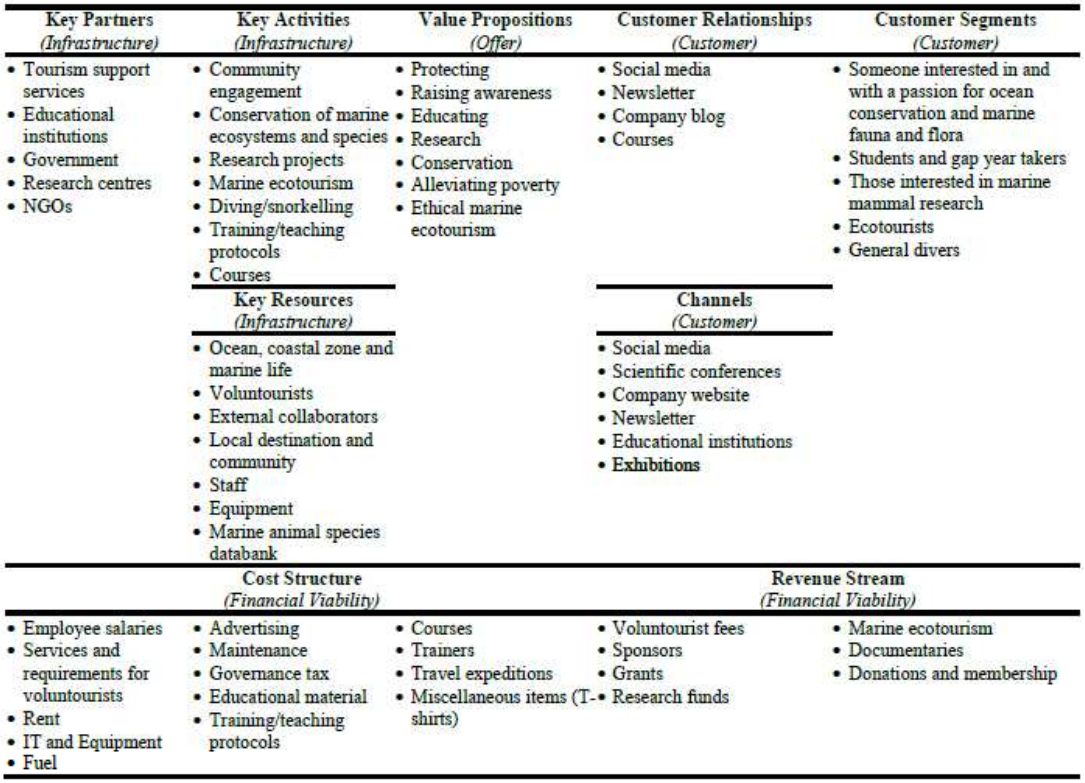

Figure 6: A business model canvas for a MVT business. Source: Cilliers *et al.*, 2022.

From a financial perspective, an MST business shares many expenses with other businesses, so-called general business expenses like fuel, rent, employee salaries, etc., but also specialized expenses like the costs of training/ teaching, courses, and travel expeditions (Wearing, 2001, Benson and Henderson, 2011, Cilliers *et al.*, 2022, Kabil *et al.*, 2023). These expenses are mostly covered by volunteer fees and donations, grants, and side activities like normal ecotourism offers, which is a narrow income source (Benson and Henderson, 2011, Roques *et al.*, 2018, Cilliers *et al.*, 2022, Kabil *et al.*, 2023).

An MST business faces several challenges. The aforementioned narrow income source and the dependency on foreign tourists can be a challenge for a business. If international travel collapses or is limited as during the COVID-19 pandemic, the main income source of many MST businesses is not available or is reduced (Lyons and Wearing, 2012, Fotiadis *et al.*,

2020; King *et al*., 2021; Rogerson *et al*., 2021, Cilliers and Hermann, 2023). Another challenge is that specialized local staff members are not always available, forcing the business to hire foreigners (Wearing, 2001, Barbieri *et al.*, 2012, Cilliers and Hermann, 2023). Further, the country of the business can create challenges. If possible participants perceive the country as unattractive or another way negatively, these participants would be reluctant to travel to it. Thus the negative image of the country can influence the availability of customers (Yoda, 2010, Cilliers and Hermann, 2023). Lastly, MST can also have a negative image, as it is criticized for commodifying nature and conservation, greenwashing, creating a dependency between the business country and the country of the participants, exploiting local people, and damaging their culture. Overcoming this critique is a challenge (Smith and Font, 2014, Cilliers and Hermann, 2023).

1.1.9 Kelp Citizen Science

Although not as frequently targeted by MCS and MST projects like coral reefs, kelp forests have been the target of several projects. Similar to coral reefs, they grow in shallow waters and can thus be reachable also without the need for much special equipment, if at all. One of these projects is Reef Check California (RCCA), which started in 2005 and is still ongoing (Reefcheck.org/kelp-forest, Freiwald *et al*., 2018). This MCS initiative is an adaptation of the Reef Check project, which is an MCS project to monitor coral reefs (Reefcheck.org). Instead of coral reefs, RCCA focuses on the kelp forest along the Californian coast. Volunteers who want to participate in RCCA have to be experienced SCUBA divers, as the monitoring is conducted exclusively with SCUBA diving. Further to this, they have to go through an extensive training program, where they learn about the ecology of kelp forests, species identification, marine protected areas, and scientific sampling and monitoring

methods. After these theoretical lectures, volunteers go through practical training too, where they apply the learned. Only after passing the final exams, the volunteers are allowed to participate in the project. Afterwards, yearly the volunteers are tested for their skills to be able to maintain a high quality of the data. The data consists of the abundance and size of fish, invertebrates, and algae species typical of the kelp forests and is collected on transects. Also, the physical habitat is characterized (Reefcheck.org/kelp-forest, Freiwald *et al*., 2018). Figure 7 shows a volunteer participating with RCCA.

Figure 7: A volunteer monitoring a kelp forest with Reef Check California. Source: reefcheck.org/kelp-forest.

Another project from the West Coast of the USA is an MCS project of the Northwests Straits Commission (nwstraits.org/our-work/kelp-recovery/, Bishop, 2014). They developed a protocol to monitor bull kelp (*Nereocystis luetkeana*) in Puget Sound and the Salish Sea using kayaks as monitoring vessels. Volunteers monitor the extension of bull kelp patches

over time using a portable GPS by paddling around kelp patches, but they also measure other abiotic factors like temperature and depth. Further, photos are taken of the patches, which are used to observe changes over time. An update to the protocol allowed participating volunteers to sample zooplankton in the kelp forests. This MCS project allowed the creation of a map with the kelp forests of the area and to witness the change in the kelp forests over time (nwstraits.org/our-work/kelp-recovery/, Bishop, 2014).

Findkelp, a kelp MCS project from Portugal, had also the goal of mapping the kelp forests of the Portuguese coast. In the summer of 2008, SCUBA divers, snorkellers, and spear-fishers were asked to report sites and the status of kelp forests along the Portuguese coast. These volunteers were first educated on the identification of kelp before they were sent into the field. Participants of Findkelp took pictures of kelp forests and GPS points of the forests which were uploaded to a database. To validate the data collected by the volunteers, scientists collected groundtruthed data. All this data allowed the researchers in the end to create a distribution map of kelp along the Portuguese coast (Assis *et al*., 2009).

A project that takes a different angle concerning kelp MCS is Floating Forests. This globally acting project uses satellite images to map kelp forests. There are no requirements to be able to participate, only a short tutorial at the beginning explains how the project works. Volunteers mark kelp forests in the satellite images by identifying them first and then outlining them. Floating Forests maintains data quality by consensus classifications. This means that a picture with kelp is maintained in the pool of photos until 15 volunteers classify it as kelp. This MCS has the advantage that participants do not need to live near the kelp forests. Everyone, who has access to the platform from a computer, tablet, etc. can participate

as a volunteer. The interface is visible in Figure 8 (https://www.zooniverse.org/projects/zooniverse/floating-forests, Rosenthal *et al.*, 2018).

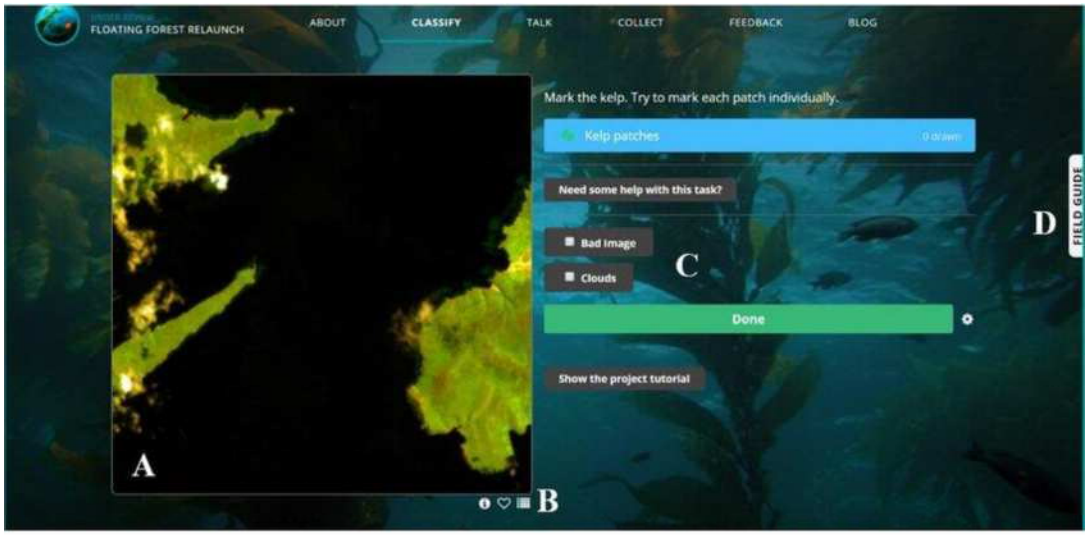

Figure 8: Floating Forest interface where volunteers can identify and map kelp forests. Source: Rosenthal *et al.*, 2018.

1.1.10 Case Study-Cape RADD: A MST Organization

Cape RADD is a marine science research field station, marine biology training school, and eco-tourism center located in the city of Simon's Town near Cape Town in the Western Cape Province in South Africa (Figure 9).

Figure 9: The Ocean Hub, the headquarters of Cape RADD. Source: caperadd.com.

It offers both MCS and MST. These offers do not target directly the kelp forests, but rather species associated with kelp forests. Their main MCS project is Finspotter. This project targets sharks, mostly the endemic shysharks and catsharks like the puffadder shyshark or pyjama shark. Cape RADD developed a program that uses machine learning and computer vision to compare, identify, and match sharks from photos with the shark photos in their database. With this, it is possible to monitor the populations of these sharks in the area. These photos can be uploaded by everyone. A possibility to take these photos is by participating in one of their offers. For casual tourists, who want to participate for one day in the collection of data for Finspotter, Cape RADD offers so-called “Snorkel for Science” and “SCUBA for Science” trips. On these trips, the tourists go out with a marine biologist snorkeling or diving looking for these sharks and to take then photos of them which are later uploaded to Finspotter. In Figure 10, examples of such trips are visible.

Figure 10: Activities offered by Cape RADD. On the left “SCUBA for Science” and on the right “Snorkel for Science”. Source: caperadd.com.

Apart from these daily trips, Cape RADD offers two to four-weeklong MST internships. These internships target everyone who wants to experience what it means to work as a marine biologist, for example, students who want to see what it means to be a marine biologist and see if it is the right path for them. In these internships, the participants learn different sampling and monitoring techniques, like belt transects, Baited Remote Underwater Videos (BRUVs), and the use of quadrats, but the participants have also a chance to improve their diving and free diving skills. In the hub activities like the parasitological analysis of blood are done too. Apart from these practical skills, participants have courses and learn about the biodiversity of False Bay and the kelp forests, as all of the activities are done within them. Almost all of the sampling excursions in these internships focus on the shark species of the kelp forests or other marine organisms like nudibranchs, fish, and marine invertebrates, instead of the kelp and the kelp forests as an ecosystem (caperadd.com).

1.2 Problem Statement

Kelp forests provide crucial ecosystem services which is why it is important to know their status and see if it changes over time (Rotmann, 1999, Teagle *et al.*, 2017, Blamey and Bolton, 2018, Wernberg *et al.*, 2019, Eger *et al.*, 2023). This task can be done using MCS and MST. In some regions already several projects are working on these matters and kelp forests are well studied. Examples are the West Coast of the United States of America, where many projects and organizations use MCS to assess the kelp forest status (Reefcheck.org/kelp-forest, nwstraits.org, Bishop, 2014, Freiwald *et al*., 2018), or the coast of New Zealand (Lucrezi, 2021). South Africa on the other hand is underrepresented in this, although the kelp forests are used commercially, and South Africa is a destination for Scientific Tourism (volunteerworld.com, goeco.org, marinedynamics.org, Alexander, 2012, Lucrezi *et al.*, 2022, Siddiqi *et al.*, 2024). Furthermore, at least for divers in South Africa, there is an interest in partaking in kelp monitoring programs as part of MCS (Lucrezi, 2021).

Most of the abovementioned projects use divers as citizen scientists (Reef Check, Findkelp, Cape RADD, Reeflife survey, etc), as they can access the forests directly, but with the cost that the pool of possible citizen scientists is limited, as not everyone has a diving certificate. In 2024 the Diving Equipment & Marketing Association (DEMA), that is the trade association for the international scuba diving industry, released an estimate that there are 2.5 Million active SCUBA divers in the USA and up to 6 Million active SCUBA divers worldwide, which is only a fraction of the world's population (Dema.com). Using a kayak would allow non-divers to participate in kelp CS, even younger participants who are not allowed to be certified divers. This could offer opportunities for school classes too. Further, doing CS using a kayak is less costly than doing it with diving. Thus, this study focuses on

developing a kayak-based monitoring protocol for kelp forests in South Africa and testing its efficacy for MCS and MST.

1.3 Aim and Objectives

This study aimed to test the efficacy of a kayak-based kelp monitoring protocol for MCS and MST in South Africa. The focus was on the validity of scientific data created with this protocol, its ability to change the attitude and learning of volunteers in the short term, and testing its potential as a part of MST offerings.

Objective 1

To develop a kayak-based-kelp-monitoring protocol and test it at the case study site, namely Simon's Town, False Bay, South Africa.

Objective 2

To assess the efficacy of the protocol to create valid scientific data. This was done by comparing the data collected by the volunteers with data collected by scientists at the same location.

Objective 3

To test if this type of activity can change the short-term attitude of the participants towards the sea and increase their learning. This was done by interviewing the participants after participation in kelp monitoring. They were asked to discuss their experiences with the activity and possible changes in their attitude and learning.

Objective 4

To assess the potential of the kelp monitoring activity as an offering in MST. To achieve that the participants in this study were asked how much they would pay for such an activity and the provided values were compared with the prognosticated expenses for the MST business.

Hypotheses

Three hypotheses were formulated for this study:

H1: There is a significant difference between data collected by volunteers in kelp monitoring and those collected by scientists.

H2: There is a difference in short-term attitude and learning outcomes among volunteers before and after participation in kelp monitoring.

H3: There is a difference between the expenses for an MST business using the protocol and the price volunteers are willing to pay to partake in kelp monitoring as a touristic activity.

Chapter 2: Methodology

The method consisted of three parts. The first part was the development of the kayak-based monitoring protocol. After the testing phase, data were collected by scientists and volunteers. The collected data were validated for their utility in generating sound scientific data. Lastly, interviews were organized with the participants to assess their possible short-term change in attitude and learning and their willingness to pay for the experience. Estimated costs were then compared with a calculated expense of the implementation of the protocol provided by the host organization. The study was done in collaboration with Cape RADD from the beginning of April to the end of June 2024.

2.1 Study Site

The study focused on the kelp forests in Simon's Town, False Bay which falls within the Cape Town Municipality in the Western Cape Province. The western coast of False Bay also lies in the Table Mountain National Park Marine Protected Area (TMNPMPA), which has different zonations (Figure 11).

Figure 11: Map of the Table Mountain National Park Marine Protected Area with zonation and allowed activities. Source: Table Mountain National Park, South African National Parks.

In Simon's Town where the host organization has its headquarters, two different sites were selected for the study. Criteria influencing the selection were:

1. Kelp forests had to be present;
2. They had to be reachable by kayak in less than one hour of paddling;

3. The area had to be sheltered from the open sea;
4. One site should be in a no-take zone of the TMNPMPA.

Two sampling sites fulfilled these requirements. These sites were: Long Beach (LB) with the coordinates 34.18757288765428 South and 18.425999382713538 East and Seaforth (SF) with the coordinates 34.193578106094215 South and 18.446361353962462 East.

LB lays northwest (around 10 minutes of paddling) of the city of Simon's Town close to the beach with the same name. It is not part of a no-take zone and is protected from the common southeastern winds and surges by the South African Navy port in Simon's Town. Three kelp beds were chosen for the study which can be seen in Figure 12, named simply LB1-3.

Figure 12: The sampling site of Long Beach. LB1, LB2 and LB3 are the chosen kelp beds for this study. Map created with QGIS.

SF is east of the South African Navy port of Simon's Town close to Seaforth Beach. It could be reached by a 30-minute paddling around the port. It lies at the border of the Boulders Restricted Zone (Figure 11). Although less protected from the wind and surge it provided extensive kelp beds for the study. Equally as in LB, 3 kelp beds were selected for the study called SF1-3 (Figure 13), although only SF1 was sampled frequently enough to be used in the study. As SF1 was a big kelp bed, often there was not enough time to sample SF2 and SF3 too, as one sampling trip was limited to a 2 ½-3 hour time frame.

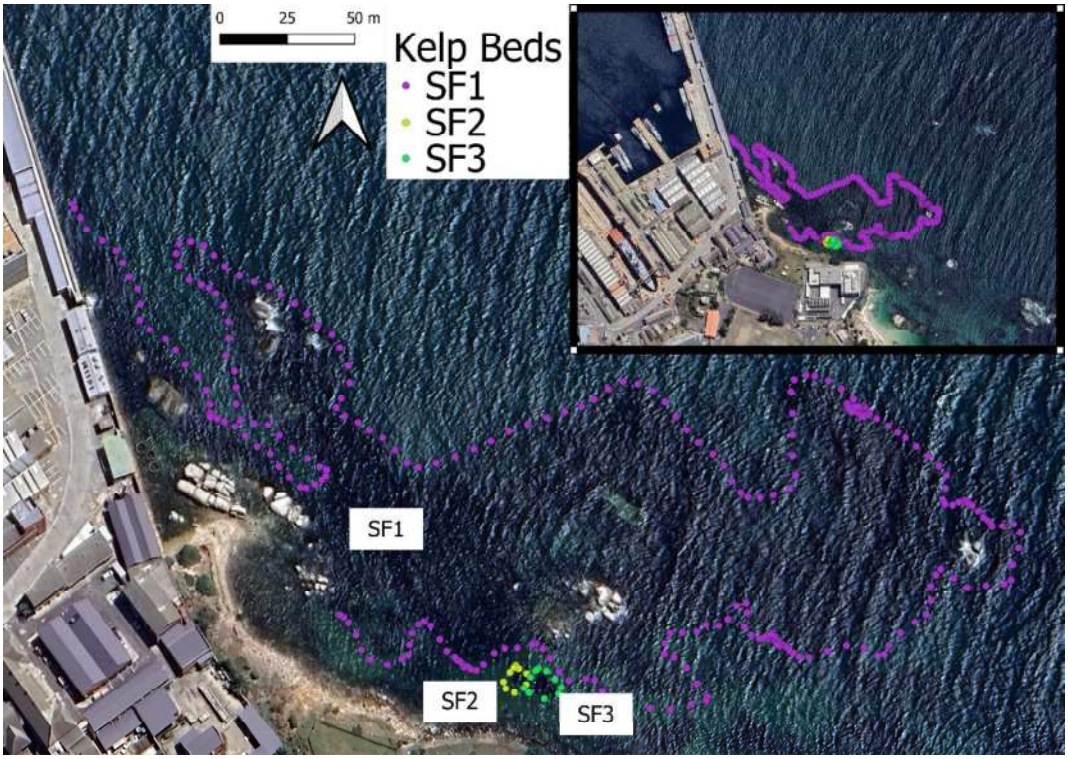

Figure 13: The sampling site of Seaforth. SF1, SF2 and SF3 are the chosen kelp beds for this study. Map created with QGIS.

2.2 Kayak-based Kelp Monitoring Protocol

The protocol was adapted from those of Rothman *et al.* (2010) and Bishop (2014). In Rothman *et al.* (2010) divers used one square meter floating surface quadrats to measure the

density of surface-reaching kelp in South Africa by counting the number of heads reaching the surface along a transect through the kelp forests. This measurement was done during low tide. They established a correlation between the total biomass of the kelp and the density of kelp heads at the surface by removing the surface-reaching kelp at the holdfast after the density measurement and weighed on the beach. This correlation was highly significant and allowed the researchers to calculate the biomass of kelp beds using only floating surface quadrats in the future, establishing a new non-destructive kelp biomass measurement method.

Bishop's (2014) is a protocol that uses kayaks to survey bull kelp in Puget Sound, USA. The protocol describes how to register the perimeter of kelp beds using a hand-held GPS device, how to measure the depth using a weighted line, and how to take photos from the kelp bed. Before explaining how to sample the protocol establishes what is considered a kelp bed and when to sample. In Bishop (2014) a kelp bed is a cluster of bull kelp with a diameter of at least five meters and away from another kelp bed by at least eight meters. Sampling should be done during low tide. To register the perimeter of kelp beds the GPS device is programmed to register a track. With this function, the kayaker paddles around the kelp bed with one meter of distance and registers like this the perimeter of the kelp beds. The depth of the kelp beds is measured in two points, one facing the shore and one on the opposite side of the first depth measurement. The weighted line is lowered to the seafloor and then the length of the submerged part of the line is counted using the marks (in feet) on the line. A waypoint is marked on the GPS where the depth was measured. Concerning the photos, the protocol describes that four photos are taken of each kelp bed. One photo is taken facing the shoreline, one facing away from the coast, one with the coast on the left side, and one with the coast on the right side. These photos are not used to measure density at all. They only

serve to have a photo record of the kelp beds over time. Further other observations like damage to the kelp or other organisms are noted. These steps are repeated for every kelp bed in the sampling area.

From these studies, three aspects were taken for the new protocol. They were:

- Kelp patch perimeter (Bishop (2014))
- Depth measurement (Bishop (2014))
- Transects with floating surface quadrats for density measurement (Rothman *et al.* (2010))

The protocol was developed for two two-person kayaks. Apart from the kayaks and paddles other equipment included one portable, waterproof GPS device (Garmin ETREX 32x), one waterproof camera, one floating 50x50cm quadrat, one measuring tape with an attached buoy, and one weighted line with marks every meter.

Sampling was done at low tide using Cape Town's low tide time. A kelp bed was established as a continuous patch of kelp with a diameter of at least 2 meters. Two kelp beds needed to be at least 2 meters apart from one another.

For the perimeter of the kelp beds, like in Bishop (2014), the portable GPS device was used. The GPS was programmed to take automatically a point every five seconds. With this setup, one of the kayaks paddled as close as possible to the kelp, without harming the kelp, around the kelp bed and registering thus the perimeter. The registration on the GPS was stopped once the kayak reached the starting position or the end of the kelp bed. A photo showing this can be seen in Figure 14.

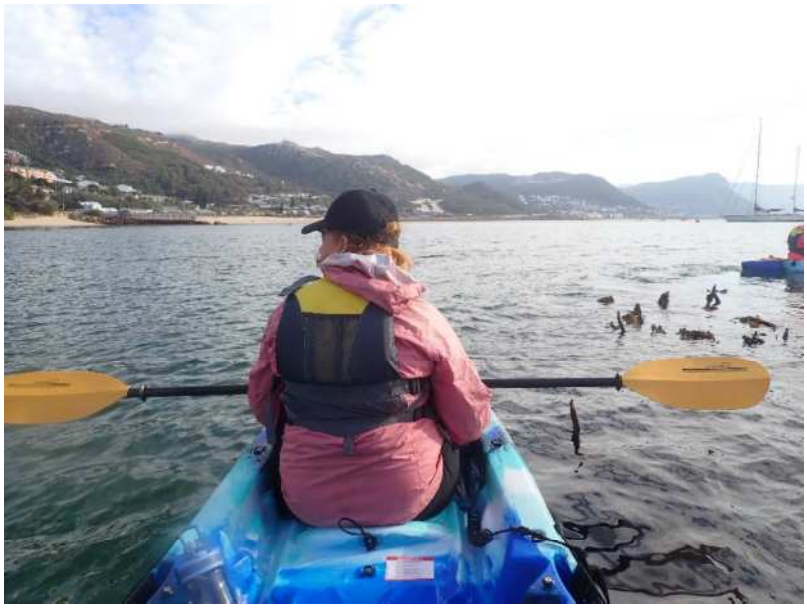

Figure 14: A participant paddling around a kelp bed in Long Beach while registering with the GPS the perimeter. Photo taken by the author.

As in Bishop (2014), the depth was measured using a weighted line marked in one-meter steps, although instead of only two spots, in four places along the kelp perimeter, the depth was measured. These points were: the beachside, the opposite open seaside, one on the left, and one on the right side of the kelp bed. The beachside point was not measured if the kelp bed reached the shoreline. At each of these points, the line was lowered until it reached the seafloor and got slack. The line was then straightened and pulled in, counting the depth using the marked points on the line. The depth was then saved on a prepared dive slate. An example of how the depth was measured can be seen in Figure 15.

Figure 15: A participant measuring the depth at a kelp bed in Long Beach. Photo taken by the author.

The percentage cover of the surface reaching kelp was measured along a transect which was set through the kelp bed. The measuring tape for the transect was fixed on each end onto two kelp heads. Four randomly chosen spots along the transect were sampled. The kayak was anchored there by holding on to one kelp head on each side of the kayak. After the kayak stopped, a visual estimation of the percentage cover in a 50*50cm surface floating quadrat was done and then noted onto a prepared dive slate. To have a backup, a photo of each quadrat was also taken. This process is visible in Figure 16.

Figure 16: A participant estimating the percentage cover in a 50*50cm quadrat at a kelp bed in Long Beach. Photo taken by the author.

The full detailed protocol can be found in the Annex 6.1.

2.3 Sampling and Data Validation

At the project's launch, a social media post was created and launched on the social media channels of Cape RADD. The poster used in the post can be seen in Figure 17. In total 18 different persons responded to the post over the study period and participated in this study. After a briefing in the hub, where the sampling techniques were shown and explained, the lead researcher of the study paddled out with all of the participants with a maximum of three volunteers per trip and sampled with them using the previously mentioned protocol. In total 12 trips were done, eight to LB and four to SF. All participants measured at least once the depth and percentage cover, while the area was only measured by the volunteers on the kayak

with the lead researcher. The sampling was only done during low tide and good meteorological and oceanographic conditions (no strong wind and no swell). The whole experience was limited to 2½-3 hours including briefing and de-briefing. This time limit meant that not always all of the kelp beds could be sampled if sampling was slower. After the sampling, all participants were asked if they would participate in an interview, to which all except one agreed. In the interview, the participants were asked about their background in science. Six participants had a background in science and marine science, while the rest were participants with various backgrounds. The data collected by the participants with a science background was classified as data collected by scientists, while the rest of the data was classified as data collected by volunteers. This separation of the data was needed, as to be able to validate the data. To do so the data collected by the volunteers and the data collected by the scientists was compared.

Figure 17: The poster which was used to attract participants to participate in this study. It was posted on the social media channels of Cape RADD.

2.4 Interviews

The efficacy of the protocol in changing the short-term attitude of the volunteers towards the sea and increasing their learning was assessed with a face-to-face semi-structured interview at the end of the activity, with prepared questions as a guideline. A phenomenology approach was used for it. Phenomenology is a research approach in qualitative research, under a post-positivist, interpretivist and descriptivist paradigm. In phenomenology, human experiences and perceptions are studied to find similarities in the experience (Lester, 1999, Tuffour, 2017). This interview consisted of three parts and was audio-recorded with the consent of the participants.

The first part consisted of collecting the demographic background of the participants. In the second part, the volunteers were asked if their attitude towards the ocean and marine life had changed after participating in kelp monitoring. Furthermore, they were asked if their understanding and learning of the sea, the kelp forests, and their inhabitants changed. Lastly, questions concerning the fun of the activity and the simplicity of the data sampling were asked.

The last part of the interview was an open question, where the volunteers were asked how much they would pay for this monitoring activity as part of MST. The full list of the questions is given in Table 1.

Table 1: The questions which were asked to all of the participants. The questions are subdivided into questions concerning the demographic background and questions concerning the feedback.

	Questions:
Demographic Background	1. What is your country of origin and residence? • Are you a local resident? 2. What gender do you identify yourself with? 3. In which year were you born/How old are you?

	4. What is your highest education level? 5. Do you have a marine science/environmental science/STEM background?
Feedback	1. Was the activity entertaining/fun/enjoyable? • What was specifically fun/entertaining/enjoyable? • How could the activity be made more fun/entertaining/enjoyable? 2. Was the protocol simple and manageable? • Is there anything that you would change about the protocol? 3. Did your attitude towards the sea and its organisms change after partaking in the kayak-based monitoring? • What exactly changed? 4. Do you feel more connected to the ocean/kelp forests and in what way? 5. Did you learn something new during this activity? • What was it specifically? 6. Did the activity motivate you to change something in your life? • What specifically? 7. Would you pay to participate in this activity and if so, how much? (The average cost of a similar activity is approximately USD 50) 8. Is there anything else you want to say or suggest about this activity?

2.5 Data Analysis

The GPS data were analyzed using QGIS (QGIS Version 3.34.5). The GPS points were cleaned by removing outliers and overlapping points, normally the starting and/or ending points. This had to be done as several times the registration of the perimeter started in the kelp bed itself or further away (the kayak drifted during the setting up of the GPS to take points) thus these points did not represent the true perimeter. Overlapping of the points happened when the starting and stopping spots for the GPS registration were overlapping. The remaining points of the perimeter measurement were connected and transformed into a polygon. From this polygon, the area was calculated. For kelp beds which stretched directly from the coast a shapefile of the South African (dataportal-mdb-sa.opendata.arcgis.com/datasets) coastline was used. The two ends of the perimeter were connected to the coastline to create the polygon. As for the other kelp beds, the area was then estimated.

The data from the depth measurements and the percentage cover were copied into Microsoft® Excel® for Microsoft 365 MSO (version 2406). The percentage cover, which was sampled, was then compared with the percentage cover of the taken photos. For that, the percentage cover of the photos was estimated by visual estimation. If the percentage cover from the sampling and the photos differed considerably (more than 10%) the percentage cover from the photos was used for the study, instead of the value from the sampling. A protocol describing these steps is added to Annex 6.1.

The data were statistically analyzed in Microsoft® Excel® for Microsoft 365 MSO (version 2406). These data were the area, the four depth measurements, and the quadrats of each kelp bed. They were divided into two categories: data sampled by volunteers and data sampled by scientists. Then in each category, the data were subdivided into the sampled kelp beds. For every kelp bed (LB1-3 and SF1), descriptive statistics (mean, standard deviation, and standard error) were calculated. Afterward, a student's t-test was conducted to compare the data and to see if there was a significant difference between the data collected by volunteers and by scientists.

The interviews were transcribed *verbatim* into a separate Excel sheet. The age and education level of the participants were categorized into the following: age = $x \leq 29$, $30 \leq x \leq 39$, $40 \leq x \leq 49$, and $x \geq 50$; education = High School, Bachelor/Master/Honors/Diploma, and PhD. These were analyzed for descriptive patterns and frequencies.

For the main data collected in the interviews (attitude change, fun, and learning), a manual thematic analysis was conducted. Here, codes were extracted from the responses of the participants (Nieuwenhuis, 2017, Nowell et al., 2017). Codes are key concepts of text which afterward can be grouped into themes.

The amount the participants were willing to pay for the experience was converted, when necessary, from ZAR into USD using an exchange rate of 1 ZAR = 0.055 USD, which was the exchange rate on 26.07.2024 (Bloomberg.com). Then the mean of all values was calculated and afterward compared to the value which was given by the host organization as the price they would charge participants of the kelp monitoring paddling tour. Possible outliers were removed from the calculation, as they would bias the mean. A one-sample t-test was executed to see if there would be a statistical difference.

2.6 Study Limitations

The study had some limitations. The first and most important limitation was the weather and tides of the sampling area. This study was conducted in the southern autumn and beginning of the southern winter. In this season bad weather and storms are common which limited the amount of days on which it was possible to sample (meteoblue.com). Then, as sampling trips had to be done at low tide, but also between 9 am and 2 pm to be able to do the whole sampling trip during the working hours of Cape RADD, the total amount of days per month was reduced to only seven days per month (tide-forecast.com). Further, the limited time of three months of the study prevented a comparison based on seasonality.

Another limitation was that sampling was conducted in the low season for tourism which limited the number of participants in this study. Residents were only available during weekends. This led to a relatively small sample size of only 18 participants and 12 sampling trips.

For some of the kelp beds, only a very limited amount of data could be sampled. For example, for SF1 only two sampling trips were done by volunteers and scientists. SF1

couldn’t be sampled more frequently as the site is more exposed to the surge and wind compared to LB. Further, as a trip was limited to a total of 2 ½ -3 hours, not always all of the kelp beds could be sampled at one site. This was mostly the case for SF, as here SF1 is a huge kelp bed, which used most of the sampling time, thus often SF2 and SF3 couldn’t be sampled on the same trip. SF2 could only be sufficiently sampled by the volunteers due to the previously mentioned limitations, thus a comparison was not possible between scientists and volunteers for this kelp bed.

It was not possible to assess the long-term effects of the project. The results of the interviews reflect only short-term results and it is unknown if the participants kept the possible changes also in the long-term. In general, all of these limitations led to a low sampling replication.

Chapter 3: Results

3.1 Kelp Monitoring Protocol

3.1.1 Area of the Kelp Beds

The results for the measurement of the area of the kelp beds can be seen in Table 2, Figure 18, and Figure 19. As visible in Table 2 and Figure 18, the first kelp bed in Long Beach (LB1) had the smallest mean area with 284.285m² measured by the volunteers and 222.050m² measured by the scientists. The largest kelp bed in LB was LB3 with an area of 872.629m² (volunteers) and 641.105m² (scientists). In SF (Table 2 and Figure 19) SF1 had a mean area of 26 857.932m² (volunteers) and 26 523.983m² (scientists), the largest kelp bed of that sampling site. SF1 was also the largest of all sampled kelp beds. On the other hand, SF2 had a mean area of 46.570m² and was the smallest of all kelp beds, although this kelp bed was only measured by the volunteers, as due to time issues scientists never sampled this kelp bed.

Table 2: The sampled area in m² for each of the samples, the mean area in m² for the kelp beds (LB1, LB2, LB3, SF1), and the standard deviation for the mean. As SF3 was only sampled once, no mean or standard deviation could be calculated The treatment of volunteers and scientists subdivides the data.

Treatment	Kelp Bed and Sample	Area (m²)	Mean Area (m²)	Standard Deviation
Volunteers	LB1-1	203.777	284.285	65.437
	LB1-2	354.586		
	LB1-3	263.213		
	LB1-4	315.563		
	LB2-1	316.769	341.648	46.601
	LB2-2	395.409		
	LB2-3	312.767		
	LB3-1	748.019	872.629	123.681
	LB3-2	1018.708		
	LB3-3	928.203		

	LB3-4	795.585		
	SF1-1	27827.331	26857.932	1370.938
	SF1-2	25888.532		
	SF2-1	54.742	46.570	11.557
	SF2-2	38.398		
	SF3-1	97.187		
Scientists	LB1-1	182.863	222.050	43.085
	LB1-2	206.4		
	LB1-3	215.669		
	LB1-4	283.269		
	LB2-1	238.691	321.763	70.807
	LB2-2	300.814		
	LB2-3	339.929		
	LB2-4	407.617		
	LB3-1	462.742	641.105	177.253
	LB3-2	817.226		
	LB3-3	643.347		
	SF1-1	27030.978	26523.983	716.999
	SF1-2	26016.988		
	SF3-1	104.354		

Table 3: The results of the student's-t-test for the comparison of the area measured by volunteers and scientists.

	SF	**LB1**	**LB2**	**LB3**
T-Test	0.78900669	0.163234596	0.693182449	0.09495608

Comparing the measurements done by the volunteers and scientists (Figures 18 and 19) it is visible that the measured area by the scientists was always smaller than the area measured by the volunteers. However, this difference was not significant, as all the p-values were over 0.05 (LB1 = 0.163, LB2 = 0.693, LB3 = 0.095, and SF = 0.789; Table 3).

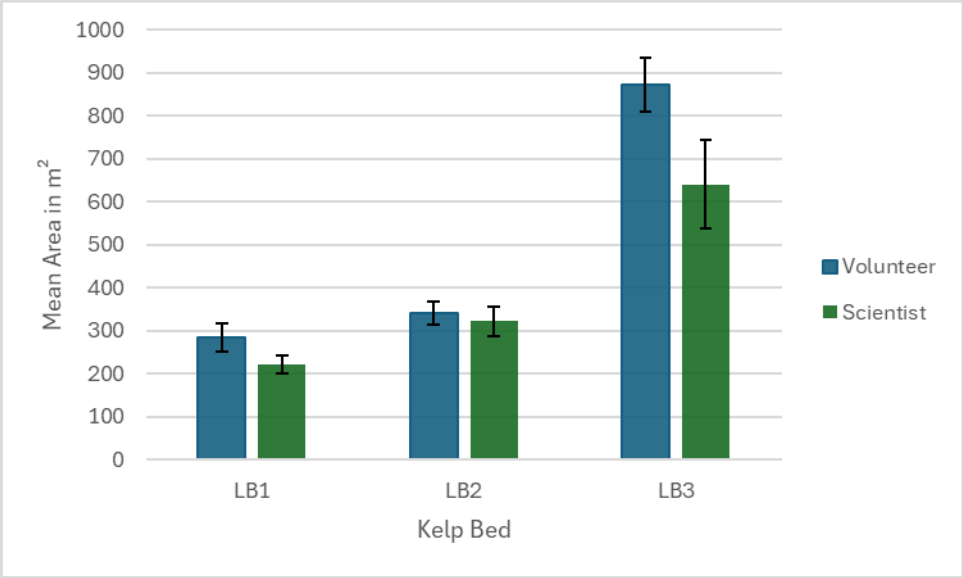

Figure 18: Comparison of the mean area in m² for the three kelp beds in Long Beach (LB). The blue columns are for the volunteers and the green columns are for the data collected by the scientists. The error bars represent the standard error.

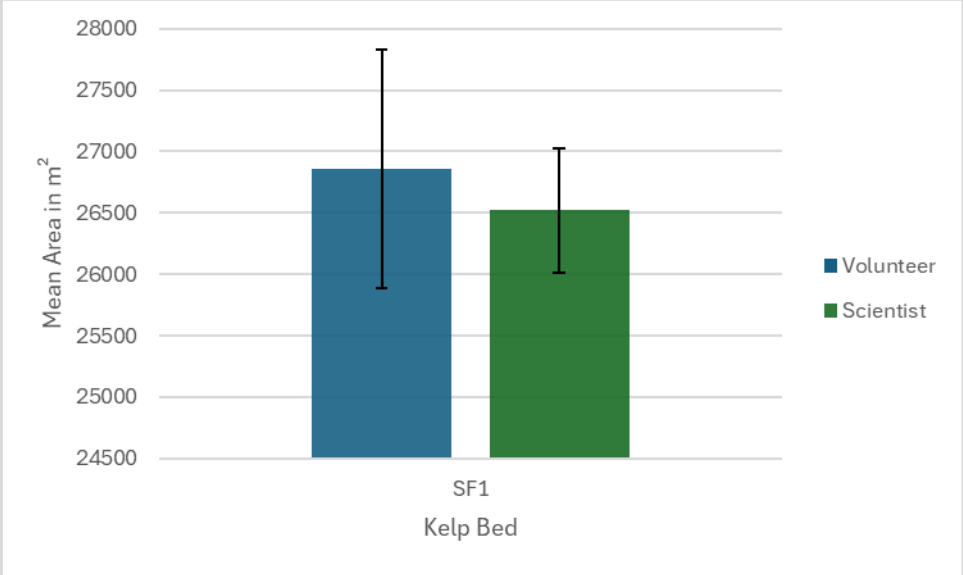

Figure 19: Comparison of the mean area in m² for the kelp bed in Seaforth (SF). The blue columns are for the volunteers and the green columns are for the data collected by the scientists. The error bars represent the standard error.

3.1.2 Depth Measurement

In Table 4, Table 5, and Figure 20 it is visible that LB3 was the shallowest of all the kelp beds with an average depth of 1.39m measured by the volunteers and 1.63m measured by the scientists. The shallowest average depth measured by the scientists was at SF1 with a depth of 1.50m. The deepest measurement was taken at SF1. Here the average depth measured by the volunteers was 5.75m and 5.05m measured by the scientists. The full dataset can be found in Table 4.

Table 4: The sampled depth in m for each of the samples and sampling positions (Beach, Right, Open, Left) for the kelp beds (LB1, LB2, LB3, SF1). The treatment of volunteers and scientists subdivides the data.

	Kelp Bed and Sample	Beach Side Depth (m)	Right Side Depth (m)	Open Side Depth (m)	Left Side Depth (m)
Volunteers	LB1-1	1	1.2	3.5	1.5
	LB1-2	2.5	1.8	3.9	2.5
	LB1-3	3.3	3.25	3.2	3.95
	LB1-4	3.24	3.5	3.9	3.7
	LB2-1	1.25	2.75	2.5	2.1
	LB2-2	2	2.3	2.5	2.1
	LB2-3	2	2.6	2.7	2.4
	LB3-1	/	1.35	1.4	2
	LB3-2	/	1	1.6	1.5
	LB3-3	/	1.7	1.98	1.9
	LB3-4	/	1.5	1.5	1.8
	SF1-1	2.2	3.05	6	5
	SF1-2	1.8	4.8	3	6.5
	SF2-1	1.5	1.9	1.9	1.85
	SF2-2	1.5	2	2	1.8
	SF3-1	1.5	1.75	1.75	1.9
Scientists	LB1-1	3.4	3.4	4.5	4.1
	LB1-2	3.5	3.3	4	4
	LB1-3	3	1.1	2.9	3.8
	LB1-4	3.7	3.5	4.15	4
	LB2-1	2.6	3.2	3.2	3.05
	LB2-2	2.7	2.95	2.9	2.5
	LB2-3	2.1	2.55	2.3	2.35
	LB2-4	2.4	2.9	2.9	2.9

	LB3-1	/	2	2.4	2.2
	LB3-2	/	1.2	1.95	1.75
	LB3-3	/	1.7	2.05	1.8
	SF1-1	1.8	3.1	3	5
	SF1-2	1.2	2.1	4.8	5.1
	SF3-1	1.5	1.7	1.8	1.9

Table 5: The mean depth in m for each kelp bed (LB1, LB2, LB3, SF1, SF2) and sampling spot (beach, right, open, left) and the standard deviation for the mean. The treatment of volunteers and scientists subdivides the data. As the scientist did not sample SF2, no data is provided in the table.

	Volunteer		**Scientists**	
	Mean Depth (m)	**Standard Deviation**	**Mean Depth (m)**	**Standard Deviation**
Beach (LB1)	2.51	1.07	3.40	0.29
Right (LB1)	2.44	1.11	2.83	1.15
Open (LB1)	3.63	0.34	3.89	0.69
Left (LB1)	2.91	1.13	3.98	0.13
Beach (LB2)	1.75	0.43	2.45	0.26
Right (LB2)	2.55	0.23	2.90	0.27
Open (LB2)	2.57	0.12	2.83	0.38
Left (LB2)	2.20	0.17	2.70	0.33
Right (LB3)	1.39	0.30	1.63	0.40
Open (LB3)	1.62	0.25	2.13	0.24
Left (LB3)	1.80	0.22	1.92	0.25
Beach (SF1)	2.00	0.28	1.50	0.42
Right (SF1)	3.93	1.24	2.60	0.71
Open (SF1)	4.50	2.12	3.90	1.27
Left (SF1)	5.75	1.06	5.05	0.07
Beach (SF2)	1.5	0		
Right (SF2)	1.95	0.07		
Open (SF2)	1.95	0.07		
Left (SF2)	1.83	0.04		

Table 6: The results of the student's-t-test for the comparison of the depth measured by volunteers and scientists. The results are given for each kelp bed and sampling spot.

T-Test	**Beach**	**Right**	**Open**	**Left**
LB1	0.15996547	0.64601637	0.52086592	0.11198876

LB2	0.00713269	0.12983454	0.3127277	0.06481471
LB3		0.39123097	0.04159212	0.53388571
SF1	0.29985996	0.31911245	0.76429774	0.45002806

Comparing the depth measurements in Figure 20 shows the trend that for LB the measurements done by the scientists were deeper than those done by the volunteers. The contrary was the case comparing the measurements at SF where the volunteers measured deeper depths than the scientists did. However, almost all the differences were not significant (> 0.05); the exception was the difference at the beach side of LB2 ($p = 0.007$) and the open side of LB3 ($p = 0.042$). These results are visible in Table 6.

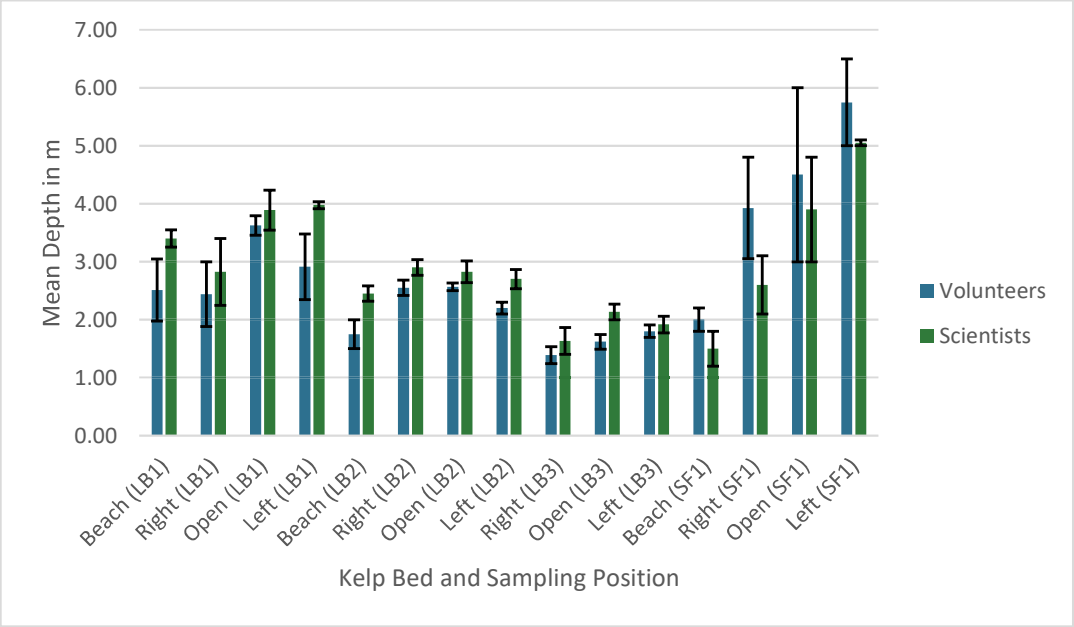

Figure 20: Comparison of the mean depth in m for the kelp beds in Long Beach (LB) and Seaforth (SF). For each site, there are four sampling spots (beach, right, open, left). The blue columns are for the volunteers and the green columns are for the data collected by the scientists. The error bars represent the standard error.

3.1.3 Percentage Cover

The lowest average percentage cover of the kelp beds measured by volunteers was at SF1 with 33%, while the lowest average percentage cover measured by scientists was at LB1 with 27% which also represents the lowest total value. The highest percentage cover differed between scientists and volunteers. For volunteers, the highest percentage of cover was measured in LB2 with 86%, being also the highest value. The highest value for scientists was at LB3 with 73%. All of this is visible in Table 8 and the whole dataset is visible in Table 7. Comparing the measured percentage covers (Figure 21), no clear trend is visible. For two of the kelp beds (LB1, LB2) the volunteers measured a higher percentage of cover, while for two kelp beds (LB3, SF1) the scientists had on average a higher percentage of cover. However, only one of the differences was significant (Table 9). This was the case for LB2, where the student's-t-test resulted in a p-value of 0.011.

Table 7: The sampled percentage cover in % for each of the samples and quadrats (Q1, Q2, Q3, Q4) for the kelp beds (LB1, LB2, LB3, SF1). The treatment of volunteers and scientists subdivides the data.

	Kelp Bed and Sample	Quadrat 1 Percentage Cover (%)	Quadrat 2 Percentage Cover (%)	Quadrat 3 Percentage Cover (%)	Quadrat 4 Percentage Cover (%)
Volunteers	LB1-1	0	5	0	20
	LB1-2	100	8	65	40
	LB1-3	45	90	50	50
	LB1-4	15	25	30	100
	LB2-1	100	100	80	40
	LB2-2	100	100	100	100
	LB2-3	100	50	60	100
	LB3-1	35	5	50	45
	LB3-2	100	90	100	90
	LB3-3	100	35	65	50
	LB3-4	20	100	40	30
	SF1-1	95	50	15	45
	SF1-2	0	50	2	4
	SF2-1	35	100	100	50

	SF2-2	20	100	100	0
	SF3-1	100	95	70	30
Scientists	LB1-1	0	0	0	0
	LB1-2	100	100	0	50
	LB1-3	0	0	40	30
	LB2-1	60	40	0	0
	LB2-2	0	0	20	65
	LB2-3	100	100	100	90
	LB2-4	90	85	15	40
	LB3-1	85	70	40	20
	LB3-2	100	100	100	100
	LB3-3	60	60	80	55
	SF1-1	55	50	100	100
	SF1-2	24	35	65	80
	SF3-1	90	100	90	75

Table 8: The mean percentage cover in % for each kelp bed (LB1, LB2, LB3, SF1, SF2) and the standard deviation for the mean. The treatment of volunteers and scientists subdivides the data. As the scientists did not sample SF2, no data is provided in the table.

	Volunteers		**Scientists**	
	Mean Percentage Cover (%)	**Standard Deviation**	**Mean Percentage Cover (%)**	**Standard Deviation**
LB1	40	34.01	27	38.69
LB2	86	22.75	50	40.48
LB3	60	32.48	73	26.41
SF1	33	33.34	64	28.20
SF2	63	41.83		

Table 9: The results of the student's-t-test for the comparison of the percentage cover measured by volunteers and scientists.

	SF	LB1	LB2	LB3
T-Test	0.06433101	0.33526493	0.01131316	0.27462142

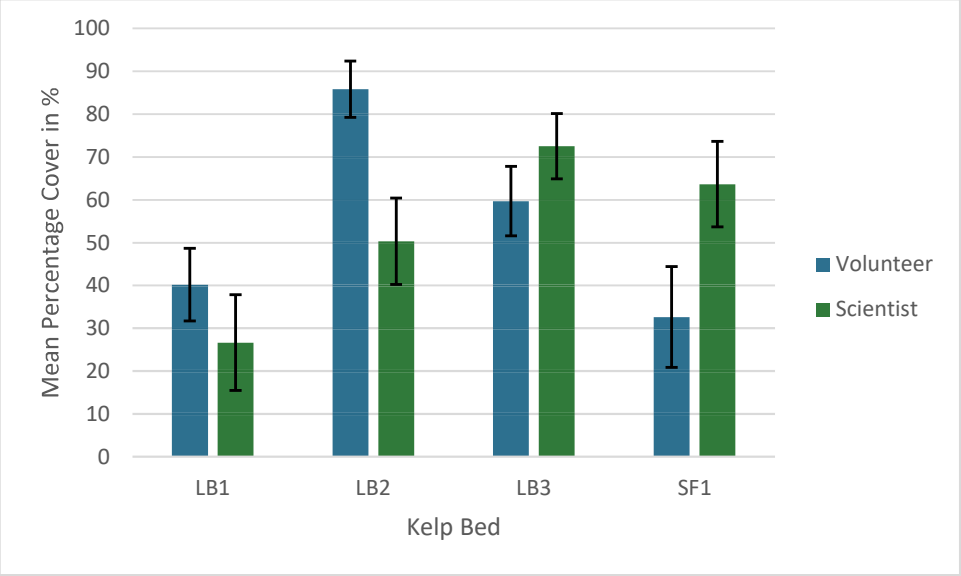

Figure 21: Comparison of the mean percentage cover in % for the kelp beds in Long Beach (LB) and Seaforth (SF). The blue columns are for the volunteers and the green columns are for the data collected by the scientists. The error bars represent the standard error.

3.2 Interviews

3.2.1 Demographic Data

Over 75% of the participants were of South African origin, while four participants were of other nationalities (Germany, UK, USA, Zimbabwe). Most (82%) of the participants were living in South Africa while the rest were residing abroad and were visiting as tourists. The majority of the participants were females (65%) and the rest were males. Of the participants

20% were younger than 29, the youngest being 22 years old, 33% were between 30 and 39 years old, and 40% were between 40 and 49 years old. Only one person was 53 years old. The average age of the participants was 36.3 years. Most of the participants (69%) had postgraduate qualifications, although only 44% were in STEM, and the rest had the equivalent of a high school diploma. All this data is given in Table 10.

Table 10: Demographic background of the participants. All answers are given with their number and percentage.

Question categories:	**Answer category**	**Number of participants**	**Percentage of all participants**
Origin	South Africa	13	76
	Zimbabwe	1	6
	Germany	1	6
	USA	1	6
	UK	1	6
Residency	South Africa	14	82
	UK	1	6
	Australia	1	6
	United Arab Emirates	1	6
Local/Tourist	Local	14	82
	Tourist	3	18
Gender	Male	6	35
	Female	11	65
Age (years)	≤29	3	20
Mean: 36.33	30≤x≤39	5	33
Min: 22	40≤x≤49	6	40
Max: 53	≥50	1	7

Education	High school	5	31
	Bachelor/Master/Honours/Diploma	10	63
	PhD	1	6
Stem/Science Background	Yes	7	44
	No	9	56

3.2.2 Attitude, Learning, Perception, and Simplicity of the Protocol

Table 11 shows the results of the manual thematic analysis of the interviews. All the participants had fun and enjoyed sampling with the protocol. From the answers, two codes emerged as the most frequently mentioned topics of why the experience was fun. The first was ***nature***. The participants enjoyed being out in nature and on the water, and being able to see marine wildlife, as some participants for example mentioned:

"*It is just I mean it's nice being out in the sun, and just being on the water.*" (Volunteer 2)

"*Just being out in the general environment, just being there in the sense of you with the nature, you are not sitting on the sidelines you are there, participating, being part of what is happening.*" (Volunteer 6)

"*I loved the paddling, I loved the marine life and the nature, just, we are so privileged.*" (Volunteer 10)

The second code that emerged was the ***sampling*** itself. People mentioned that it was nice as it was a new experience or it reminded them of their past studying experience. This was visible in the following two quotes:

"*I think the data side of it, collecting the data, because that is not something one normally does, data collection.*" (Volunteer 9)

"*I felt like I was back in university doing a field course with my friends, doing practical field work is always fun for me.*" (Scientist 3)

Concerning the question of whether their attitude towards the ocean had changed at least in the short term, the participants did not provide a uniform answer. Half (53%) said yes while 41% did not experience a change in their attitude and 6% did not give a clear answer or did not answer. The first code which emerged from this question was ***kelp forests***. The experience was eye-opening and showed the participants the importance of kelp forests as some of the participants said:

"*Yeah, I think like towards the kelp, I didn't have an idea of how much impact they have on the marine life. So, after today I see them as important as the Amazon forest. They need to be protected and preserved.*" (Volunteer 3)

"*I mean I love the sea, but I am a mountain person, so it was just wonderful to experience the collection of data and to see how you keep an eye on things like the kelp forests and how important they are. I didn't realize how important they were and so it was eye-opening*" (Volunteer 10)

The reason why for more than 40% of the participants there was no change in attitude can be described by the code ***background***. These people had already a history of interacting with kelp or the ocean as they mentioned:

"*Uhm, no, but that is because I already had a full understanding of all of the marine organisms. It is a positive no.*" (Scientist 3)

"*I have to say no because I think because of my background as a marine scientist. I think if I were someone who never experienced it before, I would have said yes, but as I am already on that side it hasn't changed much more than it was before this. It is only because of the baseline. It is not because I didn't enjoy it or something you did. It is just my baseline.*" (Scientist 6)

Half (47%) of the participants answered yes to the question if they felt more connected to the ocean and kelp forests after participating in the sampling. Only 12% answered no to the question and for 41% the answer was not clear or they did not give an answer. The reason why and to what they felt more connected is represented by the codes ***experience*** and ***nature***. The experience of being out there in nature on the water is why some of the participants experienced a change in their attitude as some of them said for example:

"*I think most people are very far removed from nature with our busy lives, so being hands-on to that kind of experience, uhm, yeah it changes you.*" (Scientist 2)

"*I do and every activity that I do in the ocean just brings me closer to the ocean, so kayaking is a new experience for me, I am usually scuba diving and snorkeling, so I am always like in the water, but just you know to kind of sit there on top of the water, taking everything in, that helped have a new perspective on the ocean.*" (Scientist 3)

As visible in the last quote, the people felt more connected to the ocean and the kelp, which is part of the code ***nature***. Volunteer 3 mentioned:

"*Just learning about the kelp forests. For me, before they were just like weeds, seaweeds, and that made me feel ambushed. But now I am taking them as more important vegetation, as part of nature. Before I used to look at them as alien species. Aggressive species that just pollute the somehow clear waters.*" (Volunteer 3)

A clear majority, 94%, learned something new during the experience. Only 6% did not learn something new. The two mentioned codes were ***knowledge*** and ***methodology***. ***Knowledge*** was mostly about the kelp forest and marine organisms that were encountered. Participants stated:

"*The kelp and its functions. I knew very little, like nothing about the kelp and now I know more about the habitat.*" (Volunteer 3)

"*I learned about the starfish how it eats the mussel and the different types of kelp, the fact that the kelp will die if it is cut off and I didn't know that, and about the different sharks.*" (Volunteer 10)

Methodology consisted of learning the sampling skills. For many, this was something new:

"*Yes, I've taken transects and captured data before, but I haven't done it in kelp forests, so for me like using that kind of methodology like taking the depth, doing these little specific quadrats, etc those are all new skills.*" (Scientist 1)

"*How to data sample in kelp forests. Something I've never done before and the research methods for the data.*" (Volunteer 9)

Most (70%) of the participants decided to change something in their life after the experience, while 12% stated no and 18% gave no clear answer. When asked, three main codes were mentioned. The first was ***teaching***. Participants wanted to raise awareness and encourage other people to think about kelp and the kelp forests. It can be summarized with these quotes:

"*I would say it changed in the sense that I would encourage more people to learn more about that issue [kelp]. I think because everything is underwater a lot of people don't take*

the time to understand what is going on. It is a very important thing on the planet."

(Volunteer 5)

"*Yes, I feel like I would want to encourage more people to look after the oceans and now and then take a look under the water instead of on the surface.*" (Volunteer 6)

Another mentioned code was ***Sea activities***, which meant going out more into nature and the sea, doing activities like kayaking, snorkeling, or other activities. Participants mentioned:

"*I think I am going to purchase a kayak and spend more time in the ocean.*" (Volunteer 10)

"*I'll be more inclined to snorkel in the kelp now.*" (Volunteer 11/Scientist 5)

The last mentioned code was ***fitness***. Participants noticed that kayaking is physically demanding and thus they decided to get more fit to be able to kayak more or spend more time on the ocean. For example, participants stated:

"*I want to become fitter now so that I can kayak more.*" (Scientist 3)

"*Yeah, get more fit.*" (Scientist 6)

Table 11: Results of the thematic analysis. Given are the questions, the percentage of people answering yes/no/no answer to the questions, and the extracted codes for each question with its keywords and quotes.

Question	Yes/No	Codes	Keywords	Key quotes
Was the activity fun and enjoyable?	Yes: 100%	Nature	• Nature • Being on the water • Marine life • Kelp • Ocean	“ It is just I mean it's nice being out in the sun, and just being on the water” “ Just being out in the general environment, just being there in the sense of you with the nature, you are not sitting on the sidelines you are there, participating, being part of what is happening” “ I loved the paddling, I loved the marine life and the nature, just, we are so privileged” “ Just being out in nature, on the water. It was a nice change of pace from the diving.”
		Samp-ling	• Scientific • Measuring • Collecting data/data collection • University • Sampling	“ I think the data side of it, collecting the data, because that is not something one normally does, data collection” “ I enjoyed doing the actual measuring itself. Uhm, once I finally understand it” “ I felt like I was back in university doing a field course with my friends, doing practical field work is always fun for me” “ Also, I did enjoy the sampling as well”
Did your attitude towards the ocean change?	Yes: 52.94% No:41.18 % No clear or no answer : 5.88%	Kelp Forests	• Kelp • Forest • Sea	“ Yeah, I think like towards the kelp, I didn't have an idea of how much impact they have on the marine life. So, after today I see them as important as the Amazon forest. They need to be protected and preserved” “ I mean I love the sea, but I am a mountain person, so it was just wonderful to experience the collection of data and to see how you keep an eye on things like the kelp forests and how important they are. I didn't realize how important they were and so it was eye-opening” “ I got more of an appreciation, uhm, because I never really been around kelp like that, so it was cool and it was very different from doing the snorkeling.” “ I would say like I didn't know how important kelp was, so, I like became more aware about it. I kind of reminds you uhm, that there are little parts of the oceans that you kind of overlook and don't know that they are so important for the ecosystem.”
		Back-ground	• Back-ground • Already full under-standding	“ I've always had respect for the sea and I've always understood that it is not so fragile, but also needing the care of, so not really still the same attitude” “ Uhm, no, but that is because I already had a full understanding of all of the marine organisms. It is a positive no.” “ I have to say no because I think because of my background as a marine scientist. I think if I were someone who never experienced it before, I would have said yes, but as I am already on that side it hasn't changed much more than it was before this. It is only because of the baseline. It is not because I didn't enjoy it or something you did. It is just my baseline.”

Question	Yes/No	Codes	Keywords	Key quotes
Do you feel more connected to the ocean?	Yes: 47.06% No:11.76% No clear or no answer: 41.18%	Expe-rience	• Experience • Hands-on • Kayaking	"I think most people are very far removed from nature with our busy lives, so being hands-on to that kind of experience, uhm, yeah it changes you" "I do and every activity that I do in the ocean just brings me closer to the ocean, so kayaking is a new experience for me, I am usually scuba diving and snorkeling, so I am always like in the water, but just you know to kind of sit there on top of the water, taking everything in, that helped have a new perspective on the ocean." "Just being able to instead of just looking at it, it is more like a feel you can have. Going through the kelp, holding the kelp is a very nice tactual thing and you can feel grounded in that sense. It is a very spiritual thing. You get to be
		Nature	• Kelp • Ocean • Life	"Just learning about the kelp forests. For me, before they were just like weeds, seaweeds, and that made me feel ambushed. But now I am taking them as more important vegetation, as part of nature. Before I used to look at them as alien species. Aggressive species that just pollute the somehow clear waters." "In like the way like I know their [kelp] significance now. Before I didn't know that there is so much life that was brought to the kelp forest."
Did you learn something new?	Yes: 94.12% No: 5.88%	Know-ledge	• Facts • Kelp • Knowledge • Organisms	"Well, I mean specifically, you know, certain facts about the kelp" "The kelp and its functions. I knew very little, like nothing about the kelp and now I know more about the habitat" "I learned about the starfish how it eats the mussel and the different types of kelp, the fact that the kelp will die if it is cut off and I didn't know that, and about the different sharks" "A lot of different things. It was why I appreciated learning about the intertidal zone as well and the relationships between the barnacles, limpets, and starfish and then even like the kelp itself obviously like seeing which had fronts and, yeah, I felt like that was very interesting."
		Metho-dology	• Equipment • Methodology • Quadrats • Sample/Sampling	"Yes, I've taken transects and captured data before, but I haven't done it in kelp forests, so for me like using that kind of methodology like taking the depth, doing these little specific quadrats, etc those are all new skills" "How to use the different pieces of equipment" "How to data sample in kelp forests. Something I've never done before and the research methods for the data"
Did the activity moti-vate you to change som-ething in your life?	Yes: 70.59% No:11.76% No clear or no answer: 17.65%	Tea-ching	• Encourage • Learn	"I would say it changed in the sense that I would encourage more people to learn more about that issue[kelp]. I think because everything is underwater a lot of people don't take the time to understand what is going on. It is a very important thing on the planet." "Yes, I feel like I would want to encourage more people to look after the oceans and now and then take a look under the water instead of on the surface."
		Sea Activ-ities	• Kayaking • Snorkelling • Sea	"Yes, I like the sea, I like water, so I want to come more to the sea" "I think I am going to purchase a kayak and spend more time in the ocean." "Like I am very nature-orientated and if anything, it makes us want to go kayaking more often" "I'll be more inclined to snorkel in the kelp now."
		Fitnes s	• Fitness • Get/become fit	"I want to become fitter now so that I can kayak more" "Yeah, get more fit"

All participants considered the sampling protocol manageable. They made some suggestions on how the protocol could be improved. These suggestions included:

- Develop some form of anchoring for the kayaks to stop their movement while sampling the depth and the quadrats;
- Add some form of floating device to the quadrats to keep them from sinking;
- Mention in the briefing the accuracy to which the percentage cover has to be measured;
- Have some maps to improve the navigation with the kayaks.

3.2.3 Cost Comparison

As visible in Table 12 there was a great range in the willingness to pay for kayak-based kelp monitoring as a tourism product. The lowest amount provided was 9.625 USD, while the highest amount provided was 250 USD. This value was considered an outlier as it doubles the next highest stated value of 110 USD and when used modifies the mean value by 14 USD. After removing this value from the calculations, the average price the participants were willing to pay was 30.53 USD, with a median of 24.75 USD. The one-sample t-test resulted in a p-value of 0.87 which means no statistical difference exists between the price of Cape RADD and the volunteers.

Table 12: Willingness to pay of the participants for their participation. The mean and median of the participants, the amount that the host organization wants to charge, and the results of the one-sample t-test are given. Answers are given in ZAR and USD. Participant 11 answered only in USD.

	ZAR	**USD**
Participant 1	550	30.25
Participant 2	250	13.75
Participant 3	450	24.75
Participant 4	400	22
Participant 5	400	22
Participant 6	200	11
Participant 7	175	9.625
Participant 8	350	19.25
Participant 9	2000	110
Participant 10	600	33
Participant 11		250
Participant 12	500	27.5
Participant 13	450	24.75
Participant 14	1000	55
Participant 15	500	27.5
Participant 16	500	27.5
Average (without Participant 11)	555	30.53
Median (without Participant 11)	450	24.75
Host Organisation	500	27.5
One sample t-test p-value	0.87	

Chapter 4: Discussion

4.1 Kayak-based Kelp Monitoring Protocol

Objective 1, the development of a kayak-based monitoring protocol for the kelp forests in False Bay near Simon's Town, was a success. The monitoring protocols of Rothman *et al.* (2010) and Bishop (2014) were successfully adapted to the local conditions of False Bay and the use of kayaks. This new monitoring protocol could be used for MCS and MST. It was tested by volunteers of different age classes (Table 10) and experiences with kayaks and the marine environment and all participants agreed that the protocol was easy enough to be managed by themselves. This study did not feature an extensive training phase for the volunteers beforehand like it is done in projects such as RCCA (Reefcheck.org/kelp-forest, Freiwald *et al*., 2018) or Findkelp (Assis *et al*., 2009), or the research studies of Lamine *et al.*, 2018, Lau *et al.*, 2019, Changeux *et al.*, 2020 and Robbins *et al.*, 2020. Instead, volunteers received a briefing beforehand and were then accompanied by a scientist who had experience with the monitoring protocol. This researcher was there to lead the trip and to support the volunteers if problems and questions arose. This was the typical procedure for all of the MST offers of the case study location of Cape RADD (caperadd.com).

Although kayaks have the advantage that they are easier accessible to volunteers (no special training and equipment needed) than for example SCUBA diving, there are few studies and projects that use them for MCS or MST. One project that uses kayaks is the MCS project from the Northwests Straits Commission (nwstraits.org/our-work/kelp-recovery/, Bishop, 2014). In that project, kayaks are used as active monitoring vessels for the kelp forest of Puget Sound and the Salish Sea. This is an active approach as specifically sampling trips

with the kayaks are planned. An example of a more passive use of kayaks for MCS is Sonic Kayaks (Griffiths *et al.*, 2017). In this project, kayaks are outfitted with sensors and hydrophones, which record underwater sounds and oceanographic parameters like temperature. The registered sounds are played over speakers to the kayaker, making the paddling a sensorial experience. Participants in Sonic Kayaks do not paddle specifically out to collect data. For them, the main reason is the sensorial experience itself. On the other hand, the temperature and the underwater sound data can be used by researchers for environmental and noise pollution research.

4.2 Efficacy of Citizen Science for Science

Objective 2 was to assess the efficacy of the protocol in providing scientific data for the research community via MCS. This objective led to Hypothesis 1: there is a significant difference between the data collected by the volunteers and those collected by scientists. The results of this study confirmed that for almost all of the sampled data, there was no significant difference between volunteers and scientists (Table 3, 6, 9), thus the hypothesis has to be rejected. The data collected by the volunteers had a similar quality to the data collected by scientists. This result is in line with other studies targeting MCS projects (Koss *et al.*, 2009, Goffredo *et al.*, 2010, Branchini *et al.*, 2015, Lamine *et al.*, 2018, Vieira *et al*., 2020, Machado *et al*., 2021, Meschini *et al*., 2021). These studies had different sampling techniques, monitoring focuses, and target organisms (biodiversity of intertidal zone, biodiversity of subtidal rocky shores and coral reefs, fish biodiversity, and the spreading of invasive species), but all used CS as a tool to collect the data and they validated the data with data independently sampled by scientists. The use of expert data is one of the possibilities how to show and prove that MCS data is of good quality. For projects, like the one in this

study or the ones cited beforehand, where volunteers actively sample the data and the amount of data is manageable, using expert validation is a good validation option (Kosmala *et al.*, 2016). For projects such as Floating Forests (Rosenthal *et al.*, 2018), where the amount of data is too big for expert validation, alternative validation methods are needed. In these cases, Kosmala *et al.* (2016) and Rosenthal *et al.* (2018) suggested a "consensus classification" as a validation method. In this form of validation, a certain number of volunteers have to agree on one fact, for example, the presence of a kelp patch in the same satellite photo, before this photo is used for research. This could be an alternative validation method to the expert validation, should this project be expanded on a bigger scale. In this case, for example, a kelp patch perimeter would only be included in the database used for research, if a certain number of volunteers registered it with no significant difference between those registrations.

Although almost all data were not significantly different between volunteers and scientists, some trends still were visible. For example, the area of the kelp beds tended to be smaller when sampled by the scientists compared with volunteers (Figures 18 and 19). The reason for this could be that scientists due to their background tried to stay as close as possible to the perimeter of the kelp bed. If this was the case, an improved briefing of the volunteers and lengthening the sampling time could make the results even more similar. An improved briefing, where the trip leader or scientist explains in more detail the sampling and what the volunteers have to keep an eye on, would help to show the volunteers how close they can go to the kelp beds. Lengthening the time of sampling could give insecure volunteers, who stay further away from the kelp because they don't want to damage it, the possibility to paddle closer to the kelp beds, as they would have now more time for it. This fear of damaging the kelp should also be addressed during the briefing. The importance of proper training in

creating high-quality data with volunteers in MCS was shown by Figuerola-Ferrando *et al.* (2024b). In their study, they compared data collected on the health status of corals in the Western Mediterranean Sea by volunteers with different amounts of training (two categories) and scientists using a rapid assessment protocol they developed earlier (Figuerola-Ferrando *et al.*, 2024a). More extensively trained volunteers sampled data with equal quality to the data collected by scientists. Meanwhile, the data collected by less-trained volunteers showed less precision than the reference data from the scientists, although the mean value of them was close to the reference mean. This suggests that more extensive training or briefing would improve the data from the protocol developed in this study.

4.3 Efficacy of the Kelp Monitoring Protocol for Volunteer Development

Objective 3 of this study was to show that MCS and MST activities can improve the learning of participants and change their attitude toward the environment and the sea in the short term. Hypothesis 2 stated that there would be a difference in learning and attitude before and after participation in kelp monitoring. The results of this study support this hypothesis (Table 11).

More than 90% of the participants stated that they learned something new during the activity, either theoretical knowledge or practical skills. This was even the case for participants who had a STEM background or worked in the marine environment. Learning something new is a typical motivation for volunteers to participate in MCS and MST (Koss *et al.*, 2009, Luh Sin, 2009, Hammerton *et al.*, 2012, Carballo-Cárdenas and Tobi, 2016, Schneller and Coburn, 2018, Lotfian *et al*., 2020, McAteer *et al.*, 2021, Lucrezi *et al*., 2022b, Lucrezi and

Cillers, 2023). As most participants in this study experienced a learning moment, this can explain part of the high participant satisfaction, expressed as enjoyment, in this study.

The ability to change the attitude of participants toward the environment and the ocean after participating in a MCS and MST project is well-studied in the literature (Carson *et al.*, 2021, Lucrezi *et al*., 2022b, Lucrezi and Cillers, 2022, Araújo *et al.*, 2023, Severin *et al.*, 2023). For example in the studies of Araújo *et al.* (2023) and Severin *et al.* (2023), participants showed a higher awareness of environmental problems related to plastic litter after participating in a MCS project. Also, the present study showed this ability of MCS and MST. More than 50% of the participants in this study stated a positive change towards the environment, ocean, and kelp forests after participating in one kelp monitoring kayak trip. It is striking that this change of attitude happened already after such a short time frame. Carson *et al.* (2021) in their study showed also pro-environmental changes in the attitude of participants after only one day of participation, but most studies evaluate changes in attitude only after a longer participation time and several MCS participation events (Carson *et al.*, 2021, Araújo *et al.*, 2023, Severin *et al.*, 2023).

The change in attitude translated further into a feeling of being more connected with the environment and gave the participants the wish to change some things in their lives. For example, the improved awareness of the kelp forest and its problems, motivated participants to teach these issues to others and encourage them to learn about the marine environment. Also, many of the participants wanted to spend more time in nature and on the sea, as they felt more connected to it. This change in pro-environmental behavior is in line with the research. Crall *et al.* (2012) showed in their study a change in planned pro-environmental behavior in volunteers after participating in an invasive plant CS project. Volunteers of a

for-profit MST showed an increase in pro-environmental behavior, such as reducing water consumption or litter collection, after participating in the MST projects (Schneller and Coburn, 2018). The feeling of being more connected is shared with the results of the study of Koss and Kingsley (2010). Volunteers of the Sea Search project stated a higher connection to the marine environment after participating and better mental well-being, similar results to the results of this study.

4.4 Efficacy of the Kelp Monitoring Protocol for Marine Volunteer Tourism

Objective 4 of this study was to test if the developed protocol would be economically viable for the host organization if sold as a product to tourists coming to Cape RADD. It was hypothesized (hypothesis 3) that the expenses of Cape RADD or the price to which they want to sell the product would be different than the average price the participants would be willing to pay. The average price given by the volunteers was 30.53 USD, while the median price was 24.75 USD. The price that Cape RADD wants to charge lies in between with a value of 27.5 USD (Table 12). The result of the statistical test revealed no significant difference between the values, thus hypothesis 3 has to be rejected. Still, this result suggests that the protocol would be a viable economic product for Cape RADD. No difference means that on average the participants are willing to pay the amount the host organization would charge. Further, the outcome of this comparison could have been different if the participants had been more foreign tourists than residents. As mentioned already in the limitations section, the study was conducted during the low tourist season, thus the participants were mostly residents of the area. The demographic background of the participants of this study

represents more the demographic background of volunteers of a MCS project instead of volunteers of MST. In MST most volunteers are young females with an average age younger than 30 years and come mostly from the global north (Gray *et al.*, 2017, Roques *et al*., 2018, Cilliers *et al.*, 2022, Lucrezi *et al*., 2022b, Lucrezi and Cillers, 2022, Lucrezi and Cillers, 2023). In this study, the average age was 36.33 years and only 18% were foreigners (Table 10). This is the typical demographic background of MCS (Hammerton *et al.*, 2012, Martin *et al.*, 2016, Lucrezi and Digun-Aweto, 2020, Lucrezi, 2021, Wichmann *et al.*, 2022). South African residents do not have the economic capacities that tourists from abroad and the global north have (GDP per capita in 2023 of the USA: 81695.2 USD, EU: 40823.9 USD, and South Africa: 6253.2 USD; https://data.worldbank.org/). This difference is also visible in the answers of this study. Two of the highest values (250 and 55 USD) were given as answers by tourists coming from abroad to participate in MST. Still, it is difficult to predict and draw conclusions, as the sample size is limited and thus the results must be taken with care.

Apart from the economic viability, another result from this study shows the potential of this monitoring protocol for MST. This is the volunteer satisfaction of the participation. The satisfaction of the activity can be expressed as the enjoyment of the activity by the volunteers (Koss and Kingsley, 2010). All participants expressed that they enjoyed the sampling and kayaking (Table 11). Satisfied volunteers will repeat such experiences more probable and suggest them to other possible volunteers (Lucrezi *et al*., 2022b). This is needed for a MST business, as volunteers are the main income source for them (Benson and Henderson, 2011, Roques *et al.*, 2018, Cilliers *et al.*, 2022, Kabil *et al.*, 2023).

4.5 Conclusions, Recommendations, and Further Outlook

All 4 objectives of this study were achieved. First, it was possible to monitor the kelp forests of False Bay as an MCS/MST activity using a kayak with the developed protocol. The developed protocol was tested successfully on several sampling and monitoring trips with both volunteers and scientists who had a background in biology. The data they collected showed in almost all cases no significant difference. Further, it could be shown that these trips had a positive impact on the participants. Their learning and environmental awareness increased and after participation, they expressed an increase in their pro-environmental attitudes. Lastly, that there was no significant difference between the willingness to pay by the participants and the price that Cape RADD wanted to charge showed that the developed product could be economically viable for the host organization.

All of these results have different implications. For the research community, this study is another example that MCS and MST can provide relevant data which can be used in research. Furthermore, other effects of MCS and MST were shown, like the ability to increase a pro-environmental attitude in participants, making this study another example of the effects of MCS and MST. A MST business like Cape RADD could use this study and the developed protocol to develop a kayak-based MST product. It was shown that this product could be economically viable and enjoyable by the participants, but also the TMNPMPA could start a MCS project with this study with the same reasoning. The following paragraph suggests how this could be done in cooperation between the TMNPMPA and Cape RADD.

Momentarily this protocol is only used by Cape RADD as a MST product. This limits its potential use, as Cape RADD only monitors some small patches of kelp beds around the city

of Simon's Town. Instead, it could be expanded similarly to the project of the Northwests Straits Commission (nwstraits.org/our-work/kelp-recovery/, Bishop, 2014) under the oversight of Cape RADD and the TMNPMPA. Cape RADD could offer training courses, where volunteers would learn how to sample and monitor independently using the protocol. After this course, volunteers could paddle out independently using their own equipment or equipment rented or provided by Cape RADD or the TMNPMPA. This could be a solution to include the local population in the conservation of the kelp forests in False Bay and the TMNPMPA, which at least in the diving community had expressed interest in participating in MCS projects (Lucrezi, 2021). Cape RADD could still maintain the one-day MST trips for tourists who visit the area only for some days and want to participate in the project. The courses and the kayak MST trips would provide income for Cape RADD, while the management of the TMNPMPA would receive valuable information about the status of the kelp forests in the national park. Figure 22 shows a concept diagram of this proposal.

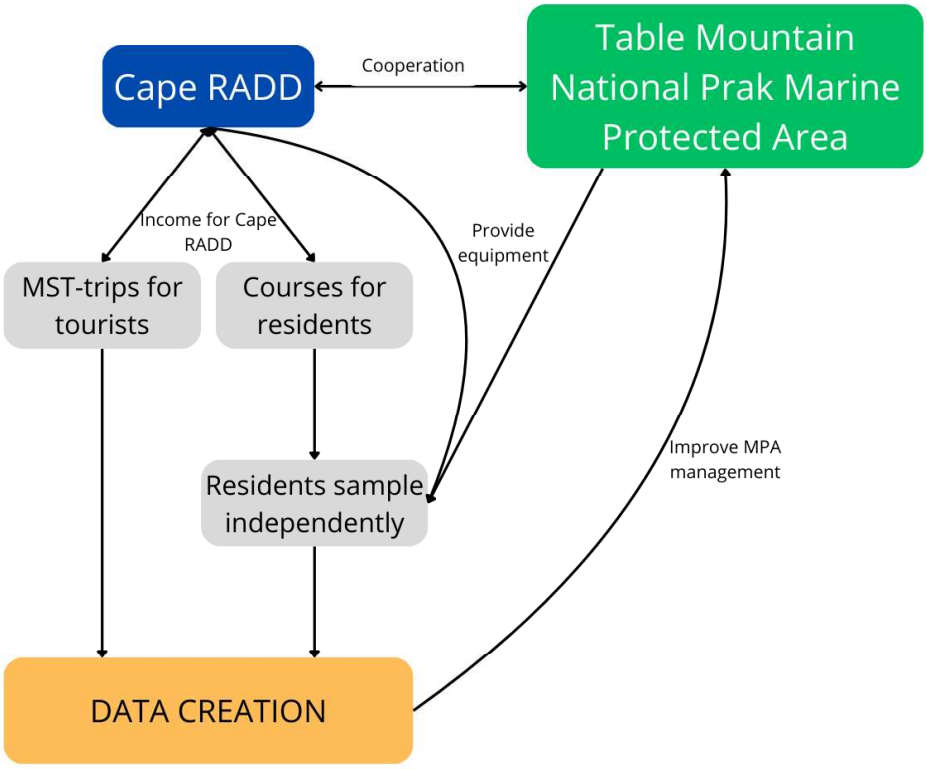

Figure 22: Conceptual diagram for the expansion of the kelp monitoring in False Bay.

Apart from the aforementioned suggestion, another idea of how the protocol could be modified would be the concept of Sonic Kayaks (Griffiths *et al.*, 2017). It would expand the type of data collected in a monitoring trip without modifying the protocol itself, as it is a passive collection of data, where the volunteer does not need to do something more.

From the limitation section, it is visible that the sampling season was not ideally chosen. It is highly suggested to repeat this study in other seasons too. This would first increase the sample number considerably, but would also allow us to compare the data on a seasonal level. Questions that could be answered would be for example if the kelp forest area and density show differences over the seasons and the year, but also if there is a demographic

difference in the participants over the year with possible consequences on the social aspect of the study. Another suggestion would be to contact the participants again after some time has passed to assess if their pro-environmental changes in attitude were only short-term or also in the long term.

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Chapter 6: Annex

6.1 Kayak-based Kelp Monitoring Protocol (adapted from the protocols of Rothman *et al.* (2010) and Bishop (2014))

Equipment:

- Kayaking:
  - 1 Kayak for each pair
  - 1 Paddle for each participant
  - 1 Life vest for each participant
  - Walkie Talkie
- Sampling:
  - 1 Portable, waterproof GPS device (Garmin ETREX 32x)
  - 1 Waterproof camera
  - 1 Floating 50x50cm quadrat
  - 1 Measuring tape with an attached buoy
  - 1 Weighted line with marks every meter
  - 1 Dive slate with columns for depth and percentage cover
  - 1 Dive slate with Q1, Q2, Q3, Q4 written on it
  - 1 Pencil
  - (1 floating net if only 1 kayak is used)
- Data transfer:
  - Cables for camera and GPS device

Prework:

1. Setup the GPS in the hub (this has to be done once only, afterwards it is saved):
    1. Start GPS by pressing the light button
    2. Select setup by moving the stick and confirm by pressing the stick
    3. Select Tracks by moving the stick and confirm by pressing the stick
    4. Select Time in Record Method
    5. Establish 5s in Recording Interval
    6. Press the back button to go to the main menu
    7. Switch the GPS off by holding the light button
2. Prepare the dive slates:
    1. Write down the date, starting time of the trip, and location of the sampling
    2. Write in the first column:

Kelp 1
Left
Open
Right
Beach
Q1
Q2
Q3
Q4

3. Repeat this for kelp 2 and 3 below

Sampling (at the kelp bed):

Perimeter:

1. Start the GPS by pressing the Light button
2. Mark a waypoint
    1. Name of the waypoint (first row): Site of sampling (LB or SF), number of the bed, date of sampling
    2. Example for 3rd kelp bed at Long Beach on the 31.05: LB33105
    3. Note: am or pm, depending on the time of sampling
    4. Click done
3. Go to Map (the GPS will automatically register the route)
4. Paddle around the kelp bed keeping as close as possible to the border of the kelp bed which is the point where the surface reaching kelp and/or submerged, but clearly visible and identifiable kelp, ends
5. At the end of the perimeter of the kelp bed switch the GPS off by holding the light button (this is needed to save the tracks separately)
6. Repeat these steps for each kelp bed

Depth Measurement:

1. Sampling is done in 4 spots at the edge of the kelp bed:
    - Left: on the left side of the kelp bed
    - Open: the side facing the open sea
    - Beach: the side facing the coast
    - Right: on the right side of the kelp bed
    - Left and right are established as if you are standing on the beach and looking towards the sea
2. 1 person takes the weighted line, the other takes the pencil and the prepared dive slate
3. The person with the line lowers the line into the sea until the line gets slack

4. Pull the line straight and grab the line with 2 fingers at the point where the surface of the sea is (keep an eye out that the line is vertical, if needed the second person on the kayak paddles the kayak into the position again)
5. Pull up the weighted line whilst still holding the line at the surface point with your 2 fingers
6. Count the number of 1m marks and guess the length of the stretch between the surface point and the first of the counted marks, example 30cm between fingers and first mark and 3 marks in total make a total length of 3.3m
7. Write down the depth value on the slate for the right position (left, open, etc.)
8. Repeat these steps for the other three spots

Transect:

1. Decide which end of the kelp bed is the starting point for the transect
2. A kelp frond is wrapped around the clip on the buoy by inserting the frond through the middle of the clip, wrapping it around one side, and reintroducing it through the middle of the clip on the same side.
    - This is repeated up to three times
3. Paddle through the kelp bed unwrapping the measuring tape until reaching the other side of the kelp bed or the tape ends
4. If two kayaks are available the kayak that unwrapped the tape anchors itself by holding onto a kelp blade on either side of the kayak holding the end of the tape and thus maintaining the transect
5. If only one kayak is available the other end of the measuring tape is wrapped around the blade of a kelp strand and then deposited into the floating net

Quadrat:

1. 4 random spots are sampled using the quadrat
2. To have random sampling the person sitting in the front gives the person in the back a random number and the person in the back of the kayak does the number of paddle strokes given by the number
3. The kayak is stopped by holding on to two kelp blades, one on each side of the kayak. This anchors the kayak in place
4. One of the two kayakers places the floating quadrat on one of the sides of the kayak and takes a top-down photo with the camera of the quadrat
5. Then the same person estimates the percentage cover of the surface reaching kelp blades also considering those up to 10cm below the surface
6. A picture of the dive slate with Q1, Q2, etc is taken afterward to be able to relate the percentage cover photo with the right quadrat. For example, if the first quadrat is done you take a photo of Q1 on the slate, if it was the second quadrat of Q2, and so on. This means that the photo(s) before the photo of Q1 is/are the first quadrat
7. The percentage cover is written down in the right place on the data slate
8. All these steps are repeated until 4 quadrats are sampled
9. Retrieve the equipment when done, and kayak back.

Data download:

Photos:

1. A photo of the filled-out dive slat is taken
2. The camera is connected to a computer using the appropriate cable
3. All photos of the sampling day are transferred into the storage folder (Cape RADD hard drive)
4. The photos are ordered by date increasing so that the first photos are the first displayed
5. The photos of the quadrats are renamed to: location kelp bed number_quadrat number: for example the 4. Quadrat of the 3. Kelp bed in Long Beach is coded as LB3_Q4

GPS data:

1. Switch the GPS on by pressing the light button
2. Scroll down to the menu Track Manager and confirm by pressing the stick
3. Choose Current Track
4. Choose Save Portion
5. Select the track that you want to save (normally they are at the end of the list) and confirm by pressing the stick
6. Select the same track again and confirm with the stick
7. Name the Track with the Site kelp bed number (day and month of sampling); for example for the 3. Kelp bed in Long Beach sampled on the 31.05: LB3(315)
8. Repeat the steps 2-7 for all kelp beds you want to save
9. Switch the GPS off by pressing and holding the light button
10. Connect the GPS to the computer using the appropriate cable
11. Go to the folder GPX and copy the files of the tracks and waypoints into the selected storage folder
12. Once copied, you can remove the GPS from your computer.
13. Open Excel and open the track and waypoint files for the tracks by selecting all file formats in the drop-down menu, as the files are .gpx files
14. Open this data as a table.
15. Copy the data of all the tracks into an empty Excel sheet, but paste them using the selecting paste values out of the paste options
16. Delete all columns except for ns1:name, lat, lon, ns1:time2
17. Save the document as an Excel sheet and CSV file with the name GPS_data_date, for example, GPS_data_31.05.2024

Dive Slates:

1. Prepare an Excel document like this:

Date:			
Location:			
	Kelp 1	Kelp 2	Kelp 3
Depth (m): Beach			
Depth (m): Right			
Depth (m): Open			
Depth (m): Left			
Q1 (%)			
Q2 (%)			
Q3 (%)			
Q4 (%)			

2. Fill the table with the data from the dive slate
3. Save the document as an Excel sheet with the name Quadrats and depth and the date, for example, Quadrats and depth 31.05.2024

Data Analysis:

Quadrats:

1. Open the photos with any photo program
2. Open the quadrats and depth excel sheet
3. Estimate the percentage cover of the quadrat in the photo by a visual estimation
4. Compare the percentage cover of the photo with the one in the Excel sheet
   - If they are equal or very similar (+/- 10 %) the one in the Excel sheet is kept
   - If they are vastly different the percentage cover in the Excel sheet is changed to the percentage cover of the photo

GPS:

1. Open QGIS
2. Go to layer, add layer, add delimited text layer
   1. In name of the archive select the CSV file of the GPS data
   2. In custom delimitators select semicolon
   3. Click on add
3. Clean the data set by eliminating outliers (normally the first and maybe last points, which are not on the kelp bed because the GPS was started and stopped away from the border of the kelp bed)
   1. In processing open the toolbox and search for points to path
   2. In Entry layer select the GPS point layer
   3. In path grouping expression select ns1:name
   4. Click on execute

5. A new layer with the name path should appear which connects the points of the GPS layer
6. Right-click on the GPS Data layer
7. Click on Table of Attributes
8. Open the GPS Data Excel sheet in Excel
9. Select the points that should be eliminated for one of the kelp beds by using the select object by area or single click option
10. Once selected go to the already open table of attributes and search for the selected points. They should be marked with a yellow point or are blue highlighted
11. In the Excel sheet eliminate those points by using the data in the ns1:time2 column to find the points in the Excel sheet
12. Repeat these steps for all the kelp beds separately
13. Eliminate all layers in QGIS by right-clicking them and then clicking on eliminate layer
14. Save the Excel sheet as a CSV file

4. Open the new CSV file as described before (layer, add layer, add delimited text layer
5. In processing open the toolbox and search for points to path
    1. In Entry layer select the GPS point layer
    2. In path grouping expression select ns1:name
    3. Click on execute
6. A new layer with the name path should appear which connects the points of the GPS layer
7. In processing open the toolbox and search for lines to polygons
    1. In the entry layer select the newly created path layer
    2. Click on execute
8. Open the table of attributes of the polygon layer by right-clicking and clicking on open table of attributes
9. Click on the field calculator
    1. Click on create new field
    2. In Name of the field type Area
    3. In Type of field select decimal number from the drop-down menu
    4. In the list of variables and functions (square in the middle of the screen), open the drop-down menu in geometry and double-click on $area
    5. Click on accept
10. A new column/variable should appear with the calculated area
11. Save the changes in the table of attributes by clicking on Save editions
12. In the GPS data Excel sheet add a new column with the title area (m^2)
13. Insert the calculated area from the table of attributes into this column by copying and pasting
14. Save the Excel sheet
15. Close the table of attributes
16. Right-click on the polygon layer

17. Click on make permanent
    1. In name of archive select the destination folder and type the name of the file (polygons_site_date, for example, polygons_LB_31.05.2024)
    2. Click on accept
18. Close QGIS
19. **For the kelp bed Seaforth 1**: This kelp bed stretches from the coast in some parts towards the sea. To be able to calculate the area some extra steps have to be done (the other kelp beds in Seaforth can be analyzed as described before):
    1. Open the CSV file as described before
    2. Eliminate the outliers as described before
    3. Right-click on the GPS data layer and then click on properties
        i. Select categorized in the first top-down menu (default it is one symbol)
        ii. In value select ns1:name
        iii. Click on Categorize
        iv. Click on apply
        v. Close the window by clicking on accept
    4. Deselect all the categories in the GPS data layer, except the SF1 category
    5. Select all the visible points by using the select object by area or single click option
    6. In processing open the toolbox and search for points to path
        i. In Entry layer select the GPS point layer
        ii. Tick the use only selected objects option
        iii. Click on execute
    7. Add the Coastline for SF1 shapefile to QGIS by dropping it into the layer list from the folder
    8. In processing open the toolbox and search for merge vector layers
        i. In entry layer select coastline for SF1 and the path layer for SF1 recently created
        ii. Click on execute
    9. Search in the toolbox for points along geometry
        i. Selected the combined layer from the previous step as entry layer
        ii. Select 2m as distance
        iii. Click on execute
    10. Continue with steps 5-17 from GPS