

21 August 2018

To Whom it May Concern,

Attached, please find the final report of the CAPE HIGHER EDUCATION CONSORTIUM (CHEC) AND CITY OF CAPE TOWN (CCT) COLLABORATION—ANNUAL CHEC-CCT RESEARCH PROGRAMME 2017/2018 INSTITUTIONAL AND MULTI-INSTITUTIONAL PROJECT:

Title:

What can help loss processes and beach-cast patterns tell us about sandy beach management?

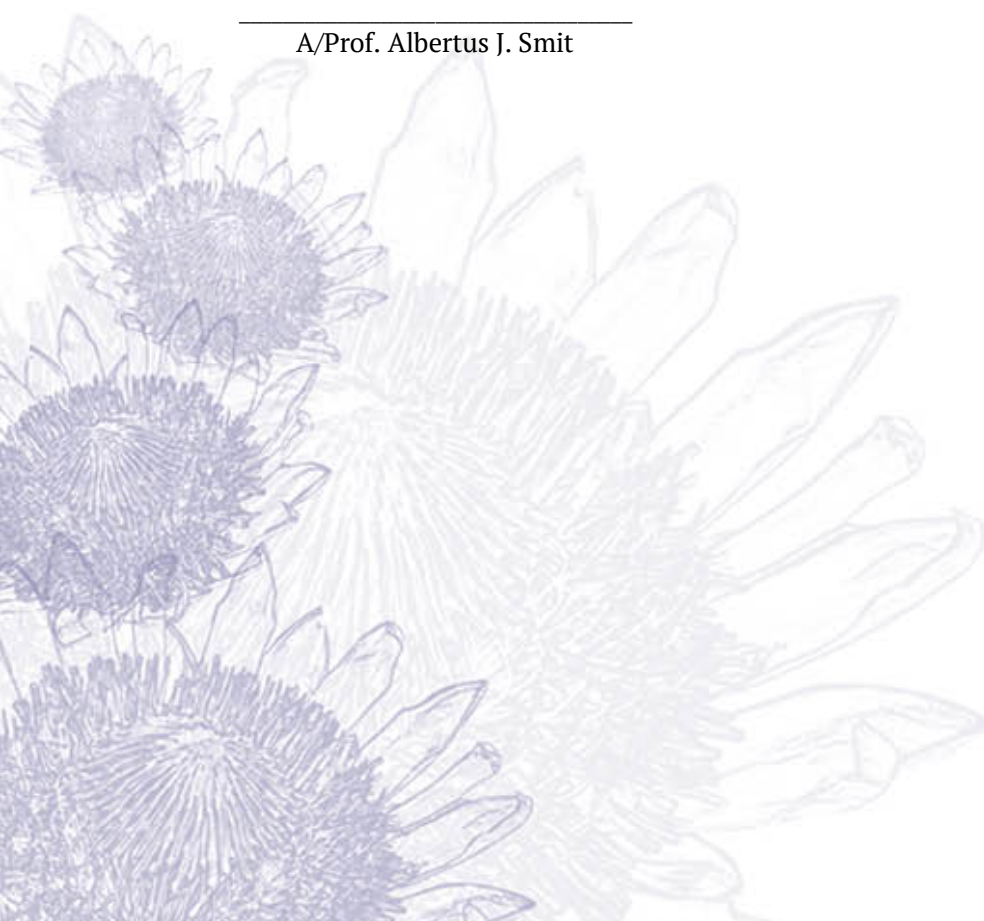
Thematic area:

Infrastructure, New Technologies and Sustainability.

Sincerely,



A/Prof. Albertus J. Smit



What can kelp loss processes and beach-cast patterns tell us about sandy beach management?

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ABSTRACT

This project set out to assess the ecological role of beach cast kelp—which tends to be routinely removed from recreational beaches—on the beach surface of selected sandy shores in the City of Cape Town municipal area. Particularly, we were interested in understanding the role that kelp wracks may provide as a nutritional source to the beach consumer biota after it had been mechanically and biologically transformed to become particulate organic matter (POM) and incorporated in the beach sediment. Our working null hypothesis is that there is no difference in the amount of POM measured in the sediments of cleared vs. non-cleared urban beaches.

The outcome of the study is that kelp removal does in fact not alter the POM matter content of beaches in areas where kelp wrack is cleared (i.e. we could not reject the null hypothesis). We suggest that this is due to the highly modified nature of the beach systems that we studied: i) the overriding influence of the anthropogenic (engineering) modifications to the beach systems override any influence that might be caused by altered inputs of kelp-derived POM; and ii) an array of additional impacts on the managed beaches may add additional confounding influences that distort the effect due to the main driver that our study intended to find.

This research links to a topical environmental management issue that the CoCT faces, and supports on an ecological basis their decision to actively manage the beaches through kelp cast removal programmes. The research also added a significant step forward to the ongoing work that the UWC Biodiversity and Conservation Biology Department's Kelp Research Group has done around the ecological functioning of kelp beds in the Western Cape region, and adds an new dimension to our current focus, climate change. Since the consequences of climate change will be especially noticeable in urban settings such as the CoCT, we would very much like to see future research efforts merging the City's climate mitigation and adaptation strategies with our studies on the ecological role that kelps may contribute towards the well-being of our urban coastline.

1. INTRODUCTION AND AIMS / QUESTIONS

Background

Kelps dominate approximately 25% of global, shallow, rocky reef ecosystems and play a significant role in the functioning of these ecosystems. Kelps are 'ecosystem engineers' that provide a critical 3-dimensional habitat for fauna and various flora, and they are also highly productive organisms (Dayton 1985; Steneck et al. 2002). The high productivity of kelps allows important nutrients to be exported to adjacent and distant habitats as allochthonous production, and therefore their role in the food web is not limited to the shallow subtidal zone; instead they are the base for many connected coastal food webs (Stuart, Field, and Newell 1982; Dayton 1985; Bustamante, Branch, and Eekhout 1995; Duggins and Eckman 1997).

Sandy beach ecosystems have low amounts of productivity compared to other ecosystems such as rocky and estuarine mud-flats, with most of the productivity in sandy beach ecosystems represented by diatoms and bacteria (Ince et al. 2007; Koop, Newell, and Lucas 1982; Colombini et al. 2003). Primary productivity of diatoms tends to be higher on beaches with fine sediment grain and low wave exposure, but never reach levels compared to other

ecosystems (Ince et al. 2007; Dugan et al. 2011). Macrofaunal communities on sandy beach ecosystems rely heavily on organic inputs from the surf zone (diatoms and flagellates) or from the ocean (kelp-wrack, carrion, dissolved organics and particulates). These inputs are regulated by oceanographic processes such as upwelling, currents, waves and tidal action (Ince et al. 2007; Orr et al. 2008). Primary consumers in the form of suspension feeders and herbivores, consume phytoplankton, particulate organic matter, kelp and seagrasses which in turn become prey items for secondary consumers (invertebrates) (Ince et al. 2007; Krause-Jensen and Duarte 2016). Predatory species (fish, lizards, shorebirds, baboons, etc.) prey upon both primary and secondary consumers as well as drift carrion (Ince et al. 2007; Dugan et al. 2011). Therefore, allochthonous input plays an important role in maintaining sandy beach food webs from a bottom-up perspective. Kelps provide a significant amount to the overall allochthonous input in the form of kelp-wrack found on sandy beaches in many coastal areas around the world (Ince et al. 2007; Krause-Jensen and Duarte 2016). When kelp biomass accumulates on a beach it undergoes various biotic and abiotic processes. Examples of such processes are fragmentation, decomposition and remineralisation by bacteria, meiofauna and grazers (Ince et al. 2007). Once kelp biomass has been fragmented and/or remineralised, it can then be transported to the nearshore marine environment, or enter the atmosphere and be transported via wind to adjacent terrestrial ecosystems or stored *in situ* within the beach sediment (Ince et al. 2007; Orr et al. 2008; Krause-Jensen and Duarte 2016). There is also evidence that kelp derived organic matter provides an important energy subsidy into sub-marine canyons (Harrold, Light, and Lisin 1998).

Beach-cast in South Africa

Beach-cast kelp biomass around the Cape Peninsula is a consistent characteristic of beaches in the region. Kelps washed up on beaches originate from near or offshore kelp populations. During times of high wave energy or pulse disturbance events such as storms, kelps dislodge or stipes break which essentially kills the plant as it has no way of re-attaching itself. Kelp plants are deposited on beaches by coastal currents regularly, and consists mainly of two species, e.g. *Ecklonia maxima* and *Laminaria pallida*; they form what is known as beach-cast kelp or simply beach-cast (Anderson 2007b). Beach-cast is an important organic input into sandy beach ecosystems (Ince et al. 2007; Koop, Newell, and Lucas 1982). In sandy beach ecosystems, kelp detritus is important in sustaining marine invertebrate communities, which in turn are important prey items for various bird species. A study by Koop, Newell, and Lucas (1982) investigated the biodegradation and carbon flow base in a sandy beach microcosm at Kommetjie beach in Cape Town, South Africa. The results showed that invertebrate and bacterial pathways contribute 23-27% of kelp-derived carbon recycling. Furthermore, some species of nematodes are also able to directly absorb kelp derived organic material (Koop, Newell, and Lucas 1982).

Drift kelp that washes up on beaches around the Western Cape are managed by two agencies; the City of Cape Town (CoCT) and the Department of Agriculture, Forestry and Fisheries (DAFF) (Yoshikawa 2013). These two agencies differ in their perspectives on managing *E. maxima* beach-cast. DAFF monitors the collection of beach-cast kelp for the South African coastline by issuing permits that allow rights holders to collect kelp for commercial reasons within specific concession areas (Yoshikawa 2013). The commercial demand for beach-cast kelp is not consistent and therefore rights holders may only collect during times of high demand (Yoshikawa 2013). Examples of commercial applications of beach-cast kelp are alginate production, pharmaceuticals and abalone feed (Yoshikawa 2013).

Within the concession areas, there are regions designated as Marine Protected Areas by the South African National Parks (SANParks), and no kelp is collected from these areas (Yoshikawa 2013). This is due to the recognition of the ecological significance of beach-cast kelp in coastal ecosystems. Kelp that is washed ashore is an important source of nutrients for invertebrate communities and provides an important bottom-up control mechanism for

beach ecosystems (Dugan et al. 2011). Furthermore, research elsewhere in the world has shown that beach-cast kelp is important in the formation and stabilisation of dunes (Ince et al. 2007). Although it has a significant role to play in beach systems, the decomposition process of kelp releases a foul odour in the form of hydrogen sulphide (Dugan et al. 2011). This is a point of concern for ratepayers who complain that these kelps need to be removed for aesthetic reasons. The CoCT recognises both the ecological significance of beach-cast kelp and is cognizant of the concern of ratepayers and the possible negative consequences on tourism at specific beaches (e.g. Clifton beach and Camps Bay) due to the smell and other unsatisfactory conditions caused by decomposing kelp. The CoCT, therefore, collects beach-cast kelp from predetermined beaches and disposes them in landfills as there is currently no procedures in place to process and dispose of kelp in a sustainable manner (Yoshikawa 2013).

Rationale, aims and objectives

Beach cast kelp provides an important ecological role to beach ecosystems (Cisneros et al. 2011; Ortega-Cisneros et al. 2017). Beneficial roles may stem from the (i) nourishment of beach-associated biota such as invertebrate meio- and macrofauna, and higher trophic levels such as birds and fish; and (ii) the promotion of dune establishment via the stabilisation of dune vegetation at the landward extent of beaches. The removal of beach cast kelps may therefore be hypothesised to harm the natural functioning (physical and biological) of beach systems.

The initial intent of the research was to test the hypothesis that primary sand dunes are established by the presence of kelp wrack, which facilitates the establishment of pioneer dune species, and this ultimately resulting in a well-vegetated dune system (i.e. (ii) in the preceding paragraph). However, events outlined in the 'Limitations' section on pg. 8 lead to a deviation from this plan, and subsequently the aim was modified. Here, we therefore aim to determine if clearing of kelp from beaches affects POM content of beach sediment (a hypothesis related to (i) above).

This aim was met through the following objectives:

- 1) Sample sediment from beaches designated as "cleared" and "non-cleared" of kelp.
- 2) Determine if there are any differences in POM content of cleared and non-cleared areas of selected beaches.
- 3) Determine if differences in POM content are driven by other factors such as kelp biomass and transect length.
- 4) Make recommendations regarding the importance of kelps for the ecological functioning of sandy beach ecosystems in the CoCT region.

2. RESEARCH APPROACH AND METHODS

Study sites

Beaches that are regularly visited by beach-goers, and some beaches surrounding residential areas, are divided into 'cleared' and 'non-cleared' areas by the CoCT. This study focuses on a subset of these beaches (Figure 1), selected to cover a range of wave dynamics as determined by Dr. Christo Rautenbach, Chief Marine Scientist, South African Weather Service (SAWS).

Hout Bay east and west

Hout Bay beach is essentially one beach divided by the mouth of the Disa River. The Disa River is highly polluted, with a clear warning sign in view for beach-goers. Due to residential development adjacent to the estuary, the mouth of the river closes more frequently causing a build-up of polluted water.

On the east side, the cleared area of the beach is characterised by a large parking lot, residential and commercial structures, and forms the "no dogs allowed" of Hout Bay beach.

Activity on the beach tends to be high in the morning and slows down in the afternoon. Small dunes with low vegetation cover are located behind the non-cleared area. Shell debris is common in the non-cleared area.

On the west side, the cleared area comprises a small parking lot and wharf which forms one end of the Hout Bay harbour, as well as a storm water pipe mouth in the parking area leading onto the beach. This is the “dog-walking” section of beach, which continues until the Disa River mouth. Activity is high in the morning and weekends, and attract beach-goers due to the wharf and harbour. The non-cleared area is characterised by dunes and little vegetation cover. During the course of this study, the non-cleared area was undergoing stabilisation/rehabilitation construction. The dunes were first graded and then fencing was placed, which covered the entire dune system.

Muizenberg

Muizenberg was the largest beach in this study compared to other beaches sampled. The cleared area comprises of a parking lot with commercial structures such as restaurants and various shops, which attracts beach-goers to the area. The non-cleared section has a slightly lower activity and consists of a mixture of structures (beach huts, bridge), and dune system with established vegetation. Shell debris is common closer to the surf zone and litter is common throughout.



Figure 1. An image showing the location of the beaches that are cleansed of the kelp beach-casts by the CoCT (red triangles). The coloured ‘ribbons’ indicate the different degrees of wave exposure as modelled by Dr. Rautenbach, SAWS.

Fish Hoek

Fish Hoek is the smallest beach in the study. The cleared area comprises of a large parking lot and small commercial and public structures (restaurant, playground, police services, etc.) and two storm water pipes on either end of the area. The non-cleared area of the beach is characterised by a dune system with well-established vegetation.

On both areas dog-walking is allowed and activity tends to be lower compared to other beaches in the study. Both areas were also well maintained with no litter found during the course of sampling.

Strandfontein

The cleared area is characterised by a large parking lot, beach pavilion and tidal pool. There are also construction activities between the tidal pool wall and beach. Activity was high on the day of sampling relative to the other beaches in the study. The non-cleared area has low activity and characterised by an extensive dune system and established vegetation. The beach is fairly well maintained and very low amount of litter was noted. Shell debris was common in surf zone in both cleared and non-cleared areas.

Methods

Data collection

The aforementioned beaches were sampled for POM content in the sediment by sampling between the low-tide and high-tide line, or as far as possible if any structures were in the way. Each transect was divided into five sections according to the length of the transect on that particular sampling occasion. Sediment samples, 20cm deep, were taken each time and placed in a small ziplock bag and labelled. Each sample was weighed, dried, re-weighed, placed in a muffle furnace at 400 °C and finally re-weighed. The difference between in grams between the start and end weight (prior to and after placed into the muffle furnace) was used as an estimate of particulate organic matter (POM) content. This method is known as “loss on ignition” (Santisteban et al. 2004; Byers, Mills, and Stewart 1978).

Data analysis

All data analyses were done using the R Software for Statistical Computation and Graphics (R Core Team 2018), the vegan package (Oksanen et al. 2018), and ggplot2 (Wickham 2016). Summary statistics were calculated and the Shapiro-Wilk normality test was run before any analyses to investigate the distribution of the data. Non-parametric visual comparisons in the form of boxplots and Kruskal-Wallis Rank Sum Test was used to test for any significant differences in POM. Boxplots were also used in each instance to investigate any significant differences in transect length.

Cleared and non-cleared areas

The POM data for entire study was pooled into cleared and non-cleared categories. These data included all sampling days of the study. A Kruskal-Wallis Rank Sum Test was used to test for differences in POM between cleared and non-cleared areas. A boxplot was used to visualise any differences in POM between cleared and non-cleared areas.

Cleared and non-cleared areas in each month

The data for each sampling date were pooled into months during which the study took place (February, March, April) as well as cleared and non-cleared areas. A combination of scatter plot and boxplot was used to investigate any differences in POM visually and a Kruskal-Wallis Rank Sum Test was used to test any differences statistically.

Cleared and non-cleared areas between sites

Data were grouped according to site and area. This allowed investigation into any possible differences in POM between sites. A boxplot was used to allow visual comparison of POM between sites and areas, and a Kruskal-Wallis Rank Sum Test was used to verify findings.

Correlations

To investigate if transect length and kelp estimates may be affecting POM content sampled, correlation between paired samples was performed. To investigate whether transect length is correlated to POM, the mean transect length and POM was calculated for cleared and non-cleared areas on a given sampling day. To investigate whether beach-cast kelp influenced POM, the mean POM and transect length was calculated by day, site and area. This approach for the beach-cast kelp estimates and POM correlations was chosen as kelp estimates were performed separately for both cleared and non-cleared areas.

3. RESULTS, DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS FOR FOLLOW-UP ACTION

Results

Cleared and non-cleared areas

Shapiro-Wilk's normality test showed that POM data was not normally distributed across samples ($w = 0.971$, $p < 0.05$). Visual comparison and a Kruskal-Wallis test showed no significant difference in total POM ($p < 0.05$, Figure 2) between cleared and non-cleared areas.

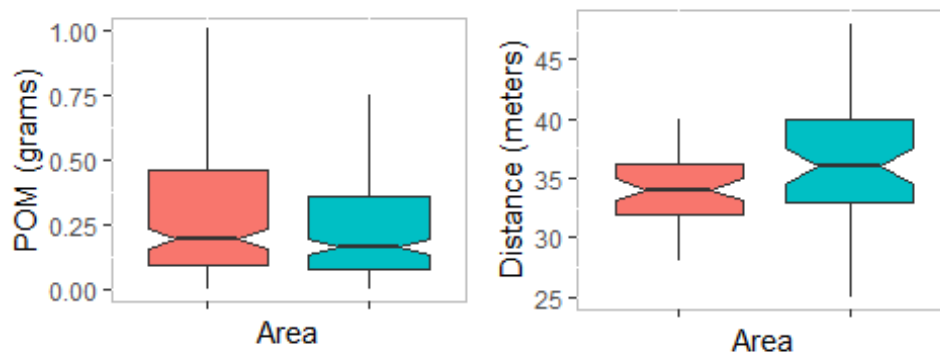


Figure 2. Boxplots comparing POM and transect distance between cleared and non-cleared areas. The horizontal black lines represent the median. If 'notches' do not overlap, the medians are considered to be statistically different from one another. The lower and upper 'hinges' correspond to the first and third quartiles, and the 'whiskers' are the 5th and 95th percentiles. Pink boxes represent cleared areas and blue boxes represent non-cleared areas.

Cleared and non-cleared areas in each month

No significant differences between cleared and non-cleared areas were found over the course of this study, and only a significant difference in transect length was found for March (see Figure 3). The POM findings were verified by a Kruskal-Wallis test which showed no significant differences ($p < 0.05$, Figure 2) in POM between cleared and non-cleared areas over the three months sampling took place.

Cleared and non-cleared areas between sites

A visual comparison showed a significant difference in POM content between cleared and non-cleared areas for Hout Bay West only. This was verified by a Kruskal-Wallis test which showed significant differences in POM ($p < 0.05$, Figure 4). Visual comparison showed significantly higher transect lengths for non-cleared areas than cleared areas at Fishoek, Hout Bay East and Muizenberg.

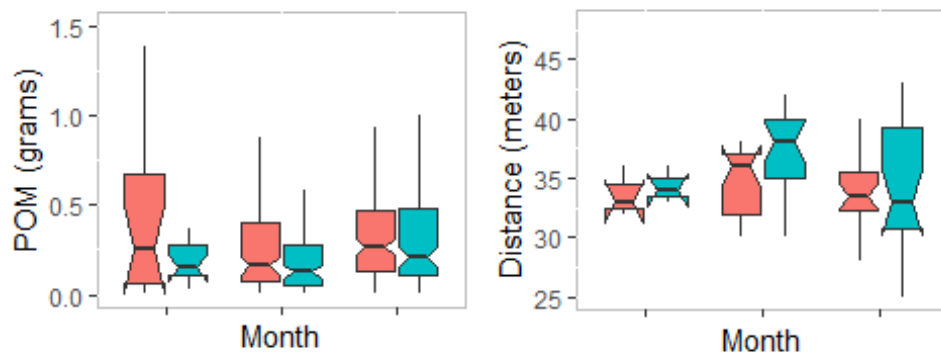


Figure 3. Boxplots comparing POM and transect distance between cleared and non-cleared areas. The constituents of the box-and-whisker plots, and their interpretation, are described in the caption to Figure 1.

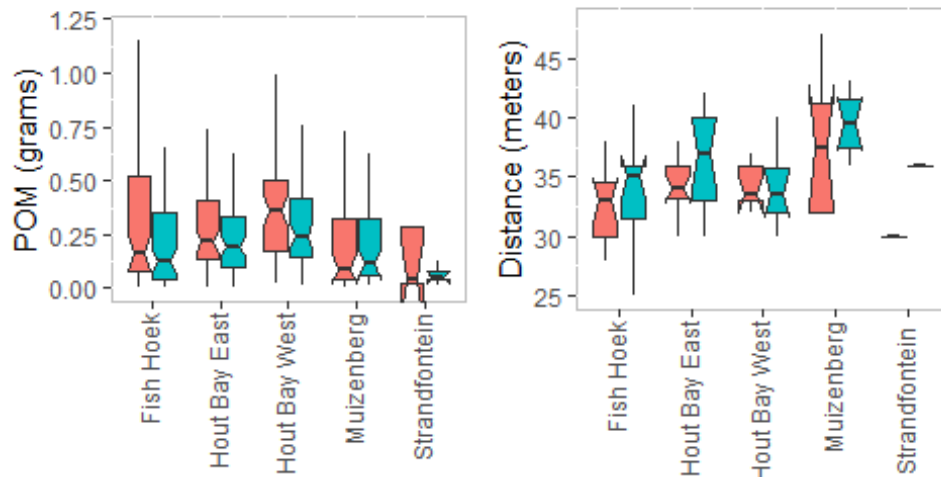


Figure 4. Boxplots comparing POM and transect length in cleared and non-cleared areas between sites. The constituents of the box-and-whisker plots, and their interpretation, are described in the caption to Figure 2.

Correlations

No significant correlation was found between transect length and POM ($z = -1.072$, $p > 0.05$) or kelp estimates in cleared ($z = -1.040$, $p > 0.05$) and non-cleared ($z = -0.491$, $p > 0.05$) areas.

Discussion

As previously highlighted, kelp wrack on beaches provides an important energy subsidy into sandy beach ecosystems, driving the “bottom-up” control of invertebrates, which affect organisms such as birds. Particulate organic matter (POM) is a breakdown product of kelp decomposition, and gets produced by combined physical (abrasion and other forms of mechanical action) and biological decomposition processes. In the absence of *in situ* autochthonous primary production such as microalgae or macrophytes, wrack-derived POM forms the sole source of nourishment for sustaining most species of sandy beach macrofauna and meiofauna (Cisneros et al. 2011; Ortega-Cisneros et al. 2017).

The results from this study were surprising as POM in cleared areas did not differ in POM content compared to that taken from non-cleared areas. There was also no measurable

difference in POM between sites, with Hout Bay West as the exception. The significantly higher POM at Hout Bay West may be due to beach activities and point sources of pollution. For instance, the cleared section of Hout Bay West is a popular area for dog walking and a drain pipe leading onto the beach from the parking lot is also present, which may be contributing to increasing POM in this area. In terms of consequences for the ecological functioning of cleared vs. non-cleared beaches, the lack of spatial patterns in POM distribution between the two management states suggest that ecologically the beaches are indistinguishable (at least in as far as meio- and macrofauna are concerned).

The study sites included here shares a common feature. They are in close proximity to a significantly altered urban landscape, and the primary dune environments that we initially hypothesised would benefit from kelp casts do in fact not exist there. All cleared beaches are flanked by infrastructure (walls, parking lots, buildings, etc.), and the presence of such built environments is known to affect the localised wind and wave dynamics, with drastic effects on the stability of the sandy beach face. These structures are having a far greater influence on the sand movement dynamics that wrack kelp can reasonably be expected to positively influence by virtue of its hypothesised stabilising action. We think that these urban influences are having such a strong signal on the already highly dynamic beach systems, that it is masking any spatial patterns that might exist in POM distribution, and hence also on the beach ecosystems themselves. We are confident that had undeveloped cleared vs. non-cleared beaches been present in the CoCT municipal areas, a signal resulting from wrack removal might have been detected.

Conclusion

Considering the highly modified beach landscapes within the CoCT region, we conclude that beach-cleaning activities that are routinely being executed are not affecting the functioning of beach ecosystems in any way. We would advise caution, however, when such management practices would be suggested for non-urban beaches.

4. CHALLENGES

This project faced several important challenges that have reduced the scope of what was achievable. In the face of these constraints, the aims and goals had to be adjusted. This is also reflected in the incomplete allocation of the budget that we received for the work. Overall, we do not feel that we could fully deliver what we had promised.

1. Initially, we established contact with Mr Daryl Colenbrander at the CoCT's Environmental Management Department. We discussed the project with him, and agreed on the intended scope. The agreement made was that we would obtain the data records of volumes of kelp removed from the cleared beach from the CoCT Sanitation Department. By February 2018, after repeat calls and emails, we had not received this data. This data were intended to serve as 'calibration' for our method for kelp removal quantification (as outlined in the proposal); this is the core data set on which success of our proposal hinged, and without it we had to find a compromise solution that would yield a much-reduced level of insight of kelp wrack dynamics on sandy beaches, but which would still be beneficial in terms of informing management options.
2. After having received the site list of cleared/non-cleared beach from Mr Colenbrander, we set out to build a site list for our sampling. It turned out that the majority of the cleared beaches are situated opposite hard engineering structures (walk-ways, promenades, car parks, sea walls, etc.), which meant that the dune systems for which we hypothesised the beach-cast kelp is having a positive, stabilising function were actually absent. In other words, removing kelps from beaches where there in fact are no dune systems that require the protective presence of kelp is not actually a problem.

3. The proximity of our sampled beaches to built-up areas meant that a host of additional impacts might be taking place there (e.g. land-use change, runoff, pollution, altered wave and wind exposure, etc.), which would confound any effects visible that might result from beach clearing. Even if issues 1) and 2) did not exist, these confounding influences would have prevented us from confidently attributing any measured effects to beach clearing. Even in terms of changes to beach-cast kelp/POM dynamics (i.e. the findings mentioned above), these unanticipated, uncontrolled influences will have confounded our interpretations.
4. Security issues at Strandfontein Beach and Strandfontein Resort meant that sampling only occurred once at these sites.

It is recommended that in future better communication between researchers and CoCT staff is established, and that requested data are shared in a timely manner. Furthermore, future studies should include beaches where other anthropogenic sources of influence are limited, and should include as many beaches along undeveloped coastlines as possible.

5. BUDGET

R100 000 was available to the project, and allocated to the following line items:

a. Stipends/bursary for 10 months of data collection	R60 000
b. Salary for short term helpers (per data collection days at R250 per day)	R5 000
c. Scale and tripod for individual, on site, kelp measurements	R10 000
d. Diving boat hire for kelp forest sampling while still embedded on sea floor @ R3 500 per day and 5 dives	R17 500
e. Running costs (mainly fuel and car mileage reimbursements)	R5 000
f. Miscellaneous expenses	R2 500

The actual spend included the following:

- a. R40 000 paid to Mr Ross Coppin for the field and lab components of the work. Field work consisted of field visits to the four beaches indicated in the Methods, and the collection of sediment samples for POM analysis. In the laboratory additional time was spend for the processing and analysis of the POM samples (weighing, combustions, etc.). Mr Coppin also prepared the full data analysis, as well as an version of the document that forms the basis of this report.
- b. R3 357 was paid to Mr Coppin as reimbursement to fuel expenses incurred.

More than half the budget was unspent due to the issues we have encountered, and which we have discussed in the 'Challenges' section, above.

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