To clean or not to clean? The effect of kelp-wrack clearing on particular organic matter content of beach soil around the Cape Peninsula, South Africa

Contents

Introduction

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 soil 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 ect) 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 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 is 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 mineralised, 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 soil (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 species are deposited on beaches by coastal currents on almost a daily basis, and consist mainly of two species, e.g. *Ecklonia maxima* and *Laminaria pallida*, and form what is known as beach-cast kelp or simply beach-cast Anderson2007b. Beach-cast is an important organic input into sandy beach ecosystems, and through wind, may be transported to adjacent and distant 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 carbon flow via grazing invertebrates and through bacteria shows that 23-27% of the carbon in kelp is converted to bacterial carbon. Furthermore some species of nematodes are 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 (CCT) 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 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 the kelp needs to be removed for aesthetic reasons. The CCT both recognises 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 CCT, therefore, collects beach cast kelp from predetermined beaches and disposes the kelp in landfills as there is currently no procedures in place to process and dispose of kelp in a sustainable manner (Yoshikawa 2013).

Since kelp biomass has been shown to be an important detrital input in sandy beach ecosystems, the removal of beach-cast may therefore affect the overall particular organic matter (POM) content available within the soil of sandy beaches, which could possibly lead to a bottom-up affect on food webs.

Aims and Objectives

The aim of this study was to determine if clearing of kelp from beaches affects POM content of beach soil. This aim will be met through the following objectives: 1) Determine if there are any differences in POM content of cleared and non-cleared areas of selected beaches. 2) Determine if differences in POM content are driven by other factors such as kelp biomass and transect length.

Study sites

Hout Bay east and west

Hout Bay 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 are 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

Muizenburg 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.

Fishoek

Fishoek was 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 beach comprises a dune system with 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 is 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 and 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

Various beaches are around Cape Town have been divided up into 'cleared' and 'non-cleared' areas by the City of Cape Town. These were sampled for POM content in the soil 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 up into 5 sections according to the length of the transect on that particular sampling occasion. Soil 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 and finally re-weighed. The difference between in grams between the start and end weight was used as an estimate as particulate organic matter content. This method is know as "loss on ignition" (Santisteban et al. 2004; Byers, Mills, and Stewart 1978)

Data analysis

All data analyses were done using the R software, and the vegan package and ggplot2. 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 was 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.

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 1) between cleared and non-cleared areas. The cleared category had a slightly higher POM median than the non-cleared category (see Figure 1).

Cleared and Non-cleared areas in each month

No significant differences between cleared and non-cleared areas were found over the course of the study, and only a significant difference in transect length was found for March (see Figure 2). The POM findings 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. The cleared areas had a slightly higher median POM than non-cleared areas.
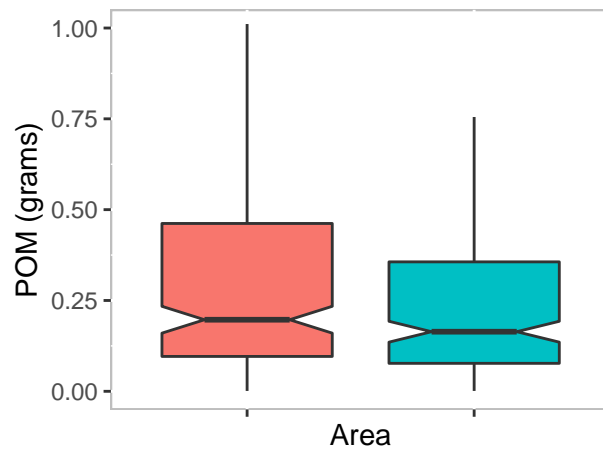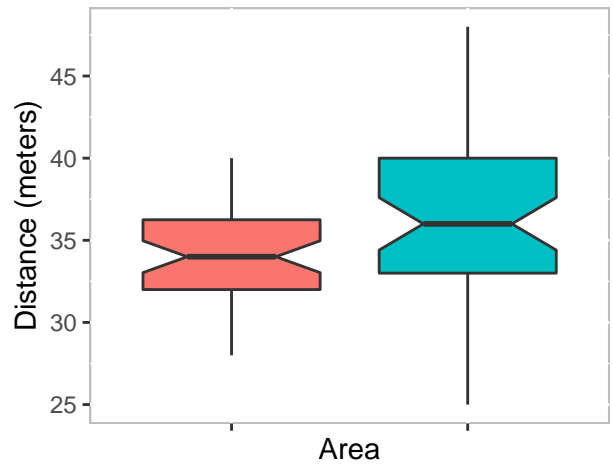
A

B

Figure 1: 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. 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
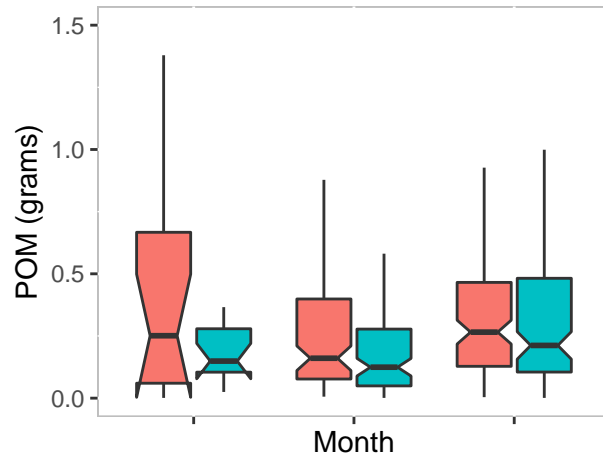
A

B

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. 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
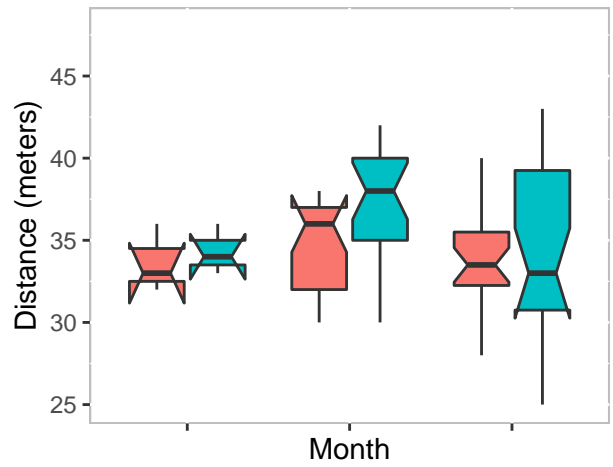
Figure 3: Boxplots comparing POM and transect length in cleared and non-cleared areas between sites, the horizontal black lines represent the median. If 'notches' do not overlap, the medians are considered to be statistically different. The lower and upper 'hinges'correspond to the first and third quartiles, and the 'whiskers' are the 5th and 95th percentiles. Pink boxes represent cleared areas and blue boxes represent non-cleared areas
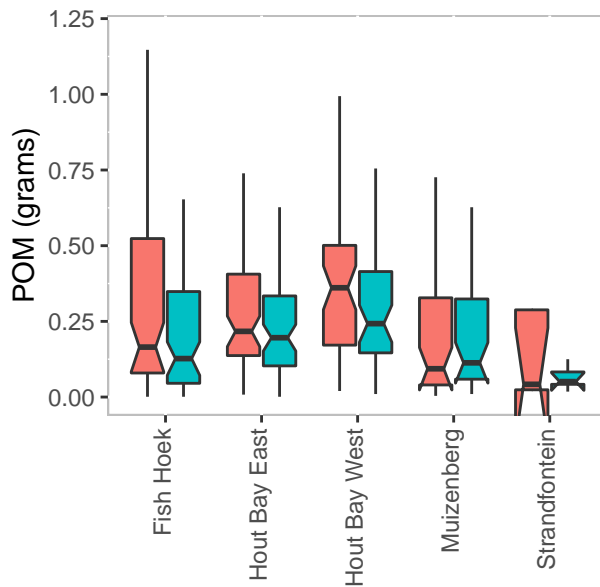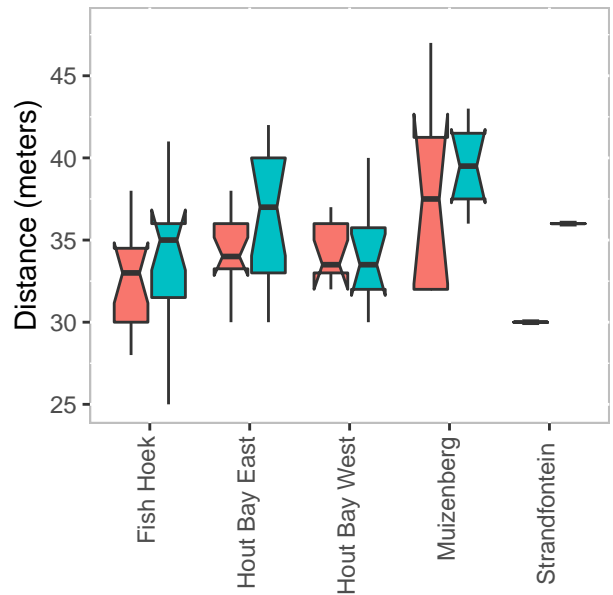
Cleared and Non-cleared areas between sites

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 3). Although not significant, POM in cleared areas was significantly higher at all sites, with Muizenberg being the exception (see Figure 3). Visual comparison showed significantly higher transect lengths for non-cleared areas than cleared areas at Fishoek, Hout Bay East and Muizenberg.

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

Kelp wrack on beaches provides an important energy subsidy into sandy beach ecosystems which drives "bottom-up" control of invertebrates, which in turn, affects other organisms such as bird species. The

results from this study were surprising as POM content in cleared areas tended to be slightly higher than in non-cleared areas.

The degree to which POM content dissolves into beach soil has been shown to be determined by the size of soil grains. The size of grains determines the amount of space available in between them. Orr et al. (2008) investigated the temporal and spatial variation of kelp wrack on different beach types. The results showed that beaches with cobble stones retained approximately 30 times more kelp wrack compared to sand beaches (Orr et al. 2008). In other words, large grain sizes will have more space between them and ultimately more dissolved matter compared to fine grain beaches. Although grain size was fine between all the beaches in the study, no differences in size of grains was noted (personal observation).

There was also no significant difference in POM content between sites, with Hout Bay West as the exception. The significanly higher POM content 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 there is a drain pipe leading onto the beach from the parking lot, which may be adding to POM content in this area.

The built up areas, lack of adjacent sand dunes in many cases and wind may be contributing to the slightly higher POM content in cleared areas. Once kelp has been washed onto beaches it begins to degrade through various abiotic and biotic processes. The organic material may also enter the atmosphere through wind action, which transports the organic matter to distant and adjacent marine and terrestrial ecosystems. However the human structures in and around the beaches (walls, parking lots, buildings ect) may be preventing the transport of POM by wind. In other words, unlike pristine sandy beaches where wind would transport some of the POM to nearby ecosystems, the sandy beach ecosystems in this study were characterised by limited dune systems and human structures. Instead, POM content builds up over time and may also be compounded by point and non-point sources of pollution such as drain pipes and runoff.

Therefore, the beach-cleaning activities by the CoCT may be necessary in order to prevent the build up of POM in beach soils, as this may become toxic in high concentrations.

Limitations and recommendations

The lack of data and communication from the City of Cape Town was a significant barrier that could not be overcome. The data-set promised by the City was not sent to us, despite various requests and meetings, and therefore the aim of the study could not be met entirely. Security issues at Strandfontein Beach and Strandfontein resort meant that sampling only occurred once at these sites. Also, the beaches sampled in this study may be significantly influenced by other factors such as land-use change, runoff, pollution, wave exposure and wind. Therefore, due to the complexity of study sites it was difficult to determine if beach cleaning activities are driving POM content in beach soil around the Cape Peninsula.

It is recommended that in future better communication between researchers and CoCT staff is established, and that requested data is 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 the coastline as possible.

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