<u>Investigating the effects of altered fire regimes on the distribution of the Cape Sugarbird (*Promerops cafer*) on the Cape Peninsula</u>

BIO3019S Project

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<u>Introduction</u>

The Cape Floristic Region (CFR) is an extremely biodiverse region that is internationally recognized as its' own floral kingdom [6]. The region is also home to a population of 4.4 million inhabitants in Cape Town [7], a number which is projected to growing exponentially, resulting in increasing pressures on biodiversity in the area [2]. The Cape Peninsula is one the most endemic areas of the CFR with over 90 taxa endemic to this region alone [5], however efforts to conserve flora and fauna of the area have been unsuccessful, with over 41% of Cape Peninsula species classified as threatened or endangered. Climate change is predicted to increase temperatures and decrease rainfall in the area [4], resulting in further losses in biodiversity.

The current increasing temperatures and decreasing rainfall has already resulted in the worst drought ever recorded in the area [3]. This change in the Cape Floristic Region (CFR) will result in altered ignition probabilities, fuel loads and consequently altered fire regimes [4]. One of the vegetation types that dominate the Cape Peninsula is the fire-prone fynbos. Prior to land transformation it covered 92% of the Cape Peninsula [5]. The boundaries between fynbos and forest have been largely determined by fire regimes. Since the introduction of humans to the area, land transformation has occurred with many locations becoming fire-protected, resulting in larger regions of forest and less of fynbos [5]. Fire is a key driver of the distribution of fynbos [4] and thus, changes to fire regimes will alter the distribution of fynbos-species as well as organisms dependent on fynbos for survival.

Altered Fire Regimes and Burnt areas

Fire intervals of 15-20 year are required to maintain a healthy fynbos community and intervals of 4-5 years are required to eliminate dominant reseeders and allow resprouters to also grow [8]. Land transformation by European Settlers resulted in 44% of the Peninsula being invaded by alien species and 37% of the Peninsula being urbanized or used for agriculture. [6]. The British Colonialists also altered fire regimes by building human settlements that could not be burnt [3]. This altered the distribution of fynbos species throughout the region as well as within fynbos communities themselves [8].

The compounding effects of climate change and human settlements in the Cape Peninsula has resulted in distorted fire regimes in the region. Fynbos species are adapted to fire, thus altering fire regimes will change their distribution throughout the region. Prolonged periods with no fires results in fynbos communities dominated by reseeders [8], bringing ecosystems in equilibria out of balance. Many endemic species are adapted to the unique vegetation composition in certain regions [5], thus alterations will undoubtedly impact the distribution of other endemic non-vegetative species. Altered fire regimes will therefore threaten the biodiversity of the region [3], due to its significant influence on fynbos species distribution.

Bird species are useful model species to understand the relationship between changing environments and biodiversity [2]. Bird species are mobile, allowing them to react to changes in their environment quickly. One of the most common fynbos birds is the Cape Sugarbirds (*Promerops Cafer*) [1].

Figure 1: Cape Sugarbird(Promerops Cafer) on Pincushion (Leucospermum) , https://tinyurl.com/bdh8fhvb

Distribution of the Cape Sugarbird

The species is restricted to the distribution of fynbos by its' specialized nesting and dietary requirements [2]. The species primarily nest and feeds on Sugarbushes (genus *Protea*) during breeding season, but also feeds on Pincushion plants (genus *Leucospermum)* when non-breeding [1], both of which are re-seeders.

It has been shown that the species avoids areas that has previously than burnt [9], however since it tracks fynbos species that are prone to fires, it cannot avoid burnt areas entirely. Cape Sugarbirds can only nest on mature proteas [9], therefore it can only occur in regions that have not burnt for ~10 years.

Altered fire regimes due to land transformations are predicted to increase the range of the Cape Sugarbird. Since the probability of a location burning (Burn probability) will decrease due to human settlements and interference, the number of viable nesting sites (Sugarbushes and Pincushions) [4] for Sugarbirds to nest on, are predicted to increase. This will cause sugarbirds to shift their range into novel gardens that have many mature proteas and low burn probabilities [4].

Altered fire regimes can also fragment habitats [3], increased burn probabilities in the Northern region of the Peninsula [3] which can fragment habitats. This paper aims to explore whether altered fire regimes will cause habitat fragmentation or range expansion in the Cape Sugarbird.

Methods

Data source

Presence-only data on *Promerops cafer* is gathered from Global Biodiversity Information Facility (GBIF repository). The GBIF repository has 33 885 point occurrences across South Africa with are 5 815 point occurrences within the Cape Peninsula. The data grouped by year, with points before 1950 considered as occurrences in an untransformed landscape. The points are cropped to locations within the Peninsula (Outliers at sea are removed). The points are also buffered into polygons due to the mobility of the Cape Sugarbird, influencing its' actual distribution. The two datasets are analysed separately with their respective burn probability layers (Untransformed and transformed).

The burn probabilities in the Cape Peninsula before and after transformation are gathered from (Slingsby et al 2020). Transformation is defined as any alterations done to the land due to European settlements which have a significant impact on the ignition catchment and burn probabilities in a location. The location of each burn probability is given in the coordinate system UTM34S. The burn probabilities of the landscape after land transformation are calculated based on the amount of land transformation that occurred in the peninsula in 2008. The untransformed burn layer shows the burn probabilities of the region before land transformation. Any data from before 1950 are about the untransformed Cape Peninsula.

The age of the vegetation in multiple regions is produced by calculating the time since its' last burning (fire) . Fire data from SANBI [9] contains details about the extent and time of the fires in the Cape Peninsula between 1962 and 2018. By 1962, many of the locations have already undergone land transformation so the age of the vegetation in several areas is already subject to altered fire regimes

Matching environmental data to the Sugarbird distribution data

The Sugarbird Distribution data and burn probabilities are firstly, projected into the same coordinate system (UTM34S). A subset of burn probabilities is then produced by selecting data points that have the same coordinates as the occurrence points in the Sugarbird Distribution data. Two subsets are produced (transformed and untransformed) and further analysed to understand whether the Cape Sugarbird prefers locations with a specific range of burn probabilities.

The age of the vegetation in locations where the Cape Sugarbird occur are also calculated. This is done by looking up the date and location of point occurrences and checking the most recent fire in the aforementioned location. This will give us the age of the vegetation at locations where the Cape Sugarbird is present.

R-Programming

All maps and data preprocessing is done in Statistical language R[11]. The packages used are raster, rgbif, Tidyverse, ggplot2, terra, ggspatial, sf and dplyr. The citations are given in references [12]-[19]

Results

The 5 815 occurrences in the Cape Peninsula contain 17 points dating back to before 1950. After cropping and slicing the data, 2 484 points occur after land transformation and 7 occur before land transformation. All points are buffered into polygons with a 500m radius based on territory data of the species. Figure 2 shows the 2484 polygons that represent the distribution of the Cape Sugarbird in the current transformed landscape. The species can be found along the entire peninsula within both the city landscapes as well as the nature reserves.

Figure 2: Current distribution of the Cape Sugarbird in the Cape Peninsula

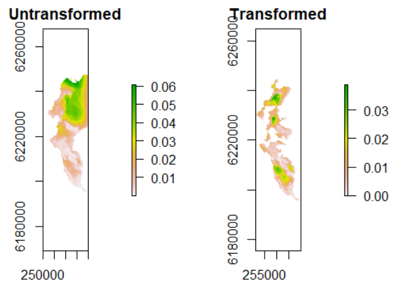

Figure 3: The Burn probabilities of the Cape Peninsula before and after land transformation

The burn probabilities of the Cape Peninsula before and after transformation are shown in Figure 3. The extrema of burn probabilities pre-transformation have a maximum value of 0.061 and a minimum value of 0.000015. After land transformation, the Cape peninsula had burn probabilities of 0 to 0.038910. The changes in burn probabilities in each location vary from -0.012840 to 0.054.

In the current transformed landscape, there are 956 locations out of the 2484 polygons that have burn probabilities. There are 7 polygon occurrence locations that have burn probabilities in the untransformed landscape. Figure 4 shows the likelihood of the Sugarbird occurring in a location given some burn probability. Historic data indicates that the species primarily occurred in locations with burn probabilities between 0 and 0.02 before land transformation.

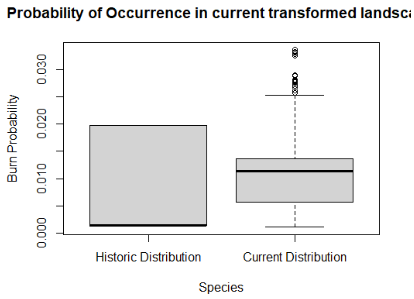

Figure 4: Boxplot of the Cape Sugarbird distribution before and after land transformation

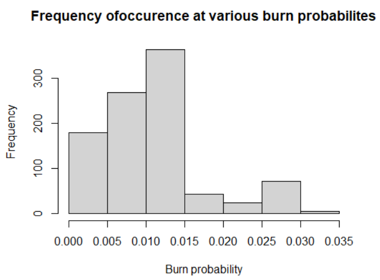

Figure 5: Frequency of Sugarbird occurrence at various burn probabilities

After land transformation, the species occurs in locations with a variety of burn probabilities. Most of the birds occur in locations with burn probabilities ranging from 0 to 0.015 as shown in Figure 5. Land transformation has caused the species to expand its' range to include regions with burn probabilities higher than their historic distribution with multiple point occurrences at locations with burn probabilities greater than 0.02. Out of the 956 occurrences, 810 are in locations with burn probabilities less than 0.015 .

The distribution of the Sugarbird before 1950 and after are shown in Figure 6. Sugarbirds have moved from the outer borders of the Cape Peninsula inwards as land transformation occurs.

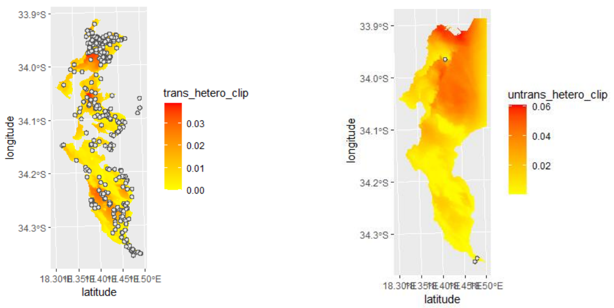

Figure 6: Distribution of the Cape Sugarbird in transformed and untransformed landscap mapped over burn layers

The age of the vegetation is calculated from data on the fires in the Cape Peninsula since the 1960s.

The change in burn probability over time due to land transformation is shown in Figure 6. The upper regions of the Cape Peninsula show an increase in burn probability; however, the lower-middle regions show a decrease or stable change in burn probability. The effect of land transformation on burn probabilities is not homogenous indicating that its' impact on Sugarbird distribution will vary from location to location. The Cape Sugarbird occurs primarily in regions where there is minimal change in burn probabilities, however the outliers indicate that it can occur in regions where the burn probability has increased. The Cape Sugarbird occurs primarily in regions where the change in burn probability is minimal.

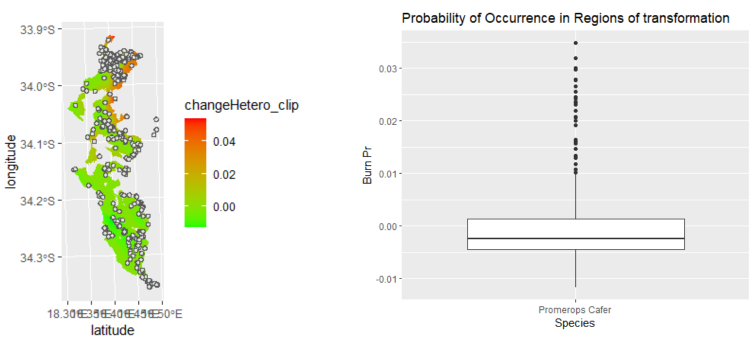

Figure 7: Distribution of the Cape Sugarbird in a map of change in Burn probabilities and the boxplot indicating Sugarbird Frequency in locations with certain burn probabilities.

Figure 8 shows the distribution of the Cape Sugarbird based on the age of the vegetation (Time since last burning). Out of the 5 815 occurrence points, only 442 occurred in locations where we have data on the age of the vegetation. The rest of the locations are assumed to not have burned since ~1970. There are 419 point occurrences in vegetation that are older than 5.21 years (1 900 days) old and younger than 39.18 years (14300 days)

Land transformation has lowered the overall burn probabilities in the Cape Peninsula. The burn probabilities of the Cape Peninsula before land transformation had a maximum of 0.061 which almost halved afterwards, to 0.03 in 2008. Land transformation reduced both the range and magnitude of the burn probabilities indicating that humans have reduced the probability of fire in the region. The heterogenous changes in burn probability means the relationship between land transformation and Sugarbird distribution is unique depending on each location.

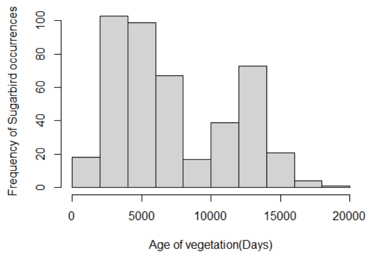

Figure 8: The number of Cape Sugarbirds in a location given the age of the vegitation

A comparison of the current and historic distribution of the Cape Sugarbird in the Cape Peninsula shows that as land transformations occur, the species is moving further towards the middle of the Cape Peninsula into regions where there are mature proteas that have been planted in gardens and protected in nature reserves [9]. The species is also occurring in locations with higher burn probabilities than its' historic range. This is common further north in the Peninsula. This is a potential threat to the survival of the species in long-term since higher burn probabilities indicates lower survival probabilities.

The Cape Sugarbird occurs in locations where land transformation has had minimal effect on the burn probability. This could also indicate that the species prefers to live in habitats that are untransformed and unaffected by land change. Land changes that cause altered fire regimes (and consequent changes in burn probability) are associated with several other factors that can cause species decline [6]. It is also associated with the removal of Fynbos species in Pine plantations [6] which could reduce the number of viable habitats for the species in that location resulting in population declines due to habitat fragmentation.

It is important to note that the historic distribution data in the untransformed landscape is made up of only 7 polygons, so the historic data may be highly inaccurate. More data on the distribution of the Cape Sugarbirds before land transformation needs to be gathered to verify the changes in Sugarbird distribution due to altered fire regimes.

The majority of Sugarbirds studied in this report occur in locations where the vegetation is older than ~5.2 years, with minimal occurrences in regions that have vegetation younger than that. This is because Sugarbirds cannot nest on young Proteas [9]. It will therefore take the species 5.2 years to return to a location after the fynbos has burnt. Sugarbirds prefer regions that do not burn frequently [9], hence it is occurs primarily in locations where the vegetation can be up to ~40 years old and the burn probability is low, but never zero since it is a fynbos species. Fynbos that has not burnt for over 40 years can become quite dry, thus Sugarbirds will migrate seek younger plants at this time, since they can no longer get nectar from the old plants.

Conclusion

The Cape Sugarbird occurs in abundance in the Western Cape with a range that covers almost the entirety of the Peninsula. Birds are a mobile species so their range is much likely greater than the one modelled in report. The range of the species is predicted to expand into regions with burn probabilities have been lowered due to land transformation. This expansion is likely into botanical and novel gardens in human settlements where they can nest on mature Proteas with minimal risks of fires.

Preliminary results found in this paper also indicate that altered fire regimes are driving the species to inhabit locations with burn probabilities higher than expected, especially in the Northern sections of the Peninsula. Higher fire frequencies will reduce the availability of Sugarbushes and Pincushion [5], eventually removing the plant species from the North of the Peninsula entirely and effectively excluding the Cape Sugarbird from that region long-term. The species will only be found in locations where it can nest on mature Proteas, so the vegetation will be older than 5.21 years.

The Cape Sugarbird does not occur in regions where the burn probabilities have changes. This is anecdotal evidence that the land transformation is driving the species out of these regions, albeit not by altered fire regimes. Overall, the Range of the Cape Sugarbird is expected to shift and expand from the Southern tip towards the middle of the region, whereas the Northern range of the species is predicted to shrink. Since birds are model species to understand how other species will react to changes in an environment, it is possible and likely that many other species that depend on Sugarbushes and Pincushions will show a similar pattern, if their original distribution is similar.

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