Postdoctoral research proposal

Climate Change Impacts on Fynbos Endemic Birds:
Spatial and temporal patterns of abundance and dispersal of Fynbos avifauna

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Rationale

Bird communities in the Fynbos biome face documented threats from alien vegetation encroachment, changes in burning regimes, and human modification of the landscape. The status of bird populations under current conditions has not been recently quantified, and while modelling assessments have determined that Fynbos bird species under vulnerable under various climate change scenarios no study has used real abundance data. There are six bird species recognised as globally restricted to the Fynbos. These are currently listed by IUCN conservation criteria as species of Least Concern, despite a lack of information on population size and little evaluation of population trends and range size changes. Recent reviews of their distribution, together with the impacts of climate change, suggest that their conservation criteria need to be re-examined. However, quantitative information on movements, densities and population sizes is lacking for most bird species that inhabit mountain Fynbos. This study aims to establish baseline density data for bird communities in the Mountain Fynbos habitat element; determine patterns of dispersal and abundance along aridity and altitudinal gradients to predict vulnerability of populations to future climate change; and determine how well these predictions could have been achieved using Southern African Bird Atlas Project data.

Introduction

Most of the Fynbos biome of the south-western and southern South Africa is included within the Cape Fynbos Endemic Bird Area (EBA), which extends from the Cederberg Mountains south and eastwards to Algoa Bay (BirdLife International 2010). While this study is focused on all the birds of the upland mountain Fynbos, several species are endemic or conservation concern. The EBA hosts at least 20 range-restricted and biome-restricted bird species, six of which are biome endemics: Orange-breasted Sunbird *Anthobaphes violacea*, Cape Sugarbird *Promerops cafer*, Protea Seedeater *Crithagra leucoptera*, Cape Rockjumper *Chaetops frenatus*, Victorin's Warbler *Cryptillas victorini* and Cape Siskin *Serinus totta* (BirdLife International 2010). Although the population of some of these species is suspected to be in decline owing to ongoing loss of habitat, it is thought that these range-restricted birds all appear reasonably adaptable to transformed landscapes and so none is classified as globally threatened (BirdLife International 2010; Table 1). In addition, the Hottentot Buttonquail *Turnix hottentottus* is restricted to within the limits of the Fynbos in restionaceous coastal and mountain Fynbos, west coast strandveld and coastal renosterveld. This species is listed on Birdlife South Africa's Checklist of Birds in South Africa 2011, which states the species is "probably Critically Endangered, but split off from former species (Black-rumped Buttonquail *Turnix nanus*) prior to latest Red List publication". It is unlikely the study design proposed here will add to our knowledge on this species – but encounters will not be ignored.

Two of the six endemics are nectarivorous (Orange-breasted Sunbird and Cape Sugarbird) and important pollinators of *Aloe, Erica, Protea* and other Fynbos plant species (Barnes et al. 1995, Botes et al. 2008). Nectarivores are resource trackers and densities change in relation to food availability (Collins and Newland 1986, Cotton 2006). For instance, seasonal movements in response to food availability have been shown for the nectarivorous Malachite Sunbird *Nectarinia famosa* and Gurney's Sugarbird *Promerops gurneyi* in KwaZulu-Natal (Symes et al. 2001). The spatio-temporal patterns of resource tracking of the nectarivorous Fynbos community are still not well understood (but see (Fraser et al. 1989)). Cape Sugarbirds are considered to be territorial and make movements away from those territories during dry seasons

(Calf et al. 2003b), with a high proportion of transient individuals recorded at a non-breeding site (Altwegg and Underhill 2006).

Table 1: Six Fynbos endemic species together with IUCN reported range (Birdlife International 2010b) and South African Bird Atlas Project2 (SABAP2) range as of 16 May 2011. Note that atlas data can give underestimates of Extent of Occurrence. Population estimate is according to Birdlife International (2010b).

Species	IUCN reported range (km^2)	SABAP2 range (km^2)	Population estimate
Cape Sugarbird *Promerops cafer*	115,000	65,296	Unknown
Orange-breasted Sunbird *Anthobaphes violacea*	93,500	56,672	Unknown
Cape Rock-jumper *Chaetops frenatus*	66,600	15,400	30,000 - 300,000
Victorin's Warbler *Cryptillas victorini*	46,400	29,568	Unknown
Cape Siskin *Crithagra totta*	66,400	46,816	Unknown
Protea Seedeater *Crithagra leucoptera*	85,500	21,560	Unknown

The Cape Sugarbird is the most studied of the Fynbos endemics as it has been identified as the most important bird pollinator of Fynbos proteas (Skead 1967, Cheke et al. 2001), foraging on the nectar of at least 22 species (Collins and Rebelo 1987). Adult Cape Sugarbirds show high site fidelity and usually return to their breeding territories every year (Henderson 2000, Calf et al. 2003). Between breeding seasons they move over large distances (up to 160km) in search of flowering protea stands (Fraser 1997b). Protea communities largely determine spatial resource distributions for Sugarbirds and hence their local abundance and movement behaviour. Sugarbirds also adapt to gardens and some exotic plant species (Cheke et al. 2001). They are also associated with protea farms (Potgieter et al. 2008), although commercial bee-keeping activities may have detrimental effects on bird abundance due to interference (Geerts and Pauw 2011).

Orange-breasted Sunbirds are described as common (Hockey et al. 2005) and reluctant to leave Fynbos (Fraser et al. 1989) but may do when displaced by fires (Fraser and McMahon 1992). They feed on nectar from a variety of endemic and exotic plants, as well as on arthropods and spiders, and are considered important pollinators for a range of *Erica* species (Fry et al. 2000). This species has been shown to be adversely affected by the invasion of alien woody plants (Fraser and Crowe

1990). The population estimate is given as >100,000 based on a review from nearly 20 years ago (Siegfried 1992). The Orange-breasted Sunbird has shown considerable range contraction between the two atlas projects (Lee and Barnard submitted), faces range contraction according to climate change prediction modelling (Huntley et al. 2011) and may well meet IUCN Vulnerable status in the near future given anticipated climate and land-use changes across the biome.

Potential range reductions due to climate change of Cape Sugarbird and Orange-breasted Sunbird are greater (62% and 63% respectively) than the median reduction (34%) across all species modelled from 94 species of bird found in Fynbos and grassland biomes (Huntley and Barnard submitted). While explicit reasons are not dealt with in the later, it is known that the major causes of nest failure are unpredictable climatic conditions, as well as predation (Broekhuysen 1959). To better understand the impact of climate change on these species comparative studies conducted in the mesic western Fynbos on breeding and fecundity (Calf et al. 2003a), territory (Calf et al. 2003b), behaviour (Calf et al. 2003c), morphology (Tiorve and Scholtz 2007), survival (Altwegg and Underhill 2006) should be repeated in the dry eastern elements of the species range.

Insectivorous Victorin's Warblers inhabit mesic mountain Fynbos from sea level to high altitude favouring rank growth along streams or seeps (Fraser 1997d). Formerly listed as 'possibly vulnerable' and as 'worthy of monitoring' (Brooke 1984), it is currently considered to be under no immediate threat (Fraser 1997d). Habitat is threatened by infestation with alien plants and damming of valley streams, but probably little affected by fynbos fires because of moist habitat (Fraser 1997d).

Cape Rockjumpers have been identified as being potentially vulnerable to climate change (Simmons et al. 2004), and simulated to decrease in range extent by 62% by 2085 (Huntley and Barnard submitted). With an apparently large decrease in range that brings it to below 20,000 km^2 (Lee and Barnard submitted), coupled with range fragmentation, increased fire frequency in parts of its range (Southey 2009), this species now probably qualifies for a higher IUCN threatened status listing due to extreme range contraction relative to ecologically and morphologically similar species, combined with probable extent of occurrence <20,000 km^2. This iconic species requires urgent attention from conservation biologists and conservation planners.

Granivorous Cape Siskin and Protea Seedeater were previously categorised as *Near Threatened* and locally common residents, or locally nomadic (Hockey et al 2005). Although also showing a high relative range contraction, Cape Siskins may be one of the more adaptable of the Fynbos endemics as they have been reported from village gardens and areas colonised by alien invasive Rooikrans *Acacia cyclops.* They also occur at the edges of pine and other exotic plantations, and seasonally they move into kloofs on the fringes of the Karoo. They are also likely to be mobile across seasons. Protea Seedeater showed a large decrease in reported range, bringing it close to the critical 20,000 km^2 mark that would classify it as *Vulnerable* (Lee and Barnard submitted). There appear to be few formal studies published featuring these species from the last 30 years – Protea Seedeater ecology was documented during the 1970's resulting in the last publication of that species in 1978 (Milewski 1978); while morphological characteristics of Cape Siskin from ringing exercises appear more recently (Ward 2001). Most of the information on these species is contained in field guides or from the South African Bird Atlas projects (Harrison et al. 1997). Again, rigorous analysis of existing data and further studies are required for all these species.

Biome integrity and conservation status

The Cape Fynbos (also referred to as Cape Floristic Region or Kingdom) is remarkable for the high levels of plant diversity and endemism; approximately 8,579 vascular plant species have been recorded, of which about 68% are endemic (Cowling and Hilton-Taylor 1994). Rapid agricultural development and spread of invasive alien *Acacia*, *Hakea* and *Pinus* trees over the last century have had a severe impact on the integrity of the biome (Kemper et al. 1999). The biome is characterized by high vegetation type heterogeneity due to strong topographic and rainfall gradients, with some authors recording up to 102 broad habitat types (Boshoff et al. 2001). Some of these habitat types have become critically endangered, such as the Renosterveld element, which has been reduced to 4% of its original extent (Kemper et al. 2000, Parker and Lomba 2009). Upland (Mountain) Fynbos is generally considered to be well protected as large areas fall within conservation areas proclaimed by Department of Water Affairs and Forestry (DWAF) in order to protect water catchment areas. However, these areas do not necessarily represent the range of habitats necessary to sustain viable populations of birds – e.g. over 50% of breeding habitat of Black Harrier *Circus maurus* (largely endemic as a breeding species to the Fynbos biome) may have been lost over the last century (Curtis et al. 2004).

Habitat fragmentation describes the emergence of discontinuities (fragmentation) in an organism's preferred environment, causing population fragmentation. Habitat fragmentation can be caused by geological processes, or by human activity such as land conversion, which alters the environment much faster. Population fragmentation can result in population bottlenecks (Martínez-Cruz et al. 2004), and population bottlenecks can result in the reduced fitness of a given population as a result of inbreeding depression (Brekke et al. 2010). Avian species richness is generally inversely proportional to fragment size (Marsden et al. 2001). In addition to declines in total species numbers, there is concern that the types of species that are lost from habitat fragments may be ones of high conservation value, such as low density or habitat specialist species or species with small geographical ranges (Rompre et al. 2009). The impact of habitat fragmentation across the biome for Fynbos avifauna has not been thoroughly investigated (but see (Fox and Hockey 2007, Dures and Cumming 2010)). The loss of a species from any fragment may have severe consequences for the overall population since it has been noted that colonisation of suitable habitats has not occurred for Protea Seedeater and Cape Rockjumper in the case of the Cape Peninsula (Fraser 1997c, a).

Protea elements in the eastern Fynbos become increasingly isolated following natural elevation and aridity related gradients. Proteas in mountain Fynbos become restricted altitudinally with mountain ranges further away from the coast i.e. on a south north gradient. This is evident from XY (Caledon) eastwards where mountains are separated by dry Karoo type valleys. In effect, this creates a series of naturally fragmented linear islands with different plant communities and associated phenological (and so food availability) patterns. Movements between these islands has yet to be documented and will provide unique insights into dispersal capabilities, and associated indices of vulnerability to extinction due to landscape modification or climate change.

Climate change prediction models for South Africa generally point to reduced rainfall across the region (Shannon 2000). Reduced rainfall will undoubtedly impact phenological patterns of the plant community, as well as nectar outputs. Range changes have been recorded for 56 of 408 southern African bird species, driven most likely by both climate and land-use change (Hockey et al. 2011). Ongoing responses by birds to changing land use include both range expansions and contractions (Okes et al. 2008, Hockey and Midgley 2009), with the former typically involving generalist species and the latter specialists. Previous studies of the potential impacts of climatic change on plants of the fynbos biome have highlighted potential reduction in its extent, species' range displacements and potential extinctions (Midgley et al. 2002, Midgley et al. 2006). Similar outcomes for the birds associated with the fynbos and grassland biomes in southern Africa have been projected with most individual species' range extents potentially reduced, with an average mean reduction by 2085 of 34% (Huntley and Barnard submitted). Both abundance and range extent are projected to decrease by 2100 for most (74%) of the 78 southern African endemic or near endemics and projected climatic changes are likely to elicit greater relative changes in species abundances than range extents (Huntley et al. 2011). Furthermore, the current southern African network of Important Bird Areas (the network of sites designated by BirdLife International as being important for the conservation of the world's avifauna) is likely to become less effective for conserving endemic birds under climate change (Coetzee et al. 2009).

Minimising negative impacts on biodiversity requires effective conservation strategies that will enhance species' opportunities to adapt to climatic change, especially as their capacity for natural adaptation is likely to be exceeded this century (Parry et al. 2007). Developing and applying such strategies requires insight into species' responses and an integrated approach to identifying vulnerable species and regions. This challenge needs to be addressed for the Fynbos bird community because with range changes in response to climate change occurring south or upwards (Foden et al. 2007), Fynbos birds may need a critical management plan sooner rather than later.

The key questions are:

1. How do mountain fynbos bird species abundances change along aridity and altitude gradients.
2. How do species abundances vary seasonally?
3. What resource parameters are the key drivers of seasonal changes in bird dispersion and abundance?
4. Do current patterns of bird dispersion and abundance along aridity and altitudinal gradients provide insight into how these patterns might change under the predicted influences of climate change?
5. Based on patterns established in (1) above, what are the estimated population sizes of mountain fynbos endemics now, and under future climate-change scenarios.
6. How successfully could these estimates of population sizes have been derived from atlas data?

Methods

Study area

The study area is essentially contained within the Cape Fynbos ‘Endemic Bird Area’, which contains 10 Important Bird Areas (IBAs) (BirdLife International 2010) encompassing large areas of Cape fold mountains e.g. Swartberg, Kammanassie and Kouga (Figure 1). The temperature regime in these mountains is temperate and the climate considered to be Mediterranean. In the lower-lying areas (<350 m a.s.l.) rainfall averages less than 250 mm per annum. The high-altitude areas (>800 m a.s.l.) generally receive more than 800 mm p.a., the west mostly in winter and the east mostly in summer (BirdLife International 2010). Local topography has a dramatic influence on rainfall events, resulting in an aridity gradient from both west (wet) to east (dry) and south (wet) to north (dry). The average midwinter temperature varies between 7 and 15 C in July, increasing to between 15 and 25 C in January, except for the inland valleys where temperatures reaches early 40s in summer (Manning 2007). Frost can occur in the interior valleys and snow in winter (Manning 2007).

Fynbos biome can broadly be divided into three major vegetation types (Cowling et al. 1997):

1. **Fynbos** dominated by Proteaceae, Ericaceae and Restionaceae which occurs on acidic sandy soils derived from quartzite and sandstones.
2. **Renosterbos**, dominated by *Elytropappus rhinocerotis* with a high proportion of subcanopy Poaceae and geophytic plant species, occurs on relatively nutrient rich soils derived from shales. Renosterbos gives way to Karoo shrublands northwards or in xeric valleys.
3. **Strandveld** is a mosaic of asteraceous or restioid fynbos and subtropical thicket which occupies about 4500 km^2 on calcareous coastal dunes. As this element represents just c5 % of the total Fynbos area, it may or may not be included in this survey, dependent on time although members of the Fynbos endemic birds are well represented here. Instead, it is suggested that this Fynbos element be the focus of a separate study.

There are 12 Fynbos bioregions (Mucina and Rutherford 2006). The following Fynbos Bioregions or habitat elements will not be considered in this survey as they contain few Fynbos bird species: The **Karoo Renosterveld** Bioregion - as atlas data show these outlying Fynbos elements contain no/few representatives of the Fynbos bird species; and **Afromontane forest** patches are found in deep, secluded, mesic gorges and bird species here are generally forest species not represented in the surrounding fynbos. Furthermore, the **East** and **West Coast Renosterveld** Bioregions are >80% modified by agriculture and the **South Coast Fynbos** Bioregion modified by agriculture and urban developments. This in effect leaves the following suitable Bioregions for survey purposes: **Northwest, Southwest, Southern Fynbos** and **Western** and **Eastern Fynbos-Renosterveld**.

1. Abundance estimates along aridity and altitudinal gradients in Fynbos and Fynbos-Renosterveld Bioregions

1.1 Survey Design

Distance sampling is a widely used technique for estimating the size or density of biological populations. An extensive distance sampling reference list, covering methods and practical application of the methods, is available at http://www.ruwpa.st-and.ac.uk/distancesamplingreferences/. Line transects are the most popular survey method, while for surveys of breeding songbirds point transect sampling is more commonly used. While line transects maximise return on effort, linking habitat variables to abundance is easier for point counts. This is a particularly important consideration given the massive habitat and environmental heterogeneity presented in the Fynbos. As such, density estimates (individuals per km^2) will be obtained using Variable Distance Point Counts (VCPs), with data recorded according to Distance sampling criteria (Buckland 2006) and using the software program DISTANCE 6.0 (Thomas et al. 2006).

Special consideration needs to be given to the three key assumptions of distance sampling especially for point counts, which are more prone to error from violations of these (Buckland et al. 2001):

1. Objects on the line or point are detected with certainty. This assumption can be violated in tall, structurally complex vegetation types e.g. rainforests (Manu and Cresswell 2007), but I envisage this assumption can be met within Fynbos. A record of any birds seen moving away from the designated central recording point on approach will be made to ensure this is not violated.

2. Objects do not move / objects are recorded in their initial position. Conceptually, distance sampling is a ‘snapshot’ method: we would like to freeze animals in position while we conduct the survey. Non-responsive movement can be problematic for point transect surveys, leading to overestimation of density (Buckland 2006). Responsive movement before detection are additionally problematic because animals are assumed to be located independently of the position of the line or point. Implications are addressed by Fewster et al. (2008). As per assumption 1, careful attention needs to be paid to bird positions on approaching the sampling point.

3. Measurements are exact. Untrained observers tend to be poor at estimating distances by eye or ear. AL has extensive experience with distance estimation, and at the current time will be the only observer recording data to minimise observer bias in

detections and detection functions. Laser rangefinders will be used rigorously to ensure adequate accuracy.

4. Animal locations are independent of the positions of the points. This can be ensured with an adequate sample of points with randomized locations. This assumption becomes critical if transects are placed along roads or tracks. Since existing paths will be used to access survey locations, efforts will be made to sample off-track wherever possible.

It is additionally assumed species are correctly identified, which should be adequately met given relatively low species diversity in the biome plus AL's two years of experience in Fynbos with the target species. Lastly, detections are independent events, but Distance analysis methods are very robust to failures of this assumption (Thomas et al. 2010)

Obtaining reliable results from a distance sampling survey depends on good survey design. This relies upon the fundamental sampling principles of replication and randomization. Sufficient replicate points ensure that variation in encounter rate can be adequately estimated. Although ideally, the points should not be placed subjectively; practically implementing such a scheme across the Fynbos biome is impossible (survey points will be generated on inaccessible land or locations). In order to capture aridity gradients which depend not only on latitude and longitude, but also on altitude, a stratified sampling approach has been selected. The 'S0' variance estimator in Distance can be used for such survey designs and post-stratification can be effective in reducing bias (Fewster et al. 2009).

Key question 2 – how do species abundances vary seasonally – needs to take into account probability of singing, which will more than likely differ between seasons given the temperate nature of the study area with associated seasonality in breeding rates and hence singing in relation to territory establishment. Ideally, species accumulation curves that account for singing rates would have to be conducted either prior or during the survey. A compromise between a separate species accumulation study would instead be Removal Sampling (Farnsworth et al. 2002, Farnsworth et al. 2005). The point period is divided into time intervals, with detections allocated to these time intervals e.g. ten minutes subdivided into two minute intervals. This allows the calculation of a parameter a bird vocalizes during one time interval across the survey period in a subtle adaptation of an accumulation curve.

Patterns of organization in ecological communities may be significantly influenced by environmental variability across multiple scales of analysis (Spiesman and Cumming 2008). Should sampling lines and their associated points not be conducted over an area representative of the key gradients being investigated, it may be possible for variables other than those of interest to introduce confounding variance e.g. differential sampling intensity (Child et al. 2009). In order to design a study of representative coverage, up to 20 north to south sampling lines distributed on a west to east gradient will be tested as follows:

The total study area will be delimited by extracting from the Fynbos biome previously mentioned bioregions and areas of extensive monoculture. The location of transect lines, as determined by accessibility, will be overlaid with possible points distributed at a c400m. A 200m polygon buffer will be created around these using Hawth's tools (Beyer 2004). Base environmental base layers to be considered include elevation (DEM or SRTM data sets); proportion of rainy days and mean annual rainfall (TRMM), vegetation and streams (Mucina and Rutherford 2010). Descriptives (mean ± standard deviation) of the base layers for the buffer polygon will be derived from extracted layers by using 1000 bootstraps of the resulting base layer values, and tested against a similar data set derived from randomized points from the total study area. Variable distributions can be presented visually using histograms.

1.2 Field Survey

A three month summer field survey is to be undertaken across the selected bioregions for February – April 2012, with a follow up spring survey from July; the later to detect seasonal changes in abundance. Survey lines will follow existing infrastructure that allows coverage of the latitude, longitude and altitude gradients to be covered. Access will be by vehicle or bicycle along roads, and on foot where necessary.

Surveys will commence at prior to sunrise (as determined by Garmen etrex GPS) until 4-5 hours after sunrise. Further sampling 2-3 hours prior to dusk will be considered. Points will be located 400 m apart on average. Each sampled point comprises several time components, with 1-10 minutes travel between points, 3 – 5 minutes ‘settling period’, 10 minutes survey. This allows 2 – 4 points to be completed per hour, allowing for from 18 – 24 points to be completed per day. In good survey conditions, this potentially results in c100 points per week. Rest periods would be required to consolidate data, plan the next survey section, restock and travel to access point. Based on these calculations, the target number of survey points is 1000 over c 500km per survey season.

Detecting rare species: There are two ways for accounting for detection of rare species: 1. playback and lures (Buckland et al. 2006); 2. spot location sampling. A playback technique was recently used to record abundance of Scottish Crossbills (Summers and Buckland 2011). A selection of calls for known skulking species (Victorin’s Warbler, Grassbird, Striped Flufftail and Cape Rockjumper) has been obtained. A standardized recording will be played every second point count at the end of the standard point count, allowing for a further minute for recording any responses. In addition, an instant point count will be conducted on detection of rare target species Protea Seedeater and Cape Rockjumper to use the resulting information to improve detection functions to model species abundance using only the methodical sampling regime.

For each point, information to be recorded during the settling period (2 – 5 minutes): **date; location** in UTM and Lat Long with points recorded for follow-up GIS overlay analysis and/or repeat visits; **altitude** (m); **Start and end times**; **cloud cover** to the nearest 20% i.e. from 1-20%; 21 – 40% etc with special cases 0 (no clouds) and 100% (completely overcast); **Mist/Fog** – a value in meters for working visibility; a Kestrel weather device will be used to record ave. **wind speed** (meters/second) and wind/humidity adjusted **temperature** at the end of the count; **Aspect** – broad compass direction of the slope face N, NE, E, SE, S etc; **% rock** outcrop to the nearest 20%; **Slope** – closest 10^o from 0 (flat) to 90 (vertical); **topographical location** – Ridge, Slope, Valley, Ravine, Riverbank, Wetland; **Geology** – Granite, Shale, Quartzite, Sandstone, Conglomerate; **Plant community classification** (Cowling et al. 1988) -

Grassy; Asteraceous; Restioid; Ericaceous; Proteiod; Closed Scrub; Renosterveld; **invertebrate presence** in two categories 1-10 and >10 for the following groups: Arachnids, flies/bees/wasps, moths or butterflies; any caterpillar or other larvae, any hemipterans; any ants, any coleopterans, any orthopterans.

For each bird group the following information will be recorded:
Time; species; group size including sex and juvenile composition if possible; **distance** from observer to individual birds or the centre of a flock in meters using a laser rangefinder for perched birds; **activity** (perched or flying); **detection** method – whether heard only, seen only or combinations there of; perched bird **behaviour** – calling; feeding/foraging (including plant species involved if applicable); breeding behaviour (e.g carrying nesting material, presence of nests or display flights).

Within 50m of the central point of the count location, the proportional representation (to the closest 10%) of the **dominant plant groups** will be recorded for proteas, ericas and restios, with proteas and ericas further sub-categorized by broad pollination syndrome (bird or other). The proportion of these groups with buds or in flower or seed will be recorded to the closest 20%. Proportion of vegetation represented by the next four most common Fynbos genera (according to Manning 2007) will be recorded, together with flower status: *Aspalathus*, *Pelargonium*, *Agathosma*, *Phylica*. Similarly for the genera *Aloe*, *Agapanthus*, *Leonotus*, *Psoralea*, *Lycium* and other long-corolla red flowered geophytes e.g. *Watsonia* which may be determinants of nectarivore presence. The presence of alien vegetation of the genus *Pinus*, *Acacia* and *Hakea* may influence ecological integrity of some locations and presence needs to be recorded.

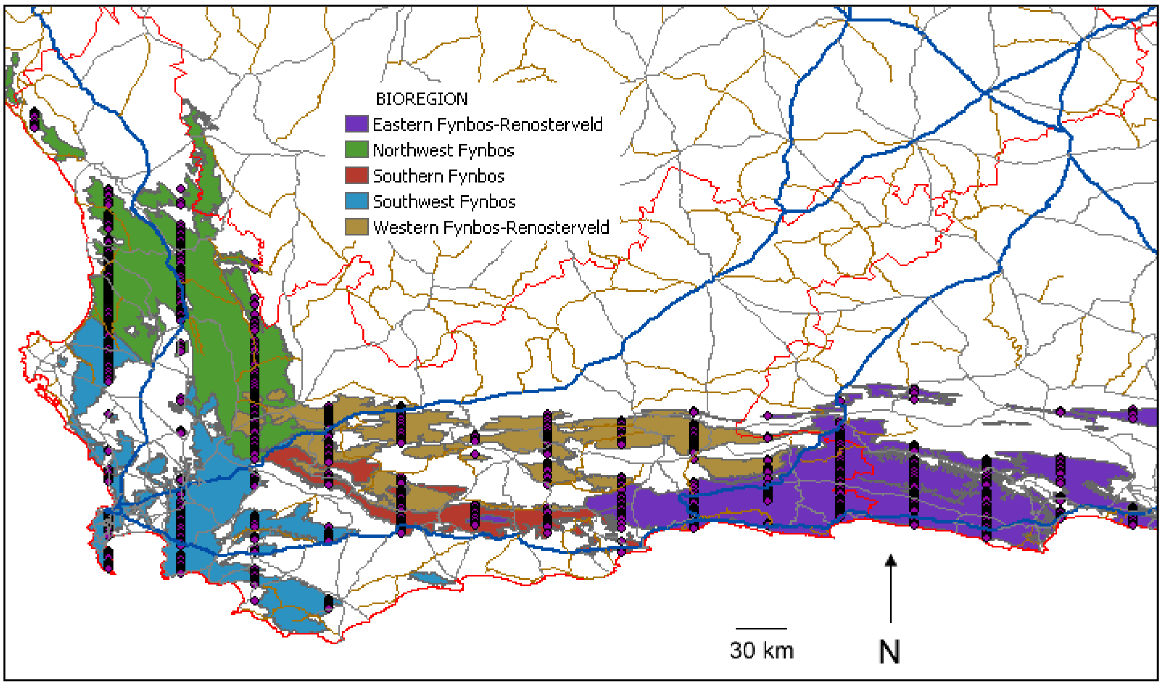

Figure 1: A map of the selected Fynbos bioregions study area indicating 15 hypothetical north – south point count transect lines (purple dots). Provincial boundaries indicated in red, national roads in blue, main roads in grey and secondary roads in brown.

Analysis of results:

Presence/absence or Density estimates will be calculated for aridity strata, with a global population calculated from strata within different habitat types or bioregions. Analysis of data will be undertaken using the Multiple Covariate Distance Sampling engine available in distance. The main use of these methods is to increase the reliability of density estimates made on subsets of the whole data (e.g., estimates for different habitats, treatments, periods, or species), to increase precision of density estimates or to allow inferences about the covariates themselves (Marques et al. 2007).

In order to investigate key resources determining species presence, initial data exploration based on encounters per point for each bird species will be undertaken using PCA techniques to reduce the number of variables – flowering vs non flowering food plants, aspect, slope, vegetation height, rockiness etc. It is predicted that flowering proteas will determine Cape Sugarbird presence, flowering ericas will determine Orange-breasted Sunbird presence, rockiness and topographical profile will influence Cape Rockjumper presence, vegetation height will influence Cape Siskin and Protea Seedeater presence, while Restio presence, aspect and slope position will influence Victorin's warbler presence.

3. Abundance and Dispersal in xeric Fynbos – further insights at a finer scale with a focus on key limiting resources for species presence

During the second year of study (2013), to determine seasonal changes in abundance in relation to key resources, a similar design as outlined in for point 1 above will be undertaken. However, here a systematic design will be employed where points (or transects) are located across Renosterveld and Protea dominated Fynbos elements around Baviaanskloof. Monitoring would be on a bi-monthly level and pay special attention to bird behaviour in relation to temperature, aridity gradients, plant phenology, structure, and nectar flow rates.

In order to determine the extent of any dispersal – i.e. bird movements (mostly nectarivores) between mountain Fynbos patches, a methodical ringing exercise will take place across the habitats to capture seasonal patterns of occurrence and movement. All ringing will be conducted according to SAFRING criteria (de Beer et al. 2001). Five sites (Blue Hill Nature Reserve, Kammanassie NR, Outeniqua NR and sites in the Baviaanskloof NR) will be visited on a bi-monthly basis. Sites have been selected in order to obtain a west-east as well as north-south gradient. At each site mist-net locations will be selected that will maximise capture rate per time effort i.e be located at flowering stands or Protea and Erica or water sources. Efforts will also be undertaken to target areas occupied by key species e.g. rock outcrops for Cape Rockjumpers using baited Spring Traps.

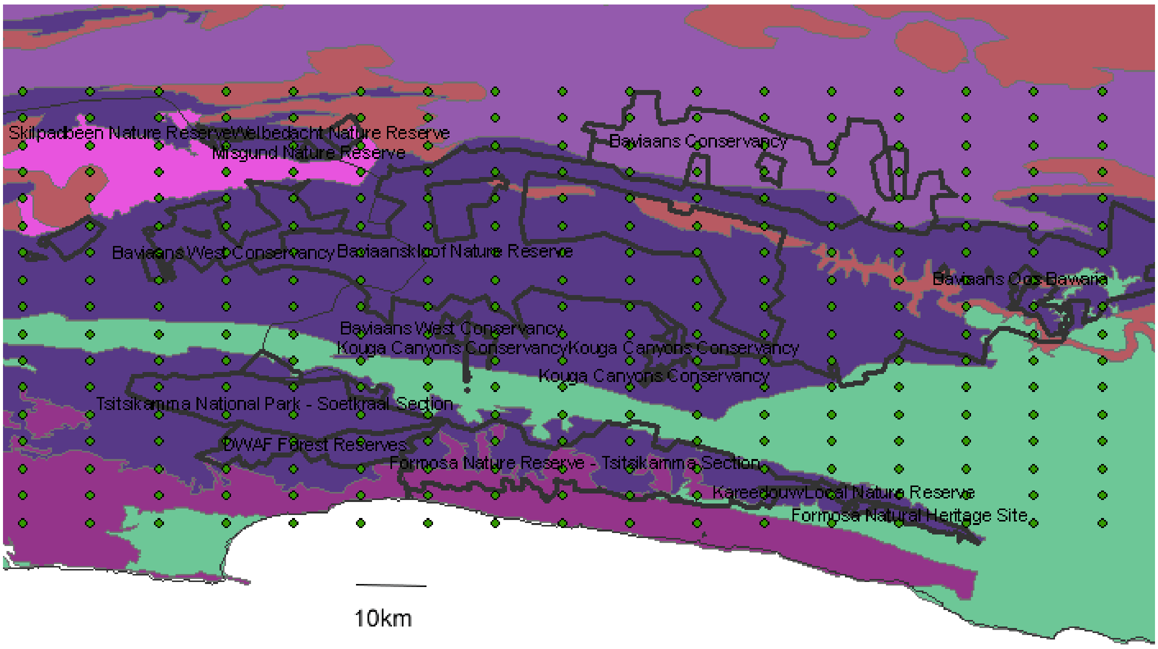

Figure 2: A hypothetical sampling array (10km x 4km) for monitoring bird movements across an arid Fynbos gradient. 10km x 0.4km would be more suitable for point counts and groundtruthing is needed. Light purple = Nama Karoo, dark purple = Montane Fynbos and Renosterveld, red = Albany thickets, pink = Succulent Karoo, green = Lowland Fynbos and Renosterveld.

The following data will be recorded for each ringing site: vegetation height, estimated biomass, plant species composition. The following data will be collected on each visit: proportion of plants in flower per species, proportion of seed set per flower per species.

Based on very large captures of immature birds at the exploratory site (Blue Hill) it is additionally envisaged that this study will provide some of the first data on juvenile survivorship rates – which has yet to be quantified for Cape Sugarbirds (Altwegg and Underhill 2006), and presumably the other Fynbos endemic bird species.

In addition, AL is currently exploring the possibility of using low cost radio frequency identification devices as this technology is now of convenient size for passerine studies and Radio frequency identification (RFI) devices are becoming increasingly affordable (Bridge and Bonter 2011). RFI devices can be used to implement automated bird-monitoring systems. The tags on the birds are modified rings. An application of this would be visitation rates to flowering proteas, requiring an array of RFIDs. Successful trials of these devices would allow instruments to be deployed in a range of protea stands at netting sites to determine presence at selected sites as well as movement between sites. There are however several outstanding questions at this stage, including the detection distance of RFIDs.

4. Using patterns of bird dispersion and abundance along aridity and altitudinal gradients to provide insight into how these patterns might change under the predicted influences of climate change.

Patterns of bird presence at a spatial and temporal scale in relation to altitude, longitude and latitude will be undertaken using generalised linear models. Determinants of these variables on each bird species presence can be calculated.

5. Based on patterns established above, what are the estimated population sizes of mountain Fynbos endemics now and under future climate-change scenarios.

Several climate model envelopes are available for incorporation of these data courtesy of Brian Huntley and the Leverhulme group (Huntley et al. 2011). However, independent analysis would also be possible using predictions using MAXENT software (Phillips 2005, Hijmans and Graham 2006), using current and future climate models. This modelling program uses ‘presence only’ data. As such there would be the need to develop a relationship between probability of occurrence and densities as determined from point count data. A variety of GIS climate related data sets can be used to refine this model e.g. (Hijmans and Graham 2006).

6. How well would these results have been predicted using South African Bird Atlas Project (SABAP and SABAP2) data?

Predictors of reporting rate can be conducted using Occupancy modelling (MacKenzie et al. 2003). Predictors can include, but are not limited to: density, site accessibility, season, life-history traits, fragment sizes, climate and land-use change. It may be possible to model future distributions based on a variety of rainfall change data as predicted by current climate change models (building on (Huntley et al. 2011)). Use this information to identify priority areas for the protection of Fynbos endemic birds and other birds of the Fynbos suite that may suffer range contractions as a result of climate change. Information may also be used to implement mitigation strategies if appropriate (objective 4).

Timeline overview

An approximate timeline for the initial two-year period is available in Appendix 2. December 2011 and January 2012 will be used to obtain research permits for Baviaanskloof Wilderness area (Eastern Cape Parks); Grootvadersbosh, Boland, Cedarberg, Kammanassie, Outeniqua and Swartberg Nature Reserves (Cape Nature); explore and set up transect lines; obtain GIS maps and data in order to determine acceptable spatial coverage of sampling in relation to key variables. Point counts will take place for a 3 month period commencing in February. An exact timeline of when particular nature reserves will be visited cannot be given due to the extent of this survey, which will be impacted by whether, transport and various other issues. However, all Reserve Managers will be advised of researcher arrival as soon as possible.

May and June will be used to establish baseline monitoring and mist netting at sites in the Baviaanskloof, Kammanassie, Kouga and Fomosa/Outeniqua mountains and associated Nature Reserves. RFIDs will be evaluated. This provides baseline data for bird movements, abundance, ecology and dispersal which will be the focus of bimonthly surveys conducted during 2013.

June / July will be a period of analysis and report writing, given weather conditions make this the most suitable time period to conduct these.

Second point count survey will commence from July, until October. November and December will be used to analyse data and work on publications.

2013 - mist netting will take place for a one year minimum period, rotating through sites in conjunction with surveys across aridity gradients from the Outeniqua to Swartberg/Baviaanskloof mountain ranges.

Publication schedule – analysis will be ongoing, culminating in a funder report after 12 months and at least one manuscript in preparation by 18 months. Project summary findings, directions for future research, and at least two publications should be ready after the two year period. It is envisaged that this will be an ongoing project.

Budget overview

Equipment	R	#	Totals
Rucksack	1000	1	1000
Tent	1400	1	1400
Sleeping Bag	2400	1	2400
Rucksack Cover	400	1	400
Thermal liner	600	1	600
Solar power battery recharger	2000	1	2000
Waterproof bags	100	2	200
Maps	500	1	500
Carrier bag	1000	1	1000
Rangefinder (see link)	3000	1	3000
1 Handheld Refractometer (Eclipse IP65)	1200	1	1200
Digital micro-sd cards (for recording point counts)	60	2	120
Rechargeable AA batteries	150	4	600
Mist Nets	500	6	3000
GPS	3000	1	3000
			0
Consumables			0
Aluminium tags, cable ties, tape, string, pegs	1000	1	1000
SAFRING rings	1	1000	1000
Batteries(recorder, rangefinder)	50	10	500
Petrol – 2012 @R3 per km, 2000km per survey x2	6000	2	12000
Petrol – ongoing access to local sites	200	12	2400
Accommodation (R150 x 80 x2)	12000	2	24000
Subtotal			61320
10% contingency			6132
Total			**67452**
Total allocated (as of Dec 2011)			**30 000**
Shortfall/Surplus			-37 452

Acknowledgements

I would like to thank Phoebe Barnard for comments, the many forms of support, and her faith in me. Thank you Phil Hockey for constructive comments leading to the current research direction of this proposal. Thanks to Rob Simmons for the loan of the Kestrel recording device. Thanks to Graham Grieve, Neil Thompson, Dieter Oschadleus and Mike Ford for bird ringing training. Thanks to Chris, Elaine and Anja Lee for logistical support.

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Date:		Observer:				Lat:	
Start time:		End time:				Long:	
Cloud cove %		Mist/Fog: m				Alt:	
Wind:		Temp:				Sunrise:	
Aspect:		Rock: %			Slope:		
Ridge Slope Valley Ravine Stream/River Wetland							
Granite Shale Quartzite Sandstone Limestone Conglomerate							
Playback?		Recorded?			Start:		
Time	Species	S/H	P/F	m	#	Demog.	Behaviour
Arachnids	Flies/Bees	Lepids	Larvae	Bugs	Ants	Beetles	GH/Crickets
Grassy; Asteraceous; Restioid; Ericaceous; Proteiod; Closed Scrub							
	% 30m	Buds	Flower	Seed	x Height		
Bird Protea:							
Other Protea:							
Bird Erica:							
Other Erica							
Restios							
	%	Flower		%	Flower		
Aspalathus			Lycium				
Pelargonium			red bulb				
Agathosma			Aloe				
Phylica			Trees				
Agapanthus			Acacia				
Leonotus			Pinus				
Psoralea			Hakea				

Other:

Appendix 2: Timeline of activities

Timeline

	2011	2012												2013									
Activity	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Registration	X	X																					
GIS coverage testing	X																						
Permit application	X																						
Fynbos survey			X	X	X			X	X	X													
Transect prep						X	X																
Xeric Transect survey								X			X	X	X	X	X	X	X	X	X	X	X	X	
Ringing	X	X				X	X				X	X	X	X	X	X	X	X	X	X		X	
Report								X												X			
Publication prep								X			X	X	X							X	X		