**BDC334 Prof AJ Smit Class Test 1, Term 3, 2025**

**1.** **Species tables** list which species are present (and often their abundances) in different locations. **Environmental tables** describe the conditions in those locations (e.g., temperature, habitat type, nutrient levels).

Explain clearly and simply why having both types of tables is valuable in ecological research. Describe what **kinds of analyses** and **insights** they make possible, and **what kinds of patterns or relationships** you might discover from them. Write your answer as if you were explaining it to an interested non-scientist with no background in ecology. [**20 marks**]

**Answer**

**Model Answer (20 marks) – A % is assigned**

The value of having both **species tables** (sites × species, often with abundances) and **environmental tables** (sites × environmental variables) lies in their ability to take an ecological study from raw description toward explanation and prediction. Separately, species data allow us to document presence, absence, and relative dominance, while environmental data provide measurements of the abiotic and habitat conditions. Brought together, they allow the formal comparison, quantification of diversity, analysis of gradients, and testing of competing theories (more correctly, hypotheses) of community assembly.

**Diversity Framework**

Species tables allow the computation of classical diversity partitions:

* **Alpha diversity (α)**: the diversity within a single site, summarised with univariate indices such as **species richness**, **Shannon’s H′**, **Simpson’s D**, and **Pielou’s J** for evenness. These indices are sensitive to richness and evenness in different ways, and thus capture different aspects of community structure.
* **Beta diversity (β)**: the turnover (or nestedness-resultant beta diversity) of species between sites, often calculated from dissimilarity matrices that compare all pairs of sites. This highlights how composition shifts across environments or distances.
* **Gamma diversity (γ)**: the total diversity across all sites combined, which links the local and between-site scales.

This three forms of diversity measures allow us to move from the question “how diverse is this site?” toward “how does diversity change across space and environment?”

**Matrices: Dissimilarity and Distance**

The two tables are transformed into pairwise matrices that become the analytical core:

* From the **species table** we compute **dissimilarity matrices** (e.g., **Jaccard**, **Sørensen**, **Bray–Curtis**). These quantify how composition differs between each pair of sites, based on either presence–absence or abundance.
* From the **environmental table** we compute **distance matrices** (commonly Euclidean on standardised variables, or other metrics if appropriate). These quantify how dissimilar the abiotic settings are across sites.

This parallel structure (*i.e.*, the matrices share the same number of rows, *i.e.*, sites) allows direct comparison of biological and environmental spaces: if sites that are environmentally similar also have similar communities, one infers an environmentally driven structuring (*i.e.*, the niche differentiation model, which is when species are sorted along gradients).

**Analytical Patterns and Curves**

A set of canonical patterns and statistical tools can be derived once both tables are present:

* **Species Abundance Distributions (SADs):** show how commonness and rarity are apportioned. They test against theoretical distributions (log-normal, geometric, broken-stick) and allow comparison across sites. Typically, communities are represented by one or two very dominant species, while the rest are less dominant but mostly scarce.
* **Occupancy–Abundance Curves:** reveal the relationship between how widespread a species is across sites and how abundant it is where present, with implications for metapopulation and niche theory.
* **Species–Area Curves:** plot richness as a function of area sampled, derived from cumulative species data across sites. They are fundamental to scaling laws and conservation planning.
* **Rarefaction Curves:** standardise richness comparisons by sample size, allowing comparison of communities with different sampling efforts.
* **Distance–Decay Curves:** show how species similarity declines as spatial or environmental distance increases, thus quantifying turnover and linking β-diversity to gradients of space or condition.
* **Elevation Gradients:** a variation of environmental gradient analysis, illustrating how richness and composition vary with altitude, often yielding unimodal (“hump-shaped”) richness patterns.

These curves provide evidence not only for description but also for discriminating among competing theories.

**Insights from Gradients and Discontinuities**

Species often respond unimodally to environmental gradients, with each taxon showing an optimum and declining abundance away from it. Across multiple species this yields coherent turnover, observable in distance–decay analyses. Patterns can be continuous (gradual replacement) or discontinuous (sharp faunal breaks at thresholds). Both kinds of structure are central to biogeography.

**Linking to Theories**

* **Niche theory** predicts strong correspondence between environmental gradients and community composition, because species are filtered by their physiological and ecological tolerances.
* **Neutral theory**, by contrast, downplays environmental filtering and emphasises stochastic processes, dispersal limitation, and demographic drift. Analyses of the degree to which species–environment associations outperform null (randomised) expectations provide tests of these theoretical perspectives.

Species–environment matrices thus create the empirical basis for adjudicating between these models of community assembly.

**Correlations and Associations**

* **Environmental tables** allow computation of **pairwise correlations** among variables (*e.g.*, whether temperature and nutrient concentrations covary), clarifying structure in the abiotic template.
* **Species tables** allow assessment of **associations among taxa** (*e.g.*, co-occurrence analyses), revealing potential interactions or shared habitat preferences.

These internal structures enrich the interpretability of cross-table comparisons.

**2.** Imagine you are studying a clear **biogeographic break** in species composition across a region in South Africa.

a) Define this region and explain aspects such as its **spatial extent**, **landscape features**, and **ecological properties**.

b) Describe how you would use the concepts of **α**, **β**, and **γ diversity** to quantify changes in community structure along this gradient. Define each diversity level in the context of your chosen system.

c) Explain how principles such as **distance decay** and species’ **unimodal responses** to environmental variables could lead to high **species turnover** (β diversity) across the gradient. [**30 marks**]

**Model answer (30 marks) — terrestrial example**

Below is an idealised model answer. Please note that students might not have the necessary in-depth understanding or experience of the South African landscape, so please permit answers built around more hypothetical landscapes, plausible within the climatic conditions and climatic gradients across the country. Permit deviations away from the correct list of species and exact description of environmental conditions present and so on. Rather focus on an answer that’s built around a plausible set of communities, an ecosystem, a landscape situated in South Africa within a real climatic gradient that provides opportunities for finding gradients and discontinuities across that landscape, and emphasise that the methods and study development are correctly described and designed.

**a) Study region, spatial extent, landscape features, ecological properties**

A clear **terrestrial biogeographic break** in South Africa occurs across the **Mpumalanga/Limpopo Drakensberg Escarpment**, where **Highveld grassland** on the cool, fire- and frost-prone plateau gives way downslope to **Lowveld savanna**—warmer, more seasonal, and increasingly woody. I would delineate a study transect that runs **~150–250 km along the escarpment** (*e.g.*, from the Long Tom Pass area northwards toward the Blyde River Canyon), and that spans an **elevation drop of ~1,500 m** (≈2,000 m a.s.l. to ≈500 m a.s.l.).

**Key features to justify this choice**

* **Spatial extent & sampling frame:** Divide the escarpment into **contiguous 10–20 km bands** along the slope, and within each band place **replicate vegetation plots** (*e.g.*, 20×20 m for woody plants; nested subplots for herbs/graminoids) on comparable slope positions/aspects.
* **Landscape & substrates:** Dissected escarpment topography with quartzitic and basaltic formations; soils vary from shallow, rocky, acidic uplands to deeper, more fertile colluvial soils downslope.
* **Ecological template:** Strong gradients in **temperature (fewer frost days downslope)**, **water balance**, **fire regime** (shorter return intervals and more intense fires on the plateau grasslands), and **woody cover** (tree/shrub encroachment potential increases downslope). These drivers underpin a **community shift** from treeless or sparsely wooded **grassland** to **savanna** (grasses plus scattered trees such as *Vachellia*/*Senegalia*, *Combretum*, *Sclerocarya*).

This escarpment thus provides a **narrow transition** between two regionally coherent terrestrial biotas, ideal for quantifying turnover.

**b) Using α, β and γ diversity to quantify change along the gradient**

**Define the diversity components in this system**

* **α-diversity (local):** Diversity **within a single plot** (or pooled plots within a band). Start with **species richness** and, where abundances/cover exist, add **Shannon/Simpson** and **evenness** to capture dominance structure (*e.g.*, grass dominance vs. mixed understory).
* **γ-diversity (regional):** The **total set of species** recorded **across the entire escarpment transect** (all bands combined). Report γ for: (i) the full transect; and (ii) the two flanking “zones” (plateau grassland *vs*. lowland savanna) to illustrate how the transition contributes to regional pools.
* **β-diversity (between-site differentiation):** **Change in composition among plots/bands** along the escarpment. Compute **pairwise dissimilarities** using **Jaccard** (presence–absence) and **Bray–Curtis** (cover/abundance). Where possible, **partition β into turnover *vs*. nestedness** to diagnose **species replacement** *vs*. simple richness loss/gain along the slope.

**Operational workflow (BDC334 methods)**

1. **Standardise the environmental table** (elevation, minimum temperature/frost days, rainfall/water balance, soil texture/chemistry, fire return interval) to comparable scales.
2. **Compute α** for each plot/band; plot **α *vs*. position** along the gradient (distance or elevation). Expect α to vary with fire, frost, and woody cover.
3. **Compute γ** for the full transect and for each side of the break; compare to show how the transition zone influences regional diversity.
4. **Compute β** in two complementary ways:
   * **Serial β** between **adjacent bands** (β\_{i,i+1}) to locate **where turnover peaks** (the “break”).
   * **All-pair β** among bands; visualise with **ordination or clustering** to test for two groups (grassland vs. savanna) with a narrow mixing zone.
5. **Partition β** (turnover *vs*. nestedness) to test whether the escarpment is a **replacement boundary** (grassland taxa replaced by savanna taxa) rather than a simple richness gradient.
6. **Link composition to environment**: regress **compositional dissimilarity** against **geographic distance** (coastline analogue = along-slope distance) and **environmental distance** (from the standardised environmental table) to separate **spatial** from **environmental filtering** effects.

**c) Why distance decay and unimodal responses yield high β across the escarpment**

**Distance–decay of similarity.** Along the escarpment, **taxonomic similarity declines with increasing along-transect distance** because:

* **Environments co-vary with distance** (systematic shifts in frost regime, temperature minima, soil depth/fertility, fire frequency/intensity).
* **Dispersal/connectivity constraints** and **landscape roughness** limit shared species pools across the break.

Plot **similarity *vs*. geographic distance** (or *vs*. environmental distance) and fit a decay model; expect a **steeper slope across the break** than within either zone, signalling **heightened β-diversity** where grassland gives way to savanna.

**Unimodal species responses to environmental variables.** Most species show a **single performance optimum** along key gradients:

* **Frost/temperature minima:** Frost-sensitive woody species peak **downslope**; frost-tolerant grasses/forbs peak **upslope**.
* **Fire regime:** Fire-avoiding or resprouting woody species peak where **fire intervals lengthen**; fire-tolerant graminoids peak where **fires are frequent**.
* **Soils/water balance:** Species tied to **deeper, more mesic soils** peak downslope; **shallow, rocky soils** favour different grass/forb assemblages upslope.

Superimposing many such **unimodal curves** across the same gradient produces **rapid species replacement** (high **turnover β**) over a relatively short spatial span. Where **environmental thresholds** are crossed (*e.g*., a frost line, a fire-regime shift, a soil transition), turnover can be especially sharp, consistent with a **biogeographic break** rather than a gradual fade.

**Indicative marking guide (30 marks)**

* **(a) Region & properties (10 marks):** clear boundary and extent; topography/substrates; key environmental gradients; plausible community contrast; defensible sampling frame.
* **(b) α/β/γ framework (12 marks):** correct, contextual definitions; appropriate indices; serial vs. all-pair β; turnover/nestedness partitioning; coherent analysis workflow.
* **(c) Mechanisms (8 marks):** correct distance–decay reasoning; clear, mechanistic unimodal responses tied to named variables; link back to observed high β at the break.

**3.** A seabird follows the seasons by instinct; a human follows them with satellites, spreadsheets, and climate models. Does our reliance on abstract representations of nature, which no other animal has ever conceived, give us a **deeper mastery** over it or merely a more **profound illusion** of control? [**20 marks**]