NATIONAL SENIOR CERTIFICATE EXAMINATION
NOVEMBER 2025

LIFE SCIENCES: PAPER II

SOURCE MATERIAL BOOKLET FOR QUESTIONS 1, 2 AND 3

SECTION A

QUESTION 1

Read the information below. Use this information and your own knowledge to answer Question 1 in the question paper.

NURTURING NATURE: STRATEGIES FOR RESTORING ECOSYSTEMS AND IMPROVING AGRICULTURE

1. Principles

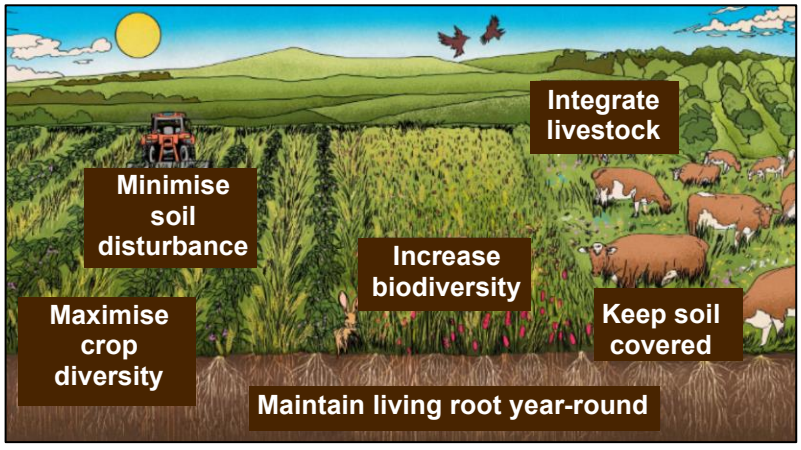
South Africa faces the urgent challenge of balancing food production, biodiversity conservation, and climate resilience. Of the country's 122 million hectares, 84,8 million hectares are classified as agricultural land, yet only 13,8 million hectares were under cultivation in 2020 (Table 1.1). This cultivated land includes field crops, planted pastures, fruit orchards, and subsistence farming. South Africa's agricultural contribution to the Gross Domestic Product has declined from 23% in 1920 to 2,62% in 2023, despite 6 million people relying on farming for their livelihoods.

Table 1.1: Area and percentage land cover categories for South Africa

Land cover category	Area (hectares-millions)	Percentage (%)
Natural or semi-natural areas	84,03	68,83
Mines	0,30	0,25
Agriculture	13,83	11,32
Barren	12,47	10,21
Eroded	0,43	0,35
Fallow land/old fields	3,72	3,05
Timber plantation	2,06	1,69
Built-up areas	3,40	2,79
Roads and rails	0,14	0,11
Waterbodies	1,70	1,39
Total	**122,08**	**100,00**

Global agriculture is increasingly focused on food systems that support biodiversity, sustain livelihoods, and reduce environmental impacts. Allowing wildlife to return to abandoned agricultural lands helps conserve what remains, boosts biodiversity, and strengthens ecosystem resilience (the ability of natural systems to recover and adapt to change). Nature-based farming further supports this by integrating ecological principles into agriculture, emphasising soil health, water conservation, and biodiversity. Together, these approaches offer a transformative path for South Africa, balancing food security with ecological sustainability.

Figure 1.1: Principles of nature-based farming

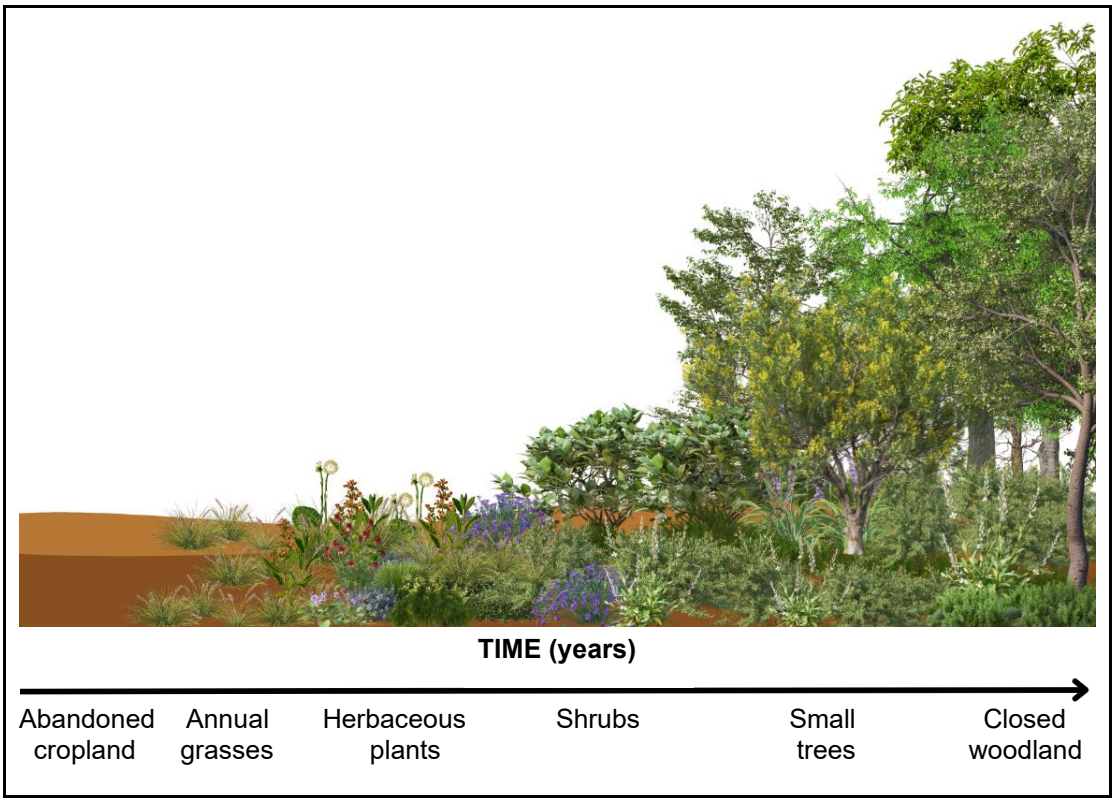


[Adapted from: Dempsey B, 2023. Bridging the divide: rewilding, farming and the triple challenge. WWF-UK, Woking; and Table 1.1; statistics adapted from: <https://www.statista.com>; Figure 1.1 adapted from: <wildfarmed.com>]

2. Natural processes drive ecological succession

When abandoned farmland is left to recover naturally, it follows a predictable sequence of species colonisation (Figure 1.2):

Figure 1.2: Sequence of plant colonisation on abandoned cropland through ecological succession



Natural recovery-driven succession encourages soil formation, improves fertility, and increases organic matter accumulation, creating a more resilient ecosystem, i.e. one that can withstand and recover from disturbances while still maintaining its essential structures, functions and biodiversity. As plant diversity increases, it stabilises the soil, preventing erosion and improving water retention, which is particularly beneficial in drought-prone areas. This process also improves habitat complexity, supporting greater biodiversity from microorganisms to larger herbivores, which in turn strengthens ecosystem balance. In degraded lands in the Eastern Cape, the return of indigenous shrubs and small trees has been observed within years of natural recovery efforts. Farmland left to recover naturally has been shown to store significantly more carbon than conventionally farmed land, contributing to climate change reduction.

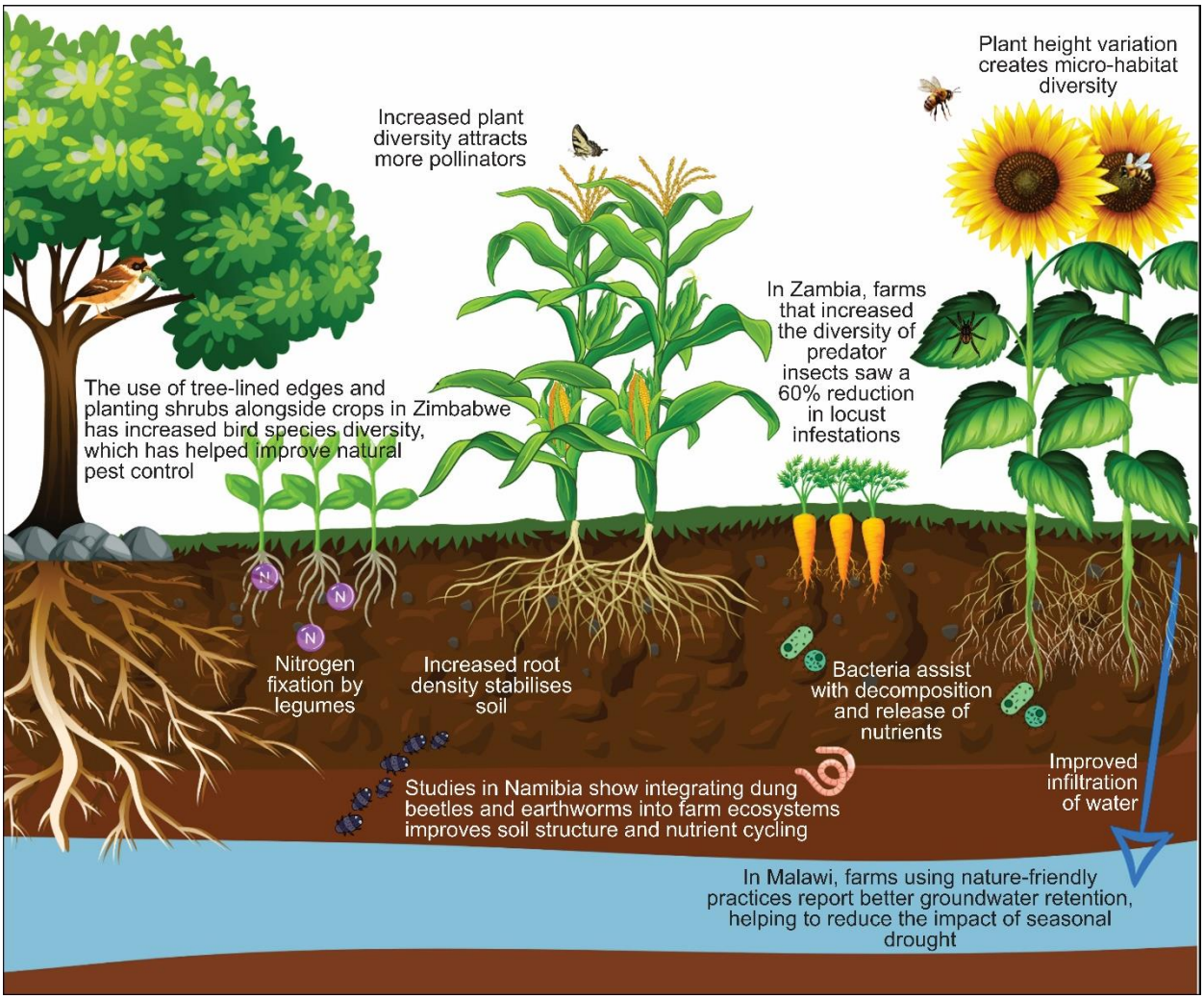
[Adapted from: Wang L et al., 2023. Rewilding abandoned farmland has greater sustainability benefits than afforestation. *npj Biodiversity* 2:5; Figure 1.2 – Examiner's own]

3. Effect of nature-based farming on ecosystem dynamics

Different rooting depths

Unlike monocultures, which compete heavily for water and nutrients at a single soil depth, nature-based farming encourages the planting of mixed species, which allows for different species to access different soil layers (Figure 1.3). For example, deep-rooted trees and shrubs can draw water and nutrients from deeper soil layers, while grasses and cover crops utilise surface moisture. Studies show that diverse plant communities with varying root depths improve soil aeration and carbon storage. In South Africa's Overberg region, integrating deep-rooted legumes with shallow-rooted grasses has improved drought resilience on farms that focus on nature-based practices.

Figure 1.3: Diagram showing the effect of different rooting depths on soil structure and ecosystem health

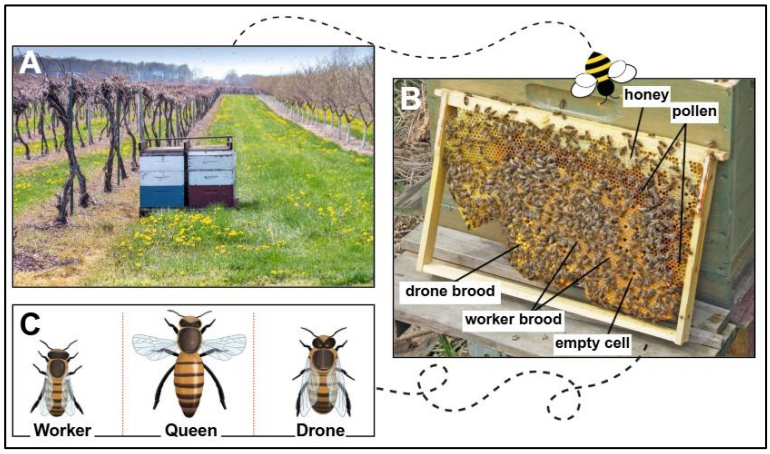


[Adapted from: Fraanje W & Garnett T, 2022. Rewilding and its implications for agriculture. TABLE Explainer Series. TABLE, University of Oxford, Swedish University of Agricultural Sciences & Wageningen University & Research; and Christianah D et al., 2024. The role of biodiversity in agricultural resilience: Protecting ecosystem services for sustainable food production. *International Journal of Research Publications and Reviews* 5(10): 1560–1573, and <crs.org/stories/farmers-restore-soil-malawi?>; and Badenhorst J et al., 2018. Dung beetle activity improves herbaceous plant growth and soil properties on confinements simulating reclaimed mined land in South Africa. *Applied Soil Ecology* 132: 53–59; Figure 1.3 – Examiner's own design]

Pollinator reintroductions

Farmers in South Africa are recognising the crucial role of honeybees in maintaining food security. Indigenous honeybee species contribute significantly to crop pollination and biodiversity preservation. Habitat destruction, pesticide use, and climate change threaten the populations of these pollinators. Increasing the density of insect visitors, such as bees, to flowers can increase crop yields, highlighting the importance of pollinator-friendly farming. With approximately 50 crops in South Africa dependent on insect pollination, the reintroduction of beehives (Figure 1.4) into nature-based farms not only supports honeybee populations but also boosts crop productivity and provides farmers with an additional income source through honey production.

Figure 1.4: A Beehives between grapevines in the Western Cape; **B** inside a beehive, showing the positions of the different broods; and **C** the different bee roles within a colony

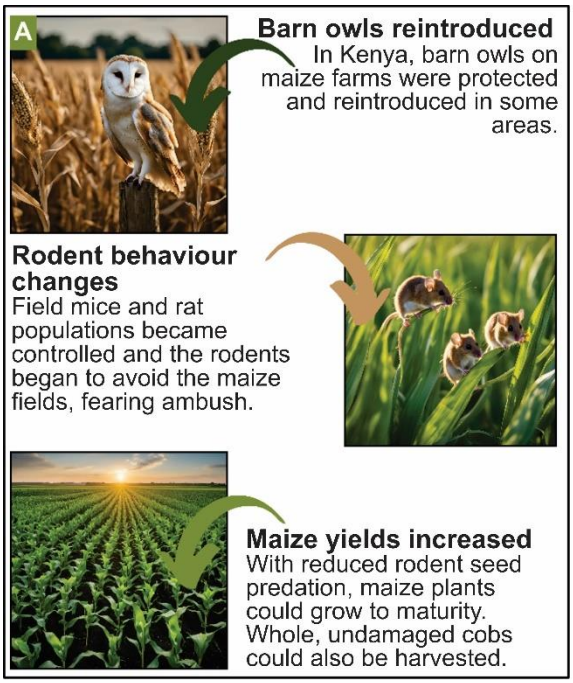


[Adapted from: Thomas V et al., 2022. Domesticating rewilding: combining rewilding and agriculture offers environmental and human benefits. In: Bruce E and Bruce A (eds). Transforming food systems: Ethics, innovation and responsibility. EurSafe. © Wageningen Academic Publishers] and [Figure 1.4: **A** – image source: <wineenthusiast.com>; **B** – image source: <honeybeesuite.com>; **C** – image source: <reviveabee.com>]

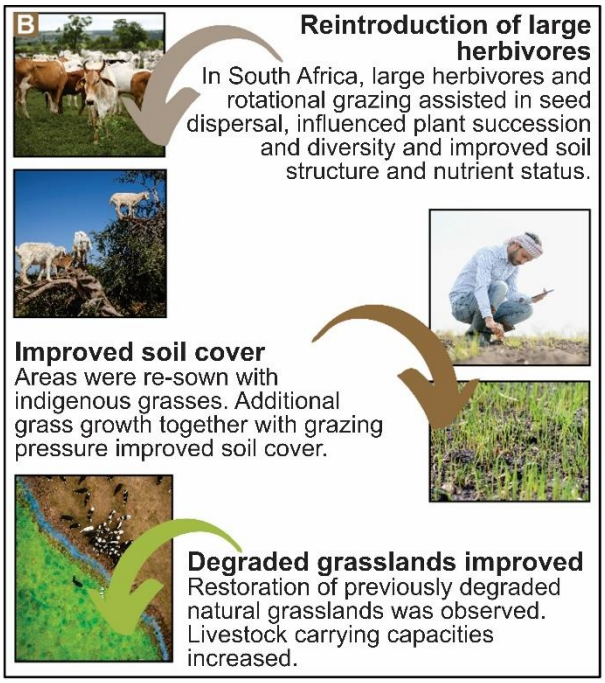
Ecological knock-on effects

Figure 1.5: Examples of knock-on effects in ecosystems from nature-friendly farming practices

A Predator reintroduction



B Large, diverse herbivore reintroductions



[Adapted from: **A** Ojwang DO and Oguge NO, 2003. Testing a biological control program for rodent management in a maize cropping system in Kenya. Pages 251–253 in Singleton GR et al., (eds). Rats, mice and people: rodent biology and management. Australian Centre for International Agricultural Research, Canberra, ACT, Australia; and **B** Treydte AC et al., 2021. Rangeland management in a changing world – active and passive restoration case studies from Ethiopia, Tanzania, and South Africa. XXIV International Grassland Congress Proceedings. [Images sourced from: <google.images.com>, generated with Canva Magic Media]

QUESTION 2

Read the information below. Use this information and your own knowledge to answer Question 2 in the question paper.

HUMAN EXPANSION THREATENS WEST AFRICAN LION'S PREY

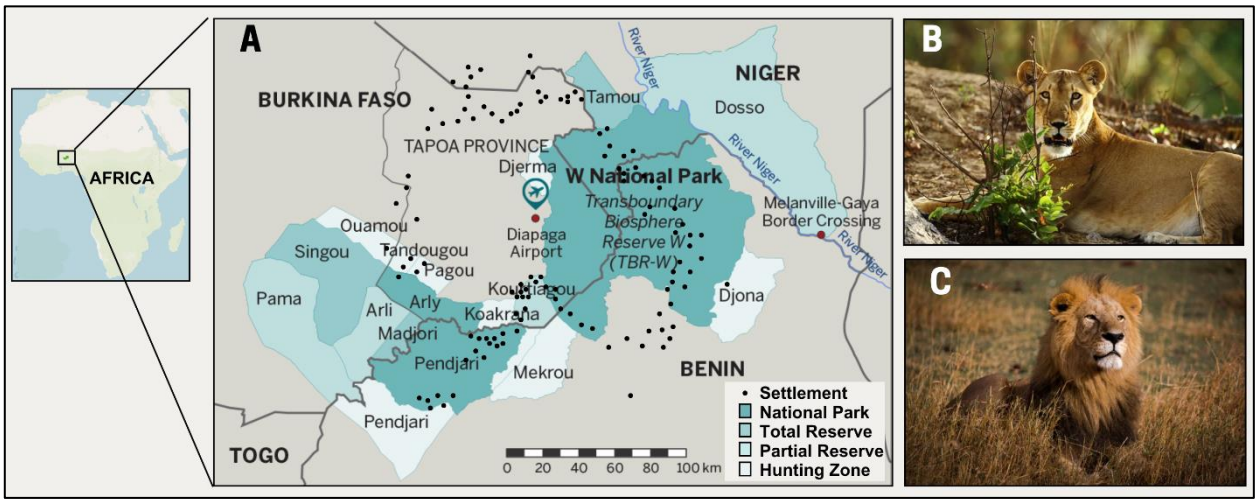
1. The state of the West African lion

The W-Arly-Pendjari (WAP) Complex spans over 30 000 km² across Benin, Burkina Faso, and Niger. This transfrontier park consists of interconnected national parks and biosphere reserves, making it a key conservation zone in West Africa. The ecological health of the complex, however, is threatened by illegal land occupation and habitat fragmentation.

TRANSFRONTIER PARKS

A transfrontier park is a conservation area that spans the borders of two or more countries, allowing wildlife to move freely across national boundaries. They promote biodiversity conservation, sustainable land use, and cooperation between nations in managing shared natural resources.

Figure 2.1: A Location of the W-Arly-Pendjari (WAP) complex in Africa, and the member national parks, hunting concessions, and reserve boundaries, together with the percentage of the Complex that spans across each of the three member West African countries; **B** Female West African lioness; **C** Male West African lion



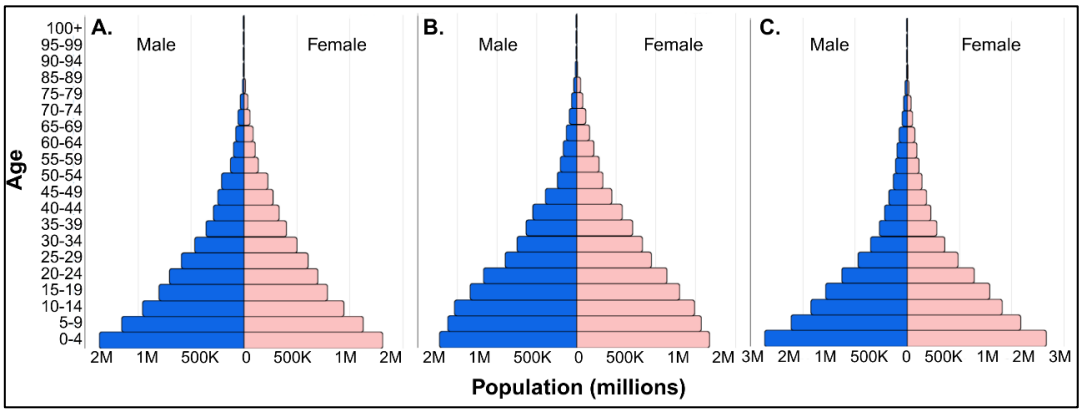
As the largest remaining habitat for the critically endangered West African lion (Figures 2.1 B & C), WAP harbours nearly 90% of the region's remaining population, currently estimated at just 350 individuals. Genetic research has confirmed that these lions belong to the *Panthera leo leo* lineage, making them more closely related to the Asiatic lion than their counterparts in East and Southern Africa. This distinct evolutionary lineage, combined with their small and fragmented population, makes the conservation of WAP's lions particularly urgent. Regular monitoring has revealed that their numbers remain far below the ecosystem's carrying capacity, due to habitat loss, prey depletion and increased human activity. Climate change has further worsened these pressures by reducing water availability, particularly during the dry season.

[Adapted from: Henschel P et al., 2016. Determinants of distribution patterns & management needs in a critically endangered lion population. *Front. Ecol. Evol.* 4:110; and World Heritage Nomination – IUCN Technical Evaluation W-Arly-Pendjari Complex, May 2017; and Figure 2.1: **A** [images adapted from: Janssens, I et al., 2022. Conservation conflict following a management shift in Pendjari National Park (Benin). *Biological Conservation*, 272], **B** [image taken by Jonas Van de Voorde], **C** [image source: <thecable.ng>]

2. Growing human populations in Benin, Burkina Faso and Niger

Benin (14,7 million), Burkina Faso (23,5 million), and Niger (26,3 million) face rapid population growth, driven by high fertility rates, with over 60% of their populations under the age of 25 (Figure 2.2). Economic opportunities are limited, and unemployment is widespread, especially in Burkina Faso, where literacy is just 33%. Agriculture dominates all three economies, employing a significant portion of the workforce – 42,7% in Benin. Agricultural land use faces continual struggles with poor soil management, overgrazing, and droughts, particularly in Niger. Extreme poverty increases reliance on natural resources and wildlife areas, leading to deforestation, desertification, and habitat loss.

Figure 2.2: Population pyramids for **A.** Benin; **B.** Burkina Faso, and; **C.** Niger for 2025



[Adapted from: Engel E et al., 2017. Benin: Towards inclusive and sustainable rural transformation. SLE Discussion Paper 02/2017-en. Humboldt-Universität ZU, Berlin; Figure 2.2 adapted from: <census.gov>]

3. Human-wildlife conflict in the WAP complex

The expansion of croplands has progressively pushed pastoralists (people who raise and herd livestock as a primary means of livelihood) northward in search of grazing land for their herds. As traditional grazing lands shrink, livestock overstocking degrades the remaining pastures, increasing conflicts between herders and conventional farmers. This displacement has intensified human reliance on the WAP complex.

Figure 2.3: Temporary settlement of pastoralist herd in Burkina Faso

The main sources of human-lion conflict:

- **Livestock encroachment and resource competition** – Seasonal cattle migration into the WAP Complex disrupts wildlife corridors, competes with lion prey animals, and increases disease transmission to lions. Illegal grazing has quadrupled since 2003.
- **Retaliatory killings and poisoning** – Lions preying on livestock lead to retaliatory poisonings and hunting, especially by pastoralists deep in WAP during the dry season.
- **Poaching and prey depletion** – Poverty drives illegal hunting for food and income, reducing wild prey for lions. Some lions are poached for traditional medicine.
- **Habitat loss and fragmentation** – Agriculture, overgrazing and deforestation shrink lion habitats, increasing human-lion conflicts.

[Adapted from: Amahowé IO et al., 2013. Transboundary protected areas management: Experiences from W-Arly-Pendjari Parks in West Africa. *Parks* 19.2; and Bouché P et al., 2016. Embargo on Lion Hunting Trophies from West Africa: An Effective Measure or a Threat to Lion Conservation? PLoS ONE 11(5): e0155763, Figure 2.3 – © Robert Ford via iStockPictures]

4. Social organisation of lion prides

Lions are the only truly social cats, living in prides composed of related lionesses, their cubs, and a coalition of one or more males (Figure 2.4). A male coalition is a group of two or more male lions that form a close alliance to increase their chances of securing and maintaining control over a pride. Lions reproduce sexually, producing fertile offspring. Larger prides hold better-quality territories, leading to higher reproductive success and lower mortality. Lionesses cooperate in hunting and communal cub-rearing, while male coalitions work together to defend their territory, protect cubs, and fend off rival males.

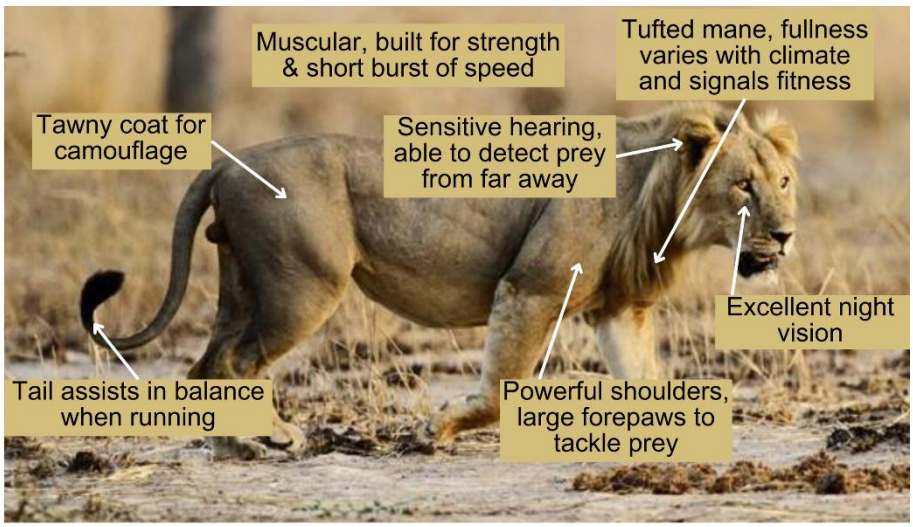
Figure 2.4: Typical lion pride

[Information and Figure 2.4 adapted from: <catsg.org/living-species-lions>]

5. Human-lion-prey interactions

Different wildlife species have developed different patterns of activity during a 24-hour time period (temporal period) to help them survive and stay safe. This has led to the creation of species-specific temporal niches. In general, prey species will often change when they are active to avoid predators, while predators adjust their timing to hunt more successfully and avoid competition with other predators. Lions hunt mostly at night (nocturnal), catching over 95% of their prey in the dark. Their prey species, typically antelope, buffalo, and warthog, are usually more active during the day (diurnal).

Figure 2.5: Physical characteristics of a lion



The fear of humans can change when both lions and their prey are active, causing ripple effects through the food chain. Since humans are most active during the day and lions hunt at night, prey species have fewer chances to avoid lions based on timing alone. In a study to determine the degree to which humans disrupt lions' access to prey species, certain prey species that became more active at night ended up being more likely to encounter lions. Others, like kob antelope and waterbuck, stayed active during the day and had less overlap with lions (Figures 2.6–2.8). This led to fewer prey species being available to lions, which may increase the hunting pressure by lions on a smaller group of animals.

Figure 2.6: Diagram illustrating the temporal niches of lions and their prey

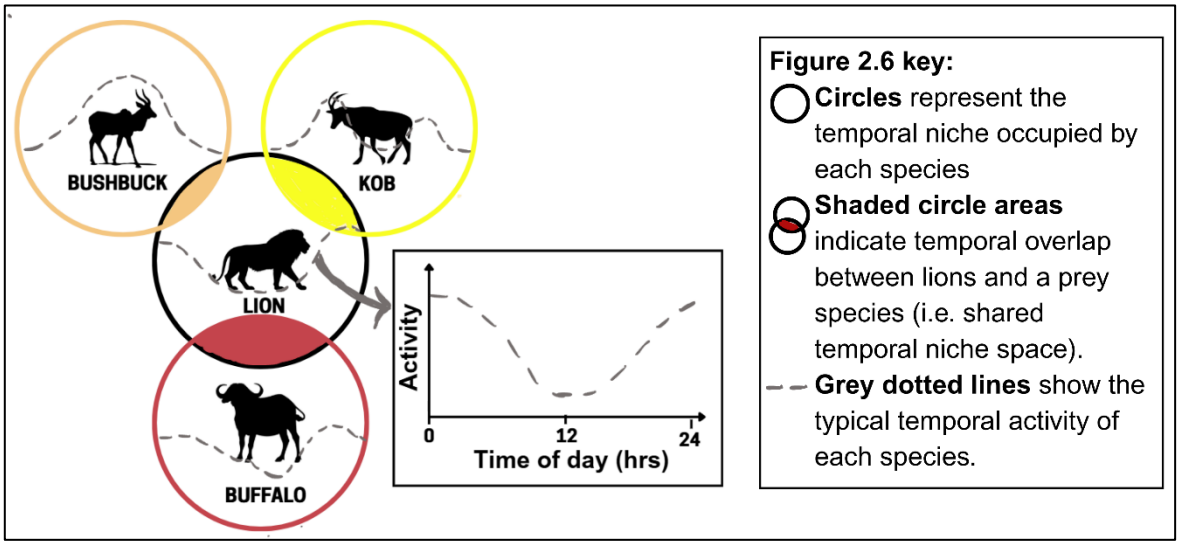


Figure 2.7: Mean differences in prey access for lions between areas of low and high human pressure

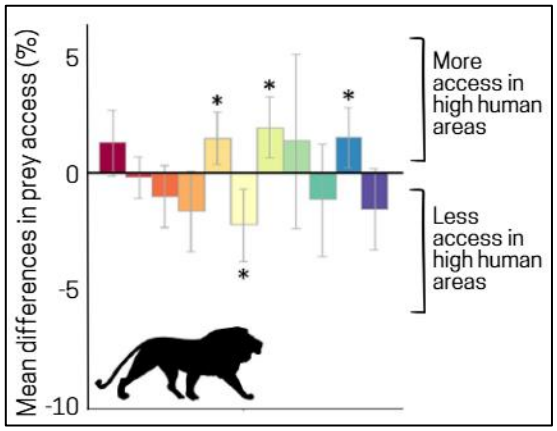


Figure 2.8: Relative contributions (coloured bands) of different prey species to the overall prey available for lions (solid black line) at each time during a 24 hour period [**Note:** the wider the coloured band of a certain prey species at a given time, the greater its potential contribution to the lions' diet]

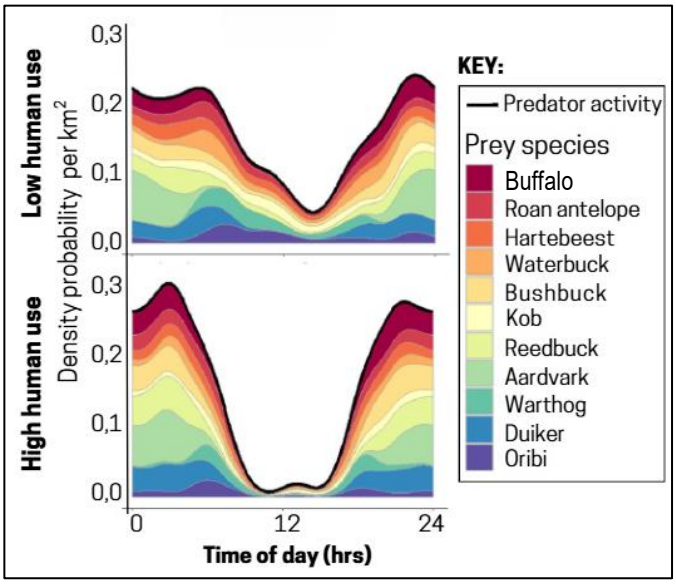
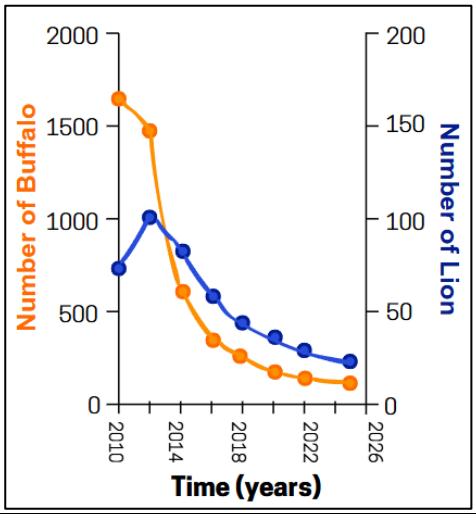


Figure 2.9: Graph of population size of lion and buffalo over time



In areas with a lot of human activity, animals like buffalo may be more at risk of being hunted by lion. These changes can cause key herbivore numbers to decrease, affecting predator survival, which is particularly concerning for endangered species like the West African lion. Human disruption of these predator-prey relationships can have far-reaching effects on how species interact and how ecosystems stay balanced.

[Adapted from: Mills KL and Harris NC, 2020. Humans disrupt access to prey for large African carnivores. *eLife* 9: e60690; and Harris NC, 2019. First camera survey in Burkina Faso and Niger reveals human pressures on mammal communities within the largest protected area complex in West Africa. *Conservation Letters* 12: e12667 and Sogbohossou EA, 2023. Transboundary conservation of large carnivores in West Africa: The case of the WAP complex. In: Houehounha D and Moukala E (eds.), *Managing Transnational UNESCO World Heritage Sites in Africa.* © UNESCO 2023, Figure 2.5 [photo source: <facebook.com/PendjariNationalPark/photos>], Figures 2.6, 2.7, and 2:8 [images adapted from: <Mills & Harris 2020>], Figure 2.9 [image adapted from: <legacy.nimbios.org>]

SECTION B

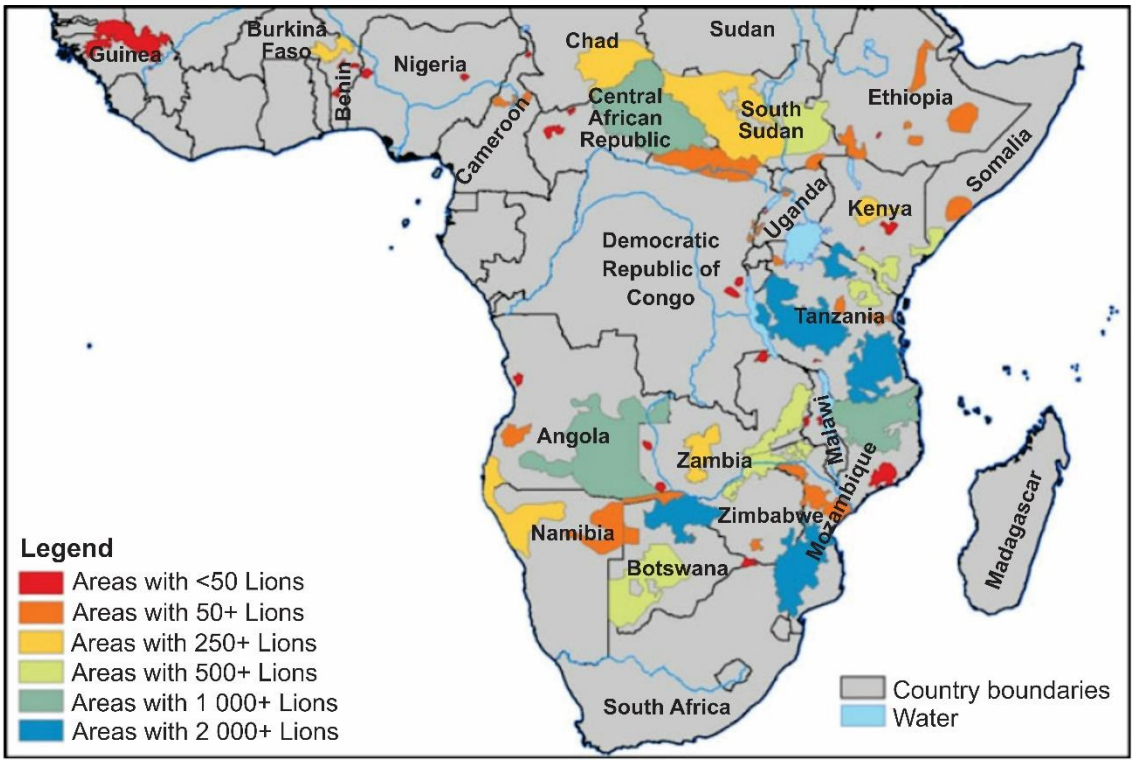
QUESTION 3

Read the information below. Refer to this information and your own knowledge to answer Question 3 in the question paper.

SOURCE A – The conservation status of the African lion

The African lion (*Panthera leo*) has recently emerged as a species of global conservation concern. Recent estimates concluded that lion populations throughout Africa numbered between approximately 20 000 and 40 000 individuals, a steep decline from previous estimates of around 100 000 lions less than a decade ago. The nearly two-fold variation in recent estimates highlights the lack of reliable data regarding the current status of lions across the continent. Currently, only nine countries support at least 1 000 lions, with Tanzania alone holding over 40% of Africa's population (Figure 3.1). Severe fragmentation threatens many populations, and poaching, prey depletion, and human-wildlife conflict continue to undermine stability.

Figure 3.1: Current distribution of lions in Africa, by estimated population size classes



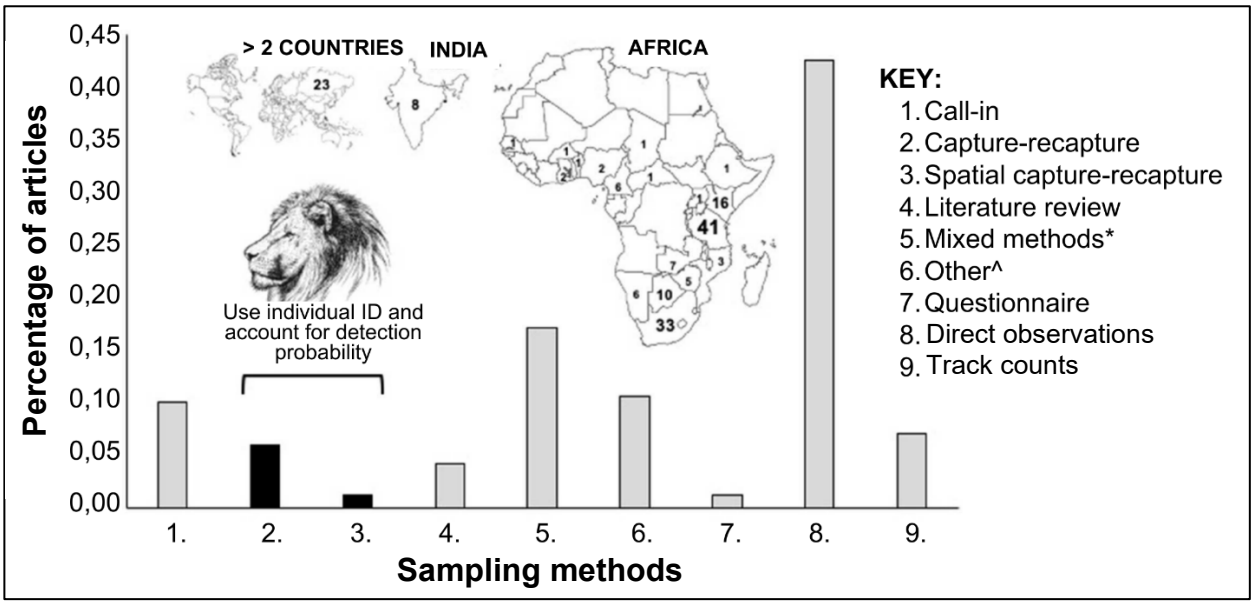
Despite being one of the most studied large predators, lion population estimates remain scarce across much of their range. Reliable data are lacking for several countries, including Angola, Central African Republic, Somalia, South Sudan, and Ethiopia, while thorough and regular surveys are absent in parts of Zambia and Tanzania. Without accurate and precise data, underestimation could lead to the mismanagement of conservation resources, while overestimation could result in insufficient protection for populations in decline. Accurate and reliable population data are essential for effective conservation planning.

[Adapted from: Bauer H et al., 2015. Lion (*Panthera leo*) populations are declining rapidly across Africa, except in intensively managed areas. *PNAS* 112:48; and Braczkowski A et al., 2020. Restoring Africa's Lions: Start with good counts. *Frontiers in Ecology and Evolution* 8:138, Riggio et al., 2016. The size of savannah Africa: a lion's (*Panthera leo*) view. *Biodiversity Conservation* 22:17–35, *PNAS*, *Frontiers in Ecology and Evolution* and *Biodiversity Conservation* all publish peer-reviewed scientific research across fundamental, applied and conservation sciences]

SOURCE B – How credible are the lion estimates?

A variety of sampling methods are used to determine lion population sizes, each with its own set of strengths and limitations (Figure 3.2). Direct methods provide more accurate estimates but are resource-intensive, whereas indirect methods allow for broader coverage but introduce more uncertainty. Many studies rely on expert opinions rather than statistically rigorous surveys, raising concerns about the objectivity of reported numbers.

Figure 3.2: A review of 169 peer-reviewed scientific articles on the determination of lion population size via varying sampling methods. *Mixed methods typically include a combination of track counts, call-ups and/or other methods. ^Other methods range from expert guestimates to a ratio of lions relative to hyenas



There have also been historical challenges with the reliability, precision, and accuracy of lion population estimation sampling methods (Table 3.1). Differences in technique application, particularly in areas with fragmented, isolated populations, make it difficult to compare results across sites and over time. This lack of consistency hampers efforts to accurately monitor population trends.

Table 3.1: Sampling methods used to estimate lion population size. Precision = the percentage of studies that reported how correct their results were; Repeatable = the percentage of studies that could be repeated with similar results.

Method	Number of Studies	Precision (%)	Repeatable (%)
DIRECT METHODS:			
• Call-in surveys	15	93	60
• Capture-recapture	10	70	50
• Camera surveys	4	75	50
INDIRECT METHODS:			
• Est. with nearby data	2	50	50
• Track counts	10	90	40
• Secondary information	8	13	33

[Table and text adapted from: Mwampeta SB et al., 2023. A review of field techniques to estimate lion presence and abundance. *Mammal Review* 54:47-62; and Riggio et al., 2016. The size of savannah Africa: a lion's (*Panthera leo*) view. *Biodiversity Conservation* 22: 17–35.] [Figure 3.2 adapted from: Braczkowski A et al., 2020. Restoring Africa's Lions: Start with good counts. *Frontiers in Ecology and Evolution* 8: 138]
Frontiers in Ecology and Evolution and *Biodiversity Conservation* publish peer-reviewed scientific research across fundamental, applied and conservation sciences, while *Mammal Review* is a leading peer-reviewed zoological journal]

SOURCE C – Sampling methods

Individual identification (capture-recapture)

Technique – Individual lions are identified based on unique features such as whisker spot patterns, ear notches, and scars. Reference cards, like the example presented in Figure 3.3 below, record these individual unique features of known individuals and over time, re-sightings of these lions are used in mark-recapture models to estimate population size.

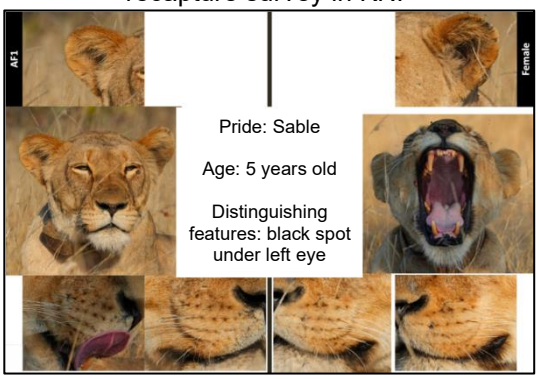
Pros – Objective; reliable; provides long-term monitoring.

Cons – Labour- and cost-intensive; requires trained personnel; relies on frequent lion sightings.

Accuracy – Very accurate.

Example – In 2024, a comprehensive lion population survey was conducted in Kruger National Park (KNP) using individual identification with location-based mark-recapture methods. Researchers used high-resolution photography to capture the unique facial features of individual lions to create reference cards (Figure 3.3). This technique ensured that each lion was counted only once, increasing the accuracy of the population estimates.

Figure 3.3: An example of a lion index card from the spatial capture-recapture survey in KNP



[Adapted from: Looking for lions – the quest to count and ID big cats in Kruger by Julia Evans 13 Aug 2024. <dailymaverick.co.za> Daily Maverick is a leading South African source of news, opinion and investigations]

Call-in surveys

Technique – Loud distress calls (of injured prey) are broadcast using speakers to attract lions. The number of responding lions is recorded.

Pros – Cost- and time-efficient.

Cons – Individual lions might not respond due to ecological factors, prey availability, age and/or human encounters.

Accuracy – Due to variations in lion responses, this method is not accurate when combined with a known distance around the survey point within which a lion is likely to hear the call and respond.

Example – An example of a call-in survey is the 2005 study in the northern region of Kruger National Park, South Africa. The initial estimate from this method was 283 lions. Subsequent surveys using similar methods, however, have yielded varying results (Table 3.2).

Table 3.2: Lion population estimates from call-in surveys in KNP

Year	Estimated Population	Notes
2005	283	Baseline survey using call-in method
2008	75	Reduced sampling effort compared to 2005
2015	119	Replication of 2005 methodology
2023	122	Latest estimate aligning with previous two surveys

[Adapted from: Nicholson SK et al., 2024. Towards effective and harmonized lion survey methodologies: A systematic review of practice across Africa. *Global Ecology and Conservation* 51: e02908. *Global Ecology and Conservation* is an open-access, peer-reviewed scientific journal]

Camera-trap surveys

Technique – Motion-activated cameras placed along trails, waterholes, and known lion corridors capture images of passing individuals. Population estimates are calculated from repeated sightings.
Pros – Non-invasive and effective for nocturnal monitoring.
Cons – Expensive and requires careful placement of cameras to maximise detections.
Accuracy – High, if used with capture-recapture methods. Moderate, if used without individual ID.
Example – Used in Ruaha-Rungwa Conservation Complex, Tanzania, together with mark-recapture techniques, as part of a study comparing the impact of different habitat types on lion population estimates.

Table 3.3: Summary of results for two camera trap grids in Ruaha-Rungwa. Ruaha National Park (NP) is the core tourist area of the complex, well protected and prey rich. The Ruaha NP woodland grid is an area of Miombo woodland

	Ruaha NP (core)*	Ruaha NP (woodland)^
Survey duration (nights)	83	90
Stations	45	26
Survey area (km^2)	223	152
Independent lion captures	390	67
Individuals recorded	48	14
Females	30	9
Male	18	5
Recapture rate (%)	74	71

Figure 3.4: Mark-recapture using camera traps involves photographic identification of individual lions.

For example: Two photographs of the same (a1, a4) and of two different (a2, a3) male lions, including dates of capture.

[Text, Table 3.3 and Figure 3.4, adapted from: Strampelli P et al., 2022. Camera trapping and spatially explicit capture-recapture for monitoring and conservation management of lions: Insights from a globally important population in Tanzania. *Ecological Solutions and Evidence* 3: e12129 –*Ecological Solutions and Evidence* is an open-access, peer-reviewed scientific journal]

Population estimates based on nearby data

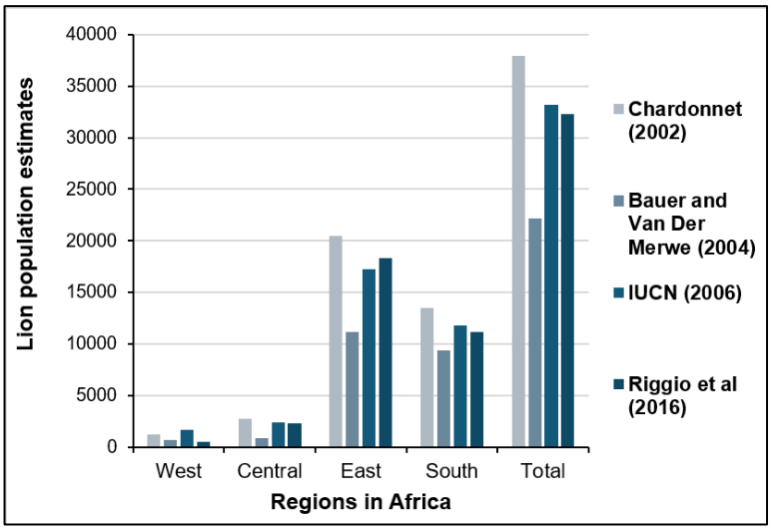
Technique – If there are no direct counts for an area of concern, lion population estimates can be assumed based on the closest place that *does* have data, i.e. a *reference site.*
Pros – Useful in remote areas where it is difficult to observe lions directly.
Cons – Limited by the availability of reference sites and the quality and quantity of data from these sites.
Accuracy – Can be accurate if reference sites are similar in terms of habitat and lion behaviour.
Example – A 2010/2011 study conducted in Serengeti National Park (SNP), Kenya, used camera traps to estimate the number of female lions in different areas. Lions were not individually identified in the photos, rather, recordings were based on how often lions appeared on camera and how much ground they typically covered in a day. To validate the accuracy of the study, estimates were compared to known lion numbers from parts of SNP that had been carefully monitored over time. The study showed that it is possible to get reasonable estimates of lion population using simple camera data if the data is interpreted carefully and compared with reliable reference areas.

[Adapted from: Ferreira SM & Funston PJ, 2010. Estimating lion population variables: prey and disease effects in Kruger National Park, South Africa. *Wildlife Research* 37(3): 194–206 – *Wildlife Research* is a peer-reviewed scientific journal covering the fields of ecology and wildlife management]

Expert opinion and interview-based surveys

Technique – Interviews conducted with local communities, park rangers, conservationists, biologists, and hunters to assess lion presence and the frequency of sightings over time.
Pros – Rapid data collection over large area; provided local insights.
Cons – Subject to recall bias and inaccuracies; difficult to standardise across regions.
Accuracy – Low accuracy due to potential conflicts of interest. The population estimates they provide are often rough and inconsistent.
Example – Figure 3.5 provides a comparison of lion population estimates generated by four different studies over the last two and a half decades. All of the studies employed a combination of questionnaires, interviews, expert opinions and literature reviews to estimate lion population numbers across different regions in Africa.

Figure 3.5: Comparison of lion population estimates from different studies across regions of Africa



Adapted from: [Loveridge AJ et al., 2022. Where have all the lions gone? Establishing realistic baselines to assess decline and recovery of African lions. *Diversity and Distributions* 28: 2388–2402; and Bauer H et al., 2003. Research needs for lion conservation in West and Central Africa. *Comptes Rendus Biologies* 326: S112–S118 – *Diversity and Distributions* and *Comptes Rendus Biologies* are open-access, peer-reviewed scientific journals covering all areas of conservation biogeography and life sciences; and Chardonnet P, 2002. *Conservation of the African Lion: Contribution to a Status Survey*. International Foundation for the Conservation of Wildlife, France, and Conservation Force, USA. The International Foundation for the Conservation of Wildlife contributes towards the conservation of wildlife, promoting reasonable harvesting of game populations]

SOURCE D – Factors influencing sampling method accuracy

Habitat size

Large, extensive habitats – are difficult to ensure complete sampling coverage due to logistical constraints. Further, some male lions are solitary and nomadic, making detection difficult.

Fragmented habitats – can isolate lion populations. Small, isolated habitats, like those in West Africa, may not support viable lion populations.

Edge effects – smaller habitats have more edges compared to their size, which makes it more likely that lions will come into contact with human activities.

Home range – lions have large home ranges (>100 km^2). In smaller habitats, lions may move beyond the sample area, leading to undercounts. In larger habitats, overlapping home ranges can result in double-counting if individual identification methods are not employed.

Studies in Queen Elizabeth National Park, Uganda, used individual identification sampling methods to account for such movements and achieve accurate population estimates.

[Adapted from: Kittle AM et al., 2016. Landscape-level movement patterns by lions in western Serengeti: comparing the influence of inter-specific competitors, habitat attributes and prey availability. *Movement Ecology* 4:17 – *Movement Ecology* is a peer-reviewed, open-access scientific journal]

Vegetation density

Dense vegetation – obstructs visibility, making lion less detectable. This can result in the under-estimation of population numbers. If camera traps are used, however, the estimates are accurate.

Open habitats – facilitate easier sightings but can result in overestimations if lions are drawn (i.e. via call-in methods) to these areas during surveys.

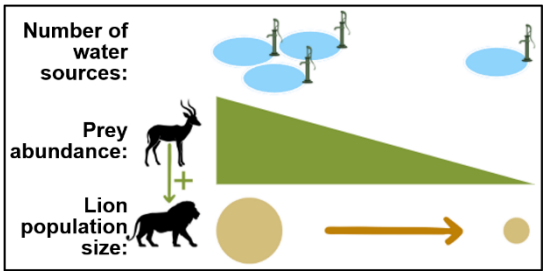
Figure 3.6: Visibility of lions in **A** dense and **B** open habitats. [Image sources: **A:** <dewetswild.com>; **B:**<africaincoming.com>]

Distribution of water

Lions are found close to water sources, especially in arid regions during the dry season. This can lead to overestimations if sampling is concentrated in their areas.

Research in Ruaha National Park, Tanzania, showed accurate lion population estimates could be achieved by accounting for the distance from water sources in sampling designs (Figure 3.7).

Figure 3.7: Influence of water point distribution on lion prey density, and therefore lion population size



Terrain accessibility

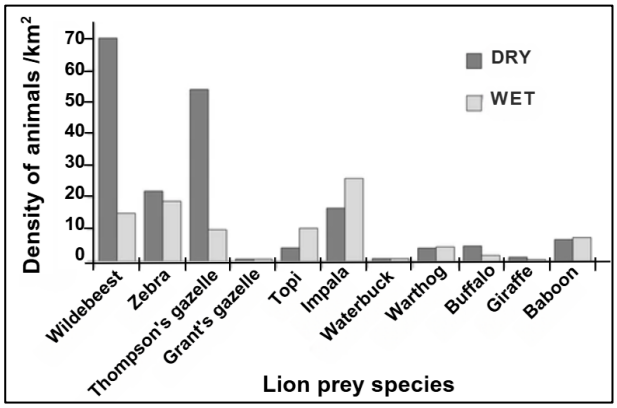
Rugged terrain can limit researcher access and reduce visibility. For example, in Ethiopia's Bale Mountain National Park, the challenging terrain required the use of alternative sampling methods to achieve an accurate estimate of the lion population. Lions occupying inaccessible areas can be undersampled.

Seasonal variations

Seasonal changes can affect lion habitats by altering vegetation cover, impacting prey movements (Figure 3.8) and changing the availability of water. Lions also spread out more in the wet season due to abundant water and prey, making them harder to locate.

Sampling methods conducted in different seasons can yield varying results. For example, in Ruaha National Park, Tanzania, lion population estimates were higher in the wet season. The inclusion of both wet and dry seasons in the sampling design ensured an accurate year-round lion population estimate for the park to be determined.

Figure 3.8: Seasonal density of selected lion prey species (per km^2) in Hwange National Park, Zimbabwe



[Text and Figure 3.7 adapted from: Kimaro MH et al., 2022. African lion population estimates in Tanzania's Ruaha National Park. *Open Journal of Ecology* 12:558-569.] [Figure 3.8: Morin A et al., 2024. Response of a carnivore community to water management in a semi-arid savanna. *Biological Conservation* 299:110777]
[*Open Journal of Ecology* and *Biodiversity Conservation* are peer-reviewed, open-access scientific journals]

SOURCE E – Lion trophy hunting quotas

Trophy hunting quota setting standards across Africa

Trophy hunting is described by the International Union for the Conservation of Nature (IUCN) as hunting that is: 1. legally regulated; 2. characterised by hunters paying a high fee to hunt an animal with specific 'trophy' characteristics; 3. characterised by low numbers being harvested; and 4. usually undertaken by hunters from outside the local area. Theoretically, the hunting is conducted with set quotas (a regulated limit on the number of a wild game species that can be legally hunted within a given area and period) and age restrictions to ensure sustainability.

The methodology used for setting lion trophy hunting quotas varies from country to country within Africa, with some countries using methods based on population data, while others rely on subjective factors (Table 3.4).

Table 3.4: Rules and basis for establishing quotas, hunting quotas for years of data (2006–2012) and actual hunts that occurred during that period for African Lions in Central and West African Countries

Country	Basis for establishing quotas	Quota	Actual hunts	Sex of lions hunted	Minimum age/size
Mozambique	Annually based on data from surveys, reports on human-lion conflict and opinions of government officials and hunting operators.	42	19	Male	6 years
Namibia	Guided by data on lion numbers.	15	14	Male & Female	Skull size 52 cm
Tanzania	Based on recommendations from hunting operators and officers working for the Wildlife Division.	315	85	Male	6 years
Zambia	Based on a set % of lion population estimates.	74	47	Male	None
Zimbabwe	Based on data from lion surveys and reports of problem lions.	101	43	Male	None
Cameroon	Based on size of hunting zone.	30	7	Male	None
Benin	Initially based on demand, but now on a lion survey conducted by independent researchers in 2002.	5	2	Male	Age restrictions agreed, not enforced
Burkina Faso	Annually based on the size of the hunting zone and the previous year's hunting quota.	20	13	Male	None
Central African Republic	Annually based on quotas of previous years.	31	14	Male	None
TOTAL		**632**	**244**		

In 2015, research was conducted by three teams tracking lions over a vast range in Cameroon. It was determined that Cameroon contained 250 lions. As a result of this accurate population estimate, the country's annual lion quota was reduced from 30 to 10. Today, this quota is still applied throughout northern Cameroon's Bénoué ecosystem.

[Adapted from: <https://cites.org/eng/node/130944> CITES **(Convention on International Trade in Endangered Species of Wild Fauna and Flora)** is an international agreement between governments. Its aim is to ensure that international trade in specimens of wild animals and plants does not threaten the survival of the species] [Lindsey PA et al., 2013. The trophy hunting of African Lions: Scale, current management practices and factors undermining sustainability. *PLoS ONE* 8(9): e73808 – *PLoS ONE* is a peer-reviewed, open-access mega journal published by the Public Library of Science]

SOURCE F – Influence of stakeholders

Government agencies

Government agencies in Africa play a crucial role in implementing wildlife policies and allocating resources for conservation efforts, directly impacting the accuracy of lion population estimates. In Kenya, the government, alongside various non-governmental organisations, has undertaken a comprehensive nationwide lion survey using a standardised capture-recapture sampling method.

[Adapted from: Blog – Lion conservation: how you can help! by Hannah Campbell September 14, 2019. <loisaba.com> Loisaba Conservancy, situated in Kenya, is owned by Loisaba Community Trust, a collaborative approach that protects landscapes, wildlife, and livelihoods]

International funding

International organisations and donors influence population estimates through funding priorities and conservation strategies. Estimates suggest that maintaining existing lion populations within protected areas may require substantial financial investment, highlighting the need for significant contributions from wealthier nations. The allocation of funds can determine the extent and quality of population monitoring efforts.

Many of the African lion population estimates came from IUCN-sponsored workshops that included biologists and policymakers. While these reports underwent peer review, some figures were accepted without rigorous scrutiny to maintain diplomatic consensus.

[Adapted from: Lions on the Brink – New analysis reveals the differing threats to African lion populations. News article from Oxford University's Wildlife Conservation Research Unit, published September 12, 2023. <ox.ac.uk> – *Oxford University* is a leading centre of learning, teaching and research globally]

Hunting operator perceptions

Hunting operators have varying opinions on lion population trends and quotas (Table 3.5). In some African countries, these opinions have a significant influence on the setting of trophy hunting quotas.

Table 3.5: Perceptions of hunting operators regarding problems associated with the trophy hunting of African lions

Perceptions of hunting operators	Mozambique	Namibia	Tanzania	Zambia	Zimbabwe
Quotas too high/unscientific	40,0	28,6	46,2	66,7	50,0
Quotas too low	0	0	0	0	10,0
Lack of guidelines/rules on age of lion trophies	20,0	0	0	16,7	0
Incompetent parks authority	0	0	15,3	16,7	0
Political influence on quotas	0	0	7,8	0	30,0

Lion population trends:

- 54,5% of operators believe lion populations are increasing in their areas. In Zimbabwe and Mozambique, increasing lion numbers are attributed to recovering prey populations (37,5%) and conservation efforts like temporary bans on hunting (9,4%).
- In contrast, 9,1% of operators in Tanzania and Zambia believe lion populations are declining. The primary reasons cited for declines include human-wildlife conflict (40%), encroachment (40%), and killings by local communities (20%).

[Adapted from: Lindsey PA et al., 2013. The trophy hunting of African Lions: Scale, current management practices and factors undermining sustainability. *PLoS ONE* 8(9): e73808 – *PLoS ONE* is a peer-reviewed, open-access mega journal published by the Public Library of Science]

Conservation bodies

Non-governmental organisations (NGOs) often drive conservation initiatives, conducting field research and advocating for policy changes. Their focus areas can influence which lion populations are monitored more intensively. Some organisations may prioritise the most threatened populations, while others focus on regions with genetic distinctiveness or significant ecological roles. This variability can lead to uneven data collection across different lion populations.

[Adapted from: Nicholson SK et al., 2023. Socio-political and ecological fragility of threatened free-ranging African lion populations. *Communications Earth & Environment* 4:302 - *Communications Earth & Environment* is a peer-reviewed, open-access, scientific journal in Earth and environmental sciences]

Scientific researchers

Researchers in Africa have significantly advanced methodologies for estimating lion populations, improving the accuracy and reliability of data crucial for conservation efforts. Traditional sampling methods such as track counts, call-up surveys, and direct observations have been widely employed. These techniques, however, can often face limitations due to factors like low detection rates and environmental variability. Recognising these limitations, scientists now use multiple sampling methods together to cross-validate their results and obtain accurate population estimates (Table 3.6). By comparing how closely lion population estimates align with known or best-available population data for specific areas, the accuracy of different sampling techniques (or sampling technique groupings) can be determined.

Table 3.6: A comparison of lion population estimates from different regions in Africa based on sampling method used, highlighting the accuracy of the resultant estimate

Region	Methods Used	Estimate	Known Number	Year of Estimate
Kruger, South Africa	Individual identification (capture-recapture) + camera traps	~1,600	~1,600	2024
Serengeti, Tanzania	Individual identification (capture-recapture) + camera traps	~3,000	~3,000	1990–present
Kafue, Zambia	Call-in surveys + track counts	~450–500	~500	2021
WAP Complex (W Africa)	Track counts + camera-traps	~400	~350–400	2018
Pilanesberg, South Africa	Individual identification (capture-recapture) + camera traps	44	~50	2022
Lake Nakuru NP, Kenya	Individual identification (capture-recapture) + camera traps	Much lower	Previously overestimated	2020
Kunene Region, Namibia	Track counts + opinion/expert based	57	~100	2022

[Adapted from: Nicholson SK et al., 2024. Towards effective and harmonized lion survey methodologies: A systematic review of practice across Africa, *Global Ecology and Conservation* 51: e02908; and Kantor Y et al., 2022. Using camera traps and spatial capture-recapture to estimate lion density in Pilanesberg National Park. *Ecology and Evolution*, 12(9), e10291. – *Global Ecology and Conservation* and *Ecology and* Evolution are both peer-reviewed, open-access international scientific journals in the disciplines of ecology, conservation and evolutionary biology. Everatt KT & Somers MJ, 2024. A call-up survey of lion abundance in Kruger National Park. *Unpublished Report*, Endangered Wildlife Trust. – Professional research report by a conservation NGO; not peer-reviewed but is written by credible scientists, Miller SM et al., 2022. Lion population survey in the Kunene Region of Namibia. *Conservation Namibia*. <conservationnamibia.com> – *conservation Nambia* is an NGO that publishes non-peer-reviewed articles written by scientists with insights into various conservation field practices; and Panthera 2020. Maasai Mara lion population estimates. *Panthera Project Brief*. <panthera.org> This article is not peer-reviewed, but is a summary written from a conservation NGO website based on internal expert-led research, Wittemyer G et al., 2020. Getting closer to a much better count of Africa's lions. *The Conversation*. <theconversation.com> – *The Conversation* is a popular science online media outlet that is not peer-reviewed, but is authored by reputable academics summarising recent research]