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Comparative Signal Ecology and Rare Species Detection: A Framework for Interpreting Anomalous Biological Report Streams

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Abstract

Reports of anomalous large-bodied mammals are typically evaluated in isolation from the established science of rare species detection. Conservation biology, however, has developed formal frameworks for interpreting sparse detections, false negatives, and rediscovery dynamics in taxa characterized by low density, cryptic behavior, and imperfect detectability. This paper introduces a comparative signal ecology framework that treats report streams as products of interacting ecological, observational, and evidentiary processes. Using five comparator cases—Florida panther, wolverine recolonization in the contiguous United States, Eurasian lynx recolonization in Western Europe, the saola, and global “Lazarus” tetrapod rediscoveries—we identify shared properties of detection under uncertainty without assuming biological equivalence. The framework reframes anomalous biological reports as a monitoring and inference problem, enabling explicit null

expectations, testable predictions, and clearly articulated limits (MacKenzie et al. 2002; Brook et al. 2019; Lindken et al. 2024).

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1. Introduction

Debates surrounding anomalous biological claims—particularly reports of large, unclassified mammals—are typically polarized between categorical dismissal and uncritical acceptance. Both positions share a common limitation: they rarely engage with how detection actually functions in real ecological systems. In practice, many known species persist for long periods with sparse, ambiguous, or contested records, even under modern monitoring regimes. Conservation biology has therefore developed analytical tools to interpret detection under uncertainty, emphasizing imperfect detection, observer effort, and structured absence (MacKenzie et al. 2002).

This paper applies those tools comparatively. Rather than asking whether anomalous reports correspond to an unknown species, we ask a narrower and more tractable question: **Do the observable properties of anomalous report streams resemble the detection dynamics of known rare species operating under imperfect detection?** The goal is not to assert equivalence, but to situate anomalous reports within a reference class drawn from established ecological practice.

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2. Detection Ecology and Imperfect Observation

Ecological detection is probabilistic, not binary. The absence of detection does not imply absence of occupancy when detection probability (p) is less than one (MacKenzie et al. 2002). Numerous factors depress p, including low population density, cryptic behavior, nocturnality, large home ranges, observer inexperience, and environmental complexity.

Occupancy and detection frameworks separate the *state process* (whether a species is present) from the *observation process* (whether it is detected), allowing inference under uncertainty (MacKenzie et al. 2003). Importantly, these frameworks were developed precisely because intuitive expectations—“if it were there, we would have seen it”—consistently fail in real systems.

This distinction is foundational to the comparative approach used here.

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3. Signal Ecology: A Comparative Framework

We define **signal ecology** as the structured relationship between:

1. **True state** (presence or absence),
2. **Detection probability** (p),
3. **Observer effort** (E),
4. **Evidentiary filters** (what qualifies as a record).

The observable outcome is a **report stream**: a time-structured sequence of records shaped by all four factors. Crucially, report streams can be compared across domains even when underlying causes differ.

Key signal ecology metrics used in this paper include:

- Encounter rate per unit effort,
- Spatiotemporal clustering,
- Evidence modality profiles (visual, acoustic, track, genetic),
- Persistence under increased surveillance,
- Effort–signal coupling strength,
- Time-to-confirmation or rediscovery.

These metrics are descriptive, not ontological. They allow comparison without presupposing explanation.

4. Comparator Case Studies

4.1 Florida Panther (*Puma concolor coryi*)

The Florida panther represents a remnant population subjected to decades of intensive monitoring within a highly modified landscape. For much of the twentieth century, evidence consisted largely of tracks, sporadic sightings, and indirect sign, with persistent debate over viability and even continued existence. Definitive confirmation and population recovery required the integration of telemetry, genetics, and sustained effort (U.S. Fish and Wildlife Service 2008; Onorato et al. 2019).

Notably, increased effort did not produce a proportional increase in casual detections. Instead, confirmation emerged through methodological escalation rather than sheer encounter frequency. This illustrates how long periods of ambiguous detection can coexist with biological reality under low p.

4.2 Wolverine (*Gulo gulo luscus*) Recolonization, Contiguous United States

Wolverines in the Lower 48 exemplify recolonization under chronic false negatives. Despite modern camera traps, genetic hair snares, and agency monitoring, detection remains sparse and spatially inconsistent. Public sightings often preceded formal confirmation, and large areas of suitable habitat produced no detections for extended periods (Lukacs et al. 2020; U.S. Fish and Wildlife Service 2023).

This case demonstrates that even technologically sophisticated monitoring does not eliminate non-detection and that absence of evidence can persist at range margins despite occupancy.

4.3 Eurasian Lynx (*Lynx lynx*) Recolonization in Western Europe

Lynx recolonization in Western Europe is well documented yet initially contested. Early records consisted largely of disputed sightings and tracks, often dismissed until corroborated by camera trap data. Institutional acceptance lagged behind biological presence, illustrating how governance and evidentiary thresholds shape signal interpretation (Breitenmoser et al. 2010).

This case highlights the role of social and institutional filters in determining when a signal is treated as legitimate.

4.4 Saola (*Pseudoryx nghetinhensis*)

The saola represents an extreme case of crypticity. Despite being a large-bodied mammal, it has rarely been directly observed alive since its scientific description. Knowledge derives primarily from remains, indirect sign, and limited camera trap imagery. Persistent non-detection has not been interpreted as evidence of nonexistence, but as a consequence of extreme rarity and habitat complexity (Robichaud et al. 2010).

This case challenges assumptions that body size or modern technology guarantees frequent detection.

4.5 Global "Lazarus" Tetrapods

Meta-analyses of rediscovered tetrapods reveal that species presumed extinct can persist undetected for decades or centuries, often with sporadic reports preceding rediscovery. Rediscovery probability is influenced by search effort, accessibility, and political context rather than time alone (Brook et al. 2019; Lindken et al. 2024).

These cases demonstrate that long-term non-detection is compatible with persistence under specific conditions.

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5. Comparative Analysis

Across the five cases, several consistent signal ecology patterns emerge:

- **Detection is non-linear with effort**: increased effort often yields diminishing returns.
- **Multi-modality convergence** is slow and uneven.
- **Hotspot stability** persists even when detections are rare.
- **Institutional thresholds** shape when signals are accepted as evidence.
- **Technology sensitivity** varies widely by species and habitat.

When anomalous biological report streams are evaluated using these same metrics, they can be assessed relative to known detection envelopes rather than against an implicit standard of perfect visibility.

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6. Predictions and Discriminators

The comparative framework yields explicit, falsifiable predictions:

1. If anomalous reports are primarily narrative artifacts, effort–signal coupling should exceed that observed in rare carnivores and increase disproportionately in high-traffic areas.
2. If anomalous reports reflect a real but rare biological target, long-term hotspots should exhibit gradual multi-modality convergence.
3. If persistence resembles Lazarus dynamics, long gaps should coexist with occasional high-quality records, with rediscovery probability sensitive to targeted effort.
4. If technology is decisive, report structure should shift markedly following widespread camera deployment; failure to shift constrains explanatory models.

These predictions can be tested without resolving ontological questions.

7. Limits and Non-Equivalence

This framework does not assert that anomalous report streams correspond to undiscovered species. Comparator cases are methodological analogs, not biological claims. Differences in ecology, cognition, and culture impose limits on inference. The purpose is constraint, not validation.

8. Conclusion

Comparative signal ecology provides a disciplined way to study anomalous biological reports without collapsing into belief or dismissal. By situating report streams alongside established cases of rare species detection, the problem is reframed from controversy to monitoring. Persistence, absence, and ambiguity become data rather than embarrassment. This reframing enables structured uncertainty, explicit exit criteria, and cumulative progress.

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