

From detection to cure: advancing wildlife diagnostics and therapeutics

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Introduction

Wildlife management is rapidly evolving from a field based mainly on observation, restraint, and postmortem diagnosis into one shaped by molecular biology, remote sensing, precision therapeutics, and biosensor technologies. This transformation is not only improving conservation practice but also strengthening the One Health approach, which recognizes that the health of wildlife, humans, domestic animals, and ecosystems is tightly interconnected. This now become impossible to neglect. A study found that 60.3% of emerging infectious diseases are zoonotic, and 71.8% of those zoonoses originate in wildlife reservoirs (Jones et al., 2008). Also, the Living Planet Report 2024 estimated an average 73% decline in monitored vertebrate wildlife populations since 1970, signifying that disease, habitat degradation, pollution, and climate change are operating together rather than separately.



So, advanced diagnostics are becoming central to modern wildlife management. Traditional tools such as clinical examination, necropsy, microscopy, histopathology, and microbial culture remain fundamental, but they are often too slow or too limited for fast-moving outbreaks in free-ranging populations. Today, real-time PCR, multiplex PCR, and high-throughput

sequencing allow managers to detect pathogens with much higher sensitivity and speed. These methods are essential for surveillance of avian influenza, rabies, canine distemper, bovine tuberculosis in wild ungulates, and white-nose syndrome in bats. Their value lies not only in confirming infection, but also in identifying subclinical circulation before mass mortality becomes visible.

Advanced technologies

1. One of the most important advances is the use of environmental DNA (eDNA) and metabarcoding. Instead of capturing an elusive animal, researchers can detect DNA shed into water, soil, snow, sediments, or even air. This has enormous practical value in wildlife systems, where capture itself may induce stress, alter behavior, or cause injury. eDNA can reveal species presence, invasive organisms, and pathogen contamination from a single environmental sample. In aquatic and amphibian systems especially, this has changed monitoring from a labor-intensive process to a scalable surveillance strategy. Under One Health, it is especially used because the same environmental sample can generate information relevant to biodiversity, livestock exposure, and zoonotic risk.

2. Genomic epidemiology adds another level of precision. Whole-genome sequencing and portable platforms such as nanopore sequencers can characterize not only whether a pathogen is present, but also which strain is circulating, how it is evolving, and how transmission is occurring across species or landscapes. This matters greatly in wildlife-livestock-human interfaces, where spillover may be silent for months. In effect, wildlife management is shifting from simple diagnosis toward prediction and pathway reconstruction.

3. Imaging technologies are also transforming care. Portable ultrasound, digital radiography, endoscopy, CT, MRI, and drone-based thermal imaging now support much faster decision-making

in both field medicine and rehabilitation centers. These tools help identify fractures, pregnancy, soft tissue injury, internal bleeding, respiratory compromise, and entanglement trauma. Thermal imaging is especially useful for locating animals non-invasively, identifying heat stress, detecting carcasses, and monitoring population-level abnormalities without repeated capture. For endangered species, this reduction in handling can be as important as the diagnosis itself.

4. A particularly exciting addition to wildlife diagnostics is the rise of electronic nose (e-nose) and electronic tongue (e-tongue) technologies. These are sensor-array systems designed to detect complex chemical patterns rather than single molecules. The e-nose analyzes volatile organic compounds (VOCs) in breath, feces, urine headspace, wound emissions, enclosure air, or environmental samples. The e-tongue analyzes dissolved chemical signatures in liquids such as saliva, urine, blood-derived fluids, milk, pond water, or feed extracts. In simple terms, they function as pattern-recognition devices that translate chemical “smells” and “tastes” into diagnostic fingerprints.

Their relevance to wildlife management is substantial. Disease, stress, diet shifts, reproductive state, microbiome imbalance, and toxic exposure often alter metabolic byproducts long before obvious clinical signs appear. An e-nose could therefore be used to screen for respiratory infection, gastrointestinal disease, wound infection, ketosis-like metabolic disturbances, enclosure hygiene problems, or decomposition signatures, while an e-tongue could help profile saliva chemistry, urine imbalance, feed quality, water contamination, or therapeutic residue patterns.

Advantages

In veterinary and biomedical studies, these tools have shown promise for rapid, non-invasive detection of infection and physiological change. In wildlife medicine, their strongest future role may be in screening where repeated blood collection is impractical or where a fast, field-deployable “red flag” test is needed before confirmatory PCR or culture. However, it is important to be scientifically cautious, their use in free-ranging wildlife is still emerging and is currently less validated than PCR, imaging, or sequencing. Even so, they fit One Health exceptionally well because they can potentially screen animals, their habitats, and even shared air or water spaces using the same analytical logic.

Wildlife therapeutics

Therapeutics are advancing alongside diagnostics. Wildlife treatment is no longer limited to sedation, basic wound care, and release. Long-acting antimicrobials, antifungals, antiparasitics, and sustained-release analgesics are reducing the need for repeated capture, which is critical because restraint can cause capture myopathy, immunosuppression, and behavioral disruption. Precision dosing informed by species-specific pharmacokinetics is improving outcomes in birds of prey, carnivores, marine mammals, and large herbivores. Rehabilitation medicine now increasingly includes point-of-care blood analysis, targeted fluid therapy, nutritional correction, and microbiome-aware support.

Vaccination is one of the examples of wildlife therapeutics. Oral rabies vaccination in wild carnivores has shown that managing disease in reservoir populations protects wildlife, livestock, and humans simultaneously. Similarly, efforts to manage bovine tuberculosis, anthrax, and brucellosis at selected interfaces. Another important therapeutic strategy is immunocontraception, especially in species where overabundance drives habitat damage or conflict. GnRH-based and porcine zona pellucida-based contraceptive approaches have been used in deer, wild horses, and elephants to regulate population size without the ecological and ethical controversy of repeated culling.

Integrated approach

Further, the most promising model for wildlife management is an integrated one, genomics for precise detection, eDNA for landscape surveillance, imaging for clinical assessment, e-nose and e-tongue for rapid non-invasive screening, and precision therapeutics for low-stress intervention. Artificial intelligence will likely amplify all of these by recognizing patterns in sensor data, camera-trap images, acoustic recordings, and movement tracks. The result is a new form of wildlife medicine that is not simply reactive and individual-based, but predictive, ecological, and preventive.

Case Study

The recent tragic incidents at Vantara, where veterinarian from Kerala, Vaisakh Viswan lost his life during elephant management, and the death of 27-year-old veterinary intern Dr. Sameeksha Reddy at Tyavarekoppa Safari in Shivamogga during sample collection from a hippopotamus, highlight the grave risks inherent in wildlife handling and clinical interventions. These

incidents strongly emphasize the need to adopt non-invasive and minimally invasive diagnostic approaches, such as fecal, urine, saliva, and environmental DNA sampling, along with remote monitoring technologies. Large wild animals are highly unpredictable and can become aggressive under stress, making close physical handling extremely dangerous. Therefore, wildlife management must prioritize strict safety protocols, remote drug delivery systems, proper sedation under expert supervision, risk assessment, and specialized training of personnel. Strengthening these measures is essential to protect veterinarians, interns, and animal handlers while ensuring better animal welfare and aligning with modern

principles of safe and ethical wildlife management.

At this juncture, the One Health concept becomes indispensable. A chemically abnormal wetland, an infected bat colony, a nutritionally stressed elephant population, and a spillover risk in nearby livestock are not separate problems. They are different signals within the same biological system. Advanced diagnostics and therapeutics, including emerging biosensors such as e-nose and e-tongue, offer wildlife management a chance to act earlier, more precisely, and with wider ecological awareness. In the twenty-first century, that may be the difference between local treatment and true planetary health protection.

Table: Advanced Diagnostic and Therapeutic Techniques for Wildlife Management

Technique	Core principle	Applications	Strengths	Limitations
Clinical exam and necropsy	Direct observation of signs and lesions	Trauma, mass mortality investigation, baseline pathology	Essential first-line and confirmatory approach	Late-stage detection, requires expertise and access
Microscopy and histopathology	Tissue and cell-level examination	Parasites, fungal lesions, inflammation, tumors	Strong for lesion interpretation	Slower, invasive, less sensitive for early infection
Culture & antimicrobial testing	Isolation of bacteria/fungi and drug susceptibility testing	Tuberculosis, wound infection, enteric disease	Gold standard for some pathogens; guides therapy	Slow, biosecurity demands, false negatives
PCR / qPCR / multiplex PCR	Amplification of specific nucleic acid targets	Avian influenza, distemper, rabies, chytrid fungus, TB	High sensitivity and specificity; rapid	Requires target knowledge and laboratory setup
Whole-genome sequencing	Full or partial genomic characterization	Strain tracking, mutation analysis, transmission mapping	High resolution; reveals evolution and resistance	Cost, expertise, data interpretation needs
eDNA/ metabarcoding	Detection of shed DNA in the environment	Species presence, invasive species, pathogen surveillance	Non-invasive, scalable, useful for elusive species	DNA degradation, contamination risk, interpretation challenges
Portable ultrasound	Real-time internal imaging	Pregnancy, trauma, fluid accumulation, organ pathology	Fast, portable, repeatable	Operator-dependent; limited by body size and air-filled tissues
Digital radiography / CT / MRI	Structural imaging of bones and soft tissue	Fractures, dental disease, internal trauma, neurologic disease	High anatomical detail	Expensive, access limitations, anesthesia risk
Thermal imaging, drones	Infrared detection of heat signatures	Detection of animals, fever proxies, carcasses, stress, anti-poaching	Non-invasive, landscape-scale monitoring	Weather effects, indirect diagnosis
Electronic nose (e-nose)	Sensor-array analysis of volatile	Early screening for infection, stress, metabolic	Rapid, non-invasive, field-	Needs calibration, strong confounders from

	organic compound patterns	change, wound status, habitat contamination	friendly, pattern-based	diet/environment, limited wildlife validation
Electronic tongue (e-tongue)	Sensor-array analysis of dissolved chemical patterns in liquids	Fluid chemistry profiling, nutritional status, toxicity screening, treatment monitoring	Rapid chemical fingerprinting without full lab chemistry	Sensitive to matrix complexity; standardization is still developing
Biosensors / lateral flow assays	Rapid antigen or biomarker detection	Field triage for selected infections and hormones	Fast	Lower sensitivity than lab methods in some contexts
Long-acting antimicrobials / antiparasitics	Sustained drug release or extended half-life therapy	Mange, helminth burden, wound infection, bacterial disease	Fewer recaptures, less stress	Resistance risk, limited species-specific dosing data
Vaccination (oral or parenteral)	Immune priming against specific pathogens	Rabies, selected livestock-wildlife interface diseases	Population-level prevention	Delivery logistics, coverage uncertainty
Immunocontraception	Reproductive suppression using immune mechanisms	Deer, elephants, wild horses, urban wildlife	Non-lethal population management	Repeat dosing may be needed; ecological effects must be monitored
Microbiome/probiotic therapy	Restoration or of beneficial microbial communities	Amphibian fungal defense, rehabilitation support	Innovative and potentially preventive	Still experimental in most wildlife species

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