

- The Origin of Science
- The Kalahari San Master Trackers and the
- The Future of Tracking Science



The Origin of Science

- Wallace Paradox: How did the evolution of the human brain enable us to do physics and mathematics?
- We need to show that tracking involves the same reasoning processes as physics and mathematics.



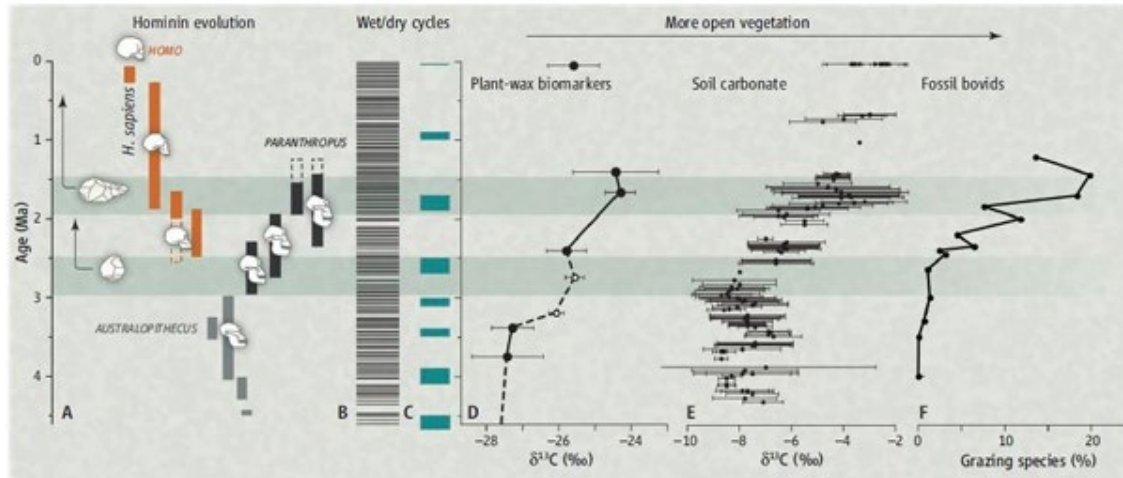
Simple, Systematic and Speculative Tracking

From Inductive-Deductive to Hypothetico-Deductive Reasoning



Climate Change towards more open vegetation

- Makgadikgadi Paleo Lake
- Kalahari Sands is most extensive in the world
- Wet/dry cycles amplify natural selection
- Ideal conditions for the evolution of tracking



The Invisible World

- Karl Popper: A theoretical science explains the visible world by a postulated invisible world.
- Observable properties of the visible world may be regarded as *signs* of invisible structures or processes.
- Nuclear particles cannot be seen. Physicists can only see *signs*, such as “particle tracks.”



The Visual Imagination

- Novel Prediction in Tracking.
- Anthropomorphic Representation, Visualizing what the Caracal was doing.
- Imagine yourself being the Caracal, feeling like you become the animal – “What would I do if I were the animal?”
- Imre Lakatos: Novel Predictions in Modern Science.



Photo: Steven Pinker

Example of Novel Solution in Mathematics

Creating a New Axiomatic Assumption

MAT201/000/81



UNIVERSITY OF SOUTH AFRICA

DEPARTMENT OF MATHEMATICS, APPLIED MATHEMATICS
AND ASTRONOMY

MATHEMATICS (MAT 201)

SOLUTIONS TO ASSIGNMENT 01 (AND 02)

By solving this system of linear equations, we obtain $\xi_1 = \xi_2 = \xi_3 = 0$. So $\text{Ker}(u) = \{0\}$ and u is therefore injective.

According to Theorem 4.8, page 118, of MAT 103,

$$\dim(\text{Ker}(u)) + \dim(\text{Im}(u)) = 3.$$

So, $\dim(\text{Im}(u)) = 3$ (because $\dim\{0\} = 0$).

Hence $\text{Im}(u) = \mathbb{R}^3$ from which it follows that u is surjective. We have thus proved that u is a bijective endomorphism and therefore an automorphism.

[15]

For u to be surjective it must be shown that $\exists \alpha$ so that

$$\forall (x_1, x_2, x_3) \in \mathbb{R}^3 \exists (x_1 - 2\alpha, \alpha, \frac{1}{2}x_3 - \frac{1}{2}\alpha) \in \mathbb{R}^3 \Rightarrow$$

$$u(x_1 - 2\alpha, \alpha, \frac{1}{2}x_3 - \frac{1}{2}\alpha) = (x_1, x_2, x_3)$$

$$\forall y \in \mathbb{R}^3 \exists x \in \mathbb{R}^3 \Rightarrow u(x) = y. \checkmark$$

we get
Solving for α , $2x_1 - 4\alpha + \frac{1}{2}x_3 - \frac{1}{2}\alpha = x_2$

$$\therefore \frac{9}{2}\alpha = 2x_1 - x_2 + \frac{1}{2}x_3 \checkmark$$

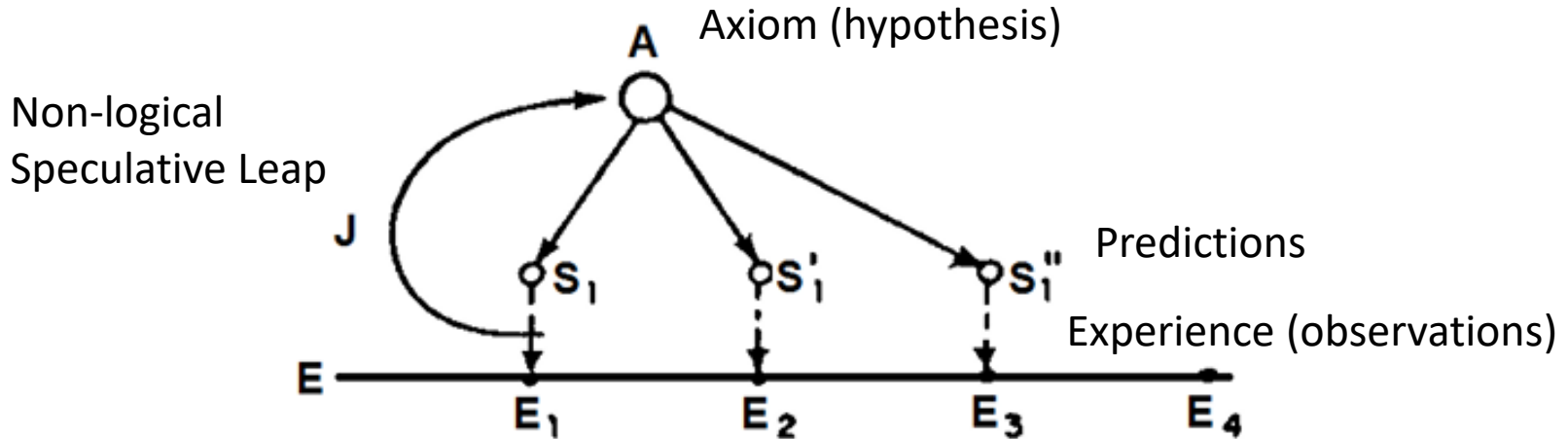
$$\therefore \alpha = \frac{4}{9}x_1 - \frac{2}{9}x_2 + \frac{1}{9}x_3.$$

How did you get this?
It is quite ingenious

assume $x_2 = u(\alpha)$
then for this to

be the case,
it can be shown
that
 $x_1 = u(x_1 - 2\alpha)$
 $x_3 = \dots$

Einstein's model for constructing a theory



Einstein's schematic model for constructing a theory (after Holton, 1986).

Resolving a Paradox

- Solving the Caracal tracks and the Mathematics problem required the *same imagination and reasoning process*.
- To resolve a Paradox or Anomaly between Observation and Theory requires a new Axiomatic Assumption.
- Einstein: Axiomatic hypothesis cannot be deduced from experience – it must be freely invented.
- Einstein: “no logical path... only an intuitive (psychological) connection”... a “free creation of the human mind” - the “free play” of the imagination.
- Peter Medawar: not illogical but non-logical, i.e. outside logic.

Thematic Presuppositions

- Underlying Simplicity, Symmetry and Unity in models explaining hoof tracks.
- Unifying “Law-Like” Generalities in Tracking.
- Models explaining shapes of animal tracks may suggest that Non-logical Aesthetic sense may be innate.
- Gerald Holton: non-testable Thematic Presuppositions (such as simplicity, symmetry and unity) may guide and narrow down options.

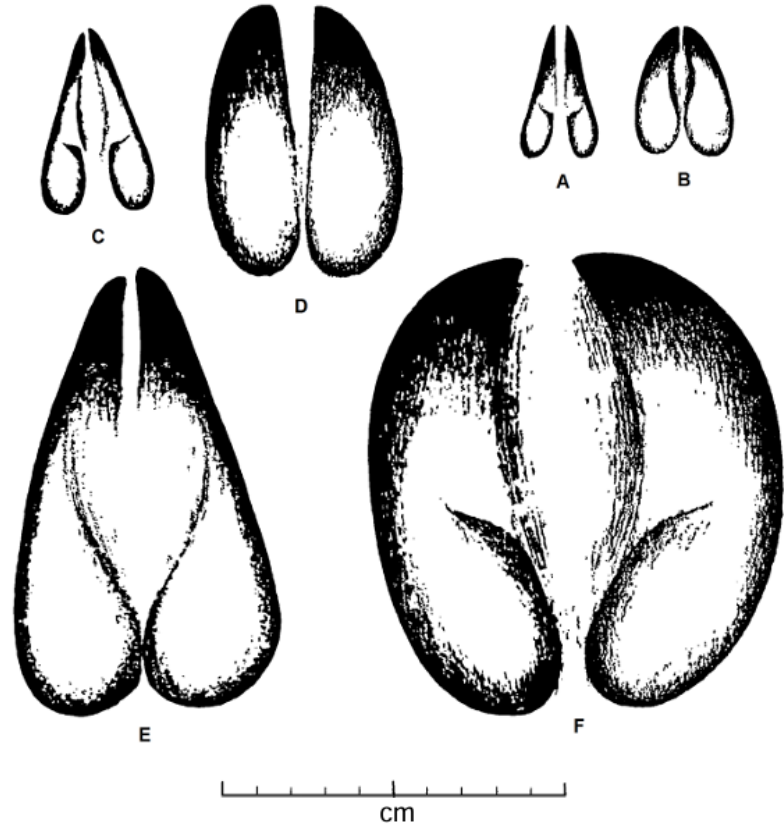


Fig. 3: The right fore tracks of (A) steenbok (B) duiker (C) springbok (D) kudu (E) gemsbok and (F) eland

Aesthetic Sense in Science

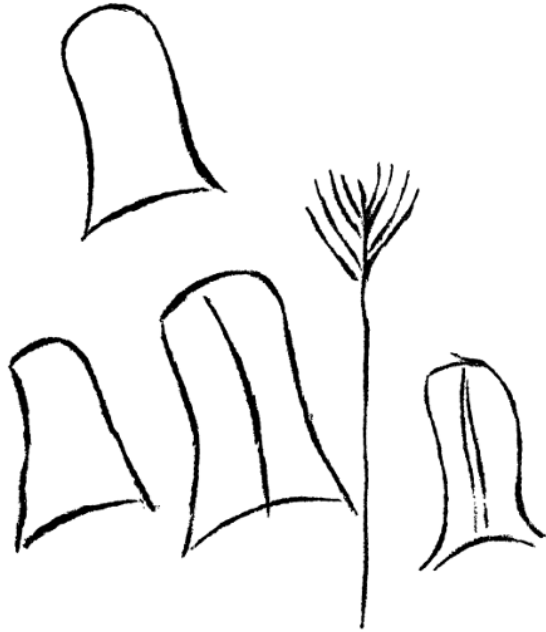
- Jacques Hadamard, *Psychology of Invention in Mathematics*: for example, Henri Poincaré – Requires a *sense of beauty* and involves period of *subconscious incubation*.
- *Subconsciously*, the human mind may be able to generate a huge number of combinations until it selects one that “fits” the data and resolves a paradox, resulting in a flash of inspiration - the “Aha” moment.
- Peter Medawar: The *intensity of the conviction* that a hypothesis is true has no bearing on whether it is true or not.
- Mathematical Beauty vs. *Scientific Beauty*: Testable Novel Predictions

Rock Art as Evidence of Science



An early Magdalenian painting in the cave of El Castillo, north-west Spain

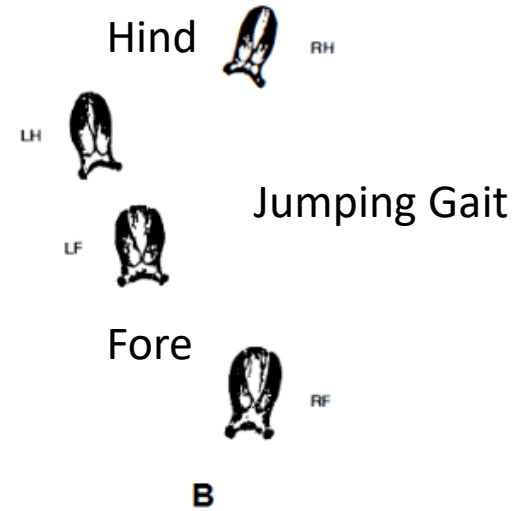
Evidence of Tracking in Prehistoric Art



Hoof track in
soft substrate



A



Tracks of a large ungulate jumping in soft substrate – evidence of persistence hunting?
A creative artist was also a tracker using scientific imagination and reasoning.



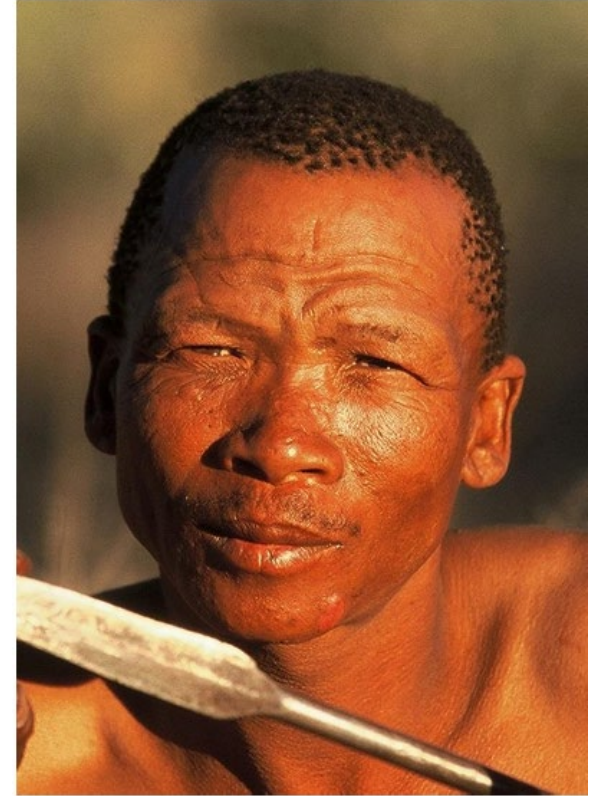
The Kalahari San Master Trackers



Lone Tree: From 1985

**Focus on Individuals to
master the art of tracking**

!Nam!kabe	/Uase
!Nate	Karoha
Kayate	NxjouKlau
Boroh//xao	





Navigating the Kalahari before GPS



Keeping lions away
at night while
sleeping in the open





Village near Lone Tree, Botswana





Introducing one of the earliest versions of CyberTracker in 1997 on a Visor/GPS (PalmPilot)



Testing CyberTracker to conduct animal track survey at Lone Tree, Botswana



Horekhwe (Karooha) Langwane teaching a younger tracker how to use CyberTracker



Using CyberTracker to conduct an animal track survey.



Master Trackers /Uase Xhukwe, Nxjouklau Kashe, !Nate Brahman and Horekhwe (Karohe) Langwane in 2010 at Lone Tree, Botswana.

The Future of Tracking Science

Empowering Communities & Preserving Biodiversity



Our vision is to develop a Worldwide Environmental Monitoring Network.

CyberTracker is being used worldwide by indigenous communities, in protected areas, scientific research, tracking science, community science, environmental education, forestry, farming, social surveys and crime prevention.



The planet saw its hottest days on record



The health of the environment is deteriorating at an alarming rate

70% Decline of wildlife populations since 1970

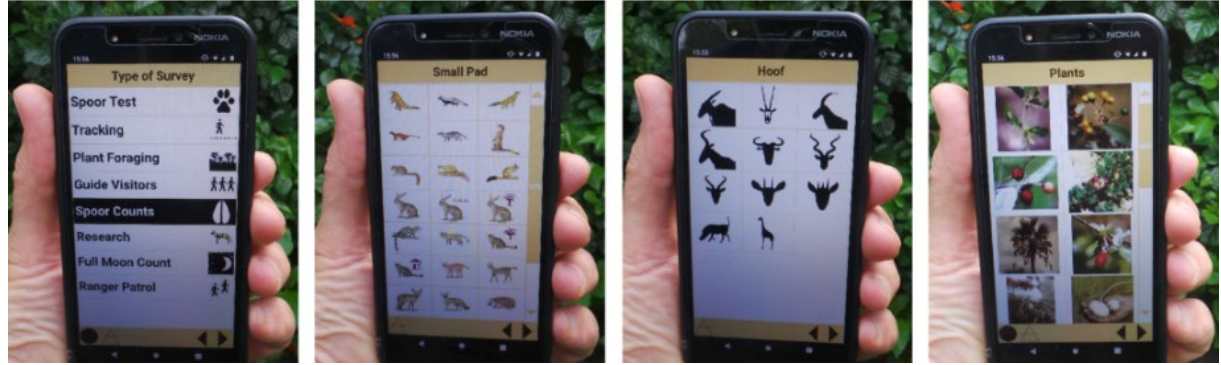
1 Million animal and plant species may go extinct



Challenges

- Not enough professional ecologists and scientists
- Technical skills are scarce in conservation
- Conservation projects cannot afford expensive solutions

CyberTracker mobile uses a simple Icon UX design for nonliterate indigenous and local communities to collect complex biodiversity data

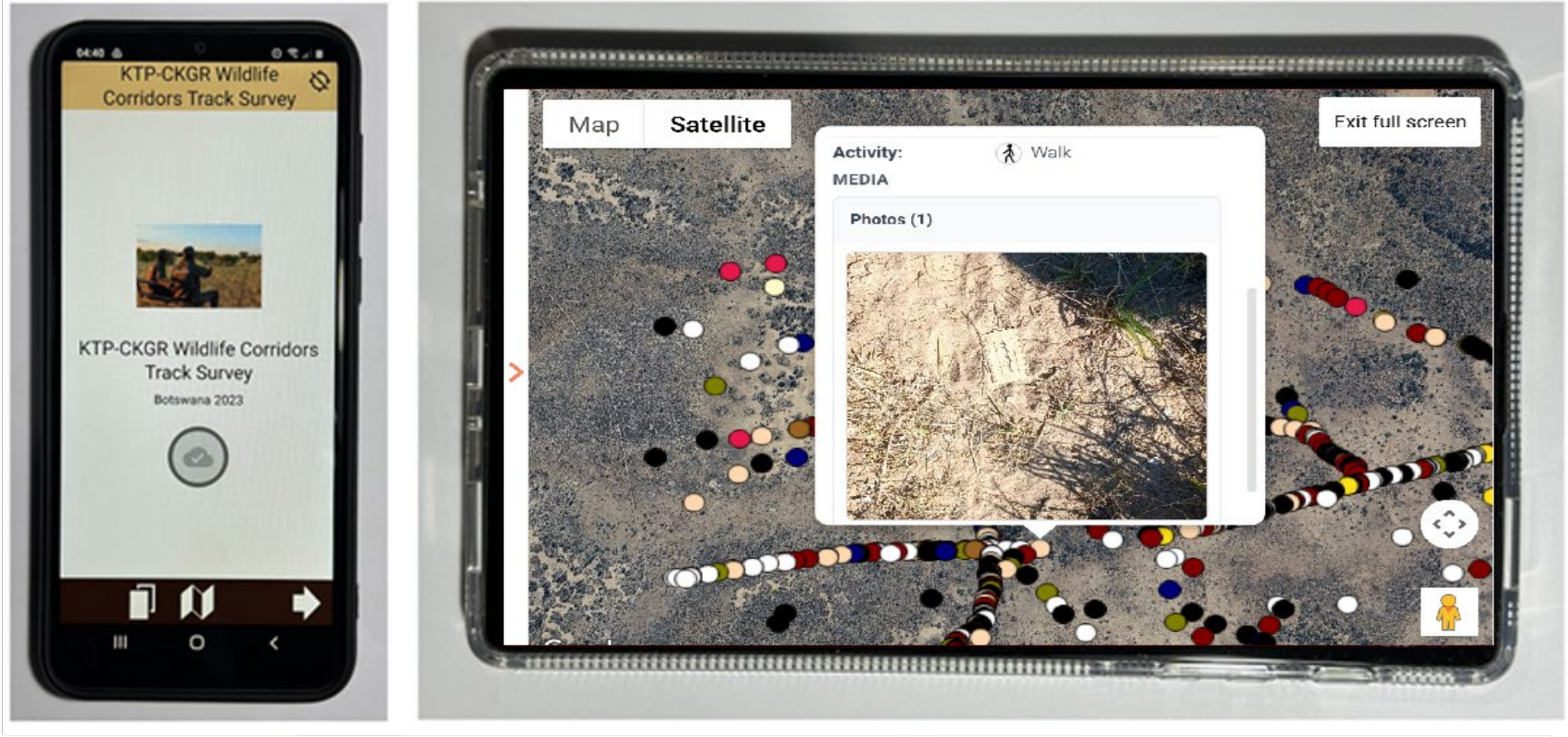


Affordable – mobile phones and tablets

Easy to Use by nonliterate expert trackers

Anyone can customise mobile application

CyberTracker Online Requires Minimal Hardware and Technical Support



Inexpensive Smartphones for data collection and Tablets to view data



View Data - Kalahari Biodiversity

Kalahari Biodiversity ▾

Hoof ▾

2025/01/01

2026/08/20

Search

Map view ▾

Export CSV ▾

Filters

Settings

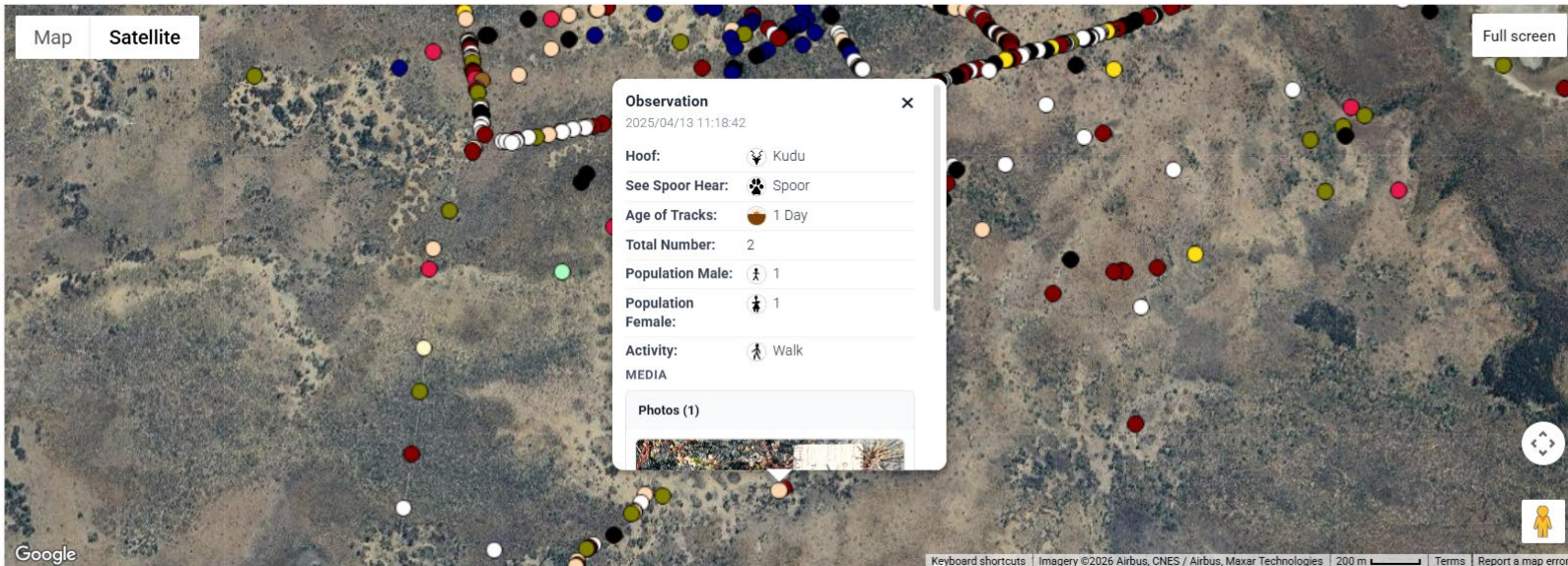
Close All

Y Observation Filters

- ☐ Type of Survey
 - ☐ Track & Sign Test
 - ☐ Spoor Transect
 - ☐ Tracking
 - ☐ Research
 - ☐ Ranger Patrol
 - ☐ Guide Visitors
 - ☐ Plant Foraging
 - ☐ Full Moon Count
 - ☐ UX Test
- ☐ Elephant Rhino Hippo

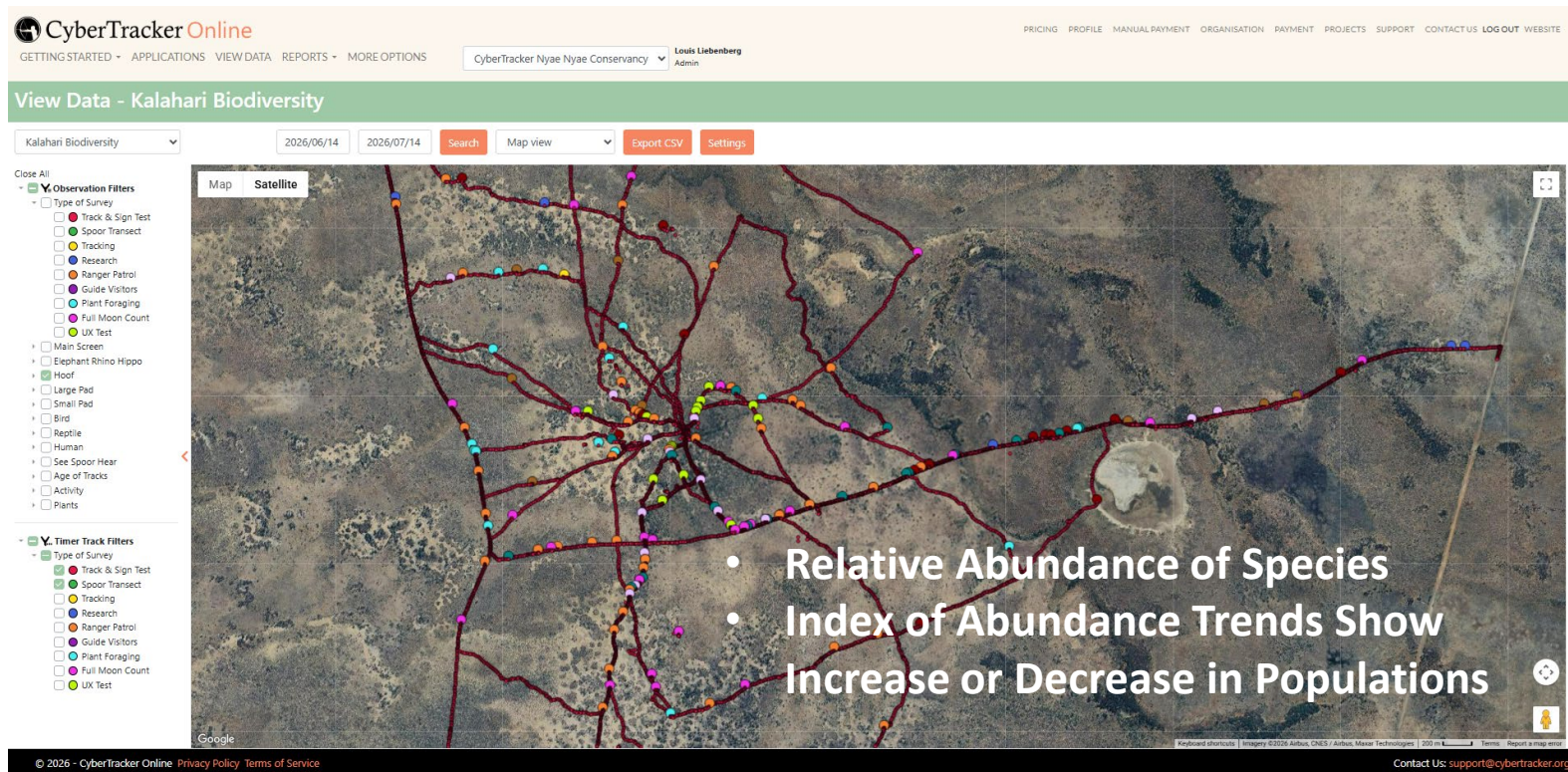
Hoof

- ☒ Eland
- ☒ Gemsbok
- ☒ Roan
- ☒ Red Hartebeest
- ☒ Wildebeest
- ☒ Kudu
- ☒ Impala
- ☒ Springbok



Nonliterate (or alate) trackers can view their own data displaying icons in map popups

Automatic Data Analysis using GPS Timer Tracks



Traditional Tracking and Remote Sensing

- Use Remote Sensing to identify Ecozones
- Tracking to Ground Truth Remote Sensing Data
- Remote Sensing at 1m to 30cm Resolution:
Trackers add data on Rare and Small Species,
Male/Female for large animals, Behaviour and
Interactions of Animals, etc
- Extrapolate to Areas not covered by Trackers to
develop Predictive Models, tested by Trackers in
an Iterative Feedback Process to Monitor
Changing Environments



Rare and Endangered Species Threatened by Climate Change



- Tracks of rare Pangolin
- Tracks of rare Small Spotted Cat - never observed in Nyae Nyae Conservancy before

Camera Traps to Verify Spoor Data

- Scientist are still not accepting animal track data as reliable
- Small Spotted Cat Specialist Group did not accept our discovery of tracks in Nyae Nyae Conservancy
- Need Camera Trap data to verify animal track data of Rare and Endangered Species
- Trackers use their knowledge of animal behaviour to place camera traps to capture photos of a specific animal





A New Sustainability for Indigenous Communities

- Indigenous Trackers (Men and Women) can be paid for Biodiversity Data they collect, resulting in Socio-Economic Benefits to Communities
- Communities empowered to Analyze their own data
- Greater independence and reduced dependency on outside consultants

UNESCO's tracker training helps safeguard Indigenous knowledge



Kalahari San Master Trackers share CyberTracker in 2025 with Hadzabe in Tanzania

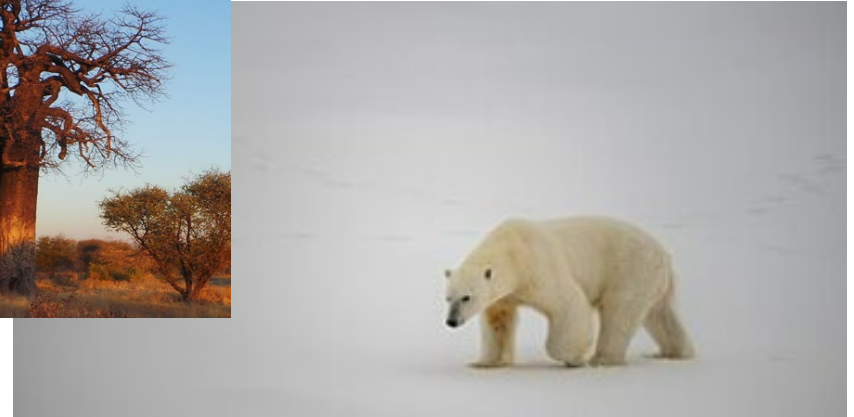
Indigenous Communities & Community Science

- Indigenous Communities share their knowledge with visitors
- Worldwide growth of tracking skills



Scientific Research

Researchers use CyberTracker to study chimpanzees, whales, polar bears, Antarctic sea birds, dolphins, baobab trees, wild dogs, and more...



Conservation Management

- CyberTracker played a critical role in the development of SMART and EarthRanger in large Protected Areas, but requires Technical Support
- New CyberTracker Online for Non-technical Users
- Numerous Small Protected Areas.
- Most Endangered Species occur outside the large Protected Areas



Beyond Communities & Biodiversity



Farming

CyberTracker used for
Integrated Pest
Management reduce the
need for pesticides



Forestry & Rewilding

CyberTracker used in
Agroforestry and tree
planting



Ebola/Diseases

CyberTracker used
from 2000 to 2003
to monitor the
spread of Ebola in
the Congo

AI and the Future of the Art of Tracking

- The Art of Tracking may be one of the last human skills that AI will be able to replicate (if ever). Rather, we need to develop AI that can augment indigenous trackers.
- Demis Hassabis, DeepMind: “Einstein Test” for AI? LLMs are unlikely to pass this test.
- Thomas Kuhn: Normal Science (based on accepted theory) vs *unexpected* novelty.
- Solution for Monitoring potential Ecological Disruption caused by Climate Change may be to combine creative Indigenous Tracking Expertise with Domain Specific World Models.





Thank you

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The Origin of Science

can be found at

<https://cybertracker.org/science/the-origin-of-science/>

Rolex Video: Following the Tracks

<https://www.rolex.org/environment/perpetual-planet/louis-liebenberg-cybertracker-online>



CyberTracker