

Reporting Summary

Nature Portfolio wishes to improve the reproducibility of the work that we publish. This form provides structure for consistency and transparency in reporting. For further information on Nature Portfolio policies, see our [Editorial Policies](#) and the [Editorial Policy Checklist](#).

Statistics

For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

n/a Confirmed

- | | | |
|-------------------------------------|-------------------------------------|--|
| ☐ | ☒ | The exact sample size (n) for each experimental group/condition, given as a discrete number and unit of measurement |
| ☐ | ☒ | A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly |
| ☒ | ☐ | The statistical test(s) used AND whether they are one- or two-sided
<i>Only common tests should be described solely by name; describe more complex techniques in the Methods section.</i> |
| ☒ | ☐ | A description of all covariates tested |
| ☒ | ☐ | A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons |
| ☐ | ☒ | A full description of the statistical parameters including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals) |
| ☒ | ☐ | For null hypothesis testing, the test statistic (e.g. F , t , r) with confidence intervals, effect sizes, degrees of freedom and P value noted
<i>Give P values as exact values whenever suitable.</i> |
| ☒ | ☐ | For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings |
| ☒ | ☐ | For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes |
| ☒ | ☐ | Estimates of effect sizes (e.g. Cohen's d , Pearson's r), indicating how they were calculated |

Our web collection on [statistics for biologists](#) contains articles on many of the points above.

Software and code

Policy information about [availability of computer code](#)

Data collection	Training, evaluation and testing datasets for deep-learning model were created (annotated, augmented and analysed) using Roboflow online platform. Dataset is available on https://github.com/obkorolev/penguin_iron_paper
Data analysis	Datasets were used to train deep-learning model for object detection. Hyperparameters of the model can be found on https://github.com/obkorolev/penguin_iron_paper . The model was obtained from https://github.com/tensorflow/models .

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Portfolio [guidelines for submitting code & software](#) for further information.

Data

Policy information about [availability of data](#)

All manuscripts must include a [data availability statement](#). This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A description of any restrictions on data availability
- For clinical datasets or third party data, please ensure that the statement adheres to our [policy](#)

The datasets generated during the current study and the code used to reproduce the results are available on https://github.com/obkorolev/penguin_iron_paper.

Human research participants

Policy information about [studies involving human research participants and Sex and Gender in Research](#).

Reporting on sex and gender

Use the terms *sex* (biological attribute) and *gender* (shaped by social and cultural circumstances) carefully in order to avoid confusing both terms. Indicate if findings apply to only one sex or gender; describe whether sex and gender were considered in study design whether sex and/or gender was determined based on self-reporting or assigned and methods used. Provide in the source data disaggregated sex and gender data where this information has been collected, and consent has been obtained for sharing of individual-level data; provide overall numbers in this Reporting Summary. Please state if this information has not been collected. Report sex- and gender-based analyses where performed, justify reasons for lack of sex- and gender-based analysis.

Population characteristics

Describe the covariate-relevant population characteristics of the human research participants (e.g. age, genotypic information, past and current diagnosis and treatment categories). If you filled out the behavioural & social sciences study design questions and have nothing to add here, write "See above."

Recruitment

Describe how participants were recruited. Outline any potential self-selection bias or other biases that may be present and how these are likely to impact results.

Ethics oversight

Identify the organization(s) that approved the study protocol.

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

☐ Life sciences ☐ Behavioural & social sciences ☒ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see [nature.com/documents/nr-reporting-summary-flat.pdf](https://www.nature.com/documents/nr-reporting-summary-flat.pdf)

Ecological, evolutionary & environmental sciences study design

All studies must disclose on these points even when the disclosure is negative.

Study description

Included in this study

Research sample

Guano samples collection (n=23) from three different substrates: from soil, ice and from a specific guano collector. Drone imagery collected over the Vapour Col colony at different heights.

Sampling strategy

Fieldwork consisted on guano samples collection (n=23) from three different substrates: randomly from soil and ice and from a specific guano collector placed in the colony 24 hours prior to sampling. Drone imagery was collected following a sweeping flying route along the entire extension of the colony. Refer to Methods section for further information about the flight parameters.

Data collection

The data collection is described in Methods section.

Timing and spatial scale

The field data collection took place from January 28, to February 8, 2021 for guano samples and February 8, 2021 for drone footage, in Vapour Col Chinstrap penguin rookery, Deception Island, South Shetland Islands, Antarctica.

Data exclusions

Neither of guano samples or drone footage data were excluded in this study. Refer to Methods section for detailed explanation about data processing.

Reproducibility

This study provides detailed information that, with the code, training data, and iron concentration in guano samples provided as Available Data, allow this study to be replicated if desired.

Randomization

Samples were randomly collected from soil (n=12) and ice (n=6) substrates. Guano collectors were placed randomly in areas with highest penguin densities (avoiding disturbance) to ensure sample collection (n=5).

Blinding

Blinding was not used for sample collection as samples specifically were required to be from three available substrates present in the region, which however were randomly acquired. All data was used for further analysis.

Did the study involve field work? ☒ Yes ☐ No

Field work, collection and transport

Field conditions	During sample collection air temperature ranged from 0°C to 4°C and occasionally it rained and snowed.
Location	Vapour Col colony (62°59'29" S, 60°43'32" W), Deception Islands, South Shetland Islands.
Access & import/export	All samples were transported to Spain under the authorization of the Spanish Polar Committee.
Disturbance	To minimize penguin disturbance caused by drones, the minimum flying height was 30 m, which according to the existing literature represents the minimum height where no disturbance effects on most terrestrial seabirds were observed.

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

Methods

n/a	Involved in the study
☒	☐ Antibodies
☒	☐ Eukaryotic cell lines
☒	☐ Palaeontology and archaeology
☐	☒ Animals and other organisms
☒	☐ Clinical data
☒	☐ Dual use research of concern

n/a	Involved in the study
☒	☐ ChIP-seq
☒	☐ Flow cytometry
☒	☐ MRI-based neuroimaging

Animals and other research organisms

Policy information about [studies involving animals](#); [ARRIVE guidelines](#) recommended for reporting animal research, and [Sex and Gender in Research](#)

Laboratory animals	The study did not involve laboratory animals
Wild animals	Aerial footage was taken using drone over the colony, flying at a minimum 30 m height, thus avoiding disturbance to the penguins.
Reporting on sex	Findings do not apply to a specific sex. Guano samples and aerial footage covered both penguin genders of a wide spectrum of development stages. Permissions for guano and drone footage data collection were granted by the Spanish Polar Committee.
Field-collected samples	Guano samples collection (n=23) from three different substrates: from soil, ice and from a specific guano collector. Drone imagery collected over the Vapour Col colony at different heights.
Ethics oversight	All sampling procedures were performed under the authorization of the Spanish Polar Committee

Note that full information on the approval of the study protocol must also be provided in the manuscript.