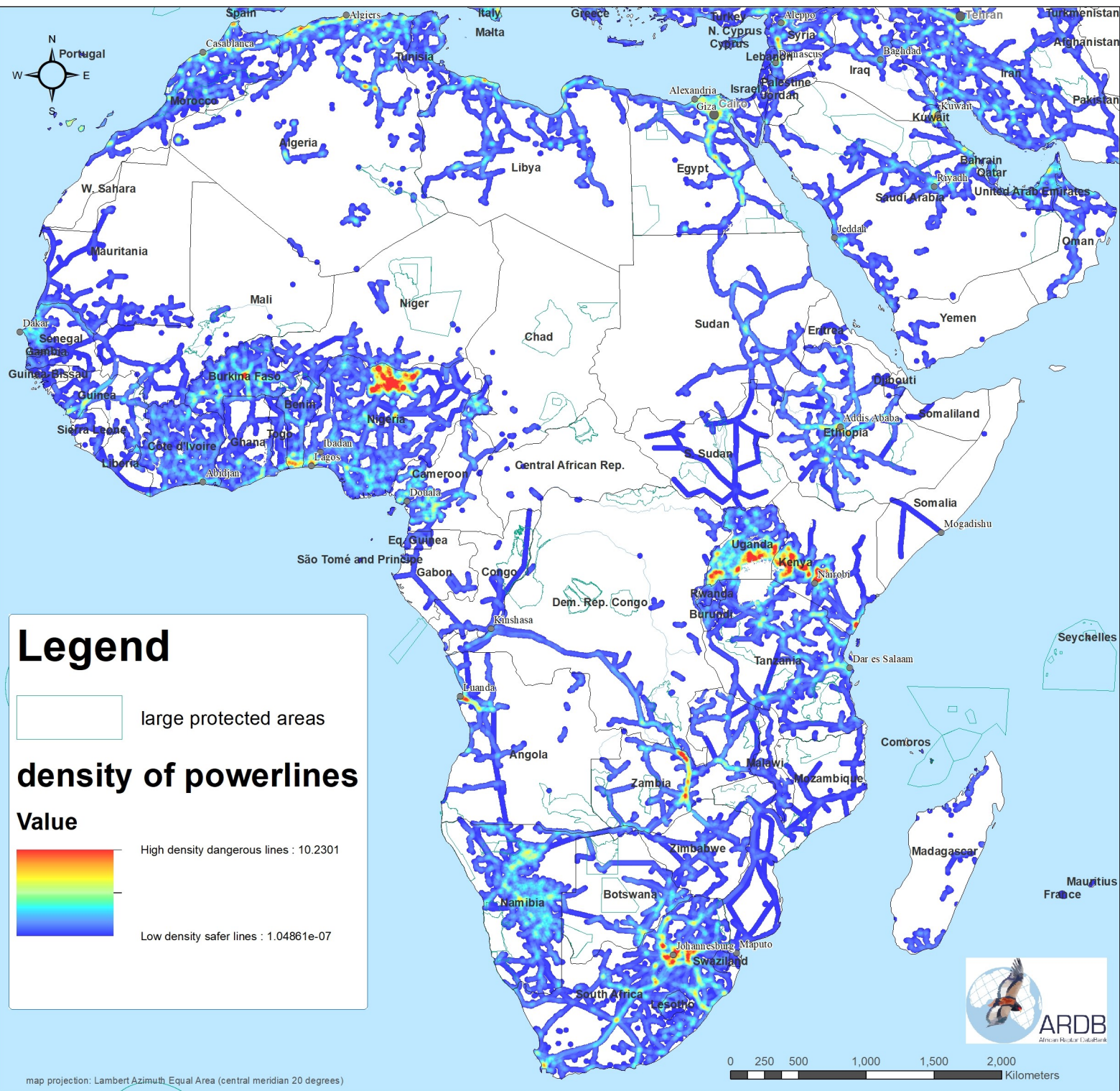


## METHODS

As before, this layer representing exposure to people is computed from three input layers: traveltime to cities (>50k), human population density and levels of protection derived as dollar spend per km<sup>2</sup> within protected areas. Each of these layers can have extremely high maxima so we used log values of each to combine in order to show the subtle changes in rural areas across Africa and Arabia. We were able to access new data for the entire modelled study area of Africa and Arabia, extending these data into the whole of the Arabian peninsula and nearby Asian countries (principally Turkmenistan). For traveltime to cities we tested new datasets developed for the World Bank by Habitat Info and also a more recent (2015) iteration by Nelson for traveltime to any urban areas but we found that the original traveltime data showed the best road network resolution. (<http://bioval.jrc.ec.europa.eu/products/gam/download.htm> - Nelson 2008). For human population density we update this layer to 2020 estimates from three sources: Gridded Population of the World v4 was used as a starter layer but was superseded by AfrPOP continental datasets for Africa and for Asia because of they are more finely modelled datasets. All three had been corrected to UNPOP population sizes for nations. We accessed the most recent data on protected areas from UNEP-WCMC (2023) and updated dollar spend per km<sup>2</sup> within these protected areas from previous 1990s values (James et al. 1999) to 2001-2008 values using national biodiversity spend data from Waldron et al. (2013) which include aid funding as well as domestic and other funding. We filled in missing values by literature search for Turkey, Turkmenistan, and Libya. The three datasets were reclassified to a scale of 1-9 and combined as (traveltime + levels of protection) - population density. In the present study we inverted the values and reclassified into the following four classes: 0 = no exposure threat, 1 = exposure threat present, 2 = medium exposure threat, and 3 = high exposure threat. So the lowest threat levels of zero are found in well protected areas with low population density and far from cities, highest threat levels are encountered outside protected areas, with high population density and readily accessible to cities.

**CREDITS:** Coordination: Andre Botha (EWT), Ralph Buij (Wageningen University & Research), Corinne Kendall (North Carolina Zoo), Ara Monadjem (University of Swaziland). Data collation: Lutfur Rahman & Lou Luddington (Habitat Info), Chris McClure, Evan Buechley, Leah Dunn (TPF), Analysis & map production: Leah Dunn (TPF) & Rob Davies (Habitat Info). Finance: The vulture surveys, data gathering and habitat and threat modeling were funded by the following organisations through Wageningen University & Research (which also contributed resources): Dutch Ministry of Economic Affairs, WWF-Netherlands, UNEP-CMS Raptors MoU, North Carolina Zoo, Fondation LePal Nature, Quagga Foundation, Stichting Vogelpark Avifauna, Stichting Koninklijke Rotterdamse Diergaarde, Detroit Zoological Society, and Stichting Wildlife. Through The Peregrine Fund this project benefited greatly from access to the ESRI Grant Scheme. Data on vultures were contributed or facilitated by the following individuals: Ylaine D'Abbe, Hicham Azafar, Laila Bahas El Din, Neil & Liz Baker, Clive R. Barrow, Keith Bickelstein, Claire Bradbridge, Andy Branfield, Erik & Asaph Brothugh, Joost Brouwer, Chris Brown, Evan Buechley, Ralph Buij & Barbara Groes, Andre Botha, Mike Cadman, Alazar Daka Rulo, Rob Davies, Maria Deskmann, Nina Farwig, Oliver Fox, Toby Galligan, Beckie Garbett, Ashwell Glasson, Roy Harel, Stratton Halfield, Ohad Hatzofe, Joseph Heymans, Constant Hoogstad, Mawdo J. Jallow, Walter Jubber, Gregory Kaltenecker, Adam Kane, Chris Kelly, Alan & Meg Kemp, Corinne Kendall, Holger & Claire Kolberg, Bernard & Anlie Madden, Glyn Maude, John Mendelsohn, Mike McGrady, Ara Monadjem, Campbell Munn, Ran Nathan, Karin Nelson, Sloyan Nikolov, Darcy Ogada, Steffen Oppel, Louis Phipps, Bram Ploet, Thomas Rabell, Sascha Rosner, Lizanne Roxburgh, Volker Salewski, Andrea Santangel, Dana Schabo, Orr Spiegel, Lindy Thompson, Simon Thomsen, Dirk van Stuyvenberg, Rien van Wijk, Munir Virani, Tim Wachter, Kerri Volter (VULPRO) and numerous other African Raptor Databank observers, and by the following organisations: AFRICAN RAPTOR DATABANK, AFRICAN IMPACT, BIRDLIFE INTERNATIONAL & NATURESERVE, BIRDLIFE BULGARIA (BSBP), BIRDLIFE TUNISIA (AAO), BOISE STATE UNIVERSITY, CITES (MIKE DATABASE), ENDANGERED WILDLIFE TRUST, HAWK CONSERVANCY TRUST, HAWK MOUNTAIN SANCTUARY, INTERNATIONAL UNION FOR CONSERVATION OF NATURE (AFRICAN ELEPHANT DATABASE & REDLIST MAPS), ISRAEL NATURE & PARKS AUTHORITY, NATURAL HISTORY MUSEUM (TRING), MOVEBANK, NIKOLKO-KOBA CITIZEN SCIENCE PROJECT, NORTH CAROLINA ZOO, RAPTORS BOTSWANA, RARE AND ENDANGERED SPECIES TRUST, ROYAL SOCIETY FOR THE PROTECTION OF BIRDS, TANZANIAN BIRD ATLAS, THE PEREGRINE FUND, UNIVERSITY OF UTAH, VULPRO, WEST AFRICAN BIRD DATABASE, WILDLIFE ACT and WILDLIFE CONSERVATION SOCIETY.





**METHODS:**

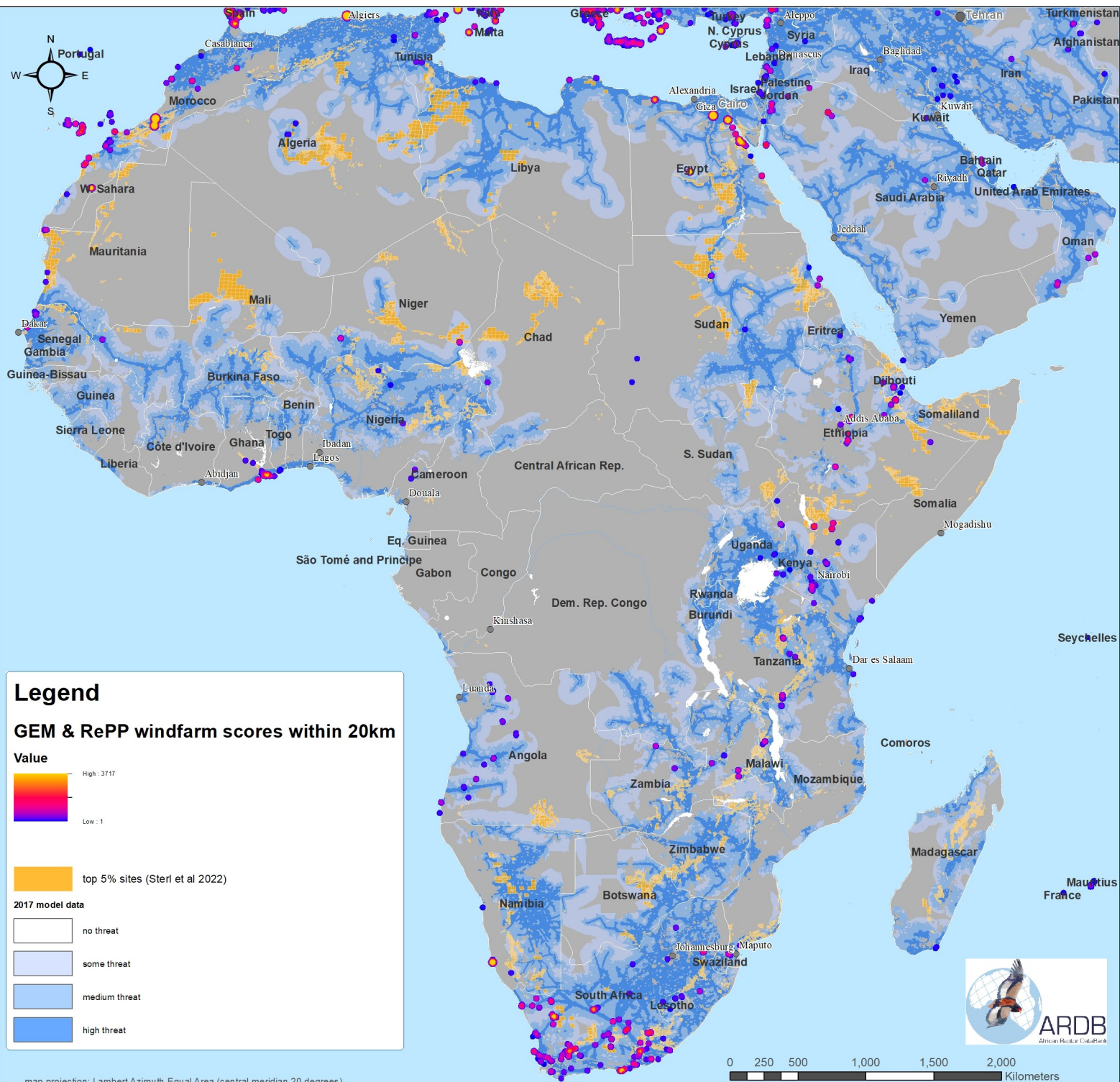
We accessed new electricity grid data and compared these by intersection to our 2017 sources: Africa Infrastructure Country Diagnostic AICD, Foster & Brice-Garmendia 2010; data on powerlines accessed from OpenStreet Map for North Africa and Arabia (OpenStreetMap contributors 2015); the Digital Atlas of Namibia published by the ACACIA (Arid Climate, Adaptation and Cultural Innovation in Africa) project. The World Bank data catalogue offers an updated AICD version but we found the Electricity Grid Africa dataset from JRC (Kakoulaki & Moner-Girona 2020) to be the far superior coverage for the continent. These data have been more rigorously obtained from a variety of sources, including OSM, for the purpose of assessing local electricity supplies to medical centres across Africa so they offer more detail than the other datasets. We used their data in preference but imported our previous data for several locations in Africa and for the Middle East & Europe where the JRC dataset offers no coverage. As before, all powerlines were given weighting scores. Those without useable attribute information on KV or status were given a median score of 3; existing or under construction powerlines > 40kv carried a score of 2; while powerlines that were planned, missing, proposed, under study and > 40kv were given lowest scores of 1; a maximum score of 5 was attributed to any existing powerlines of voltage < 40KV which are considered to be of greatest threat to raptors, and a value of 4 was allocated to <40kv lines under construction; any powerlines which were planned and of voltage < 40kv carried a median score of 3 but we deleted the trans continental planned line which appears unlikely to happen. We conducted a line density analysis per km2 in ArcGIS using the score values as the population field and a search radius of 20km. These data are shown unclassified for any cells within 20km of a powerline ranging from blue for low density of relatively safe lines through to red for high density of dangerous lines to raptors. This presentation helps visualise hotspots of electrocution threat.

Kakoulaki, Georgia; Moner-Girona, Magda (2020). Electricity grid Africa. European Commission, Joint Research Centre (JRC) [Dataset] PID: <https://data.europa.eu/89h/624c6e71-3b9c-4f48-8c67-645911798d41>

<https://datacatalog.worldbank.org/search/dataset/0040465/Africa---Electricity-Transmission-and-Distribution-Grid-Map>

<http://africagrid.energydata.info/>

**CREDITS:** Coordination: Andre Botha (EWT), Ralph Bui (Wageningen University & Research), Corinne Kendall (North Carolina Zoo), Ara Monadjem (University of Swaziland). Data collation: Lutfur Rahman & Lou Luddington (Habitat Info), Chris McClure, Evan Buechley, Leah Dunn (TPF), Analysis & map production: Leah Dunn (TPF) & Rob Davies (Habitat Info). Finance: The vulture surveys, data gathering and habitat and threat modeling were funded by the following organisations through Wageningen University & Research (which also contributed resources): Dutch Ministry of Economic Affairs, WWF-Netherlands, UNEP-CMS Raptors MoU, North Carolina Zoo, Fondation LePal Nature, Quagga Foundation, Stichting Vogelpark Avifauna, Stichting Koninklijke Rotterdamse Diergaarde, Detroit Zoological Society, and Stichting Wildlife. Through The Peregrine Fund this project benefited greatly from access to the ESRI Grant Scheme. Data on vultures were contributed or facilitated by the following individuals: Yimn D Abadie, Hicham Azafzal, Laila Bahash El Di, Neil & Liz Baker, Clive R Barlow, Keith Bickelstein, Claire Brackenridge, Andy Branfield, Erik & Asaph Brohaugh, Joost Brouwer, Chris Brown, Evan Buechley, Ralph Bui & Barbara Grose, Andre Botha, Mike Cadman, Alazar Daka Rulo, Rob Davies, Maria Deskmann, Nina Farwig, Oliver Fox, Toby Galligan, Beckie Garbett, Ashwell Glasson, Rof Harel, Stratton Halfield, Ohad Hatzofe, Joseph Heymans, Constant Hoogstad, Mawdo J Jallow, Walter Jubbey, Gregory Kallenecker, Adam Kane, Chns Kelly, Alan & Meg Kemp, Corinne Kendall, Holger & Claire Kolberg, Bernard & Anlie Madden, Glyn Maude, John Mendelsohn, Mike McGrady, Ara Monadjem, Campbell Mum, Ran Nathan, Karin Nelson, Sloyan Nikolov, Darcy Ogada, Steffen Oppel, Louis Phipps, Bram Plot, Thomas Rabel, Sascha Rosner, Lizanne Roxburgh, Roger Salewski, Andrea Santangeli, Dana Schabo, Orr Spiegel, Lindy Thompson, Simon Thomsen, Dirk van Stuyvenberg, Rien van Wijk, Munir Yran, Tim Wachter, Kerri Voller (VULPRO) and numerous other African Raptor Databank observers, and by the following organisations: AFRICAN RAPTOR DATABANK, AFRICAN IMPACT, BIRDLIFE INTERNATIONAL & NATURESERVE, BIRDLIFE BULGARIA (BSBP), BIRDLIFE TUNISIA (AAO), BOISE STATE UNIVERSITY, CITES (IUCN DATABASE), ENDANGERED WILDLIFE TRUST, HAWK CONSERVANCY TRUST, HAWK MOUNTAIN SANCTUARY, INTERNATIONAL UNION FOR CONSERVATION OF NATURE (AFRICAN ELEPHANT DATABASE & REDLIST MAPS), ISRAELI NATURE & PARKS AUTHORITY, NATURAL HISTORY MUSEUM (TRING), MOVEBANK, NIKOLO-KOBA CITIZEN SCIENCE PROJECT, NORTH CAROLINA ZOO, RAPTORS BOTSWANA, RARE AND ENDANGERED SPECIES TRUST, ROYAL SOCIETY FOR THE PROTECTION OF BIRDS, TANZANIAN BIRD ATLAS, THE PEREGRINE FUND, UNIVERSITY OF UTAH, VULPRO, WEST AFRICAN BIRD DATABASE, WILDLIFE ACT AND WILDLIFE CONSERVATION SOCIETY.



**METHODS:**

In this map we include two new datasets overlaying our original 2017 model layer for turbine collision risk (which is shown in shades of blue). The first is another wind farm suitability model by Steri et al. (2022) which shows in pale orange the top 5% best areas for wind farm development for each suitable African country. Their model uses more recent and more complete data than our 2017 model and takes account of further aspects of supply and demand and e.g. population size of closest city. These areas matched well with our 2017 highest suitability predictions. Upon this, in bold localised colours we show empirical data we have compiled on existing, planned and under construction wind farm locations. These locations, along with status and the power capacity of each wind farm are compiled from two sources: Global Wind Power Tracker data (2023 release for global sites) supplemented by RePP data for the African continent (Peters et al. 2023). For each wind farm location we estimated the footprint area of the wind farm on the basis that a 2mw turbine within a wind farm placement usually occupies a footprint of 0.5km<sup>2</sup>. We calculated the radius of the wind farm if it were circular as the square root of area/π and buffered the points by this radius to obtain a polygon coverage of the wind farms. We gave the following scores to wind farms on the basis of their status: 5 for existing and operational, 4 for under construction, 3 for planned, proposed, and 1 for retired or not operational. We then converted the polygons to rasters using the score field for value and we summed the scores of all grid cells within a 20km radius to provide an indication of collision risk from these data representing actual wind farms.

Steri, S., Hussain, B., Miketa, A. et al. An all-Africa dataset of energy model "supply regions" for solar photovoltaic and wind power. Sci Data 9, 664 (2022). <https://doi.org/10.1038/s41597-022-01786-5>

<https://www.nature.com/articles/s41597-022-01786-5#data-availability>

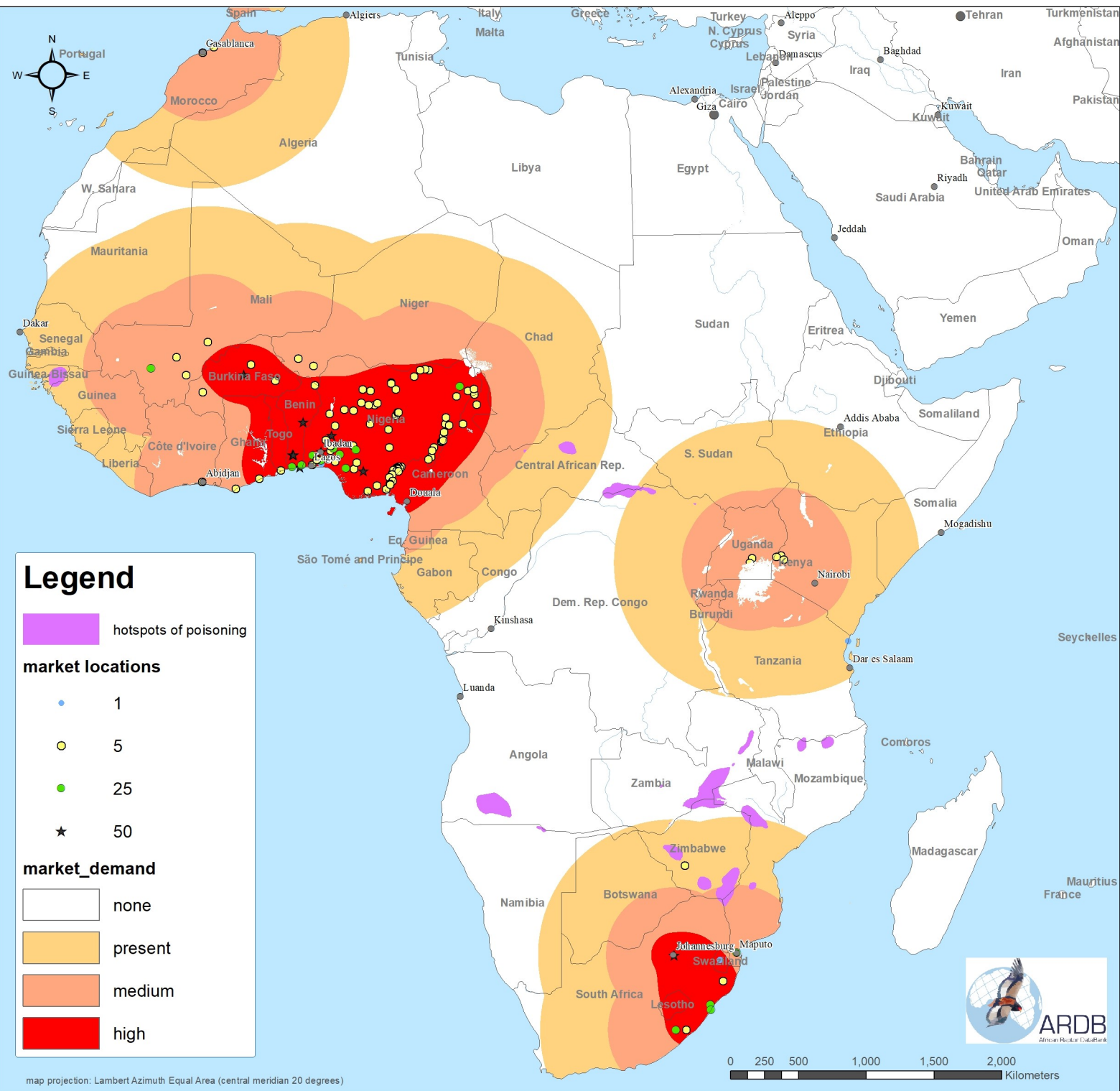
"Global Wind Power Tracker, Global Energy Monitor, May 2023 release."

<https://globalenergymonitor.org/projects/global-wind-power-tracker/>

Peters, R., Berlekamp, J., Tockner, K. et al. RePP Africa – a georeferenced and curated database on existing and proposed wind, solar, and

**CREDITS:** Coordination: Andre Botha (EWT), Ralph Buij (Wageningen University & Research), Corinne Kendall (North Carolina Zoo), Ara Monadjem (University of Swaziland). Data collation: Lutfur Rahman & Lou Luddington (Habitat Info), Chris McClure, Evan Buechley, Leah Dunn (TPF), Analysis & map production: Leah Dunn (TPF) & Rob Davies (Habitat Info). Finance: The vulture surveys, data gathering and habitat and threat modeling were funded by the following organisations through Wageningen University & Research (which also contributed resources): Dutch Ministry of Economic Affairs, WWF-Netherlands, UNEP-CMS Raptors MoU, North Carolina Zoo, Fondation LePal Nature, Quagga Foundation, Stichting Vogelpark Avifauna, Stichting Koninklijke Rotterdamse Diergaarde, Detroit Zoological Society, and Stichting Wildlife. Through The Peregrine Fund this project benefited greatly from access to the ESRI Grant Scheme. Data on vultures were contributed or facilitated by the following individuals: Ylme D Abadie, Hicham Azafar, Laila Bahari El Dr, Neil & Liz Baker, Olive R Barlow, Keith Beldstein, Claire Bracebridge, Andy Branfield, Erik & Asaph Brohaugh, Joost Brouwer, Chris Brown, Evan Buechley, Ralph Buij & Barbara Grose, Andre Botha, Mike Cadman, Alister Daka Rulo, Rob Davies, Maria Deskmann, Nina Farwig, Oliver Fox, Toby Galligan, Beckie Garbett, Ashwell Glasson, Roy Harel, Stratton Halfield, Ohad Hatzofe, Joseph Heymans, Constant Hoogstad, Mawdo J Jallow, Walter Jubber, Gregory Kallenecker, Adam Kane, Chris Kelly, Alan & Meg Kemp, Corinne Kendall, Holger & Claire Kolberg, Bernard & Anjie Madden, Glyn Maude, John Mendelsohn, Mike McGrady, Ara Monadjem, Campbell Mum, Ran Nathan, Karin Nelson, Sloyan Nikolov, Darcy Ogada, Steffen Oppel, Louis Phipps, Bram Pilot, Thomas Rabiel, Sascha Rosner, Lizanne Roxburgh, Volker Salewski, Andrea Santangeli, Dana Schabo, Orr Spiegel, Lindy Thompson, Simon Thomsett, Dirk van Stuyvenberg, Rien van Wijk, Munir Virani, Tim Wachter, Kerri Volter (VULPRO) and numerous other African Raptor Databank observers, and by the following organisations: AFRICAN RAPTOR DATABANK, AFRICAN IMPACT, BIRDLIFE INTERNATIONAL & NATURESERVE, BIRDLIFE BULGARIA (BSBP), BIRDLIFE TUNISIA (AAO), BOISE STATE UNIVERSITY, CITES (MKE DATABASE), ENDANGERED WILDLIFE TRUST, HAWK CONSERVANCY TRUST, HAWK MOUNTAIN SANCTUARY, INTERNATIONAL UNION FOR CONSERVATION OF NATURE (AFRICAN ELEPHANT DATABASE & REDLIST MAPS), ISRAEL NATURE & PARKS AUTHORITY, NATURAL HISTORY MUSEUM (TRING), MOVEBANK, NIKOLO-KOBA CITIZEN SCIENCE PROJECT, NORTH CAROLINA ZOO, RAPTORS BOTSWANA, RARE AND ENDANGERED SPECIES TRUST, ROYAL SOCIETY FOR THE PROTECTION OF BIRDS, TANZANIAN BIRD ATLAS, THE PEREGRINE FUND, UNIVERSITY OF UTAH, VULPRO, WEST AFRICAN BIRD DATABASE, WILDLIFE ACT and WILDLIFE CONSERVATION SOCIETY.

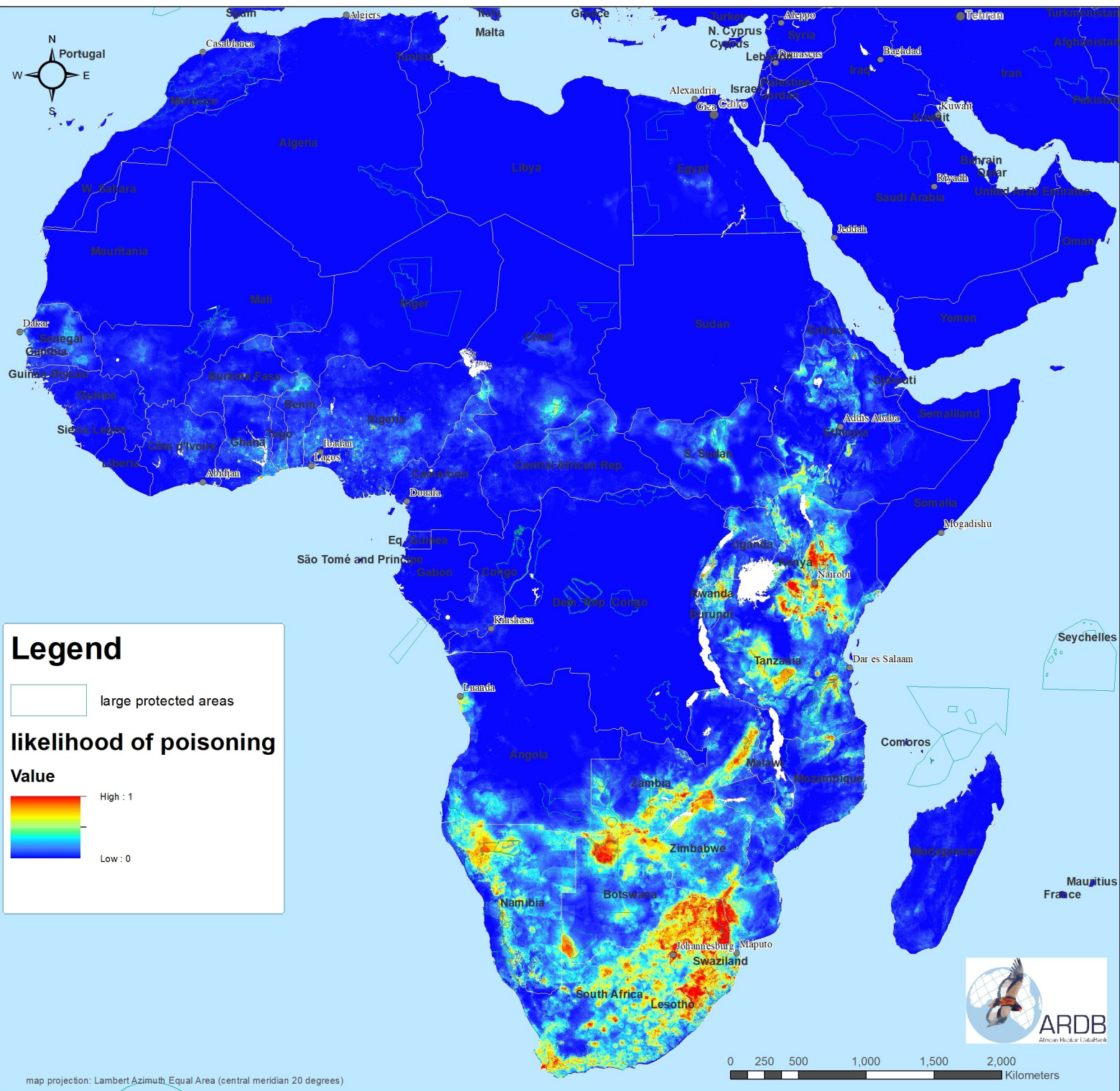




For the original map in 2017 we digitized and georeferenced the locations of 125 traditional medicine markets. Lou Luddington assisted with this work. These were mainly in West & Central Africa provided by Buij et al. (2016) but we supplemented these with several known locations for Southern and Eastern Africa from Williams et al. (2014), McKean et al. (2013) and other sources (Ogada, Thomsett, Monadjem, Pomeroy, Baker & Baker in litt.). We also tabulated information on the size of these markets. We do not yet have a systematic way of measuring this but we looked at the number of stalls with vulture products and the number of vultures traded over time periods (McKean et al. 2013). We classed markets as non-trading in vulture parts (weighted 1), small (weighted 5), medium (weighted 25) or large (weighted 50) – these weights were roughly based on the frequency histogram of number of stalls with vulture products. We conducted a kernel density analysis across Africa measuring the density of markets within a 500km radius and using the weights as a population field. The resultant dataset was then reclassified into four threat levels: 0 = no threat, 1 = threat present, 2 = medium threat / demand, 3 = high threat / demand. For the 2023 update we also ran the poisoning likelihood model (see method for map T1) but using only records of poisoning where the heads of carcasses had been removed and any other indications for belief-based use (n=116). We tried various methods to overcome biases in the recording effort. The latest records (since 1976) from the GRIN database of raptor provided a convenient bias layer for incorporation into the maxent model. This run of the model yielded Area Under the Curve (AUC) value of 0.903 for test records (15% of data were held back for evaluation purposes). Of the explanatory variables sheep density made the largest contribution to this model followed by treecover (curiously more poisoning in areas where sheep are absent and tree density low). There are some indications that poisoning for belief-based use is more prevalent in highly populous areas, close to protected areas. The model results were granular so we ran a focal statistics on the results calculating sum of values within 50km. We show the top half of these results as magenta areas on the map to indicate predictions of belief-based poisoning hotspots which are mostly disparate from market concentrations.

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**METHODS:** The African poisonings database has been compiled, geo-referenced and maintained by the Endangered Wildlife Trust (Lizanne Roxburgh & Andre Botha), Habitat Info and The Peregrine Fund (Darcy Ogada). Between 2017 and 2023 this database (all species) has grown from 444 to 2369 records. As before we conducted an inductive modelling exercise using the same 97 explanatory variables and Maxent software that were used in the vulture distribution modelling in 2017. The result was a poisoning likelihood map that indicated very strong likelihood of poisoning in Southern and Eastern Africa with little likelihood in Western Africa where several thousand vultures have been reported poisoned at a single location. We were concerned that there may be observer bias in the poisoning location gathering exercise because many of these data are collected by wildlife rangers and many are trained and deployed in southern and Eastern regions. We addressed the possibility of observer bias in the data in a number of ways. We tried replicating point location by the number of vultures poisoned at that location but this amplified bias effects. We created a representation layer for observer effort from the total number of recent sightings of birds of prey from the GRIN database representing the activities of good observers across the continent. We rarefied the poisoning locations data by only using records that were at least 10km apart. Our most satisfactory model results were finally obtained by using only the records of vultures and other raptors (884 records) and by restricting the explanatory variables to 50 which represented anthropogenic effects (Southern and Eastern Africa comprise the Afrotropical belt with shared physiognomic and climatic factors so these non-anthropogenic variables may have been contributing to the original bias). This run of the model yielded better results than previously with Area Under the Curve (AUC) value of 0.93 for test records (15% of data were held back for evaluation purposes). Of the explanatory variables % Non-Christian made the largest contribution to this model (more poisoning in Christian areas, previously ranked third), followed by distance to any protected area (which also had the highest permutation importance, more poisoning close to protected areas), and then by density of fires within 50km (also high permutation importance) – this is perhaps a good indicator of poaching activity – which after grassland cover is followed by GDP per km<sup>2</sup> with high permutation importance indicating more poisoning in poverty stricken areas.

**CREDITS:** Coordination: Andre Botha (EWT), Ralph Buij (Wageningen University & Research), Corinne Kendall (North Carolina Zoo), Ara Monadjem (University of Swaziland). Data collation: Lutfur Rahman & Lou Luddington (Habitat Info), Chns McClure, Evan Buechley, Leah Dunn (TPF), Analysis & map production: Leah Dunn (TPF) & Rob Davies (Habitat Info). Finance: The vulture surveys, data gathering and habitat and threat modeling were funded by the following organisations through Wageningen University & Research (which also contributed resources): Dutch Ministry of Economic Affairs, WWF-Netherlands, UNEP-CMS Raptors MoU, North Carolina Zoo, Fondation LePal Nature, Quagga Foundation, Stichting Vogelpark Avifauna, Stichting Koninklijke Rotterdamse Diervogel, Detroit Zoological Society, and Stichting Wildlife. Through The Peregrine Fund this project benefited greatly from access to the ESRI Grant Scheme. Data on vultures were contributed or facilitated by the following individuals: Ylme D Abadie, Hichem Azafzal, Laila Bahaa El Din, Neil & Liz Baker, Clive R Barlow, Keith Bickelstein, Claire Brassbridge, Andy Branfield, Erik & Asaph Brohaugh, Joost Brouwer, Chris Brown, Evan Buechley, Ralph Buij & Barbara Groen, Andre Botha, Mike Cadman, Alazet Daka Rulo, Rob Davies, Maria Deskmann, Nina Farwig, Oliver Fox, Toby Galligan, Beckie Garbett, Ashwell Glasson, Roy Harel, Stratton Halfield, Ohad Hatzofe, Joseph Heymans, Constant Hoogstad, Mawdo J Jallow, Walter Jubber, Gregory Kaltenecker, Adam Kane, Chns Kelly, Alan & Meg Kemp, Corinne Kendall, Holger & Claire Kolberg, Bernard & Anlie Madden, Glyn Maude, John Mendelsohn, Mike McGrady, Ara Monadjem, Campbell Mum, Ran Nathan, Karin Nelson, Sloyan Nikolov, Darcy Ogada, Steffen Oppel, Louis Phipps, Bram Plot, Thomas Rabel, Sascha Rosner, Lizanne Roxburgh, Volker Salewski, Andrea Santangeli, Dana Schabo, Orr Spiegel, Lindy Thompson, Simon Thomsen, Dirk van Stuyvenberg, Rien van Wijk, Munir Yran, Tim Wacher, Kerri Volter (VULPRO) and numerous other African Raptor Databank observers, and by the following organisations: AFRICAN RAPTOR DATABANK, AFRICAN IMPACT, BIRDLIFE INTERNATIONAL & NATURESERVE, BIRDLIFE BULGARIA (BSPB), BIRDLIFE TUNISIA (AAO), BOISE STATE UNIVERSITY, CITES (MIKE DATABASE), ENDANGERED WILDLIFE TRUST, HAWK CONSERVANCY TRUST, HAWK MOUNTAIN SANCTUARY, INTERNATIONAL UNION FOR CONSERVATION OF NATURE (AFRICAN ELEPHANT DATABASE & REDLIST MAPS), ISRAEL NATURE & PARKS AUTHORITY, NATURAL HISTORY MUSEUM (TRING), MOVEBANK, NIKOLKO-KOBA CITIZEN SCIENCE PROJECT, NORTH CAROLINA ZOO, RAPTORS BOTSWANA, RARE AND ENDANGERED SPECIES TRUST, ROYAL SOCIETY FOR THE PROTECTION OF BIRDS, TANZANIAN BIRD ATLAS, THE PEREGRINE FUND, UNIVERSITY OF UTAH, VULPRO, WEST AFRICAN BIRD DATABASE, WILDLIFE ACT AND WILDLIFE CONSERVATION SOCIETY.

