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LIVESTOCK PRODUCTION PROGRAMME



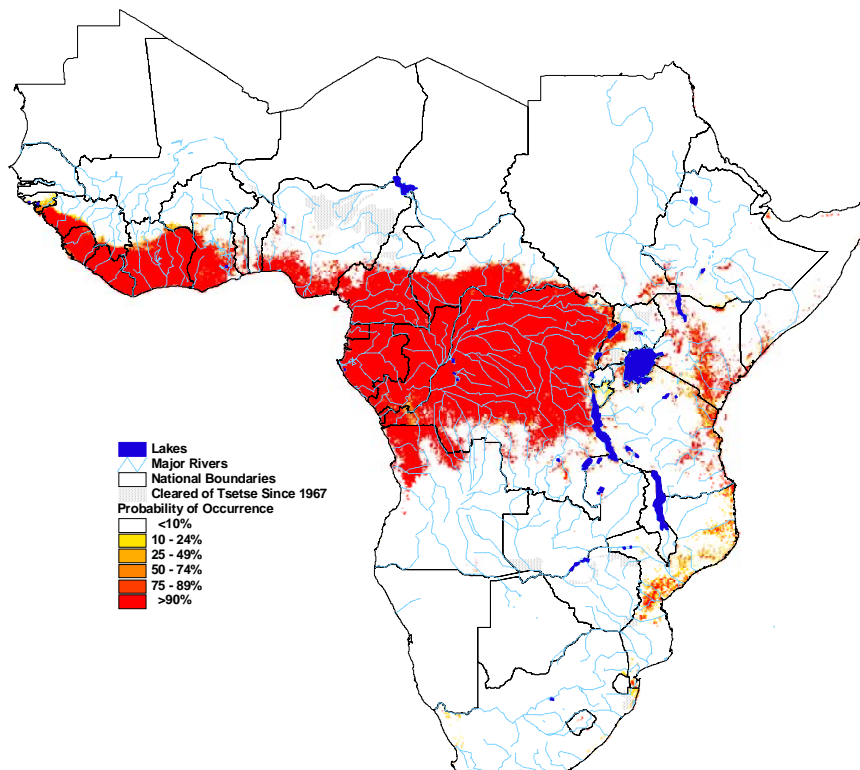
Department For
International
Development



ANIMAL HEALTH PROGRAMME

Food and Agriculture Organisation of the United Nations
Viale delle Terme di Caracalla, 00100 Rome, Italy
CONSULTANTS' REPORT

PREDICTED DISTRIBUTIONS OF TSETSE IN AFRICA



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Trypanosomiasis And Land-use in Africa

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Cover Illustration

The figure shows the predicted distribution of the Fusca Group, as presented on a poster produced by ERGO Ltd and TALA, for the Animal Health Programme of the UK Department for International Development, London and the Food and Agriculture Organisation of the United Nations

Copies are available from FAO AGAH and AHP

1 Introduction and Background

The tsetse fly (genus *Glossina*) is found throughout the continent of Africa and is the primary vector of human and animal sleeping sickness. It is of substantial significance to human health and, through its impact on livestock, the economic welfare of rural farmers and stockowners. It is estimated that eradicating the disease would lead to as much as a threefold increase in cattle numbers within the afflicted areas (PAATIS) and to economic benefits of billions of dollars per year.

As a result, the distributions of the various tsetse species are of significant interest to those concerned with rural poverty in developing Africa. Reliable assessments would permit planned disease prevention programmes through the suppression or control of the disease vector.

Though substantial efforts have gone into mapping tsetse distributions, much of the currently available information dates back to the late sixties and early seventies. Limited resources have prevented any systematic updating for the continent as a whole, although a significant number of sub-national surveys have been carried out.

Much of the widely available data on tsetse are in the form of presence or absence maps, and provide little information on the fly abundance which is more closely allied to disease risk. Unfortunately, the extensive collection of fly abundance figures is well beyond existing resources.

Two solutions present themselves: either to extrapolate from comparatively few, and small area abundance surveys, or to use alternative measures of fly population levels. Whilst the first is inappropriate for continental level predictions, the second is made more feasible by estimating the probability of presence, rather than just presence or absence. It may be reasonable to assume that fly abundance is related to the probability of fly presence, although it will be necessary eventually to test this assumption by careful field studies.

2 Methodology

Over the past twenty years it has been shown that the distribution of tsetse flies is related to climatic conditions (Rogers and Randolph, 1993), and that satellite imagery can provide reliable surrogates for a range of climatic parameters (Hay *et al.*, 1996). More recently, tsetse distributions have been quite accurately mapped for a wide range of ecological conditions, using Fourier processed time series of satellite imagery of various types – especially those relating to vegetation cover, rainfall, temperature and elevation discussed by Rogers *et al.*, (1996) and Gilbert *et al.*, (1999).

These techniques have largely been based on discriminant analytical and maximum likelihood methods which use known presence and absence distribution data to ‘train’ the prediction process – in essence by establishing statistical relationships between the predictor (satellite image) variables and the observed fly presence/absence data. Output is given as the probability of presence for each sample point in the training dataset. The modelled data can be then compared with the known data to provide various indices of accuracy, such as the proportion correctly modelled, and the proportion of false negatives and positives produced. Typically, the technique gives accuracies of better than 85 percent. These relationships can then be applied to areas which have not been sampled, to provide a predicted probability of presence for areas outside the original training data set.

The present work draws on this experience to produce continent wide predictions of the probability of presence of twenty three tsetse species, as well as the three major species groups. A number of adaptations were made to improve predictions:

- A larger training set sample was taken from the same distribution maps as were used previously (Ford and Katondo, 1977), supplemented by more recent information (see notes later). Sample points were taken at regular c. 50km spacings throughout sub-Saharan Africa, resulting in a total of 12,000 data points.
- The range of predictor variables was extended to include a series of additional parameters as shown in the Appendix.
- Logistic regression modelling was used in place of discriminant analytical/maximum likelihood methods. Logistic regression methods give equivalent or slightly greater predictive accuracies than discriminant analysis by relaxing the assumptions of multi-variate normality of the predictor data set: in the present case, logistic regression tended to over-estimate the absent category, whilst discriminant analysis tended to over-estimate the present category. Recent comparisons show that there is little to choose between these alternative methods (Manel *et al.*, 1999). Logistic regressions are easier to implement within current commercial software, although it is more difficult to interpret the results biologically.
- Analyses were run at four geographical levels: continental, regional, national, for each of a series of 50 satellite derived ecozones (described in FAO 1999). Models were also run using either the area of fly presence and a 200 kilometre buffer zone of absence, or for the whole of the geographical region. The models used were for the largest area that gave a 90% or greater correct output.

3 Appendix

3.1 Fly Distribution Data Used

The underlying data are from (Ford and Katondo, 1977) modified by information from a wide range of sources. These include:

Togo, Burkina Faso: data provided by Dr G. Hendryckx (FAO regional Animal Trypanosomosis Control project for Togo and Burkina Faso; Ethiopia: Survey data provided by Dr M. Vreysen IAEA/UNDP and altitude in consultation with FAOAGAH; Cote D'Ivoire: FAO Consultancy by Dr A Douati (undated); Kenya: data prepared for Kenya Trypanosomiasis Research Institute by ERGO and TALA; Central African Republic and Chad: Data extracted from Réactualisation de la Situation des Tsé-Tsé et des Trypanosomoses Animales au Tchad. by D. Cuisance, May 1995; Zimbabwe and Zambia: data provided by the Regional Tsetse and Trypanosomosis Control Programme and Mr Hem Thakersi, Livestock Development Programme, Ministry of Agriculture, Food and Fisheries; Botswana: data provided by the Tsetse Control Division; Nigeria, Rwanda, and Mali: Reports by FAO Liaison Officers to the Programme Against African Trypanosomiasis for each country; South Africa: data extracted from Kappmeier, K, Nevill, E.M. and Bagnall, R.J., (1998) Review of tsetse flies and trypanosomiasis in South Africa. Onderspoort Journal of Veterinary Research, 65: 195-203; Continental: The Tsetse Fly – A CD produced by ORSTOM and CIRAD; and TALA Research Group Archives.

Draft predicted distribution maps were presented to delegates of Jubilee Meeting of The International Scientific Council for Trypanosomiasis Research and Control (ISCTRC). 27th Sept – 1st Oct 1999. Momabsa, Kenya. and a number of comments incorporated.

3.2 Predictor Variable Data Used

A range of information has been incorporated into these analyses, including eco-climatic data, elevation, cattle density, cultivation level, and human population, summary details of which are given below. The analyses underlying their acquisition and generation is presented in FAO (1999).

3.2.1 Eco-climatic data

3.2.1.1 Satellite Imagery

The study used the following satellite-derived measures of land-surface or atmospheric characteristics for both Africa and Asia:

- a) Normalised Difference Vegetation Index (NDVI) from the Advanced Very High Resolution Radiometer (AVHRR) commonly used as an indicator of vegetation cover (data from the Pathfinder Program, initially supplied by the NASA Global Inventory Monitoring and Modelling Systems (GIMMS) group);
- b) Ground surface temperature, derived using the Price split window technique by TALA personnel, from two of the thermal channels (Channel 4 and 5) of the same instrument that produces NDVI data (Price, 1984);
- c) Middle infra-red reflectance (allied to temperature but less susceptible to atmospheric interference) derived from Channel 3 of the AVHRR data;
- d) Vapour Pressure Deficit also derived from the AVHRR channels 4 and 5 and ancillary processing; and, for Africa only
- c) A measure of surface rainfall, the Cold Cloud Duration (CCD), derived from the METEOSAT satellite (from FAO ARTEMIS).

More details of the performance of each satellite series in relation to interpolated climate data are available in (Hay and Lennon, 1999).

All the AVHRR satellite data were available in dekadal images for a 13 year series from 1982-1994. The CCD imagery runs from 1988 to 1998. Each series was subjected to temporal Fourier analysis, re-sampled to 0.05 degree resolution and re-projected to latitude/longitude (geographic) projection where necessary. Fourier processing extracts, from each multi-temporal data stream, the characteristics of the annual, biannual and tri-annual components, details of which are given in (Rogers et al., 1996). Mean values, and the amplitudes and phases (*i.e.* timing of the seasonal peaks) of the annual, bi-annual and tri-annual cycles were recorded and turned into IDRISI image data layers, together with the maximum, minimum and ranges (maximum - minimum) of each Fourier description of the observed signal. The percentage of the total variance attributable to each of the three Fourier components (a measure of the relative importance of each component) was also calculated for each parameter series. Further details of these variables can be found in Appendix Tables A1 and A2.

Table A1: Prediction Equation Fourier Variable Names

Fourier Variable	Data				
	NDVI	CCD	VPD	PRICE	CH3
Mean	NDVIAMP0	CDDAMP0	VPDAMP0	PRIAMP0	CH3AMP0
Amplitude1	NDVIAMP1	CDDAMP1	VPDAMP1	PRIAMP1	CH3AMP1
Amplitude2	NDVIAMP2	CDDAMP2	VPDAMP2	PRIAMP2	CH3AMP2
Amplitude3	NDVIAMP3	CDDAMP3	VPDAMP3	PRIAMP3	CH3AMP3
Phase1	NDVIPHS1	CDDPHS1	VPDPHS1	PRIPHS1	CH3PHS1
Phase2	NDVIPHS2	CDDPHS2	VPDPHS2	PRIPHS2	CH3PHS2
Phase3	NDVIPHS3	CDDPHS3	VPDPHS3	PRIPHS3	CH3PHS3
Variance of Mean	NDVIVAR	CDDVAR	VPDVAR	PRIVAR	CH3VAR
Variance 1*	NDVIDPF1	CDDDPF1	VPDDPF1	PRIDPF1	CH3DPF1
Variance 2*	NDVIDPF2	CDDDPF2	VPDDPF2	PRIDPF2	CH3DPF2
Variance 3*	NDVIDPF3	CDDDPF3	VPDDPF3	PRIDPF3	CH3DPF3
Variance All*	NDVIDPFA	CDDDPFA	VPDDPFA	PRIDPFA	CH3DPFA
Min	NDVIMIN	CDDMIN	VPDMIN	PRIMIN	CH3MIN
Max	NDVIMAX	CDDMAX	VPDMAX	PRIMAX	CH3MAX
Range	NDVIRNG	CDDRNG	VPDRNG	PRIRNG	CH3RNG

*e.g. Variance 1 refers to the % of total signal variance accounted for by the annual cycle of variation.

3.2.1.2 Other

Digital Elevation Model (DEM) data were obtained from the GTOPO30 1km resolution elevation surface for Africa, produced by the Global Land Information System (GLIS) of the United States Geological Survey, Earth Resources Observation Systems (USGS, EROS) data centre.

Potential Evapotranspiration (PET) data for Africa were provided by FAO AGL, as averaged dekadal means for the years 1961-1990, from which were calculated the mean, minimum and maximum dekadal PET, which were then re-sampled to a 0.05 degree resolution.

Maps of the Length of Growing Period for both continents, at a resolution of 0.5 by 0.5 degrees, was made available by FAO AGL, and are shown in Figure 2 for Africa and Figure 3 for Asia.

A series of parameters were calculated using GIS procedures within IDRISI: these include topographic slope; distance to major rivers and the sea; and the x and y image pixel coordinate.

3.2.2 Human Population

The human population data used for Africa and Asia are derived from three sources: a global coverage of population number per image pixel obtained from University of California at Berkeley provided by FAO AGL at 5 minute resolution; a population density coverage at the same resolution from the Consortium

for International Earth Science Information Network (CIESIN: <http://www.ciesin.org>), derived from data collated by the National Centre for Geographic Information and Analysis (NCGIA: <http://www.ncgia.ucsb.edu>); and the population data from the Intergovernmental Authority on Drought and Development countries used in the earlier work (FAO, 1996). The average of these three estimates was calculated through the raster image manipulation functions within the IDRISI software.

3.2.3 Agricultural Data

Cattle and cultivation levels used were predicted using regression analyses, fully described in FAO (1999). This process requires an observed data set for each that can be used to ‘train’ the predictor variables described above, thereby establishing the relationships between observed and predictor variables using a large number of sample points. These can then be applied to the predictor variable images to produce predictions at the imagery resolution.

An ongoing project, funded by the UK Department for International Development (DFID), is currently extending these approaches to produce continental predictions of cattle density and cropping level, to incorporate into an Information System, comprising a GIS, a Knowledge Base and a Resource Inventory for sub-Saharan Africa. This work is being undertaken by ERGO Ltd in collaboration with the Programme Against Animal Trypanosomiasis (PAAT) in FAO Rome, the UK Natural Resources Institute (NRI) and the Trypanosomiasis and Land Use in Africa Research Group (TALA) at Oxford University. These data have been used extensively in the following study, and are fully described in the forthcoming PAATIS documentation. They are summarised below.

The observed data for cattle density are compiled from a wide variety of sources. These include the International Livestock Research Institute, ERGO aerial survey archives for Niger, Nigeria, Sudan, Chad, and Mali, and Government Agricultural Census data from Botswana and Kenya and Ghana.

The observed cultivation data were also obtained from: the Africa Data Dissemination Service (http://edcintl.cr.usgs.gov/adds/adds.html#adds_data_anchor); FAO AGDAT as used in the FAO GEOWEB service, produced by FAO GIEWS (<http://geoweb.fao.org/>); ERGO/TALA aerial survey archives for Togo, Nigeria, Niger, Mali, Chad, and Sudan; transcribed Government Census data from Zambia, Botswana, South Africa, and Swaziland; and FAO GIEWS reports for Angola, Lesotho Tanzania, Ethiopia, Eritrea, Zaire, and Mozambique.

Table A2: Other Regression Variables Used

Name	Description
CDNDLAG	Scaled lag between NDVI and CCD, indicative of delay in growth after rain
RGEZCTPR	Predicted Cattle Density
AFCPRZPR	Predicted Cultivation Percentage
AFKMSEA	Distance to sea (km)
AFXPIX	X coordinate (image pixel column)
AFYPIX	Y coordinate (image pixel row)
AFRIVDEG	Distance to major rivers (degrees)
AFSLPLL	Topographic slope (degrees)
MASK	Continent and Water Mask (Value 255)
POPDN	Human Population Density
ELEV	Elevation
PHEZ50	Addapix Ecozones - 50 Zones
PETMXDK	Maximum Dekadal Potential Evapotranspiration (Mean 1961-1990)
PETMNDK	Minimum Dekadal Potential Evapotranspiration (Mean 1961-1990)
PETAVDK	Average Dekadal Potential Evapotranspiration (Mean 1961-1990)
LGPR	Predicted Length of Growing Period (Days)

4 Maps

Two sets of maps are presented: the estimated probabilities of presence and predicted presence, which is assumed when the predicted probability of presence is $\geq 50\%$ (N.B. the 50% threshold probability is not always the one giving the greatest predictive accuracy in logistic regressions: in general inspection is required to decide the appropriate cut-off, especially with unequal sample sizes of presence and absence areas in the training set). These maps are also provided in Arcview© 3.2 grid format on the accompanying CD. All are contained in the directory \Tsetse, within one of three subdirectories: \Fusca, \Morsitans, and \Palpalis. Each subdirectory contains the maps for the tsetse species belonging to that species group. The \Tsetse directory also contains arcview shape files for country boundaries (*subsahcnt*), and cleared areas (*dbalclear*), and an arcview project file (*tsetse.apr*)

Each of the group folders also contains a series of bitmap images (*.bmp) of both probability and presence absence, as exported from arcview. These may be imported into most wordprocessing/graphic packages for display. The legends are in a separate Powerpoint file *tselegends.ppt*.

A powerpoint file (*ahpposter.ppt*) of the A2 poster from which the cover illustration is taken is also provided in the *Tsetse* folder.

To view the maps, all the files should be copied in their existing directories, onto the C:\ drive of a users computer, which should be equipped with Arcview 3.2 with the Spatial Analyst© extension loaded. Opening the project file will produce six Views, two for each species group – one with presence/absence maps, the other with % Probability of Presence Maps. To display a particular map, check the appropriate box as well as those labelled *Cleared since 1967* and *Countries* in the left hand view pane. Only one map will be visible at a time within a particular view.

If it is necessary to put the files onto a disk other than C:\, the project file must be edited to replace all occurrences of C:\ with the different disk letter (e.g. D:\). Note that the project file must be saved in text format.

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List of Maps

Page:

Map 1: Palpalis Group: Predicted % Probability of Presence 8

Map 2: *G. calliginea*: Predicted % Probability of Presence 9

Map 3: *G. fuscipes fuscipes*: Predicted % Probability of Presence 10

Map 4: *G. fuscipes martinii*: Predicted % Probability of Presence 11

Map 5: *G. fuscipes quanzensis*: Predicted % Probability of Presence 12

Map 6: *G. pallicera newsteadi*: Predicted % Probability of Presence 13

Map 7: *G. tachinoides*: Predicted % Probability of Presence 14

Map 8: Morsitans Group: Predicted % Probability of Presence 15

Map 9: *G. austeni*: Predicted % Probability of Presence 16

Map 10: *G. longipalpis*: Predicted % Probability of Presence 17

Map 11: *G. morsitans*: Predicted % Probability of Presence 18

Map 12: *G. pallidipes*: Predicted % Probability of Presence 19

Map 13: *G. swynnertoni*: Predicted % Probability of Presence 20

Map 14: Fusca Group: Predicted % Probability of Presence 21

Map 15: *G. brevipalpis*: Predicted % Probability of Presence 22

Map 16: *G. fusca fusca*: Predicted % Probability of Presence 23

Map 17: *G. fuscipleuris*: Predicted % Probability of Presence 24

Map 18: *G. hanningtoni*: Predicted % Probability of Presence 25

Map 19: *G. longipennis*: Predicted % Probability of Presence 26

Map 20: *G. medicorum*: Predicted % Probability of Presence 27

Map 21: *G. nashi*: Predicted % Probability of Presence 28

Map 22: *G. nigrofusca*: Predicted % Probability of Presence 29

Map 23: *G. schwetzi*: Predicted % Probability of Presence 30

Map 24: *G. severini*: Predicted % Probability of Presence 31

Map 25: *G. tabaniformis*: Predicted % Probability of Presence 32

Map 26: *G. vanhoofi*: Predicted % Probability of Presence 33

Map 27: Palpalis Group: Predicted Presence and Absence 34

Map 28: *G. calliginea*: Predicted Presence and Absence 35

Map 29: *G. fuscipes fuscipes*: Predicted Presence and Absence 36

Map 30: *G. fuscipes martinii*: Predicted Presence and Absence 37

Map 31: *G. fuscipes quanzensis*: Predicted Presence and Absence 38

Map 32: *G. pallicera newsteadi*: Predicted Presence and Absence 39

Map 33: *G. tachinoides*: Predicted Presence and Absence 40

Map 34: Morsitans Group: Predicted Presence and Absence 41

Map 35: *G. austeni*: Predicted Presence and Absence 42

Map 36: *G. longipalpis*: Predicted Presence and Absence 43

Map 37: *G. morsitans*: Predicted Presence and Absence 44

Map 38: *G. pallidipes*: Predicted Presence and Absence 45

Map 39: *G. swynnertoni*: Predicted Presence and Absence 46

Map 40: Fusca Group: Predicted Presence and Absence 47

Map 41: *G. brevipalpis*: Predicted Presence and Absence 48

Map 42: *G. fusca fusca*: Predicted Presence and Absence 49

Map 43: *G. fuscipleuris*: Predicted Presence and Absence 50

Map 44: *G. hanningtoni*: Predicted Presence and Absence 51

Map 45: *G. longipennis*: Predicted Presence and Absence 52

Map 46: *G. medicorum*: Predicted Presence and Absence 53

Map 47: *G. nashi*: Predicted Presence and Absence 54

Map 48: *G. nigrofusca*: Predicted Presence and Absence 55

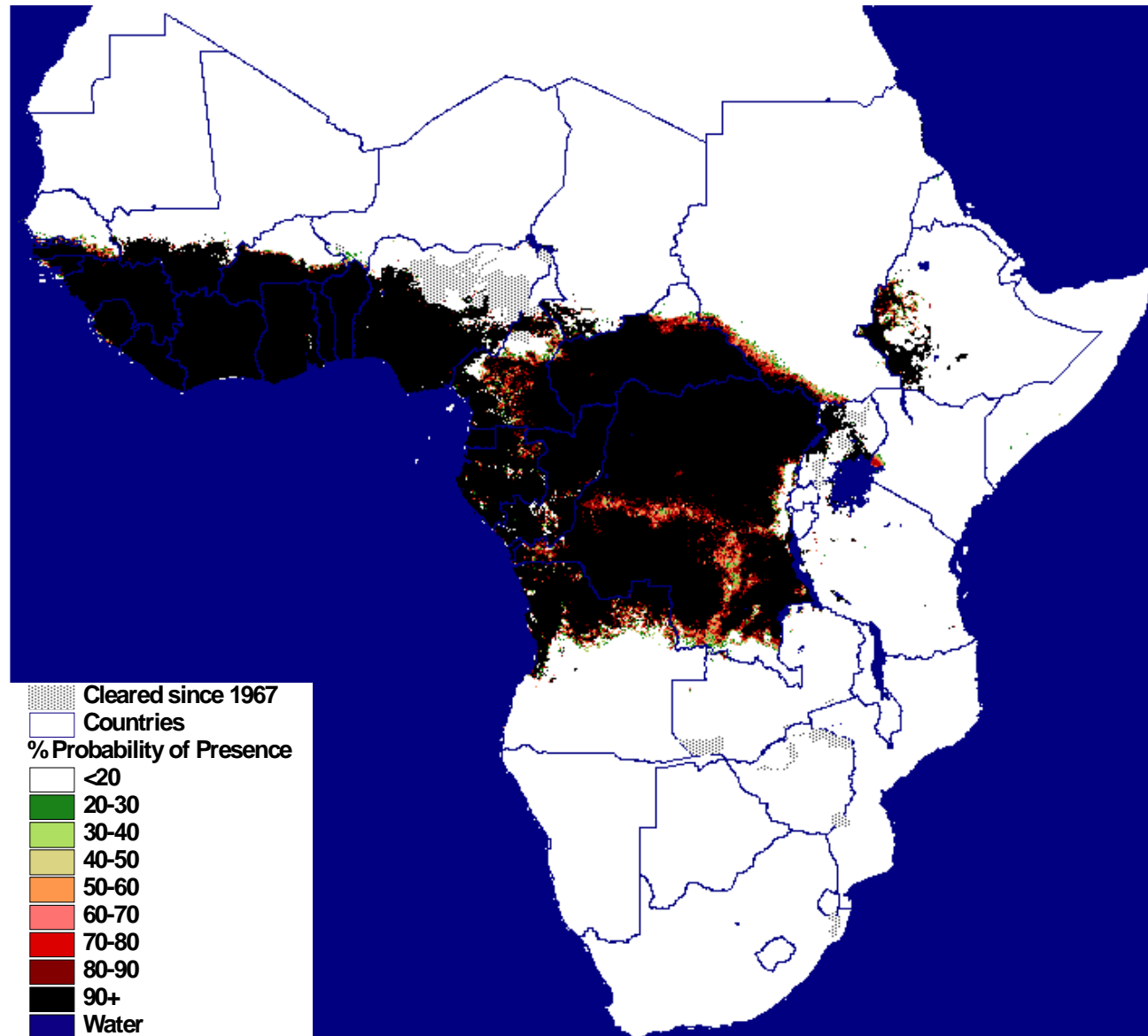
Map 49: *G. schwetzi*: Predicted Presence and Absence 56

Map 50: *G. severini*: Predicted Presence and Absence 57

Map 51: *G. tabaniformis*: Predicted Presence and Absence 58

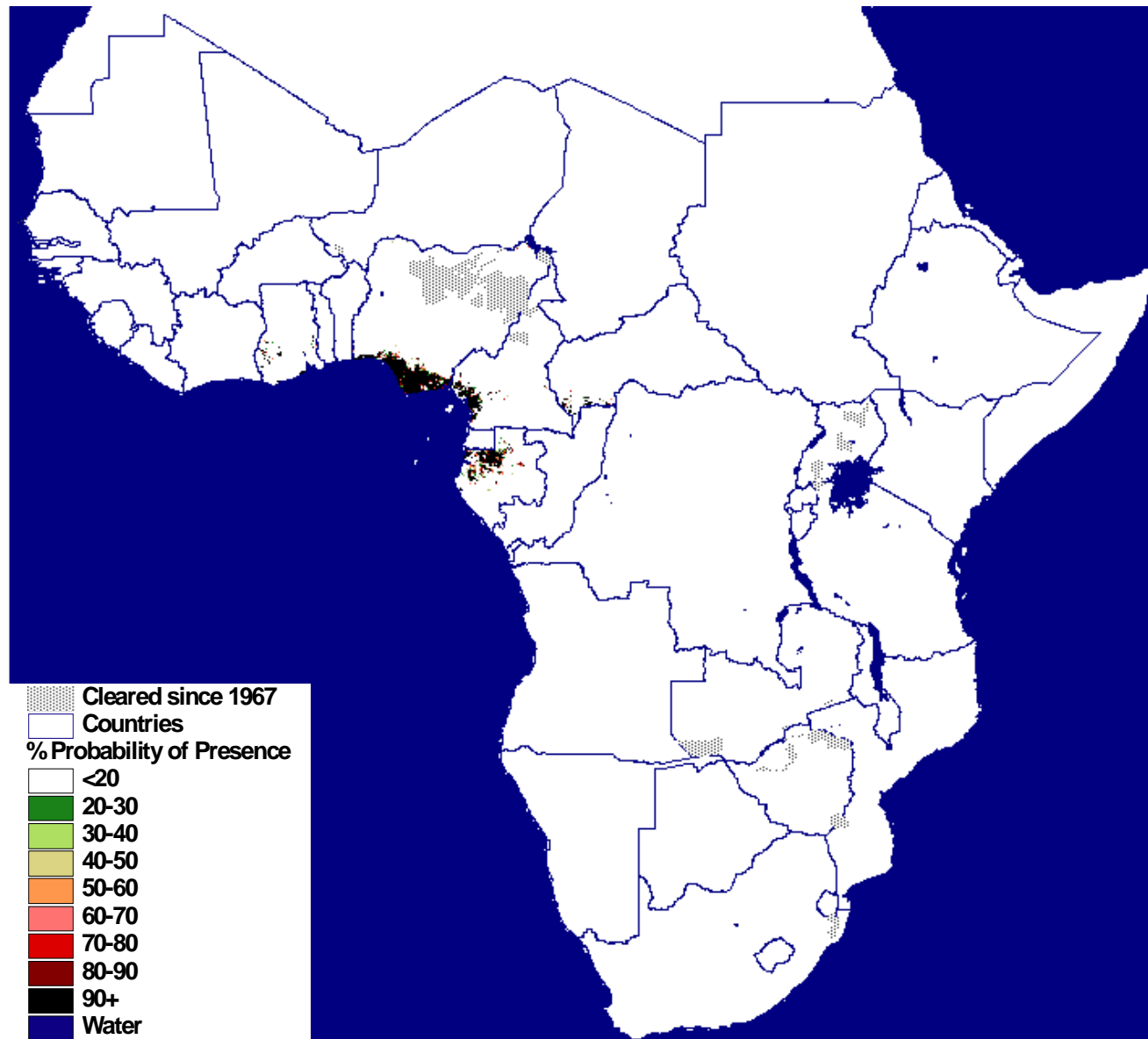
Map 52: *G. vanhoofi*: Predicted Presence and Absence 59

Map 1: Palpalis Group: Predicted % Probability of Presence



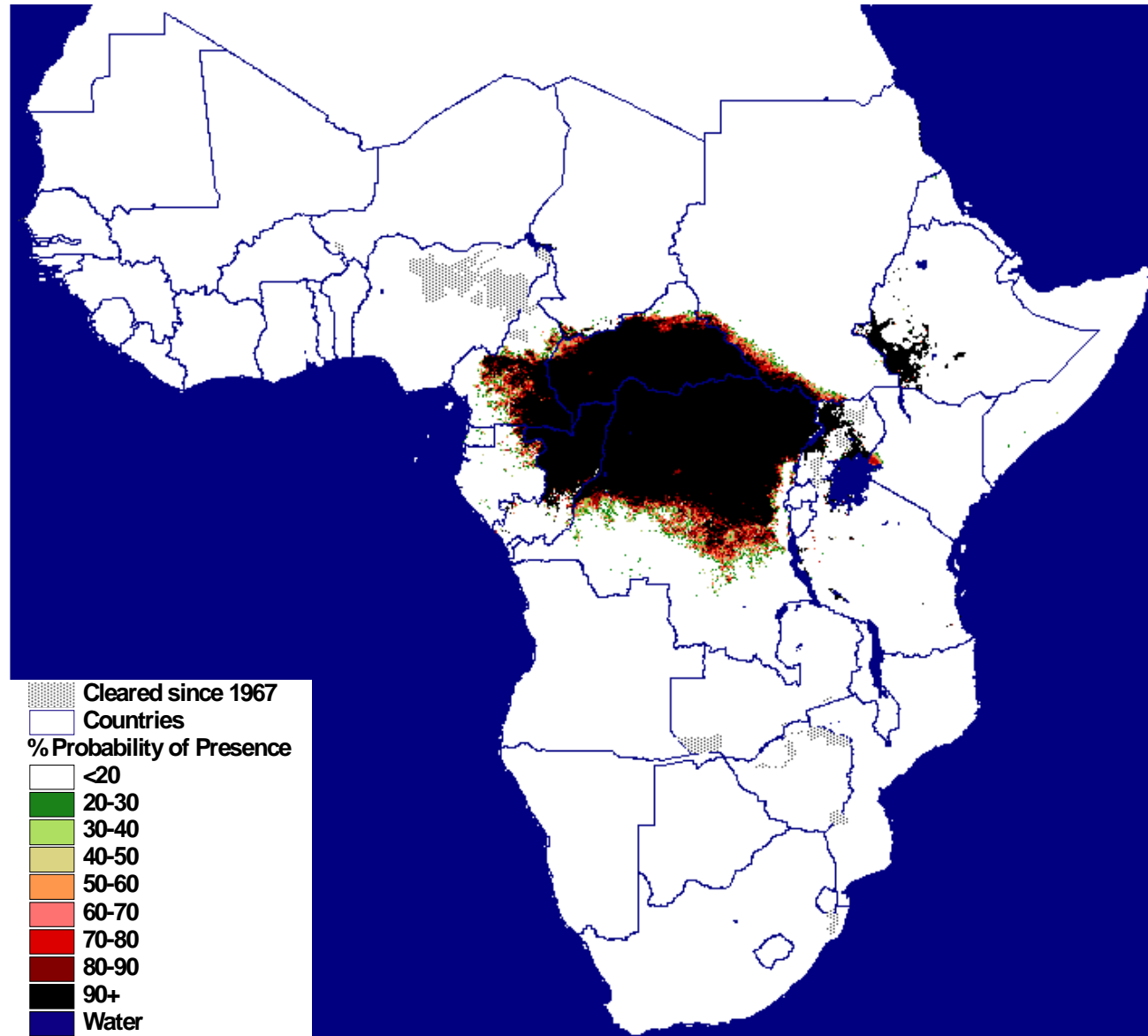
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Map 2: *G. calliginea*: Predicted % Probability of Presence



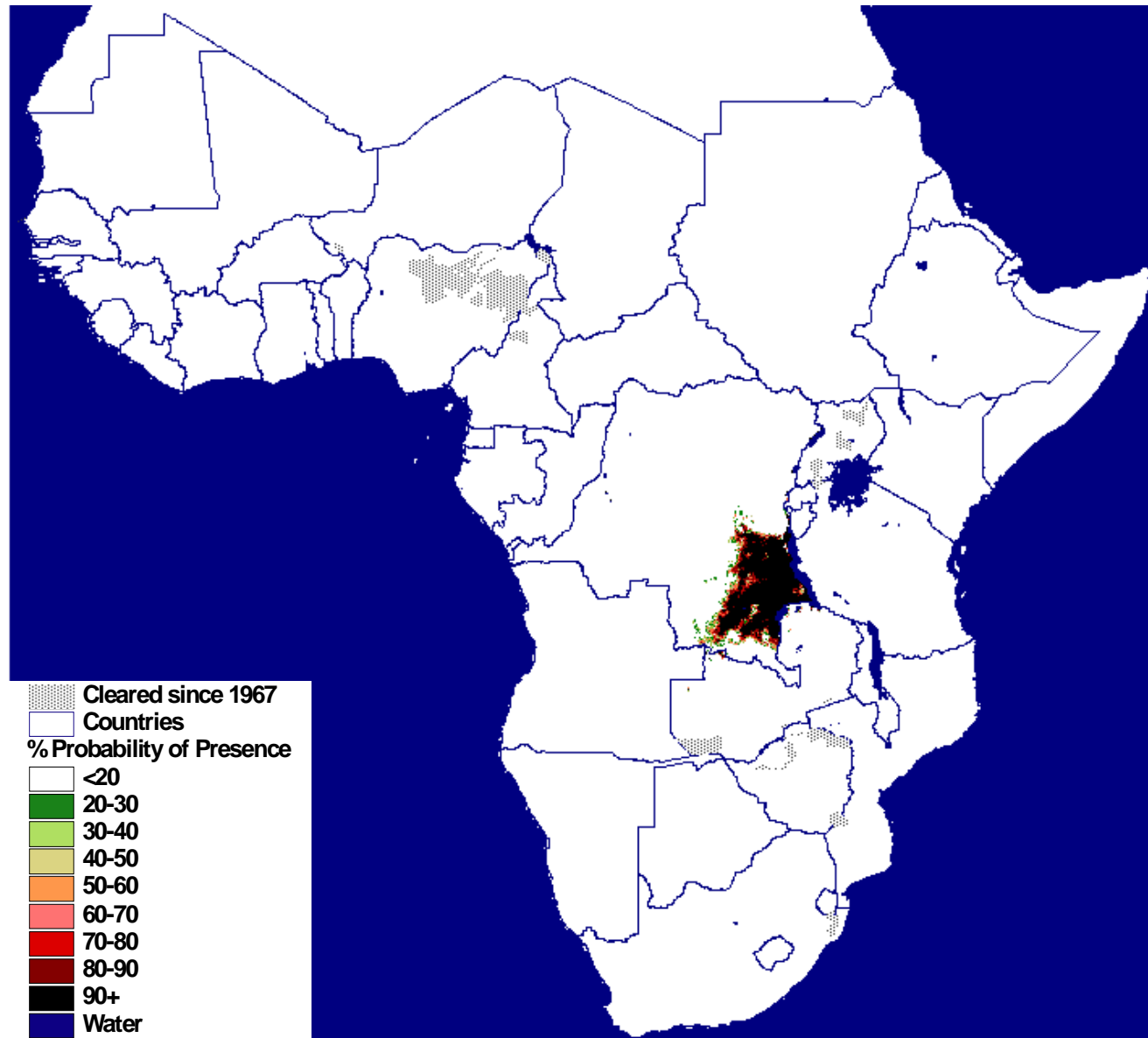
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Map 3: *G. fuscipes fuscipes*: Predicted % Probability of Presence



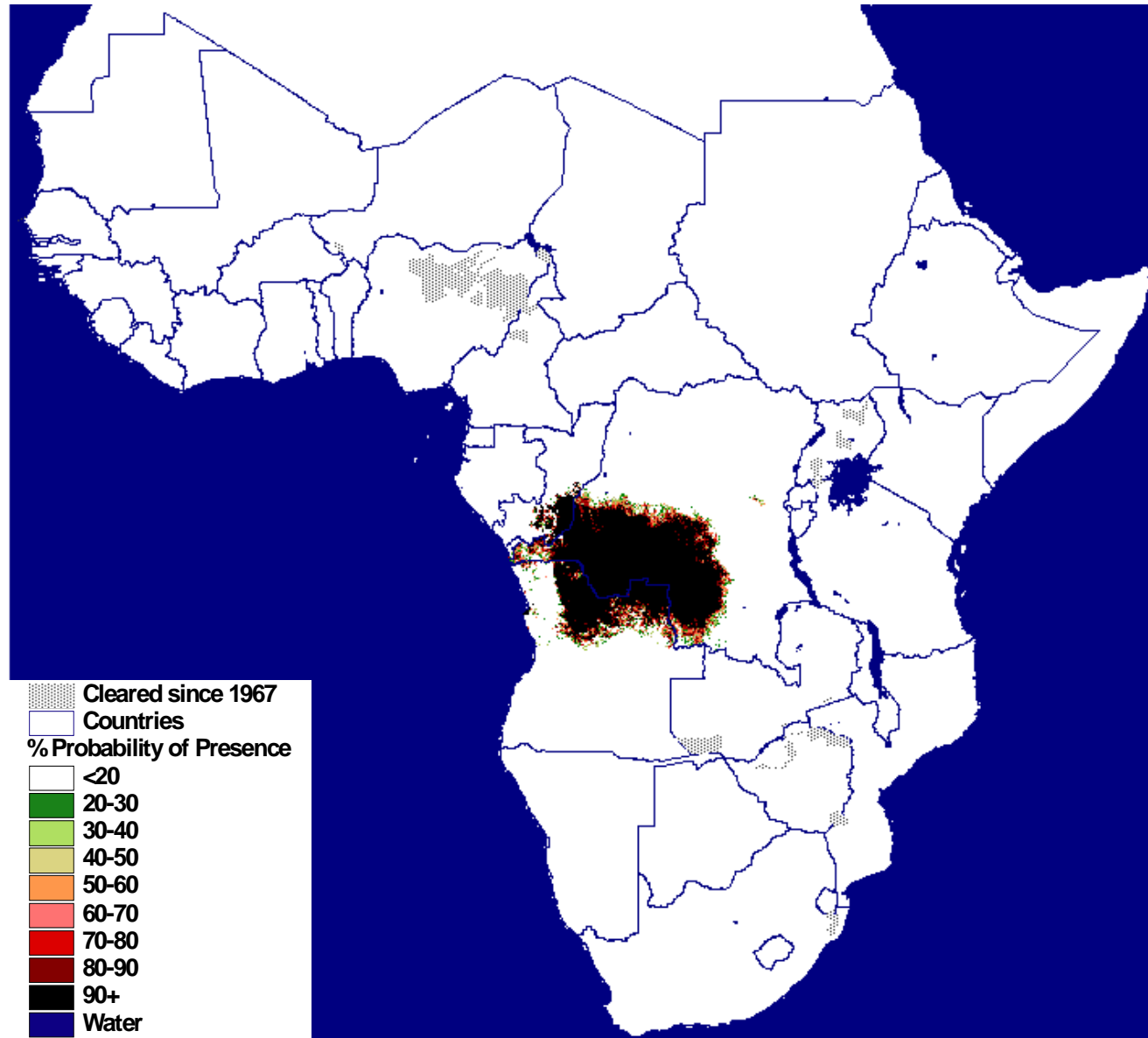
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Map 4: *G. fuscipes martinii*: Predicted % Probability of Presence

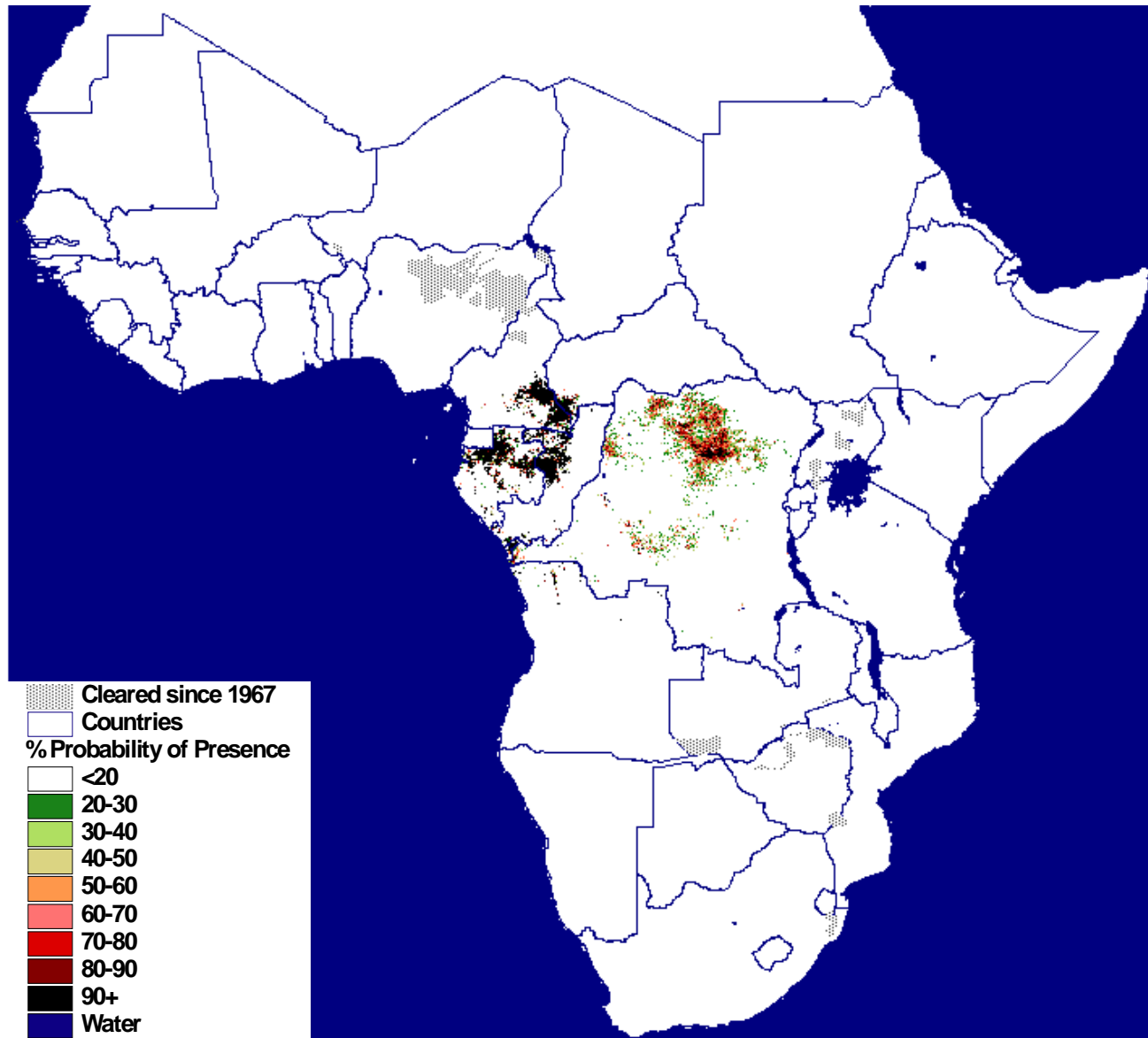


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Map 5: *G. fuscipes quanzensis*: Predicted % Probability of Presence

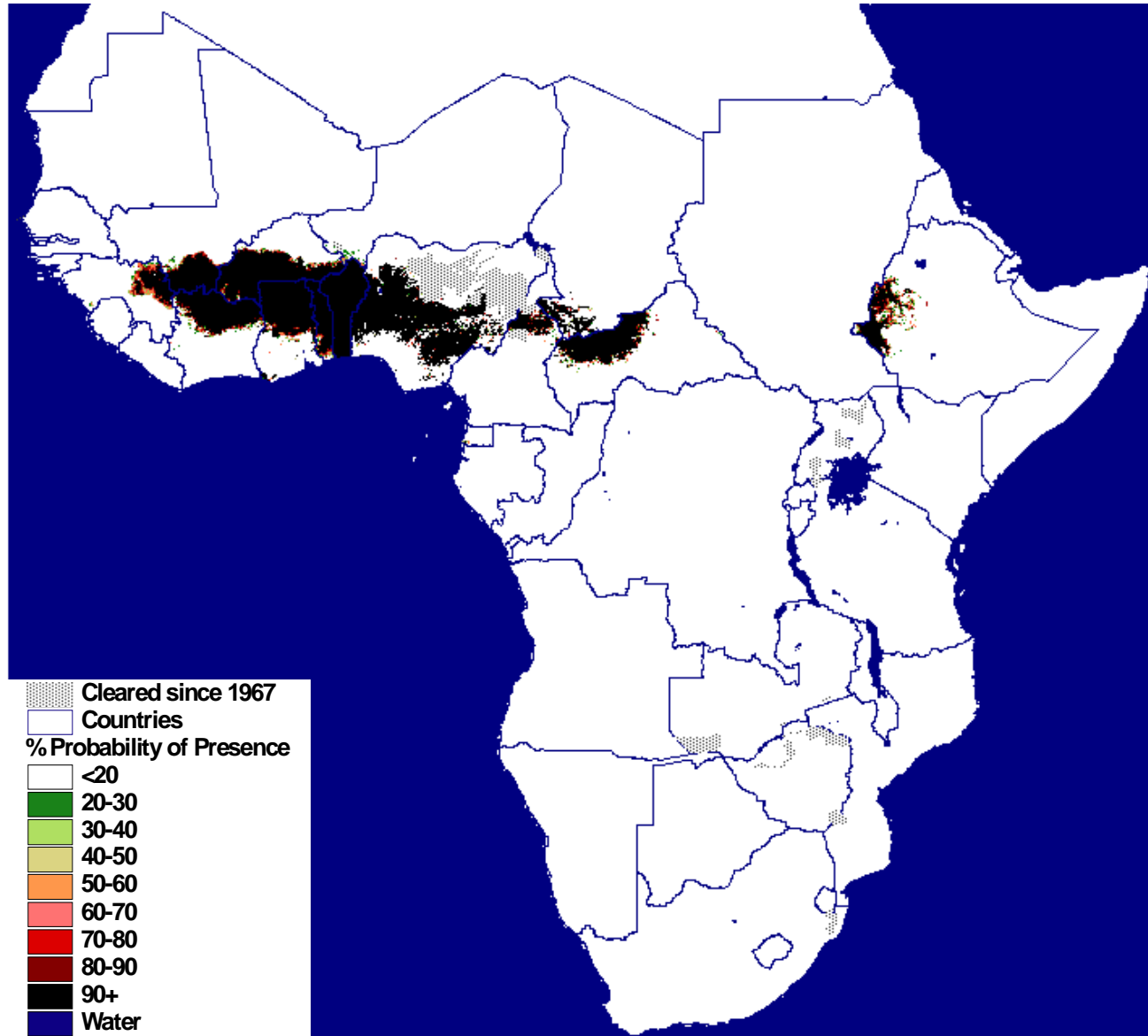


Map 6: *G. pallicera newsteadi*: Predicted % Probability of Presence

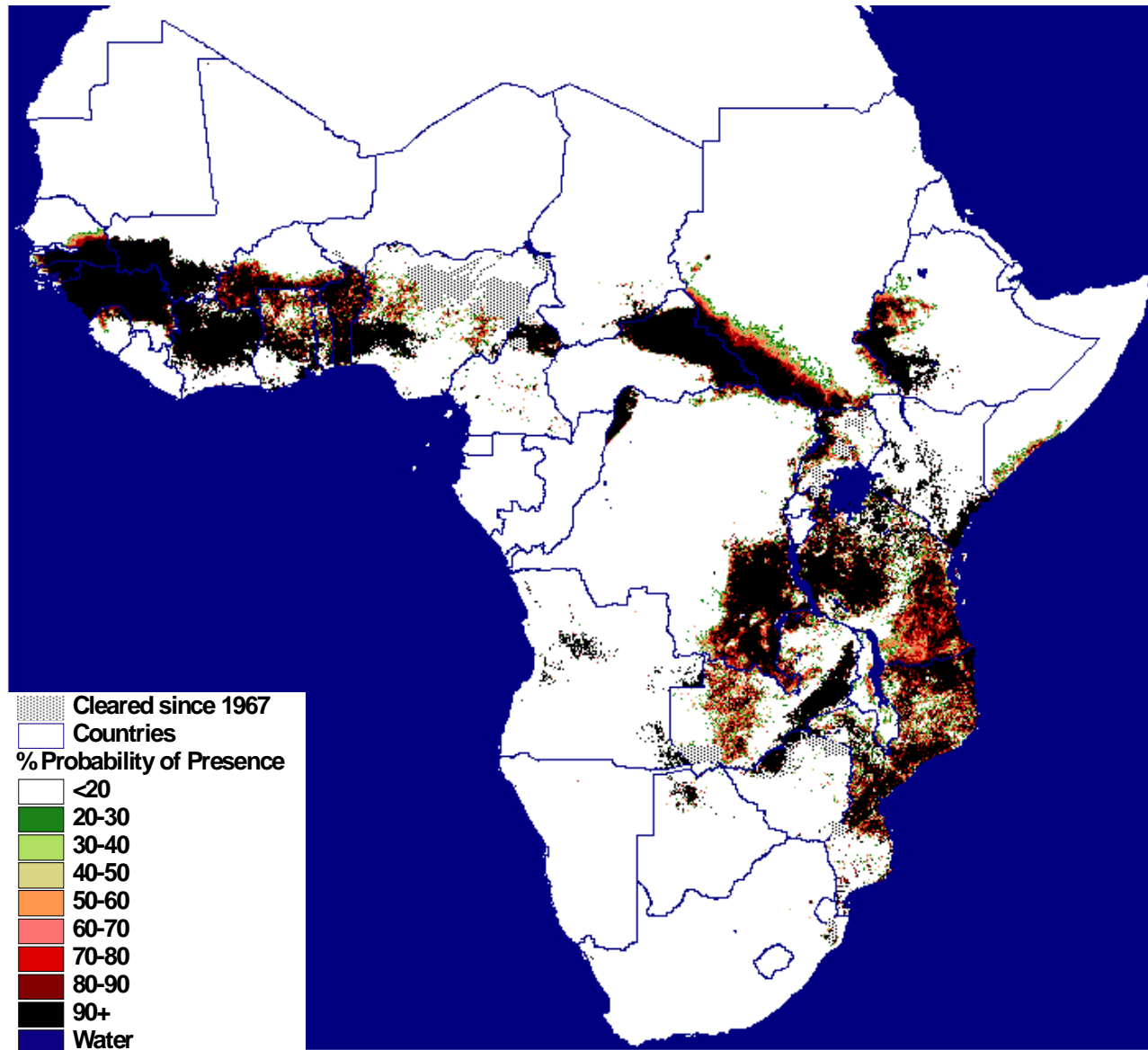


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Map 7: *G. tachinoides*: Predicted % Probability of Presence

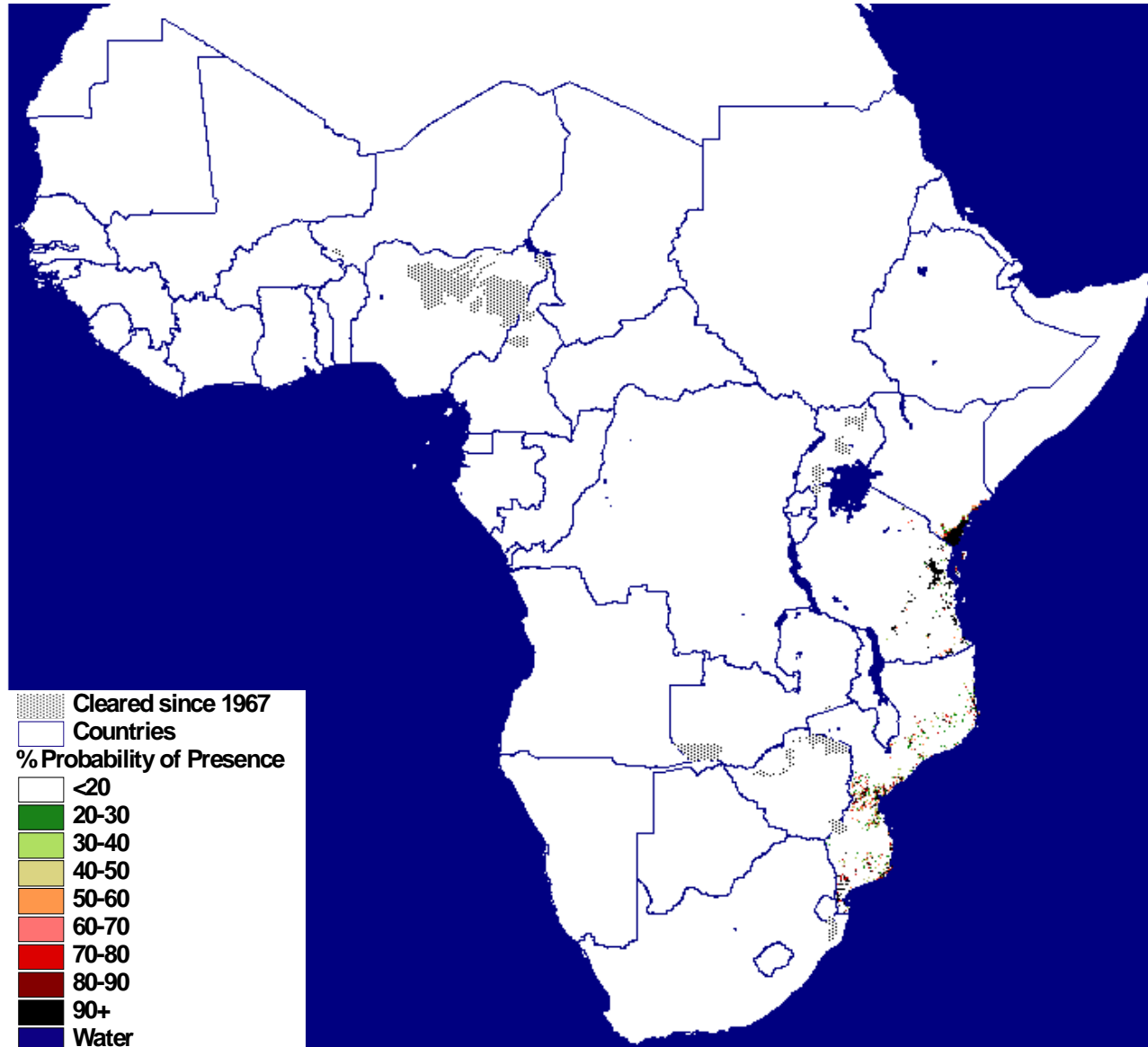


Map 8: Morsitans Group: Predicted % Probability of Presence



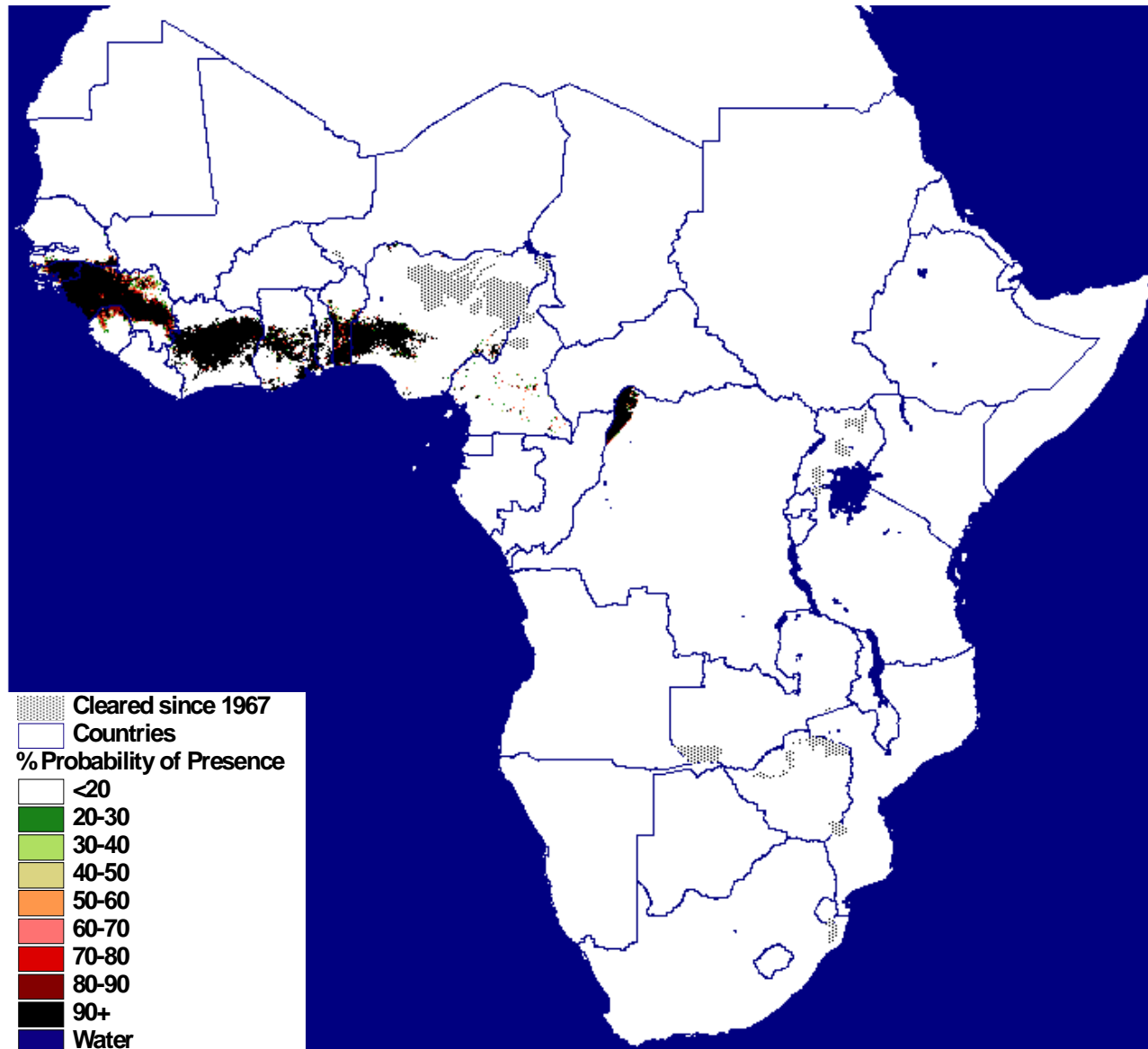
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Map 9: *G. austeni*: Predicted % Probability of Presence



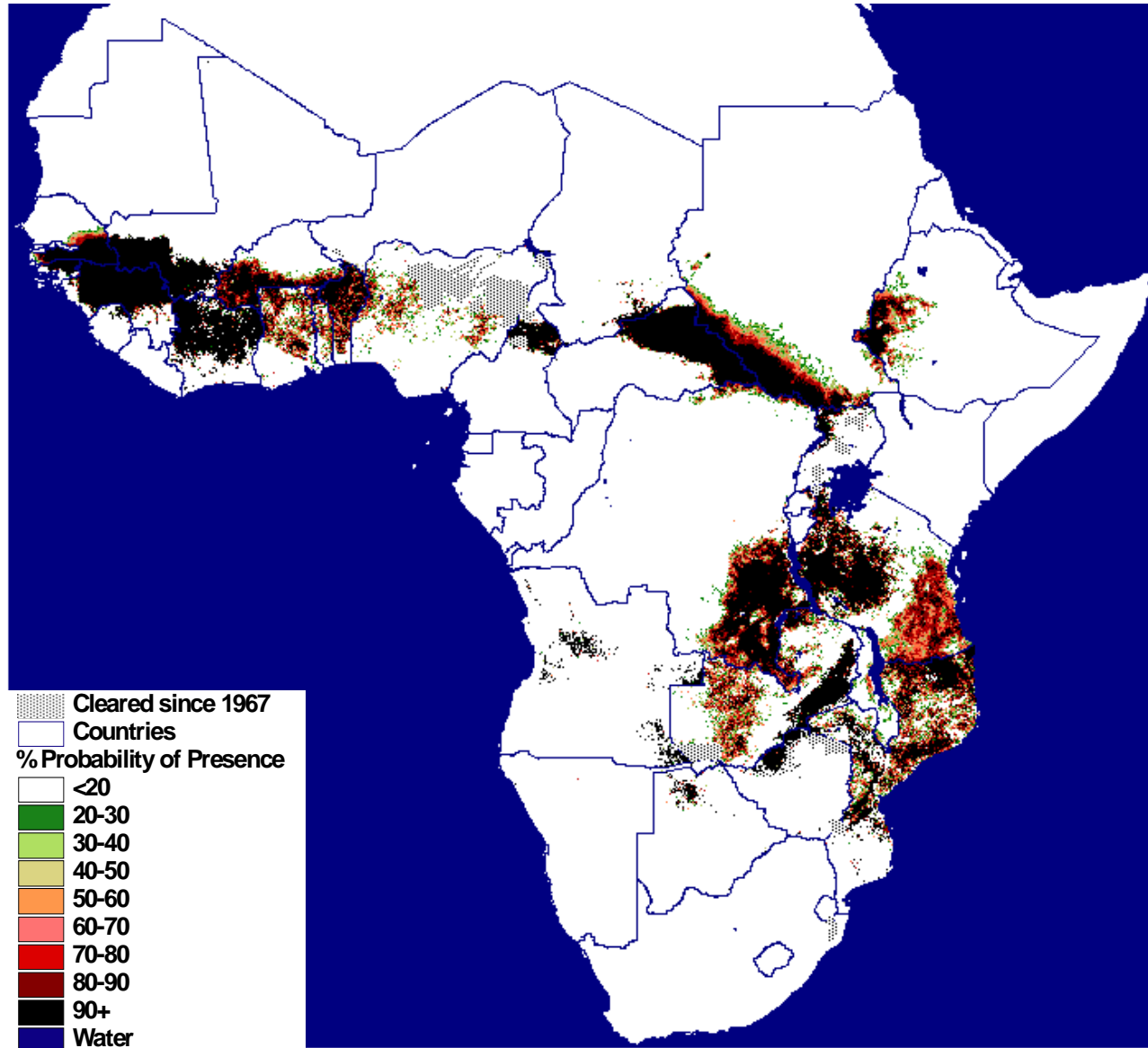
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Map 10: *G. longipalpis*: Predicted % Probability of Presence



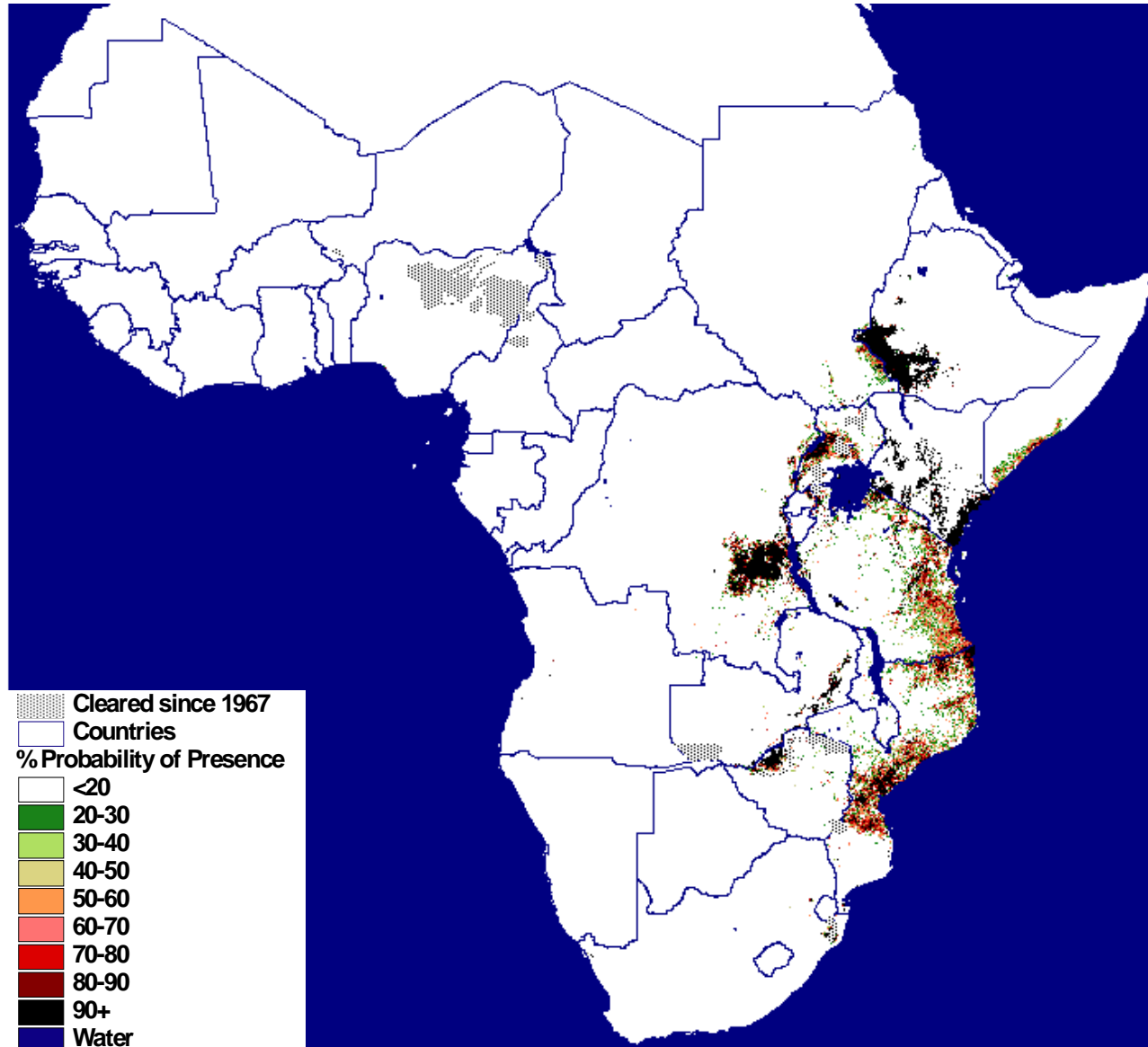
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Map 11: *G. morsitans*: Predicted % Probability of Presence



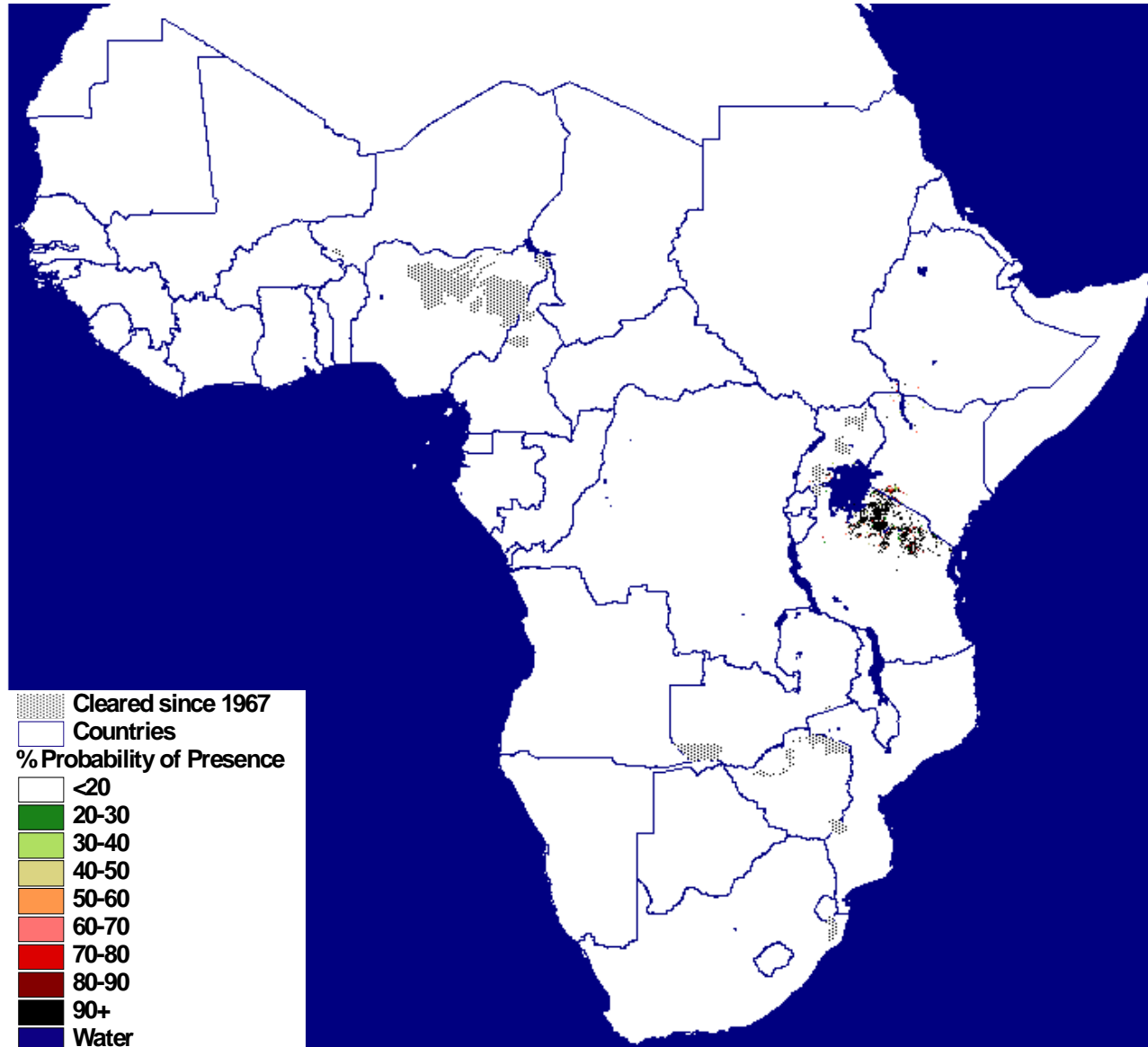
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Map 12: *G. pallidipes*: Predicted % Probability of Presence



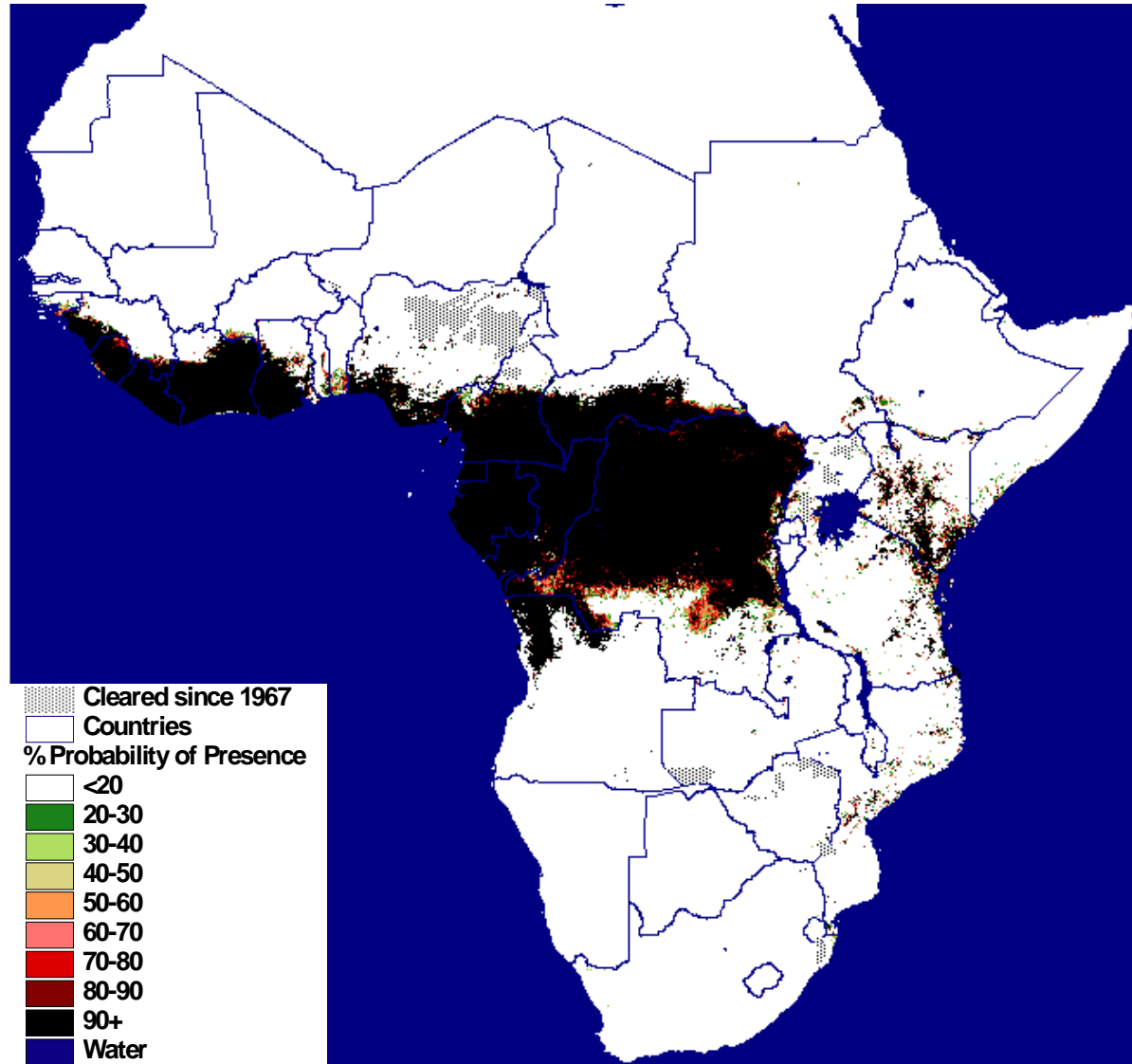
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Map 13: *G. swynnertoni*: Predicted % Probability of Presence

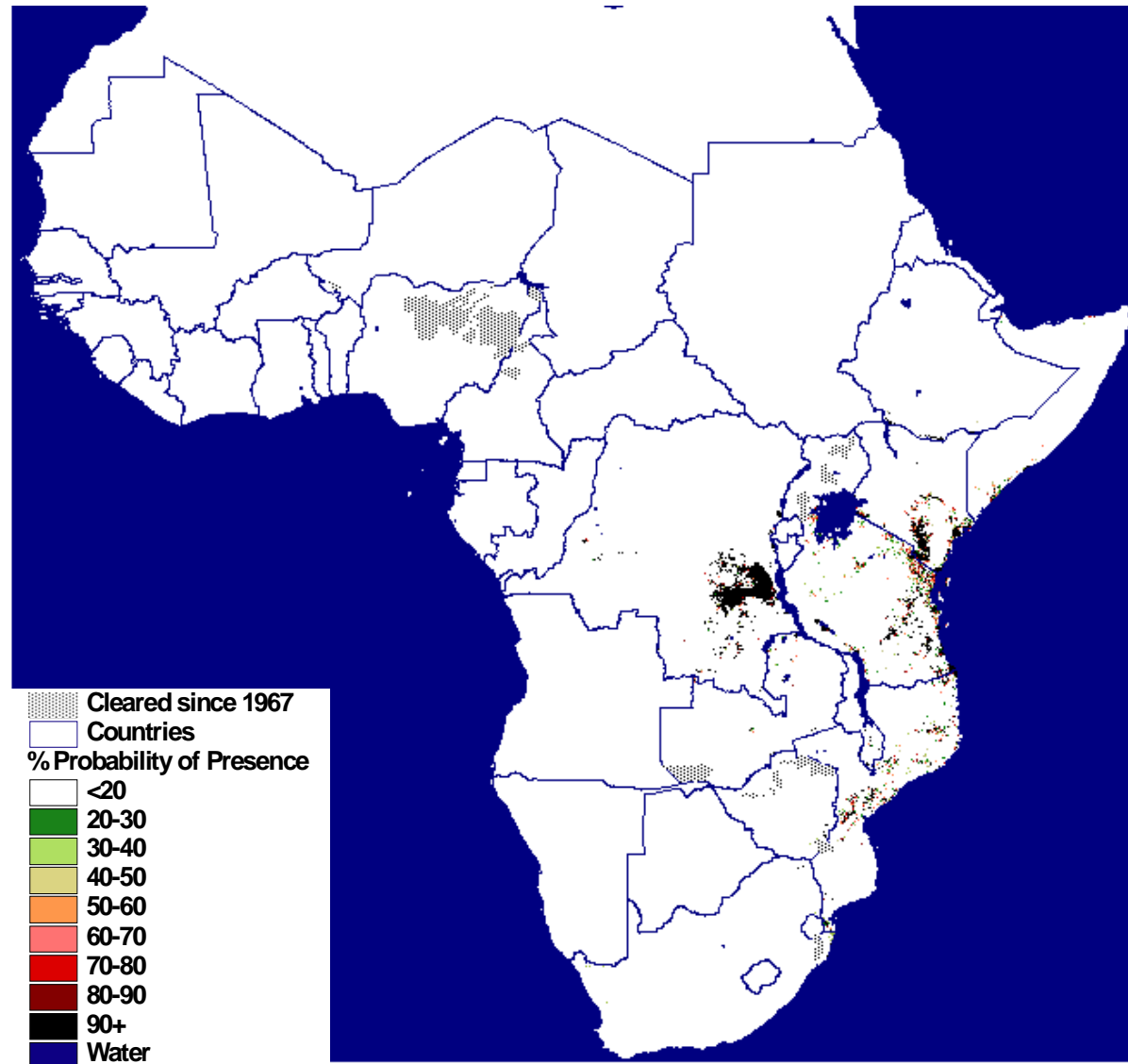


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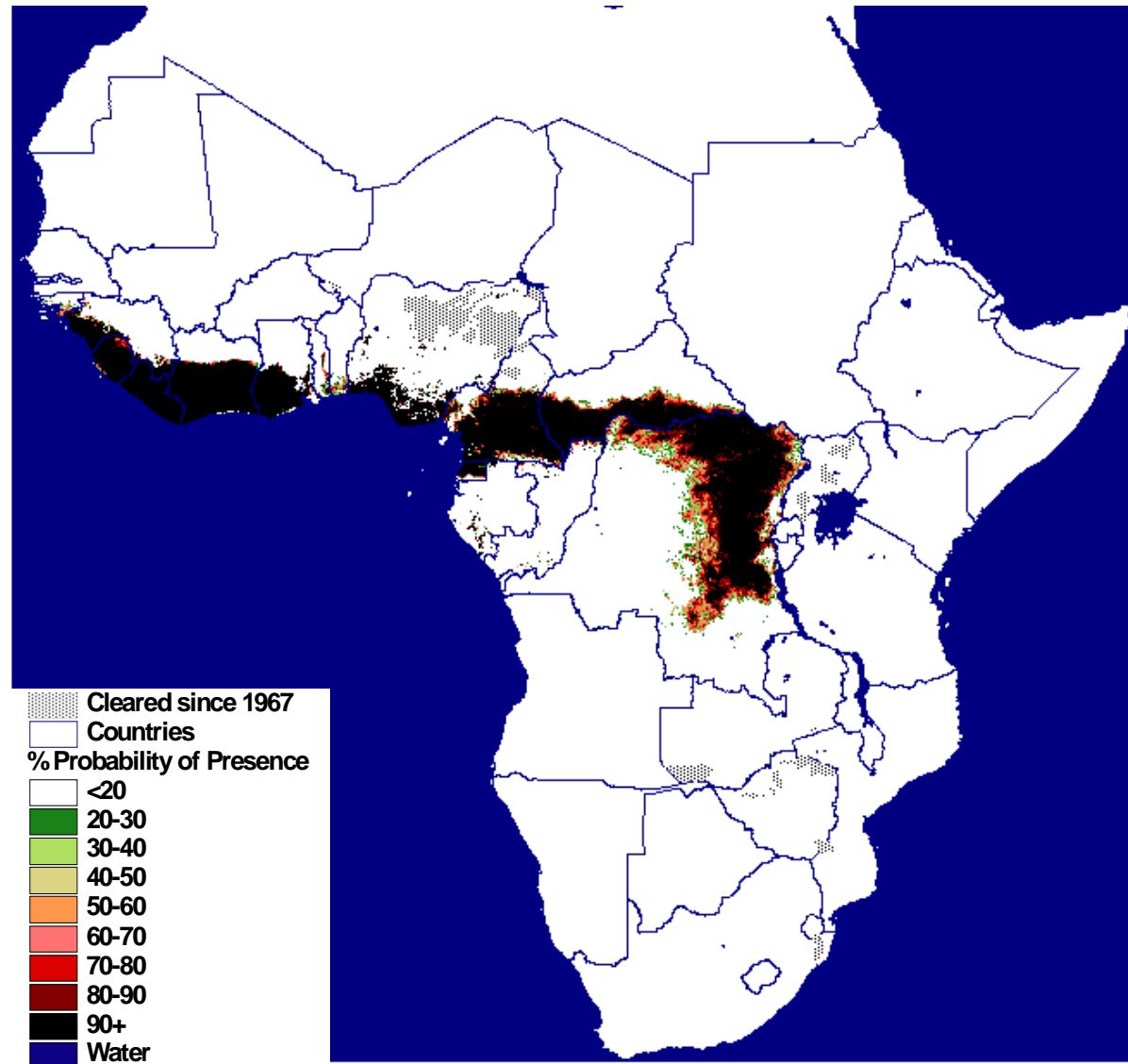
Map 14: Fusca Group: Predicted % Probability of Presence



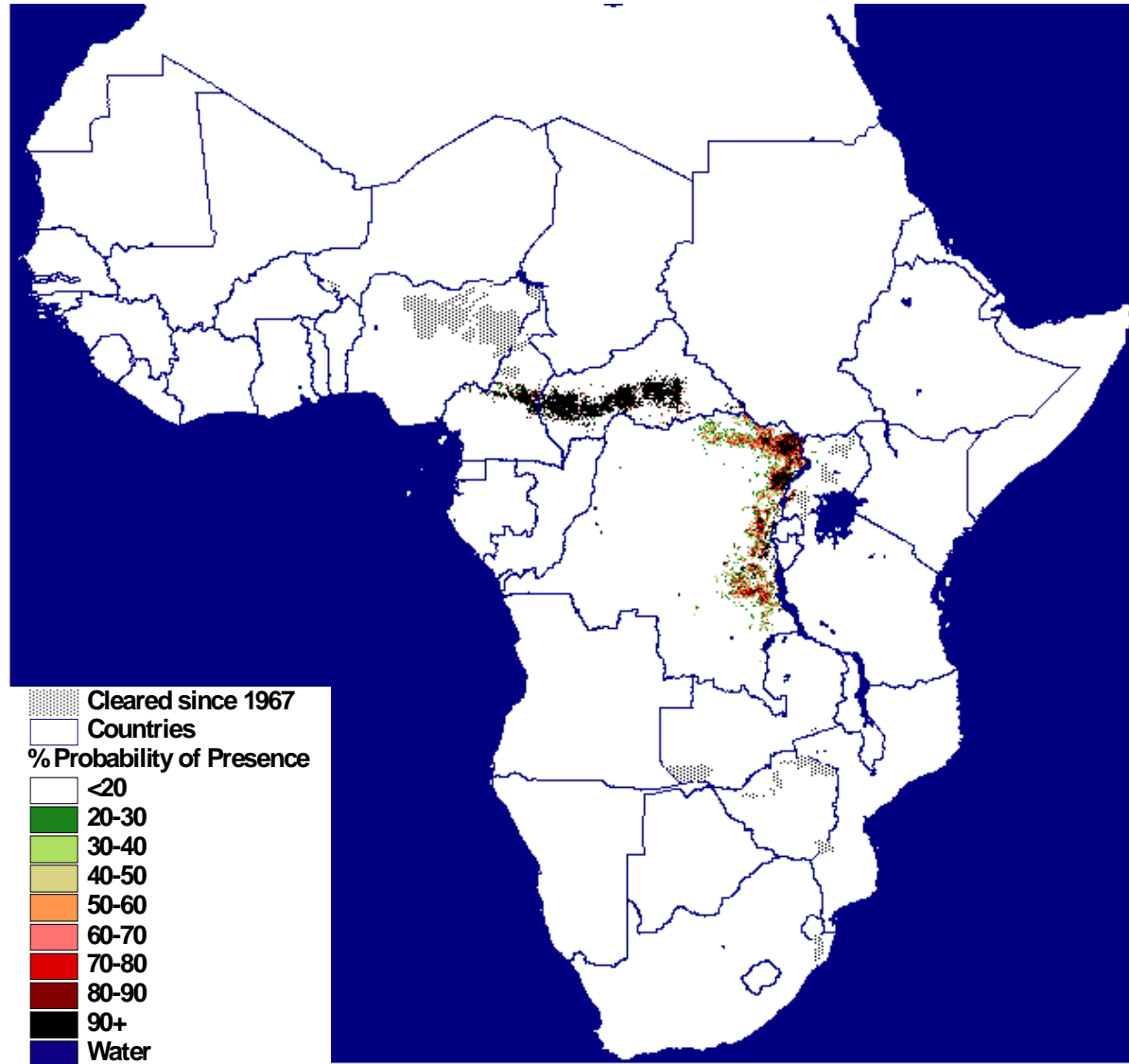
Map 15: *G. brevipalpis*: Predicted % Probability of Presence



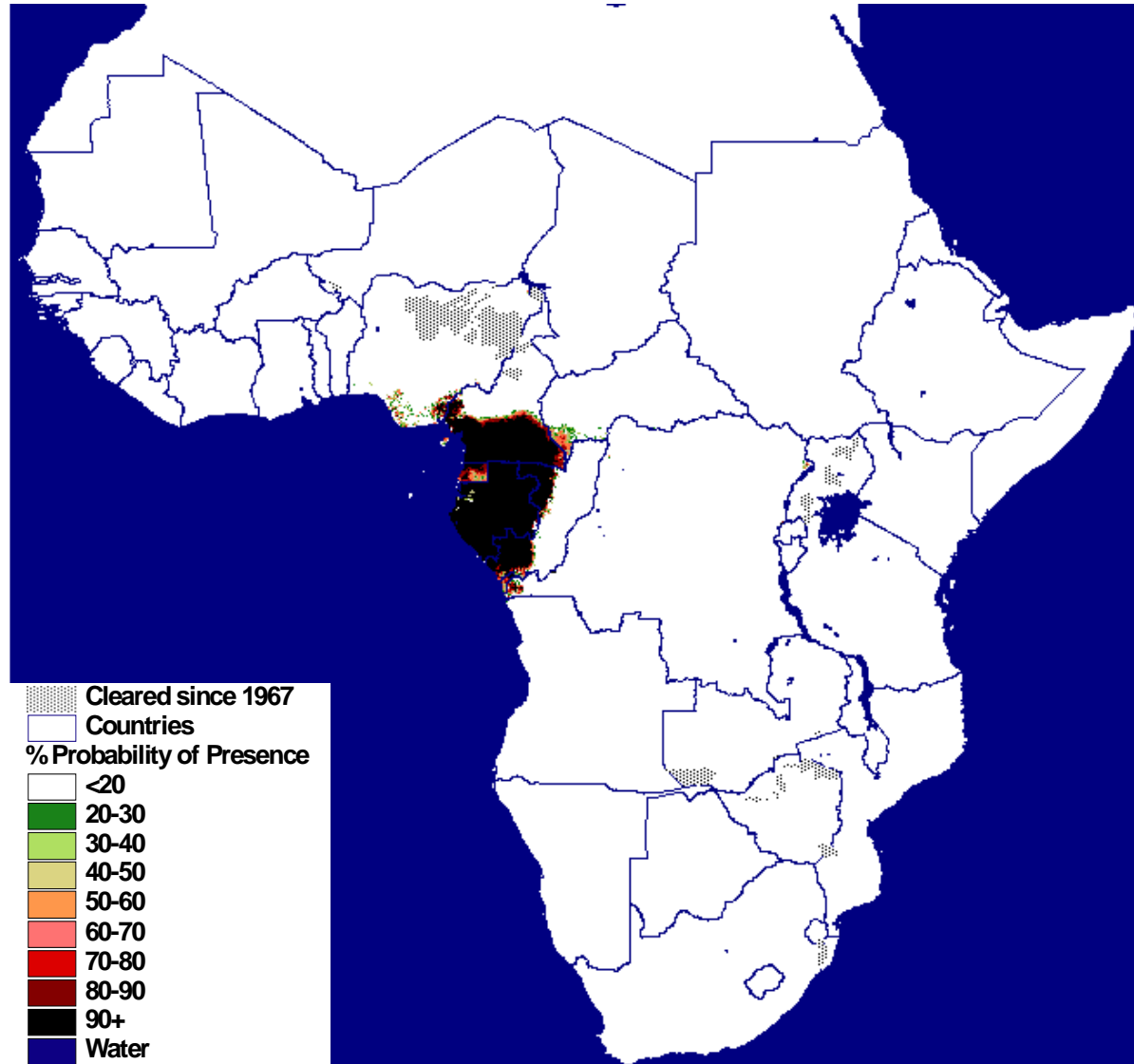
Map 16: *G. fusca fusca*: Predicted % Probability of Presence



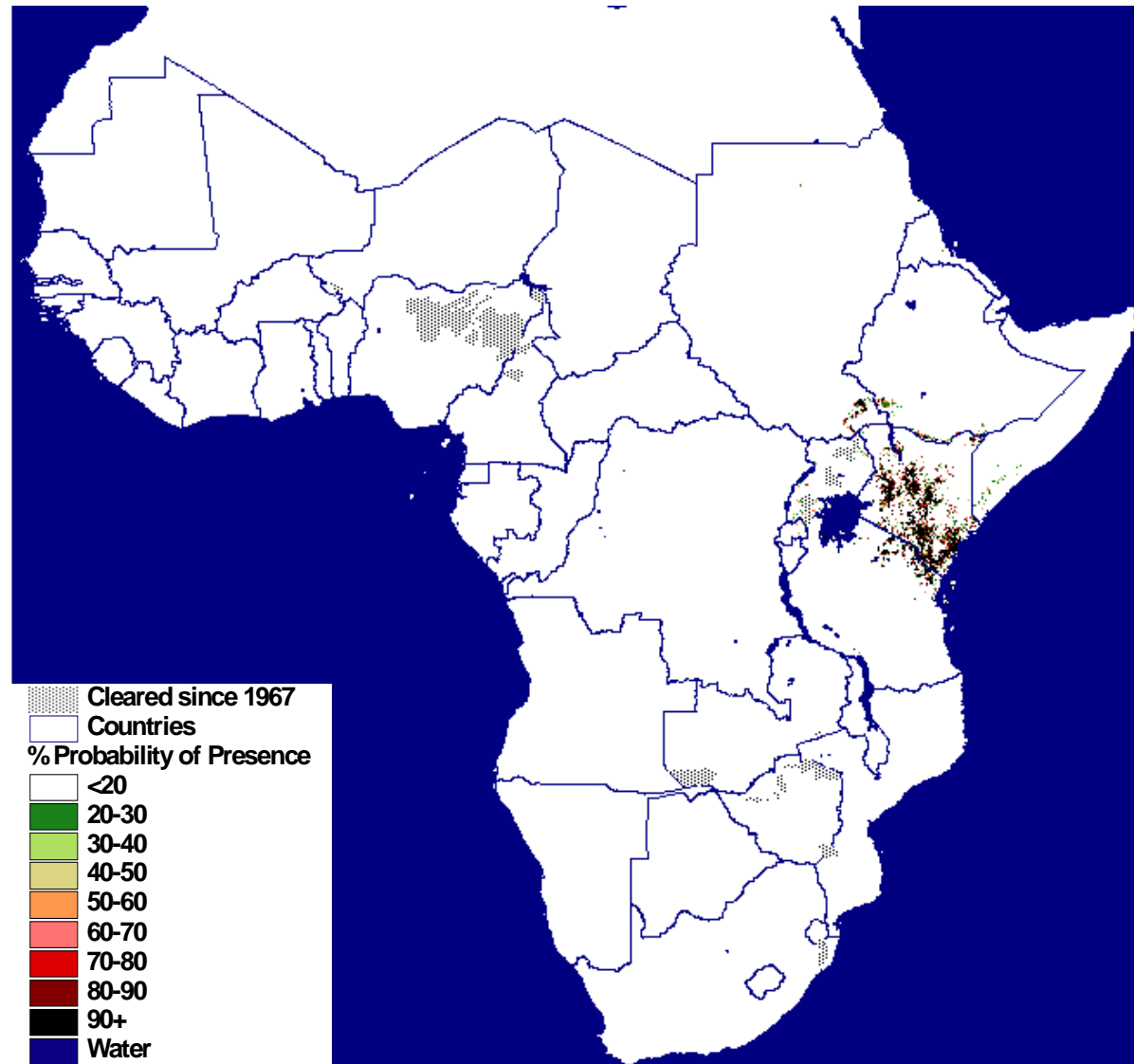
Map 17: *G. fuscipleuris*: Predicted % Probability of Presence



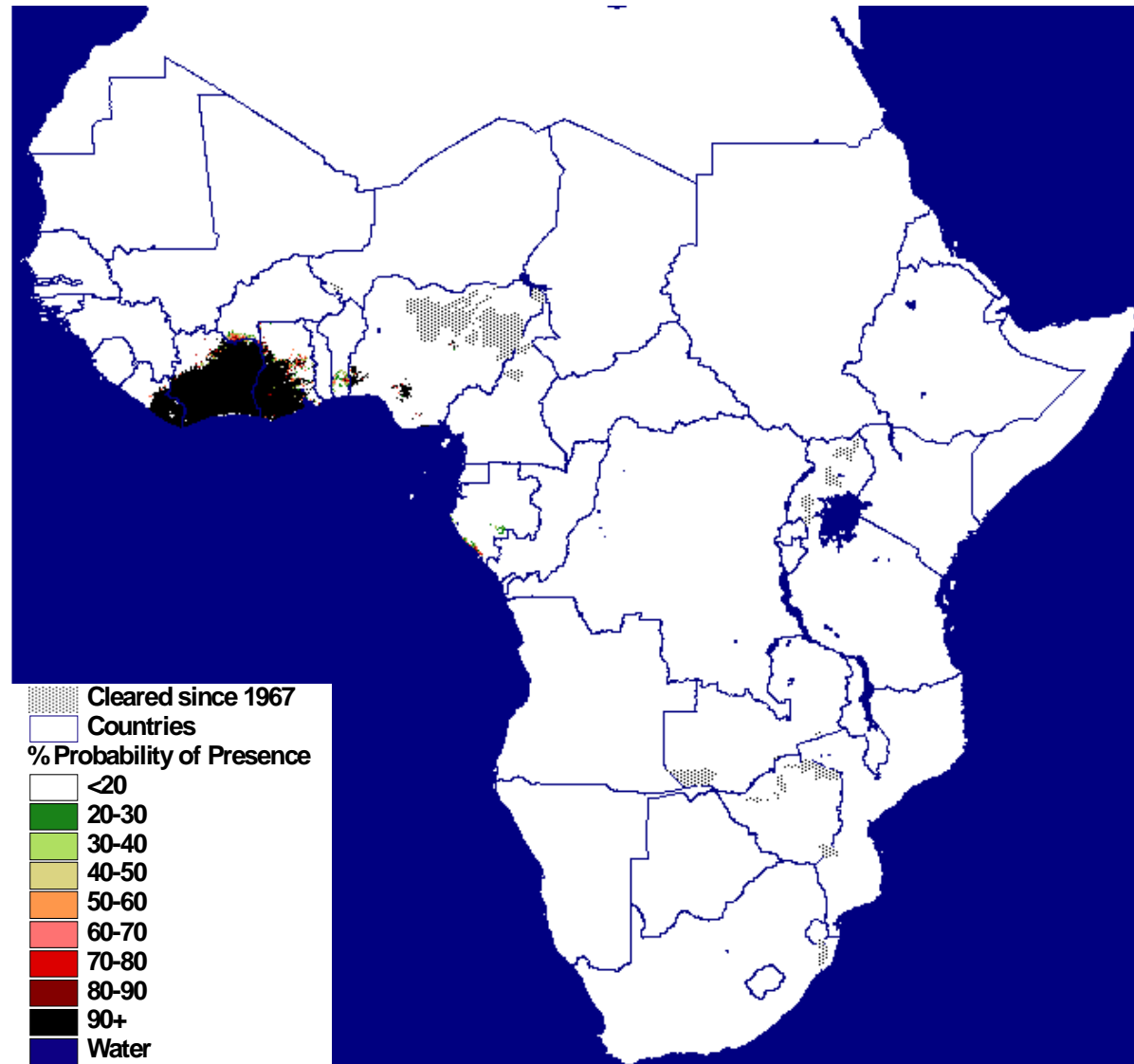
Map 18: *G. hanningtoni*: Predicted % Probability of Presence



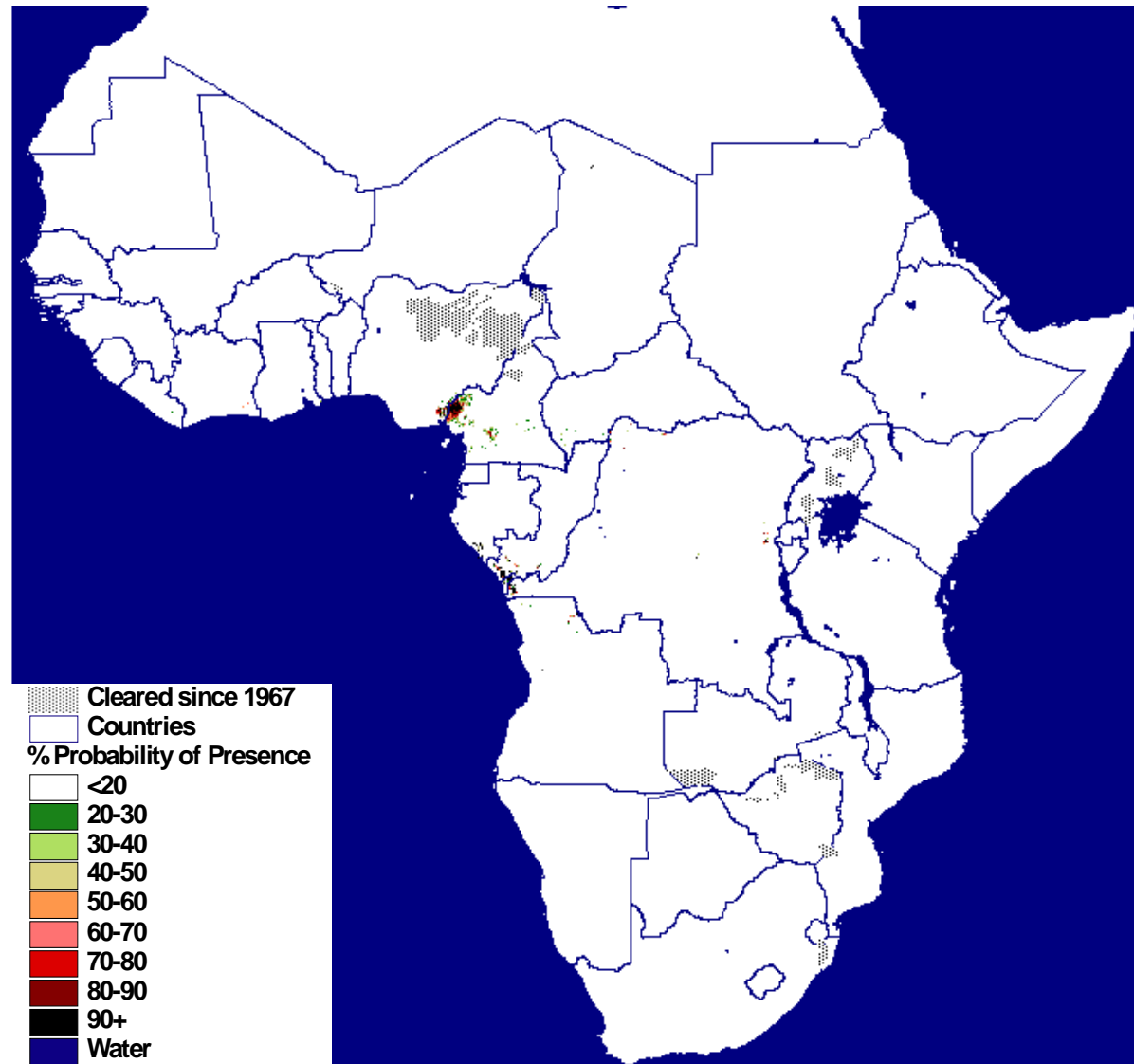
Map 19: *G. longipennis*: Predicted % Probability of Presence



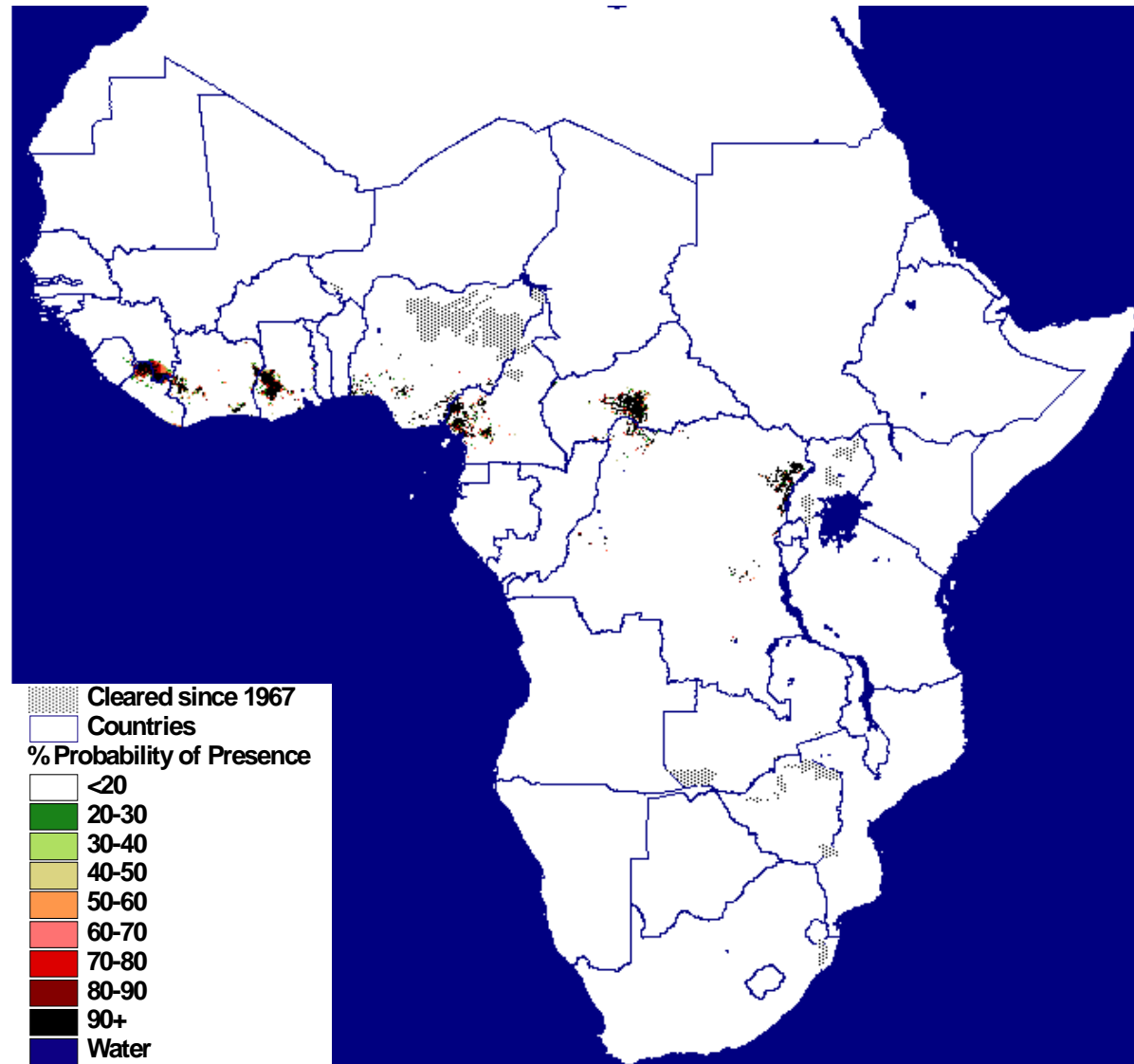
Map 20: *G. medicorum*: Predicted % Probability of Presence



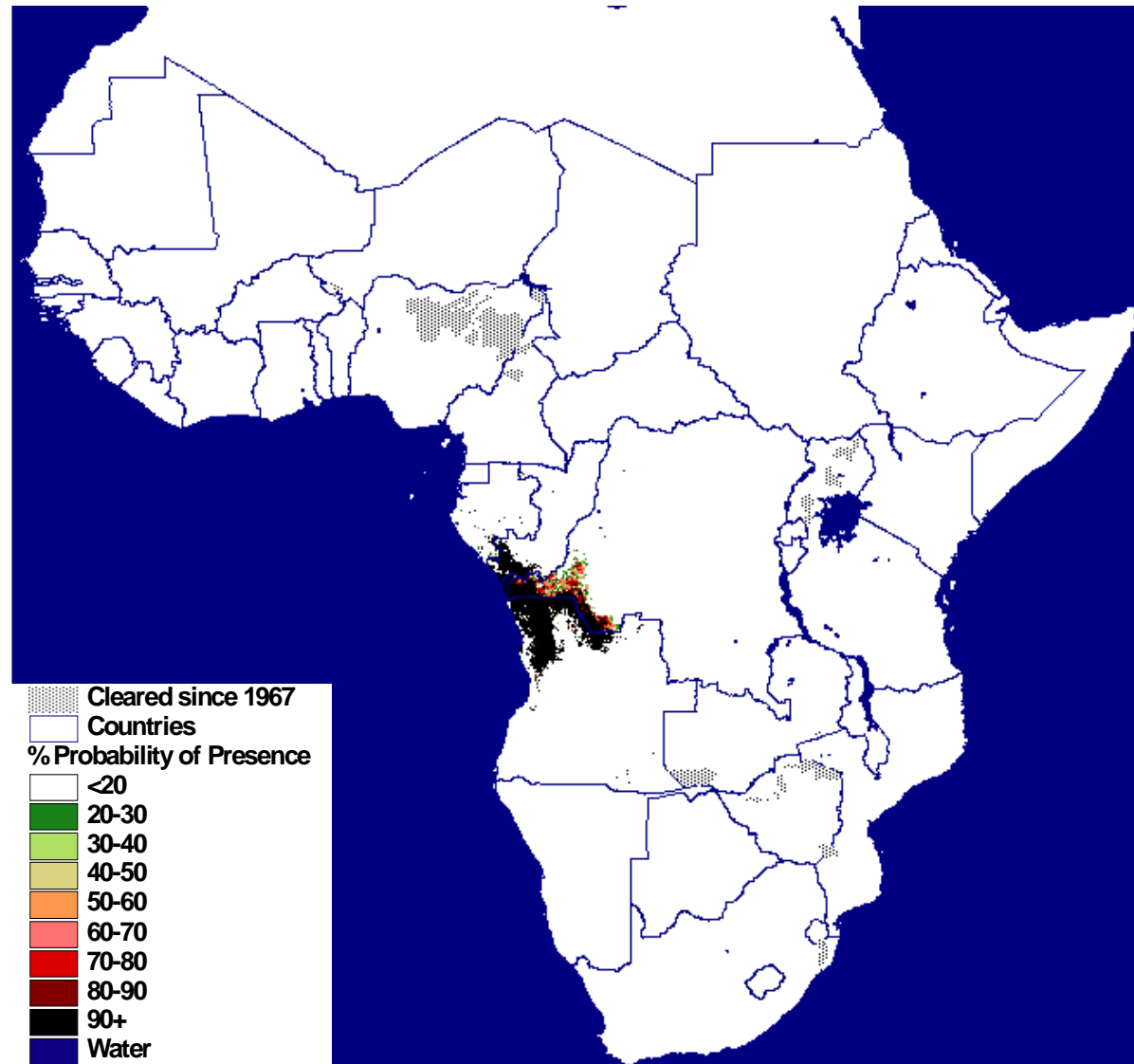
Map 21: *G. nashi*: Predicted % Probability of Presence



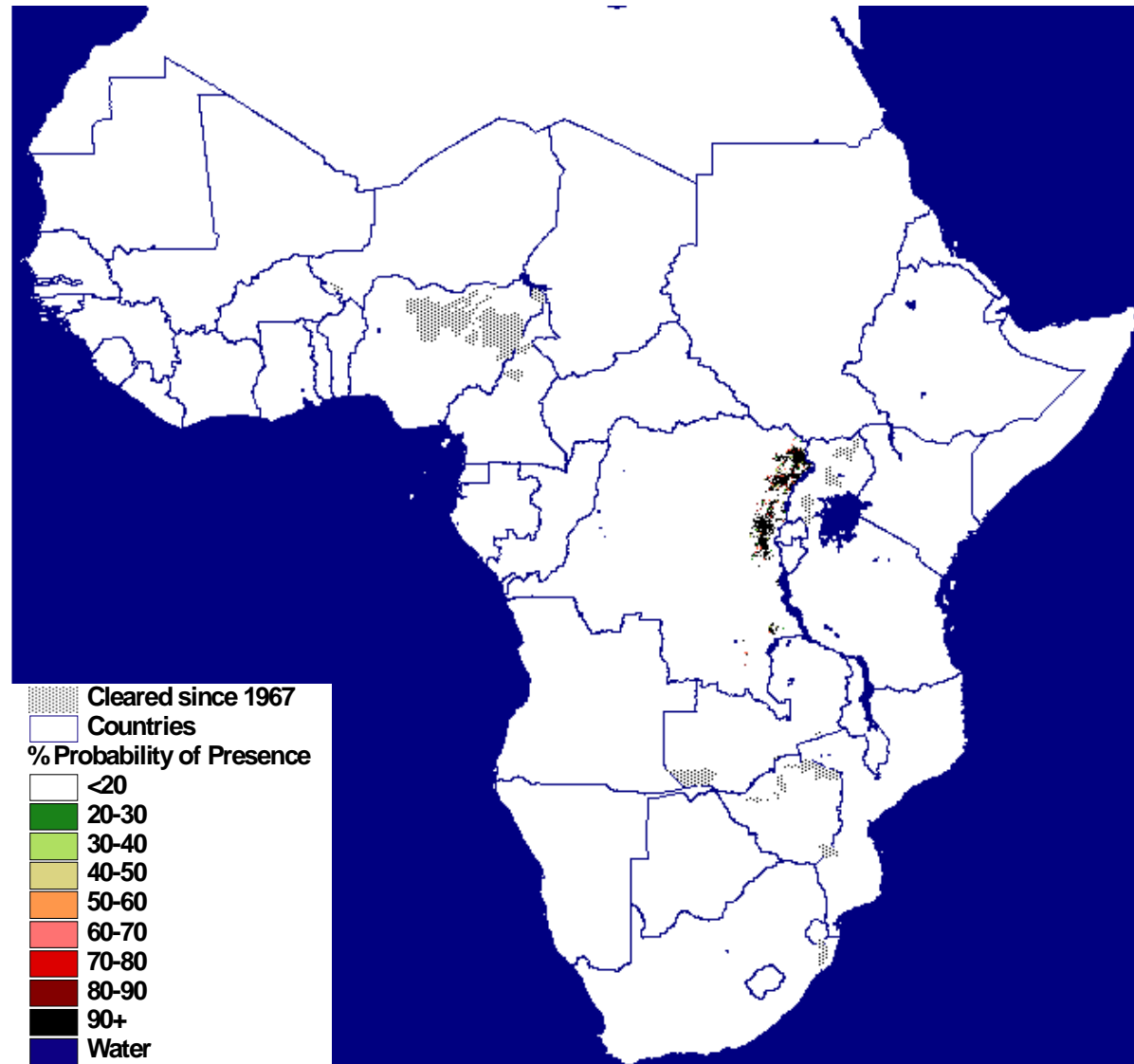
Map 22: *G. nigrofusca*: Predicted % Probability of Presence



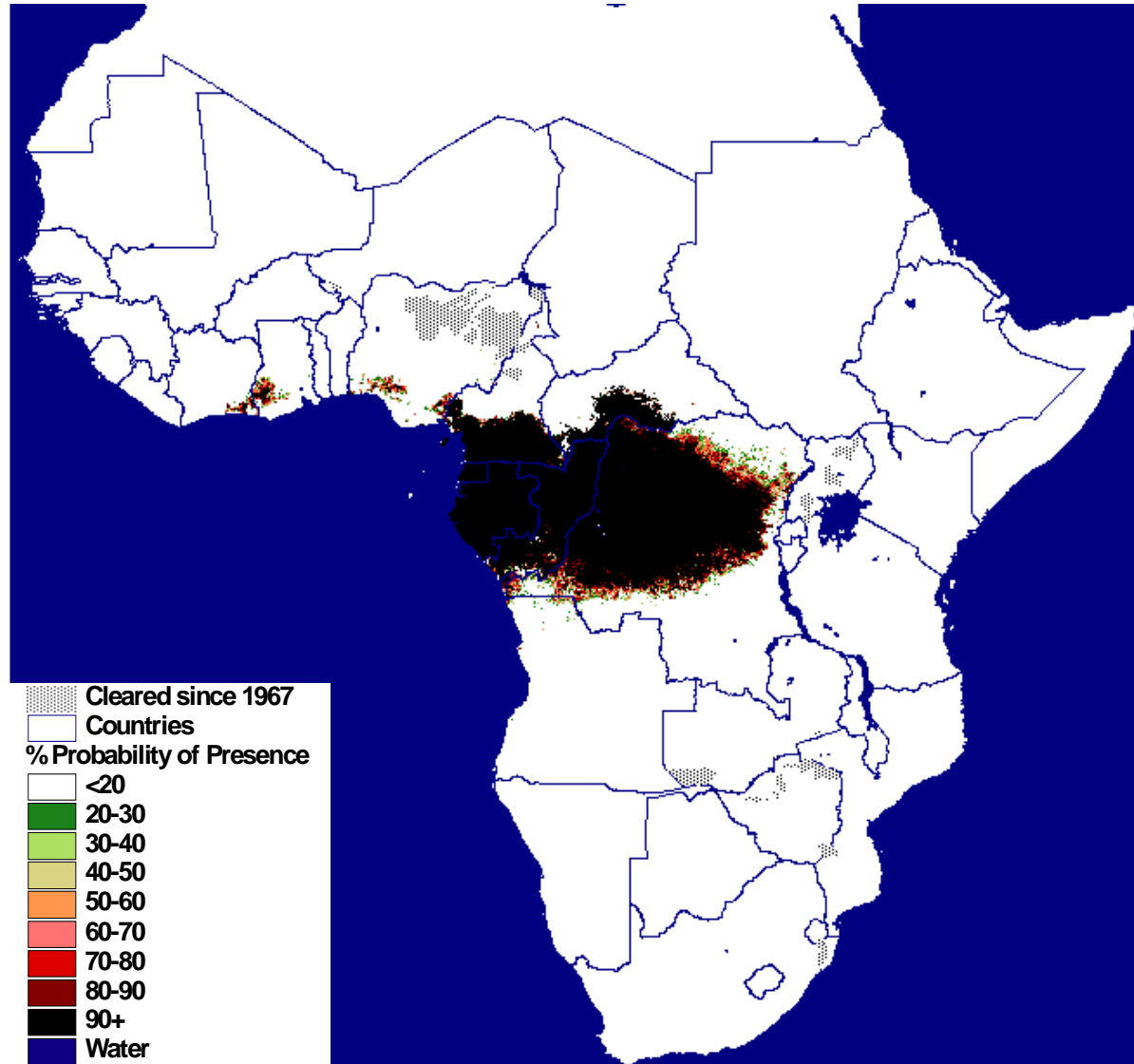
Map 23: *G. schwezei*: Predicted % Probability of Presence



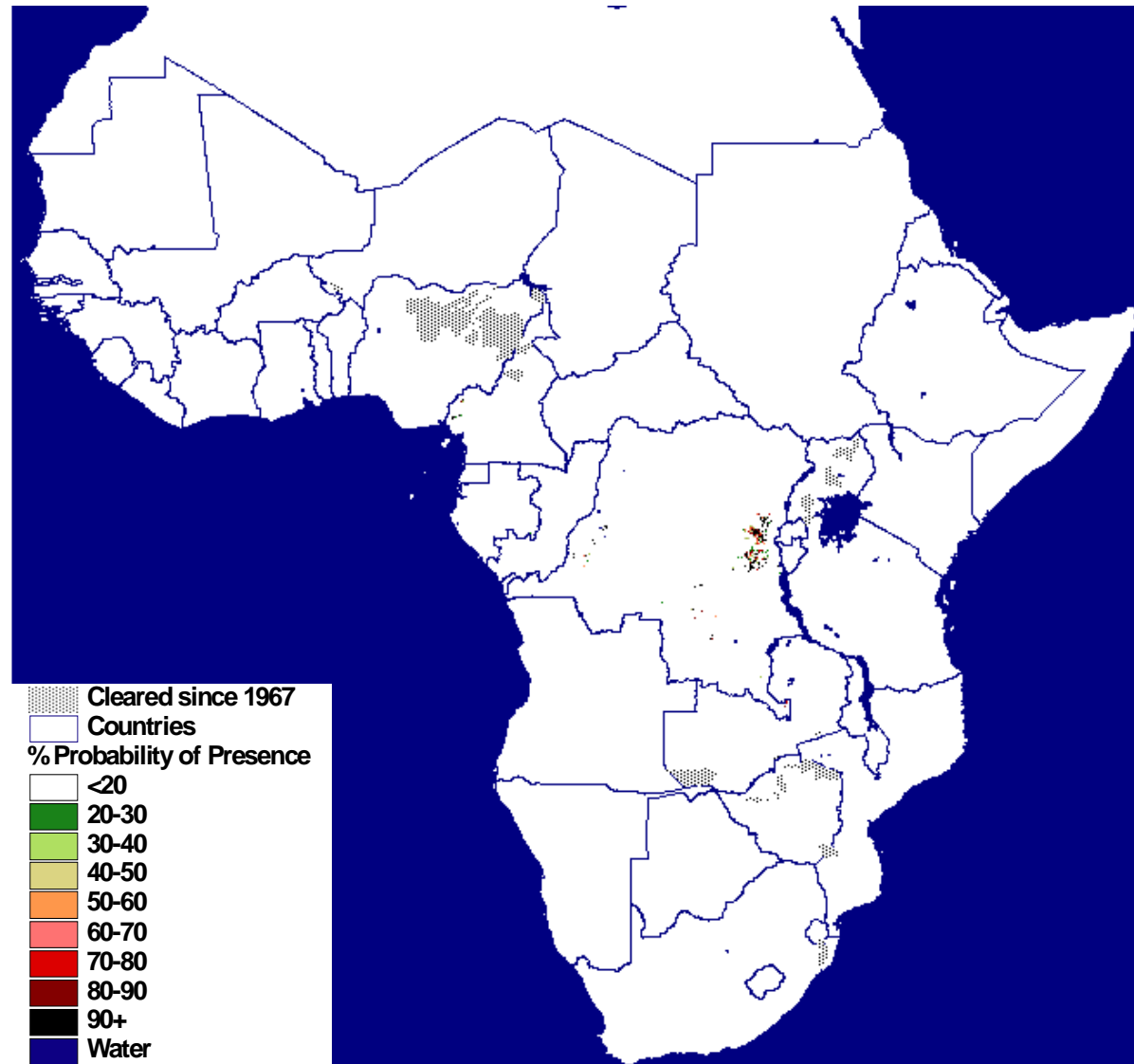
Map 24: *G. severini*: Predicted % Probability of Presence



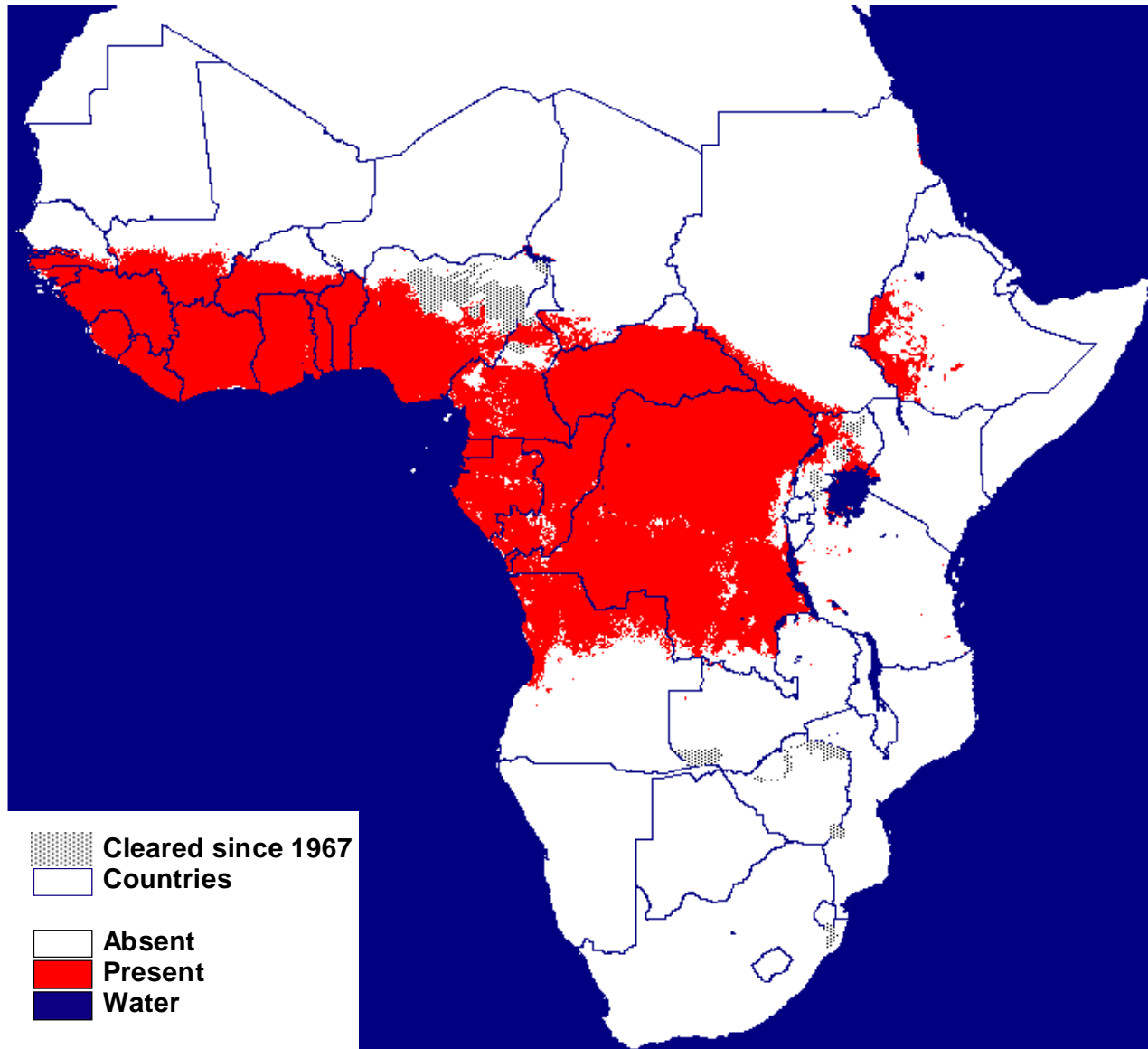
Map 25: *G. tabaniformis*: Predicted % Probability of Presence



Map 26: *G. vanhoofi*: Predicted % Probability of Presence

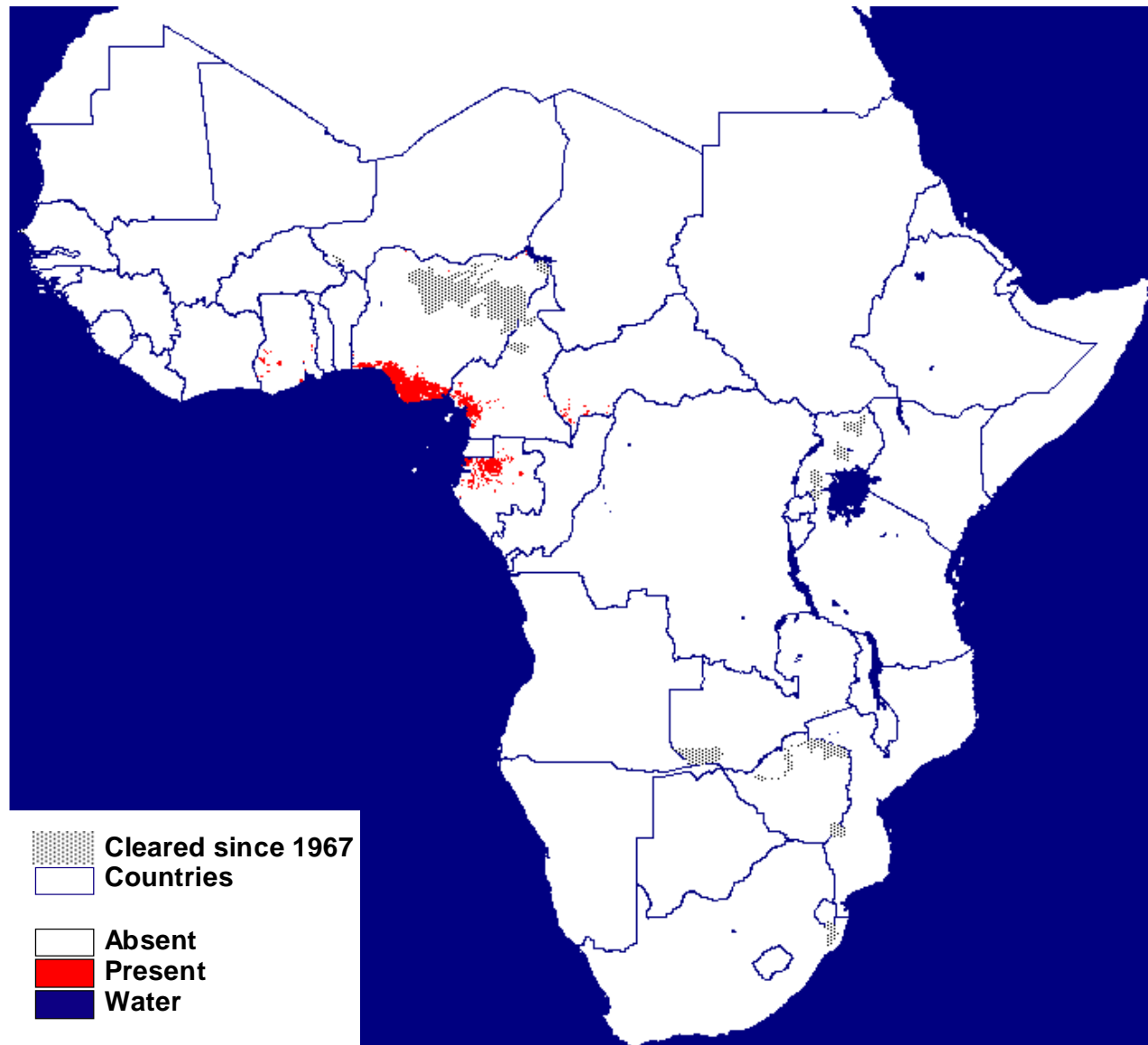


Map 27: Palpalis Group: Predicted Presence and Absence

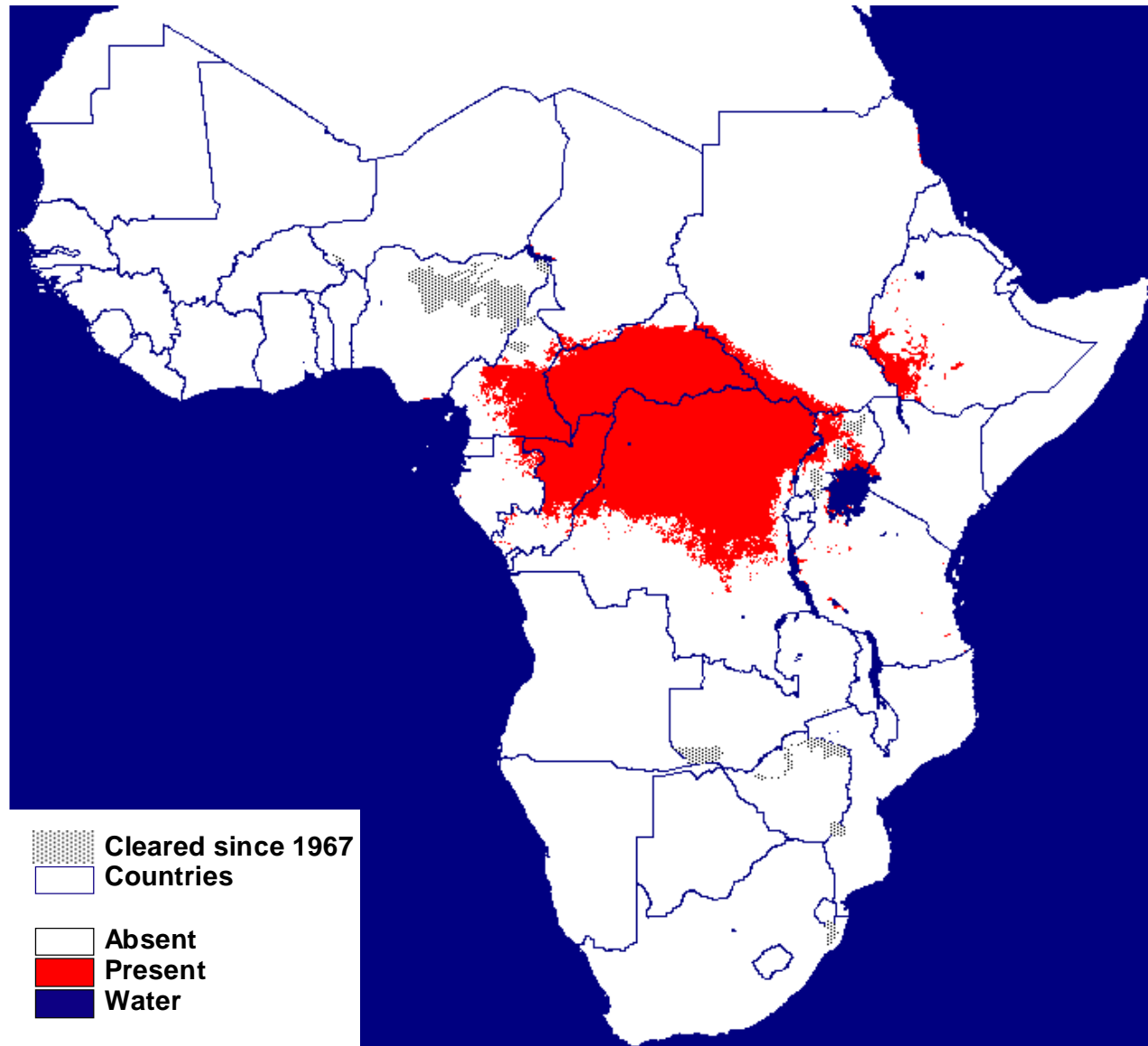


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Map 28: *G. calliginea*: Predicted Presence and Absence



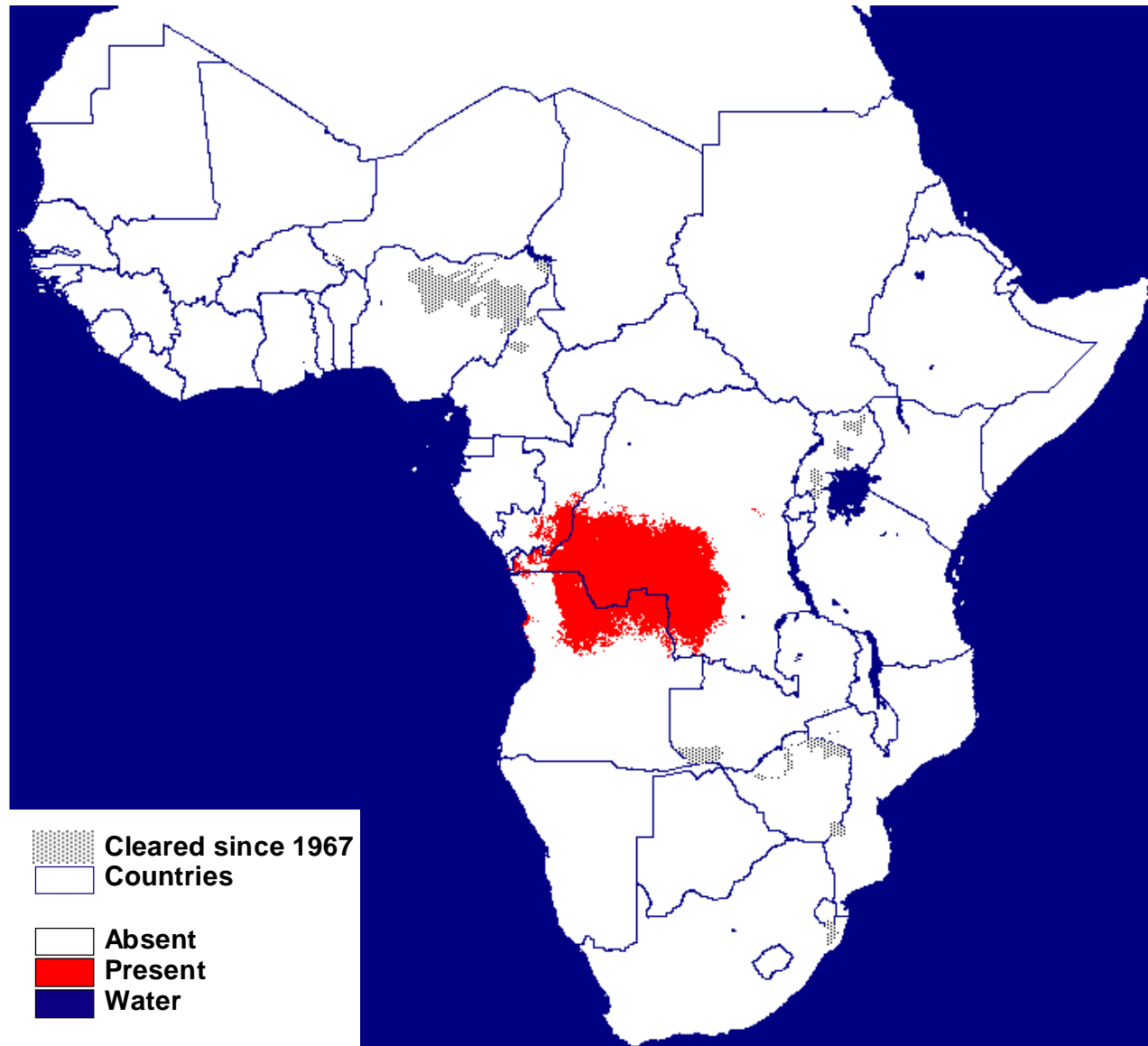
Map 29: *G. fuscipes fuscipes*: Predicted Presence and Absence



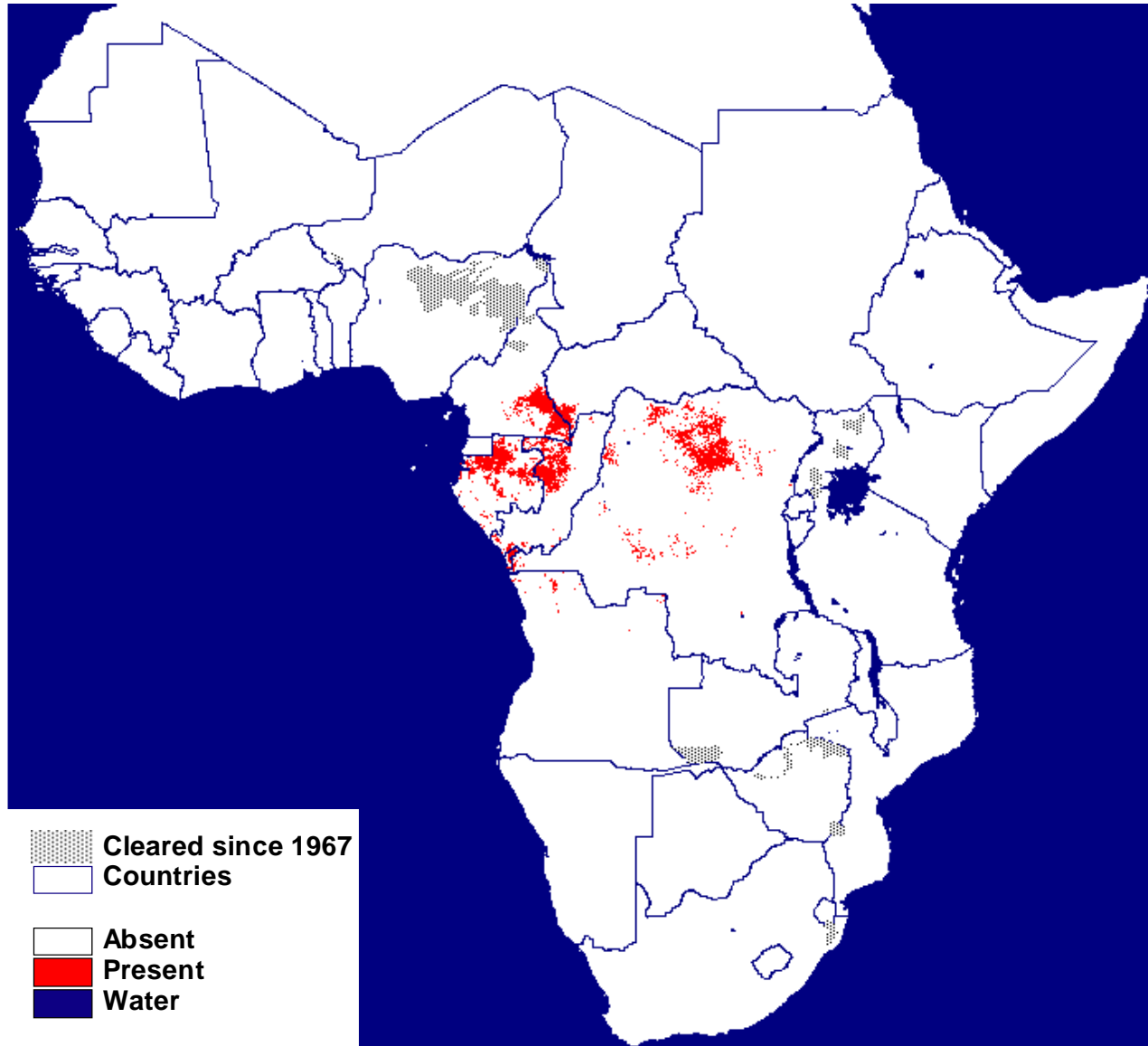
Map 30: *G. fuscipes martinii*: Predicted Presence and Absence



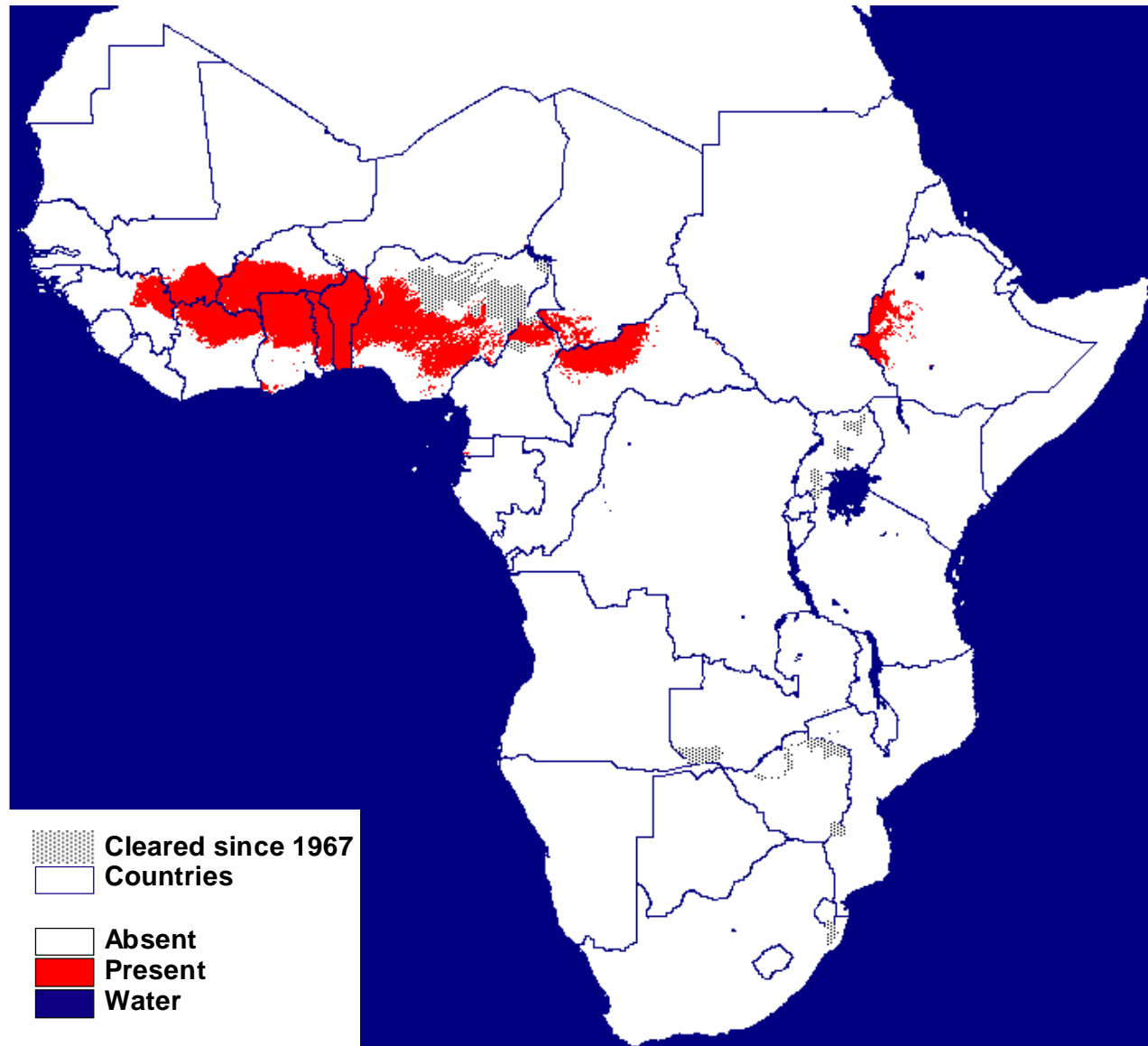
Map 31: *G. fuscipes quanzensis*: Predicted Presence and Absence



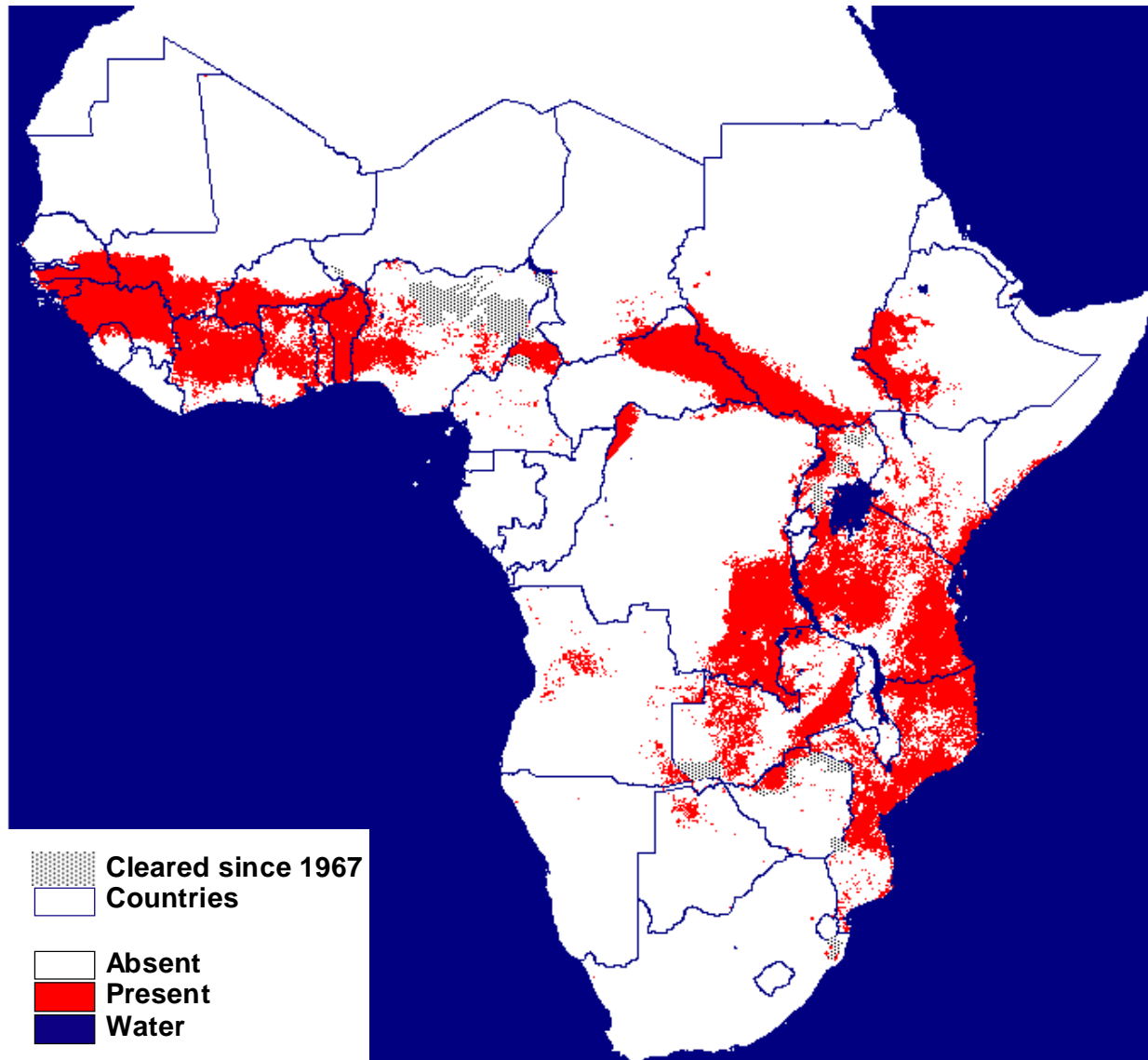
Map 32: *G. pallicera newsteadi*: Predicted Presence and Absence



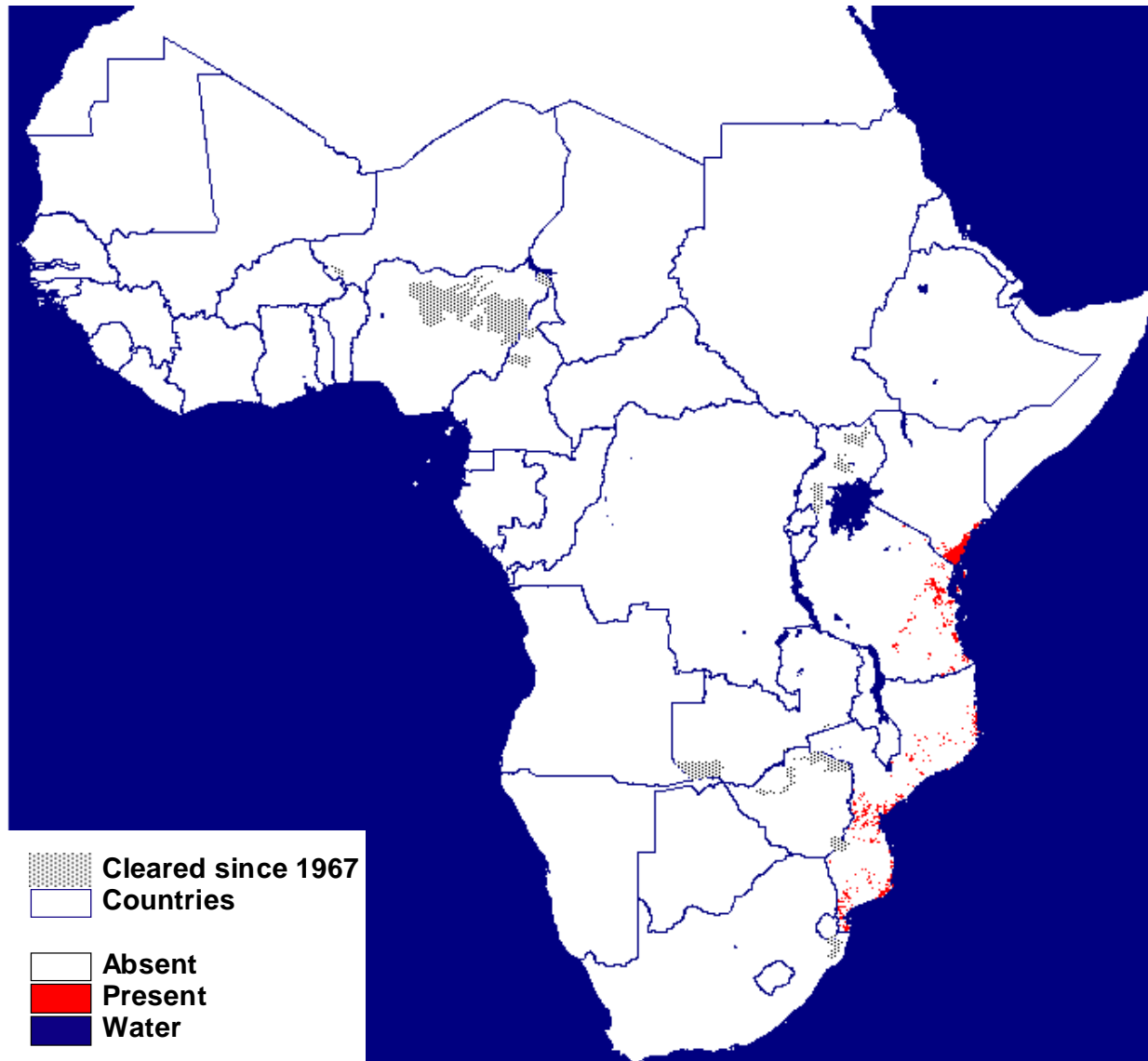
Map 33: *G. tachinoides*: Predicted Presence and Absence



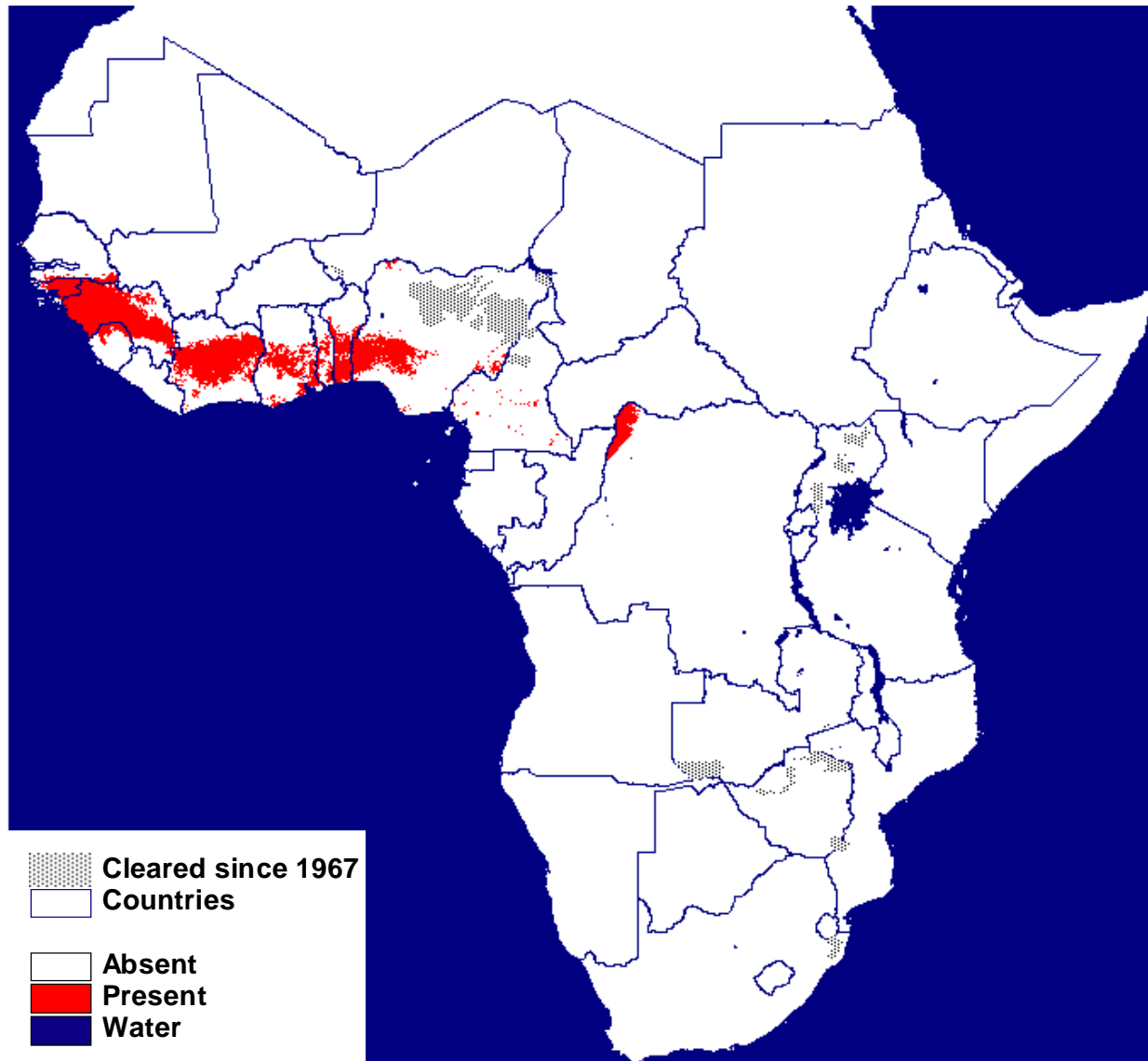
Map 34: Morsitans Group: Predicted Presence and Absence



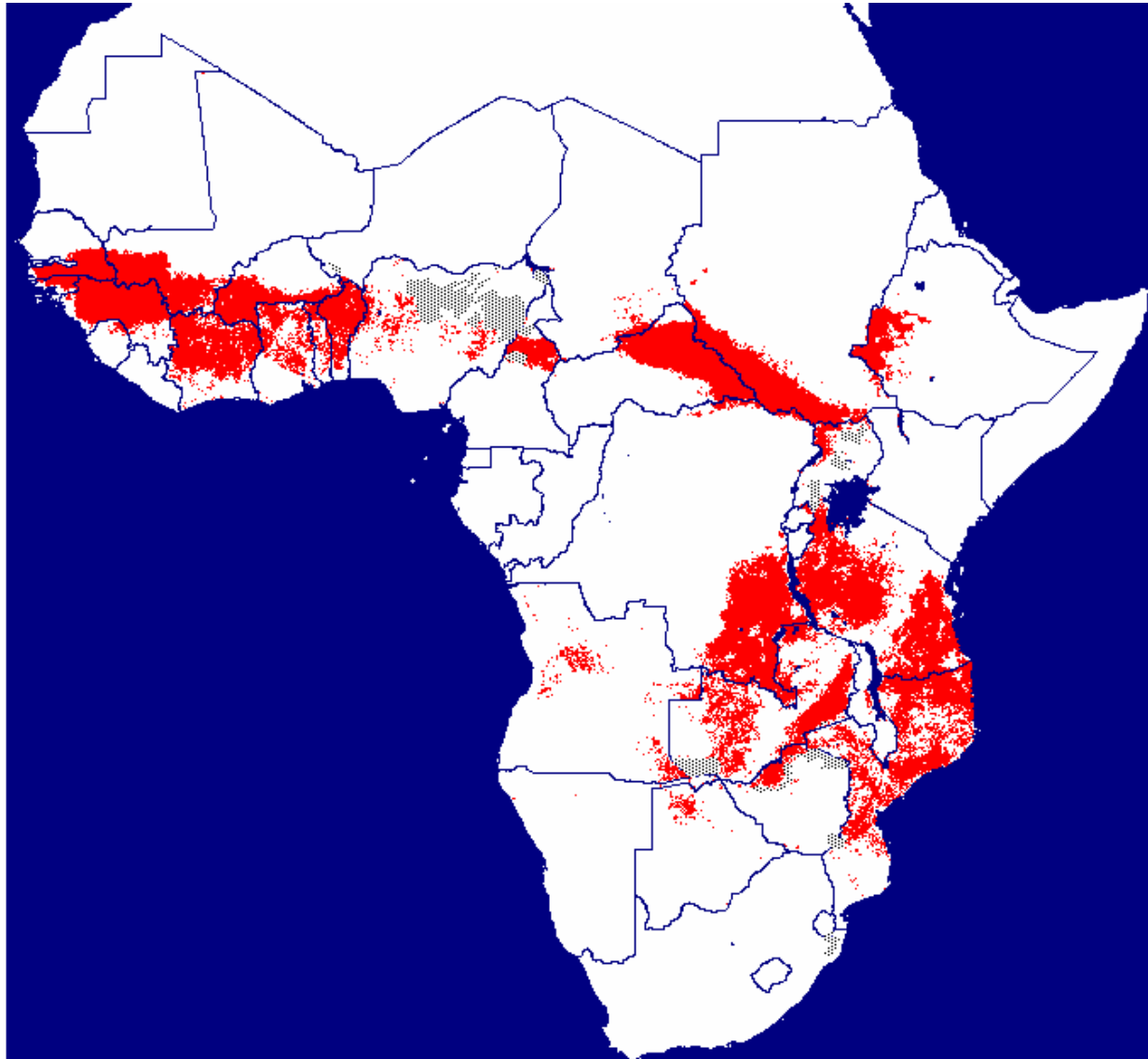
Map 35: *G. austeni*: Predicted Presence and Absence



Map 36: *G. longipalpis*: Predicted Presence and Absence

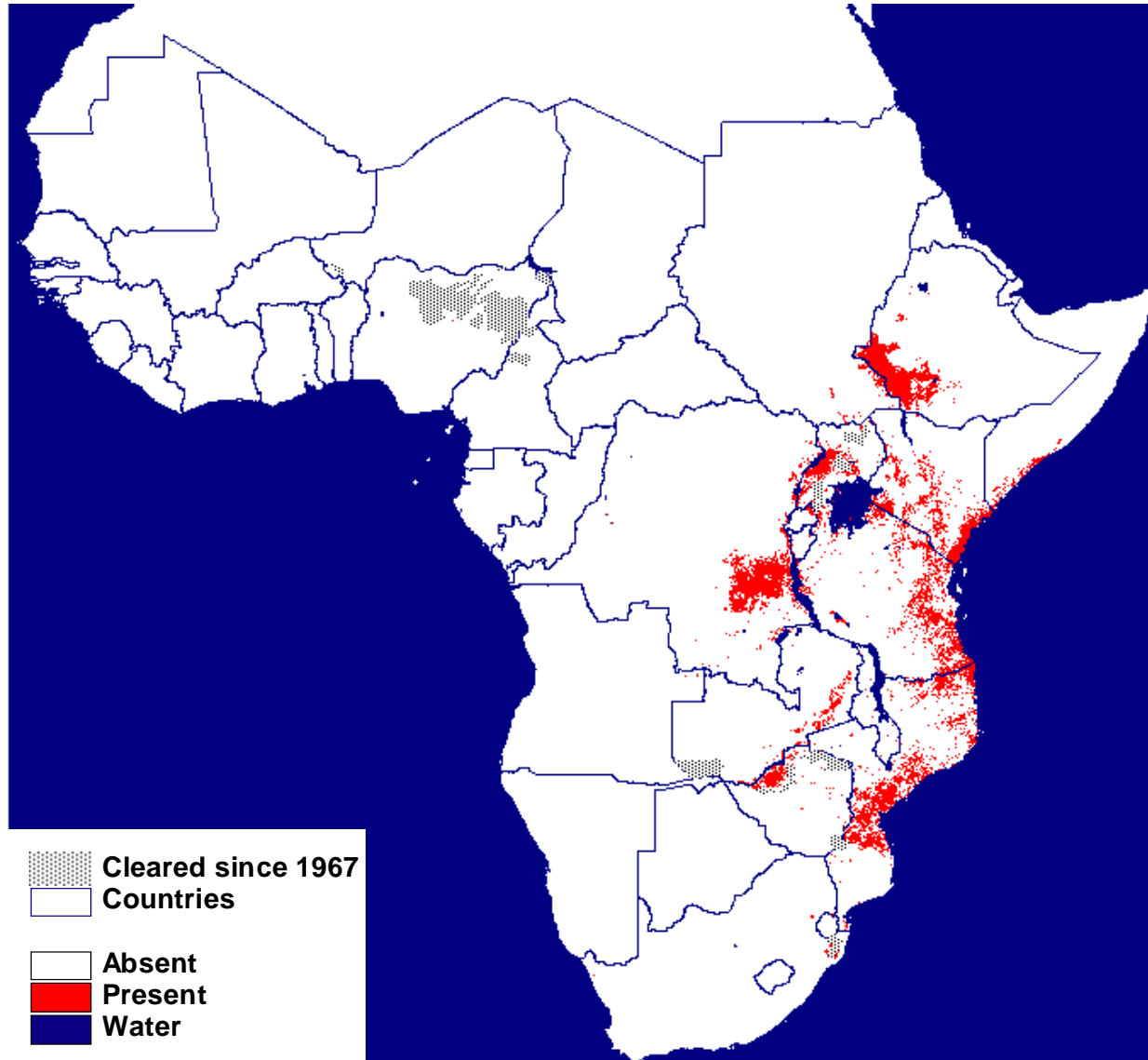


Map 37: *G. morsitans*: Predicted Presence and Absence

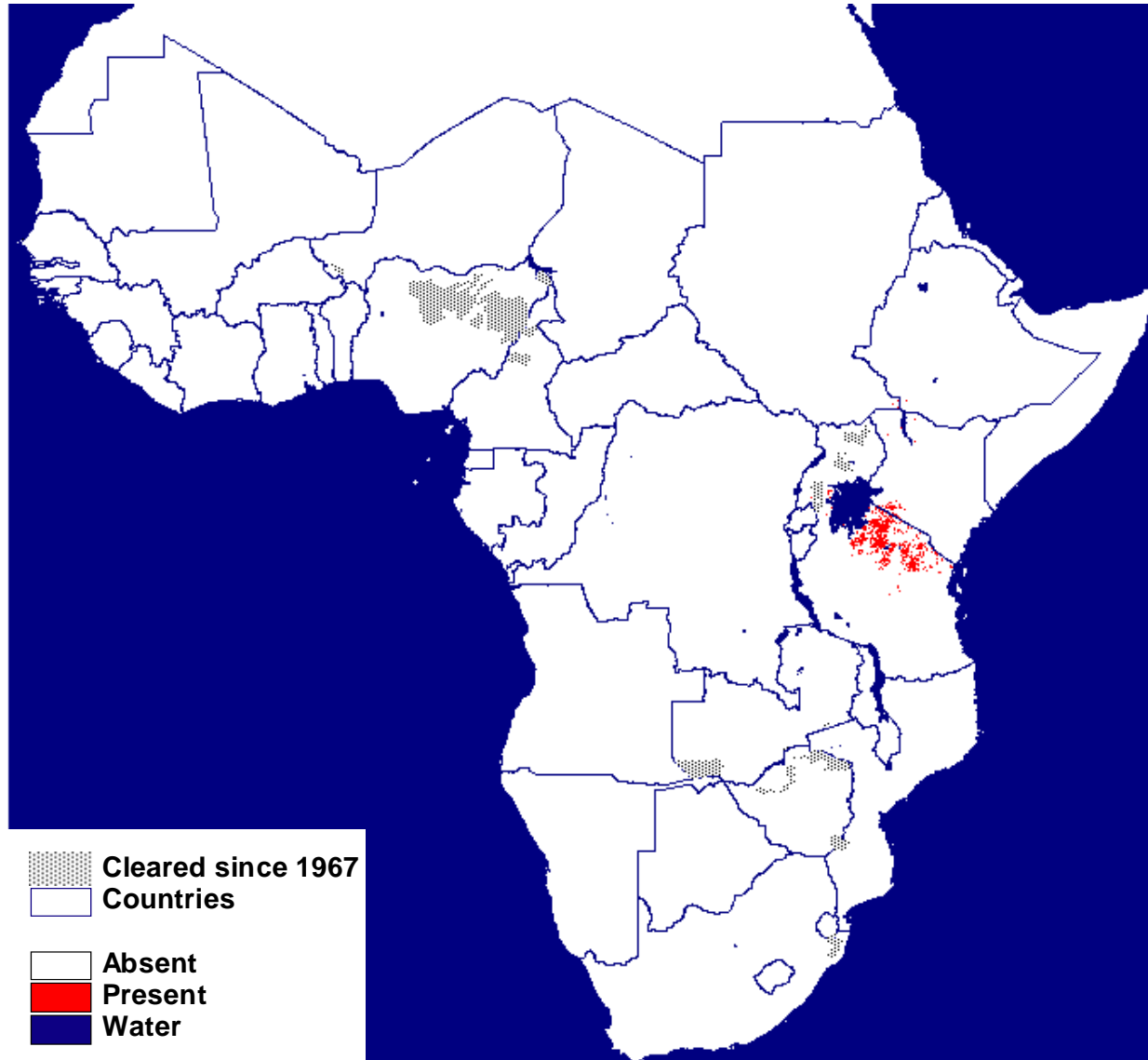


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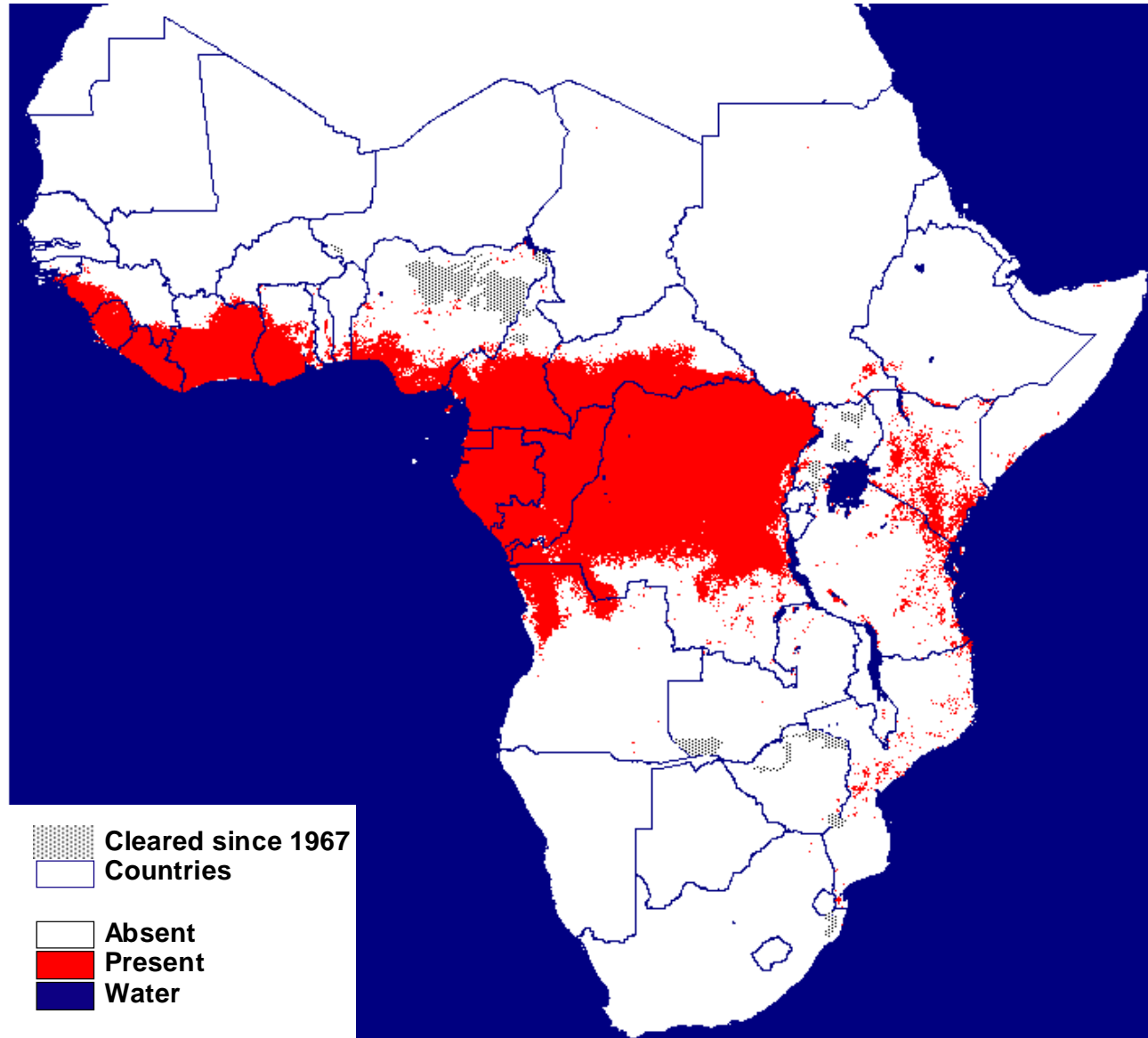
Map 38: *G. pallidipes*: Predicted Presence and Absence



Map 39: *G. swynnertoni*: Predicted Presence and Absence

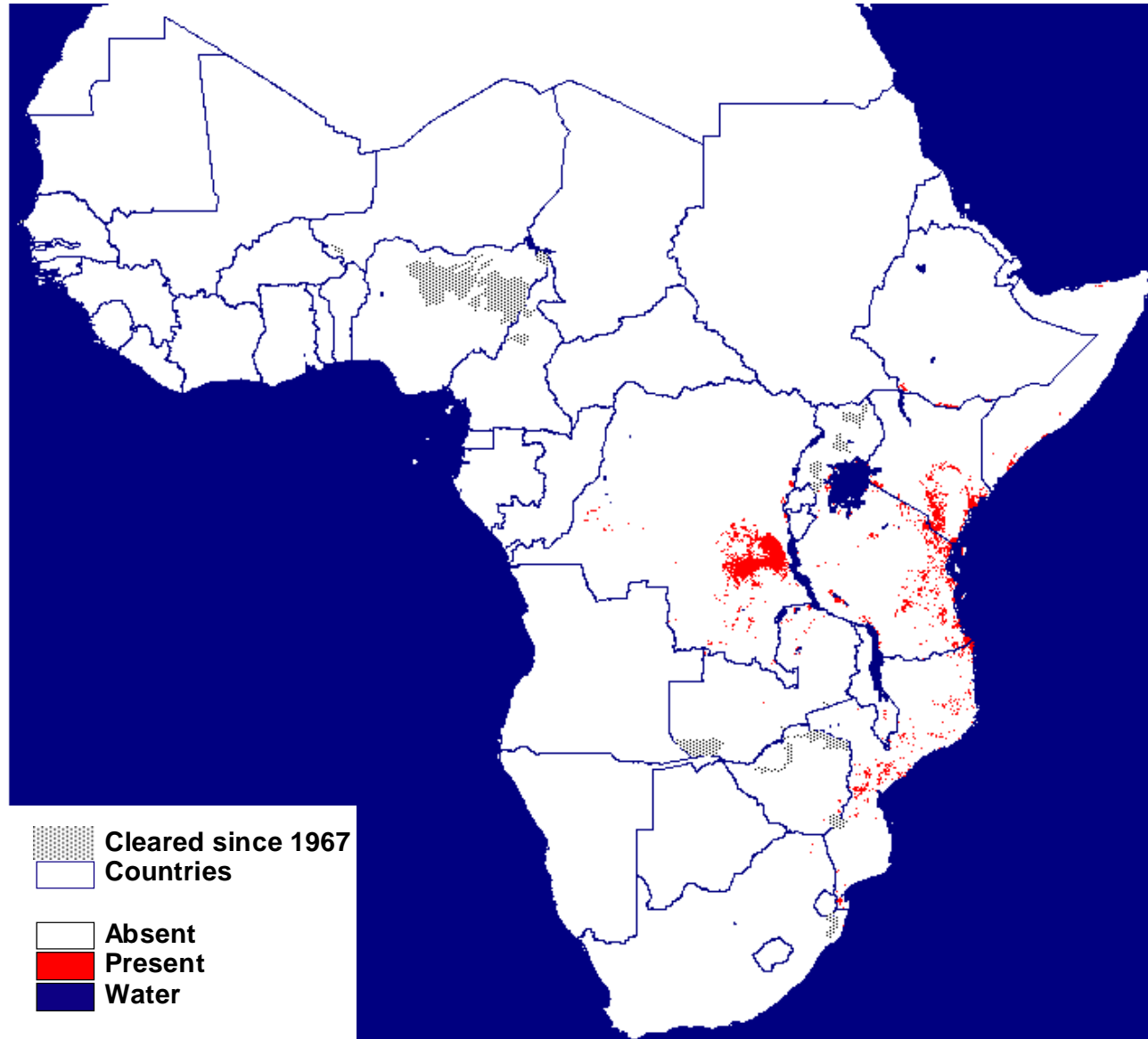


Map 40: Fusca Group: Predicted Presence and Absence



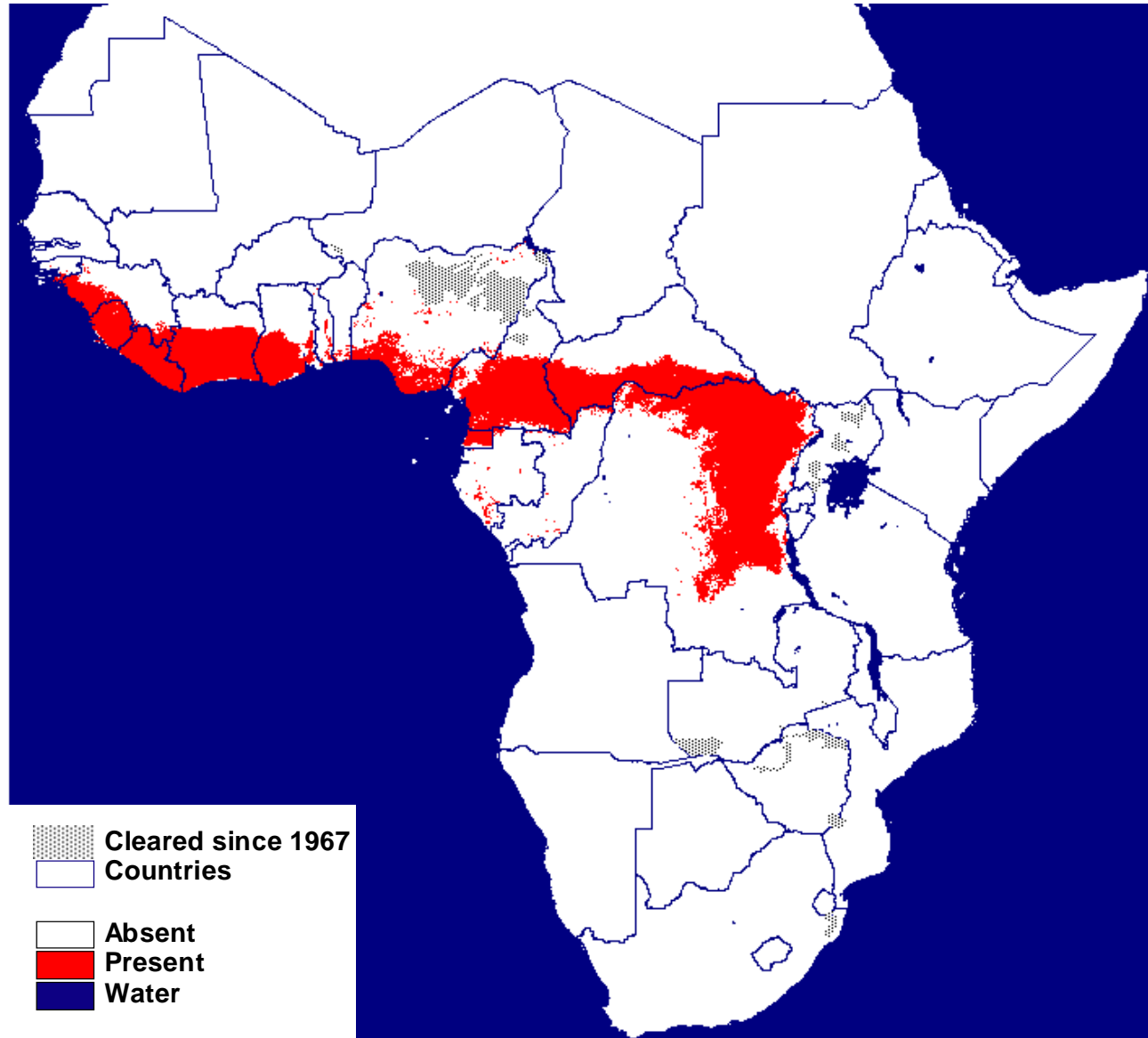
Prepared by ERGO Ltd and TALA Research Group. February 2000.

Map 41: *G. brevipalpis*: Predicted Presence and Absence



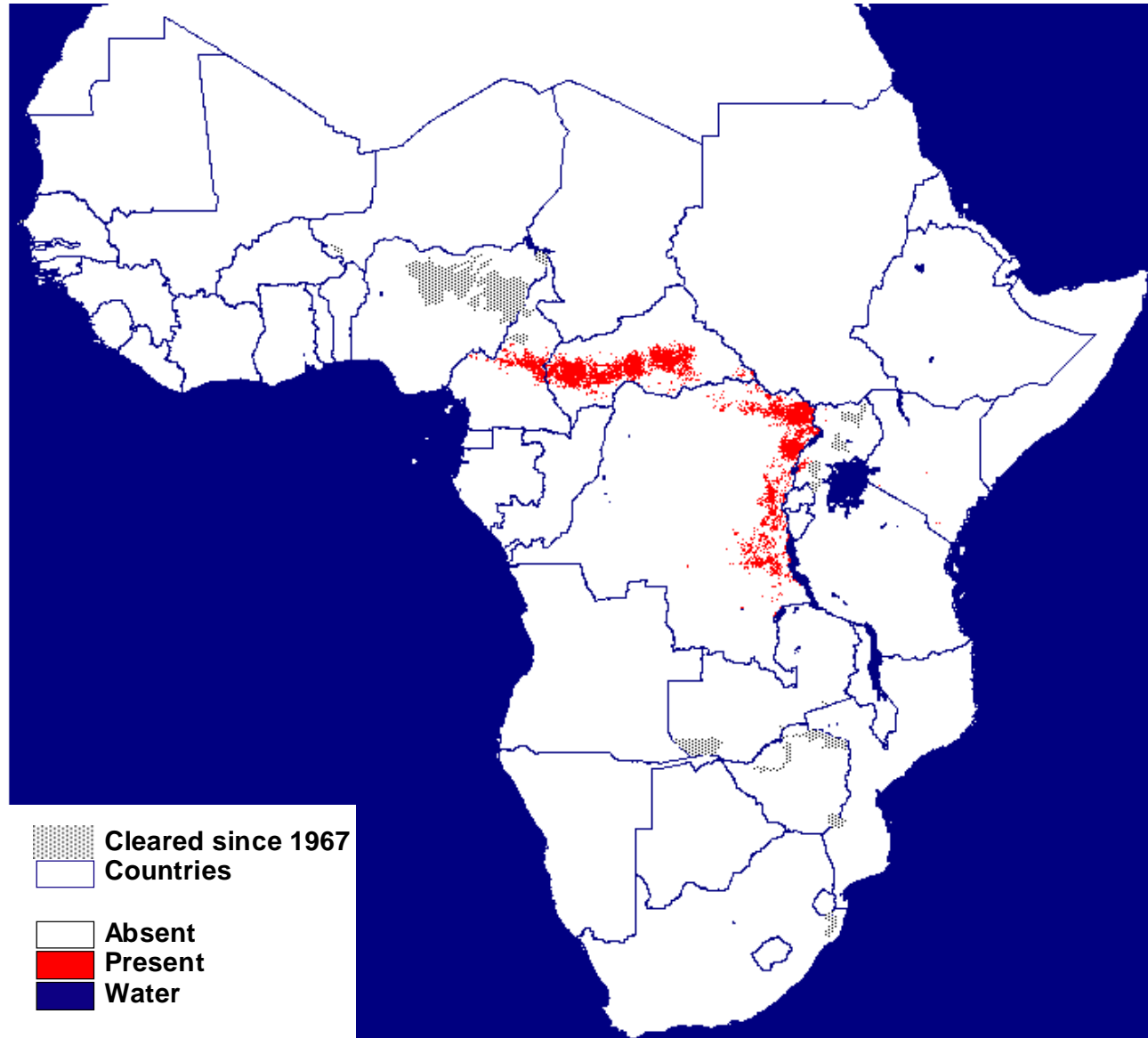
Prepared by ERGO Ltd and TALA Research Group. February 2000.

Map 42: *G. fusca fusca*: Predicted Presence and Absence



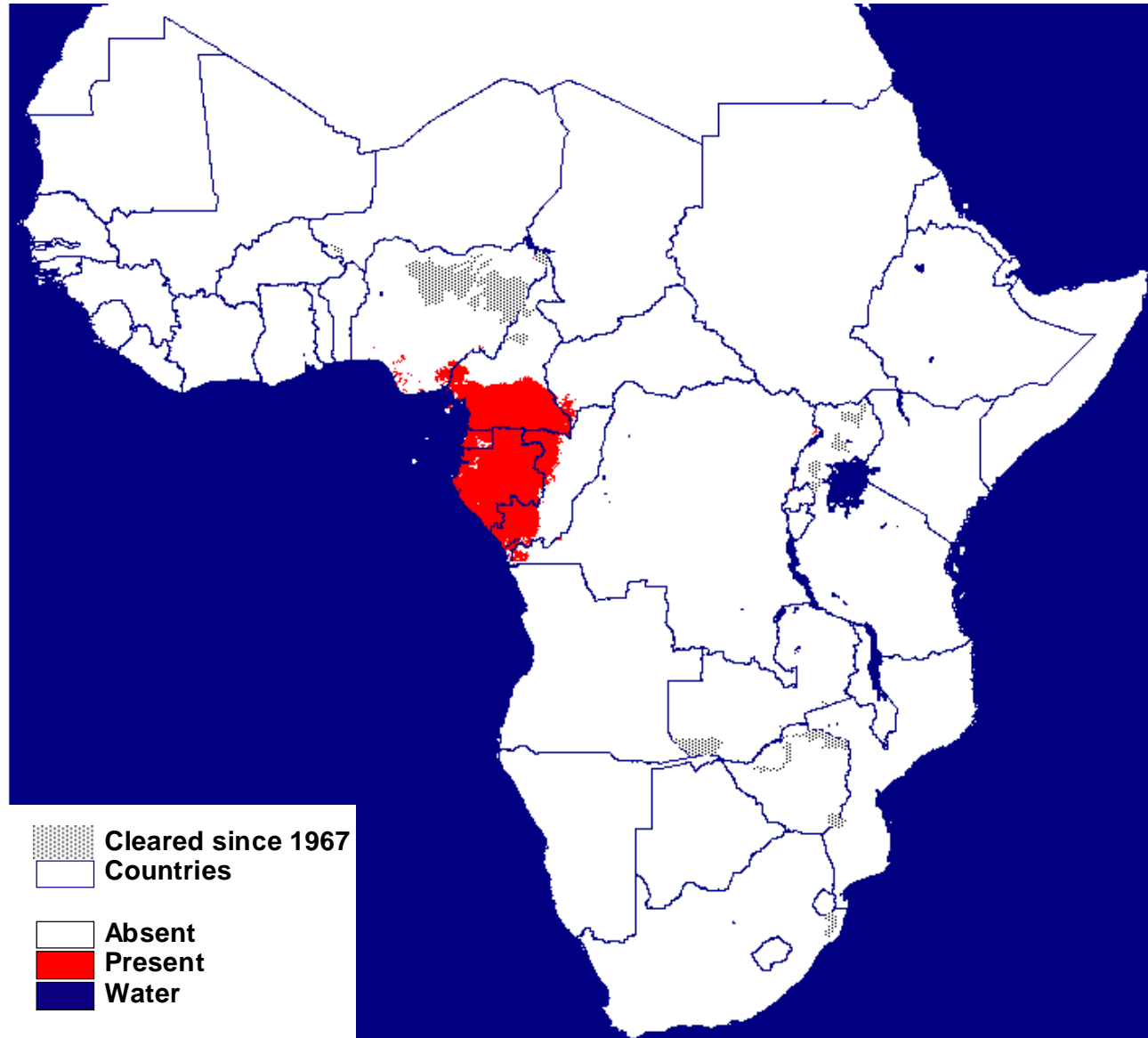
Prepared by ERGO Ltd and TALA Research Group. February 2000.

Map 43: *G. fuscipleuris*: Predicted Presence and Absence



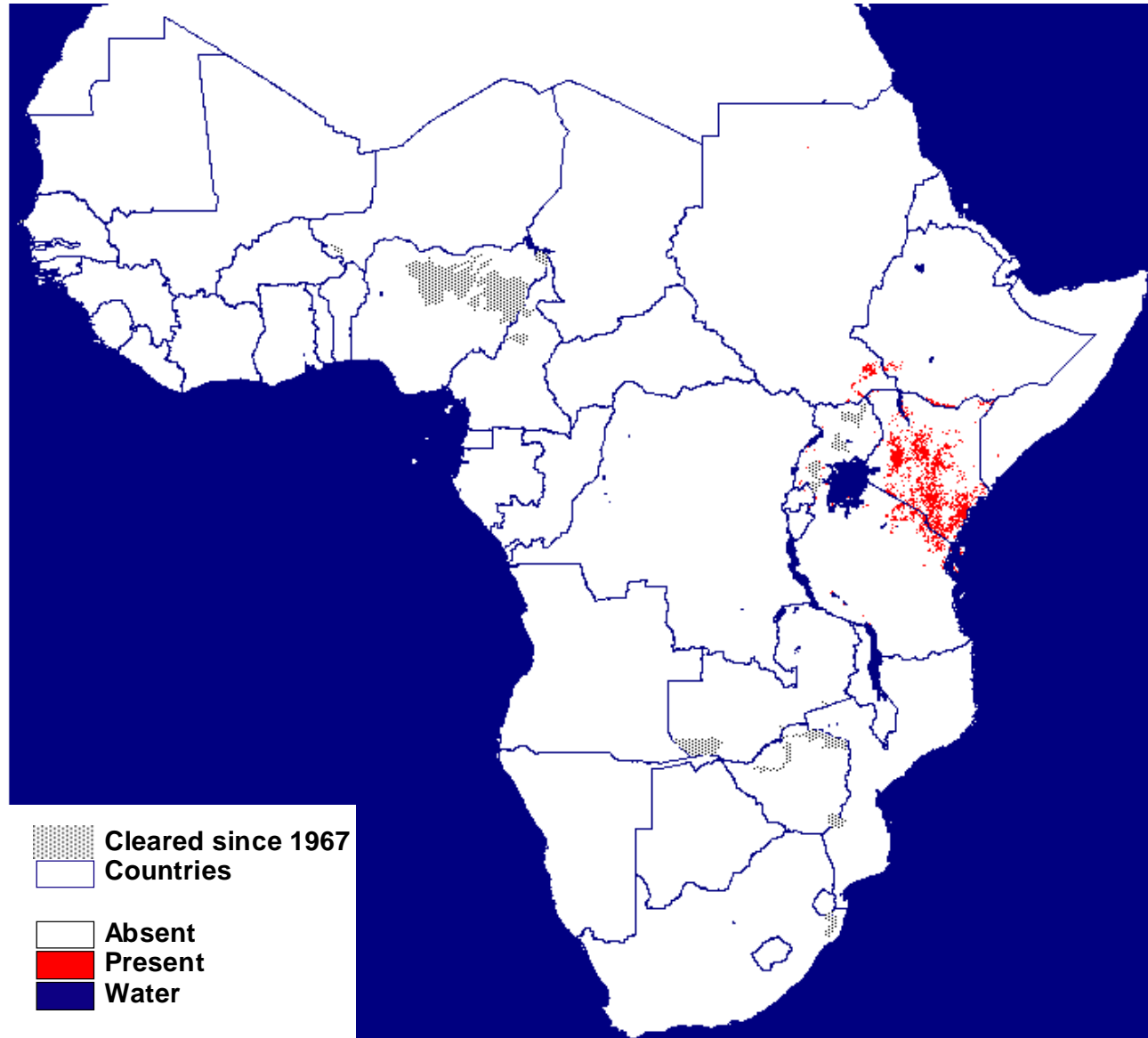
Prepared by ERGO Ltd and TALA Research Group. February 2000.

Map 44: *G. hanningtoni*: Predicted Presence and Absence



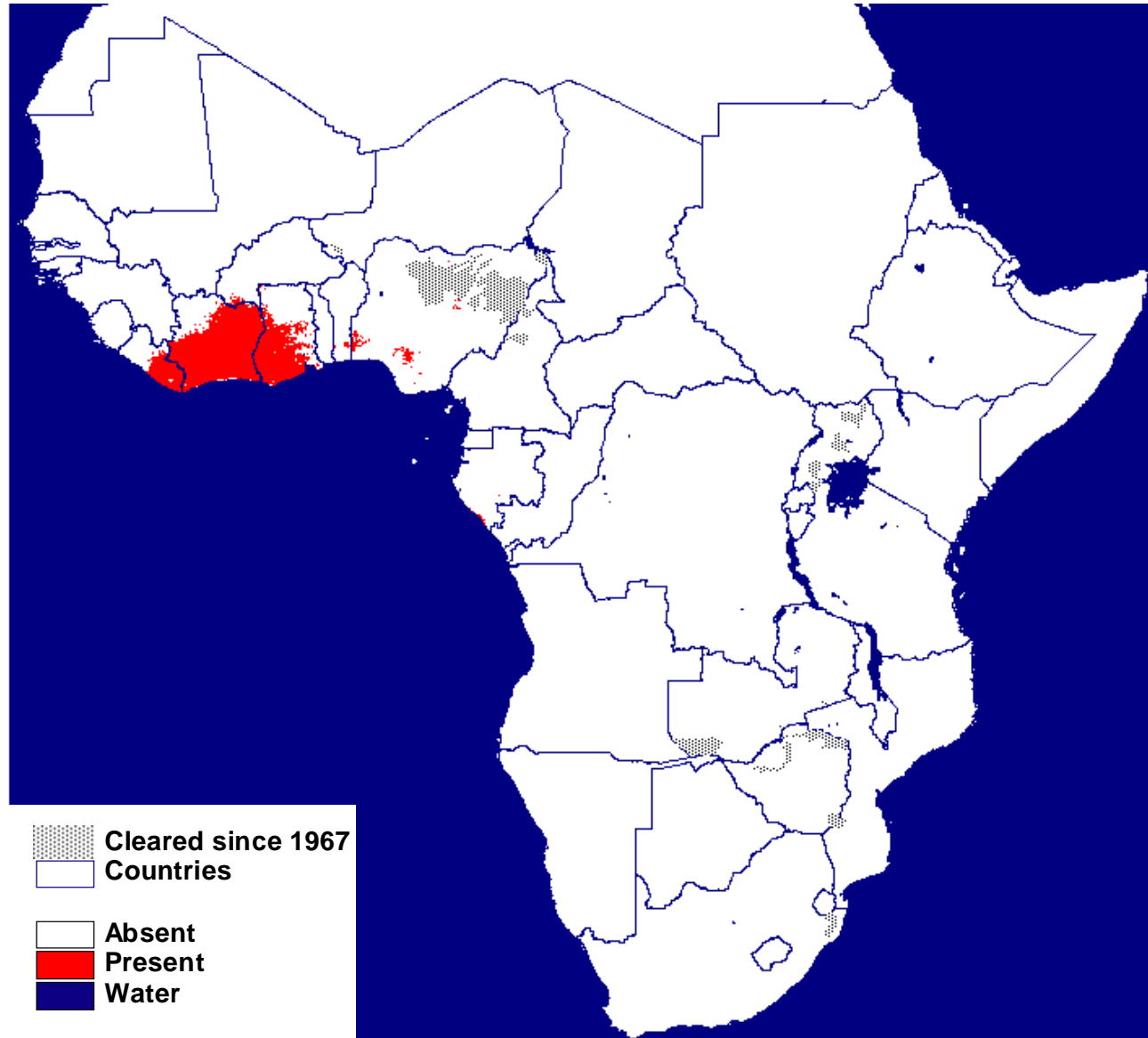
Prepared by ERGO Ltd and TALA Research Group. February 2000.

Map 45: *G. longipennis*: Predicted Presence and Absence



Prepared by ERGO Ltd and TALA Research Group. February 2000.

Map 46: *G. medicorum*: Predicted Presence and Absence



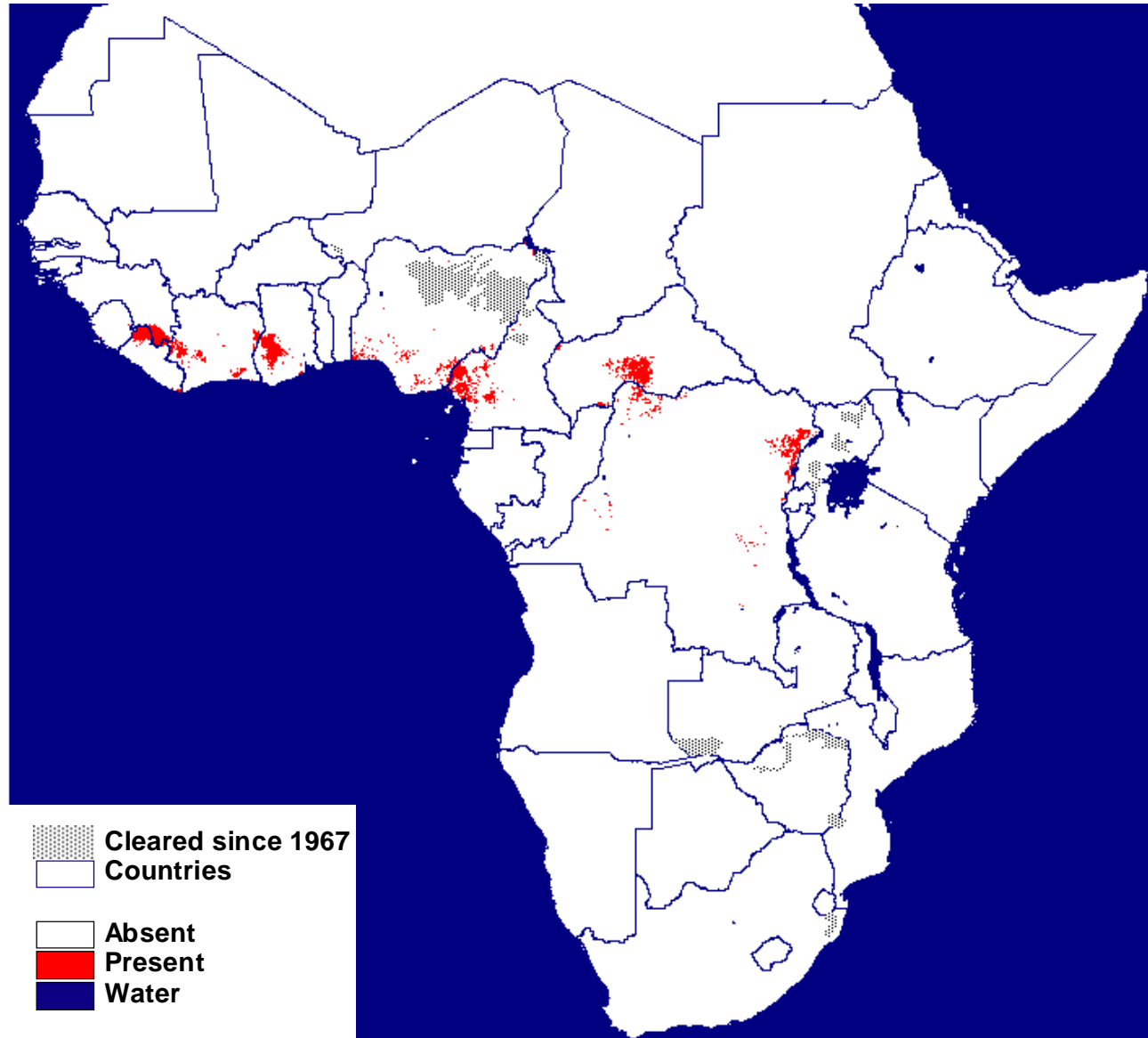
Prepared by ERGO Ltd and TALA Research Group. February 2000.

Map 47: *G. nashi*: Predicted Presence and Absence



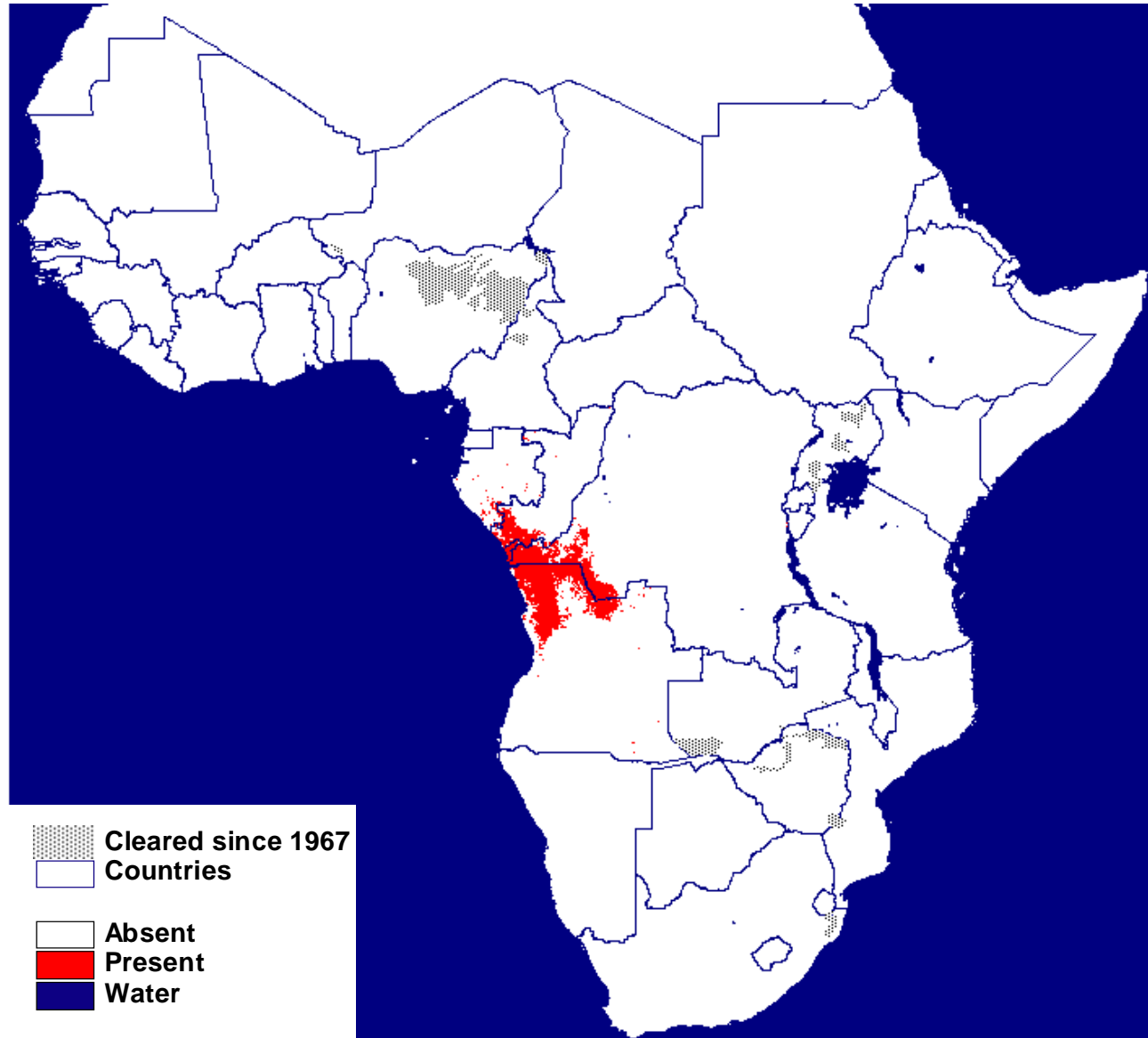
Prepared by ERGO Ltd and TALA Research Group. February 2000.

Map 48: *G. nigrofusca*: Predicted Presence and Absence



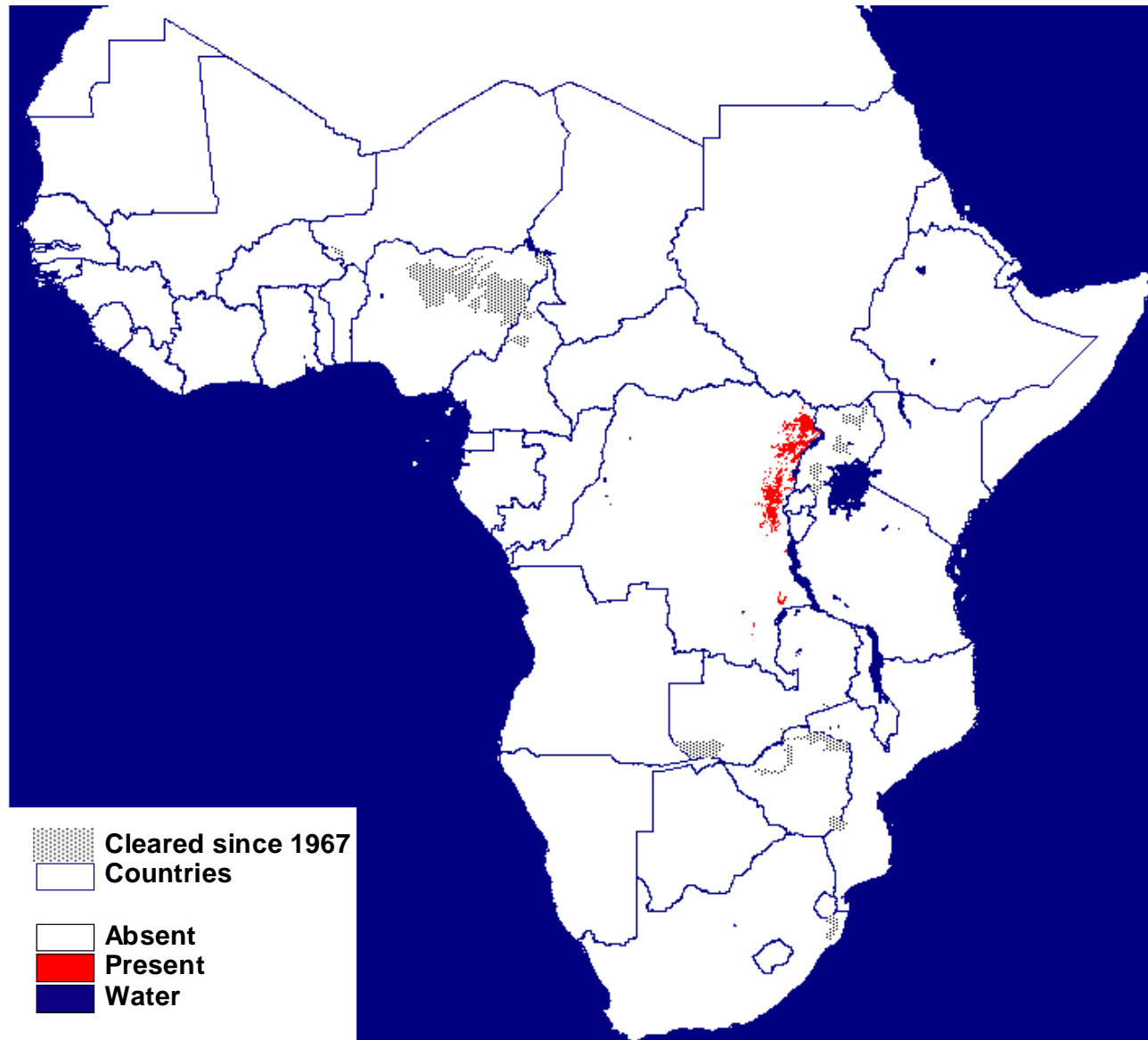
Prepared by ERGO Ltd and TALA Research Group. February 2000.

Map 49: *G. schwetzi*: Predicted Presence and Absence



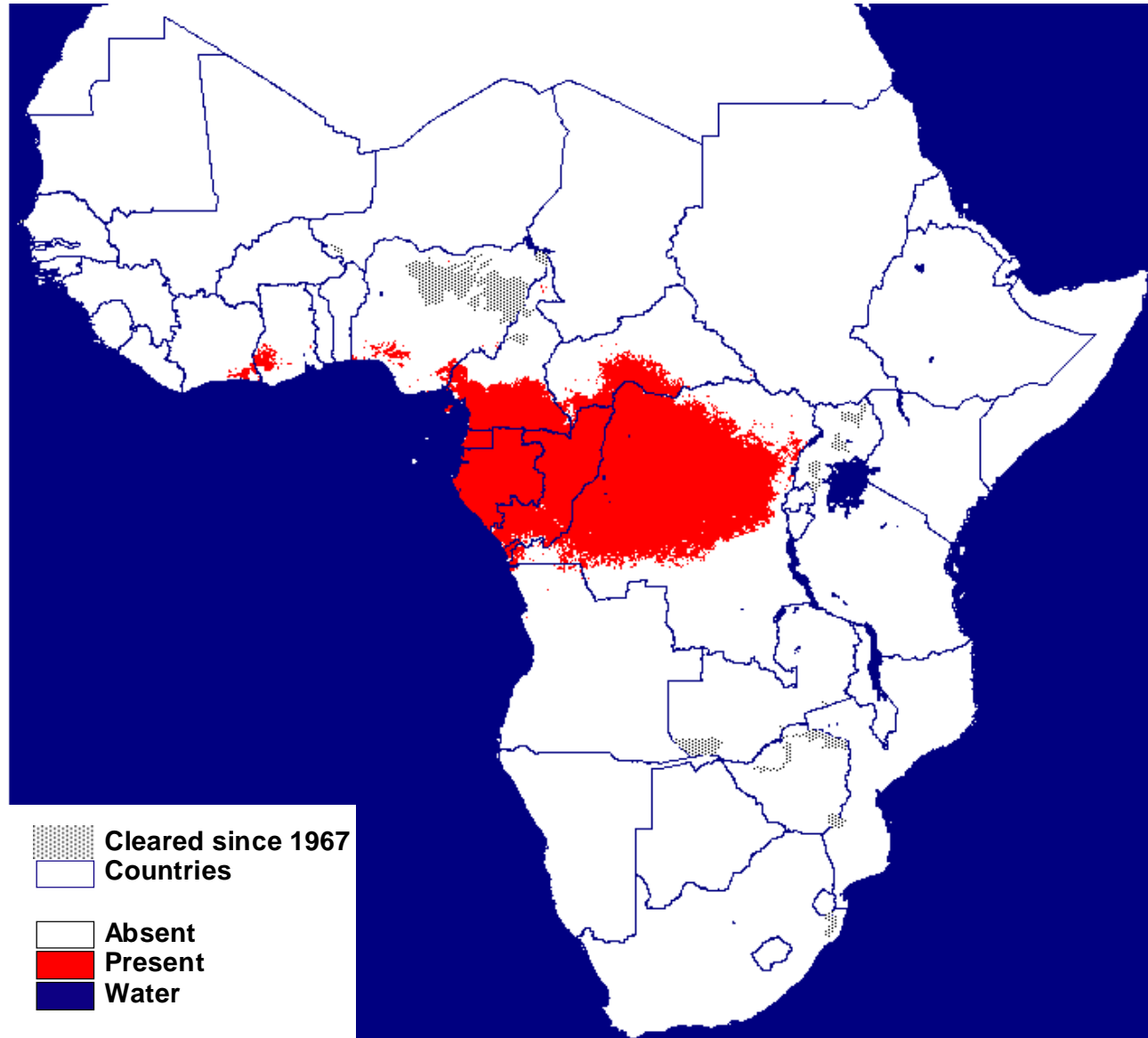
Prepared by ERGO Ltd and TALA Research Group. February 2000.

Map 50: *G. severini*: Predicted Presence and Absence



Prepared by ERGO Ltd and TALA Research Group. February 2000.

Map 51: *G. tabaniformis*: Predicted Presence and Absence



Prepared by ERGO Ltd and TALA Research Group. February 2000.

Map 52: *G. vanhoofi*: Predicted Presence and Absence

