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Prediction of the distribution of *Glossina tachinoides* (Diptera: Glossinidae) in the Volta basin of northern Ghana

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Abstract

The classification of a Landsat Thematic Mapper satellite image helped demonstrate prevailing habitat types and land use intensity in the Volta basin of the Northern Region of Ghana. A geo-referenced data layer comprising the capture results of a cross-sectional survey of *Glossina tachinoides* Westwood was over-laid on a data layer of habitat types within 500 m of either bank of the Volta river and its tributaries. An evaluation of the relationship between habitat types and the capture results of *G. tachinoides* suggested a strong preference of *G. tachinoides* for woodland, followed by shrubland, grassland and flood plains. The findings were used to classify the suitability of habitat types for *G. tachinoides* as 'high', 'medium' and 'low' and a prediction map for the distribution of *G. tachinoides* in the entire river network was produced. The usefulness of this method in estimating the potential distribution of *G. tachinoides* in an area of increasing agricultural expansion is discussed.

Introduction

Tsetse flies (Diptera: Glossinidae) of the *Palpalis* group, *Glossina tachinoides* Westwood and *G. palpalis gambiensis* Vanderplanck, are important vectors of human and animal trypanosomoses and are therefore a constraint to rural development in areas where they occur (Morris, 1947; Jordan, 1986). However, the distribution of tsetse flies in 38 African countries was updated in a tabular form by Moloo (1985) using information from the second edition of the tsetse distribution maps of Ford & Katondo (1975, 1977) and unpublished data. Tsetse distribution maps produced from past and present information may be of limited value at the country level as land use and environmental change have altered the distribution of the flies (Bourn *et al*., 2001). In West Africa, it has long been known that species such as *G. morsitans submorsitans* Westwood decrease and even disappear when human density and rural development increase (Nash, 1948). In the Sideradougou area of Burkina Faso, 15 years of agricultural development has resulted in a change in the distribution of tsetse of the *Palpalis* group (de la Rocque *et al*., 2001). To ensure the judicious use of resources, tsetse control operations should rely on maps based on current distributions. Surveys to update distribution maps are desirable, but expensive and time consuming. The potential of remote sensing as an alternative tool for epidemiological studies has been stressed by Hay (1997) and Hay *et al*. (2000). The objective of the present study was to utilize remote sensing as a means of characterizing the habitat of *G. tachinoides* Westwood in the Volta river basin of northern Ghana and to determine the extent to which this has been affected by land use.

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Table 1. Number of traps and catches of *Glossina tachinoides* in each habitat type in the Volta basin, northern Ghana.

Habitat	Number of traps	Transformed mean catches (± SD)	De-transformed mean catches
Open woodland	13	0.618 ± 0.403	3.1[a]
Shrubland	22	0.438 ± 0.331	1.7[a,b]
Closed woodland	43	0.747 ± 0.567	4.6[a]
Grassland	9	0.267 ± 0.298	0.8[b]
Flood plains	33	0.357 ± 0.297	1.3[b]

SD, standard deviation.
[a,b]means not associated with the same letter are different at $P = 0.05$.

Materials and methods

Study area

The study area was in the Volta basin, in the northern part of Ghana between latitude 9° 41 85 to 10° 69 86 N and longitude 0° 52 25 to 1° 21 22 W. The drainage network comprises the main river, locally referred to as the 'White Volta', and its tributaries. The sub-humid climate is classified as Tropical Continental with a single rainy season from May to October, followed by a prolonged dry season from November to April (Dickson & Benneh, 1970). Total annual rainfall ranges from 670 to 1570 mm. Mean monthly temperatures range from 27°C in August to 36°C in March. The area comprises two administrative districts referred to as the Savelugu and West Mamprusi.

Tsetse surveys

A survey by Draeger (1983) suggested that there are only two species of *Glossina*, namely *G. palpalis gambiensis* Vanderplanck and *G. tachinoides* in the area. While *G. tachinoides* was found along almost the entire riparian vegetation of the White Volta, *G. palpalis* was restricted to the southern half of the study area below latitude 10°N (Draeger, 1983: unpublished report). These findings were confirmed by a complementary survey (TTCU, 1998). Data on tsetse populations in this study were derived from a cross-sectional survey carried out in March 2001 at 12 trapping sites along the White Volta river. Ten traps were deployed at each site. The tsetse survey was conducted in March because it is during this period that most areas in the Volta basin are accessible and that *G. tachinoides* would confine itself close to riparian vegetation (Nash, 1948).

The main habitat types along the White Volta in which *G. tachinoides* has been caught in the past (Draeger, 1983) were selected for the sampling. These habitat types were: closed woodland, open woodland, shrubland, grassland and flood plains. The selection of sites was determined mainly by accessibility. At each site, biconical traps (Challier & Laveissière, 1973) were deployed along the river at intervals of 200–300 m for 24 h. Catches were expressed as number of flies per trap per day (CTD). The coordinates of each trap position were recorded with a global positioning system (GPS) and the habitat type, in which the trap was located, noted. The numbers of traps deployed per habitat type are shown in table 1.

Processing of satellite images

Demonstration of habitats

A Landsat TM® (thematic mapper) image with a resolution of 30 m, which covered a rectangle of 182 km × 175 km, was used for the study. The image was taken on 27 October 2001, i.e. the early dry season, and had radiometric and orthogonal corrections. The image contained only TM data. With the aid of the software ENVI® (2001), three channels – 4, 3, 2 assigned to red, green and blue bands, respectively, were used to produce a coloured composition of the image. The study area was then extracted as a subset of the processed image. Six of each of the ecological units of interest (open woodland, closed woodland, shrubland, grassland, flood plains and farmland) were selected by ground inspection and used as training samples to conduct a supervised classification of the image. Only channels 4, 3 and 2 were used to conduct the classification by 'maximum likelihood' (Curran *et al.*, 2000). The accuracy of the classification was high as shown by the kappa coefficient (0.86). Further field inspections using 48 randomly selected points showed a concordance of 66%. Habitat description was conducted in an area within 500 m of both banks of the river along the entire drainage network of the study area.

Land use

From the classification, the layer corresponding to farmland was extracted and analysed in MapInfo® (MapInfo Corporation, 2001) as quadrants of 5 km^2, to reveal the percentage of each quadrant cultivated. Pixels of 5 km × 5 km were most appropriate because field inspections revealed that the mean distance between villages was 5 km and that most cultivation occurred near settlements.

Statistical analysis

Daily catches of *G. tachinoides* from each trap were grouped according to the habitat within 500 m of the trap, and transformed to log (x + 1) for an F test of habitat effects.

Results

Habitat types

Within 500 m of the river banks, the predominant habitat types were: closed woodland, open woodland, shrubland, grassland and flood plains (fig. 1). The description of the habitat around the traps by the tsetse survey team accorded fully with the classification.

Land use

The intensity of land use was highly variable (fig. 2). In the southern part of the study area around the town of Savalugu, the intensity ranged from 5% to 90%, being highest in the south-west and lowest in the east. Intensity was generally low (< 20%) around the town of Nasia (central part of the study area). In the northern area around the town

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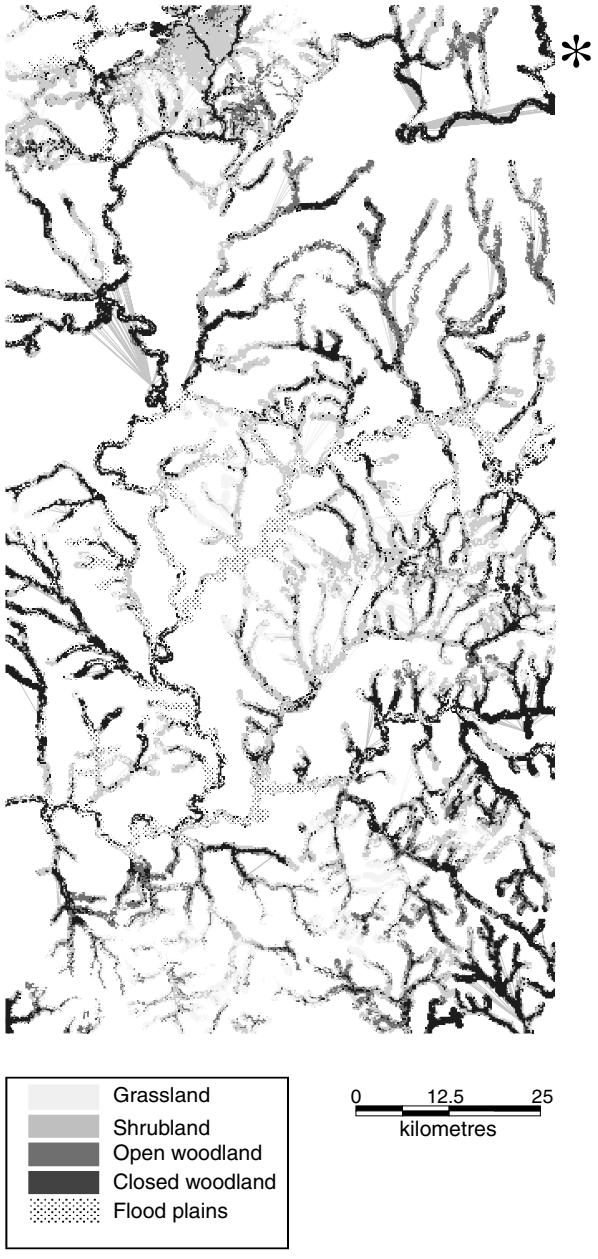

Fig. 1. Habitat types within 500 m of river banks along the river network in the Volta basin, northern Ghana.

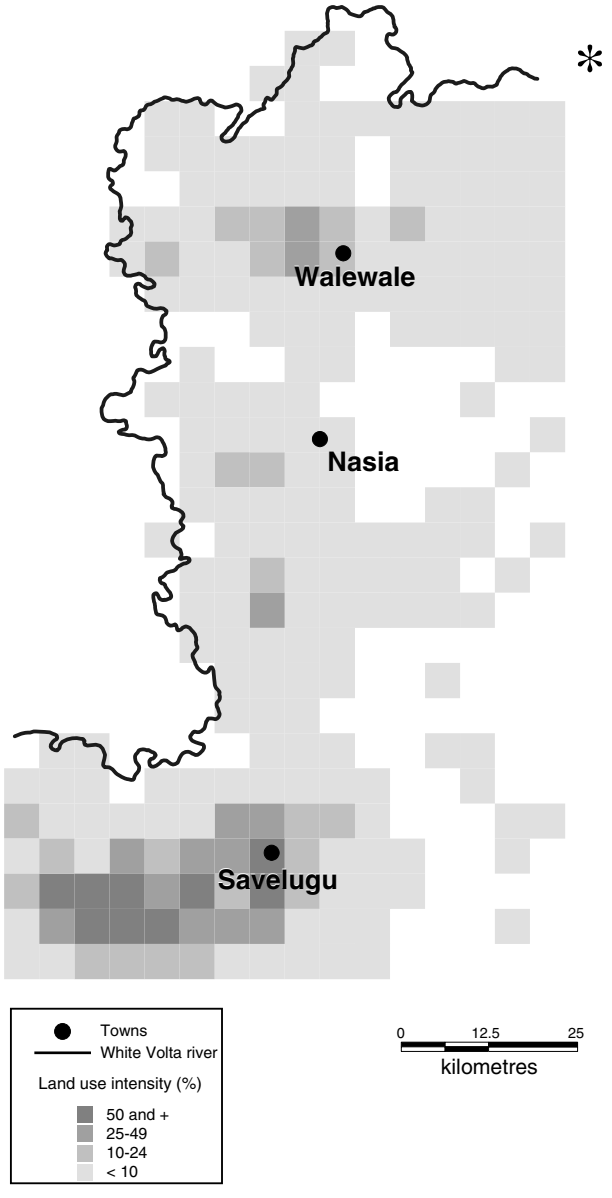

Fig. 2. Land use intensity in the Volta basin, northern Ghana.

of Walewale, the land use intensity ranged from 10% to 50% with the highest intensity observed within 2 km of the township. From the town of Walewale, land use intensity decreased progressively westward toward the left bank of the White Volta river.

Relationship between habitat and catches

Catches of *G. tachinoides* (table 1) showed significant effects of habitat ($F_{4,115} = 5.297$ $P = 0.001$). A one-way ANOVA post hoc test using the least significant difference (LSD) showed a significant difference ($P = 0.05$) between the mean catches of *G. tachinoides* in closed woodland and the mean catches in grassland and in flood plains. There was no significant difference between the mean catches of *G. tachinoides* in closed woodland and those of open woodland and shrubland. There was also no significant difference between the mean catches of *G. tachinoides* in shrubland and those of flood plains and grassland.

Table 1 clearly shows that the mean catches of *G. tachinoides* were highest in closed woodland, followed by open woodland. These two habitat types were thus regrouped and empirically classified as habitat type with a 'high suitability' for *G. tachinoides*. The mean catches in shrubland were intermediate and the habitat was empirically classified as having a 'medium suitability' for *G. tachinoides*. The habitat types of grassland and flood plains were pooled and classified as having a 'low suitability' for *G. tachinoides*. On the basis of this classification, a prediction map for the distribution of

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G. tachinoides, using suitability of habitats as an indicator, for the entire drainage network in the study area was produced (fig. 3). For the purpose of illustration, closed and open woodland are depicted as black, shrubland as grey, while grassland together with flood plains are depicted as light grey. The results of the analysis of mean catches per site are also shown in fig. 3.

The map predicting the suitability of habitats was superimposed on the land use intensity map to ascertain the relationship between land use and the suitability of habitat types for *G. tachinoides*. It was generally observed that, where the land use intensity in proximity to riparian vegetation exceeded 10%, the suitability of the habitat for *G. tachinoides* diminished; the opposite was found to be generally true, with the exception of the Nasia area, when land use intensity was less than 10%.

Discussion

Decades of systematic hunting and agricultural expansion have eliminated game animals and pristine woodland. As a result, tsetse of the *Morsitans* group which depend on high densities of warm blooded animals (Reid *et al*., 2000) and woodland have been eliminated in the Savelugu and West Mamprusi Districts (Draeger, 1983). In the last three decades, woodland has been cleared between Savelugu and Walewale to prepare lands for the commercial cultivation of cereals. The high level of cropping is particularly evident in the south-west of Savelugu which is densely populated.

The increase in cultivation was demonstrable because the image was taken in October when crops were yet to be harvested. Settlements to the east of Savelugu are sparse and this is reflected in the predominance of closed woodland in the eastward direction. The town of Nasia has very few settlements nearby and is surrounded by large areas of flood plains, as shown in the classified image. Flood plains were also clearly identifiable in October, at the end of the rains because flooding was evident. Due to the very sparse settlement to the west of Walewale township there is a gradual transition from an open woodland habitat to closed woodland.

About 160 km^2 of riparian vegetation was selectively cleared of bush to eradicate tsetse of the *Palpalis* group in the Nabogu Valley in the southern part of the study area (Stewart, 1937). Riverine tsetse are, however, relatively more resilient to environmental change (Jordan, 1986) and have persisted in the Volta basin despite the drastic measures applied in the 1930s.

Present results allow the relationship between habitat and the abundance of *G. tachinoides* to be established only qualitatively. The low suitability for *G. tachinoides* of riparian systems in the Nasia area, despite the low land use intensity, could be ascribed to the fact that the area consists mainly of flood plains. Nonetheless, the qualitative assessment of the overall impact of agricultural activity (felling of trees and cultivation in close proximity to river banks) on the integrity of gallery forests and consequently on the population of *G. tachinoides* as observed in this study is consistent with the findings of de la Rocque *et al*. (2001) in Burkina Faso. In an earlier report on work done in Togo, at a 14 × 14 km resolution, Hendrickx *et al*. (1999) demonstrated that the population of *G. tachinoides* tends to decline in areas of intense agricultural activity. In the present study it was observed that the fragmentation of riparian vegetation is particularly pronounced on the tributaries of the White Volta around towns with high human population density. The fragmentation of riparian vegetation around the Nasia area is attributable to the large-scale rice farming that took place in the late 1970s (fig. 3).

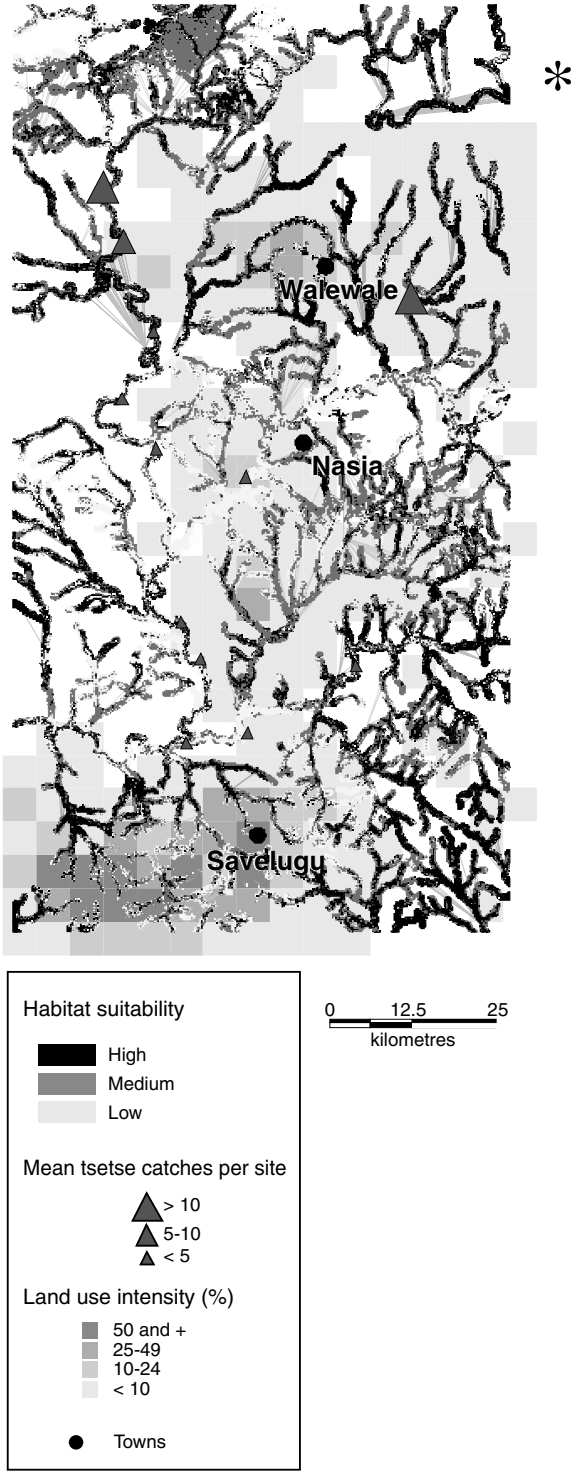

Fig. 3. Land use in the Volta basin, northern Ghana and the predicted habitat suitability for *Glossina tachinoides*.

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In this study, the description of the most favourable habitat for *G. tachinoides* was aimed at developing a method for predicting the actual distribution of the species in the Volta river basin taking into consideration the impact of land use attributable to agricultural expansion. It is acknowledged, in this study, that the precise floral formation of gallery forests, where *G. tachinoides* is normally captured, cannot be amply demonstrated with the aid of a Landsat TM image. However, it is possible to use habitat types within 500 m of the river network as indicators for the integrity of gallery forests and hence the presence of *G. tachinoides*. Closed to open woodland are indicators of minimal encroachment by man and offer those conditions that minimize runoff and its adverse effects on the integrity of gallery forest. The two habitat types would therefore be logically classified as having a high potential to harbour *G. tachinoides*. In our observation, flood plains had very little tree cover; this could be attributed to tree felling by man and/or the fact that soil structure and type allow only the survival of water-resistant plants, although this was not verified in our study. Grassland (or fallow fields) and shrubland were considered as having an intermediate suitability because the two habitat types are utilized by man for cropping as and when they are needed. They could lie fallow for a year or more depending on human population pressure and the demand for food crops. The method used in this study for the production of a tsetse habitat suitability map differs from previous work (Rogers *et al*., 1996; Robinson *et al*., 1997; Hendrickx *et al*., 1999) that used both meteorological and ground based tsetse data and worked at lower resolutions. Our method of prediction should be considered as a simplified method to the aforesaid methods, when decisions on tsetse control are to be taken at a local level. It can be concluded from this study that remote sensing can help to rationalize and predict the distribution of tsetse.

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References

Bourn, D., Reid, R., Rogers, D., Snow, B. & Wint, W. (2001) *Environmental change and the autonomous control of tsetse and trypanosomiasis in sub-Saharan Africa*. 248 pp. Oxford, Information Press Limited.

Challier, A. & Laveissière, C. (1973) Un nouveau piège pour la capture des glossines (Glossina: Diptera, Muscidae): description et essai sur le terrain. *Cahier ORSTOM Série Entomologie Médicale et Parasitologie* **11**, 251–252.

Curran, P.J., Atkinson, P.M., Foody, G.M. & Milton, E.J. (2000) Linking remote sensing, land cover and disease. *Advances in Parasitology* **47**, 37–80.

de La Rocque, S., Guillobez, S., Michel, V. & Bauer, B. (2001) The changing distribution of two riverine tsetse flies over 15 years in an increasingly cultivated area of Burkina Faso. *Bulletin of Entomological Research* **91**, 157–166.

Dickson, K.B. & Benneh, G. (1970) *A new geography of Ghana*. pp. 17–21. London, Longman.

Draeger, N. (1983) *Tsetse and trypanosomiasis control in Ghana*. 24 pp. End of Project Report (German Technical Cooperation). Unpublished Report, Pong Tamale.

Ford, J. & Katondo, J.M. (1975) Revision of the *Glossina* distribution map of Africa. *OAU/ISCTRC Publication* **109**, 252–256.

Ford, J. & Katondo, J.M. (1977) Maps of tsetse flies (*Glossina*) distribution in Africa, 1973, according to sub-generic groups on scale of 1:5,000,000 (plus a set of 9 maps in colour). *Bulletin of Animal Health and Production of Africa* **25**, 187–193.

Hay, S.I. (1997) Remote sensing and disease control: past, present and future. *Transactions of the Royal Society of Tropical Medicine and Hygiene* **91**, 105–106.

Hay, S.I., Randolph, S.E. & Rogers, D.J. (2000) Remote sensing and geographical information systems in epidemiology. *Advances in Parasitology* **47**, 1–357.

Hendrickx, G., Napala, A., Dao, B., Batawui, D., De Deken, R., Vermeilen, A. & Slingenbergh, J. (1999) A systematic approach to area-wide tsetse distribution and abundance maps. *Bulletin of Entomological Research* **89**, 231–234.

Jordan, A.M. (1986) *Trypanosomiasis control and African rural development*. 357 pp. London, Longman.

Moloo, S.K. (1985) Distribution of *Glossina* species in Africa. *Acta Tropica* **42**, 275–281.

Morris, K.R.S. (1947) The control of trypanosomiasis by entomological means. *Bulletin of Entomological Research* **37**, 501–531.

Nash, T.A.M. (1948) *Tsetse flies in British West Africa: The Gold Coast*. pp. 28–47. London, Her Majesty's Stationery Office.

Reid, S., Kruska, R.L., Deichman, U., Thornton, P.K. & Leak, S.G.A. (2000) Human population growth and the extinction of the tsetse fly. *Agricultural Ecosystems and Environment* **77**, 227–236.

Robinson, T., Rogers, D. & Williams, B. (1997) Mapping tsetse habitat suitability in the common fly belt of southern Africa using multivariate analysis of climate and remotely sensed vegetation data. *Medical and Veterinary Entomology* **11**, 235–245.

Rogers, D.J., Hay, S.I. & Packer, M.J. (1996) Predicting the distribution of tsetse flies in West Africa using temporal Fourier processed meteorological satellite data. *Annals of Tropical Medicine and Parasitology* **3**, 225–241.

Stewart, J.L. (1937) *Report on the eradication of tsetse flies of the* G. palpalis *group from the Pong Tamale Area, Northern Territories, Gold Coast*. 15 pp. Pong Tamale, Ghana, Veterinary Services Department.

TTCU (1998) *Tsetse and trypanosomiasis control activities under the National Livestock Services Project*. 20 pp. Annual Report, Pong Tamale, Ghana, Veterinary Services Department.

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