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Autor: Warrell, David A. / Arnett, Charles
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The Importance of Bites by the Saw-Scaled or Carpet Viper *(Echis carinatus)*: Epidemiological Studies in Nigeria and a Review of the World Literature*

DAVID A. WARRELL[1] and CHARLES ARNETT[2]

Abstract

The incidence of *Echis carinatus* (saw-scaled or carpet viper) bite and its mortality have been investigated in the Nigerian savanna region. A geographical area was defined in which the snake was particularly abundant and bites were frequent. Perennial and seasonal fluctuations in incidence and mortality, the circumstances in which bites occurred and the types of people bitten were studied at Bambur, Zaria, Kaltungo and Gombe hospitals. Peak incidence coincided with the increase in farming during the rains whereas percentage mortality seemed to be greatest during the cold dry season. The majority of the patients were young males bitten on the foot while walking or farming.

A review of the world literature indicated that *E. carinatus* was the principal cause of snake bite morbidity wherever data were available throughout its wide geographical range. Official statistics have seriously underestimated this important rural health problem.

Introduction

During the past century reports from Asia and Africa have indicated that the Saw-scaled or Carpet Viper *(Echis carinatus)* is a very dangerous snake. In Nigeria, the serious rural medical problem created by *E. carinatus* bite led to clinical and laboratory investigations of a large group of patients (WARRELL et al., 1976b), and to epidemiological studies which are presented here in the context of a review of the medical importance of *E. carinatus* throughout its wide range.

1. Zoology of E. carinatus

The genus *Echis* comprises two species, *E. coloratus* Günther (Burton's Carpet Viper) and *E. carinatus* (SCHNEIDER, 1801) (Fig. 1), which are sufficiently similar to have been regarded by ANDERSON (1898) as merely varieties of the same species. *E. coloratus* occurs in Egypt east of the Nile, Sinai, Israel, Jordan, parts of Arabia and Sokotra, whereas *E. carinatus* is extensively distributed (Fig. 2).

At least eight subspecies of *E. carinatus* have been proposed (DERANIYAGALA, 1951; ROMAN, 1972; PITMAN, 1973; DREWES & SACHERER, 1974) some of which may achieve the status of species (HUGHES, 1976). *E. carinatus ocellatus* STEMMLER (1970) was responsible for the bites in the present study.

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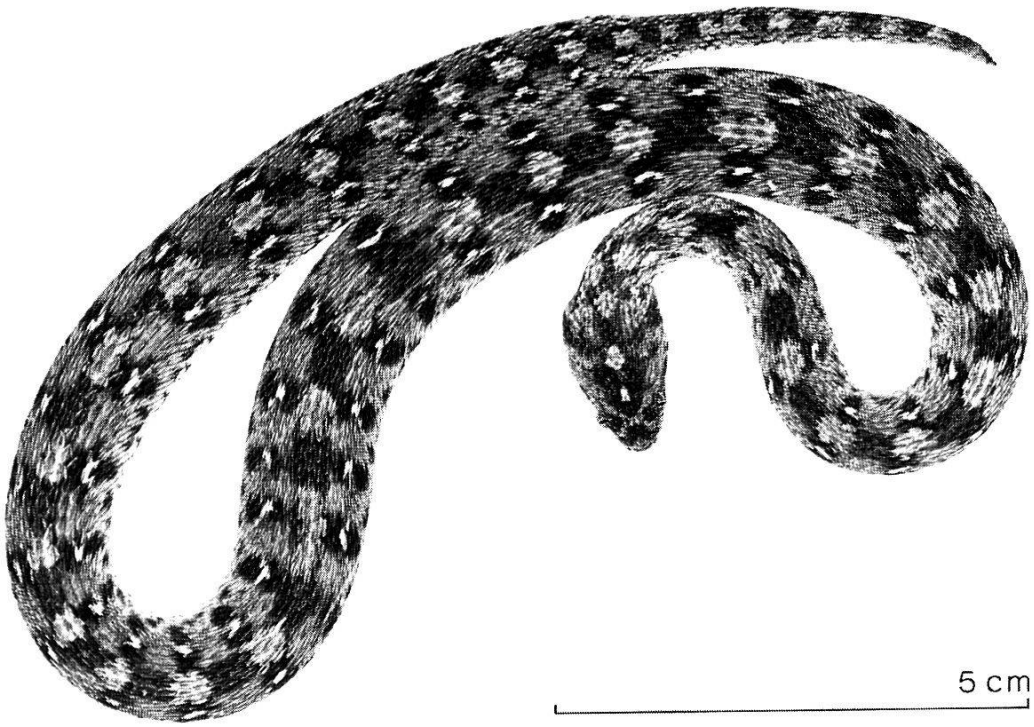
[1] Department of Medicine, Ahmadu Bello University, Zaria, Nigeria; present address: Radcliffe Infirmary, Oxford OX2 6HE, England

[2] Guinter Memorial Hospital, S. U. M. Bambur, P. O. Box 659, Jos, Nigeria



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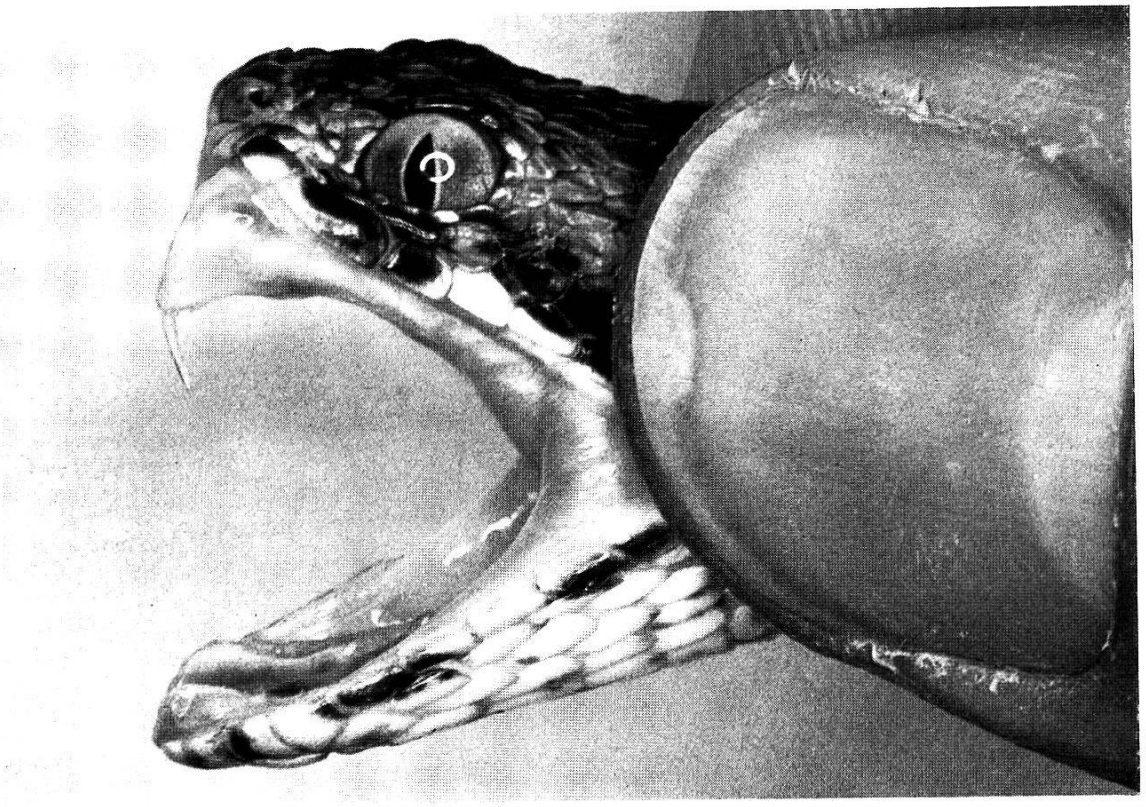

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Fig. 1. E. carinatus (subspecies *ocellatus*): live male specimen from Kaltungo, Nigeria. a) Showing defensive posture in which a characteristic rasping sound is made by friction between the carinate lateral scales; b) showing erectile fangs in dental sheath – typical of *Viperidae*.

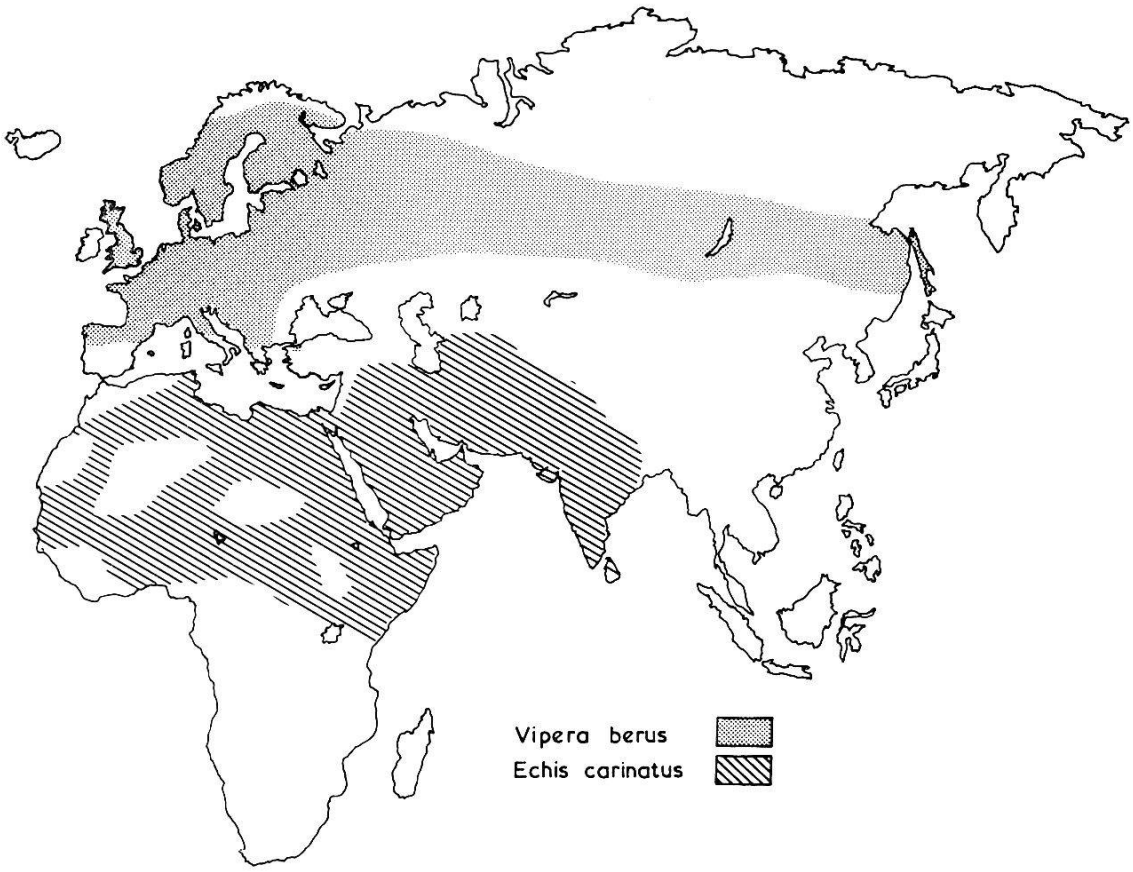

Fig. 2. World distribution of *E. carinatus* compared to that of the Adder *(Vipera berus).*

Fig. 3. Hilly savanna in north eastern Nigeria: a habitat favoured by *E. carinatus.* The view is from the summit of Tangale Peak (1,300 m) looking towards Kaltungo.

The average length varies throughout the geographical range but is usually between 35 and 40 cm, very rarely exceeding 85 cm (PITMAN, 1973; VILLIERS, 1975).

The habitat (Fig. 3) varies from semi arid rocky terrain to frank desert up to an altitude of 1800 metres (WALL, 1921; MINTON, 1966), and occasionally includes thin jungle and lake shores. The snake sometimes enters houses, but much less often than, for example, the Spitting Cobra *(Naja nigricollis)* in Africa or the Krait *(Bungarus caeruleus)* in India. It is discovered beneath rotting tree trunks or boulders, and in holes, and may climb plants or trees up to a height of two metres.

E. carinatus is mainly nocturnal, lying under a rock at the burrow's mouth during the day, but some authors have observed it to be diurnal (WALL, 1908; GHARPUREY, 1962). The snake is irritable if disturbed, rubbing its coils together in continuous motion (Fig. 1a), so that the carinate lateral scales produce a rasping sound responsible for its many onomatopoetic native names (WALL, 1908; VILLIERS, 1975; PITMAN, 1973), and striking repeatedly with such energy that it seems to jump off the ground. WALL (1908) described it as the most vicious and FAYRER (1872) as the most aggressive snake they knew. It moves by throwing its head and forepart of its body forwards and then advancing the rest of its body by a side-winding motion (MENDELSSOHN, 1965).

The mating season, associated with increased activity, is in winter in India (WALL, 1921), in February to March in captivity (STEMMLER-GYER, 1965), but as late as August in Kenya (IONIDES & PITMAN, 1965). Live young 110–150 mm long were born from April to August in India and in July in Pakistan (MINTON, 1966). In Africa eggs were laid from February to December (B. HUGHES, personal communication; DUFF-MACKAY, 1965).

The food includes small rodents, lizards, amphibians, locusts, centipedes and scorpions.

Parts of the range are very densely populated with *E. carinatus*. At Parachinar in Pakistan 186 specimens were collected in one day (TAYLOR & MALLICK, 1935b) and in the Ratnagiri district in India, 115,921 were killed in eight days (VIDAL, 1890a). During four months, 7,281 were killed near Gujranwala in the Punjab (WHISTLER, 1916). In northern Kenya, Ionides collected up to 39 specimens in one day (IONIDES & PITMAN, 1965) and DUFF-MACKAY (1965) collected 6,933 in five months.

2. *Clinical effects of E. carinatus bite* (Fig. 4)

A proportion of those bitten develop local swelling at the site of the bite indicating that venom was injected (Fig. 4a). These patients may subsequently develop local blistering (13%) and necrosis (11%), incoagulable blood (93%) and spontaneous bleeding (57%) (WARRELL et al., 1977). The venom contains a procoagulant which activates prothrombin (KORNALIK & BLOMBÄCK, 1975) causing disseminated intravascular coagulation, and a haemorrhagin which damages vessel walls (TAYLOR & MALLICK, 1935a). Deaths result from haemorrhagic shock following massive intra abdominal haemorrhage or from intracranial haemorrhage (Fig. 4b), and may occur one to twelve days after the bite. Mortality among hospital cases with proven *E. carinatus* bite poisoning, treated with specific antivenom, was 2.8% in a group of 107 Nigerian patients (WARRELL et al., 1977) and 3.4% in a group of 117 Indian patients (BHAT, 1974). (See Appendix 2 for references to clinical studies of *Echis* bite.)

Methods

1. The snake fauna of the region was established by collection, by examination of museum specimens and by discussion with other herpetologists familiar with this area. Local names for the important species were obtained in 38 of the local languages.

Fig. 4. Typical victims of *E. carinatus*. a) 22-year-old Dadiya man bitten on the volar surface of the left wrist while farming. A native doctor applied a popular herbal remedy – the root of *Crinum yuccaeflorum (Amaryllidaceae)* – and made multiple incisions. The patient arrived at Kaltungo Hospital four days later severely anaemic (haematocrit 18%) and still bleeding from nose, gums and incisions. He responded well to specific antivenom and was discharged 12 days later. b) 12-year-old Wurkum boy bitten on the left middle finger while farming; 36 hours later he developed headache, confusion and neck stiffness. He recovered completely after antivenom treatment. Subarachnoid haemorrhage was confirmed retrospectively by finding xanthochromic cerebrospinal fluid one week later. This is one of the commonest causes of death from *Echis* bite poisoning.

These names were tested by frequent use: their correctness was confirmed by discussion of the symptoms of envenoming and by reference to live or preserved specimens.

2. Useful preliminary information was obtained by discussing snake-bite problems with State Medical Officers, doctors from rural State General Hospitals and Mission Hospitals and dispensers throughout Nigeria.

3. Selected hospitals in Kano, North Eastern and Benue Plateau States were visited. Hospital records were examined and snake-bite and snakes were discussed with hospital and dispensary staff and with local people, especially the village elders. Snake-bitten patients admitted to hospitals and dispensaries during the survey were seen and investigated.

4. Records of antivenom issued to hospitals and dispensaries were obtained from State Central Stores and from the Central Christian Pharmacy, Jos (Pharmacist, Mr. F. E. Williams) which supplies many of the mission hospitals in Nigeria.

5. At Guinter Memorial Hospital (GMH), Bambur, Northeastern State, reliable monthly snake-bite statistics were available for the 13 year period 1961–1973. The data for 1961–1971 were circulated in stencilled form under the title "*Echis* bites at Guinter Memorial Hospital, Bambur" by ARNETT, C., THOMPSON, A., MATHISON, J. & MATHISON, J. (1971). These data were used to assess year-by-year and seasonal fluctuations in the incidence and mortality of *E. carinatus* bite. Diagnosis was based on detection of spontaneous bleeding and incoagulable blood, and in many cases by identification of the snake. *E. carinatus* is the only species in this area whose bite causes incoagulable blood, apart from *Dispholidus typus* (boomslang), which very rarely bites and is unlikely to cause confusion (WARRELL et al., 1976b). In other parts of the geographical range of *E. carinatus*, incoagulable blood will not be a diagnostic clinical sign of envenoming: e. g. in India *Vipera russelli* bite will also cause incoagulable blood (BHAT, 1974).

6. Clinical and epidemiological features of 120 cases of proven *E. carinatus* bite were investigated in detail. These patients were admitted to Ahmadu Bello University (ABU) Hospital, Zaria, North Central State (1971 to 1974) and to Gombe and Kaltungo General Hospitals, North Eastern State (July and August, 1973, June 1974). Diagnosis was based on identification of the snake brought by the patient, on immunological detection of *E. carinatus* venom in wound aspirate (GREENWOOD, WARRELL, DAVIDSON, ORMEROD, & REID, 1974) and on finding that the blood was incoagulable indicating systemic poisoning by this species.

Results of the clinical and laboratory studies have been published elsewhere (WARRELL et al. 1974 and 1976b).

Results

1. Snake fauna of the Nigerian savanna region

Fourteen venomous species/subspecies were found:

Colubridae (Boiginae)	*Dispholidus typus*	Boomslang
Elapidae	*Naja nigricollis*	Spitting Cobra
	N. mossambica katiensis	Brown Spitting Cobra
	N. haje	Egyptian Cobra
	N. melanoleuca	Forest Cobra
	Elapsoidea semiannulata	Garter Snake
Viperidae	*Bitis arietans*	Puff Adder
	Echis carinatus ocellatus	Carpet Viper
	E. carinatus leucogaster	Roman's Carpet Viper
	Atractaspis dahomeyensis	Burrowing Viper
	A. aterrima	Burrowing Viper
	A. microlepidota	Burrowing Viper
	Causus maculatus	Night Adder
	C. resimus	Green Night Adder

Local names for the three most important species (*E. carinatus*, *N. nigricollis* and *B. arietans*) are given in appendix 1.

Table I. Snake-bite data from 13 selected hospitals in the Nigerian savanna region

Hospital[1]	Period covered	Snake bites Mean annual incidence All species	*E. carinatus* (% total)	Basis for diagnosis of *E. carinatus* bite	Snake bite deaths Mean annual incidence (mortality %) Total	*E. carinatus*
North Central State:						
Zaria	1971 (March) to 1974 (November)	46	12 (26%)	snake identification, incoagulable blood immuno diagnosis	1.5 (3.3%)	0.75 (6.3%)
North Eastern State:						
Gombe	1972 and 1973	320	208 (65%)	snake identification	28 (9%)	25 (12%)
Kaltungo	1971 to 1973	258	197 (76%)	snake identification	19 (7.4%)	19 (9.6%)
Bambur[2]	1961 to 1973	121	121 (100%)	bleeding, incoagulable blood	7.6 (6.4%)	7.6 (6.4%)
Yola	1973 (January) to 1974 (April)	125	?	–	6.7 (5.4%)	?
Garkida	1972 and 1973	12	9 (75%)	snake identification or clinical signs	0.5 (4.2%)	0.5 (5.6%)
Lassa	1969 to 1970 1973 (August) to 1974 (January)	21	?	–	0.5 (2.3%)	?
Gwoza	1972 (May) to 1974 (January)	12	?	–	1 (8.3%)	?
Ngoshe	1971 (January) to 1973 (December)	42	?	–	0.6 (1.5%)	?
Benue Plateau State:						
Takum[4]	1965 to 1967	81	33 (41%)	snake identification, bleeding	1.3 (1.5%)	1.3 (4.0%)
Wukari[3]	1956 (September) to 1957 (April)	30	9 (30%)	bleeding	4.5 (15%)	3 (33.3%)
Shendam	1973	264	66 (25%)	bleeding	26 (9.8%)	26 (39.4%)
Wawa	1973 and 1974	0.5	?	–	0	0

[1] See Fig. 5 for hospital locations;
[2] Data of ARNETT, THOMPSON, MATHISON & MATHISON (1971) unpublished;
[3] Data of ONUAGULUCHI (1960);
[4] Data of Dr. H. H. GRAY (1971) unpublished.

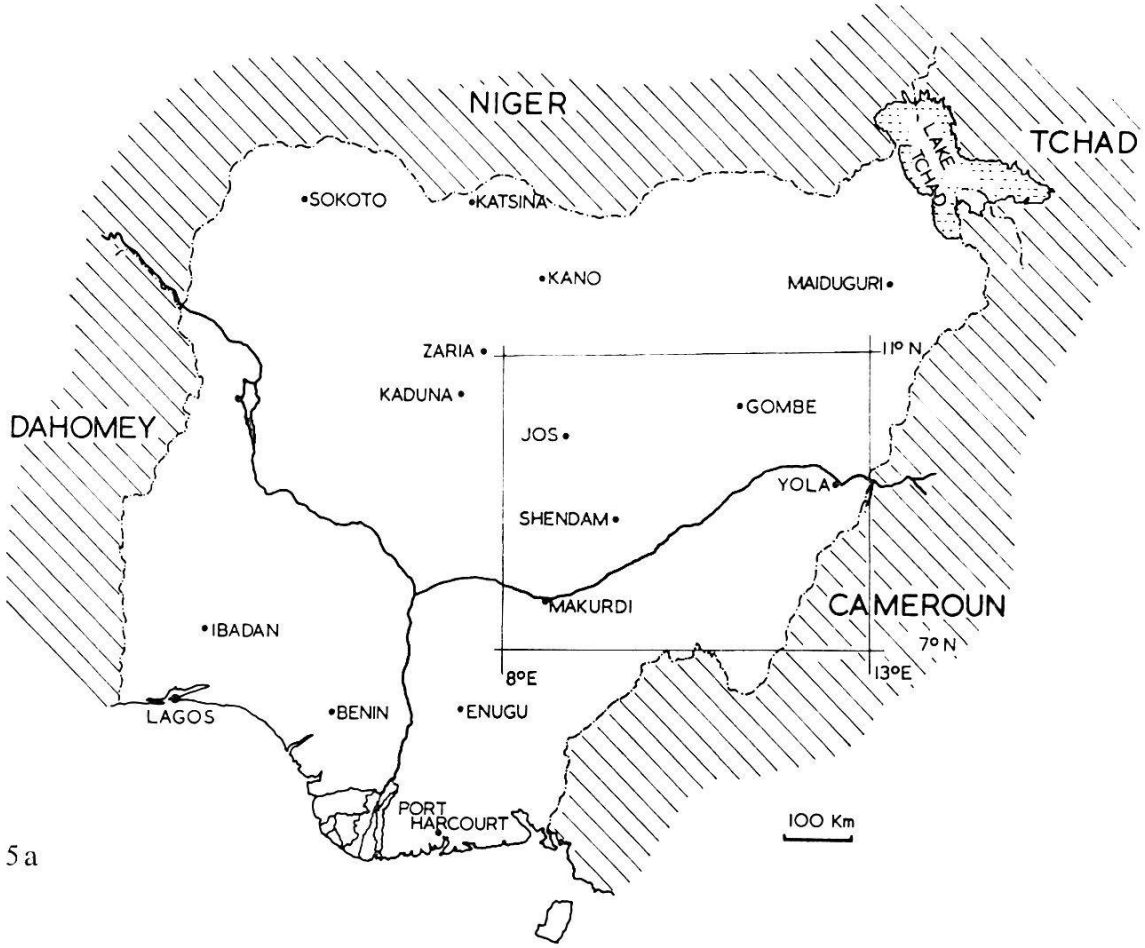

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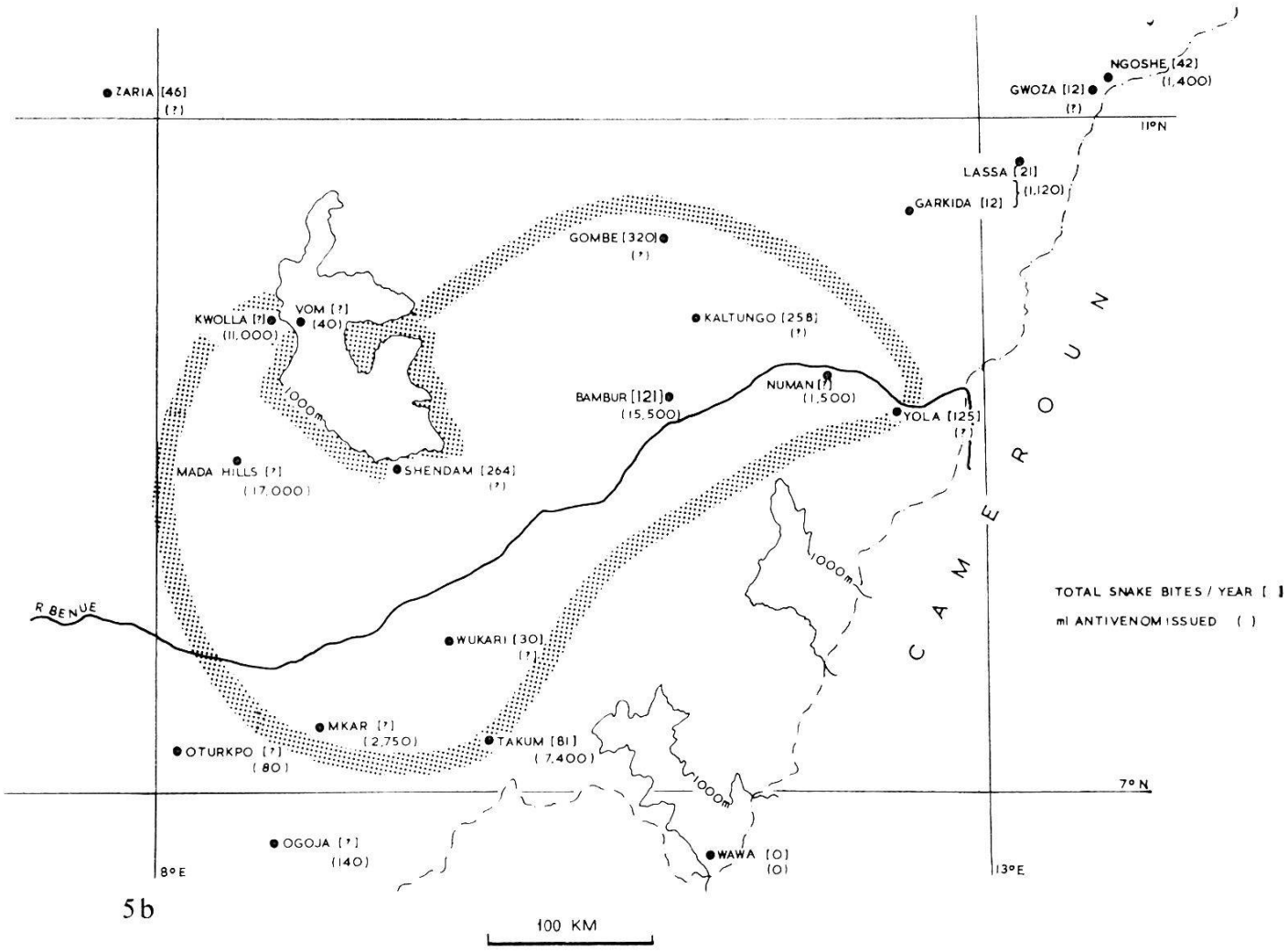
Fig. 5. "Endemic" area for *E. carinatus* bite in Nigeria as suggested by hospital statistics, issues of antivenom and information gathered by discussion during travels throughout the country. The western boundary is particularly speculative. "Kwolla" refers to a dispensary of that name and not to the town, which is 12 km west of Shendam.

2. *Incidence of E. carinatus bite throughout the Nigerian savanna region*

2.1. Hospital records (Table I): apart from the data of ONUAGULUCHI (1960) and H. H. GRAY (1971) unpublished, these records were checked by us during visits to the hospitals. The unusually high apparent mortality from *E. carinatus* bite at Wukari and Shendam is probably due to the fact that the bites were identified entirely by the presence of spontaneous bleeding which selects a high-risk group.

2.2. Antivenom Issues (Fig. 5): quantities of antivenom issued for the treatment of *E. carinatus* bite provided a rough indication of the relative incidence of bites in the areas served by the various hospitals and dispensaries. Local differences in use of antivenom (dosage and indications for treatment) prevent any precise inference from these data about numbers of bites.

2.3. «Endemic» area for E. carinatus bite: hospital records and antivenom issues were combined with information from medical staff



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working in other parts of the savanna region in an attempt to define the area of highest incidence of *E. carinatus* bite (Fig. 5). This is obviously a very rough guide but is based on all the evidence available to us. It should serve as a preliminary estimate which can be refined by further work.

3. *Yearly and seasonal fluctuations in incidence and mortality of E. carinatus bite at GMH, Bambur*

3.1. Annual incidence and mortality (Fig. 6): the gradual increase in numbers of patients attending hospital from 1961 to 1968 is attributed to the growth of confidence in hospital medicine among the local communities. This resulted from the availability of South African Institute for Medical Research (SAIMR) *Echis* antivenom which was found to be very effective, achieving in 1963 a survival of 95.5% at an average intravenous dose of 15 ml, compared with a survival of 80% produced by an average of 40 ml of Pasteur Institute, Paris, *Echis* antivenom. Political difficulties with supply of SAIMR antivenom led to the use of a new antivenom from Pasteur Institute, Iran (LATIFI, 1973) starting in mid 1970. There was a dramatic increase in mortality: in June 1970 16 patients

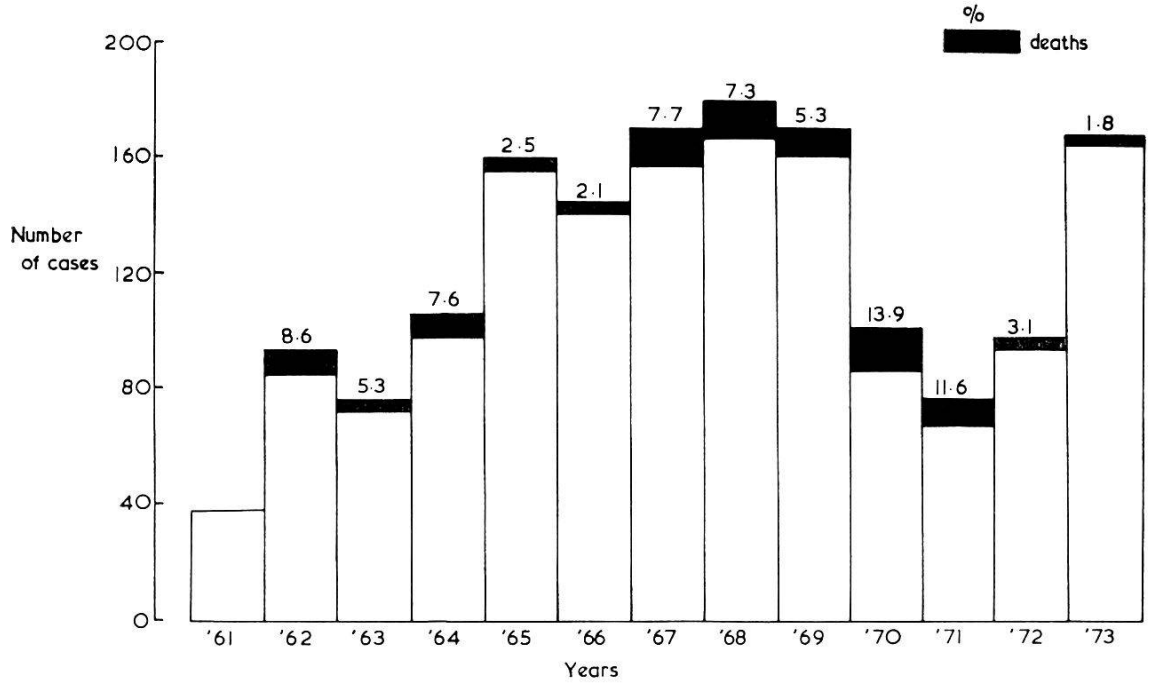


Fig. 6. Fluctuations in annual incidence and mortality of *E. carinatus* bite at Guinter Memorial Hospital, Bambur. The figure above each column is the mortality %.

were given 30–160 ml (average 84 ml) of Iranian antivenom but six died. These failures were quickly noticed in the community and there was a fall in hospital attendances (1970 to 1972); information from the villages suggested that there was no decrease in incidence of snake bite, but that snake-bitten patients had resorted to local herbal medicines. Results of antivenom treatment improved in 1972 after further supplies of SAIMR antivenom had been obtained. Confidence in hospital treatment was restored and by 1973 snake bite admissions were back to their original levels.

3.2. Seasonal incidence and mortality (Fig. 7 and 8): the number of bites by *E. carinatus* increased from February to reach a peak in May and June. The rains usually began towards the end of April.

Seasonal mortality appeared, on the basis of four years' data only, to be highest in the winter months (December and January) when the incidence of snake bite was at its lowest.

3.3. Effect of antivenom on mortality: the average mortality of treated patients over the 13 year period was 6.4%. Since antivenom cannot be withheld it is impossible to determine untreated mortality. But from June 1970 to November 1971 two clinically-ineffective antivenoms had to be used exclusively – Pasteur Institute, Iran and Paris *Echis* antivenoms: during this period there were 19 deaths amongst 120 cases of treated *E. carinatus* bite – a mortality of 16%.

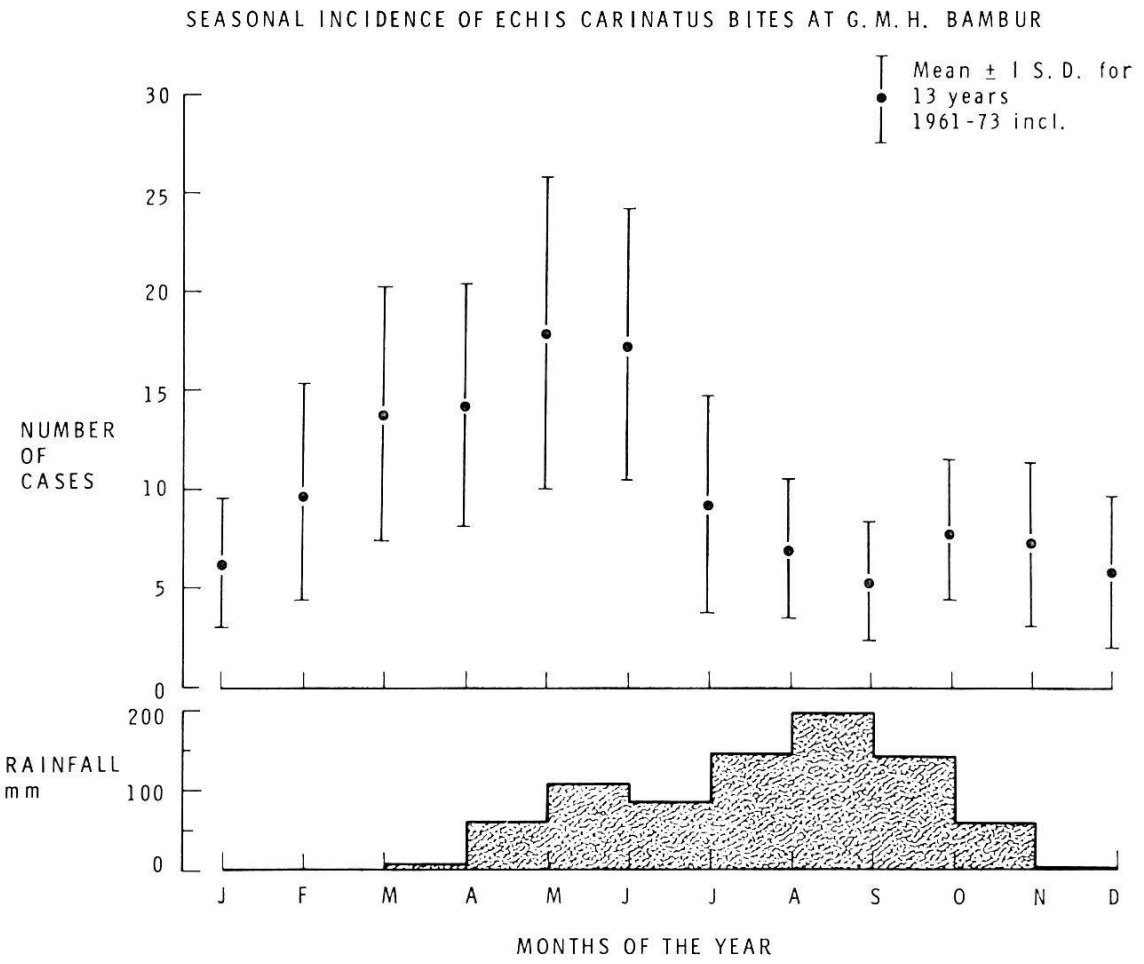


Fig. 7. Seasonal incidence of *E. carinatus* bite at Bambur showing relationship to average monthly rainfall at Lau (20 km south-west of Bambur), 1955–1962 (KOWAL & KNABE, 1972).

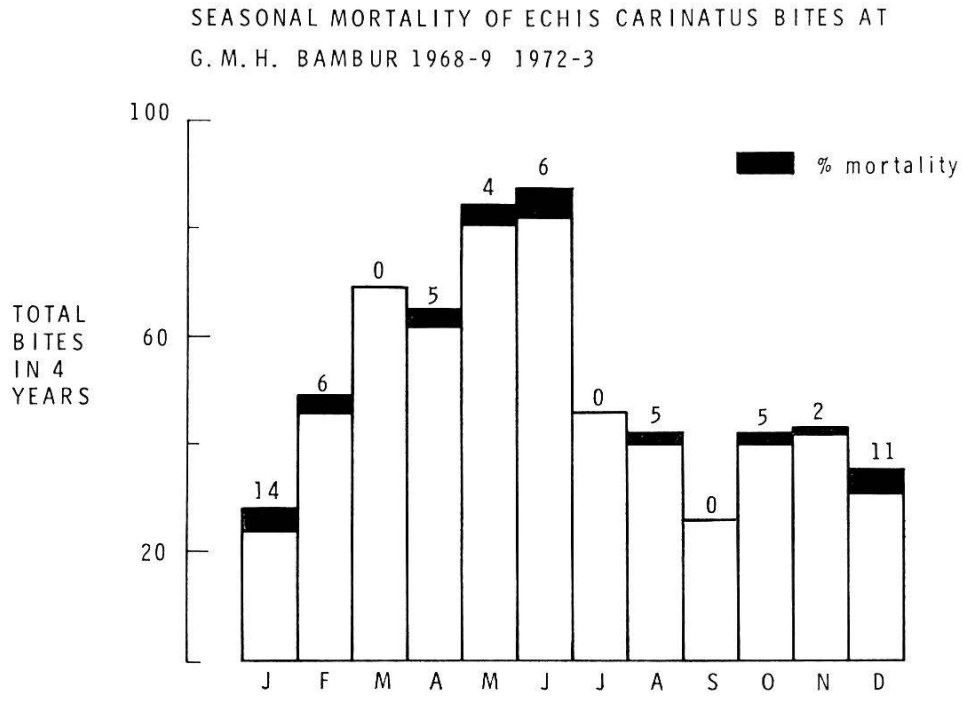


Fig. 8. Seasonal fluctuations in mortality from *E. carinatus* bite at Bambur during a four-year period. The figure above each column is the mortality %.

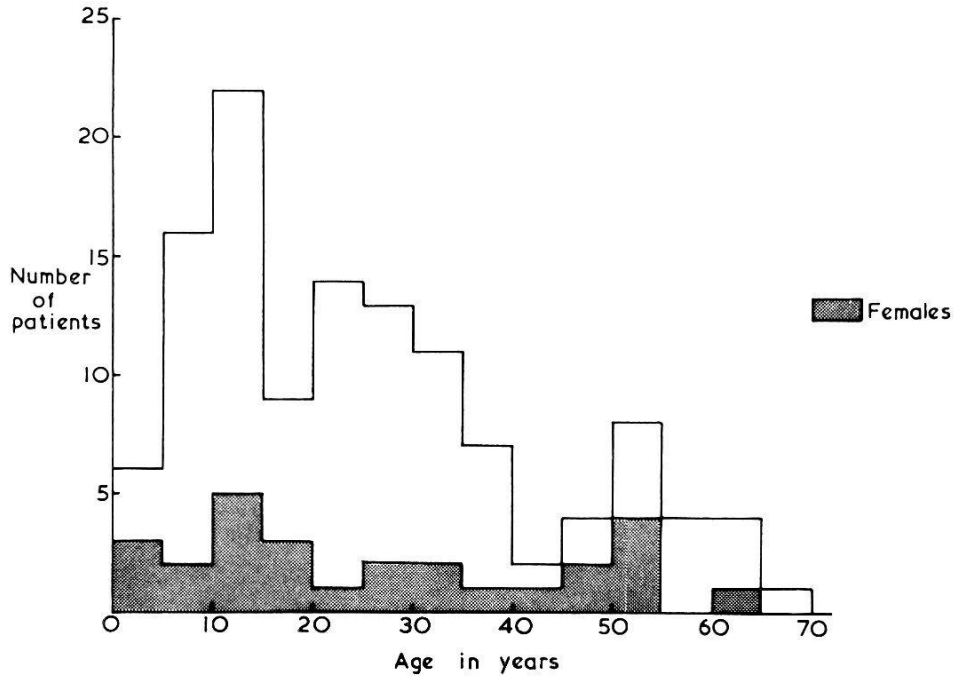


Fig. 9. Age distribution of 120 patients with *E. carinatus* bite admitted to Zaria, Gombe and Kaltungo hospitals.

3.4. Incidence of *E. carinatus* bite in the population: the part of Muri Division served by GMH Bambur and its dispensaries has an area of approximately 65,000 km^2 and an average population (1961–73) of approximately 250,000. The estimated average number of *E. carinatus* bites per year treated at GMH and its dispensaries is about 300, giving an incidence of *E. carinatus* bite of 120 per 100,000 population per year and, with an average mortality of 6.4% the incidence of death from *E. carinatus* bite is 7.7 per 100,000 population per year. These figures must be underestimates because of the large number of cases who do not go to hospital or dispensary.

4. Epidemiological investigation of 120 patients admitted to Zaria, Gombe and Kaltungo Hospitals

4.1. Sex, age, tribe, occupation: there were 27 females (22.5 per cent) and 93 males (77.5 per cent). Age distribution (Fig. 9) showed a predominance of young adults and children; 37 per cent were children less than 15 years old. The principal tribes represented were Fulani (30%), Hausa (28%) and Tangale (23%). Thirty-nine per cent were farmers, 20% children not working or attending school, 14% housewives, 10% cattle or sheep herds and 8% school children. The remaining 9% were traders, guards, railway workers or beggars.

4.2. Site, time and circumstances of bite: 81 per cent of bites involved the lower limb and 19 per cent the upper limb. Seventy-seven per cent

Fig. 10. Digging before the first rains near Kaltungo. *E. carinatus* bites on the bare feet are very common in these circumstances.

Table II. Circumstances of bites in 106 patients

Walking	34 (32%)	Passing urine	8 (8%)
Farming	22 (21%)	Inside compound	3 (3%)
Collecting	15 (14%)	Unprovoked	3 (3%)
Herding	9 (8%)	Lying down	2
Playing	9 (8%)	Railway work	1

were on the ankle or below. Thirty-two per cent of the patients were bitten while walking outside their compounds, usually to or from their farms (Table II). Twenty-one per cent were farming (hoeing or ploughing) (Fig. 10), 14 per cent were collecting firewood or grass, eight per cent were herding cattle or sheep, eight per cent were children bitten while playing (two of these put their hands into snakes' burrows while hunting rats and were bitten on the finger), and eight per cent were bitten while passing urine outside the compound, usually at night. Only three patients maintained that bites had resulted from unprovoked attacks by the snake. Sixty-eight per cent of bites occurred during daylight hours (Fig. 11) and were associated with walking to the farms and farming activities. An evening peak was probably due to people's stepping on snakes in the dark as they walked home from the fields. The bulk of these data were collected

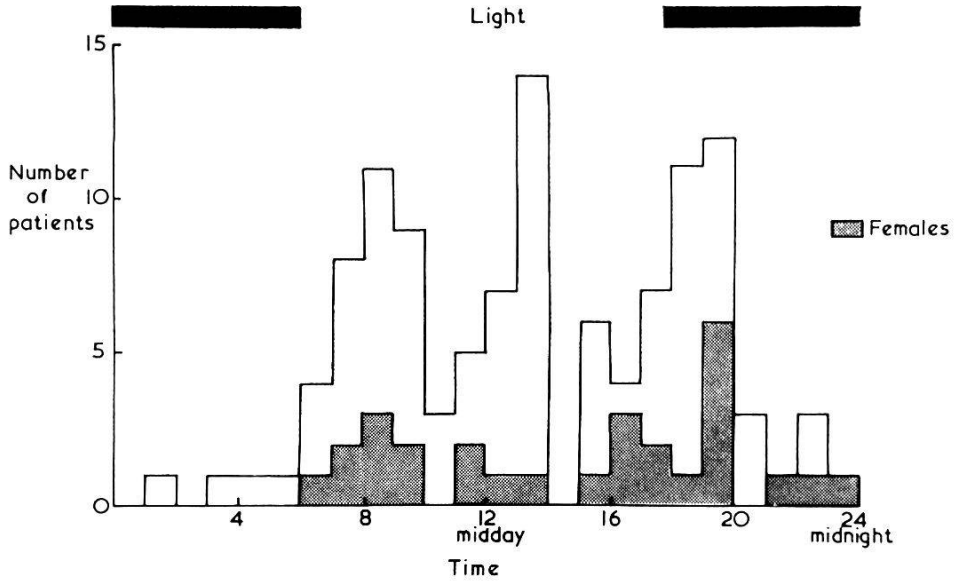


Fig. 11. Time of day when bites occurred: same group of patients as in Fig. 9.

Table III. Journey to hospital after the bite

	Zaria (40 patients)	Gombe (30 patients)	Kaltungo (50 patients)
Distance travelled to hospital average (range) km.	33 (8–125)	41 (3–95)	20 (2–108)
Time taken to reach hospital after bite average (range) hours	22 (0.5–120)	12 (1.5–72)	20 (0.25–120)

in Gombe and Kaltungo at the peak of the farming season (June to August).

4.3. Journey to hospital after the bite: on average, patients arrived at hospital about 18 hours after the bite, after a journey of about 30 km (Table III). Most had walked or been carried on bicycle crossbar, horse or donkey as far as the motor road, and had then travelled to hospital by lorry.

Discussion

1. Evaluation of snake bite statistics

Although snake bite is recognised locally as an important medical problem in many rural areas of the tropics its incidence has been grossly under-reported. SWAROOP and GRAB (1954) found records of only 166 bites and nine deaths in the whole of the northern region of Nigeria

from 1947 to 1952, whereas at G.M.H. Bambur, which serves a population of about 250,000 there were 953 bites and 50 deaths during an equivalent period from 1964 to 1969. In most areas where snake bite is common, snake bite victims go first to the herbalist or witch doctor and seek hospital care only when their remedies seem to have failed. This defect of medical statistics was emphasised by REID and LIM (1957), who, by talking to villagers along the northwest coast of Malaya, discovered details of 114 sea snake bites, only 18 of which had been treated in hospital.

Since most surveys depend largely on hospital records the incidence of snake bite will be seriously underestimated and the group of patients arriving at hospitals will be selected. Severely envenomed patients from distant areas are unlikely to reach hospital, whereas patients from the vicinity of the hospital will tend to be the more severely affected ones who have not recovered spontaneously with herbal medicine. The effect of change in local confidence in hospital treatment on snake bite admissions and hence on the apparent incidence of snake bite is clearly shown by the Bambur data 1961–1973 (see Results 3.1.). Since most bites occur in rural areas where hospitals and dispensaries are overworked and understaffed, the records may not be kept accurately and a precise diagnosis of the biting species is particularly unlikely. Thus, for many parts of the range of *E. carinatus* it is impossible to estimate the incidence of snake bites as a whole, let alone bites likely to have been caused by this species.

In the present study hospital statistics were critically examined and were combined with information gained from discussions with local people, the latter tending to give an impression rather than precise numbers. *E. carinatus* bites were identified using various techniques (see Methods 5 and 6): the diagnosis was helped by the fact that this species was sufficiently familiar to most of the patients to be distinguishable from the other venomous species.

2. Identification of E. carinatus in West Africa

E. carinatus should be easily identified in the field by its typically viperine proportions (distinct head, relatively short tail), characteristic dorsal pattern (Fig. 1a) and its behaviour when disturbed (see Introduction 1.). Closer examination will reveal erectile front fangs (Fig. 1b), undivided anal and subcaudal scales and black-spotted ventral scales (Fig. 12b) except in *E. carinatus leucogaster* (ROMAN, 1972). (For diagnosis by key see HUGHES & BARRY, 1969.)

In West Africa *E. carinatus* has been confused, however, with four other species. *Dasypeltis scabra* (egg-eating snake) resembles *E. carinatus* in its colouring, keeled scales and habit of rubbing its coils together to

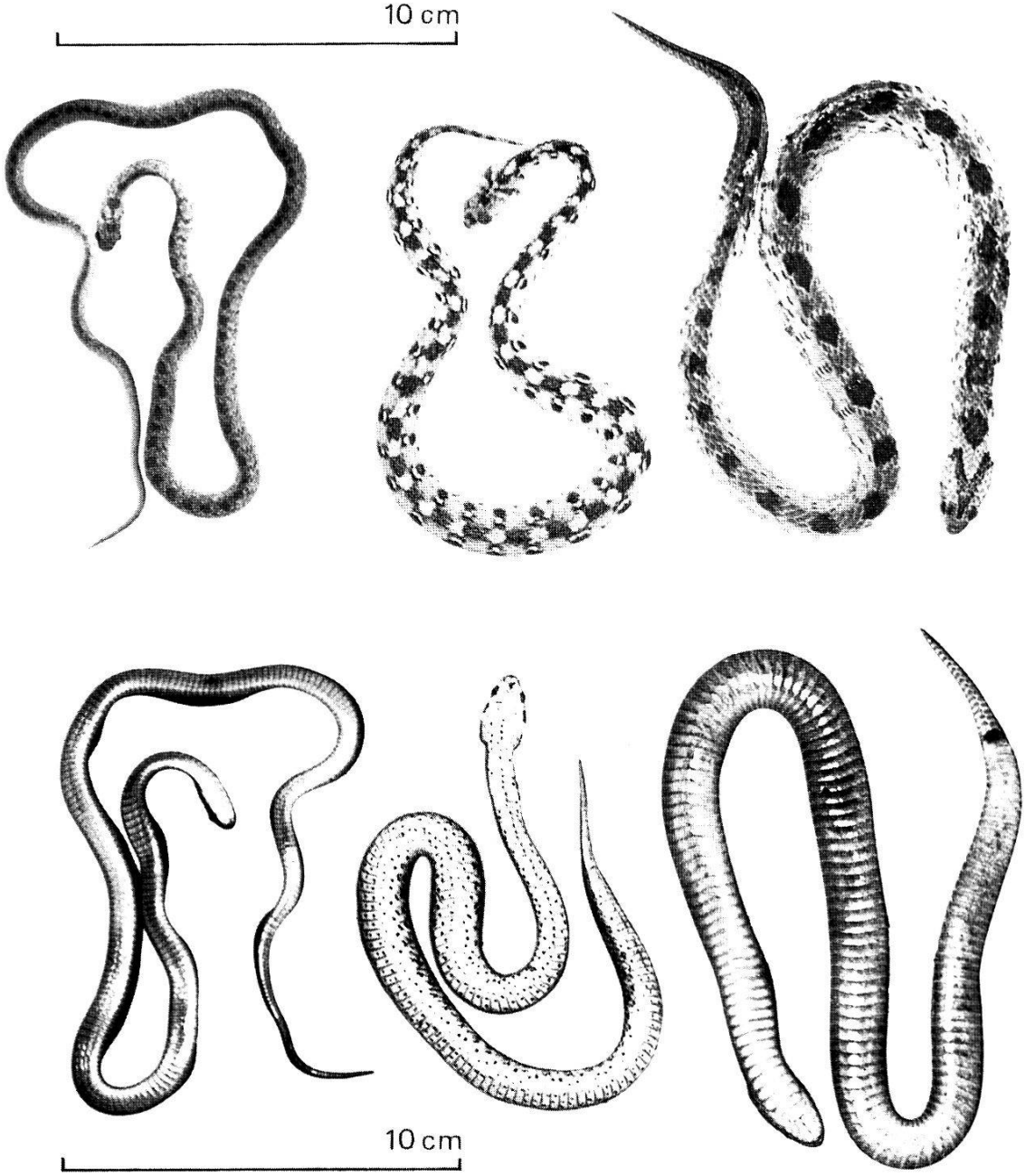
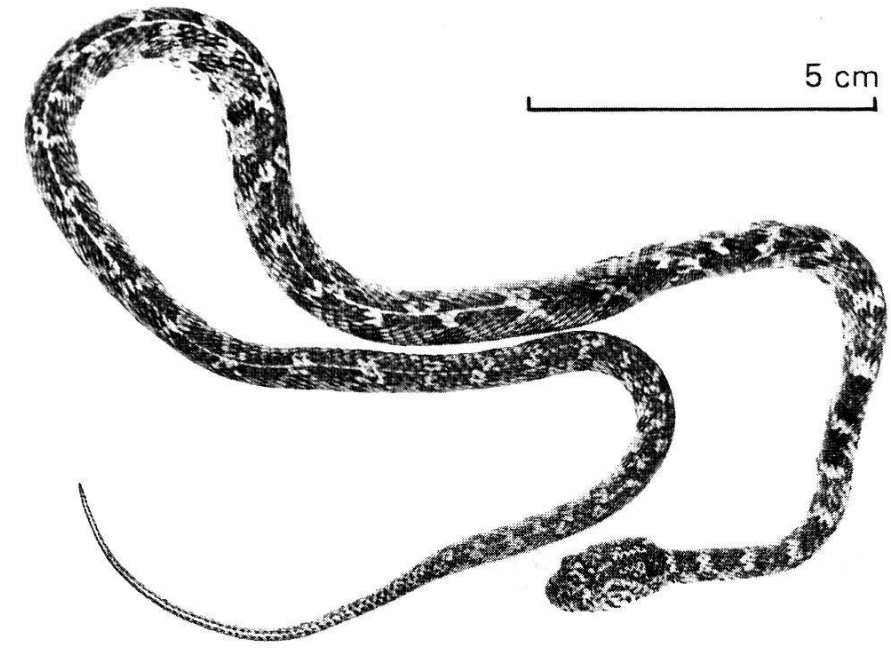
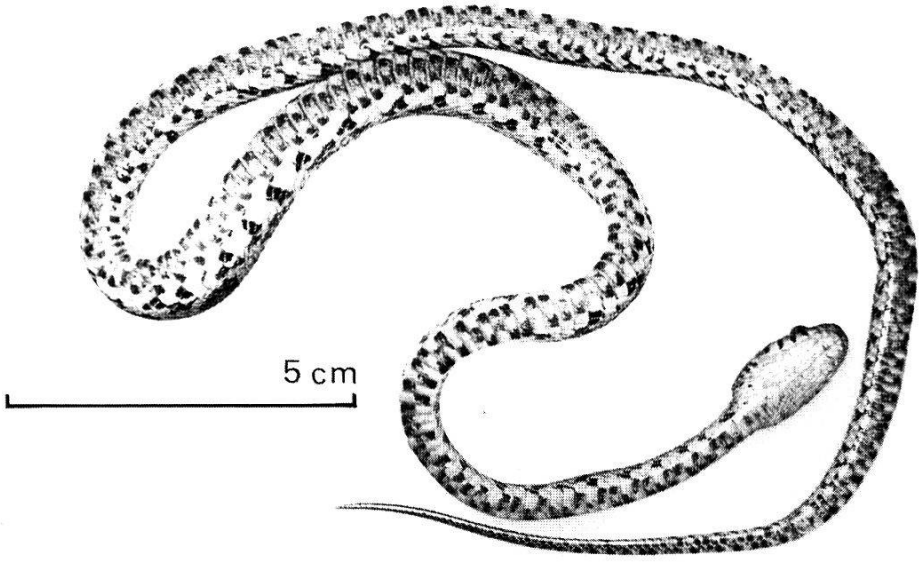


Fig. 12. Comparison of *E. carinatus ocellatus* (centre) with two species with which it may be confused: *Dasypeltis* (egg-eating snake) (left) and *Causus maculatus* (night adder) (right): dorsal (a) and ventral (b) aspects. *E. carinatus ocellatus* has distinctive dorsal ocelli and black-spotted ventral scales. Live sedated specimens from Zaria.

produce a rasping sound (CORKILL, 1956; DUFF-MACKAY, 1965). GANS (1961) has suggested that these features represent protective mimicry. *Dasypeltis* is thinner than *Echis* and far more likely to be arboreal. Its lack of fangs, the absence of spotting of ventral scales and the completely different lepidosis are decisive diagnostic features (Fig. 12). *Telescopus*



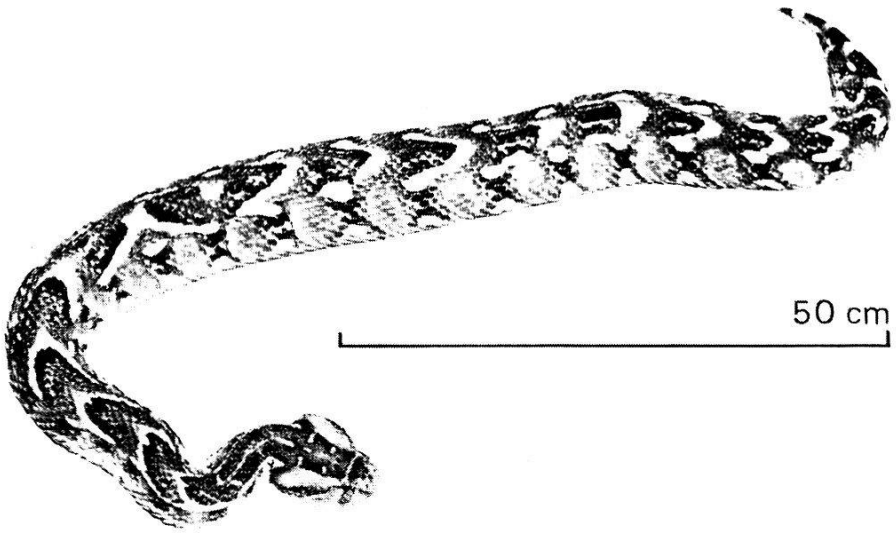
13a



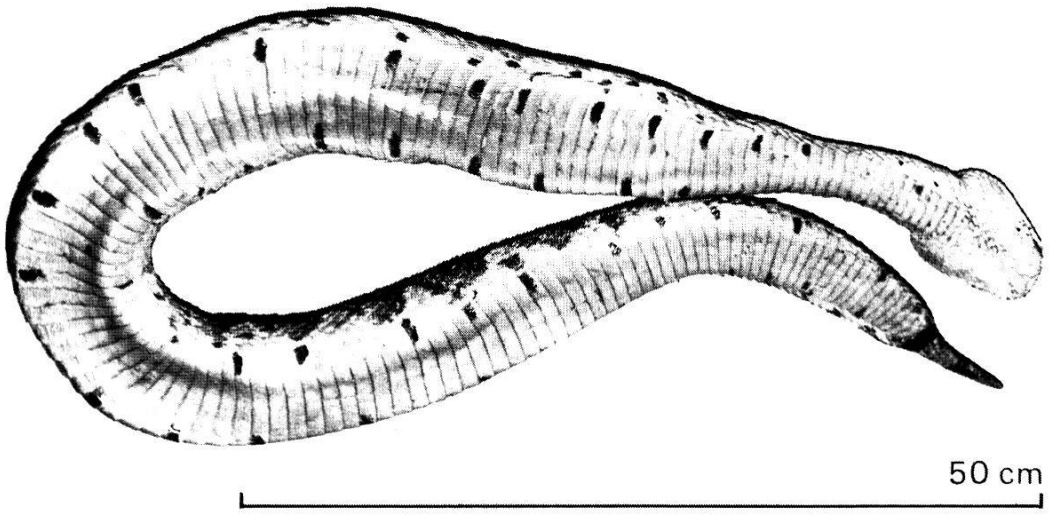
13b

Fig. 13. Telescopus variegatus (cat or tiger snake): dorsal (a) and ventral (b) views. The viper-shaped head, dorsal pattern and black-flecked ventral scales may cause confusion with *E. carinatus*. Live sedated specimen from Kaltungo.

variegatus (cat or tiger snake) looks somewhat viperine because of its large distinct triangular head, repeated dorsal pattern (Fig. 13) and aggressive behaviour, but its colubrid head scales, smooth scales and lack of fangs prevent more than a passing confusion with *E. carinatus*. *Bitis arietans* (puff adder) is a relatively thicker snake than *E. carinatus* and



14a



14b

Fig. 14. Bitis arietans (puff adder): very young specimens have been confused with *E. carinatus*. a) Live specimen from Garki showing distinctive dorsal "V" or "U" pattern and relatively thick body. b) Preserved specimen from Sokoto: ventral surface showing paired subcaudal scales.

has a distinctive "U" pattern along its back. Adults are very much larger than *E. carinatus* which is considered by some tribes to be the female or young of this species (PITMAN, 1973). Young *B. arietans* have been mistaken for *E. carinatus*, but the differences in dorsal pattern and paired subcaudal scales should prevent confusion (Fig. 14). *Causus maculatus* (night adder) resembles *E. carinatus* in its size and general configuration but it has smooth scales and does not coil and rasp when threatened. Instead it inflates itself and hisses like *B. arietans*. The head scales are

large and colubrid in type, the ventral scales are not spotted, and it lacks the lateral ocelli of *E. carinatus ocellatus* (Fig. 12). Despite these obvious differences, both *B. arietans* and *C. maculatus* have been wrongly identified as *E. carinatus* in published reports by experienced herpetologists.

3. E. carinatus bite in the Nigerian savanna

E. carinatus is widely distributed in Nigeria, avoiding only the thickly-wooded areas, southern rain forests and parts of the Jos plateau. It has been found at Naraguta near Jos (Dr. G. T. DUNGER, personal communication) and as far south as Enugu and the Udi Hills (PITMAN, 1973). It is particularly abundant in the hilly savanna of north eastern Nigeria and in the Benue valley (Fig. 3). In this area only three species *E. carinatus*, *N. nigricollis* and *B. arietans* are sufficiently common and venomous to be medically important: they are generally recognised and given local names (see appendix 1). *E. carinatus* is particularly feared: most people expect it to cause death almost immediately and many know that its venom causes bleeding.

We have defined an area (Fig. 5) in which *E. carinatus* is common and bites are frequent. It is not clear why this area is preferred by the snake. Geographically, the area is within the Benue valley complex which has a relatively high humidity, low relief (less than 1000 metres) and Guinea or sub-Sudan vegetation. Geologically it is composed of cretaceous sediments and luvisols. The southern boundary may follow the limits of derived savanna. Most of the area is lightly populated except in the southwestern corner (MORTIMORE, 1971). The area seems to cross two distinct climatic zones – a northeastern drier one (rainfall less than 1000 mm per year, rainy season less than 200 days) and a southwestern wetter one. The western boundary of the "endemic" area is the most speculative and impossible to explain in terms of climate, vegetation etc. for the Benue and Niger valleys are continuous in all senses (M. J. MORTIMORE, personal communication).

The "epidemic" increase in numbers of deaths from *E. carinatus* bite in Togo after 1949 was associated with an apparent increase in geographical range, abundance and average length of this species (GIBOIN, 1951; PITMAN, 1973), implying some change in environment favouring its multiplication and growth. Little is known, however, about the environmental factors influencing the density of *E. carinatus* populations and the size of individual snakes. PITMAN (1973) suggests that there may be competition with *B. arietans;* for the two species are never abundant in the same area.

Only in the Bambur area was it possible to guess at the incidence of *E. carinatus* bite, which may be as high as 120 per 100,000 population per

year with eight deaths per 100,000 per year. Untreated mortality must be more than 16% of hospital cases (see Results 3.3.). The results of the survey of other hospitals in the savanna region confirm that *E. carinatus* is the most important cause of snake bite morbidity and mortality. In the whole of Nigeria this species probably bites several thousand people each year causing several hundred deaths.

The Nigerian patients described here resembled a group of 310 patients, most of them bitten by *E. carinatus*, who were studied by BHAT (1974) in Jammu in northwest India. In both groups the majority were males less than 30 years old who were bitten on the foot while walking or farming barefooted. Sixty-eight per cent of our patients and 84% of Bhat's were bitten during daylight hours (Fig. 11), whereas 67% of the *E. carinatus* victims reported from India by AHUJA and SINGH (1954) were bitten at night. Only 3% of our patients and 6% of Bhat's were bitten in their homes in contrast to 64% of patients bitten by *Naja nigricollis* (WARRELL et al., 1976a) and 83% bitten by *Bungarus caeruleus* (AHUJA & SINGH, 1954).

As in most other studies (e. g. AHUJA & SINGH, 1954; CORKILL, 1949b) there was a marked seasonal variation in snake bite incidence in both Bambur and Jammu, peaks being reached in May-June and July-August respectively. In Bambur the increase in frequency of bites coincided with a surge of farming activity anticipating the start of the rains (Fig. 7). Fields, fallow since the previous season, were dug or ploughed for the first time, opening burrows occupied by *E. carinatus* during the winter. By May or June, areas of the Benue valley around Bambur became water-logged after the heavy rains driving snakes to drier land and so increasing local population density and the risk of bites, as was reported following the floods in Pakistan in 1973. Another factor may be the increase in snake activity and irritability associated with mating and egg-laying. Seasonal mortality data (Fig. 8) were too few to allow statistically valid inferences to be drawn, but they may suggest that snake bite is more dangerous in the coldest months, December and January. One possible explanation might be that snakes feed less frequently at this time and are therefore more likely to have a full dose of concentrated venom to inject when they bite. CORKILL (1949b) also noticed that mortality and the proportion of haemorrhagic bites tended to increase during the cold dry season in the Sudan. He suggested that the patients' poorer nutritional state in the dry season might contribute to their apparently-increased susceptibility to snake venoms. Much larger numbers of patients than Corkill's or our own will be needed to investigate these possibilities.

Fig. 15. The first illustration of *E. carinatus*, a specimen from Arni, in PATRICK RUSSELL's "An Account of Indian serpents" (1796). By courtesy of the Wellcome Trustees.

4. *Importance of E. carinatus throughout the rest of its geographical range*

4.1. India and Pakistan

Echis carinatus was first described scientifically by Patrick Russell in India under the name "Horatta Pam" (Fig. 15) (RUSSELL, 1796). It had the reputation of being very dangerous. Russell demonstrated "poisoning organs (which) show it to be noxious", and also described a British soldier who was bitten by the snake. SCHNEIDER named it from Russell's illustration in 1801.

The danger of *E. carinatus* bite was appreciated by IMLACH (1857) who had seen 306 cases with a mortality of 21% in six months at Shikarpur (Pakistan). The venom killed a fowl in 45 seconds. Imlach described this species as "without exception the most deadly poisonous snake in Sind." Yet GÜNTHER (1864) wrote that, "no case is known of its bite having proved fatal", an opinion reiterated by ANDERSON as late as 1898. Meanwhile FAYRER (1872) had reported some human victims of *E. carinatus* and WALL (1883) had rated it the third most poisonous snake in India (after *Naja naja* and *Bungarus caeruleus* but ahead of *Vipera russelli*). MURRAY (1884) wrote that in Sind numerous deaths occurred annually from its bite. VIDAL (1890a) provided evidence of its astonishing abundance in Ratnagiri (see Introduction 1.) and found records of 62 fatal cases treated at the local hospital in one year (1890b). Subsequent reports (reviewed by WALL, 1908; MOLE & EVERARD, 1947) confirmed the dangers of *E. carinatus* bite. For example, in Jodhpur it was regarded as by far the most poisonous snake (PUROHIT, 1944). But failure to recognise the true importance of *E. carinatus* in India had the serious consequence that Haffkine and Kasauli polyvalent antivenoms did not include specific activity against its venom until 1953. During that period AHUJA and SINGH (1954) discovered a mortality of 33% among cases of probable *E. carinatus* bite treated with Kasauli *Naja naja-Vipera russelli* antivenom. In Hyderabad (Pakistan), KHAN & ZUBERI (1959) reported 21 bites with three deaths in four months and MINTON (1966) estimated that in the Sind and Las Bela regions there were several hundred cases each year with 20–50 deaths. In recent studies from Jammu (BHAT, 1974) and Bombay (TEMBE et al., 1975), *E. carinatus* was the principal species identified as being responsible for bites and deaths.

4.2. Sri Lanka

In the north bites by *E. carinatus* (subspecies *sinhaleyus*, DERANIYAGALA, 1951) do occur but there is no information about their incidence (DERANIYAGALA, 1955; STEMMLER-GYER, 1965).

4.3. U.S.S.R.

E. carinatus is the commonest snake of the Transcaspian region (NIKOL'SKII, 1916), but no information about bites could be discovered.

4.4. Middle East

In Iraq snake bite is not common. All reported cases of *E. carinatus* bite occurred in the middle Euphrates region (SINDERSON, 1924; CORKILL, 1932 and 1933), but a fatal case with spontaneous bleeding seen by THESIGER (1964) in the marshes near Kubaish may have been a victim of this species. In Egypt, ANDERSON (1898) was not impressed by the dangers of *E. carinatus* bite, yet in 1871 he had written: "It is very deadly and is the cause of much mortality among the field-labourers in the north-west of India." In Israel, *E. carinatus* is replaced by *E. coloratus* (MENDELSSOHN, 1965). Records of 13 bites and three deaths have been found in the literature (see appendix 2).

4.5. Sudan

In the north, *E. carinatus* is responsible for most cases of snake-bite (CORKILL, 1949a; KIRK, 1953), but it does not occur in the south (BLOSS, 1951; OWEN, 1952; LOVERIDGE, 1955). In an area east of Rashad it was described by OWEN (1942) as, "probably the commonest and most widely distributed poisonous snake in the country and not infrequently fatal."

4.6. Somalia

E. carinatus is said to be the principal venomous snake in the region (LOVERIDGE, 1936; SCORTECCI, 1939; PARKER, 1944; SWAROOP & GRAB, 1954), but snake bite appears to be uncommon (PITMAN, 1973). At the main hospital in Hargeisa 20 cases were admitted in one year, but there were no deaths.

4.7. Ethiopia

In Eritrea, *E. carinatus* is regarded as the most widespread and dangerous snake, especially in the western lowlands (GANORA, 1932; CILLI, 1951). It does not occur on the high plateau of Ethiopia but is very numerous in the Rift valley, around Lake Tana and at Ambo (SWAROOP & GRAB, 1954). LANZA (1972) regarded it as the most frequent and dangerous snake in Awash National Park. Other reported locations include the Dahlak Islands in the Red Sea (M. LARGEN, personal communication).

4.8. Kenya

E. carinatus occurs north of the Tana river and is particularly abundant in the northwest, towards Lake Rudolph (DUFF-MACKAY, 1965; IONIDES & PITMAN, 1965; PITMAN, 1974). PITMAN (1973) gives records of patients admitted to Wajir hospital, which serves a population of about 30,000 people. On average there were 52 cases of *E. carinatus* bite each year with a low mortality (1.2%) during an eight year period. S.A.I.M.R. polyvalent antivenom (presumably the "tropical" polyvalent including *Echis*) was used for some of the time.

4.9. West Africa

More than 100 years after its discovery in India, *E. carinatus* was described in Togo by STERNFELD (1909). It is now known to be widely distributed in West Africa (STEMMLER, 1970; ROMAN, 1972 and 1973;

HUGHES, 1976). Probable *E. carinatus* bites were seen in Togo by Juguet in 1936 and Merveille in 1941 (quoted by GIBOIN, 1954) and in Cameroun by Casteight in 1936 (quoted by SALOU, 1951), but the first fatality definitely attributable to this species in West Africa was the case mentioned by LEESON (1950)

In Togo, there were 5–10 reported deaths from snake bite each year before 1951; but in 1951 there were 12 deaths attributed to *E. carinatus* and in 1952, 24 deaths (GIBOIN, 1954). SALOU (1951) reported the clinical features of 16 fatal cases seen at Sokodé in northern Togo. According to GIBOIN (1954) the mortality was 47% among cases thought to have been bitten by *E. carinatus* who were treated with Pasteur Institute "Afrique Orientale" antivenom. Mortality was later reduced to 5.5% in a group of 55 patients treated with polyvalent *(Naja naja-Bungarus caeruleus-Vipera russelli-E. carinatus)* antivenom from the Haffkine Institute Bombay, with or without Pasteur antivenom. PITMAN (1973) mentions that there was also serious mortality in Dahomey before an effective antivenom became available.

At Jirapa in northwest Ghana, 62 bites were seen in two and a half years with 30 per cent mortality; in many cases *E. carinatus* was identified (BOWESMAN, 1960). At least five deaths from *E. carinatus* bites were reported during two years at Tema, on the coast near Accra (PITMAN, 1973). LESAGE (1954), analysing questionnaires from all over Ghana, discovered that vipers were chiefly responsible for 237 bites in one year, with a mortality of 17%. *E. carinatus* was not collected from the forest area of southwest Ghana by SWIECICKI (1965).

Listed in appendix 2 are the published case reports of *Echis* bites in which the snake responsible was adequately identified.

5. Conclusions

For large areas of the very extensive range of *E. carinatus* no information about the incidence and mortality of snake bite is available. The data reviewed above indicate, however, that wherever records exist within its range. *E. carinatus* is cited as the most important cause of snake bite morbidity and mortality. This was confirmed in the savanna region of Nigeria. On the basis of our findings we agree with REID's (1974) opinion that this species is the most dangerous snake in the world to man. The large number of bites is partly the result of its enormous range (Fig. 2), which is second only to that of *Vipera berus* among venomous snakes, and of the high density of its population in many areas (see Introduction 3) leading to many encounters with human beings, and is partly due to its irritable disposition, which makes it likely to strike when trodden on.

The high incidence of morbidity and mortality following *E. carinatus* bite is explained by the potency of the venom in causing severe local effects including necrosis, and death from bleeding.

Unlike some elapids, *E. carinatus* rarely lives in or enters houses. The people at risk are those, particularly younger males, who work and walk barefooted and barehanded as farmers, herds, hunters and collectors in *E. carinatus*-infested terrain. The obvious means of prevention such as wearing shoes and avoiding undergrowth are usually impracticable for these people. Reduction of the snake population (e. g. by offering a reward for dead snakes) has been forcefully advocated (FAYRER, 1882–3) but is ecologically ill-advised and has failed in the past (VIDAL, 1890a; CANDY, 1890). Protection of severely-exposed communities by vaccination has been attempted, for example, in the case of Habu *(Trimeresurus flavoviridis)* bite, but with disappointing results (SAWAI et al., 1969). An approach more likely to succeed is to educate these communities, and the doctors and dispensers who serve them, about the effects and first aid treatment of bites. Undesirable local treatments, such as incisions and tourniquets which increase morbidity (BHAT, 1974; WARRELL et al., 1976b), and useless herbal remedies which cause vomiting, should be discouraged. In the hospital or dispensary specific antivenom should be available to be given intravenously to those patients whose blood will not clot in a glass tube – the most sensitive sign of systemic poisoning (WARRELL et al., 1974). Dosage of antivenom can be controlled by the same simple clotting test. Antivenom should be given only by those who can recognise the signs of an immediate-type serum reaction and know how to treat it with adrenaline. These reactions will occur in at least 20% of cases and rarely may be life-threatening. Practical difficulties in providing this treatment will include the high cost of antivenom and its preservation and regular supply in the developing countries where *E. carinatus* bite is most prevalent.

Acknowledgements

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Appendix 1. Some local names for the three principal venomous snakes.

Language	Approximate area where language spoken	*E. carinatus*	*Bitis arietans*	*Naja nigricollis*
Bayangi	Mamfe (Cameroun)		efei	mburinyo
Bura	Biu, Garkida	fufukr	tsafa	linga
Cham	between Kaltungo & Numan	sojil mabinakimte		
Dadiya	near Kaltungo	kuntimi/kuntame		
Dghwe'de	near Ngoshe, Gwoza	pisabule	makhtapa	ghavle
Dume	Pulka	nabir	mtsappe	ngavala
Fulani	extensive	buneri for'doyri	kasari	sharkori shulaidi
Glavda	near Ngoshe	pusha	mtsapa	papilama
Hardkala	near Gwoza	bila	majawaya	lafarfa
Hausa	extensive	kububuwa gajera gobe danisa	kasa	kumurci ba'ki gam'sheka*
Higi	Michika, Madagali	shishi	mbsapa	
Igbo	extensive (east-central)	mvuru		
Jaba	Kwoi (Southern Zaria)			shuck
Jaku		sigarum		mbam
Jenjo	Muri	tso		

Kagoma	Southern Zaria	shwett		
Kaje	Southern Zaria	shon	asumsum	angba-su
Kamo	near Biliri	sobwir		
Kanuri	extensive (north-eastern)	hushi, fushi		
Kilba	Little Gombi	chithi		papurvi'i
Ksughwa	near Ngoshe	push		
Mandara	near Ngoshe	naza'dale		
Margi	Lassa etc.	mubu	mtapa	paburvi'i
Matakam	near Ngoshe	djudje	timish	dumhal
Mwana	near Gwoza	girsinte		
Pia	Bambur	chambam	panagunda	wunan
	Kode	kyambam		amo
Piapung	Shendam	zem	pang	mir
Shendam	Shendam	zuwan	pang	meisa
Tangale	Biliri, Kaltungo, Pindiga	kurot	toro	m'pipide afifide
Tera	Zambuk, Kwaya Tera – near Biu	fuskar		
Tiv	extensive (south-east)	gbinde	ihom	abuku
Tula	near Kaltungo	barakam, bazagam, shiremon	kukkita	jobalah, tu, kegageta
Waja	near Kaltungo	bagaje, bagafi		tuko
Wurkum	Bambur	yohaw		
Yalla		ogbiji		
Yandang	near Bambur	yodiri	kulumbaka	huma
Yarwadadaghe	Gavva near Ngoshe	pusha	mtsapa	kohoha
Zalidva	Near Ngoshe, Gwoza	pusha	mtsapa	pohoha

* Gam'sheka: restricted by some experts (snake charmers) to *Naja haje* (Egyptian cobra).

Appendix 2. Reported cases of *Echis* bite in which the identity of the snake was definitely established.

Reference	Town	Country	Cases*	Deaths	Comment
E. coloratus					
Biran, Stern & Dvilansky (1972)	Beersheba	Israel	2	0	No clinical details given
Dvilansky & Biran (1973)	Beersheba	Israel	1	0	
Fainaru, Eisenberg, Manny & Hershko (1974)	Jerusalem	Israel	5	0	
Flower (1933)	Jordan Valley	Israel	3	3	Dr. P. H. Manson-Bahr's cases – all bitten by the same snake
Ravina, Lehman, Gottfried & Stern (1965)		Israel	1	0	
Yatziv, Manny, Ritchie & Russell (1974)		Israel	1	0	
E. carinatus					
Alcock (1888)	Dera Ghazi Khan	Pakistan	1	1	Death on 41st day after bite. Complicated by Bright's Disease
Asana (1919)	Kaira	India	1	1	
Bhat (1974)	Jammu	India	117	4	
Branford (1913)	Hissar	India	1	0	Local swelling only
Corkill (1933)	Diwaniyah	Iraq	3	0	
Corkill (1956)		Sudan	21	0	84 per cent had haematuria
Davenport & Budden (1953)	Kaduna	Nigeria	1	0	Visual field defect after six days
Deraniyagala (1955)		Sri Lanka	1	0	Bite by *E. carinatus* (subspecies *sinhaleyus*)
Duff-Mackay (1965)	Laisamis	Kenya	4	0	Bites by *E. carinatus* (subspecies *pyramidum*)
Fayrer (1872)	Calcutta	India	3	1	Fatality was Major McMahon's case
Fraser (1910)	Hyderabad	Pakistan	1	0	
Gharpurey (1931)	Ahmadnegar	India	1	0	

GIBOIN & DILLÈ (1953)	Sokode	Togo	15	1	
GRAY, H. H. (1971) unpublished	Takum	Nigeria	17	0	Blood coagulation not tested. Out of 100 cases diagnosed by bleeding four died
HALL (1962)	Wajir	Kenya	1	0	
HEATH (1899)	Rutlam State	India	1	0	Description of his own symptoms
KHAN & ZUBERI (1958)	Hyderabad	Pakistan	21	3	Deaths from cerebral haemorrhage on 3rd–12th days
LAMBA (1972)	Zaria	Nigeria	1	0	
LEESON (1950)		Ghana	1	1	Died on sixth day after the bite
McCALMAN (1886)	Ratnagiri	India	1	0	
MARTIN & LAMB (1907)	Bombay	India	1	1	Bitten on the head. Died after 25 hours
MEADEN (1928)	Nasirabad	India	1	0	No poisoning
MOLE & EVERARD (1947)	Karachi	Pakistan	1	0	
MONCRIEFF (1909)	Kotah and Deoli	India	2	0	
MURISON (1902)		India	1	0	Local swelling only
NICHOLSON (1874)	Arconum	India	1	0	Bled from healing wound
ORAM, ROSS, PELL & WINTELER (1963)	Lake Rudolph	Kenya	1	0	Haemorrhagic shock resulting in bilateral renal cortical necrosis with calcification and chronic renal failure
OWEN, C. A. (1908)	Lahore	Pakistan	1	1	Died of cerebral haemorrhage on 7th day
OWEN, T. R. H. (1942)	Rashad	Sudan	1	0	
PITMAN (1973)		Somalia	2	0	
PITMAN (1973)	Nairobi	Kenya	1	0	Captive specimen being handled
	Makurdi	Nigeria	1	1	Died of cerebral haemorrhage on 5th day. Retinal haemorrhages, thrombocytopenia (Dr. G. T. Dunger's case)
PUROHIT (1944)	Jodhpur	India	2	0	
REINHOLD (1910)	Hangu	Bangladesh	1	1	Fatal retroperitoneal haemorrhage, 27 hours after the bite
RICE (1926)	Satara	India	1	0	Local swelling only
ROBERTSON (1935)	Hyderabad	Pakistan	1	0	Local necrosis
RUSSELL (1796)	Madras	India	1	0	First reported case: no poisoning, probable hysteria

Reference	Town	Country	Cases*	Deaths	Comment
SALOU (1951)	Sokodé	Togo	3	3	Deaths from haemorrhagic shock or cerebral haemorrhage 4–9 days after the bite
SINDERSON (1924)	Diwaniyah	Iraq	1	1	Died of haemorrhagic shock 63 hours after the bite
SINGH, C. (1924)	Hurnai	Pakistan	1	0	Haemorrhagic shock treated with hypertonic saline
STEMMLER-GYER (1965)		Pakistan	1	0	Bite by *E. carinatus* (subspecies *pyramidum*)
		Sri Lanka	1	0	Bite by *E. carinatus* (subspecies *carinatus*)
STRIP (1929)	Karachi	Pakistan	1	0	No poisoning
SWINSON (1976)	Bambur	Nigeria	23	1	
TEMBE, R. S. (1921)	Sadra	India	2	0	Secondary infection of local incision
TEMBE, V. S., SANT & PURANDARE (1975)	Bombay	India	20	3	Deaths from cerebral haemorrhage, retroperitoneal haemorrhage and ? direct myocardial effect 2–5 days after the bite
WALL (1908)		India	2	0	Major Irvine's cases
		India	1	0	Major Browning's case: recurrent bleeding from bite
WALL (1909)	Rawalpindi and Lahore	Pakistan	2	1	Died of haemorrhagic shock on 7th day after the bite
WARRELL et al., (1976 b)	Zaria, Gombe Kaltungo	Nigeria	115	5	Deaths from cerebral haemorrhage and haemorrhagic shock 28 hours to six days after the bite
WEISS, PHILLIPS, HOPEWELL, PHILLIPS, CHRISTY & NITTI (1973)	New York	U. S. A.	1	0	Large (71 cm) captive specimen. Patient treated with heparin
WIG & VAISH (1960)	New Dehli	India	2	0	

* Apparent discrepancies with reported numbers are due to selection here of only those cases with adequate evidence of *E. carinatus* bite.

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