Timescale: Summer 1973/74

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Standing crop as an index of precipitation in the Central Namib grassland

by

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CONTENTS

ABSTRACT

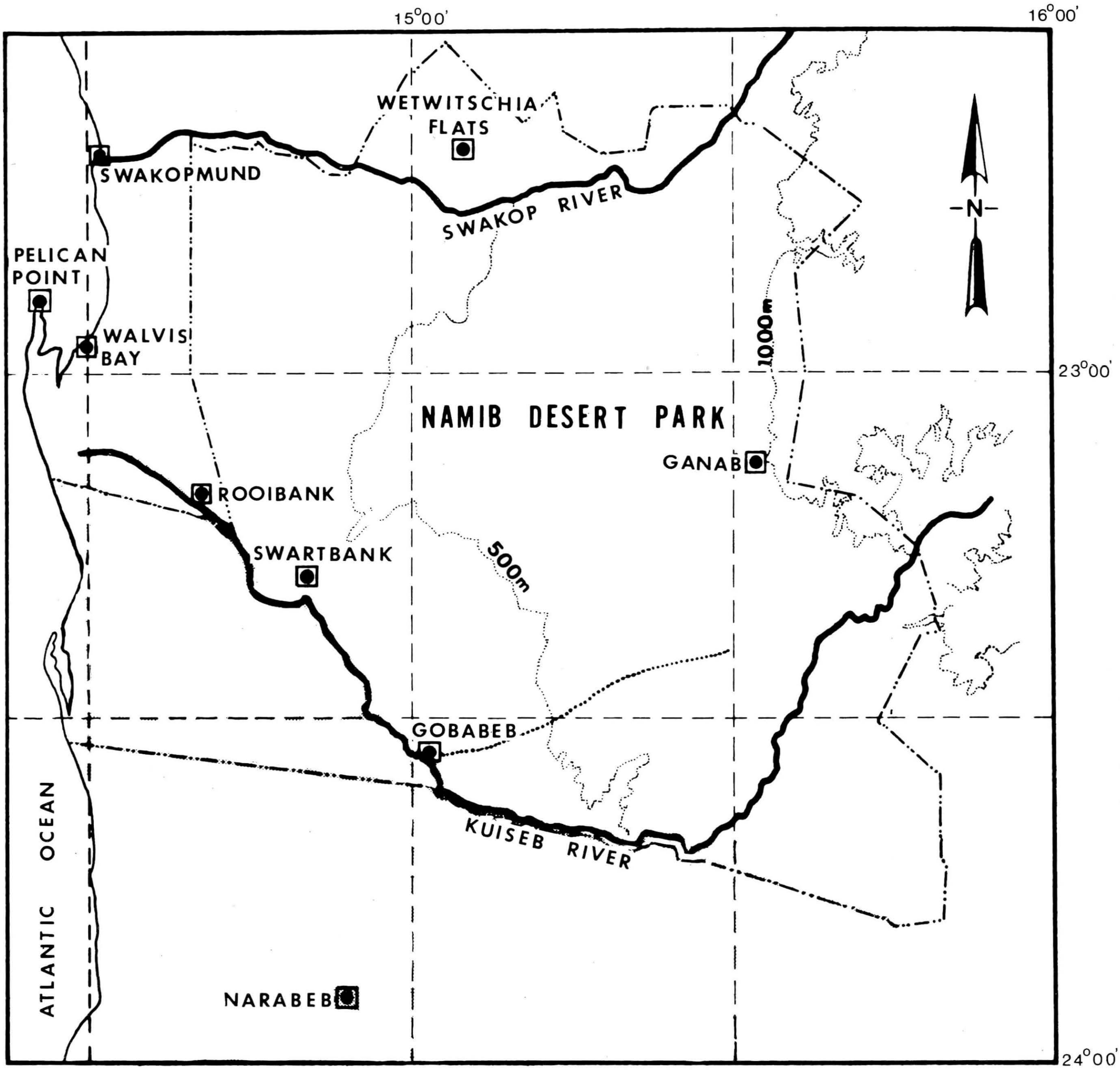
Precipitation, standing crop accumulation and insect biomass were measured in the central Namib grassland. Temporal and spatial patchiness of rainfall in deserts causes accurate measurement of this parameter to be prohibitively expensive. By solving for precipitation in the regression equation relating standing crop to precipitation as determined for this area, measurements of standing crop from selected sites provide approximate values for precipitation.

1 INTRODUCTION

Limited and irregular precipitation is a common characteristic of true deserts (Wallén 1966), and the Namib is no exception (Schulze 1969; Seely and Stuart 1976; Walter 1936).

The quantitative relationship between precipitation and phytomass production (Noy-Meir 1973; Rosenzweig 1968; Walter 1939) and the secondary relationship between precipitation and faunal production (Holm 1970; Noy-Meir 1974), indicates the importance of accurate precipitation measurements. In an area where rainfall events are rare, unpredictable and patchy, the expense of maintaining an adequate network of rain guages is prohibitive. The purpose of this paper is to explore methods of indirectly determining precipitation amounts in low rainfall areas after an event has occurred. Both phytomass and insect biomass measurements were employed.

In the central Namib on the south western coast of Africa, precipitation of less than 100 mm produces an intermittent grassland which varies each year with rainfall. Annual rainfall varies from an average of 15 mm on the coast to 65 mm on the 1 000 m contour 110 km to the east (Map 1, Table 1). Although late summer rainfall predominates in the Namib (Schulze 1969; Seely and Stuart 1976), the central Namib in the vicinity of 23°S, 15°E is situated at the northern extremity of the Cape winter rainfall region. Rain has been recorded during every month of the year. Precipitation occurs in the central Namib both as fog and rain (Besler 1972; Logan 1960; Seely and Stuart 1976). Fog is used by certain specialized desert plant species (Vogel 1955; Bornman *et al.* 1973; Walter 1936) but only rain is significant to the grasses of the central Namib plain. In this area it is only between Gobabeb and Ganab that a grass cover occurs with any regularity. The western boundary of this cover is variable (Willoughby 1971) and grass may be entirely absent during years of low rainfall. While this plant cover is termed a grassland and the community is dominated by Gramineae, other ephemeral dicotyledonous plant species occur.

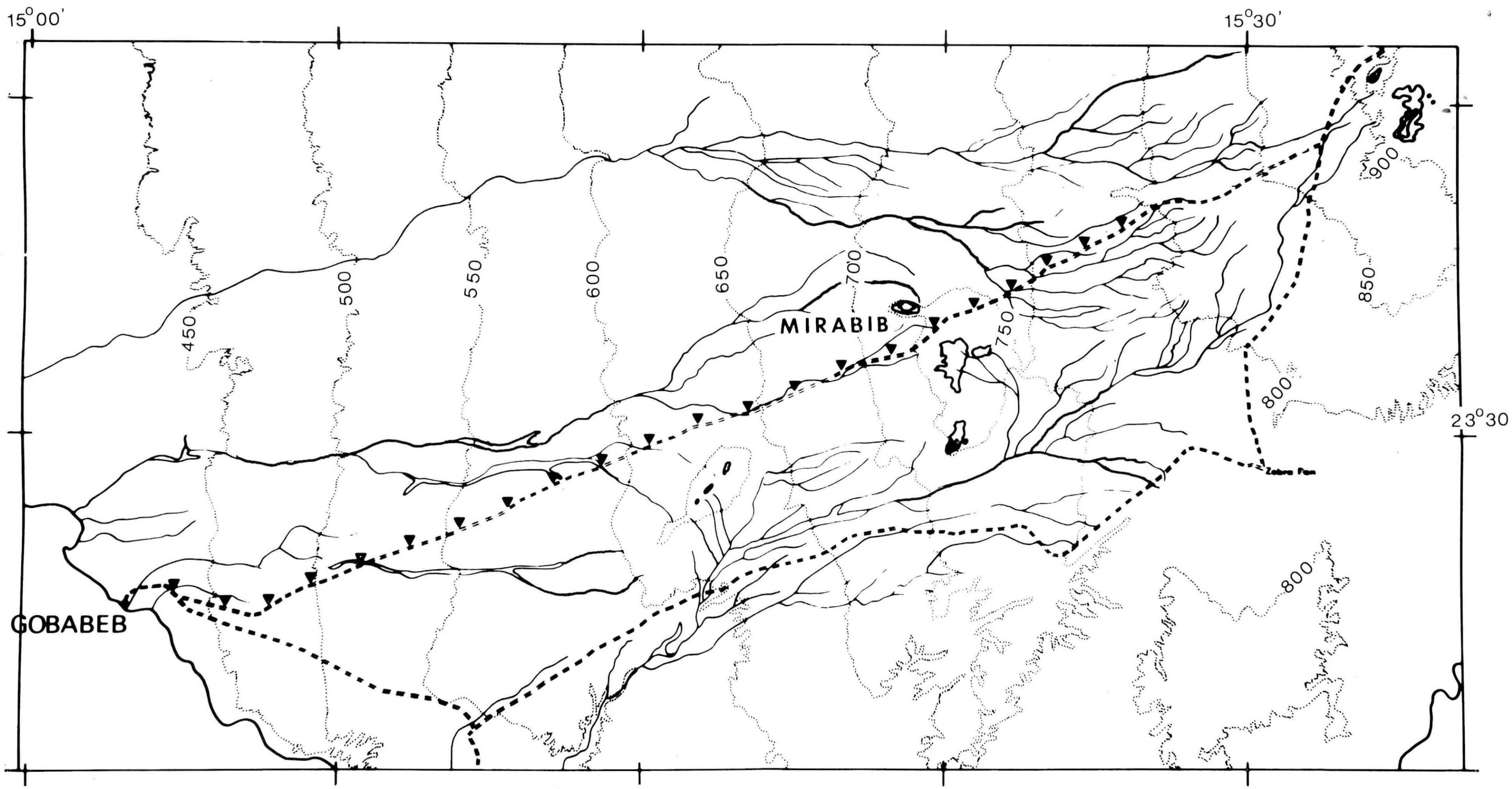


MAP 1: Map of the central Namib with location of meteorological stations (□) and temporary rain gauges of transect.

TABLE 1: Precipitation in the Central Namib.

Station		Coordinates	Air distance from coast (km)	Elevation (m)	Average precipitation (mm)	* Variability	Duration of record (years)	References
Swakopmund	(1)	22°40'S 14°34'E	2	20	18 (2,5–150,2)		64	(3)
Swakopmund	(2)				11,6 (1,4– 45,0)	113,7%	9	(4)
Walvis Bay	(1)	22°53'S 14°26'E	0	10	15 (0,0– 99,3)		69	(3)
Rooibank	(2)	23°13'S 14°40'E	22	100	18,2 (1,3– 92,4)	149,4%	10	(5)
Swartbank	(2)	23°20'S 14°51'E	33	340	10,8 (0,4– 26,6)	94,2%	7	(5)
Narabeb	(2)	23°51'S 14°57'E	40	410	10,0 (0,8– 28,6)	127,6%	4	(5)
Welwitschia Flats	(2)	22°40'S 15°02'E	53	420	11,2 (3,0– 17,3)	65,7%	3	(5)
Gobabeb	(1)	23°34'S 15°03'E	56	410	22,1 (0,0–105,5)	116,5%	14	(6)
Gobabeb	(2)				27,6 (3,5–125,2)	129,4%	10	(5)
Ganab	(2)	23°10'S 15°32'E	110	1000	97,0 (6,1–363,4)	117,6%	9	(5)

1) Weather Bureau Records, standard rain gauge employed.
2) Desert Ecological Research Unit, autographic Lambrecht gauge employed.
3) South Africa (Union of): South African Air Force Met. Service of the Royal Navy. "Weather on the Coasts of Southern Africa" 2: 38, Cape Town 1944.
4) Nieman, W. A., Heyns, C. and Seely, M. K. A note on precipitation at Swakopmund. Madoqua, in press.
5) Desert Ecological Research Unit, original data.
6) Weather Bureau, Monthly Weather Report, Pretoria.
* Variability = SD / Average × 100.



MAP 2: Gauges used to determine precipitation along the transect extended 44 km east of Gobabeb.

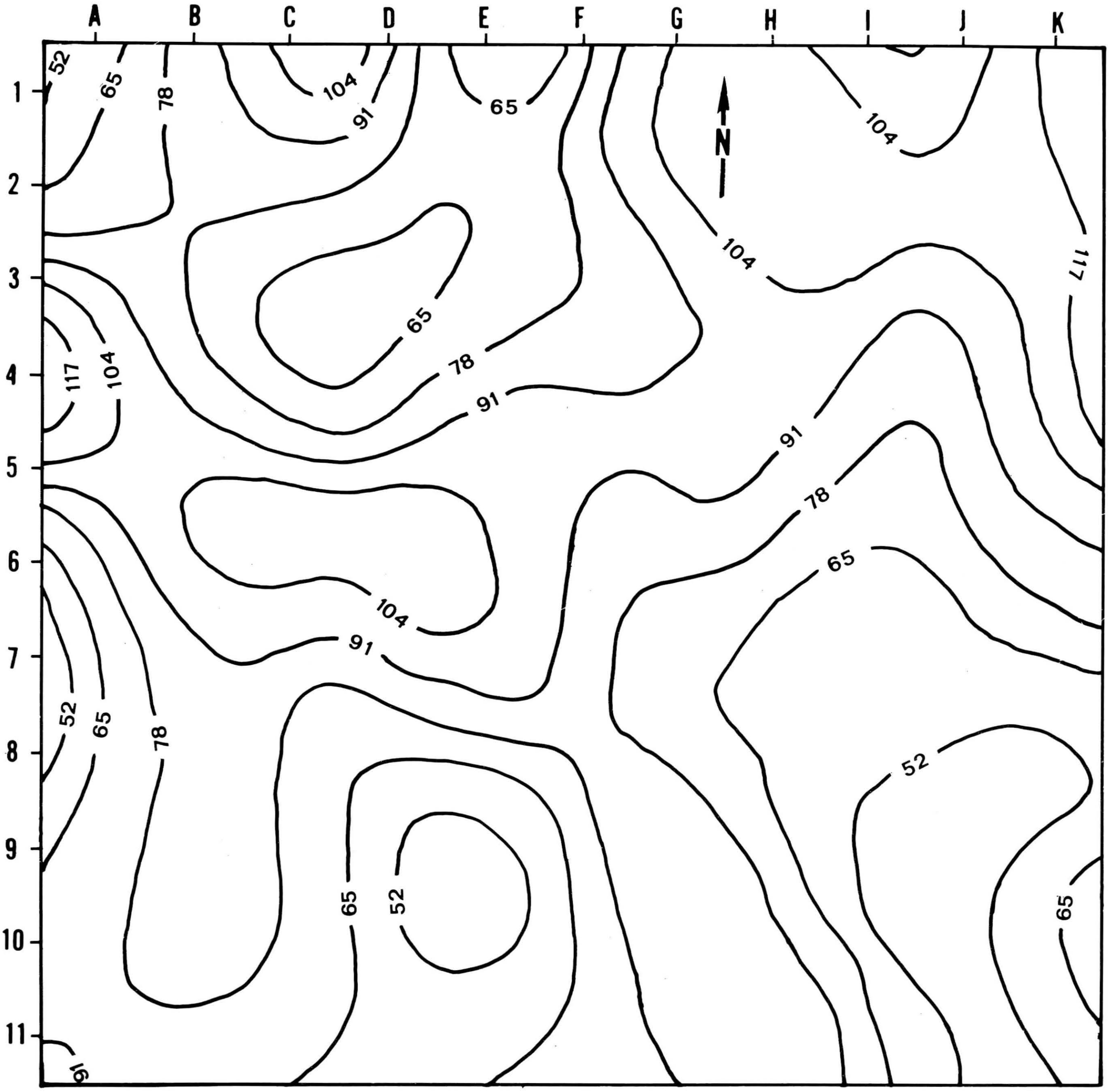


FIGURE 1: Computer generated rainfall isohyets from the season's total precipitation on the grid of gauges on the central Namib plain.

2 PROCEDURE

2.1 Experimental area

The area from Gobabeb eastwards was selected for a quantitative study of the relationship of rainfall to standing crop production. This area is subjected to minimal grazing and is free from human activity, an advantage in such studies if valid comparisons of the vegetation response to various rainfall regimes are to be made (Walter and Stadelmann 1974). The area has a uniform climate covering a similar geological formation consisting of alluvial fans surrounding an inselberg grading into quartz gravel covered plains underlain by calcrete (Besler 1972; Logan 1960). In addition, it supports a vegetation cover of approximately uniform species composition.

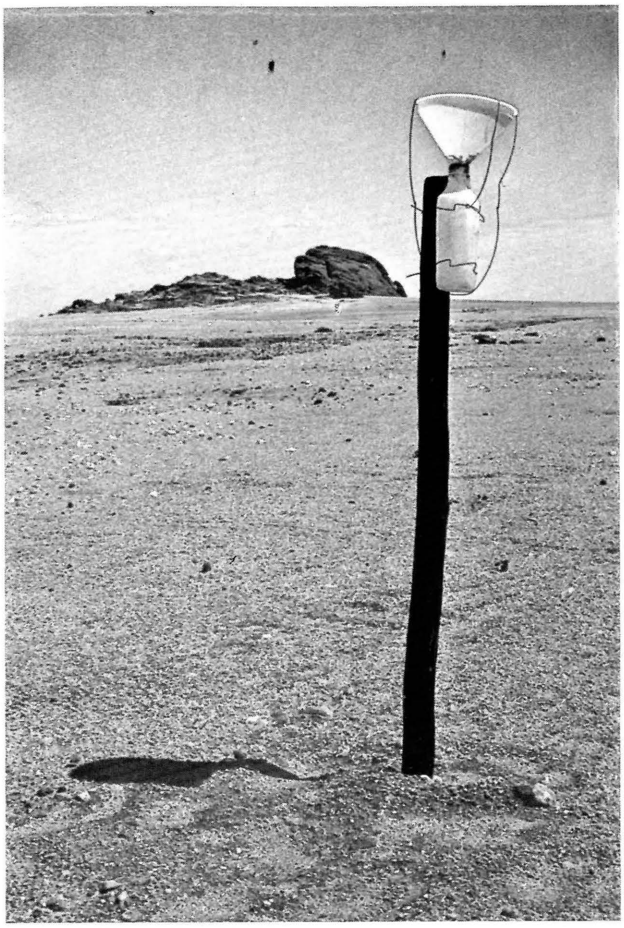


PLATE 1: Simple rain gauges were erected on the almost unvegetated plains to obtain the rainfall figures for this study.

2.2 Sampling

2.2.1 Rainfall

During the 1973 / 1974 summer, simple rainfall gauges were erected at 2 km intervals extending 44 km ENE from Gobabeb along a transect intersecting the area where the western boundary of the grass cover commonly occurs (Map 2). The transect follows the Namib Desert Park road, passing immediately south of the inselberg Mirabib. In the vicinity of Mirabib a grid of 10 km × 10 km with gauges at 1 km intervals was centred over an archaeological site (Nivin in prep.; Sandelowsky 1974) (Fig 1). The gauges consisted of funnels inserted into collection bottles erected at 1,5 m above the ground (Plate 1). Soft plastic funnels with broad rims were employed introducing some error of measurement (± 10 %). Total precipitation collected was measured the same day or the day following each rainfall event.

2.2.2 Vegetation

In March 1974, following the rains and the seeding of all the grasses, 5 × 1 m^2 quadrats of vegetation were clipped at ground level at randomly selected sites on the plains near each rain gauge along the transect. The sites were all situated on the level plain avoiding water courses or pans where growth was greater.

In addition, 5 × 1 m^2 quadrats of vegetation were clipped near each of the 5 gauges on the grid collecting the most precipitation (H2, J2, K1, K3, K4) and each of the 5 gauges where the least precipitation was measured (A1, J9, K8, K9, K10). These latter sites were selected completely randomly and included water courses with greater plant production than the surrounding level plains.

All samples were sorted to species and dry masses determined. As none of the area had supported a grass cover the previous year, the contribution of standing dead carry over from previous growing seasons was negligible. All samples were obtained using a square wooden frame. The sparse nature of the plant cover allowed the frame to be inserted easily to ground level. In agreement with general practice, grass species together with annual dicotyledons are included in this study (Milner and Hughes 1968).

Following the same rainfall events, 40 × 1 m^2 randomly located plots were clipped on the base of the adjoining dunes and 10 × 1 m^2 randomly located plots were clipped in the interdune valleys. These plots were clipped in the adjoining dune area to allow comparison with the plains values.

2.2.3 Insects

At the same time insects were collected near each rain-gauge of the transect. One hundred sweeps of approximately 3 m each were made over the vegetation. Areas with no vegetation and water courses with a more luxuriant vegetative growth were avoided. On the grid, insect collection sites were entirely randomly selected in a similar manner to the vegetative plots. Otherwise the same collection technique was employed. This material was immediately placed in alcohol and the dry weight determined. No attempt was made to identify the species involved.

3 RESULTS AND DISCUSSION

3.1 Rainfall

Over the 44 km distance of the transect precipitation varied by 860 % (11,1 mm to 95,8 mm) during the period January to March 1974 (Fig 2). Measurements from the two permanent meteorological stations Gobabeb and Ganab (Map 1), approximately 70 km apart, varied by 740 % (23,6 mm and 173,5 mm) during the entire 1973 / 1974 season. On the 10 × 10 km grid rainfall totals varied 360 % (27,3 mm to 98,0 mm) (Fig 1) during January to March 1974. The lowest and highest values were obtained from gauges (K9 and

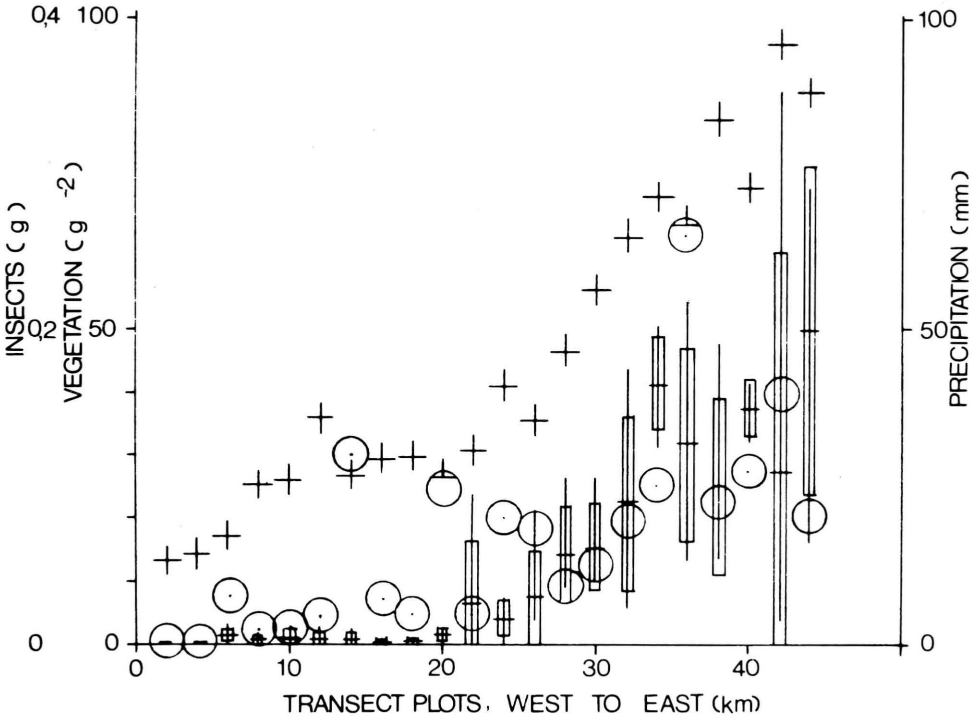


FIGURE 2: Rainfall (+), insect biomass (O) and standing crop of vegetation along the 44 km transect extending eastward from Gobabeb. Range of grass production is indicated by the vertical line, average productivity by the centrally situated horizontal line and one standard deviation by the enclosed rectangular area.

K1) only 8 km apart. The overall average from the entire grid and the transect was 48,0 mm (S.D. 17,6 mm, n = 144). This patchiness of precipitation makes accurate determinations of rainfall in an arid area extremely difficult. Variability through time can be calculated where records have been kept for several years (Table 1). When variability is calculated as S.D. / mean × 100, the precipitation is shown to be very irregular. Thus the extreme patchiness of rainfall in the central Namib is both spatial and temporal.

3.2 Vegetation

Data from various arid regions show that the average annual aboveground production (or standing crop accumulation) varies between 30 and 200 g m^{-2} (Noy-Meir 1973). In this study the average standing crop accumulation is 14,6 g m^{-2} on the transect and 43,8 g m^{-2} on the grid. The transect values were obtained from the gravel plains excluding runoff concentrations or pans. On the grid, the average standing crop accumulation was determined by combining standing crop values obtained nearby the 5 gauges which collected the most precipitation and the 5 gauges which collected the least precipitation. The values were obtained from randomly selected plots which included sites located in ephemeral water courses. The overall average standing crop value from 23 transect localities and 10 grid localities where rainfall varied from 11,1 mm to 90,0 mm thus averaged 22,1 g m^{-2}.

Thus above ground standing crop accumulation in the central Namib is on the lower extreme of reported values for desert vegetation. Table 2 compares these values with those of the other major Namib habitats, the dunes and the inderdune valleys.

Throughout the transect *Stipagrostis ciliata* predominated, composing from 80,6 % to 100 % of the dry matter of each set of clippings, except at kilometre 12 where *S. subacaulis* made up 87,9 % of the total. On the grid *S. ciliata* also predominated. Other species occurring on the transect and grid are listed in Table 3.

Productivity in arid ecosystems is highly correlated with rainfall (Noy-Meir 1973). This linear relationship may be expressed as Y = b (P − a) (Noy-Meir 1973) where Y = productivity and P = precipitation. The term *a* has been called 'ineffective precipitation' or 'water losses (evaporation and runoff)' but it may represent the genetically and environmentally determined minimal rainfall required for germination. This will be especially true where runoff is insignificant, as on the transect plots but not the grid plots of this study. The coefficient *b* represents efficiency or mg dry matter per g water.

Regression analysis of standing crop and precipitation data along the transect (Fig 3) yielded the equation Y = 0,5476 (P − 11,2986) with a correlation coefficient of 0,90 ($P < 0{,}01$). From these data it would appear that the linear relationship between precipitation and grass standing crop accumulation holds at the lower

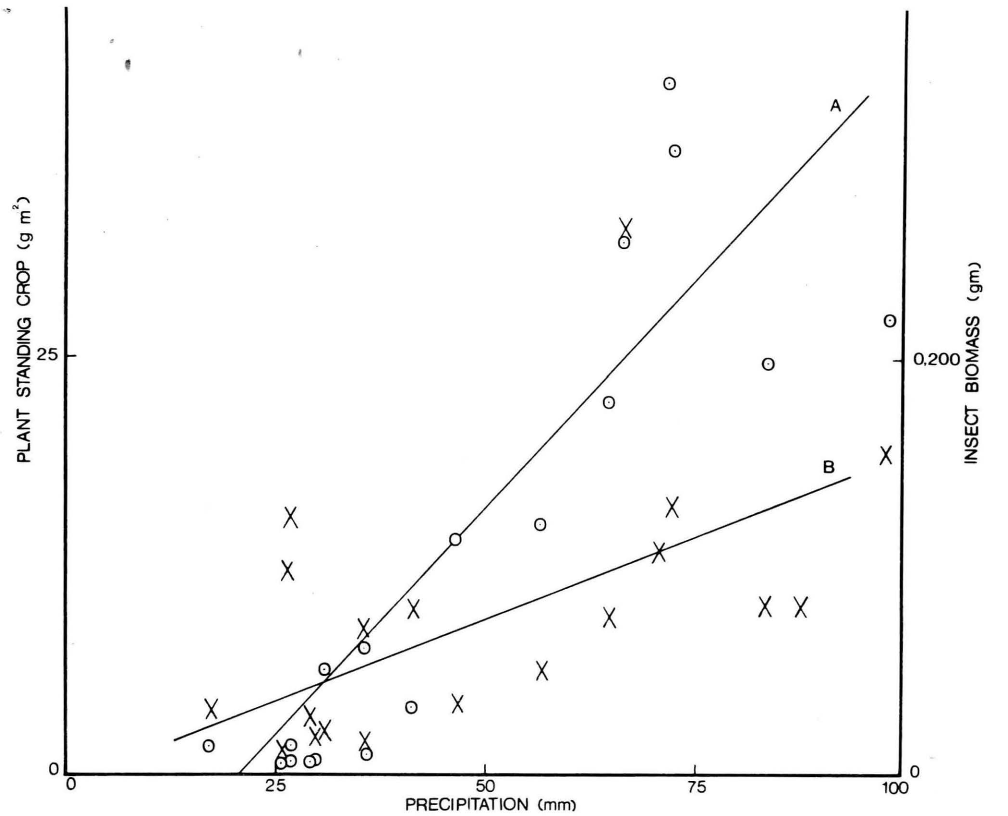


FIGURE 3: Regression lines for standing crop of grass — A — (O) and insect biomass — B — (X) as related to precipitation on the transect.

TABLE 2: Central Namib standing crop.

	Average standing crop accumulation g m^{-2}	Range g m^{-2}		
Plains transect	14,63	0,0— 88,68	18,99	100
Plains grid	42,76	0,65—162,27	28,74	50
Interdune valleys	4,87	2,88— 7,24	1,24	10
Dunes	13,94	2,95— 59,71	12,35	40
Noy-Meir 1973	30—200			

extremes of precipitation. Published values for the 'zero-yield intercept' a range between 25 and 75 mm year^{-1} (Noy-Meir 1973). From regression analysis of the Namib transect data this value for a is 20,6 mm. In one instance vegetative growth occurred with only 16,9 mm of precipitation. This value was obtained in an area where runoff did not occur and may represent the minimal precipitation required for germination. Noy-Meir (1973) indicates that values of b range from 0,5 to 2,0 mg dry matter g water^{-1}. When calculated from these Namib data $b = 0{,}59$ mg g^{-1}. These measurements were made at the lower range of precipitation values at which *Stipagrostis ciliata* grows, which may explain the linear relationship observed. Increasing production of an annual would probably assume a logarithmic relationship to rainfall in the higher rainfall ranges.

TABLE 3: Species contribution to the standing crop accumulation in the central Namib transect and grid.

Species	Percent of total dry mass by species: transect	grid
Stipagrostis ciliata (Desf.) de Winter	93,2	94,0
S. subacaulis (Nees) de Winter	4,7	2,8
S. obtusa (Delile) Nees ex Kunth	1,0	0,8
Tephrosia dregeana E. Meyer	0,4	1,1
Trianthema triquetra Willd.	0,4	0,8
Monechma desertorum (Engler) C. B. Clarke	0,3	0,3
Triraphis pumilio R. Br.	0,1	< 0,1
Salsola tuberculata (Fenzl ex Moq.) Schinz	—	0,2
Lotononis platycarpa (viv.) Pic. Ser.	< 0,1	—
Limeum argute — carinatum Wawra and Peyr.	< 0,1	—
Helichrysum leptolepis DC.	—	< 0,1
Hermannia modesta (Ehrenb.) Mast	—	< 0,1
Monsonia senegalensis Guill. & Perr.	—	< 0,1

To further assess the validity of the transect standing crop data as an indicator of precipitation, the 5 lowest and 5 highest precipitation values were selected and the t-statistic for two means employed. The standing crop values from the precipitation extremes were shown to be significantly different ($P < 0{,}001$) as were precipitation values themselves ($P < 0{,}001$).

The grid data obtained from randomly selected plots near the gauges with the 5 highest and 5 lowest rainfall values were also subjected to a t-test. While the rainfall at the two extremes was significantly different ($P < 0{,}01$) the vegetation values were not ($P > 0{,}05$). This reflects the completely random selection of plots on the grid as opposed to the siting of plots on the transect away from all precipitation runoff concentrations.

3.3 Insect biomass

Statistical analyses of insect biomass along the transect also yielded significant differences. Linear regression of insect biomass on precipitation (Fig 3) gave the equation $I = 0{,}0016\ (P - 3{,}2500)$ ($P < 0{,}01$) where I = insect biomass and P = precipitation.

The regression of insect biomass (I) on standing crop (Y) yielded the equation $I = 0{,}0025\ (Y + 13{,}0400)$ ($P < 0{,}01$). A t-test comparison of insect biomass from near the 5 gauges with the highest precipitation values and the 5 gauges with the lowest precipitation values which supported vegetation on the transect showed significant differences ($P < 0{,}01$). Statistical analysis of insect biomass values from the grid showed no correlation with either rainfall or standing crop of vegetation ($P > 0{,}05$). Thus uniformity of substrate as it effects vegetative growth has a secondary influence on insect biomass also.

4 CONCLUSIONS

The results obtained from the Namib grassland plots suggest that a measure of approximate precipitation in an area can be determined from standing crop values. The most precise approach would be to determine equations applicable to local rainfall regimes, soil types and specific plant species. Plots selected for uniformity of runoff characteristics should be employed rather than those totally randomly selected. By solving the regression equation for P, ($P = Y/b + a$) the measured productivity could be employed to calculate an approximate precipitation value for any locality with similar characteristics. In the central Namib gravel plains $P = Y/\ 0{,}5476 + 20{,}6329$ has been established to yield significant values when uniformity of surface characteristics and species composition is taken into account. Insect biomass values could be employed in the same manner although this procedure is not recommended. Variability with time would be greater with insects than with vegetation measurements.

5 ACKNOWLEDGEMENTS

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