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A preliminary account of aerial plant biomass in fynbos communities of the Mediterranean-type climate zone of the Cape Province

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ABSTRACT

Aerial plant biomass has been sampled by harvesting on several sites in fynbos communities of the south-western Cape Province.

Biomass in stands of about two years old ranged from about 2 200 kg per ha to about 7 500 kg per ha. Mature stands comprised about 11 000 to 15 000 kg per ha in heaths and 15 000 to 26 000 kg per ha in sclerophyllous scrub. The data indicate a maximum annual growth rate of 1 000 to 4 000 kg per ha early in the development of a stand, but growth rates appear to decline rapidly as communities age.

Young stands are dominated by hemicryptophytes, which comprise about 2 000 to 6 000 kg per ha, or about 60 to 75 per cent of the biomass in stands of about four years old. Shrubs become prominent later, but the hemicryptophytes persist.

The data indicate that the biomass, growth rates and the shape of the growth curves of fynbos communities are on the whole similar to those of analogous vegetation in other zones of mediterranean type climate. However, there are important structural differences in that analogues of the northern hemisphere (garrigue, chaparral) do not have a significant component of persistent hemicrytophytes. Although Australian heath communities do have this feature, the hemicryptophytes are not as prominent as in fynbos.

RESUME

RAPPORT PRELIMINAIRE SUR LA BIOMASSE DE LA VEGETATION AERIENNE DANS LES MAQUIS (FYNBOS) DE LA ZONE CLIMATIQUE DE TYPE MEDITERRANEEN EN PROVINCE DU CAP

On a obtenu un échantillonnage de la biomasse de la végétation aérienne en en récoltant à divers endroits du maquis (fynbos) du sud-ouest de la Province du Cap.

Dans des stations vieilles d'environ 2 *ans la biomasse a varié de* 2 200 *à* 7 500 *kg par ha (approximativement). A maturité, ces chiffres se montent à* 11 000–15 000 *kg par ha dans les bruyères et* 15 000–26 000 *kg par ha dans les brousses sclérophylles. Les données indiquent un taux de croissance annuel maximal de* 1 000 *à* 4 000 *kg par ha au début du développement d'une station, mais les taux de croissance semblent diminuer rapidement quand les communautés vieillissent.*

Les jeunes stations sont dominées par des semi-cryptophytes qui comprennent environ 2 000 *à* 6 000 *kg par ha, ou de* 60 *à* 75 *pour* 100 *de la biomasse dans des stations âgées d'environ quatre ans. Plus tard les arbrisseaux prédominent mais les semi-cryptophytes persistent.*

Les données indiquent que la biomasse, les taux de croissance et la forme de la courbe de croissance de ces maquis sont au total semblables à celles des associations végétales analogues dans d'autres zones du type climatique méditerranéen. Néanmoins, il y a d'importantes différences structurelles en ceci que les analogues de l'hémisphère Nord (garrigue, chaparral) n'ont pas une constituante significative de semi-cryptophytes persistants. Bien que les associations de bruyères australiennes possèdent cette caractéristique, les semi-cryptophytes n'y sont pas aussi importants que dans le fynbos.

INTRODUCTION

The ecology of natural communities of Mediterranean-type ecosystems has recently received considerable attention, particularly from the point of view of ecosystem convergence, and much more information on plant communities has become available (Specht, Rayson & Jackman, 1958, and previous papers; Specht, 1969a, 1969b; Jones *et al*., 1969; Mooney *et al*., 1970; di Castri & Mooney, 1973). However, few data on the Cape fynbos† have reached the press.

In this paper data have been collated on the biomass of fynbos communities, which have become available during the course of ecological studies from 1967 to 1974. The studies were not aimed at measuring community production nor are the data such that they may be used as direct measures of productivity. Nevertheless, they represent an index of productivity and contain other useful information.

STUDY AREAS

Biomass surveys were conducted on various sites in three research areas, each described below.

1. **Jonkershoek Forest Research Station** (sites 1.1–1.4). The research area at Jonkershoek is situated at about 33°57′S and 18°55′E. The ecosystem has been described by Wicht *et al.* (1969). The communities sampled are situated on the slopes and near the bottom of a steep-walled valley (Fig. 1) and occur on soils derived from Cape granites. Soils are about one metre deep with a brown structureless loam A-horizon on a yellow-brown apedal B. They are acid, with pH ranging from about 4,50 to 5,00. Extractable phosphorus (citric acid extract) amounts to about 12 to 40 p.p.m. and total nitrogen and organic carbon content amount to 0,1 to 0,2 per cent and three to eight per cent respectively, in the A-horizon (Joubert, 1965).

2. **Zachariashoek Research Catchment** (sites 2.1–2.3). This catchment research area is situated at 34°49′S and 19°02′E and has been described by van der Zel (1974). The communities studied are situated in the Kasteelkloof subcatchment (Fig. 2). Soils are derived from sedimentary orthoquartzites and shales of the paleozoic Table Mountain Group. The soils here have not been studied, but would resemble those at Jakkalsrivier rather than those at Jonkershoek. Site 2.2 is phreatic and the soil has an organic A-horizon.

Few climatic data are available. Rainfall at the top of the catchment amounts to about 1 300 mm per annum, and at the bottom, 1 100 mm per annum (six-year records at 701 m and 274 m a.s.l., respectively).

3. **Jakkalsrivier Research Catchment** (sites 3.1–3.10). Plathe & van der Zel (1969) and Kruger (1974) have described the Jakkalsrivier area in some detail (Fig.

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† Also known as sclerophyll bush (Adamson, 1938), and including the types described by Acocks (1953) as Macchia, False Macchia and Coastal Macchia.

FIG. 1.—View of sclerophyllous scrub community at site 1.2, Jonkershoek, shortly after sampling. Prominent shrubs are *Rhus tomentosa* and *Anthospermum aethiopicum*. Asteraceae dominate the lower shrub stratum.

FIG. 2.—View of open sclerophyllous scrub community at Zachariashoek (site 2.1) at age five years. Here, the sclerophyllous shrubs have not yet emerged and the community is dominated by Restionaceae: *Chondropetalum paniculatum, Hypodiscus argenteus* and *Cannomois virgata* are prominent.

FIG. 3.—View of microphyllous evergreen dwarf scrub (low heath) community at Jakkalsrivier (site 3.7), at age 14 years. The shrub stratum is dominated by *Erica hispidula.*

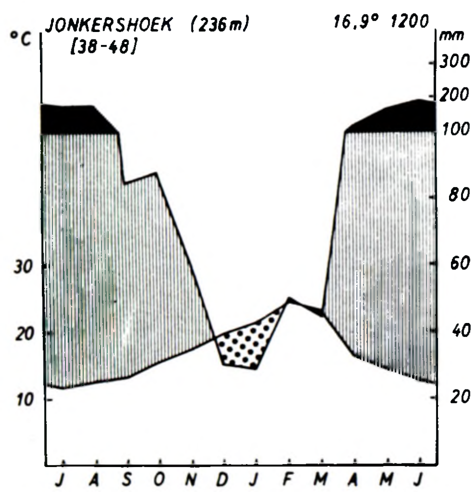
3). It is centred at 34°09'S and 19°09'E. Soils are derived from the orthoquartzites and shales of Table Mountain Group. In most cases, these are coarse rocky sands with a humic A-horizon, dystrophic, with pH ranging from 3,5 to 5,0, total exchangeable cations from 0,2 to 7,9 me/100 gm, and cation exchange capacity from 0,5 to 44,0 me/100 gm. Base saturation is very low. Phosphorus is present at about one to four parts per million (Bray No. 2 extract). Total nitrogen ranges from 0,01 to 0,1 per cent, and organic carbon from about two to four per cent, in the A horizon.

The principal climatic features of Jonkershoek and Jakkalsrivier are illustrated by means of Walter diagrams (Walter, 1963) in Fig. 4. The mean total radiation for the region is 450 to 500 cal per square centimetre per day. Table 1 summarizes the principal physical features of the sample sites, and includes names of plant communities. Fosberg's (1967) structural-functional classification was used and refers to the mature community. Community names based on character species are given where possible and are those assigned in prior studies (Kruger, 1972; 1914). Figs. 1, 2 and 3 illustrate typical communities.

METHODS

Communites which appeared structurally homogeneous were selected for sampling. Stratified random sampling was used wherever conditions permitted, and in these cases a ranked-set sampling procedure (Halls & Dell 1966) was followed. Most samples were collected in late summer or early autumn, when the communities are nearly dormant. Successive harvests were completed on sites 2.1, 2.2, 2.3, 3.1, 3.2, 3.3, 3.4, 3.5 and 3.6.

Biomass was determined by clipping aerial plant parts from one-metre-square quadrats in all cases except site 1.1, where 0,5 m² plots were used, and the six-year stand at 2.2, where 2,5×2,5 m plots were used. In most cases an apparatus described by Hetherington (1967) was used to define the cylinder within which material was collected. Plants were



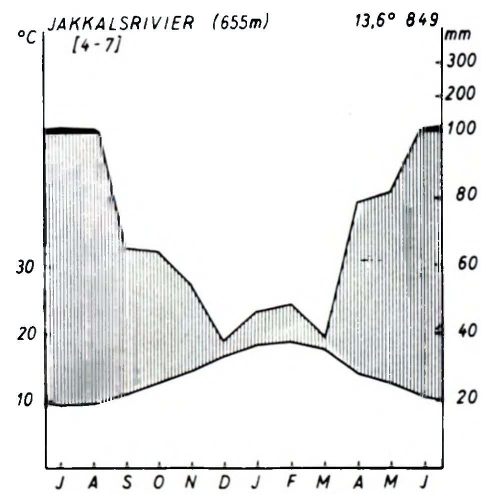


FIG. 4.—Walter diagrams for Jonkershoek (Manor House Station) and Jakkalsrivier (Main Station).

TABLE 1.—Communities and physical factors for each sample site

Site no.	Alt. metres	Aspect (slope, azimuth, degrees)	Slope, degrees	Geology	Community
1.1......	405	218	14	Cape granite.............	Mesophyllous evergreen broad sclerophyll scrub.
1.2......	250	24	17		
1.3......	250	24	17		
1.4......	250	24	17		
2.1......	630	195	23	Quartzite, T.M.G.........	Mesophyllous open evergreen broad-sclerophyll scrub; *Cannomois virgata-Hypodiscus albo-aristatus* Community.
2.2......	510	121	22	Quartzite, T.M.G.........	Evergreen broad-sclerophyll swamp scrub; *Elegia thyrsifera–Osmitopsis asteriscoides* Community.
2.3......	360	98	23	Tillite & shale, T.M.G.....	Mesophyllous open evergreen broad-sclerophyll scrub; *Montinia caryophyllacea–Helichrysum tomentosulum* Community.
3.1......	870	156	15	Quartzite, T.M.G.........	Microphyllous evergreen dwarf scrub(heath); *Willdenowia sulcata–Protea cynaroides* Community.
3.2......	1 065	132	34	Quartzite, T.M.G.........	Open microphyllous evergreen scrub (heath); *Willdenowia sulcata–Klattia partita* Community.
3.3......	880	238	27	Quartzite & shale, T.M.G.	Mesophyllous evergreen broad-sclerophyll scrub and heath; *Tetraria bromoides–Erica plukeneti* and *Willdenowia sulcata–Protea cynaroides* Communities.
3.4......	865	195	17		
3.5......	785	248	18	Tillite & shale, T.M.G.....	Mesophyllous evergreen broad-sclerophyll scrub; *Tetraria bromoides–Erica plukeneti* Community.
3.6......	850	98	15	Quartzite, T.M.G.........	Microphyllous evergreen dwarf scrub (heath); *Tetraria thermalis–Hypodiscus aristatus* Communities.
3.7......	785	81	5		
3.8......	815	317	22		
3.9......	745	263	19		
3.10.....	740	280	20		

TABLE 2.—Aerial plant biomass statistics for each site

Site no.	Age	Sample size	BIOMASS (KG/HA) Shrubs	Sub-shrubs	Graminoid	Restioid	Herbs	Total	Coefficient of variation (%)	Std deviation, total biomass	Confidence interval (P=0,95)	Litter mass (Kg/ha)††
1.1	6 yrs 3 mo	20	—	—	—	—	—	15704	14,9	2341	1 096	—
1.2	17 yrs	9	—	—	—	—	—	25 700	43,1	11 080	17 034	—
1.3	10 yrs	9	—	—	—	—	—	18 430	37,0	6 82o	10 499	—
1.4	10 yrs	9	—	—	—	—	—	13 078	55,7	7 280	11 192	—
2.1	6 yrs	18	1 016	—	1 029	4 951	264*	7 260	—†	—†	—†	994
2.1	1 " 9 mo	18	424	20	573	1 982	248	3 247	66,0	2 144	2 134	—
2.2	6 "	6	10 581	—	1 597	8 527	643*	21 349	—†	—†	—†	4 950
2.2	1 " 9 mo	18	1 963	913	2 207	2 194	297	7 574	56,4	4 273	4 253	≈0
2.3	6 "	18	1 081	—	1 992	2 089	570*	5 731	—†	—†	—†	2 385
2.3	1 " 9 mo	18	167	95	1 140	523	306	2 230	28,8	643	640	≈0
3.1	3 " 4 mo	18	414	739	3 028	1 711	683	6 574	40,3	2 652	2 639	≈0
3.1	4 " 4 mo	18	310	810	3 554	2 719	980	8 373	33,9	2 839	2 826	≈0
3.2	4 " 4 mo	18	3 014	425	2 013	2 830	986	9 226	35,8	3 319	3 303	≈0
3.3	4 " 1 mo	18	981	358	2 201	1 990	735	6 264	24,8	1 555	1 548	≈0
3.4	3 " 3 mo	18	1 013	446	1 377	1 543	550	4 928	36,0	1 773	1 765	≈0
3.4	4 "	18	703	1 177	1 453	2 405	898	6 636	26,0	1 726	1 718	≈0
3.5	3 " 6 mo	18	1 196	790	1 744	1 605	400	5 736	35,5	2 037	2 028	≈0
3.5	4 " 4 mo	18	1 728	740	1 592	2 303	609	6 972	29,1	2 030	2 020	≈0
3.6	3 " 7 mo	18	656	169	1 301	1 994	730	4 850	35,0	1 697	1 689	≈0
3.6	4 " 4 mo	18	691	166	1 256	2 968	985	6 065	27,3	1 653	1 645	≈0
3.7	16 "	18	3 253	≈0	1 819	6 946	347	12 365	49,3	6 093	6 064	2 230
3.8	16 "	18	3 062	12	4 246	4 469	1 109	12 987	72,3	9 326	9 282	3 819
3.9	16 "	18	5 710	≈0	1 397	3 564	401	11 072	28,8	3 190	3 175	2 318
3.10	16 "	9	7 627	97	1 146	4 184	1 475	14 529	34,0	4 932	7 582	2 412

* Includes sub-shrubs.
† Could not be calculated—non-random samples.
†† Dash = could not be collected; = 0 = trace collected.

clipped as close to the soil surface as possible, using secateurs. If litter was present in significant quantities, it was collected by raking the soil surface with the fingers. Dead plants were included as litter. Clipped material was segregated into growth-form categories during the clipping routine. The plant material was stored in 2 mm-mesh plastic-coated fibre-glass gauze bags and hung in a well-ventilated place until it could be treated in the laboratory.

The categories used for the segregation of clipped material are detailed below.

(i) Shrubs: microphanerophytes and nanophanerophytes of families such as Proteaceae, Ericaceae and Leguminosae.

(ii) Sub-shrubs: sub-ligneous nanophanerophytes and chamaephytes of genera such as *Stoebe* and *Metalasia* (Asteraceae).

(iii) Graminoid: hemicryptophytes typical of Poaceae and Cyperaceae.

(iv) Restioid: leafless hemicryptophytes of the family Restionaceae and, sometimes, Cyperaceae, described as assimilating stem type hemicryptophytes by Adamson (1931).

(v) Herbs (forbs): non-ligneous elements not included in above categories, and including ferns.

In the laboratory the fresh mass of the contents of each bag was determined before the material was chopped mechanically in lengths of 0,5 to 3,0 cm. A sample of four 50–100 gm units was drawn from the chopped material after thorough mixing. The moisture content of these was determined by normal oven-drying procedures (105°C for 24 hours). The mean moisture content of the subsample was used to estimate the oven-dry mass of the original material.

Table 2 includes the 'age' of the communities. This represents the time since the last burn and closely approximates the real age of the shrubs that have regenerated from seed. Age was determined from Department of Forestry records or, where this was not possible, by node-counts on Proteaceae as described by van der Merwe (1969).

RESULTS AND DISCUSSION

Data are presented in detail in Table 2 and further depicted in Fig. 5. The curves in Fig. 5 were drawn by hand and fitted to represent the approximate upper and lower limits of the data set.

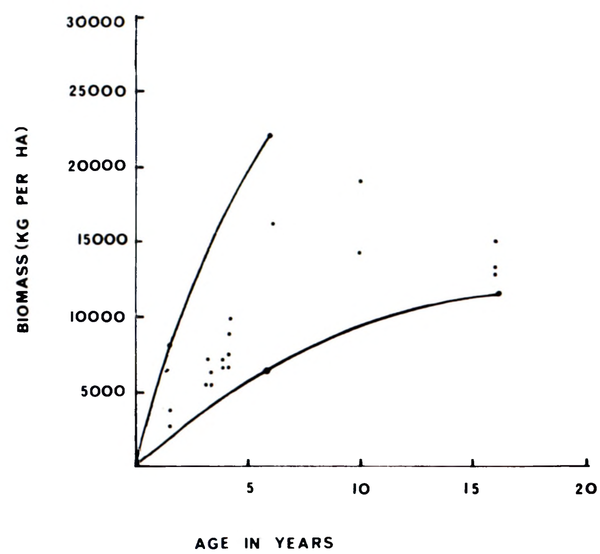


FIG. 5.—Approximate regression of biomass on age. Dots represent actual data points from Table 2.

Sample efficiency

The coefficients of variation for total biomass shown in Table 2 clearly indicate that, in many cases, random samples of clipped quadrats need to be large for reasonably precise biomass estimation. The number of sample units used here was seldom adequate to ensure a confidence interval equal to or less than 20 per cent of the mean, at five per cent probability of error. For a confidence interval of 20 per cent of the mean, about thirty to sixty quadrats would be required (and in some cases a great deal more). Furthermore, the samples were not large enough to show a significant difference (at P=0,95) between harvests in successive years on the same site, though the vegetation had obviously grown.

These estimates are much less precise than those reported by Jones & Specht (1967) and Jones (1968), who obtained estimates with 95 per cent confidence interval of about 12 per cent of the mean, using 12 to 20 one-metre-square quadrats. These authors concluded that successive harvests were not appropriate in production studies in heath.

Since the information reported here was collected with the aim of monitoring long-term trends in biomass, it was not thought profitable to improve precision by increasing sample size. Nevertheless, future studies would benefit if larger quadrats were used. Where greater precision is required and alternative techniques of production measurement (such as gas-exchange measurement) are not feasible, a combination of sampling by vegetation strata and allometric subsampling of dominant species populations should solve some of the problems due to heterogeneity in fynbos communities.

Precision in these data sets is felt adequate for the purposes of this discussion.

Rates of growth

Fig. 5 may be used to indicate means and ranges in the rate of growth of fynbos communities. The data do not cover a full range of fynbos communites: old stands of tall sclerophyllous scrub are hardly represented. Nevertheless, a reasonable picture has emerged. The highest rate was exhibited by the phreatic community at site 2.2—about 4 000 kg per ha per annum during the first two years. In contrast, the heath community in the same locality, at site 2.3, grew at about 1 000 kg per ha per annum during the same period. These values are close to the upper and lower limits of mean annual increment represented by the curves in Fig. 5. A rate of 2 500 kg per ha per annum appears to be a reasonable average.

Growth rates appear to fall off rapidly as communities age.

Sclerophyllous scrub (represented by sites 1.1 to 1.3) would seem to grow about as fast as the phreatic community, although that at Jakkalsrivier (site 3.5) appears subnormal. Heath communties show rates between normal and the minimum.

Fynbos as fuel

Fynbos communities readily sustain a running fire under average summer conditions once they have reached four years of age and may burn at three years under severe fire hazard conditions.

Several communities of about four years old have been sampled. These had biomasses of about 5 000 to 10 000 kg per ha, which may be accepted as reasonable minimum fuel levels for a successful burn. Site 3.4, with about 7 000 kg per ha at four years, sustained a hot fire in a prescribed burn 11 months later.

At four years of age most communities are dominated by graminoid and restioid plants. These are all fine fuel (i.e. with particle diameters less than six millimetres). Furthermore, cured material forms a significant proportion of the fuel after the second or third year when leaves and stems from the first and second growing seasons die, but remain attached and erect for a further one or two seasons. At this stage, therefore, the vegetation provides a fine, porous but reasonably compact fuel bed, much like a grassland fuel. This would explain why they burn readily at this age in spite of the rather small quantities of available fuel.

The rapid rate of growth of a phreatic community like that at site 2.2 does not necessarily imply inflammability at an earlier age. Plant material in such communities is green and does not cure readily in the early stages: in fact, an inflammable stage is often delayed longer than in other communities.

Heaths from Jakkalsrivier have a low biomass (11 000 to 15 000 kg per ha at 16 years), but dead plants and litter can comprise up to a quarter of the total. As a result, and because the communities are dominated by plants with fine leaves and branches, they burn fiercely under dry conditions, and fires are often extremely difficult to control.

The mature sclerophyllous scrub communities at Jonkershoek provide considerably more fuel, but much of this is coarse and available only under extreme fire hazard conditions.

Community structure and development

Most plants in the fynbos sprout after fire (Wicht, 1945; van der Merwe, 1966). The graminoid and restioid plants are almost all of this nature, whereas many shrubs and subshrubs are not. Communities in the early stages are dominated by the former (which comprise about 60 to 75 per cent of the biomass at three to four years) and the vegetation has the physiognomy of a grassland. Since individual shoots and leaves of the hemicryptophytes do not live longer than about two years, and fall after another two years, this component reaches its maximum in about the fourth year. Thereafter woody elements become prominent if conditions are suitable, although herbs persist and maintain their biomass for many years. Communities on moist or wet sites (as at 2.2 and 3.3) have a rather different initial physiognomy, since they frequently contain a high proportion of sprouting shrubs, which reach early prominence in development.

CONCLUSION

Considerable data on growth and biomass of shrub communities in mediterranean type ecosystems have become available recently.

Specht (1969a, 1969b) has compared analogous communities from the southern regions of France, California and Australia. He estimated mean annual increments (M.A.I.) for the first five years after fire, as follows:

	M.A.I. kg per ha
Montpellier	4 200
San Dimas	1 200
Dark Island, S. Australia	640
Southern Victoria	1 500

Maximum biomass reported was about 49 700 kg per ha at 13 years for garrigue, and 49 100 at 37 years for chaparral (of which 21 800 kg consisted of standing dead sticks).

Specht suggests that his data for the garrigue near Montpellier are atypical, and this is confirmed by Long & Thiault (pers. comm.). Data from more typical garrigue indicate a mean annual increment of about 1 400 kg per ha per annum during the first six years, and total biomass of about 15 000 kg per ha at 18 years (Long *et al.*, 1967 in Specht, 1969b; Long & Thiault, pers. comm.). These also show that the garrigue growth curves also resemble the typical cases illustrated by Specht (1969b) and Jones *et al.* (1969).

Aerial biomass of an evergreen chaparral community of unspecified age at Echo Valley, California (mean annual precipitation 450 mm) amounted to 23 000 kg per ha; that of a similar community on a similar site in Chile amounted to about 7 400 kg per ha (Mooney, pers. comm.).

Jones *et al.* (1969) have collated growth data for Australian heath communities. They produced two curves for growth of aerial portions of the communities, one representing the drier and the other the wetter limits of the geographical range of heat in Southern Australia. Growth rates during the first five years amount to about 800 kg per ha per annum in the first instance, and 1 500 kg per ha per annum in the second. Maximum biomass for coastal sites was about 16 000 kg per ha at 18 years (sand heath at Tidal River, Victoria). They caution that: "The growth curves do not necessarily indicate the maximum production of each site. This may be influenced by the development (or invasion) of taller-growing species . . . .". Such cases are reported by Specht *et al.* (1958). Communities dominated by *Banksia ornata* have a biomass of almost 20 000 kg per ha at 15 years of age.

The data for fynbos are similar to those for analogous communities in other areas with mediterranean type climates. The curves in Fig. 5 indicate a minimum rate of growth of about 1 000 kg per ha per annum, and a maximum of 3 400, over the first five years after fire. The most vigorous community is that on the phreatic site (2.2), but the maximum biomass measured is that of a 17-year old sclerophyllous scrub community at Jonkershoek: this is about the same as that of the 18-year old chaparral community sampled by Specht. The mature heath communities at Jakkalsrivier, however, have a lower biomass than all those of equivalent age studied elsewhere except the mallee-broombush (Specht, 1969b), which is not a good fynbos analogue.

On the whole the figures support Specht's conclusion that "The growth rates of these distinctive plant communities, composed of entirely different species, are largely controlled by the major factors—solar radiation and available water. In similar homoclimes essentially the same growth rate results." More information is necessary to explain differences within the data sets, but there is good evidence that soil moisture availability overrides the effect of soil fertility, and that community production is strongly affected by the presence or absence of tall long-lived shrubs, at least in Australia and South Africa.

Data for the biomass of growth-form categories in fynbos stands provide a limited basis for comparisons of community structure. They do indicate that persistent perennial herbs, particularly hemicryptophytes, are a feature which distinguishes fynbos from northern analogues. Chaparral is known for the rich herbaceous annuals which appear after fire, with peak abundance within one to five years, and disappear almost completely thereafter (Sweeney, 1956; Vogl & Schorr, 1972; Mooney & Parsons, 1973; Biswell, 1974). These comprised 75 and 14 per cent respectively of total live biomass in one- and three-year old chaparral sampled by Specht (1969b), but were absent in the nine-year old stand.

The herbaceous flora of the mediterranean maqui and garrigue also respond strongly to fire, but include perennials which persist in old stands in small quantities (Naveh, 1974; Long & Thiault, pers. comm.), though their biomass is never large. The communities studied by Specht were dominated from the start by phanerophytes and chamaephytes: herbs amounted to 30 per cent of total biomass in the first year after fire, of which hemicryptophytes contributed about 500 kg per ha or 10 per cent of total biomass. The hemicryptophytes became insignificant after the sixth year of development, but other herbs persisted. Long & Thiault report that biomass of herbs may often be over 10 per cent of the total in the first year.

In fynbos, herbs contribute up to about 4 500 kg per ha after two growing seasons; as noted, hemicryptophytes dominate communities up to at least four years after burning. Herbs in sixteen-year old heaths have biomasses up to 8 000 kg per ha, with restioid and graminoid plants predominant.

Australian communities are similar in this respect, but the perennial herbaceous component is not as large as in fynbos. Data from a "sand heath" at Frankston, Victoria (Jones & Specht, 1967; Jones, 1968) show that hemicryptophytes (Restionaceae and Cyperaceae) reached a maximum of about 2 100 kg per ha at four years, comprising about 32 per cent of the biomass. At eight years the proportion was 26 per cent. Comparative studies on Wilson's Promontory in the same State (Groves & Specht, 1965) showed that hemicryptophytes in a "wet heath" had twice the mass of those in a " sand heath" (2 000 vs 1 000 kg per ha), but persisted in old (twelve-year) stands in both cases. Specht *et al.* (1958) noted, of Dark Island "sand heath", that certain understorey plants including hemicryptophytes regenerate rapidly after fire and persist for 25 years in the ageing community. Some Restionaceae and Cyperaceae continue to increase as the community develops, but the biomass of the herbaceous elements does not appear to have exceeded about 1 000 kg per ha.

Certain Australian communities of infertile soils, such as the *Gymnoschoenus* hummock sedgelands or "Button-grass plains" and Restionaceous sedgelands of Tasmania (Jackson, 1965; 1972; Paton & Hosking, 1975) and forb heaths of Southern Queensland (Coaldrake, 1961) have a high proportion of perennial hemicryptophytes, and resemble fynbos in this way.

Fynbos and the Australian equivalents therefore have a characteristic persistent herbaceous component, which distinguishes them from analogous shrublands elsewhere, but they differ in that the component is more prominent in the former.

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UITTREKSEL

Bogrondse plantbiomassa van fynbosgemeenskappe is bemonster op verskeie groeiplekke in die suidwestelike Kaapprovinsie.

Biomassa van opstande met 'n ouderdom van ongeveer twee jaar wissel van omtrent 2 200 kg per ha tot 7 500 kg per ha. Volwasse opstande bestaan uit om en by 11 000 tot 15 000 kg per ha in heideveld, en 15 000 tot 26 000 kg per ha in sklerofiele struikgemeenskappe. Die data toon 'n maksimum jaarlikse aanwas van 1 000 tot 4 000 kg per ha in jong opstande, maar groeitempo's neem waarskynlik vinnig af soos gemeenskappe ouer word. Jong opstande word gedomineer deur hemikriptofiete, waarvan die massa ongeveer 2 000 tot 6 000 kg per ha beslaan, d.w.s. 60 tot 75 persent van die biomassa in die opstande van min of meer vier jaar oud. Struike word prominent in ouer opstande alhoewel die hemikriptofiete bly voortbestaan.

Volgens die data is die biomassa, aanwas en vorm van groeikurwes van fynbosgemeenskappe oor die

algemeen dieselfde of gelykstaande aan dié van gelyksoortige plantegroei in ander wêrelddele met 'n mediterreense klimaattipe (garrigue, chaparral). Daar is egter belangrike strukturele verskille. Die analogiese plantegroei van die noordelike hemisfeer bevat nie 'n beduidende deel van hemikriptofiete nie. Alhoewel die Australiese 'heide'-gemeenskappe hierdie eienskap vertoon is die hemikriptofiete nie so prominent as in fynbos nie.

REFERENCES

ACOCKS, J. P. H., 1953. Veld types of South Africa. *Mem. Bot. Surv. S. Afr.* 28.

ADAMSON, R. S., 1931. The plant communities of Table Mountain. II. Life-form dominance and succession. *J. Ecol.* 19: 304–320.

ADAMSON, R. S., 1938. *The vegetation of South Africa.* London: British Empire Vegetation Committee.

BISWELL, H. H., 1974. Effects of fire on chaparral. In T. T. Kozlowski, & C. E. Ahlgren (eds.), *Fire and ecosystems.* New York: Academic Press.

COALDRAKE, J. E., 1961. Ecosystems of the coastal lowlands, southern Queensland. *CSIRO Bull.* 283.

DI CASTRI, F. & MOONEY, H. A., 1973. *Mediterranean type ecosystems.* Berlin: Springer Verlag.

FOSBERG, F. R., 1967. A classification of vegetation for general purposes. In G. F. Peterken (ed.), *A guide to the check sheet for IBP areas.* Oxford: Blackwell.

GROVES, R. H. & SPECHT, R. L., 1965. Growth of heath vegetation. I. Annual growth curves of two heath exosystems in Austrialia. *Aust. J. Bot.* 13: 261–80.

Halls, L. K. & DELL, T. R., 1966. Trial of ranked-set sampling for forage yield. *For. Sci.* 12: 22–26.

HETHERINGTON, T. C., 1967. A quadrat for use in sampling the field layer of understorey vegetation in forest stands. *Comm. For. Rev.* 128: 4–5.

JACKSON, W. D., 1965. Vegetation. In J. L. Davies (ed.), *Atlas of Tasmania.* Hobart: Mercury Press.

Jackson, W. D., 1972. Vegetation of the Central Plateau. In *The Lake Country of Tasmania,* Symp. Roy. Soc. Tasmania.

JONES, R., 1968. Estimating productivity and apparent photosynthesis from differences in consecutive measurements of total living plant parts of an Australian heathland. *Aust. J. Bot.* 16: 589–602.

JONES, R. & SPECHT, R. L., 1967. Productivity studies on heath vegetation in South Australia. A comment on sampling problems. *Folia Geobot. Phytotax. Praha* 2: 337–346.

JONES, R., GROVES R. H. & SPECHT, R. L., 1969. Growth of heath vegetation. III. A reassessment. *Aust. J. Bot.* 17: 309–314.

JOUBERT, G. P. J., 1965. *Die verband tussen opstandsboniteit van* Pinus radiata *en grondeienskappe.* Unpublished M.Sc. thesis, University of Stellenbosch.

KRUGER, F. J., 1972. Unpubl. research report, Jonkershoek Forest Research Station.

KRUGER, F. J., 1974. *The physiography and plant communities of Jakkalsrivier catchment.* Unpublished M.Sc. thesis, University of Stellenbosch.

MOONEY, H. A. & PARSONS, D. J., 1973. Structure and function of the California chaparral—an example from San Dimas. In F. de Castri & H. A. Mooney (eds.), *Mediterranean type ecosystems.* Berlin: Springer Verlag.

MOONEY, H. A., DUNN, E. L., SHROPSHIRE, F. & SONG, L., 1970. Vegetation comparisons between the mediterranean climatic areas of California and Chile. *Flora* 159: 480–496.

NAVEH, Z., 1974. Effects of fire in the Mediterranean region. In T. T. Kozlowski & C. E. Ahlgren (eds.), *Fire and ecosystems.* New York: Academic Press.

PATON, D. F. & HOSKING, W. J., 1975. Wet temperate forests and heaths. In R. M. Moore (ed.), *Australian Grasslands.* Canberra: ANU Press.

PLATHE, D. J. R. & VAN DER ZEL, D. W., 1969. 'n Veldbrandeksperiment op meervoudige opvanggebiede in Jakkalsrivier, Lebanon. *For. in S. Afr.* 10: 63–71.

SPECHT, R. L., 1969a. A comparison of the sclerophyllous vegetation characteristic of the mediterranean type climates in France, California and southern Australia. I. Structure, morphology and succession. *Aust. J. Bot.* 17 :277–92.

SPECHT, R. L., 1969b. A comparison of the sclerophyllous vegetation characteristic of the mediterranean type climates in France, California and southern Australia. II. Dry matter, energy and nutrient accumulation. *Aust. J. Bot.* 17: 293–308.

SPECHT, R. L., RAYSON, P. & JACKMAN, M. E., 1958. Dark Island Heath (Ninety-nine Mile Plain, South Australia). VI. Pyric succession: changes in composition, coverage, dry weight and mineral nutrient status. *Aust. J. Bot.* 6: 59–89.

SWEENEY, J. R., 1956. Responses of vegetation to fire. *Univ. Calif., Berkeley, Publ. Bot.* 28: 143–250.

VAN DER MERWE, P., 1966. Die flora van Swartboskloof, Stellenbosch en die herstel van die soorte na 'n brand. *Annals Univ. Stell.* 414 (14).

VAN DER MERWE, P., 1969. Datering van veldbrande met behulp van *Protea mellifera* Thunb. *Tydskr. Natuurwet.* Des. 1969.

VAN DER ZEL, D. W., 1974. Catchment research at Zachariashoek. *For. in S. Afr.* 15: 23–40.

VOGL, R. J. & SCHORR, P. K., 1972. Fire and manzanita chaparral in the San Jacinto Mountains, California. *Ecology* 53: 1179–1188.

WALTER, H., 1963. Climatic diagrams as a means to comprehend the various climatic types for ecological and agricultural purposes. In A. J. Rutter, & F. N. Whitehead, (eds.), *The water relations of plants.* London: Blackwell.

WICHT, C. L., 1945. *Preservation of the vegetation of the Southwestern Cape.* Cape Town: Roy. Soc. S. Afr. Special Publication.

WICHT, C. L., MEYBURGH, J. C. & BOUSTEAD, P. G., 1969. Rainfall at the Jonkershoek Forest Hydrological Research Station. *Annals. Univ. Stellen.* 44A (1).