TREE-RING CHRONOLOGIES

OF THE

SOUTHERN HEMISPHERE

5. SOUTH AFRICA

V. C. LaMarche, Jr., R. L. Holmes, P. W. Dunwiddie and L. G. Drew

CHRONOLOGY SERIES V LABORATORY OF TREE-RING RESEARCH UNIVERSITY OF ARIZONA TUCSON, ARIZONA 85721 1979

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CHRONOLOGY SERIES V LABORATORY OF TREE-RING RESEARCH UNIVERSITY OF ARIZONA TUCSON, ARIZONA 85721 1979 Volumes in Laboratory of Tree-Ring Research Chronology Series V:

- 1. Argentina
- 2. Chile
- 3. New Zealand
- 4. Australia
- 5. South Africa

PREFACE

This report is one of a series documenting dendrochronological studies in the Southern Hemisphere carried out by the Laboratory of Tree-Ring Research from 1973 to 1979 with the support of the U. S. National Science Foundation. Initial studies in Chile and Argentina in 1973-1974 were part of the International Biological Program, Origin and Structure of Ecosystems project, administered by the San Diego State University Foundation. Subsequent work there, and in Australia, New Zealand and South Africa was supported directly by grant GV 41450, from the Office of Polar Programs, and by grants ATM 75-15495, ATM 76-24267, and ATM-7823008, all from the Climate Dynamics Program, Division of Atmospheric Sciences.

The purpose of these investigations was to develop long, accurately dated, and climatically sensitive tree-ring records and to use them as a basis for inference about past climatic fluctuations. We have collected several thousand tree-ring samples from some 200 sites in temperate latitudes in South America, New Zealand, Australia and southern Africa. We have developed 71 ring-width index chronologies, each incorporating the growth records of a large number of trees. The longest approaches 1000 years in length. In these reports, we present these time series of average annual ring-width indices together with information on the sample size, the location and nature of the sample site, and statistics describing both the site chronology and its component series. Information is also presented on other sample collections where no index chronology was developed.

In order to make our Southern Hemisphere tree-ring records as widely available and as useful as possible, the data have also been entered in the International Tree-Ring Data Bank. Two types of data are available in machine-readable (punched-card or magnetic tape) form. First, we have entered the basic data in the form of all the measured radial ring-width series that were used in development of each site chronology. Second, we have also entered the derived site chronologies themselves, as published in this volume. For information on current holdings, cost, and formats, contact:

> Manager International Tree-Ring Data Bank Laboratory of Tree-Ring Research University of Arizona Tucson, Arizona 85721

Although we had overall responsibility for site selection, sample collection, preparation, dating, ring-width measurement, and for data processing, evaluation and analysis, we received a great deal of help in this effort. Information, logistic and other support, and field assistance were generously provided by individuals, academic institutions and government agencies in each of the countries that we visited. They are acknowledged in the introduction to each volume. Dating of the samples was carried out mainly by R. L. Holmes, P. W. Dunwiddie and B. J. Richards, assisted at times by J. Ambrose, P. Brown, H. L. Fleischauer, V. C. LaMarche, and D. A. Campbell. T. P. Harlan and J. B. Harsha dated the initial Chilean collections. Ring-width measurements and measurement checks were made by those listed above, and by S. D. Morton, B. L. Fine, M. R. Henry, J. B. Heider, P. Houghton and K. A. Black. M. S. Crebbs, M. A. Kempinski and J. G. Miller aided in sample preparation. Computer operations were managed by L. G. Drew, with assistance from D. J. Buecher, R. B. Minton, C. S. Carlson, K. L. Kreutzer, S. L. Ward and others in the Data Processing Section of the Laboratory. M. K. Cleaveland developed some of the computer software that was used, and also helped with processing. Typing of the manuscripts was ably handled by A. K. Allen.



Plate 1. Podocarpus elongatus in rocks, Kliphuis site, Cape Province.

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INTRODUCTION

Background

Southern Africa probably presents greater problems in the application of dendrochronological techniques than any other region in the Southern Hemisphere. A variety of forest and woodland types exist in the moister areas along the coast, ranging from mediterranean scrub woodland and forested patches in the extreme southwest, through mesic temperate forest along the southern coast, to the warm-temperate and subtropical forests along the east coast. The vegetation of the interior ranges from desert to dry scrub or savanna, with a broad belt of tropical woodlands to the Hardwoods of several species offer some possibilities for dendronorth. chronological study (Lilly, 1977). The ring definition may depend on zonation of vessels, changes in tracheid cell diameter, on alternate banding of xylem and parenchyma, or on a combination of these features. Unfortunately, many of these trees apparently do not attain great age, and some are restricted to streamside habitats and show little ring-width variation. In others, there is no assurance that the rings are annual, and this would have to be carefully investigated before attempting treering chronology development. The wood of these angiosperms is anatomically more complex than that of gymnosperms, and new criteria both for dating and for analysis of ring-width variability probably would have to be developed in order to study and interpret past growth fluctuations in climatic terms. Thus, we decided to concentrate our efforts on the study of South Africa's few coniferous species.

The conifers of South Africa include three species of <u>Widdringtonia</u> (a genus in the cypress family, related to Australia's <u>Callitris</u>), four species of <u>Podocarpus</u>, and a juniper. From examination of reconnaissance samples taken in 1976, and from study of wood sample collections, it appeared that <u>Widdringtonia cedarbergensis</u> and <u>Podocarpus elongatus</u>, restricted to southwestern Cape Province, offered the greatest immediate potential for dendrochronological study. However, because of their large size and probable great age (Hall, 1976), both <u>Podocarpus falcatus</u> and <u>P</u>. <u>latifolius</u>, of the mesic forests of southern and eastern Cape Province, were also selected for further study.

Because of time limitations and the very difficult nature of much of the material, we were able to develop only one ring-width index chronology from our South African samples - for <u>Widdringtonia</u> <u>cedarbergensis</u> at a site in the Cedarberg Mountains north of Cape Town. Thus, this volume is intended primarily to document our much more extensive collections from the Cedarberg, and elsewhere in Cape Province.

Sample Collection and Documentation

Most of the tree-ring samples described in this volume are housed at the Laboratory of Tree-Ring Research, and were collected during the period 1976-1978 by members of the Laboratory working in cooperation with South African scientists. The general procedure was to collect increment core samples from several radii of each of a number of trees on a geographically limited and ecologically homogeneous site. In a few cases it was also possible to collect discs (complete or partial transverse sections) from stumps or logs of recently felled trees. Because both Podocarpus and Widdringtonia are protected in South Africa, special precautions were taken. No living Widdringtonia were felled, but discs were cut from logs, stumps, and dead branches. The holes left after coring live trees were sealed with a petroleum-base compound. Similarly, the Podocarpus discs were cut from logs or stumps of trees that had previously been felled for other reasons. An embossed aluminum tag bearing an identification number was attached to most of the trees sampled. A brief site description accompanies the chronology; a description and pertinent collection information are also presented for those sites from which no index chronology was developed. Site location maps (Figures 2a and 2b) are keyed to an Index to Localities (Table 1) by use of a 3-letter site code.

Dating and Chronology Development

Each collection was evaluated, both in the field and upon return to the Laboratory, in terms of its dendrochronological potential. Criteria included clarity of ring structure, circuit uniformity, sensitivity, and the feasibility of cross-dating patterns of wide and narrow rings and of other features between different radii and between different trees in the site. Development of the dating chronology followed standard cross-dating procedures (Stokes and Smiley, 1968). We adopted Schulman's convention of assigning the date of the annual ring to the year in which ring growth begins. The annual rings in all suitable samples from the site were dated; others were rejected because of complacency, short length, poor wood quality, an unusually high frequency of locally absent rings, the presence of pronounced growth surges or suppression or for other reasons. One person normally had responsibility for evaluating and dating all the material from a particular site. The dating was then independently checked by another worker to ensure the accuracy of assignment of each annual ring in each sample to the correct calendar year.

After dating and checking were completed, the ring widths in each dated sample were measured to the nearest 0.01 mm using a Henson (Bannister model) measuring machine in conjunction with a Bausch and Lomb stereoscopic microscope with crosshairs, normally at 15X to 30X magnification. In the case of particularly difficult material measurements were made of the accuracy of ring-width measurements using a test based on the Chi-square statistic. The printed tapes produced by the measuring machine were checked for errors, and the ring widths transferred to punched cards by keypunch operators.

A standard procedure was followed in the processing and evaluation of the data. First, descriptive statistics were calculated for each ring-width series and the series was listed and plotted for visual inspection and an error check, using the Laboratory's RWLST and TRPLT programs. Some series were deleted from the data set at this stage because of poor statistical quality, or because the plots showed evidence of gross non-climatic growth surges or periods of extreme growth suppression.

The remaining ring-width series were then transformed to dimensionless ring-width indices using the Laboratory's program INDXA. The purpose of this transformation is to remove effects of non-climatic growth trends or fluctuations, as well as the effect of differences in average growth rate between different trees (Fritts, 1976). The curve-fitting option for each ring-width series was carefully selected, based on the general appearance of the plotted series, as well as our knowledge of the local site history and general environmental conditions. In a majority of cases, a negative exponential or straight-line curve was fit, although the orthogonal polynomial option was occasionally used with considerable discretion.

Finally, the individual radial ring-width index series were combined by averaging to produce the site chronology, either as part of the INDXA run, or in a subsequent step using the SMSR or SUMAC programs. In addition to the site chronology, which normally includes all the good quality ring-width index series available for a site, we also produced a so-called "statistical" chronology, incorporating a selected sub-set of the available index series.

Descriptive Statistics

Two sets of statistics are presented. These can be very useful in providing a quantitative basis for evaluating the dendroclimatic potential of a tree-ring chronology (Fritts, 1976).

The first set, designated "Sample Statistics", is based on analysis of the data sub-set incorporated in the statistical chronology. Most of the parameters provide measures of the relationships among the component radial ring-width index series, and are calculated for a period common to all the series, using a replicated sample in which, in most cases, at least two radii are available for each tree in the sub-set. The results of the analysis of variance show how the total variance in the chronology is partitioned among potential sources of variation. A high percentage of the variance retained by the mean chronology generally indicates that ring-width fluctuations are very similar in all the radii. However, differences between trees often account for a large percentage of the variance, particularly on more complacent sites or on those that have been disturbed. Other sources of variation may include differences between radius classifications, differences between groups of trees in different areas of the site, and other "unexplained" sources of variation that are not explicitly considered in the analysis. The estimated mean square of Y, as given here, is the estimated population value of the amount of variance in common among all series that is retained in the final chronology, and corresponds to the "Variance Component" used by Fritts in his Table 6.VII (1976, p. 288). The cross-correlation analysis duplicates the analysis of variance results to some extent, but also provides additional insights. The values given are the average linear cross-correlation coefficients between different sets of ring-width index series. The average correlation between radii within trees is always larger than the average correlation among radii from different trees, and reflects the tendency for growth records from individual radii of the same tree to be more similar than records from radii of different trees. Another measure of the similarities or differences between trees is provided by the average correlation between the tree mean chronologies, obtained by averaging the replicated records from the different radii of the same trees, and calculating correlation coefficients.

The second set of data, labelled "Chronology Statistics", describes the properties of the site chronology presented on the facing page. The chronology is identified by a 6-character code. The three letters correspond to the site code given in Table 1 and used in Figure 2. The first two numbers constitute a two-digit species code, and the "9" in the last position of the code follows a Laboratory convention indicating that it is a site chronology, incorporating all available good-quality radial index Three statistics are given that describe time-series properties series. of the chronology (Fritts, 1976). Autocorrelation is the first-order autocorrelation coefficient - a measure of the tendency for high or low index values to persist from one year to the next. The standard deviation of the series is calculated in the usual way, and measures the total amount of variation at all frequencies. The mean sensitivity is a statistic developed for the description of tree-ring series, but corresponds to the mean average first difference. High mean sensitivity indicates that there are large differences in index value from one year to the next. The standard error measures the amount of dispersion of the index values in the sample about the mean value in each year; they are averaged for the entire series to produce the mean standard error given here. In general, the closer the individual values are to the mean value, and the larger the sample size, the smaller the standard error.

Acknowledgments

We are indebted to a number of individuals and organizations for their help, advice, and kind hospitality during our work in South Africa. The assistance of the South African Department of Forestry is greatly appreciated. Dr. H. A. Luckhoff of the Forestry Research Institute in Pretoria gave valuable advice on <u>Widdringtonia</u> localities, and was instrumental in obtaining permission for us to sample on Forestry Department lands. Dr. Kromhout made available his excellent collection of wood samples and photographs, and advised us on potentially useful species. We are especially grateful to Mr. F. J. Kruger, then in charge of the Jonkershoek Forestry Research Station, near Stellenbosch. He was our main contact throughout the project. He shared his extensive knowledge of South African vegetation, made logistic arrangements, helped us to and corresponds to the "Variance Component" used by Fritts in his Table 6.VII (1976, p. 288). The cross-correlation analysis duplicates the analysis of variance results to some extent, but also provides additional insights. The values given are the average linear cross-correlation coefficients between different sets of ring-width index series. The average correlation between radii within trees is always larger than the average correlation among radii from different trees, and reflects the tendency for growth records from individual radii of the same tree to be more similar than records from radii of different trees. Another measure of the similarities or differences between trees is provided by the average correlation between the tree mean chronologies, obtained by averaging the replicated records from the different radii of the same trees, and calculating correlation coefficients.

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establish a number of valuable contacts, and made available laboratory space and technical assistance at his headquarters. He was also responsible for the collections at Groot Koupoort and Chisel Peak, and took the initial samples at Heuningvlei Plantation and at the Die Bos site, which led ultimately to the development of the first tree-ring chronology in southern Africa. Ross Haynes and Alan Lamb, also from Jonkershoek, lent invaluable assistance in several phases of the work, and participated in much of the sampling. Ross also made the bulk specimen collection at the Hoogvertoon site. Alexandra, Lawrence and Glaudine Kruger (and Moose) also aided in the field work. The personnel at Algeria Forestry Research Station were very helpful. We used Algeria as a base camp for our work in the Cedarberg, and thank Chief Forester Van der Merwe and Mr. Pierre Rabe for their help in locating known-age stands in the Algeria Widdringtonia plantation. Mr. Frederick Hanekom greatly assisted our sampling work in the Cedarberg in 1978. The personnel of the Saasveld Forest Research Station, near George, were also very helpful. The Officer in Charge, Mr. P. W. Lange, identified potential sites in the region and arranged transportation. Mr. Johan Manson took us into the sites in the Kayasna Forest and the Kouga Mountains, and his help is greatly appreciated.

Several people at the University of Stellenbosch were very helpful. We especially thank Professor Henne Vermaas of the Faculty of Forestry, for providing shop facilities and laboratory space and equipment during our stay in Stellenbosch. Mr. Jan Swart collaborated with us on a photomicrographic study of South African wood specimens. Dr. Hilary Deacon and Dr. Derek Donald supplied useful information and some wood samples.

We particularly enjoyed our contacts with several of the faculty and students at the University of Cape Town. Professor Nikolaas J. van der Merwe and Mr. J. E. Parkington of the Department of Archaeology, and Professor Richard Fuggle of the School of Environmental Sciences, showed a continuing interest in our work. Professor van der Merwe, with several students, also participated in the initial Cedarberg collecting. Dr. Eugene Moll of the Department of Botany offered useful advice on dendrochronological potential of several South Africa species, and Mr. Bruce Campbell helped us to locate and sample the Skeleton Gorge site on the Cape Peninsula.

The faculty and staff of the Department of Geography and Environmental Studies, University of the Witwatersrand, in Johannesburg, were among our first contacts in South Africa, and have continued to be a source of collaborative support. Professor Peter D. Tyson recognized the potential importance of tree rings for studies of long-term climatic variability in South Africa, and had initiated a program of dendrochronological research prior to our first visit. We are especially grateful for the help of Dr. T. G. J. Dyer and Dr. Jane Gillooly, who were involved in the early phases of this work. Dr. Gillooly and Ms. Mary Anne Lilly arranged a short sampling trip in the northern Transvaal, and Dr. Gillooly participated in the initial sampling trips to the Cedarberg and the south coast. Ms. Lilly also took considerable time to show us their tree-ring sample collections.

We thank Dr. D. M. van Zinderen Bakher and Dr. J. A. Coetzee, of the Institute of Environmental Sciences, University of the Orange Free State, for their hospitality, and for arranging a field excursion in the vicinity of Bloemfontein during our visit. Finally, we express special thanks to Mr. Pierre Kaufmann, who served as field assistant on the final collecting trips to the Cedarberg, the Cape Town area, and along the south coast.



Plate 2. Enlarged view of cross-section of *Podocarpus elongatus* from Geelhoutskloof site showing rings wedging out around circumference. This characteristic makes the species difficult or impossible to date.

TABLE 1. INDEX TO LOCALITIES

Site Code	Site Name	Species Codes	Lat.	Long.	Alti- tude, mts.	Site Chron- ology
ALG	Algeria	WICE	32°22'S	19°03'E	670	
BTJ	Boontjieskloof	POEL	32°10'S	19°05'E		
DIB	Die Bos	WICE	32°23'S	19°12'E		DIB249
DKK	Donkerkloof	POEL	33°45'S	19°03'E		
DPW	Diepwalle	POLA, POFA	33°52'S	23°12'E		
GKA	Groot Koupoort 1	WICE	32°15'S	19°07'E	1250	
GKB	Groot Koupoort 2	WICE	32°15'S	19°07'E		
GPK	Chisel Peak	WICE	32°15'S	19°07'E	1500	
GRT	Grootland	WICE	32°23'S	19°07'E		
GWH	Groot Winterhoek	POEL	32°58'S	19°08'E		
HPL	Heuningvlei Plantation Site	POEL	32°14'S	19°07'E		
HOO	Hoogvertoon	WICE	32°07'S	19°08'E	1250	
ISI	Isidenge	POLA, POFA FADA	32°43'S	27°22'E		
KLE	Jonkershoek	MASP	33°58'S	18°57'E		
KLO	Geelhoutskloof	POEL	32°20'S	19°02'E	480	
KLP	Kliphuis	POEL	32°08'S	19°00'E		
KNY	Knysna	POLA, POFA PTTR, OCBU	33°58'S	23°10'E	350	
кои	Kouga River	WISC	33°39'S	23°35'E	800	
LTG	Lottering	POLA, POFA	33°58'S	23°42'E		
PKH	Pakhuis Pass	WICE	32°08'S	19°03'E	927	
SBK	Swartboskloof	POEL	33°59'S	18°57'E		
SKG	Skeleton Gorge	POLA	33°59'S	18°26'E		
TJA	Tjandokloof	WISC	33°36'S	23°50'E	1200	
TLK	Tontelskloof	WICE, MASP	32°25 'S	19°08'E	1070	

TABLE 2. SPECIES COLLECTED

Species	Alphabetic Species Code	Numerical Species Code	Number of Sites Collected
Fagara davyi	FADA		1
Maytenus sp.	MASP		2
Ocotea bullata	OCBU		1
Podocarpus elongatus	POEL	~	7
Podocarpus falcatus	POFA		4
Podocarpus latifolius	POLA		5
Pterocelastrus tricuspidatus	PTTR		1
Widdringtonia cedarbergensis	WICE	24	9
Widdringtonia schwarzii	WISC		2





 $\boldsymbol{\sigma}$



SITE CHRONOLOGY

Site name DIE BOS Country SOUTH AFRICA State or Province CAPE Latitude 32°24'S Longitude 19°13'E Altitude 1330 m Species collected <u>Widdringtonia cedarbergensis</u> Date of collection 6-7 March 1978 Collectors V.C.LaMarche, P.W.Dunwiddie, A.Lamb, F.Hanekom No. of trees sampled 46 No. of cores 58 No. of discs 25 Site description:

The <u>Widdringtonia</u> stand is one of the largest and least disturbed in the Cedarberg. It is located about 3 km by hiking track, west of the settlement of Langkloofrivier. It can also be reached by trail from Welbedacht Forest Station. The trees grow on talus deposits below high sandstone cliffs on the north side of the canyon. Many are quite large (10 m tall, 80 cm diameter) and most are multiple-stemmed. Some show pronounced strip-bark growth. Discs were cut from dead branches, stumps and logs, and an extensive collection of cores was taken from living trees. This site has yielded the first replicated and accurately cross-dated tree-ring chronology in southern Africa.

SAMPLE STATISTICS

Interval analyzed (A.D.)	1892 - 1976
No. of trees 9 No. of radii per tree 2	
Mean ring width (mm)	1.28
% locally absent rings	0
Analysis of variance:	
Estimated mean square of Y	0.041
Sources of variation, % variance	
Mean chronology	29
Differences between trees	18
Other	53
Cross-correlation analysis:	
Radii within trees	0.48
Radii among trees	0.30
Between tree means	0.31

CHRONOLOGY STATISTICS

Identification		DIB249
Interval (A.D.)		1564 - 1976
No. of trees 32	Total no. of radii 52	
Autocorrelation	0,61	
Standard deviation		0.23
Mean sensitivity		0.15
Mean standard error		0.09

DIB249 DIE BUS WIDDRINGTONIA CEDARBERGENSIS

			TRE	ERIN	G IND	TCES								NUM		06	SAMPL	53			
DATE	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	
						-	0			,	Ŭ	•	e	5	-	,	0	'	e	-	
1564					28	47	33	55	48	40					2	2	2	2	2	2	
1570	62	47	60	84	95	79	86	85	122	90	2	2	2	2	3	3	3	3	3	3	
1580	108	102	117	171	140	112	155	95	115	169	3	3	3	3	3	3	3	3	3	2	
1590	115	76	72	85	75	88	52	38	41	49	3	3	3	3	3	3	3	3	3	3	
1500	110	124	134	91	96	76	76	71	71	65	3	3	4	4	4	4	4	4	4	4	
1510	75	102	99	88	103	108	76	72	93	108	4	4	4	4	4	4	4	4	4	4	
1620	123	96	91	81	79	90	90	94	104	111	4	5	5	5	5	5	5	5	5	5	
1530	116	94	100	93	106	108	99	116	117	121	5	5	5	5	6	6	6	6	6	6	
1540	112	108	94	97	109	136	115	137	138	135	6	6	6	6	6	6	6	6	6	6	
1650	116	97	98	93	89	88	82	99	94	86	7	7	7	7	7	7	7	7	7	7	
1660	85	97	109	110	113	94	98	83	120	152	7	7	7	7	7	8	8	9	9	9	
1670	124	104	126	111	108	71	82	88	98	99	9	9	9	9	9	9	9	9	9	10	
1680	88	96	98	110	107	112	127	1 37	132	147	10	11	11	11	11	11	11	11	11	11	
1690	103	135	97	84	136	115	131	113	117	126	11	11	11	11	11	11	12	12	16	16	
1700	99	111	129	128	102	117	89	105	102	117	18	18	18	18	18	18	19	19	19	19	
1710	108	104	83	99	94	88	78	77	81	81	19	19	20	20	21	21	21	21	21	21	
1720	67	101	119	104	95	72	84	73	76	81	20	20	21	21	21	21	21	22	22	22	
1730	80	67	79	87	102	85	85	104	88	71	22	22	22	22	22	22	22	22	22	22	
1740	65	76	95	97	109	119	94	94	100	104	25	22	22	22	22	22	22	22	22	25	
1750	121	121	134	105	98	79	95	99	98	75	23	23	23	23	23	23	22	22	2?	22	
1760	104	84	97	115	104	81	105	105	124	107	23	23	23	23	23	23	23	23	23	23	
1770	112	110	104	106	111	132	151	1 35	113	99	2.5	24	24	24	24	25	25	25	25	26	
1780	91	91	103	101	108	97	105	215	182	138	26	26	26	26	26	26	25	25	25	25	
1790	127	94	101	87	91	146	93	94	69	89	25	25	25	25	25	25	25	25	25	25	
1800	79	87	88	94	84	99	101	105	103	103	26	26	26	26	26	26	26	26	26	26	
1810	124	110	104	108	107	85	157	97	90	97	25	25	26	27	27	27	27	27	27	27	
1920	78 95	67 103	70	81	85 95	62	73	71	96	76	27	27	27	27	27	27	28	28	<u>8 S</u>	28	
1940	84					103	91	79	92	101	2 P	2.8	28	28	28	28	28	28	28	28	
1940	113	85 102	85	125	85 97	91 82	98 100	93 83	39	105	28	28	28	28	28	28	28	28	29	29	
1860	89	88	96	116	97	92	86	75	99	103	31 32	31	31	31	31	31	31	30	31	32	
1870	92	85	61	76	107	106	110	132	101	124	28	32	32	32	33	33	32	32	31	31	
1880	86	73	115	133	106	115	95	103	110	115	25	20	27	27	24	25	25	25	26	26	
1890	93	92	119	107	110	132	93	117	107	127	33	33	34	34	27	27	27	27	28	28	
1900	152	113	89	95	92	79	101	88	80	99	36	36	36	36	34	34	35	35	36	36	
1910	30	80	90	86	85	138	125	107	129	127	36	33	33	33	33	36	33	33	36	36	
1920	134	101	106	96	101	116	103	94	74	111	33	33	37	33	33	37	33	33	-		
1930	71	109	75	115	115	101	106	99	85	71	33	33	23	33	33	33	33	33	33	33	
1940	33	92	104	117	110	113	112	120	128	139	33	33	33	33	33	33	33	33	33	33	
1950	184	167	131	127	120	123	108	90	59	90	33	32	33	33	33	33	33	33	33	33	
1960	58	68	92	79	76	73	64	73	35	84	33	32	32	32	32	32	32	32	32	32	
1970	86	79	91	89	96	85	145	~		-14	31	31	31	31	31	31	31	56	24		
1.1.0		.,		0.4	70	0)	1.4.1				21	51	21	31	21	21					

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OTHER COLLECTIONS

Site name ALGERIA PLANTATION Country SOUTH AFRICA State or Province CAPE Latitude 32[°]22'S Longitude 19[°]03'E Altitude 670 m Species collected <u>Widdringtonia cedarbergensis</u> Date of collection 18 March 1976 and 2 March 1978 Collectors V.C.LaMarche, J.Gillooly, P.W.Dunwiddie, A.Lamb No. of trees sampled 15 No. of cores 7 No. of discs 22

Site description:

The samples were collected from <u>Widdringtonia</u> cedarbergensis on the north side of Helsekloof on the southeast-facing slope opposite Algeria Forest Research Station. The trees were planted mainly in the period 1906-1914, although reseeding took place on later occasions. Living and dead trees near the southern and western margins of the stand were sampled, and offcuts were made from poles cut in thinning operations about 1971, and stacked at a loading dock. The stand is open, with a sparse ground cover of herbs and grass and small shrubs. The largest trees have reached a maximum height of about 8 m, and a diameter of 30 cm, but most are much smaller. They are generally straight, single-stemmed, with moderate crowns. The slopes are moderately steep (20°), on rocky sandstone soil. The locality is shown on the Wuppertal 1:50,000 sheet (#3219AC).

SITE AND COLLECTION INFORMATION

Site name	BOONTJIES	SKLOOF						
Country	SOUTH AFI	RICA	State o	r Prov	Ince CA	APE		
Latitude	32 ⁰ 06'S	Longitu	de 19°07	7 'E	Altit	ude 45	0 m	
Species col.	lected	Podocarpa	us elong	gatus				
Date of col	lection	23 March	1978					
Collectors	P.W. Dunwi	iddie						
No. of trees	s sampled	13	No. of	cores	21	No. o	f discs	11

Site description:

<u>Podocarpus elongatus</u> are found in sandstone crevices along a small stream near "Boontjieskloof", a farm south of the Clanwilliam-Calvinia road (Pakhuis 1:50,000 sheet, #3219AA). The site is in very rocky, open country about 11 km east of Pakhuis Pass. The species in this area is very shrubby, with many leaders, generally less than 4 m tall. Although the region is quite arid, the protected environments in crevices are most likely more mesic. A few individuals are also found in sand near the stream.

Site name CHISEL PEAK Country SOUTH AFRICA State or Province CAPE Latitude 32°15'S Longitude 19°07'E Altitude 1500 m Species collected Widdringtonia cedarbergensis Date of collection Summer 1977 Collectors F. Kruger No. of trees sampled 3 No. of cores 4 No. of discs 0 Site description:

The site is located on the east slope of Chisel Peak, extending down to the streambed of Kampkloof, about 4 km south of Heuningvlei Forest Station on the east side of the Cedarberg. It

is shown on the Forestry Department 1:50,000 scale map, Noordelike Sederberge.

SITE AND COLLECTION INFORMATION

Site name DIEPWALLE Country SOUTH AFRICA State or Province CAPE Latitude 33°57'S Longitude 23°09'E Altitude 450 m Species collected Podocarpus latifolius, P. falcatus Date of collection 29 March 1978 Collectors P.W.Durwiddie, P.Kaufmann No. of trees sampled 25 No. of cores 2 No. of discs 38

Site description:

Diepwalle State Forest is approximately 20 km north of Knyasna (Oudtshoorn 1:250,000 sheet, #3322). Dense forests of large <u>Podocarpus falcatus</u> and P. <u>latifolius</u> are frequent in this area. Moisture is high, epiphytes common, and undergrowth lush in these coastal forests. Discs were collected from logs or stumps of P. latifolius that had been cut at various times in scattered areas around the forest. Terrain was level to gently rolling, with thick soils. Little data could be obtained on individual trees, since usually only the stump remained, the rest having been removed for lumber. Discs from two individuals of <u>P. falcatus</u> were also collected.

Site name DONKERKLOOF Country SOUTH AFRICA State or Province CAPE Latitude 33°46'S Longitude 19°04E Altitude 790 m Species collected <u>Podocarpus elongatus</u> Date of collection 25 March 1978 Collectors P.W.Durwiddie, P.Kaufmann No. of trees sampled 10 No. of cores 18 No. of discs 0 Site description:

Donkerkloof, a narrow valley in the Klein-Drakensteinberge, crosses the road to Worcester 10 km east of Paarl (Worcester 1:250,000 sheet, #3319). <u>Podocarpus elongatus</u> up to 14 m tall are found near the stream and on the talus slopes along the valley sides. These trees generally share the canopy with other species on the mesic site. They are found on variable slopes, frequently with steeply inclined trunks, and sometimes with roots in the stream. Soils are thin and very rocky.

SITE AND COLLECTION INFORMATION

Site name GEELHOUTSKLOOF Country SOUTH AFRICA State or Province CAPE Latitude 32°20'S Longitude 19°02'E Altitude 480 m Species collected Podocarpus elongatus Date of collection 21 March 1976, 25 May 1977 Collectors V.C.LaMarche, J.Gillooly, F.Kruger No. of trees sampled 5 No. of cores 9 No. of discs 5 Site description:

Small, slow growing <u>Podocar</u>pus grow in dense riparian vegetation in the bouldery stream bottom, near the point where Geelhoutskloof emerges from the mountains, about 5 km northwest of Algeria Forest Research Station. Five trees were cored in 1976, and discs were collected from one stem of each of 2 multiplestemmed trees in 1977. The locality is shown on the 1:50,000 Forestry Department map of the northern Cedarbergs.

Site name GROOT KOUPOORT 1 Country SOUTH AFRICA State or Province CAPE Latitude 32°15'S Longitude 19°07'E Altitude 1250 m Species collected <u>Widdringtonia cedarbergensis</u> Date of collection January, 1977 Collectors F. Kruger No. of trees sampled 290 No. of cores 160 No. of discs 150

Site description:

The site is located on the lower slopes of Koupoortpiek, north of the Jeep track up Groot Koupoort, about 6 km due south of Heuningvlei Forest Station. All samples are from trees killed in a fire in February 1975, and were collected for age structure information. Part of the collection (cores and large cross-sections) are stored at the Laboratory of Tree-Ring Research. The locale is shown on the Department of Forestry 1:50,000 map, "Noordelike Sederberge."

SITE AND COLLECTION INFORMATION

Site name GROOT KOUPOORT 2 Country SOUTH AFRICA State or Province CAPE Latitude 32°15'S Longitude 19°07'E Altitude Species collected Widdringtonia cedarbergensis Date of collection January, 1977 Collectors F. Kruger No. of trees sampled 13 No. of cores 3 No. of discs 14

Site description:

The site is located about 1 km southwest of "Groot Koupoort 1", 6 km due south of Heuningvlei Forest Station, on the lower slopes of Koupoortpiek. The samples are from trees killed by fire in February, 1975, and were collected for age structure information. Part of the collection is stored at the Laboratory of Tree-Ring Research. The locale is shown on the Department of Forestry 1:50,000 map, "Noordelike Sederberge."

Site name GROOTLAND Country SOUTH AFRICA State or Province CAPE Latitude 32[°]23'S Longitude 19[°]07'E Altitude 1340 m Species collected Widdringtonia cedarbergensis Date of collection 3-4 March 1978 Collectors V.C.LaMarche, P.W.Dunwiddie, A.Ladd, F.Hanekom No. of trees sampled 40 No. of cores 41 No. of discs 25 Site description:

The site is 6.5km east of the Algeria Forest Station (see Algeria site) in rough terrain with numerous rock outcrops. Access is by jeep track and hiking trail from Welbedacht Forest Station, 6.5 km southeast of the site.

Widdringtonia cedarbergensis occurs as the only tree in this arid, rocky area, scattered about the outcrops. A great majority are dead snags, apparently killed by frequent fires. The occasional living tree frequently exhibits a contorted strip bark growth form, and is found protected by crevices or cliffs, Shrubby Proteas are the only other common woody plants in the area. Cores were collected from living trees, and discs from dead snags and logs. The latter were often perforated by holes drilled by carpenter bees in the dead wood.

SITE AND COLLECTION INFORMATION

Site name GROOT WINTERHOEK Country SOUTH AFRICA State or Province CAPE Latitude 32°58'S Longitude 19°08'E Altitude 900 m Species collected Podocarpus elongatus Date of collection 24 March 1978 Collectors P.W.Dunwiddie, P.Kaufmann No. of trees sampled 7 No. of cores 15 No. of discs 3

Site description:

The site is located in the Groot Winterhoek mountains southeast of Porterville (Kaapstad SE 35/17½ 1:500,000 sheet). A steep, gravel road climbs up to Dassieklip Pass, and continues across rolling country in the mountains. Trees are almost nonexistent in the exposed, rocky terrain. A few <u>Podocarpus elongatus</u> are found in deep, protected crevices on the rock outcrops, or "koppies." These trees may be quite large, up to 50 cm diameter and 10 m tall, but are difficult to find, since they barely extend above the protective rocks. Aridity, rather than wind, is probably the major factor limiting the distribution.

Site name HEUNINGVLEI PLANTATION Country SOUTH AFRICA State or Province CAPE Latitude 32⁰14'S Longitude 19⁰07'E Altitude 950 m Species collected Widdringtonia cedarbergensis Date of collection 22 March 1978. Summer, 1977. Collectors P.W.Durwiddie, P.Kaufmann, F.Kruger No. of trees sampled 9 No. of cores 8 No. of discs 4

Site description:

The increment cores and 1 cross-section of a limb were collected from native <u>Widdringtonia</u> on the rocky knobs about 2 km south of Heuningvlei Forest Station (Pakhuis 1:50,000 sheet, #3219AA), on the east side of the Cedarberg Mountains. Cross-sections were also taken from 3 trees in the plantation, which was established in the late 1800's.

SITE AND COLLECTION INFORMATION

Site name HOOGVERTOON Country SOUTH AFRICA State or Province CAPE Latitude 32°07'S Longitude 19°08'E Altitude 1250 m Species collected <u>Widdringtonia</u> sp. Date of collection 20 March 1976. Summer, 1977. Collectors V.C.LaMarche, J.Gillooly, R.Haynes No. of trees sampled 34 No. of cores 24 No. of discs 16

Site description:

An extensive stand of <u>Widdringtonia</u> occupies the sandstone ridges near the crest of the Sneeuberge, south of the track leading up the Sederhoutkloof to Sneeuberge Hut about 25 km southeast of Algeria Forest Station. Slopes are steep and rocky, and associated vegetation is sparse. Increment cores were taken from 8 living trees in 1976; in 1977, 16 cross-sections and 10 cores were taken from 26 dead saplings and trees that had been killed in a 1975 fire. The locality is shown on the Wuppertal 1:50,000 sheet (#3219AC).

Site name ISIDENGE Country SOUTH AFRICA State or Province CAPE Latitude 32°41'S Longitude 27°17'E Altitude 950 m Species collected <u>Podocarpus latifolius</u>, <u>P. falcatus</u> Date of collection <u>3 April 1978</u> Collectors <u>P.W.Dunwiddie</u>, <u>P.Kaufmann</u> No. of trees sampled <u>27</u> No. of cores 0 No. of discs <u>29</u>

Site description:

Isidenge Forest Station is located about 10 km west of the main road between King William's Town and Stutterheim (King William's Town 1:250,000 sheet, #3226). Forests of <u>Podocarpus latifolius</u> and <u>P. falcatus</u> are preserved in the area, interspersed with blocks of exotic pines. Cutting of both <u>Podocarpus</u> species since 1977 provided numerous stumps for sampling. Twenty-nine discs of <u>P. latifolius</u>, and 5 discs of <u>P. falcatus</u> were collected from a pile of cut logs, and from stumps just below a pine plantation that was recently felled. The latter were growing on a 25°, south-facing slope in moderately dense virgin forest. Soils are moist and welldeveloped.

SITE AND COLLECTION INFORMATION

Site name Country Latitude	JONKERSHOEK SOUTH AFRICA State or Province CAPE 33 58'S Longitude 18 57'E Altitude	
Species coll	lected various native and exotic species	
Collectors	lection 26 March 1976 V.C.LaMarche, F.Kruger	
No. of trees	s sampled θ No. of cores θ No. of discs θ	
Site descrip	ption:	

Exploratory collections were made along the loop road in the valley of the Eerstrivier above Jonkershoek Forestry Research Station. Species sampled included native <u>Maytenus</u> (<u>M. oleo</u>ides and <u>M. acuminatus</u>) as well as exotic <u>Quercus alba</u> (?) and <u>Pinus radiata</u>. The locality is shown on the Cape Town 1:250,000 sheet (#3318).

Site name KLIPHUIS Country SOUTH AFRICA State or Province CAPE Latitude 32°08'S Longitude 19°00'E Altitude 700 m Species collected <u>Podocarpus elongatus</u> Date of collection 19 March 1976 Collectors V.C.LaMarche, J.Gillooly No. of trees sampled 7 No. of cores 9 No. of discs 0

Site description:

Podocarps were sampled at 2 subsites in the northern Cedarberg. The first is about 1 km west of Kliphuis, near the Calvinia-Clanwilliam road. The trees grow among very large quartzite boulders as well as in sandy alluvium near the stream. The other subsite is east of the track, about 2 km south of Pakhuispass, where the trees also grow among boulders at the base of a quartzite kopje. The localities are shown on the Clanwilliam 1:250,000 sheet as well as the South African Forestry Department 1:50,000 Northern Cedarberg sheet.

SITE AND COLLECTION INFORMATION

Site name KNYASNA Country SOUTH AFRICA State or Province CAPE Latitude 33°58'S Longitude 23°10'E Altitude 350 m Species collected various Date of collection 23 March 1976 Collectors V.C.LaMarche, J.Gillooly, J.Manson No. of trees sampled 9 No. of cores 16 No. of discs 0

Site description:

The main collection site is about 15 km north of Knyasna, near the Uniondale road, in a temperate forest. Cores were taken from 4 Podocarpus latifolius, a Pterocelastrus tricuspidatus, an <u>Ocotea bullata</u>, and 2 Podocarpus falcatus. The trees grow in deep soil on a gentle slope with dense understory and groundcover vegetation. The podocarps are fairly large, up to 60 cm in diameter and about 30 m in height. A core was also taken from a large <u>P</u>. falcatus near Diepwalle campground, about 4 km to the north. More extensive collections in this area were made in 1978 (see Diepwalle site). The localities are shown on the Oudtshoorn 1:250,000 sheet (#3322).

Site name KOUGA RIVER Country SOUTH AFRICA State or Province CAPE Latitude 33[°]39'S Longitude 23[°]50'E Altitude 800 m Species collected <u>Widdringtonia schwarzii</u> Date of collection 24 March 1976 Collectors V.C.LaMarche, J.Gillooly, J.Manson No. of trees sampled 12 No. of cores 21 No. of discs 0

Site description:

The locality is about 15 km north of the Joubertina-Uniondale highway along the track following the canyon of the Kouga River. The area supports a dense, shrubby vegetation, with <u>Widdringtonia</u> occurring as isolated individuals on rocky outcrops and in the sandstone cliffs. Most of the trees sampled grow above and just to the north of a 150 m-high overhanging cliff with a rock shelter at its base. The trees are predominantly single stemmed, and are heavily branched from near ground level. They attain heights of about 10 m and diameter of up to 70 cm; some show extensive cambial dieback. The locality is shown on the Oudtshoorn 1:250,000 sheet (#3322).

SITE AND COLLECTION INFORMATION

Site name	LOTTERING						
Country	SOUTH AFI	RICA	State or Pro	vind	ce CAPE		
			tude 23 ⁰ 45 'E			275 m	
			pus latifolius,	P_{\bullet}	falcatus		
Date of co	llection	4 April	1978				
Collectors	P.W. Dunw	iddie					
No. of tree	es sampled	8	No. of cores	0	No.	of discs	9
Site descr	iption:						

The main coastal highway passes through mature, moist forests of <u>Podocarpus</u> and other native species. Ten kilometers west of Storms River is Lottering Forest Reserve, which includes several stands of this genus (Oudtshoorn 1:250,000 sheet, #3322). Both <u>Podocarpus latifolius</u> and <u>P. falcatus</u> are frequent here, the latter reaching diameters over 1.5 m, with many epiphytic lichens and mosses. Discs were collected from stumps and cut logs felled within the last year. Three discs of <u>P. falcatus</u> were also collected.

Site name PAKHUIS PASS Country SOUTH AFRICA State or Province CAPE Latitude 32°08'S Longitude 19°03'E Altitude 950 m Species collected <u>Widdringtonia cedarbergensis</u> Date of collection 21 March 1978 Collectors P.W.Dunwiddie, P.Kaufmann No. of trees sampled 9 No. of cores 4 No. of discs 6

Site description:

A few Widdringtonia cedarbergensis are found at the top of the bluffs near Pakhuis Pass, 16 km east of Clanwillian (Pakhuis 1:50,000 sheet, #3219AA). The trees are located at the south edge of the bluffs, north and east of the pass in an area known as "Rheeboksvlei Extension," and west of a draw known as "Groenpoort." These were reported to be the northernmost individuals of this species. The site is exposed and very dry, with very little soil present on the extensive bedrock. Cores were taken from the only two living trees found. Discs were collected from 7 other dead trees. A few Proteas Aloes, and xerophytic herbs are the only other plants in the area.

SITE AND COLLECTION INFORMATION

Site name SKELETON GORGE Country SOUTH AFRICA State or Province CAPE Latitude 33°59'S Longitude 18°26'E Altitude 175 m Species collected <u>Podocarpus latifolius</u> Date of collection 13 March 1978 Collectors V.C.LaMarche, P.W.Dunwiddie, B.Campbell No. of trees sampled 3 No. of cores 5 No. of discs 0

Site description:

Podocarpus is scattered among broad-leaved trees, with a sparse ground cover, on shallow rocky soil in a small patch of indigeneous forest above Kirstenbosch Botanical Gardens on the east side of the Cape Peninsula. The trees are of moderate to large size, reaching about 70 cm in diameter and perhaps 20 m in height. The locality is shown on the Cape Town 1:250,000 sheet (#3318).

Site name SWARTBOSCHKLOOF Country SOUTH AFRICA State or Province CAPE Latitude 33°59'S Longitude 18°57'E Altitude 600 m Species collected Podocarpus elongatus Date of collection 11 March 1978 Collectors V.C.LaMarche, P.W.Durwiddie, A.Lamb No. of trees sampled 7 No. of cores 13 No. of discs 0

Site description:

The site is located on the west slope of the valley of the Eerstrivier, above Jonkershoek. In the Swartboschkloof Nature Reserve, along the trail leading to the Triplets, <u>Podocarpus</u> grows on blocky sandstone talus and in the rocky, dry steambed. Trees in the streambed are fairly large, up to 6 m tall and 30 cm in diameter. Those on the slopes are smaller, but all are multiple-stemmed, with large prostrate branches beginning just above ground level. The locality is shown on the Cape Town 1:250,000 sheet (#3318).

SITE AND COLLECTION INFORMATION

Site name TJANDOKLOOF Country SOUTH AFRICA State or Province CAPE Latitude 33°37'S Longitude 23°50'E Altitude 1200 m Species collected <u>Widdringtonia schwarzii</u> Date of collection 25 March 1976 Collectors V.C.LaMarche, J.Gillooly, J. Manson No. of trees sampled 5 No. of cores 6 No. of discs 1

Site description:

The site is in the upper reaches of Tjandokloof on the north side of the Kouga Mountains about 10 km by track south of Verlorerivier. Scattered <u>Widdringtonia</u> grow on the steep, west facing talus and on the cliffs above. The trees on the talus are reportedly among the largest known Willomore cedars (about 13 m tall and 100 cm diameter). Cores were collected from 5 trees, and a cross-section was taken from a small burned log on the upper part of the talus. The locality is shown on the Oudtshoorn 1:250,000 sheet (#3322).

Site name TONTELSKLOOF Country SOUTH AFRICA State or Province CAPE Latitude 32°25'S Longitude 19°08'E Altitude 1070 m Species collected Widdringtonia cedarbergensis Date of collection 18 and 20 March 1976 Collectors V.C.LaMarche, J.Gillooly No. of trees sampled 5 No. of cores 13 No. of discs 1

Site description:

The site is on the southwest side of the Driehoeksrivier valley, about 10 km southeast of Algeria Forest Station. Several living trees were cored, which grow on a steep north-trending ridge just east of the mouth of the kloof. The area was reportedly burned on 16 December, 1975, and many trees were scarred or killed. A section was also cut from a log remaining from a tree previously cut, which had grown on a rock outcrop on the opposite side of the kloof where no <u>Widdringtonia</u> grow today. The locality is shown on the Forestry Department 1:50,000 scale map of the Southern Cedarberg and the Wuppertal 1:50,000 sheet (#3219AC).



Plate 3. Widdringtonia cedarbergensis, Cedarburg Mountains, Cape Province.

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