MONITORING PLANT DIVERSITY: SIMPSON'S INDEX AND SPECIES RICHNESS ASSESSMENT

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1.0 INTRODUCTION

There appears to be increasing public perception that forest management practices, such as clearcut harvesting, negatively impact ecosystems as compared to natural disturbance events (i.e. fire). Use of diversity indices allow objective assessment of whether ecosystems are adversely affected by various management practices such as herbicide use, thinning, season of harvest, etc. Forest management practices may indeed impact site and the use of diversity indices can help identify negative and positive trends for plant diversity.

Canfor currently uses the Shannon-Weiner plant diversity index as an indicator of plant diversity for their Sustainable Forest Management Plan (SFMP) (Wade, 2002). The Shannon-Wiener Index was selected as the first of several diversity indices to assess vascular plant diversity across the Prince George Timber Supply Area (PG TSA). The index provides objective data to assess various forest management practices in the PG TSA.

The Shannon-Wiener index for a plant community is derived using the following equation:

$$\mathbf{H} = - \sum_{i=1}^{s} (p_i)(\ln p_i)$$

where:

H = index of species diversity
S = number of species
p_i = proportion of total sample belonging to the ith species
ln = natural log[1]

Due to its logarithmic nature, the Shannon-Wiener Index is sensitive to uncommon plant species and less sensitive to very common species (Krebs, 1989). More value is given to the presence of each species than is given to the abundance of each species.

In operational trials, it is more effective and scientifically accepted to use a combination of indices or measures to assess plant diversity (Reich *et al*, 2001; Sullivan *et al*, 1998). Each index is used to identify particular trends in plant diversity that the Shannon-Wiener index may not reveal.

Simpson's index and **species richness** are commonly used to evaluate different trends in plant diversity (Reich *et al*, 2001). Simpson's index is not logarithmic in nature and therefore is more sensitive to shifts in dominant plant species. In essence, equal value is given to the presence of any species, allowing the abundance of those species to increase the diversity value for a given plant community.

[1] Any base of logarithms can be used for this index, as they are convertible to one another by a constant multiplier (Krebs, 1989).

Simpson's index is calculated as follows:

$$SI = \sum_{i=1}^{s} p_i^2$$

where:

SI = Simpson's index of species diversity
S = number of species
p_i = proportion of total sample belonging to the ith species

The Simpson's index values range between 0 and 1. The closer to 0 the value is, the more diverse the plot is. A plot with only one species would have a Simpson's index value of 1.0. Trends are opposite to those found for Shannon-Wiener values since Simpson's Index values decrease with increased diversity.

Species richness (S) is simply a count of the number of plant species present in a sample plot. When used in combination with diversity indices, a species richness assessment can reveal other trends in plant diversity that the more complex indices may not reveal. At certain points in seral development, it is possible for the Simpson's and Shannon-Wiener indices to decrease while the species richness increases i.e. plant communities transitional between seral stages can result in a more diverse assemblage of species, captured only by the richness measure (Reich *et al*, 2001).

The objectives of this project are:

- to evaluate the effects of forest harvesting on vascular plant diversity in the PG TSA, using the Simpson's Index and species richness counts;
- to compare the results with existing Shannon-Wiener index calculations; and
- to develop and document a standard protocol for yearly assessments of plant diversity using the Simpson's index, species richness counts, and the Shannon-Wiener index.

2.0 INDEX CALCULATIONS

2.1 Data Sources and Assembly

There were two main database sources for this project. The NIVMA TRENDS 2002 SNAPSHOT ALL 20030224 database provided the vegetation data for managed stands. The BC Ministry of Forests ecosystem databases provided vegetation data for naturally regenerating stands.

A previous Timberline report Monitoring Plant Diversity for Certification Initiatives (Bernier and Smyth, 2002) described the selection of ten grouped site associations for monitoring across the PG TSA, identified NIVMA TRENDS plots to provide managed stand data and identified natural stands plot data that were adequate for providing baseline data. The reader is encouraged to read this previous report for effective interpretation of this current document. Appendix 1 provides the Biogeoclimatic unit to grouped site association key.

A comparison was made between the 2001 TRENDS database used in Timberline's report and the new TRENDS 2002 database to ensure all original plots were available and to add any new NIVMA plots

established that could be used for monitoring. All of the original 2001 plots were found in the 2002 database, and several new plots were also identified as being of the appropriate grouped site association for monitoring on the PG TSA.

Six of the 2001 plots were subsequently dropped from this project when it was determined that they had been established within TFL 30, which is not part of Canfor's PG TSA planning areas and therefore deemed ineligible for monitoring purposes. A total of 110 NIVMA plots are now considered appropriate for plant diversity monitoring, up from 97 in 2001-2002. Four additional natural regeneration plots were identified in 2003 when compared to the previous Timberline report, increasing the total of natural regeneration plots to 12. A breakdown of NIVMA plots and natural regeneration plots by grouped site association is provided in Table 1.

Table 1 Number of NIVMA TRENDS and Natural Regeneration Plots By Grouped Site Association for the PG TSA

Harvest Area Rank	GROUPED SITE ASSOCIATION	NIVMA Plots	Natural Regeneration Plots
1	Sxw - Huckleberry	14	4
2	Sxw - Devil's club	16	0
3	Sxw - Oak fern	25	0
4	SxwFd - dry	7	2
5	PlSb - Feathermoss	7	0
6	Bl - Rhododendron	7	3
7	Sxw - Horsetail	3	2
8	Bl - Oak fern	7	0
9	Sxw - Twinberry	11	1
10	SxwFd - wet	13	0
Totals		**110**	**12**

2.2 MSAccess-based Calculation Tool

A primary objective of this project was the development of a tool to calculate measures of plant diversity based on NIVMA TRENDS data that could be easily applied each year when the updated version of NIVMA TRENDS data became available. The tool has been provided digitally to Canfor and Appendix 2 provides a user manual for future application of the MSAccess tool.

The MSAccess tool was designed to calculate the three plant diversity index values for all plots in a standard NIVMA TRENDS database. Multiple queries were also provided to assist Canfor in summarizing required data for plots found within its planning areas of the PG TSA, as well as within Tree Farm Licence 30 (TFL 30). A separate report has been provided to Canfor that summarizes all plant diversity monitoring efforts to date on TFL 30 (Timberline, 2003). The tool can be readily modified to calculate the three diversity index values for any plot with data in the MSAccess database format.

2.3 Plant Diversity Calculation Results

Plant Diversity calculations were undertaken for all NIVMA TRENDS plots and natural regeneration plots, using the MSAccess tool. Results for each NIVMA TRENDS plot are presented in Table 2 and the natural regeneration plot index values are presented in Table 3. The values presented for the NIVMA TRENDS plots are for the most recent measurement only. This provides an effective summary of the

existing plant diversity status on the landbase. Previous methods (per Bernier and Smyth, 2002; Wade, 2002) used an average of all measurements over time for each plot. While the averaging method reduces uncertainty about individual plot measurements, it does not provide an effective means of monitoring the existing condition. Table 4 provides the mean diversity index values for the most recent measurements of all NIVMA TRENDS plots in a grouped site association.

Table 2 Plant Diversity Index Values for all NIVMA TRENDS Plots Monitored in the PG TSA

GROUPED SITE ASSOCIATION	TM	CP	BLK	INS	Harvest Year	Year Measured	Shannon-Wiener Index	Simpson's Index	Species Richness
Bl - Oak fern	FJ3745	745	155	1	2002	2002	3.219	0.056	37
Bl - Oak fern	FJ3745	745	125	1	1999	2002	3.052	0.077	44
Bl - Oak fern	EJ4207	207	1	1	1997	2002	2.604	0.156	32
Bl - Oak fern	FJ3655	655	61	1	1997	2002	2.985	0.091	44
Bl - Oak fern	EJ3704	704	1	1	1999	2001	2.695	0.132	29
Bl - Oak fern	EJ3136	136	6	1	-	1999	-	-	-
Bl - Oak fern	EJ4208	208	1	1	-	1997	-	-	-
Bl - Rhododendron	EJ3953	953	11	1	-	2002	-	-	-
Bl - Rhododendron	FJ3433	433	1	1	2001	2002	3.366	0.052	41
Bl - Rhododendron	FJ3130	130	146	1	2000	2002	3.045	0.060	27
Bl - Rhododendron	FJ3488	488	94	1	1998	2002	2.440	0.203	30
Bl - Rhododendron	EJ4931	931	1	1	1997	2002	2.561	0.155	35
Bl - Rhododendron	FH3528	528	2	1	-	2001	-	-	-
Bl - Rhododendron	FJ3097	97	39	1	-	1999	-	-	-
PlSb - Feathermoss	FJ3U14	U14	31	2	-	2002	-	-	-
PlSb - Feathermoss	FJ3328	328	3	1	1999	2002	3.383	0.074	59
PlSb - Feathermoss	EJ3975	975	5	1	1997	2002	2.342	0.184	34
PlSb - Feathermoss	FJ3577	577	2	1	1999	2001	3.748	0.034	56
PlSb - Feathermoss	EJ4406	406	1	1	1996	2001	2.633	0.171	38
PlSb - Feathermoss	EJ4910	910	1	1	1996	2001	2.923	0.107	46
PlSb - Feathermoss	FJ3577	577	1	1	-	1997	-	-	-
Sxw - Devil's club	EJ370I	70I	1	1	-	2002	-	-	-
Sxw - Devil's club	EJ370L	70L	1	1	-	2002	-	-	-
Sxw - Devil's club	EJ3133	133	1	1	-	2002	-	-	-
Sxw - Devil's club	EJ370D	70D	1	1	-	2002	-	-	-
Sxw - Devil's club	EJ3942	942	1	1	-	2002	-	-	-
Sxw - Devil's club	FJ3731	731	3	1	2000	2002	3.285	0.055	50
Sxw - Devil's club	FJ3636	636	93	1	1997	2002	2.743	0.144	43
Sxw - Devil's club	FD7058	58	3	1	1994	2002	3.433	0.056	57
Sxw - Devil's club	FD7058	58	3	2	1994	2002	3.354	0.062	54
Sxw - Devil's club	FD7015	15	1	1	1993	2002	2.927	0.121	54
Sxw - Devil's club	EJ3701	701	1	1	1998	2001	3.116	0.079	45
Sxw - Devil's club	EJ3057	57	2	1	1997	2001	3.098	0.062	35
Sxw - Devil's club	EJ4707	707	4	1	1993	2001	2.891	0.087	42
Sxw - Devil's club	EJ4707	707	4	2	1993	2001	3.069	0.066	39
Sxw - Devil's club	EJ3099	99	4	1	-	2000	-	-	-
Sxw - Devil's club	EJ3105	105	1	1	1996	2000	3.296	0.063	47
Sxw - Horsetail	FJ3680	680	9	2	1999	2002	3.306	0.070	57
Sxw - Horsetail	FJ3319	319	6	1	1998	2002	2.588	0.186	54
Sxw - Horsetail	FD7015	15	1	2	1993	2002	2.366	0.194	37

GROUPED SITE ASSOCIATION	TM	CP	BLK	INS	Harvest Year	Year Measured	Shannon-Wiener Index	Simpson's Index	Species Richness
Sxw - Huckleberry	EJ3918	918	4	1	-	2002	-	-	-
Sxw - Huckleberry	FJ3338	338	237	1	2001	2002	3.607	0.028	40
Sxw - Huckleberry	EJ3844	844	1	1	2000	2002	3.478	0.045	56
Sxw - Huckleberry	FJ3467	467	310	1	2000	2002	3.132	0.046	25
Sxw - Huckleberry	FJ3681	681	265	1	2000	2002	3.390	0.063	55
Sxw - Huckleberry	EJ3800	800	1	1	1999	2002	3.285	0.068	57
Sxw - Huckleberry	FJ3662	662	147A	1	1999	2002	3.208	0.070	53
Sxw - Huckleberry	FJ3300	300	84	1	1999	2002	3.200	0.060	46
Sxw - Huckleberry	FJ3306	306	65	1	1997	2002	3.719	0.044	63
Sxw - Huckleberry	EJ4621	621	1	1	1996	2002	3.534	0.041	59
Sxw - Huckleberry	FJ3C16	C16	503	1	-	2001	-	-	-
Sxw - Huckleberry	FJ3029	29	55	1	-	1999	-	-	-
Sxw - Huckleberry	FJ3124	124	285A	1	1999	1999	2.422	0.167	27
Sxw - Huckleberry	FJ3029	29	36	1	-	1998	-	-	-
Sxw - Oak fern	EJ3975	975	6	1	-	2002	2.907	0.085	28
Sxw - Oak fern	EJ3942	942	1	3	-	2002	-	-	-
Sxw - Oak fern	EJ3942	942	1	2	-	2002	-	-	-
Sxw - Oak fern	FJ3C20	C20	515	1	-	2002	-	-	-
Sxw - Oak fern	FJ3U15	U15	27	1	-	2002	-	-	-
Sxw - Oak fern	FJ3X08	X08	117	1	-	2002	-	-	-
Sxw - Oak fern	EJ3984	984	1	1	1999	2002	2.804	0.106	34
Sxw - Oak fern	FJ3439	439	267	1	1999	2002	2.890	0.100	42
Sxw - Oak fern	FJ3333	333	8	1	1998	2002	3.102	0.093	51
Sxw - Oak fern	FJ3654	654	24	1	1998	2002	2.821	0.107	34
Sxw - Oak fern	EJ4628	628	1	1	1997	2002	3.367	0.053	54
Sxw - Oak fern	EJ4811	811	2	1	1997	2002	2.861	0.091	29
Sxw - Oak fern	FJ3750	750	127	1	1996	2002	3.671	0.034	52
Sxw - Oak fern	FH3525	525	3	1	1996	2002	2.351	0.206	42
Sxw - Oak fern	FD7060	60	10	1	1994	2002	3.599	0.047	56
Sxw - Oak fern	FD7060	60	8	1	1993	2002	2.896	0.125	50
Sxw - Oak fern	FD7060	60	8	2	1993	2002	3.012	0.146	51
Sxw - Oak fern	EJ3B03	B03	5	1	-	2001	-	-	-
Sxw - Oak fern	EJ3048	48	1	1	1996	2001	3.277	0.063	56
Sxw - Oak fern	EJ4707	707	1	2	1993	2001	3.033	0.089	45
Sxw - Oak fern	EJ3040	40	1	1	1994	2000	3.640	0.036	52
Sxw - Oak fern	EJ3952	952	2	1	1995	1999	2.726	0.126	44
Sxw - Oak fern	FJ3257	257	105	1	-	1997	-	-	-
Sxw - Oak fern	EJ370B	70B	1	1	2001	1997	-	-	-
Sxw - Oak fern	EJ3947	947	1	1	-	1996	-	-	-

GROUPED SITE ASSOCIATION	TM	CP	BLK	INS	Harvest Year	Year Measured	Shannon-Wiener Index	Simpson's Index	Species Richness
Sxw - Twinberry	EJ3941	941	5	1	-	2002	-	-	-
Sxw - Twinberry	FJ3680	680	9	1	1999	2002	3.702	0.036	61
Sxw - Twinberry	EJ4922	922	2	1	1997	2002	2.645	0.143	41
Sxw - Twinberry	FJ3091	91	53	1	1997	2002	3.294	0.074	63
Sxw - Twinberry	FD7057	57	2	3	1994	2002	2.999	0.086	56
Sxw - Twinberry	FD7057	57	2	4	1994	2002	2.986	0.091	55
Sxw - Twinberry	FD7060	60	10	2	1994	2002	3.214	0.072	51
Sxw - Twinberry	FD7060	60	11	2	1993	2002	2.882	0.135	53
Sxw - Twinberry	FD7060	60	11	1	1993	2002	3.231	0.086	50
Sxw - Twinberry	EJ3B03	B03	4	1	-	2001	-	-	-
Sxw - Twinberry	EJ4939	939	1	1	-	1997	-	-	-
SxwFd - dry	EJ4528	528	1	1	2000	2002	3.550	0.039	47
SxwFd - dry	EJ3039	39	2	1	2000	2002	3.177	0.089	60
SxwFd - dry	FJ3094	94	54	1	1999	2002	3.725	0.036	63
SxwFd - dry	FJ3307	307	81	1	1998	2002	3.105	0.106	57
SxwFd - dry	EJ4554	554	1	1	1996	2002	2.903	0.142	48
SxwFd - dry	FJ3566	566	2	1	1997	2001	2.971	0.114	43
SxwFd - dry	EJ4551	551	1	1	-	1999	-	-	-
SxwFd - wet	FJ3628	628	4	1	1999	2002	1.788	0.315	23
SxwFd - wet	FJ3044	44	43	1	1999	2002	2.473	0.218	44
SxwFd - wet	EJ4809	809	3	1	1998	2002	2.559	0.141	33
SxwFd - wet	FJ3015	15	41	1	1998	2002	3.154	0.122	74
SxwFd - wet	EJ3975	975	3	1	1997	2002	2.440	0.128	29
SxwFd - wet	EJ3960	960	5	1	1996	2002	3.216	0.049	30
SxwFd - wet	EJ3047	47	1	1	1996	2002	3.403	0.060	60
SxwFd - wet	EJ3981	981	1	1	1996	2002	2.617	0.102	22
SxwFd - wet	EJ3940	940	2	1	1998	2001	2.415	0.259	37
SxwFd - wet	FH3534	534	1	1	1997	2001	2.156	0.200	21
SxwFd - wet	FJ3442	442	181	1	1996	2001	3.544	0.039	45
SxwFd - wet	EJ3952	952	2	2	1995	1999	2.719	0.099	37
SxwFd - wet	EJ3930	930	3	1	-	1996	-	-	-

Table 3 Plant Diversity Index Values for Natural Regeneration Plots in the PG TSA

PlotNumber	Grouped Site Association	Shannon-Wiener	SIMPSONS	RICHNESS
9629701	Bl - Rhododendron	1.523	0.303	25
9801837	Bl - Rhododendron	2.192	0.143	28
9801841	Bl - Rhododendron	1.763	0.247	16
9624792	Sxw - Horsetail	1.663	0.308	32
MOGR30	Sxw - Horsetail	2.014	0.176	11
MOJD19	Sxw - Huckleberry	2.007	0.153	9
Mor9412	Sxw - Huckleberry	2.247	0.121	41
Mor9419	Sxw - Huckleberry	2.079	0.164	35
Mor942	Sxw - Huckleberry	2.451	0.113	48
Mor9418	Sxw - Twinberry	2.467	0.111	45
9625424	SxwFd - Dry	2.062	0.200	27
9626611	SxwFd - Dry	2.458	0.128	41

Table 4 Plant Diversity Index Means, by Grouped Site Associations of Most Recent NIVMA TRENDS Plot Measurements in the PG TSA

Grouped Site Association	Mean Shannon Wiener Index	Mean Simpson's Index	Mean Species Richness
Bl - Oak fern	2.911	0.102	37
Bl - Rhododendron	2.853	0.118	33
PlSb - Feathermoss	3.006	0.114	47
Sxw - Devil's club	3.121	0.080	47
Sxw - Horsetail	2.753	0.150	49
Sxw - Huckleberry	3.297	0.063	48
Sxw - Oak fern	3.060	0.094	45
Sxw - Twinberry	3.119	0.090	54
SxwFd - dry	3.238	0.088	53
SxwFd - wet	2.707	0.144	38

2.4 Expanded Plant Diversity Targets for Managed Stands

Canfor's 2002 PG TSA SFMP presented tentative targets for plant diversity on managed stands, based solely on the Shannon-Wiener index. The new diversity index values calculated for natural regeneration stands were used to set some additional tentative targets for managed stands in order to compare the effectiveness of each index. Table 5 presents tentative targets for all three diversity measures for the ten grouped site associations being monitored by Canfor in the PG TSA. Targets are listed as To Be Determined (TBD) if there are less than two natural regeneration plots available, or if the quality of the data in the natural regeneration plots is suspect.

Table 5 Diversity Targets for Managed Stands

Grouped Site Association	Shannon-Wiener Mean	Shannon-Wiener Range	Tentative Shannon-Wiener Target	Simpson's Mean	Simpson's Range	Tentative Simpson's Target	Richness Mean	Richness Range	Tentative Richness Target
Sxw - Huckleberry	2.196	2.007 - 2.451	> 2.007	0.138	0.164 - 0.113	< 0.164	33.25	9 - 48	TBD
Sxw - Devil's club	-	-	TBD	-	-	TBD	-	-	TBD
Sxw - Oak fern	-	-	TBD	-	-	TBD	-	-	TBD
SxwFd - dry	2.26005	2.062 - 2.458	> 2.062	0.16425	0.200 - 0.128	< 0.200	34	27-41	> 27
PlSb - Feathermoss	-	-	TBD	-	-	TBD	-	-	TBD
Bl - Rhododendron	1.826	1.523 - 2.192	> 1.523	0.231	0.303 - 0.143	< 0.303	23	16 - 28	> 16
Sxw - Horsetail	1.839	1.663 - 2.014	> 1.663	0.242	0.308 - 0.176	< 0.308	21.5	11 - 32	TBD
Bl - Oak fern	-	-	TBD	-	-	TBD	-	-	TBD
Sxw - Twinberry	2.467	-	TBD	0.111	-	TBD	45	-	TBD
SxwFd - wet	-	-	TBD	-	-	TBD	-	-	TBD

3.0 DISCUSSION

3.1 Target Review

A review of stand plot data from the NIVMA TRENDS database suggests that with one exception, all stands are within their currently known Ranges Of Natural Variation (RONV) for plant diversity. Similar to the Shannon-Wiener index results from previous studies, One Sxw – Huckleberry plot (FJ3124-124-285A-1) is slightly less diverse than the target diversity value for the Simpson's Index. However the plot is within the RONV using Shannon-Wiener and species richness criteria.

When all managed stand plots are grouped by site associations, the mean index values for all plant diversity measures are well above existing targets. Table 6 compares mean index values for managed stands with their corresponding tentative targets. While many of the targets have yet to be established, the mean values for each grouped site association appear to be within expected diversity ranges.

Table 6 Comparison of Mean Index Values With Tentative Targets

Grouped Site Association	Mean Shannon-Wiener Index	Range Shannon-Wiener Index	Tentative Shannon-Wiener Target	Mean Simpson's Index	Range Simpson's Index	Tentative Simpson's Target	Mean Species Richness	Range Species Richness	Tentative Richness Target
Bl - Oak fern	2.911	2.604 - 3.219	TBD	0.102	0.156 - 0.056	TBD	37	29 - 44	TBD
Bl - Rhododendron	2.853	2.440 - 3.366	> 1.523	0.118	0.203 - 0.052	< 0.303	33	27 - 41	> 16
PlSb - Feathermoss	3.006	2.342 - 3.748	TBD	0.114	0.184 - 0.034	TBD	47	34 - 59	TBD
Sxw - Devil's club	3.121	2.743 - 3.433	TBD	0.080	0.144 - 0.055	TBD	47	35 - 57	TBD
Sxw - Horsetail	2.753	2.366 - 3.306	> 1.663	0.150	0.194 - 0.070	< 0.308	49	37 - 57	TBD
Sxw - Huckleberry	3.297	2.422 - 3.719	> 2.007	0.063	0.167 - 0.028	< 0.164	48	25 - 63	TBD
Sxw - Oak fern	3.060	2.351 - 3.671	TBD	0.094	0.125 - 0.034	TBD	45	28 - 56	TBD
Sxw - Twinberry	3.119	2.645 - 3.702	TBD	0.090	0.143 - 0.036	TBD	54	41 - 63	TBD
SxwFd - dry	3.238	2.903 - 3.725	> 2.062	0.088	0.142 - 0.036	< 0.200	53	43 - 63	> 27
SxwFd - wet	2.707	1.788 - 3.544	TBD	0.144	0.315 - 0.039	TBD	38	21 - 74	TBD

3.2 Comparison of Indices

Some interesting trends emerge when all three indices are calculated for individual managed stand plots. Three representative plots were selected to demonstrate how the different indices can be used to evaluate plant diversity in managed stands. The values for the three indices were plotted over time since harvesting occurred, and these values are presented in Figures 1, 2 and 3.

Comparison of the trends reveals that the Shannon-Wiener and the Simpson's Index show similar trends over time, while the species richness trend is somewhat different.

While the diversity indices fluctuate substantially over the first few years post-harvest, the species richness trends consistently increase.

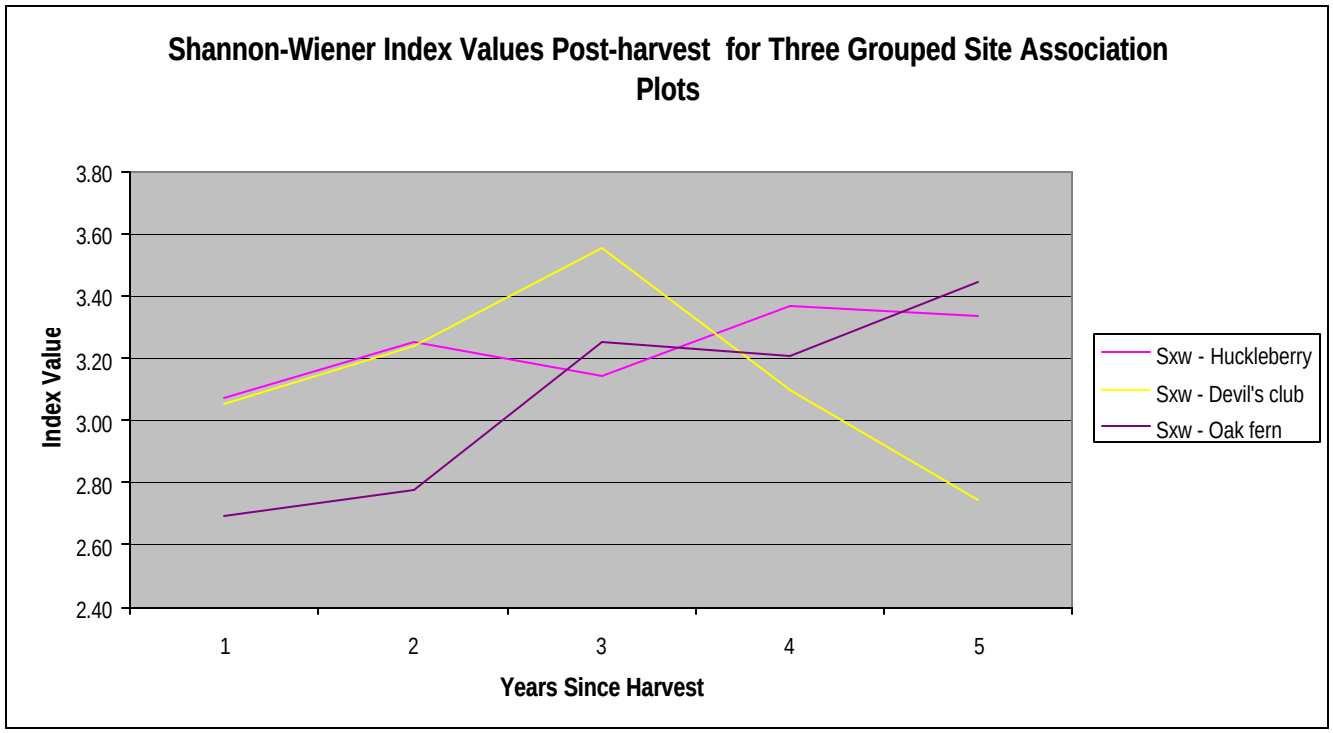

Figure 1 Shannon-Wiener Index Values Post-Harvest for Three Grouped Site Association Plots

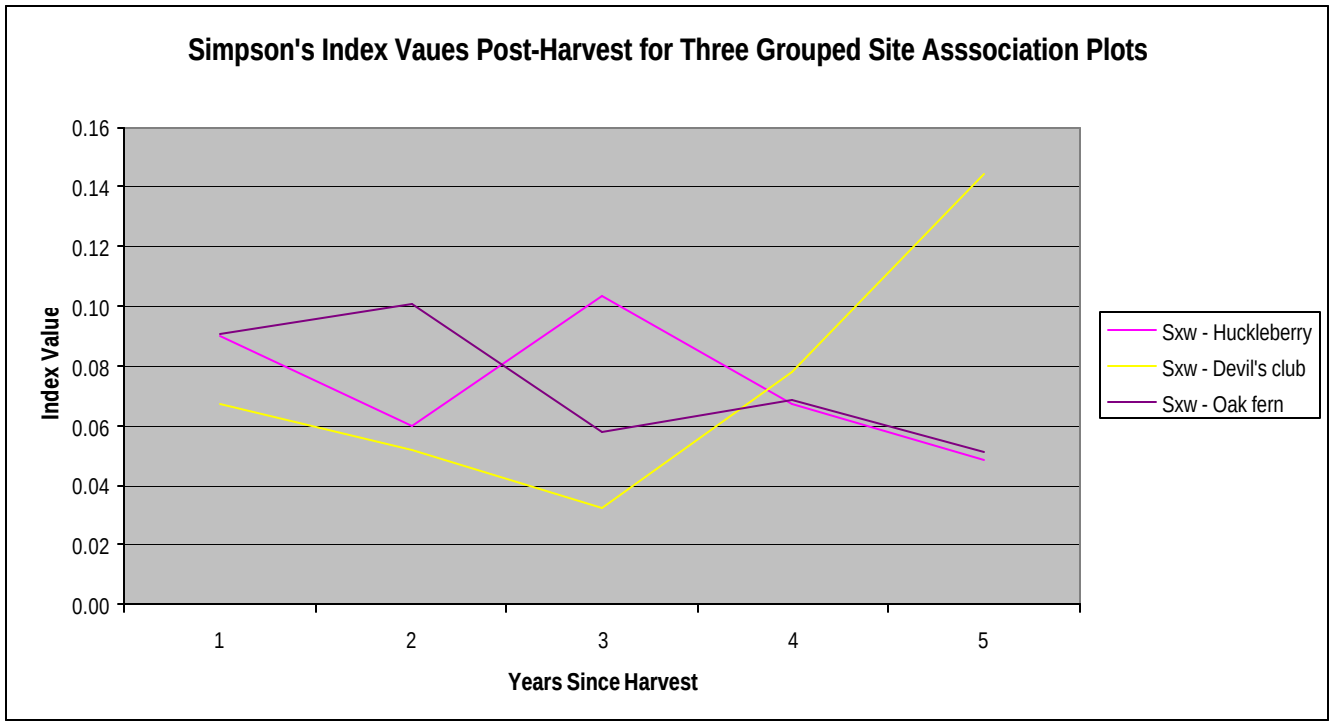

Figure 2 Simpson's Index Values Post-Harvest for Three Grouped Site Association Plots

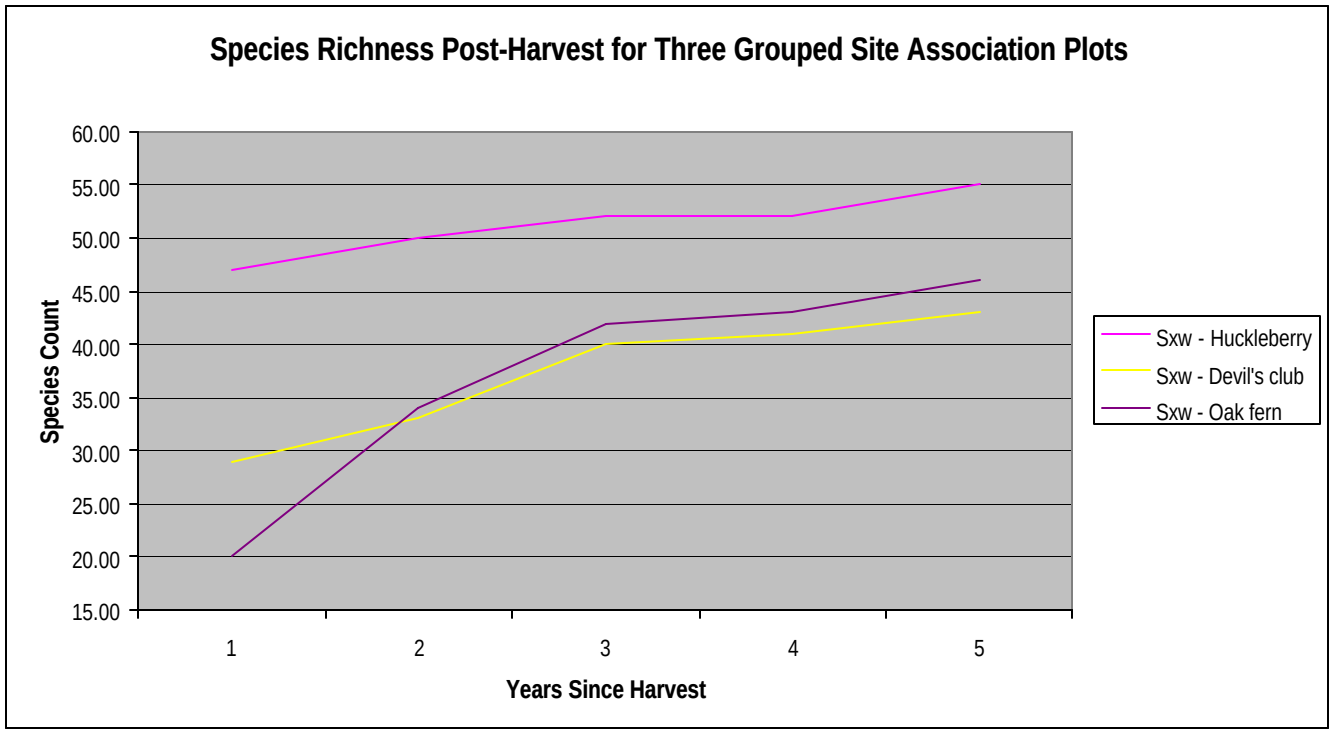

Figure 3 Species Richness Values Post-Harvest for Three Grouped Site Association Plots

It is likely that during the early successional pathways in these stands, certain species are slowly beginning to dominate the vegetation, decreasing the overall diversity as measured by the Shannon-Wiener and the Simpson's index. The species richness values demonstrate that the less competitive species are not being eliminated and additional species are being recruited over time.

Making comparisons between indices for any given year can also provide insight into the plant diversity of managed stands. For example, in the Sxw – Oak fern grouped site association, the change between year one and year two is quite different for each index. The Shannon-Wiener index increases, the Simpson's index decreases (in diversity; value increases), and the species richness almost doubles. If only one index is used, there is a very strong possibility that diversity trends for particular grouped site associations could be misinterpreted.

It is recommended that Canfor continue to use more than one diversity index to monitor plant diversity in managed stands. Although all stands monitored appear to be within the plant diversity RONV, the three indices will assist Canfor to evaluate the effect on plant diversity of various silviculture activities as they are completed over time on the stand.

If the plant diversity of a particular managed stand is determined to be outside itsRONV for its site association, analysis of the individual diversity indices may provide an explanation. If natural successional pathways do not provide insight into the deviation, the management strategies employed on the stand should be reviewed to determine if they are directly responsible for any detrimental effects on plant diversity.

However, without statistically valid natural early successional pathway data, the RONV for plant diversity will be difficult to determine and managed stands will remain difficult to monitor. It is recommended that Canfor's program of field verifying the RONV for grouped site associations continue, thus allowing for meaningful interpretation of trends in managed stand plant diversity indices.

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APPENDICES

APPENDIX I

GROUPED SITE ASSOCIATION KEY

Grouped Site Association	SITE_ASSOCIATION	Correlated BEC Unit(s)
Act - Dogwood - Prickly rose	Act - Dogwood - Prickly rose	SBSdk/08
Alder - Lady fern	Alder - Lady fern	ESSFwk1
		SBSvk/11
Bl - Devil's club	Bl - Devil's club - Lady fern	ESSFwk1/05
	Bl - Devil's club - Rhododendron	ESSFmv3/05
		ESSFwk2/04
Bl - Horsetail	Bl - Globeflower - Horsetail	ESSFwc3/03
	Bl - Horsetail - Feathermoss	ESSFmv2/07
		ESSFmv3/07
	Bl - Horsetail - Glow moss	ESSFmv1/05
	Bl - Horsetail - Sphagnum	ESSFwk1/06
		ESSFwk2/06
	Bl - Lady fern - Horsetail	ESSFwk1/07
Bl - Huckleberry	Bl - Huckleberry - Feathermoss	ESSFmv1/03
		ESSFwk1/02
	Bl - Huckleberry - Gooseberry	ESSFmv1/04
Bl - Oak fern	Bl - Oak fern - Bluebells	ESSFwk2/03
	Bl - Oak fern - Brachythecium	ESSFwk1/01
	Bl - Oak fern - Knight's plume	ESSFmv3/04
		ESSFwk1/03
		ESSFwk2/01
	Bl - Oak fern - Sarsaparilla	ESSFwk2/02
	Bl - Twinberry - Lady fern	ESSFwk1/04
Bl - Rhododendron	Bl - Rhododendron - Feathermoss	ESSFmv1/01
		ESSFmv3/01
	Bl - Rhododendron - Lady fern	ESSFwk2/05
	Bl - Rhododendron - Oak fern	ESSFwc3/01
BlPl - Crowberry - Cladina	BlPl - Crowberry - Cladina	ESSFmv3/02
BlSb - Labrador tea	BlSb - Labrador tea	ESSFmv3/03
Cw - Mesic to Hygric	Cw - Devil's club - Ostrich fern	ICHvk2/05
	CwHw - Devil's club - Lady fern	ICHvk2/01
	CwHw - Oak fern	ICHvk2/04
	CwSxw - Skunk cabbage	ICHvk2/06
Fd - Xeric to Subxeric	Fd - Pinegrass - Alder	SBSdw2/04
	FdPl - Cladonia	SBSdw2/02
		SBSdw3/02
HwCw - Xeric to Subxeric	HwCw - Cladonia	ICHvk2/02
	HwCw - Step moss	ICHvk2/03
Pl - Cladina	Pl - Cladina - Step moss	SBSmk1/02
	Pl - Feathermoss - Cladina	SBSdk/03
		SBSdw3/03
		SBSmc3/03

Grouped Site Association	SITE_ASSOCIATION	Correlated BEC Unit(s)
		SBSmk1/03
Pl - Huckleberry	Pl - Huckleberry - Cladina	SBSvk/09
		SBSwk1/02
		SBSwk3/09
	Pl - Huckleberry - Cladonia	ESSFmv1/02
		SBSmc2/02
	Pl - Huckleberry - Velvet-leaved blueberry	SBSvk/02
		SBSwk1/03
Pl - Pinegrass	Pl - Juniper - Dwarf blueberry	SBSmc3/02
	Pl - Juniper - Feathermoss	SBPSdc/01
	Pl - Juniper - Ricegrass	SBSdk/02
	Pl - Kinnikinnick - Cladonia	SBPSdc/02
	Pl - Kinnikinnick - Feathermoss	SBPSdc/03
	Pl - Kinnikinnick - Wavy-leaved moss	SBSdw2/03
	Pl - Pinegrass - Feathermoss	SBSdw2/06
PlSb - Feathermoss	PlSb - Feathermoss	SBPSdc/04
		SBSdw2/07
		SBSdw3/05
	Sb - Huckleberry - Spirea	SBSmc3/05
		SBSmk1/06
	Sb - Labrador tea	SBSwk3/4.1
	SbPl - Feathermoss	SBSmc2/03
		SBSmc3/06
		SBSwk1/12
Sb - wetlands	Sb - Scrub birch - Sedge	SBSmk1/10
	Sb - Soft-leaved sedge - Sphagnum	SBSdk/10
		SBSdw2/11
		SBSdw3/10
	Sb - Sphagnum	ICHvk2/07
	SbPl - Bog-laurel - Sphagnum	SBSvk/08
	SbSxw - Scrub birch - Sedge	SBSmc2/12
		SBSmc3/09
		SBSwk1/11
	Scrub birch - Sedge - Sphagnum	ESSFwk1/08
Sxw - Devil's club	Sxw - Devil's club	SBSmc2/09
		SBSmk1/08
		SBSvk/01
		SBSwk1/08
		SBSwk3/6.1
		SBSwk3/6.2
		SBSwk3/07
	Sxw - Devil's club - Knight's plume	SBSdw2/09

Grouped Site Association	SITE_ASSOCIATION	Correlated BEC Unit(s)
	Sxw - Devil's club - Lady fern	SBSwk1/10
	Sxw - Devil's club - Ostrich fern	SBSvk/07
	Sxw - Devil's club - Spiny wood fern	SBSvk/05
Sxw - Horsetail	Sxw - Horsetail	SBSdk/07
		SBSdw2/10
		SBSmc2/10
		SBSmc3/08
		SBSmk1/09
		SBSvk/06
		SBSwk1/09
		SBSwk3/7.1
		SBSwk3/7.2
		SBSwk3/08
	Sxw - Horsetail - Glow moss	SBSdw3/09
		SBSmc2/11
	Sxw - Horsetail - Meadowrue	SBPSdc/06
	Sxw - Horsetail: Fluvial phase	SBSmk1/09a
	Sxw - Horsetail: Organic phase	SBSmk1/09b
	Sxw - Skunk cabbage	SBSvk/10
Sxw - Huckleberry	Sxw - Huckleberry	SBSmc2/01
		SBSmc3/01
	Sxw - Huckleberry - Dwarf blueberry	SBSmc2/04
	Sxw - Huckleberry - Highbush-cranberry	ESSFmv3/06
		SBSmk1/01
		SBSwk1/05
		SBSwk3/03
		SBSwk3/04
	Sxw - Huckleberry - Soopolallie	SBSmc3/04
Sxw - Oak fern	Sxw - Oak fern	SBSdw3/08
		SBSmc2/06
		SBSmk1/07
		SBSvk/04
		SBSwk1/01
		SBSwk3/01
Sxw - Pink spirea	Sxw - Pink spirea - Oak fern	SBSwk1/06
	Sxw - Pink spirea - Prickly rose	SBSdw3/06
	Sxw - Scrub birch - Feathermoss	SBPSdc/05
		SBSmc2/07
Sxw - Spirea	Sxw - Spirea - Feathermoss	SBSdk/05
	Sxw - Spirea - Purple-peavine	SBSdk/01
Sxw - Twinberry	Sxw - Twinberry	SBSdw2/08
		SBSdw3/07

Grouped Site Association	SITE_ASSOCIATION	Correlated BEC Unit(s)
		SBSmc3/07
	Sxw - Twinberry - Coltsfoot	SBSdk/06
		SBSmc2/05
		SBSwk3/05
		SBSwk3/06
	Sxw - Twinberry - Oak fern	SBSmc2/08
		SBSwk1/07
SxwFd - dry	SxwFd - Cat's-tail moss	SBSdw2/05
	SxwFd - Pinegrass	SBSdw1/01
		SBSdw3/01
		SBSwk3/02
	SxwFd - Ricegrass	SBSdw3/04
SxwFd - wet	SxwFd - Knight's plume	SBSmk1/04
		SBSwk1/04
	SxwFd - Purple peavine	SBSwk3/02
	SxwFd - Thimbleberry	SBSvk/03
	SxwFd - Toad-flax	SBSmk1/05

APPENDIX II

USER MANUAL FOR PLANT DIVERSITY INDEX CALCULATION TOOL

Timberline
Forest Inventory Consultants

Plant Diversity Index Tools
(PDItools - Version 1.1)
User Manual

Introduction:

PDItools (version 1.1) is an Access database that will connect to a NIVMA TRENDS database and calculate and summarize plant diversity index (PDI) values for selected NIVMA vegetation plots. The purpose of this tool is to facilitate periodic monitoring of plant diversity and support certification monitoring initiatives.

This user manual provides direction on generating PDI values from a NIVMA TRENDS database and summarizing the results using the queries that have been provided.

This manual accompanies the report,"*Monitoring Diversity: Simpson's Index and Species Richness Assessment*" (March 2003) by Timberline Forest Inventory Consultants Ltd. The assumptions described in this report were incorporated into the PDI calculations within PDItools.

Step 1: Open PDItools1.1.mdb Database File

Open the Access database PDItools1.1.mdb. The form [SelectNIVMAdbase] will open automatically.

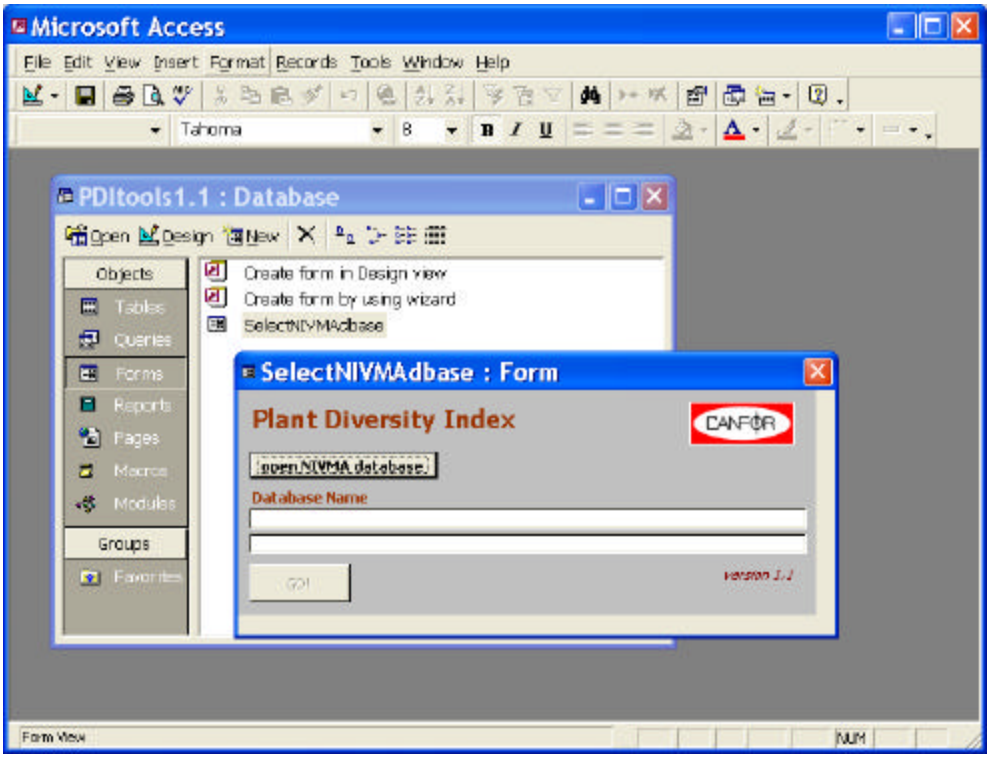

Figure 1 Open PDItools

Step 2: Select the NIVMA Database

Press the [open NIVMA database] button and select the NIVMA database you wish to use to calculate plant diversity index values. Select the appropriate Access database file and hit the [Save] button.

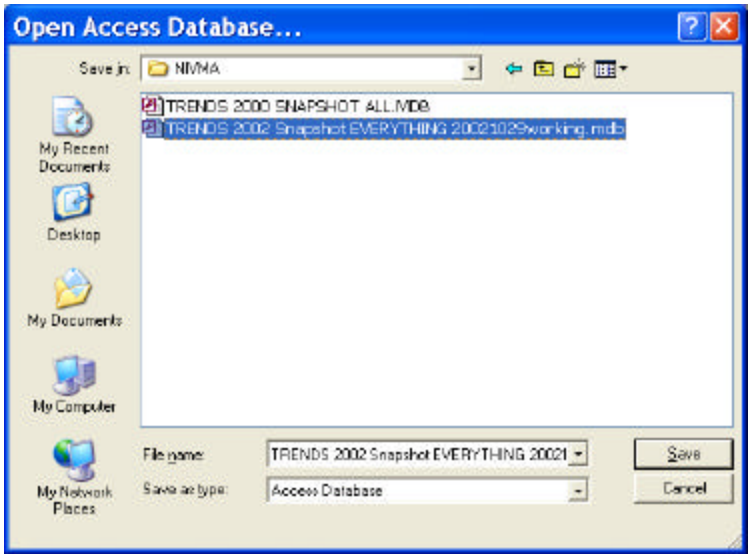

Figure 2 Select Nivma Database

Step 3: Run PDItools

The name and path of the selected database file will appear in the text boxes. Double check that this is the appropriate database and hit the [GO!] button to begin the calculations.

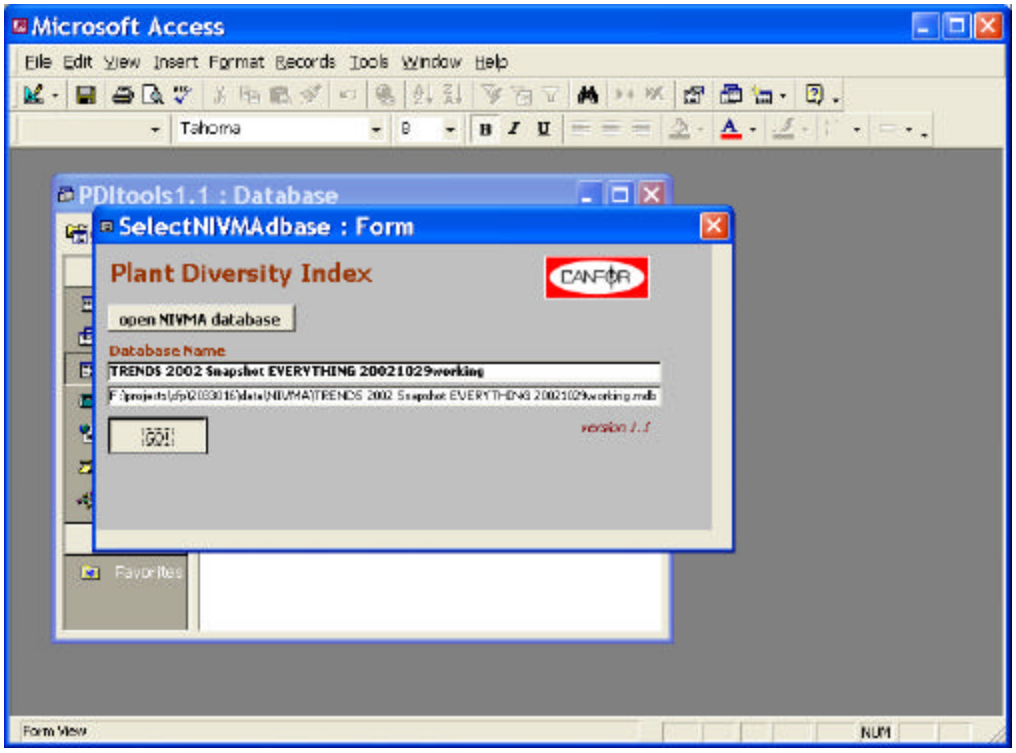

Figure 3 Run PDItools

This process should take between 3 and 5 minutes. Once the process has completed (a message will appear) you can begin running the queries to summarize the data for reporting.

This utility connects to the selected NIVMA database to retrieve the required information. It stores all of the data generated in the PDItools database and does not store any data within the NIVMA database.

Indexes are built within the NIVMA database to expedite the process. This may present problems if the NIVMA database is read-only. If this becomes a problem the code can be altered to remove this.

This process calculates plant diversity index values for all of the plots in the NIVMA database selected. The queries, which summarize the data, have been designed to only display relevant plots from the Prince George Timber Supply Area (as defined by the timber mark in the NIVMA database). These queries can be adjusted to display any of the plots within the NIVMA database and can be formatted to meet changing reporting requirements. The data from each run is stored in a table called [nivmaPDIdata] within the PDItools database. This table will be overwritten each time the process is run (when you hit the [GO!] button. So, if you wish to save the results of a previous run you must rename or export the table or save another copy of the PDItools database.

Standard queries have been provided to summarize the results in the [nivmaPDIdata] table to meet the current reporting requirements of Canfor's *Sustainable Forest Management Plan – Fort St. James and Prince George Operations – September 5th, 2002.*

Step 4: Run Queries as required

Once the PDI values have been calculated the queries contained within the PDItools database can be run to summarize the data. Separate queries have been designed for the TSA as well as TFL 30 (based on timber mark). The queries display average Shannon-Weiner Index, Simpson's Index and Richness for each plot and grouped site association pre and post harvest. The results of these queries will be based on the last version of the NIVMA database for which PDI values were calculated.

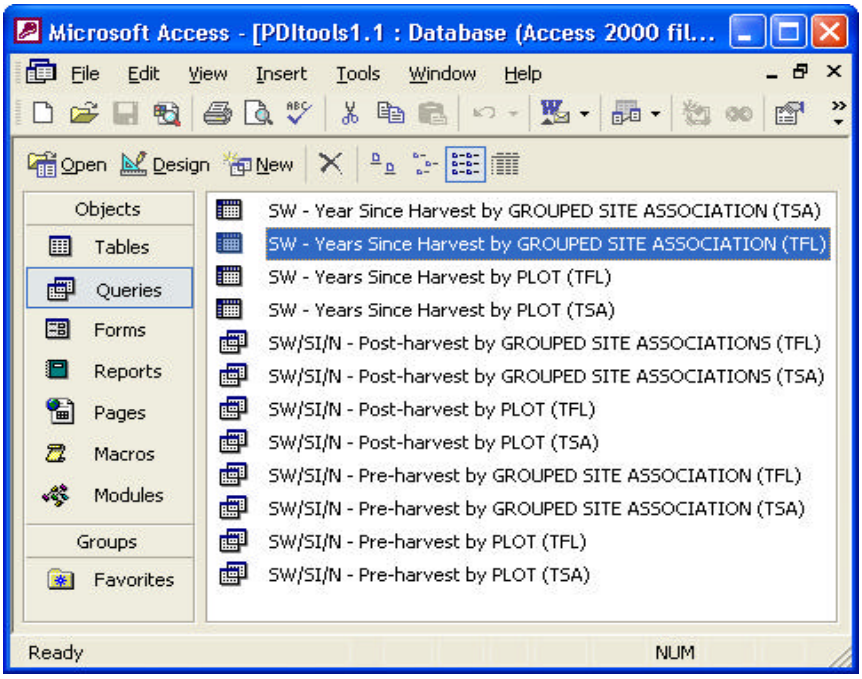

Figure 4 PDItools Queries

APPENDIX III

PLANT DIVERSITY INDEX CALCULATION TOOL

(under separate cover)