COMPUTER PROGRAMS FOR ESTIMATING THE ALPHA DIVERSITY: THE BASIS OF SUSTAINABLE MANAGEMENT PLANS TO CONSERVE DIVERSITY

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Astract. The conservation of biological diversity is the first criteria of all processes (Montreal, Helsinki, ITTO, Tarapoto, Lepaterique, etc.) and the certification processes (FSC) dealing with the development of sustainable management plans of forest resources. An understanding of the alpha diversity is critical for the environmental management of trees and other tree-dependent communities. There are several computer programs available for the calculation of several parameters and indices of the alpha diversity. However, they lack flexibility to accommodate for testing several management options and for estimating diversity indices simultaneously for several communities. In this research, I present computer programs developed in Statistical Analysis System to estimate the alpha diversity for any number of communities. Examples of calculations of diversity indices (species richness, Margalef, Menhinick, Shannon-Weiner, Simpson, McIntosh, Berger-Parker, Brillouin) and diversity-abundance models (the broken stick, the geometric series, the truncated lognormal model, and the logarithmic series) are presented for fish, benthic insects, riparian trees, and for temperate and tropical communities, as well as for permanent sampling plots of temperate mixed coniferous forests of Durango, México. Examples of sustainable harvesting practices to conserve diversity are part of the simulations carried out in this computer environment.

Key words: Long term sustainable management plans to conserve diversity at the stand scale.

1. Introduction

In the last two decades, there has been an increasing interest in ways to measure and forecast biological diversity of natural and human-disturbed landscapes in order to conserve genes, species, ecosystems and landscapes (Boyle and Bontawee, 1995). Primary productivity, nutrient cycling, and disturbance adaptation are ecosystems processes regulated by diversity. Regardless of its importance, the biological diversity is currently being lost at an unprecedent rate in the formation and development of earth. Therefore, it is the first criteria of all Processes (Montreal, Helsinki, Tarapoto, Lepaterique, Dry Forests of Africa, ITTO, etc.) and requires several indicators at several spatial and temporal scales to understand it.

The alpha diversity index, the species richness and abundance of a particular habitat considered to be homogeneous, has received considerable attention since disturbances measured at the community scale are recognized to be the center of human control (Leitner and Turner, 2001; Magurran, 1988; 2004; Chao, 2005). Indices based on species richness and evenness is two types of information considered when measuring the alpha diversity.

There are several computer programs available to measure the alpha diversity; i.e., SDR (Species-Diversity-Richness V. 4.0) and Biodiversity (Krebs, 1989). However, they compute single values and give little opportunity to conduct research to establish sustainable management alternatives to conserve diversity at the community scale. The objective of this report was to develop a computer program to estimate simultaneously indices of alpha diversity and to provide information for the decision making of natural resource management and the environment.

2. Materials and Methods

The computer program calculates the diversity indices of: a) species richness, b) Margaleff, c) Menhinick, d) Shannon, e) Brillouin, f) Simpson, g) McIntosh, and h) Berger–Parker. It also computes and fits four diversity-abundance models: a) geometric series, b) the log series, c) the truncated log normal distribution, and the d) broken stick. The diversity indices and diversity - abundance models are reported in Table 1.

Table 1. The diversity-abundance models to estimate the alpha diversity for scientific issues as well as for the sustainable management of natural resources.

Equation	Name
$D_{mg} = (S-1)/\ln N$	Margaleff
$D_{mn} = S/\sqrt{N}$	Menhinick
$H' = -\sum p_i \ln pi$	Shannon
$D = \sum pi^2$	Simpson
$Mci = (N-ni^2)/(N-\sqrt{N})$	McIntosh
$B\text{-}P = (1/Nmax)/N$	Berger-P
$Br = (\log (N!)- \Sigma ni!)/N!$	Brillouin
$ni = NC_k k(1-k)^{i-1}$	Geometric S.
$\alpha x, \alpha x^2/2, \alpha x^3/3, \ldots,$	Logarithmic S.
$S(R) = S_o \exp(-\alpha R)^2$	T. Log-normal S.
$S(n)=[S(S/1)/N](1-n/N)^{s-2}$	Broken Stick M

Where S= number of species or species richness, N= total number of individuals or abundance, ln= natural logarithm, p_i = proportion of the total sample belonging to the ith species (n_i /N), ni = the number of species i, Nmax = the maximum abundance of the species i, Ck= a constant, which assures that Σni = N, i = species rank, αx= the number of species with one individual, $\alpha x^2/2$= the number of species with two individuals, α= (N(1-x))/x, S/N = (1-x)/x(/ln(1-x)), $\alpha= (2\sigma^2)^n$= a constant describing the amount of spread in the distribution, S(R) = number of species to occur in the Rth octave (=class) to the right or left of the symmetric curve , S_o= number of species in the modal octave (the largest class), S(n) = number of species in the abundance class that present n individuals.

The program can be manipulated to obtain insights into management alternatives with the aim to develop and conduct sustainable management plans of natural resources by conserving the diversity of flora and faunal diversity. Information collected at the Facultad de Ciencias Forestales of UANL in the northeastern of Mexico on fish, benthic insects, riparian trees, and temperate and tropical forests was available for running the computer program. Results of diversity indices and the abundance-diversity models are presented in the results section. In addition, several options for example for harvesting timber in temperate forests were asked before running the program with the aim for testing management options. In addition, for temperate forest ecosystems, the diameter structure of the tree community was simulated for several harvesting intensities to understand the sustainability of diameter structure as well. To accomplish this, a diameter growth model was employed and the diameter increment as a function of current diameter was derived from this model. The diameter structure of harvested trees was selected from forest inventories of eight of the largest forest communities of Durango, México. The diameter structure of inventoried trees was fitted by the Weibull distribution. The procedure included the current diameter structure, harvesting trees with diameter dimensions of choice, running the diameter increment until standing volume attained original values. Harvesting intensity was simulated from 5 to 40% of the standing volume since this range is the most popular in harvesting programs in northern Mexico.

Results of these calculations and simulations are presented in tabular and graphical formats below.

3. Results

Examples of diversity indices and diversity-abundance models estimated for each plant and faunal community is presented in Table 2.

Table 2. Alpha diversity indices for several plant and faunal communities of northern Mexico.

D.I.	Mg	Mh	Sh	Si	G S	L S	N L	B S
BI	1.94	1.19	1.41	0.35	0.00	0.91	0.32	0.00
Fish	1.07	0.38	0.94	0.55	0.00	0.37	0.30	0.00
RT	1.60	1.00	1.33	0.34	0.00	0.46	0.16	0.00
ESTT	1.19	0.48	1.58	0.27	0.00	0.33	0.01	0.00

LSTT	0.88	0.69	0.99	2.84	0.00	0.46	0.00	0.00
TF	0.61	0.19	0.89	0.81	0.00	0.27	0.15	0.00

Note: D.I. = diversity index, BI = Benthic Insects, RT= Riparian Trees, ES =Early Succession, LS=Late Succession, TT = Tamaulipan Thornscrub, TF=temperate forests, Mg =Margaleff, Mh = Menhinick, Sh = Shannon, Si=Simpson, GS=Geometric Series, LS =Logarithmic Series, NL= Normal Logarithmic, BS=Broken Stick.

Diversity indices are variable between plant and faunal communities and they cannot be compared since they come from different communities, with the exception of data on diversity abundance for the Tamaulipan thornscrub, which was sampled at two different successional stages. Most communities are in the secondary successional stages since the logarithmic series did fit better diversity-abundance data. Indeed, the geometric series and the broken stick models, which represent the early and late sucessional stages, are not good descriptors of the diversity-abundance data.

Other alpha diversity indices averaged for each of six different silvicultural treatments, consisting on the percentage of the removal of basal area, for data of temperate forests of central Durango, Mexico and measured during 2004 are reported in Table 3.

Table 3. Alpha diversity indices and hypotheses testing for fitting diversity-abundance models for 36 permanent sampling plots pooled in six different basal area removal treatments.

Trt	N	S	Mg	Mh	Sh	Br	Si	Mc
0	282	8	1.21	0.47	1.33	1.08	2.95	0.42
20	302	7	1.02	0.39	1.30	1.08	2.88	0.42
30	305	7	1.02	0.39	1.26	1.04	3.12	0.40
50	333	7	1.04	0.39	1.26	1.05	2.97	0.40
70	293	7	1.03	0.40	1.21	1.00	2.80	0.39
100	474	6	0.79	0.27	0.63	0.53	1.53	0.17

Tabl 3. Continued…

Trt	BP	G.S	LS	NL	BS
0	1.97	Ho	Ha	Ha	Ha
20	1.90	Ha	Ho	Ho	Ho
30	2.06	Ha	Ho	Ho	Ho
50	2.05	Ho	Ha	Ho	Ho
70	2.01	Ha	Ho	Ho	Ho
100	1.24	Ha	Ho	Ho	Ha

Where: Trt = Silvicultural treatment, N = abundance in 25 x 25 m quadrats, S = Species richness, Mg = Margaleff, Mh = Menhinick, Sh = Shannon – Weiner, Br = Brillouin, Si=Simpson, Mc = McIntosh, BP=Berger-Parker, GS = Geometric Series, LS = Logarithmic Series, NL = Truncated Log Normal Model, BS = Broken Stick Model.

Diversity changes between silvicultural treatments and plots treated with 100% basal area removal present smaller diversity values. That is, in order to recover diversity of tree species, forests require longer than 38 years since treatments were conducted during 1968. Diversity is developing in clearcut treatments showing that the pioneer pine species (*P. cooperi*) dominate stands but there are other species incorporating as well. The rest of the treatments fit well other diversity-abundant models indicating a better balance between species and abundance.

The development of tree diversity in time (species richness and the Shannon & Weiner index) is presented in Figure 1 and these variables fit well a power relationship.

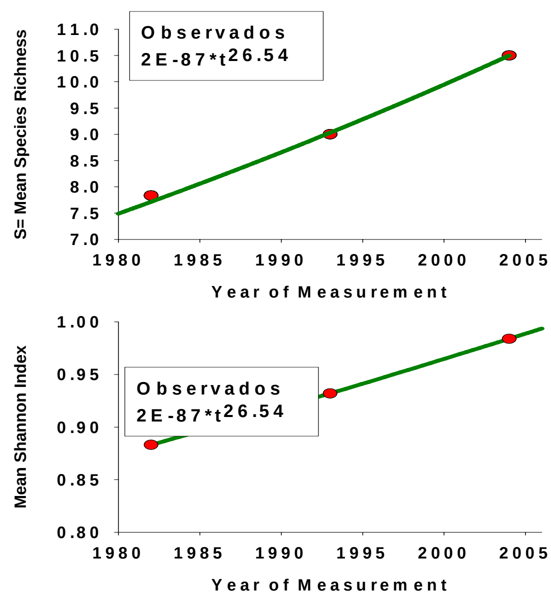

Fig. 1. The development of average diversity indices in time in clearcut treatments conducted in 1968 in temperate forests of Durango, México.

The average species richness recovers well in time and attains similar values as those observed in control plots or in selective cuttings with less basal area removal during the last observation conducted in 2004. However, simulations indicate that forests take about 80 years to attain similar values of diversity indices as those of the control plots. That is, the proportional abundance of trees for each species takes longer than the number of species to recover from the harvesting disturbance. The slope of the power relationship between each diversity index and standing volume after harvesting is presented in Fig. 2. The slope drops sharply for all diversity indices after removing a harvesting volume larger that 20% of the standing one. That is, the largest diversity disturbance is caused because of the inclusion of other tree species that meet the diameter requirements.

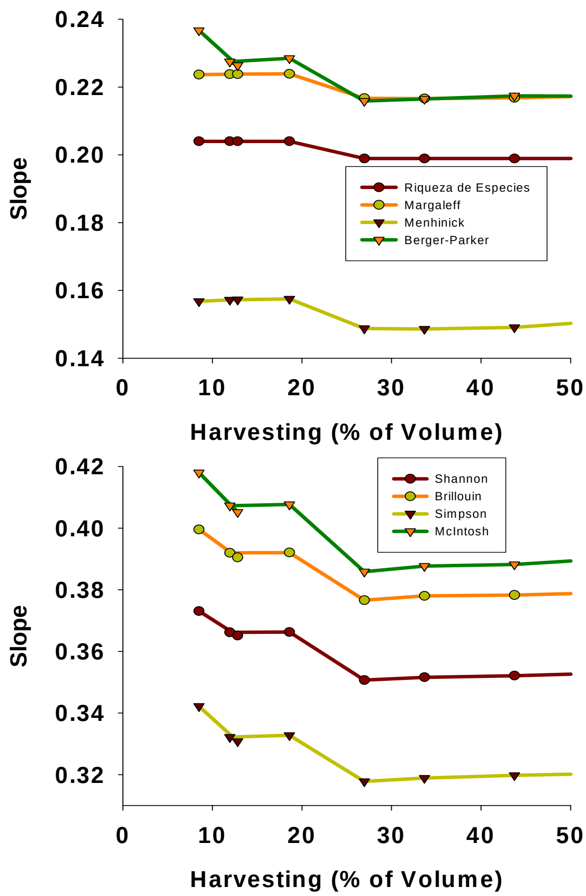

Fig. 2. The relationships between the slope of the diversity index and standing volume removal and harvesting for permanent sampling plots of Durango, México.

The starting and final diameter structures after the removal of eight different harvesting volume intensities and permitting the original standing volume to recover simulated by a diameter growth model is presented in Fig. 3.

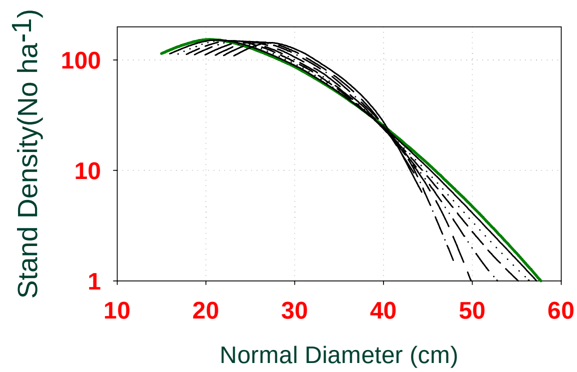

Fig. 3. The initial and final diameter structures of temperate forests of Durango, Mexico after removal of timber and letting the forest recover the initial standing volume.

Trees with the largest diameters disappear as the harvesting intensity increases but the modal diameter displaces to the right to accommodate for the original standing volume. This process of harvesting by the choice of forest managers simplifies the diameter structure of temperate forests. It has been reported that the structural complexity, as well as diversity, enhances stand productivity. These simulations may forecast future declines in forest productivity because of harvesting operations conducted by selecting the largest trees to meet fiber and wood market demands.

The disappearance of large trees is an environmental problem reported elsewhere, in most forest ecosystems that have been harvested for long periods of time. Because of the importance of large trees in several process and states (hydrology, microclimate, shade, bird, insect, mammal, and other populations that use them for shelter, prey, nest, etc.) harvesting schedules must not disturb diameter structures as well.

Therefore, in order to sustainable manage these forest stands with the goal to conserve tree diversity and the relative abundance, it is recommended to harvest less than 20% of the standing volume or less than 3 m^2 ha^{-1} of basal area since the relationship between the species richness and standing volume or basal area, which fitted a power relationship, drops sharply after harvesting above 20% of the standing volume for all diversity indices. The time interval between harvesting cycles must last between 15 and 20 years in order to recover the diameter structures.

4. Conclusions

The computer program calculates well the alpha diversity indices since comparisons with values estimated in spreadsheets are in good agreement. Although further information is required in order to conduct full simulation studies, including the density and diversity of natural and harvesting-impacted recruitment, to better understand the effect of harvesting on the diversity indices, several conclusions are derived from preliminary simulations conducted on the computer program. Species richness are less disturbed than other diversity indices or diversity-abundance models by harvesting practices. In order to conserve diversity-abundance and to recover diameter structure of trees, it is required to harvest selectively less than 20% of the standing volume and the time interval between harvesting cycles must last between 15 and 20 years.

5. References

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