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CONJECTURES AND SCENARIOS IN RECOVERY STUDY

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Abstract. When pasture land is abandoned, logged area left unattended, or in general, when severe perturbation stops, vegetation recovery begins. The process that unfolds from initiation to the new steady state is my topic of discussion. I believe that the recovery process is rapid initially and strongly directed, but as time passes, deceleration occurs, the changes become increasingly chaotic, and in chaos, a new steady state is approached. I also believe that the space-time scale matters not only in our the perception of the process, but also in the natural unfolding of the process independently from us. I present general thoughts in this paper and introduce the idea that boundary conditions exist not only on the ground, such as Walt Conley's edges, but also in interactions and association in their own analytical space. I describe conjectures that I and A. Garcia chose to delineate recovery studies in Cantabrian Spain and Carolinian Ontario.

Postdiction or prediction?

The problems of a recovery study can be posed as the postdiction or prediction of space-time changes in the community. In the broadest sense, these involve composition, interaction and association processes. In postdiction, the past is the subject of inference. In prediction, alternatives are posed as conjectures and evaluated by model. Prediction just as much as postdiction relies on evidence that describes what has already elapsed.

Much work has been done on the composition process which McIntosh (1980) reviewed. Work that addresses interactions and association in a developmental context, and especially the evolution of boundary conditions, known as edges, during recovery is probably nonexistent. Yet these are important for the understanding of recovery.

Edges

The edges of interest are landscape elements only in some cases and only on some sampling scales. Most edges are analytical constructs, yet their patterns are not less characteristic of the process than any of the landscape elements. Furthermore, the spaces within which we find *prima facie* evidence for these patterns are always abstractions (Goodall 1954, Benzecri 1969, Krummell *et al.* 1987, Ludwig and Cornelius 1987, Lippe *et al.* 1985, Orlóci and Orlóci 1990, Brunt and Conley 1990). The main tools of edges detection include regression analysis, deviations-based profile analysis and ordination analyses:

1. Regression analysis removes the serial effects that mask the edges.

2. Deviations profiles mirror reality in comparative terms, since all deviations are measured away from a vegetation 'null state', the zero line defined under the assumption of random compositional variation and smooth serial effects void of edges.

3. Ordinations create mappings that clarify ambiguities in the deviations profiles.

Figures 1 and 2 give examples of ordination mappings and deviations profiles created by program CONAPACK (Orlóci 1991c) from transect data. It is important that if the reference system includes time, the line mappings and line profiles will expand into surfaces (not incorporated into CONAPACK).

Conjectures

Recovery carries imprints of conditions that existed at the time of initiation, and of the secondary effects that happened along the way. While familiarity with both initial conditions and secondary effects is essential for the understanding of recovery in a site, the space-time scale provides the framework through which the conclusions of recovery studies can be generalized. The following underlie the design of our recovery experiments in Cantabrian Spain and Carolinian Ontario (Orlóci, Garcia, Orlóci and Bermudez 1989):

CONJECTURE 1. *The recovery process unobstructed by significant new perturbation is predictable from knowledge of the initial conditions.* When the beginning of recovery is put in the past and reasoning is backwards in time from a known advanced state, the process will doubtless appear deterministic. If the process is deterministic, it is sufficient to know the composition of the last disturbed state and the

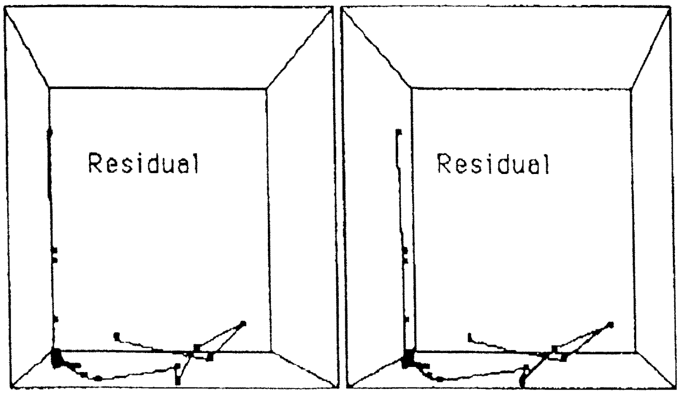

Figure 1. Ordination map of the Jornada transect for stereo viewing (after Orlóci and Orlóci 1990). The construction uses metric coordinates (not given) from canonical contingency table analysis (Orlóci 1991c). The stereo coordinates are computed from data residuals free of serial dependencies. The irregular line is the transect's ordination map. The axes correspond to the first 3 canonical variates which jointly account for about 50% of the total variation. The 90 full squares (many overlapping in the ordination view) are the mappings of sampling units. These are 30 m long and 30 m wide contiguous transect segments given in the graph in their natural progression from basin floor (topmost square in the graph, segment 1 in the transect) to montane rockland (transect segment 90). The distances (internodes) between mappings are proportional to sampling units' compositional divergences between the sampling units. Sharp apices in the transect mapping identify dramatic vegetation changes in nature. These often coincide with areas of abrupt environmental change. It should be noted that the apices in this graph closely correspond to the high peaks in the D and D profiles (1st and 3rd in Fig. 2) and low points in the A profile (2nd in Fig. 2). Graphics computed and drawn in CONAPACK (Orlóci 1991c).

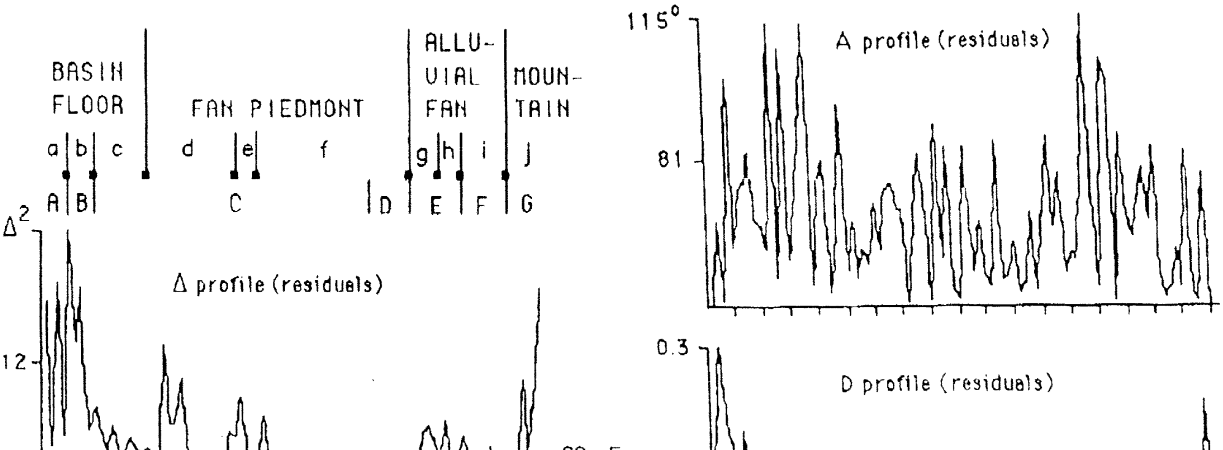

Figure 2. Vegetation transect profiles on the Jornada site (after Orlóci and Orlóci 1990). Vertical axis displays squared deviations from null state in thousand data units (pooled over 38 CSTs) in the 1st profile, angles subtending to ordination apices in the 2nd profile (scale in squared units), and squared Euclidean distances in the Ludwig- Cornelius type profile (3rd profile). Tick marks on horizontal axis identify every 5th of 90 sampling units from basin floor (transect segment 1) to montane rockland (segment 90). Ground distances (0 to 2700 m) are shown from transect origin to transect segment. The graphs are based upon data residuals free of serial dependencies. The high peaks in the D and D profiles correspond closely to the low points in the A profile. The mirroring index (m) is 75% and the mean square contingency coefficient (CC) is - 0.5 for directional changes (up/down, down/up) above the 2500 deviation level marked by the dotted line. The high peaks in the D and D profiles coincide with dramatic land form and soil changes along the transect. *Legend to soils and vegetation zones*: a - Dalby soil series; b - Headquarters series; c - Buckle Bar series; d - Berino series; e - Onite series; f - Doña Ana series; g - erosion fan remnant channel, h - side slope, i - summit (Aladdin soil series); j - montane rockland; A - playa grassland; B - playa fringe *Prosopis* thicket; C - mixed basin slope vegetation; D - *Larrea* shrubland; E - lower grassland; F - upper grassland; G - montane shrubland. The computations and graphics are performed in CONAPACK (Orlóci 1991c).

Table 1. Ordination mappings of a pure Markov type recovery process (Graph 1, Fig. 4), random-adjusted Markov type recovery process (Graph 2, Fig. 4) and the associated natural process in Atlantic heathland (Graph 3, Fig. 4). The table contents and mapping methods follow Orlóci and Orlóci (1988) and Orlóci (1991c). The data represent percentage point cover recorded annually between 1963 - 1981 in a study described by Lippe et al. (1985, their Table 2).

Graph in Fig. 4	Process	Canonical correlation	Total χ^2	% total
Graph 1	Pure Markov	0.5175	508.913	97.2
Compositional order: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19				
Graph 2	Markov (15% random variation)	0.5013	481.100	96.3
Compositional order: 1 2 3 4 6 9 8 17 7 11 14 10 16 5 18 13 15 12 19				
Graph 3	Observed	0.4520	388.430	88.5
Compositional order: 1 2 3 4 5 15 6 16 9 7 14 12 17 13 10 8 18 19 11				

'grammar' of the process to be able to predict the future. This approach to prediction is typical in Markov mathematics in which the 'grammar' is a transition matrix. When the beginning is put into the future, there may be no knowledge of the initial conditions or future episodes of perturbation. Under these conditions, the transition matrix can only be guessed and the predictions will be burdened by uncertainty.

CONJECTURE 2. *Recovery has characteristic chronological phases.* Initially, the changes are rapid and the compositional order of the successive vegetation states coincides with the chronological order (linear phase). As the process moves forward and unfolds without new perturbation, deceleration occurs. This is manifested in a Doppler type crowding of the states (see Table 1 and Fig. 4). The crowding inten-

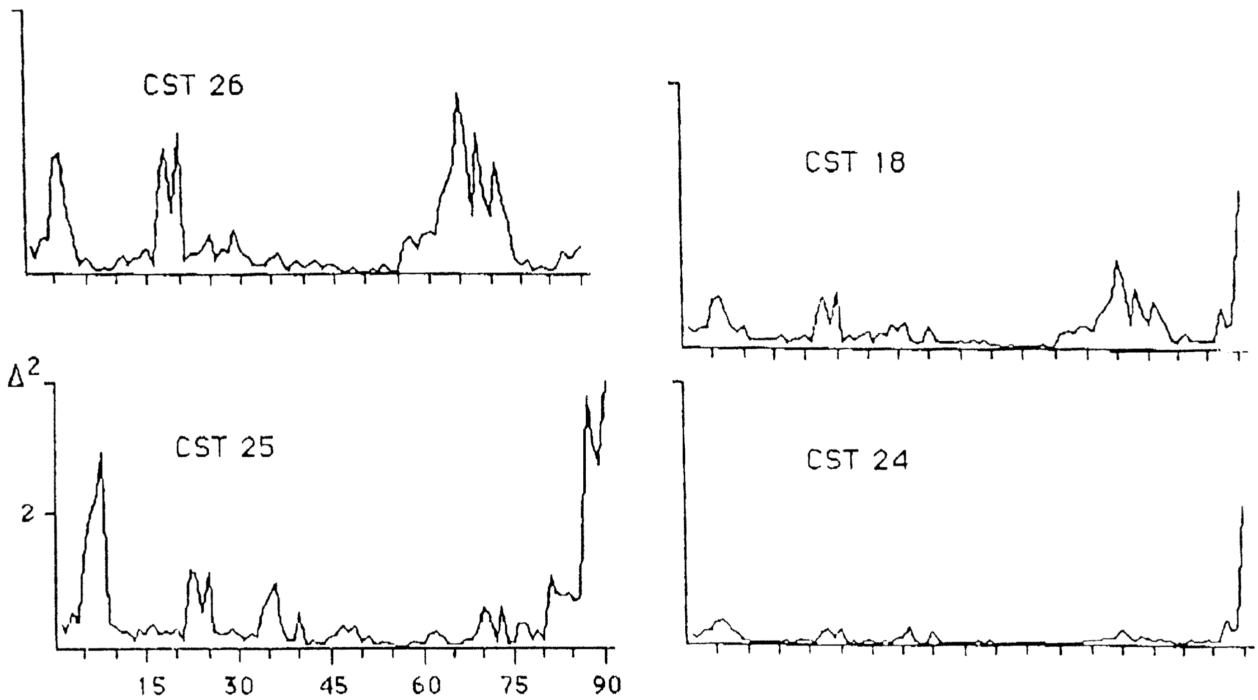

Figure 3. Selected population transect profiles for the Jornada transect (after Orlóci and Orlóci 1990). Populations are character set types (Orlóci 1991a) designated as CSTs. Profile construction follows the method described in Orlóci (1991c). Squared deviations from random expectation are plotted on the vertical axes in thousand data units. The tick marks on the horizontal axes identify transect segments as explained in Fig. 2. Since squared deviations are plotted, peaks may indicate under performance or over performance in the populations.

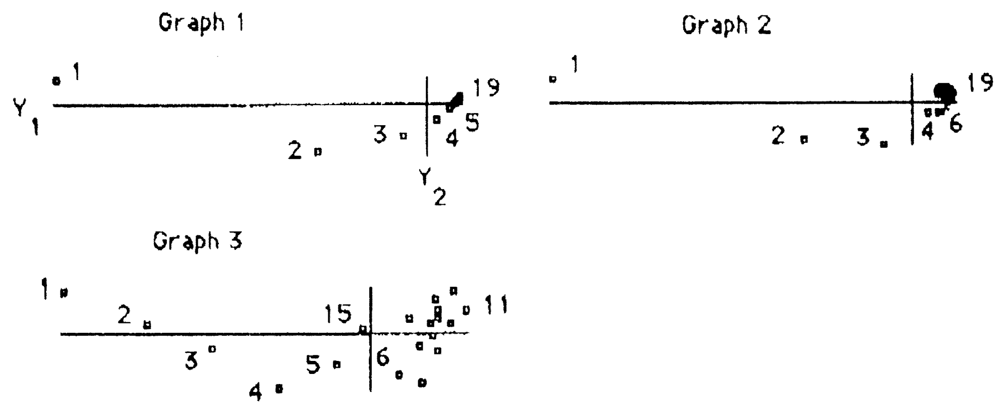

Figure 4. Ordination mappings of vegetation states (points 1 to 19) as recovery progresses and the steady state is approached. Graph 1 depicts the pure Markov process generated with transition probabilities from Lippe *et al.* (1985). Graph 2 shows the Markov process with 15% random variation superimposed. Interesting to note the perfect correspondence of chronological order (1 to 19) and the compositional order of the states in the pure Markov model and the loss of this after the 5th or so time step in the random-adjusted Markov model and in the natural process (Graph 3). The natural process carries the unmistakable signature of a 1st order, stationary Markov chain with some random variation superimposed.

sifies as the process approaches a steady state. At some point in time the compositional order of the states loses its simple relationship with the chronological order and the dynamics is reduces to low-level, chaotic compositional oscillations (non-linear phase). These signal that a steady state has been reached at the space-time scale of the observer.

CONJECTURE 3. *Recovery is a multiscale phenomenon.* The space-time scale constraints the process and its effect is hierarchical. The observer's perception depends on the time step and sampling unit size. Because of the scale effect, it is impossible to make generalizations about vegetation recovery from observations independently of the space-time scale.

CONJECTURE 4. *Vegetation edges and edges patterns evolve and their coincidences with environment edges and their pattern sharpens as community recovery approaches a steady state.* A vegetation edge is to be expected where an environmental edge exists. This principle is consistent with ecological theory. The converse, that a vegetation edge necessarily signals the presence of an environmental edge, is probably false. Furthermore, it is unlikely that a single type of edges pattern would exist throughout the entire recovery process. It is more likely that edges patterns evolve through scales, and stabilize as the steady state is approached. At that state the dynamics increases homogeneity between the edges and sharpens the differences across the edges. Significant perturbation may reverse this, so that homogeneity will increase across the edges and the edges become blurred.

CONJECTURE 5. *Recovery is a hierarchical process.* The basic entity that arrives, exists and goes extinct in a site is the plant individual. Dynamics in populations, their interactions and associations bind the community into a coherent unit. In these terms recovery is a convolution of hierarchical processes in which each level (individual, population, community) plays a role inseparable from any of the others.

The evidence

Scenarios

The approaches differ in their handling of the time element. In one scenario, the recovery process is reconstructed from direct observation of the process in nature. This emits true time-series data. If transect based, the records capture the true space-time dynamics of recovery at the chosen space-time scale. In another scenario, the reconstruction uses indirect evidence, such as compositional changes in a fossil-pollen profile, or concatenation of conditions observed in spatially isolated sites with vegetation in different stages of the same recovery process. For obvious reasons, the latter scenario is most common.

Sampling considerations

Traditional sampling methods are geared for estimation and they optimize the design to minimize the sampling error. This kind of optimality is largely irrelevant in pattern recognition and also in recovery studies whose objective is structure recognition. In these, the optimal sample should be a function of sample structure stability (Orlóci and Pillar 1989, Orlóci 1991a).

Vegetation description

Extrinsic and intrinsic taxonomic schemes are conventional. In the extrinsic scheme, plant populations

Table 2. Relevés from arid climate. Relevé 1 - Sonoran Desert (Avra Valley, Arizona). Relevé 2 - the Monte (Bolsón de Pipanaco, Catamarca). Reduced species lists are shown. The two sites have similar elevation, temperature and precipitation values and their soil characteristics are also similar.

Species	Relevé 1	C/A	Relevé 2	C/A
1	Acacia constricta	+	Acacia aroma	1
2	Cercidium floridum	+	Cercidium praecox	+
3	Cercidium microphyllum	2	Bulnesia retama	1
4	Cereus giganteus	2	Trichocereus terscheckii	+
5	Cylindropuntia fulgida	+	Cylindropuntia glomerata	+
6	Jatropha cardiophylla	+	Jatropha macrocarpa	+
7	Larrea tridentata	2	Larrea cuneifolia	2
8	Prosopis velutina	1	Prosopis chilensis	+
	etc.		etc.	

are recognized based on uniform inheritance, such as in the case of the taxonomic species. The species-based extrinsic scheme is optimal floristically. In the intrinsic scheme, the groupings are uniform with regard to the survival potential of the member plant individuals under the same type of environmental stress. This scheme is optimal ecologically, but it lacks sufficient floristic information. In the intersection scheme of Orlóci (1988a), the floristic and ecological information are balanced. In this scheme the plant taxa may be extrinsic, but they are rediscribed as Character Set Types (CSTs, Orlóci 1991b) based on an intrinsic character set[1].

The dominant descriptive scheme of phytosociology is typically extrinsic, species based, although intrinsic schemes which use life-form, growth-form and like characteristics, common in early vegetation descriptions (Humboldt 1806, Kerner von Marilaun 1864, Warming 1884, Raunkiaer 1907) and which Lacza and Fekete (1969, Fekete and Lacza 1970) reviewed, have sporadic applications in modern vegetation studies (Knight and Loucks 1969, Orshan 1989, Barkman 1988). The species based scheme emits Braun-Blanquet (1927) type relevés which are vectors of cover-abundance values. The columns in Table 2 and last row (C/A) in Table 3 are this kind. Note that in the Braun-Blanquet scheme the taxa are non overlapping, except in cases of mistaken identification. A sequential intrinsic scheme yields descriptor vectors such as in Knight and Loucks (1969) in which the taxa are delineated by plants possessing the same individual character state. Since several character states are involved, the Knight and Loucks taxa always overlap. If we combine the CSTs of Table 2 into groups according to individual character states and gave an estimate of performance for each group, the resulting vector would be similar to the Knight and Loucks relevé. The intersection scheme produce score matrix relevés of which Table 3 is an example. The score matrix relevé is the most generalizable vegetation description, since it combines floristic information (CSTs), which by itself is local, with life-form, growth- form and other types of character based information, which are global.

Table 2 gives the relevés of two highly converged communities. The ecological inadequacy of the species based scheme is clear: although the communities score identically on the chosen characters (Table 3), they have different species lists (Table 2). Community level ecological equivalence of this type is measurable by use of score matrix relevés, but not on the basis of the species lists. The character set shown in Table 3 is an arbitrary sample. Future users may wish to select characters for their own purposes.

Analytical environment

The basic algorithm is two-parted. Ordination mappings of the transect, profiles of deviations, and profiles of angles and distances (Figs. 1,2,3) help to detect edges. The evolution of these is captured by projecting spatial edges on the time axes. Modeling produce predictions either of the Markov type or of a simulation type combined with evaluation of alternatives.

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1 Technical terms in this section follow usage in Orlóci and Orlóci (1985) and Orlóci (1988a,b, 1991a,b,c).

Table 3. Score matrix relevé of Sonoran Desert vegetation (relevé 1 in Table 2). The score matrix from the Bolsón de Pipanaco site (not given) is identical, except for minor differences in scores on dimension-related characters and cover-abundance (C/A) estimates.

Relevé no.: 1 Locality: Silver bell, Avra Valley, Arizona
Date: 89.12.05 Elevation: 1050 m Climate: 280 mm 19.5 °C Land type: Upper bajada
Soil type: Skeletal Soil texture: gravel/stone Exposure: SW Slope: 5% %bare ground: 80%
Vegetation type: Cereus-Cercidium-Simondsia-Franseria

	Character set type: (CSTs):							
	1	1	3	4	5	6	7	8
BIOLOGICAL TYPE 1. Type 1: bryoid, 2: lichen, 3: pt-ridophyte, 4: conifer, 5: graminoid, 6: cactoid, 7: other	7	7	7	6	6	7	7	7
STEM (stem-like structure) 2. Tissue type 1: succulent, 2: herbaceous, 3: woody, 4: no stem	3	3	3	1	1	1	3	3
3. Function 1: regular, 2: twin-purpose, 3: no stem	1	2	2	2	2	1	1	1
4. Armature type 1: thorn/spine, other vestitures, 2: none, 3: no stem	2	2	1	1	1	2	2	1
Plant growth form 5. See rowth form code inkey	2	2	2	19	18	6	7	2
LEAF (leaflet, leaf-like structured) 6. Duration 1: aseasonal deciduous, 2: seasonal deciduous, 3: withering, 4: persistent, 5: aphyllous	2	1	2	5	5	2	4	2
7. Tissue type 1: succulent, 2: herbaceous, 3: fibroid/leathery, 4: aphyllous	2	2	2	4	4	2	3	2
8. Type 1: scale, 2: filiform/neadl, 3: other, 4: aphyllous	3	2	3	4	4	3	3	3
9. Arrangement 1: simple, 2: compound, 3: aphyllous	2	2	2	3	3	1	2	2
10. Epidermal surface 1: glabrous, 2: gloucous, 3: trichomous, 4: aphyllous	3	3	3	4	4	1	3	3
11. Width 1: <2.5 mm, 2: 2.5-5, 3: 5-10, 4: 10-50, 5: 50-100, 6: 100<, 7: aphyllous	2	2	1	7	7	4	2	1
12. Length 1: <5 mm, 2: 5-25, 3: 25-75, 4: 75-125, 5: 125<, 6: aphyllous	2	2	1	6	6	3	1	2
13. Thickness 1: <1 mm, 2: 1-3, 3: 3-5, 4: 5<, 5: aphyllous	1	1	1	5	5	1	1	1
Plant height 14. Height class 1: <5 cm, 2: 5-25, 3: 25-75, 4: 75-125, 5: 125-250, 6: 250-500, 7: 500-1000, 8: >1000	6	6	6	7	5	3	4	5
C/A	+	+	2	2	+	+	2	1

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