Waves of Evolutionary Activity of Alleles in Packard's Scatter Model

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The document contains fourteen pictures of waves of evolutionary activity created by alleles in the sensory-motor strategies of agents in Packard's Scatter model.[1] The quality of these waves indicate different kinds of evolutionary phenomena involving significant adaptations in sensory-motor rules. The purpose of this document is only to *depict* a variety of kinds of evolutionary phenomena, not to *explain* those phenomena (a job for another occasion). The following papers contain more background on evolutionary activity waves and Packard's Scatter model:

1. Bedau, M. A. and N. H. Packard. 1992. Measurement of evolutionary activity, teleology, and life. In C. Langton, C. Taylor, J. D. Farmer, S. Rasmussen, eds., *Artificial Life II* (pp. 431–461). Redwood City, Calif.: Addison-Wesley.

2. Bedau, M. A., S. Snyder, N. H. Packard. 1998. A classification of long-term evolutionary dynamics. In C. Adami, R. K. Belew, H. Kitano, and C. E. Taylor, eds., *Artificial Life VI* (pp. 228–237). Cambridge, Mass.: MIT Press. Available on the web through www.reed.edu/˜mab/papers.html.

3. Bedau, M. A., and C. Titus Brown. 1999. Visualizing evolutionary activity of genotypes. *Artificial Life* 5 (1999): 17-35. Available on the web through www.reed.edu/˜mab/papers.html.

4. Bedau, M. A., S. Joshi, and B. Lillie. 1999. Visualizing waves of evolutionary activity of alleles. To appear in *Proceedings of the GECCO-99 Workshop on Evolutionary Computation Visualization*. Available on the web through www.reed.edu/˜mab/papers.html.

[1] *Technical note*: The activity values shown in the following figures are actually activity divided by 100.

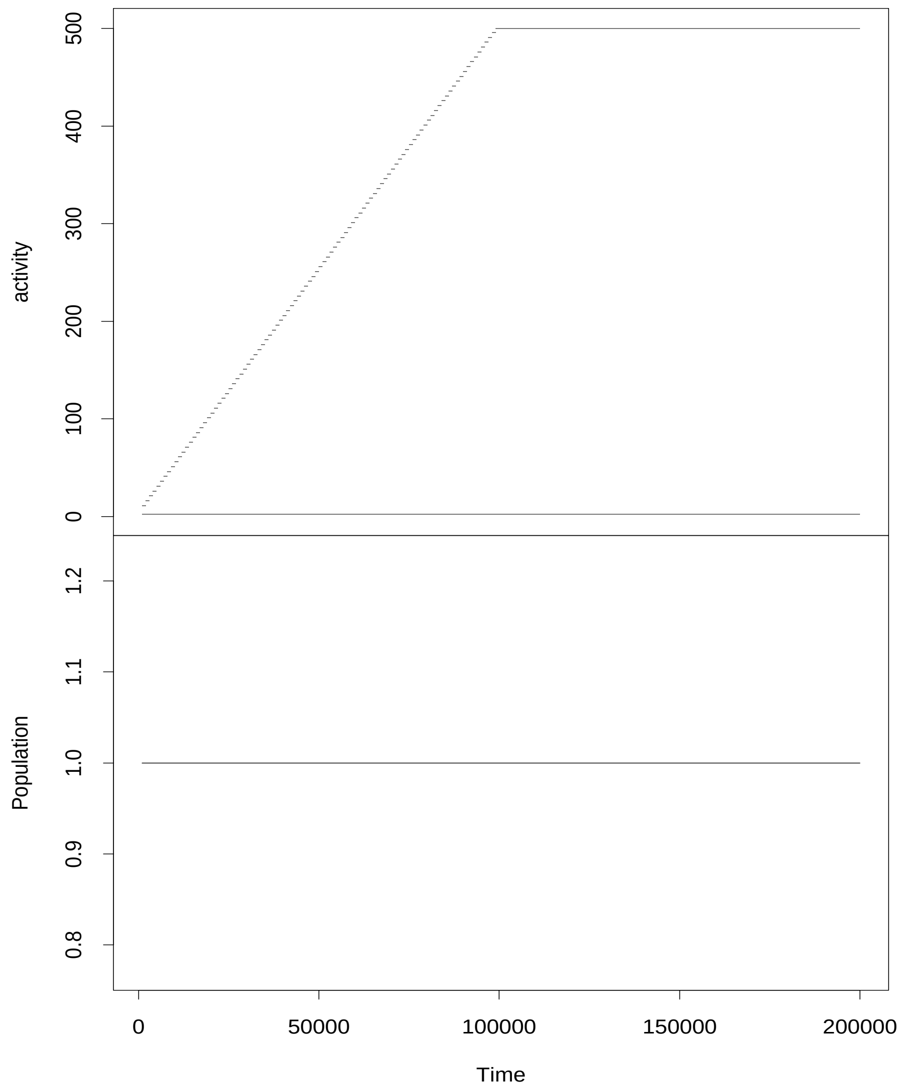

Figure 1: Allele activity waves and population level in scatter run 9.11. The single activity wave corresponds to the coordinated activity of two sensory-motor rules forming cyclic strategy of length two. Only one agent lives during the course of the entire run.

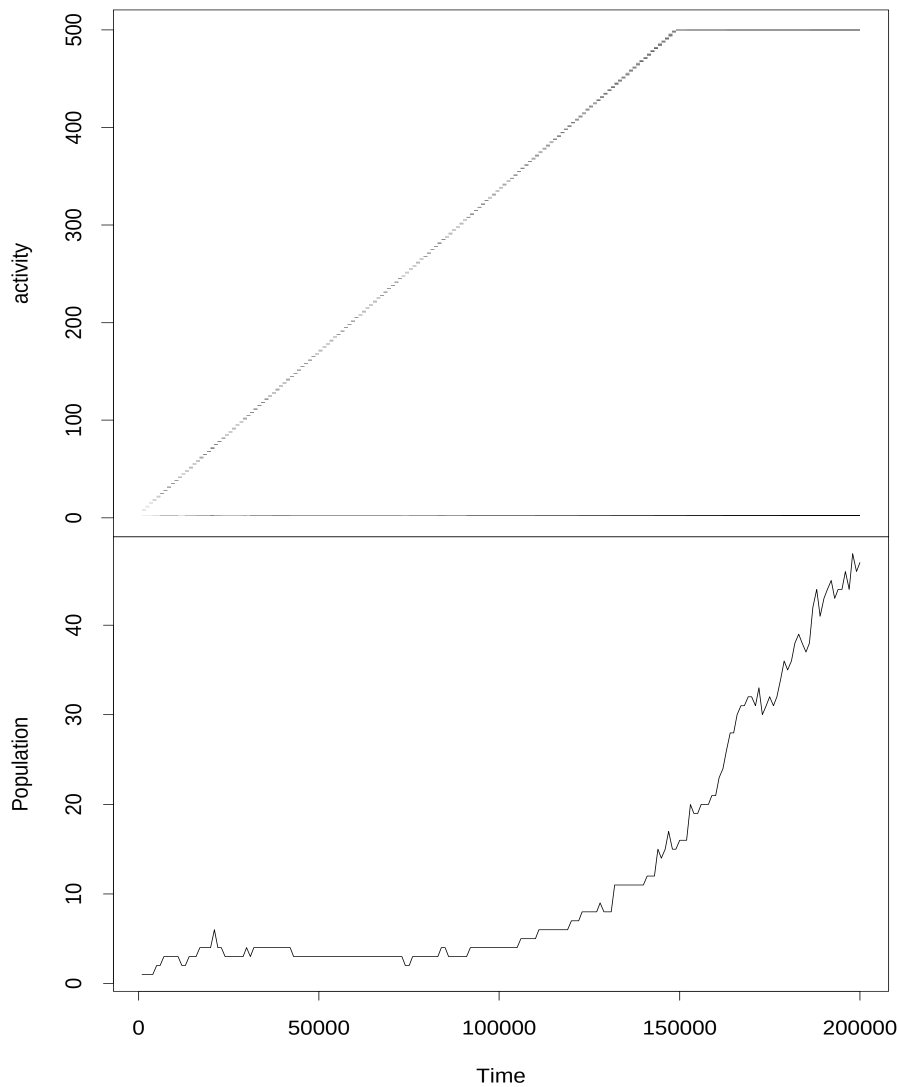

Figure 2: Allele activity waves and population level in scatter run 12.9. The single wave here is caused by the coordinated activity of three sensory-motor rules, forming a cyclic strategy of length three. Note that the population eventually explodes as the agents following this strategy reproduce and spread through the world.

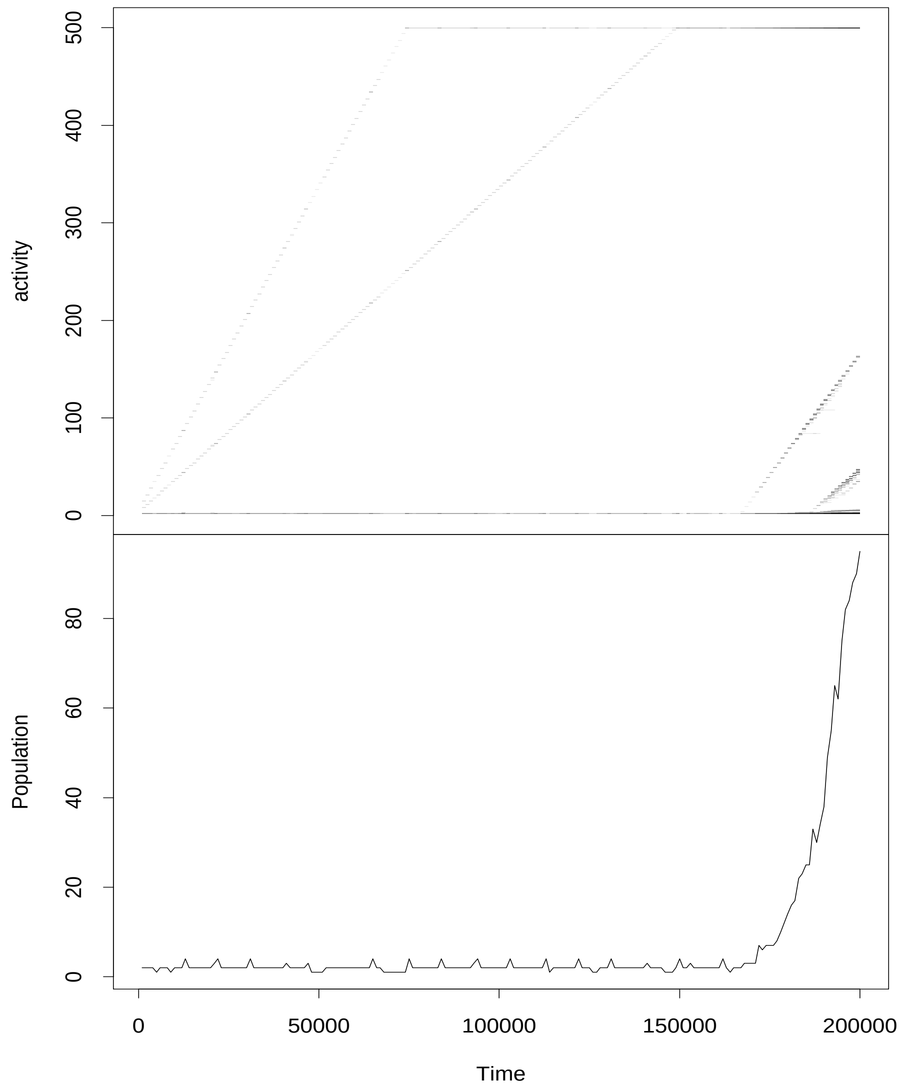

Figure 3: Allele activity waves and population level in scatter run 10.21. Note two simultaneous different slope activity waves in the initial population, indicating an "unbalanced" sensory-motor strategy with two rules being used with different frequencies. Here, it looks like the rules are being used with the relative frequencies of two thirds and one third. (Unbalanced strategy cycles can occur only when the little blocks in the Scatter model accidently overlap.) Note also two significant adaptive innovations at the end of the run, causing the population to explode.

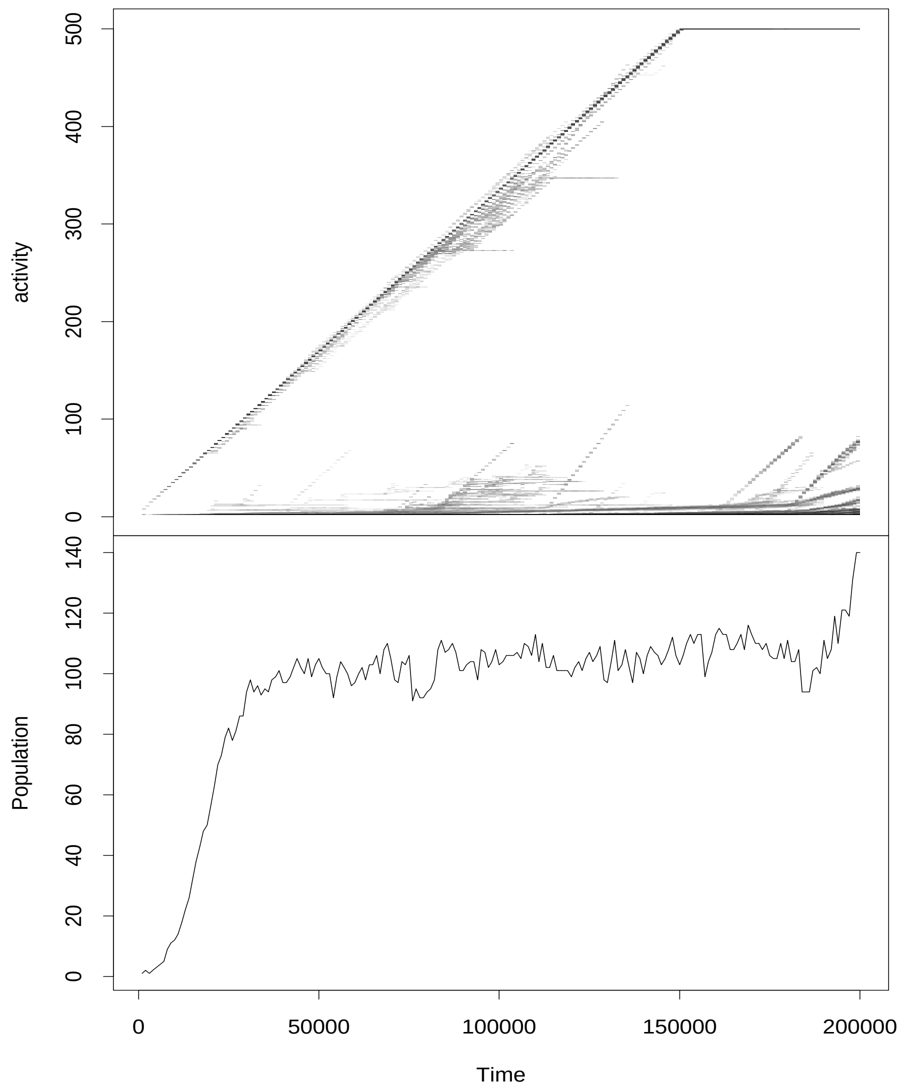

Figure 4: Allele activity waves and population level in scatter run 12.7. A strategy cycle of length three dominates the bulk of this run. Note that when the available space is filled (when the population reaches about 100) noise starts show up in the waves, as other rules get used from time to time.

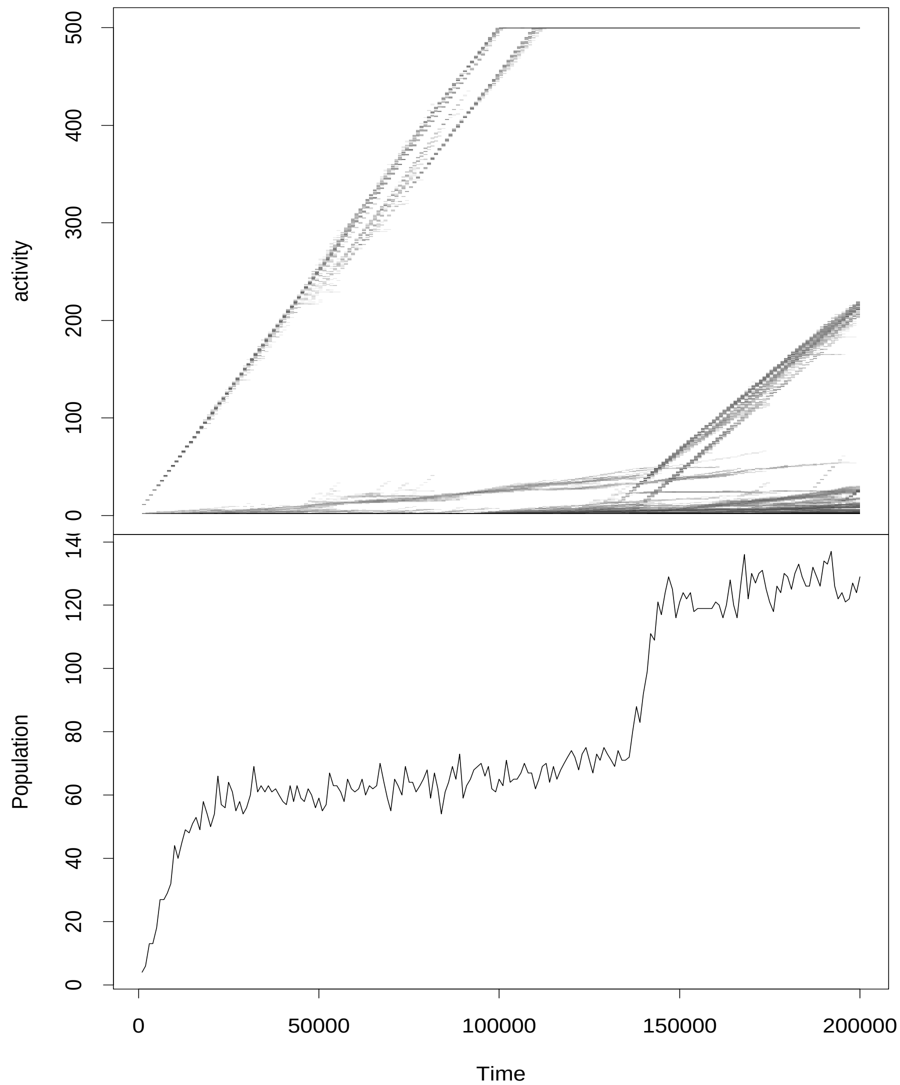

Figure 5: Allele activity waves and population level in scatter run 10.2. A strategy cycle of length two dominates the first two thirds of this run, but this strategy is replaced by a length-three cycle (an adaptive innovation). Notice also that when the space available for the length-two strategy becomes filled (when the population reaches about 60), a very low slope wave starts. One hypothesis for explaining this is that, when agents are accidently bumped into a certain cell (or cells) on the little block, they jump back into the two-rule strategy. Note also that the initial two-cycle wave splits in two.

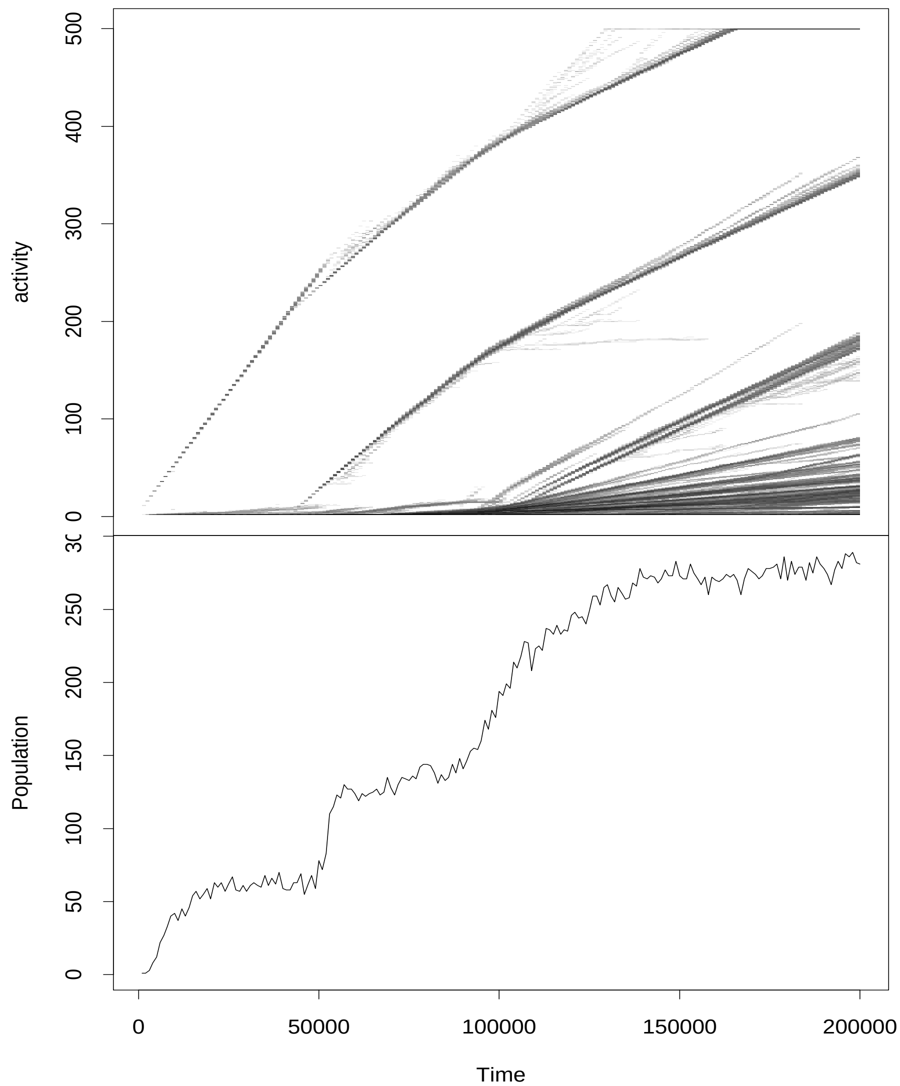

Figure 6: Allele activity waves and population level in scatter run 10.5. A classic example of a series of adaptive innovations due to lengthening the cycle length of sensory-motor strategies, described in the caption of Fig. 4 in Bedau, Joshi, and Lillie (1999). The first wave corresponds to a two-cycle. The second wave corresponds to an innovation which transforms the two-cycle into a three-cycle (and incorporates one of the rules in the two-cycle, hence extending the initial wave). By the same sort of mechanism, the third wave corresponds to an innovation which turns the three-cycle into a four-cycle, but this is quickly followed by another innovation turning the four-cycle into a five-cycle strategy. Evolution from one one cycle structure to the next is clearly shown by the kinks in the activity waves.

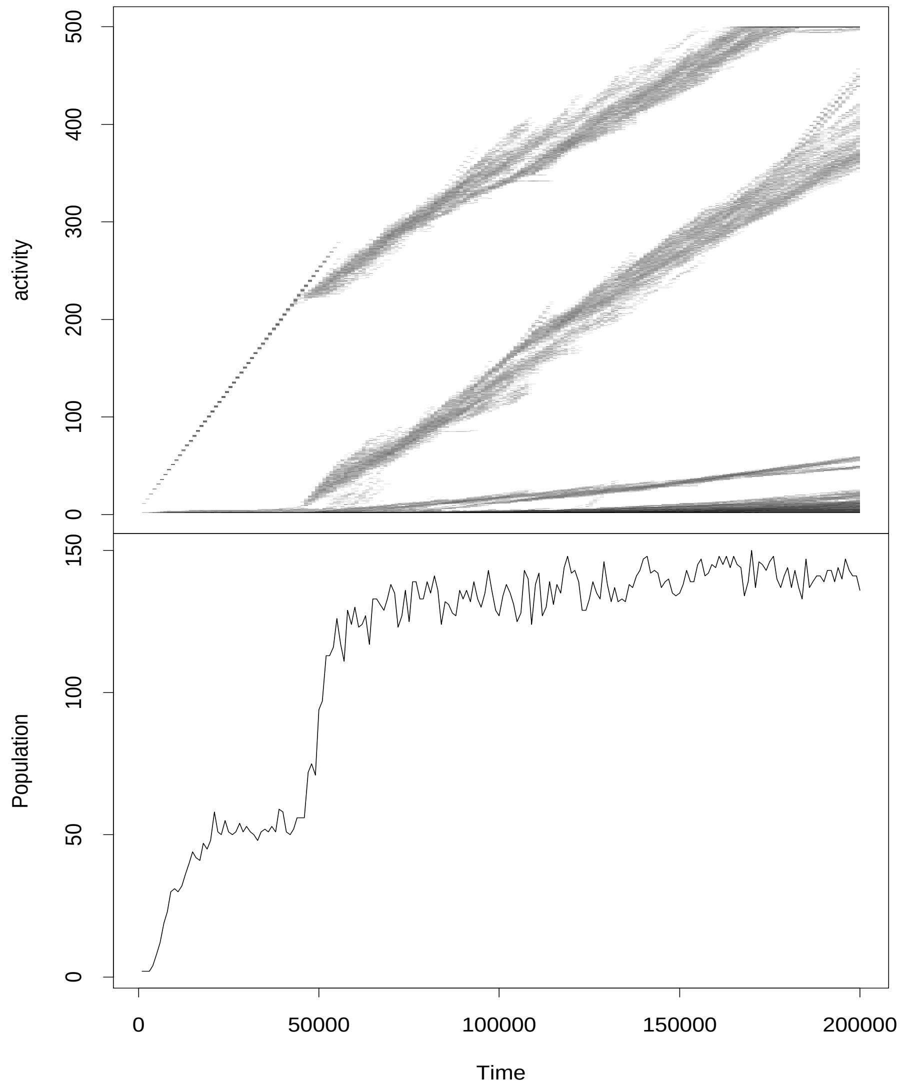

Figure 7: Allele activity waves and population level in scatter run 10.9. A length-two strategy cycle is replaced by the innovation of a second compatible length-two cycle. From that point on, the population intermittently switches between those two two-cycles, causing a characteristic "fuzzy" activity wave. For more details, see Fig. 5 in Bedau, Joshi, and Lillie (1999).

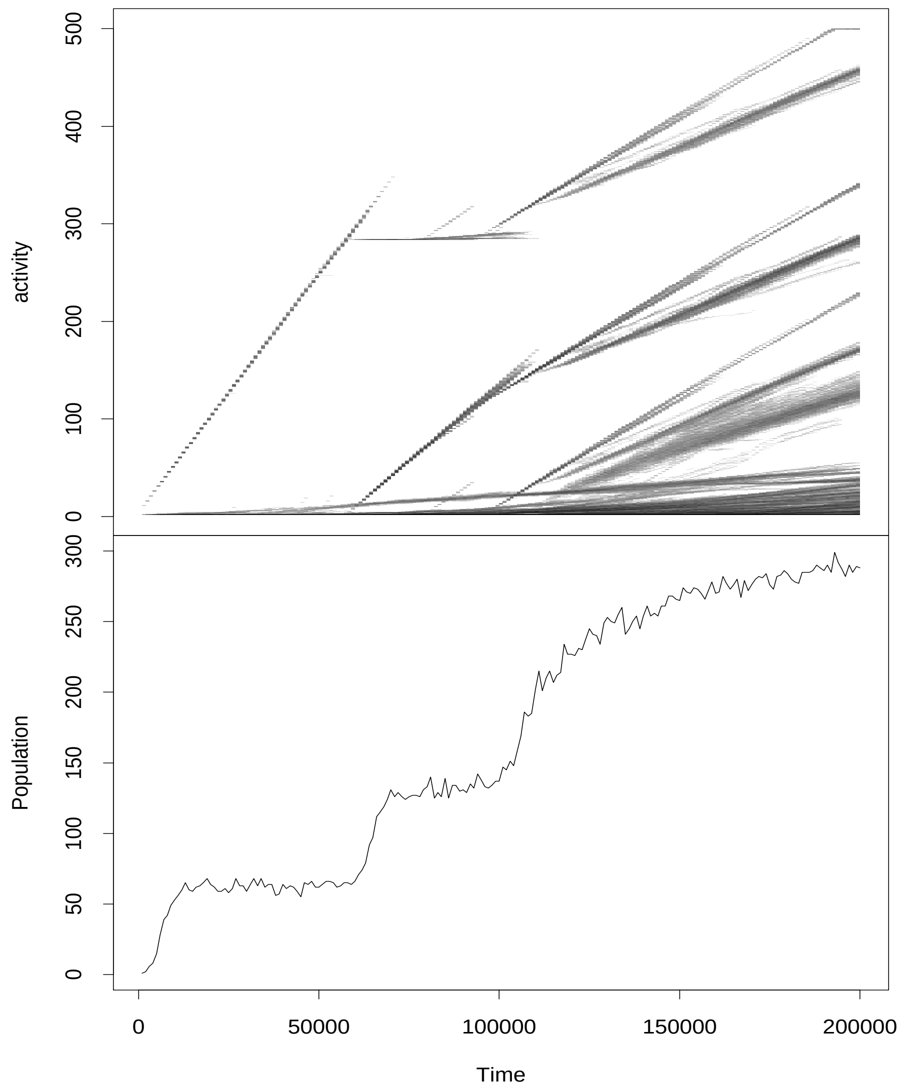

Figure 8: Allele activity waves and population level in scatter run 10.30. A two-rule strategy cycle is replaced by a three-rule strategy cycle, but in this case the three-cycle does *not* use either rule in the two-cycle. This causes one of the two-cycle rules to cease being used, leaving the signature horizontal wave of a "vestigial" rule. For more details, see Fig. 4 in Bedau, Joshi, and Lillie (1999). (The other two-cycle rule was replaced through mutation with a rule in the three-rule strategy.) Later, this vestigial rules becomes reincorporated into a four-rule strategy cycle via a new mutation. Note also that this four-cycle shortly comes to co-exist with a five-rule strategy cycle, indicated by the fork in the three persisting waves.

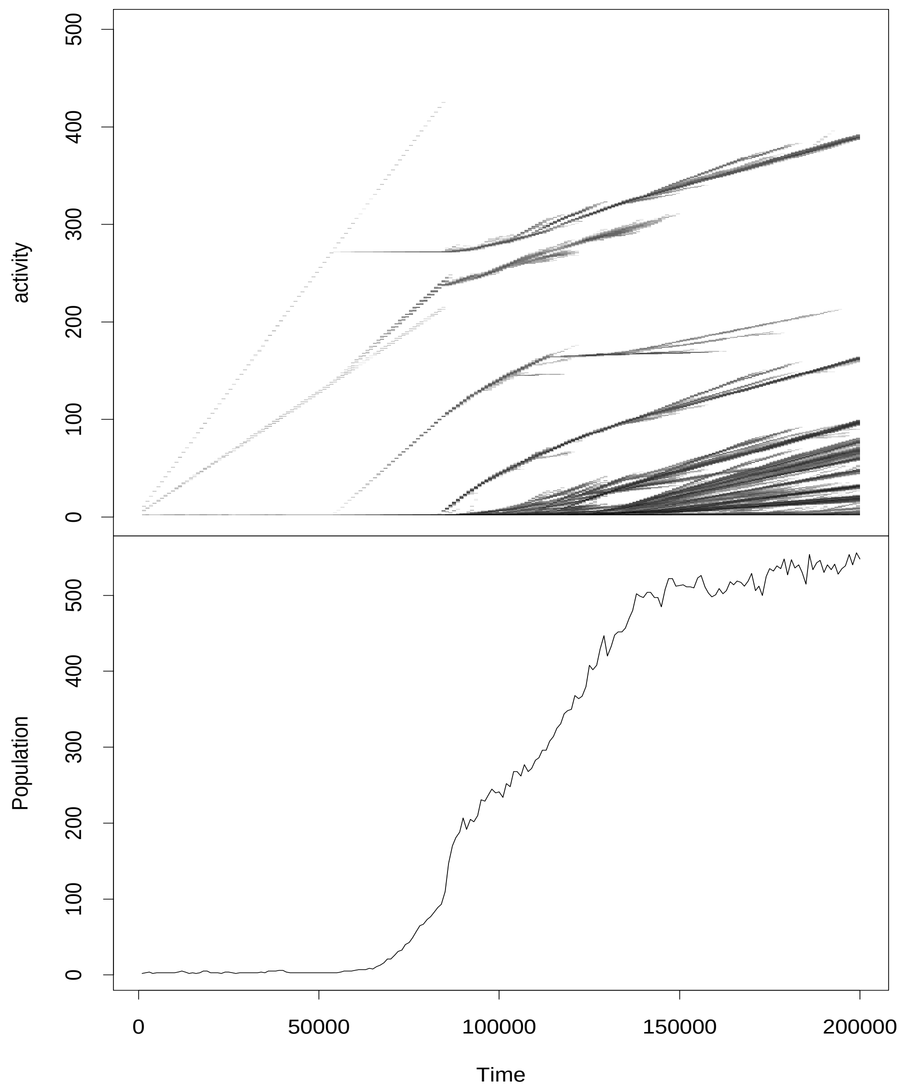

Figure 9: Allele activity waves and population level in scatter run 12.10. A complex combination of many of the phenomena identified in earlier figures.

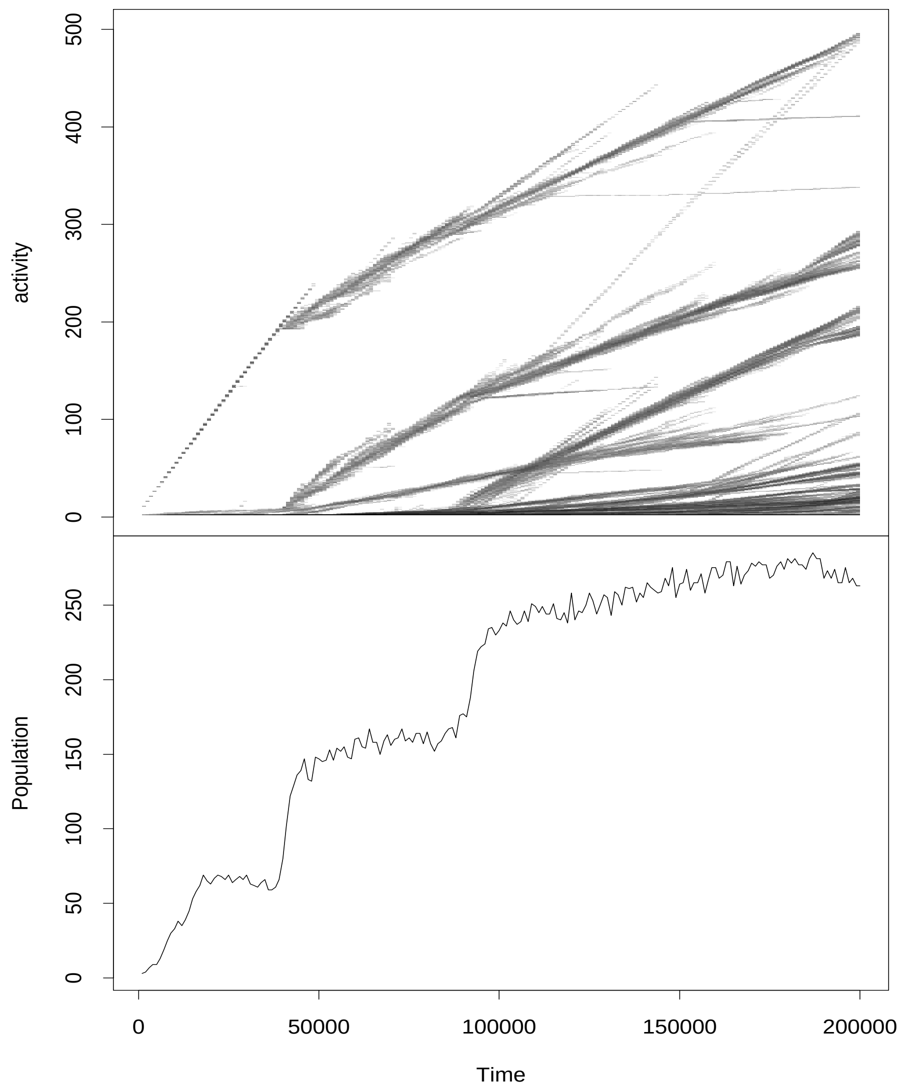

Figure 10: Allele activity waves and population level in scatter run 8.15. A complex combination of many of the phenomena identified in earlier figures.

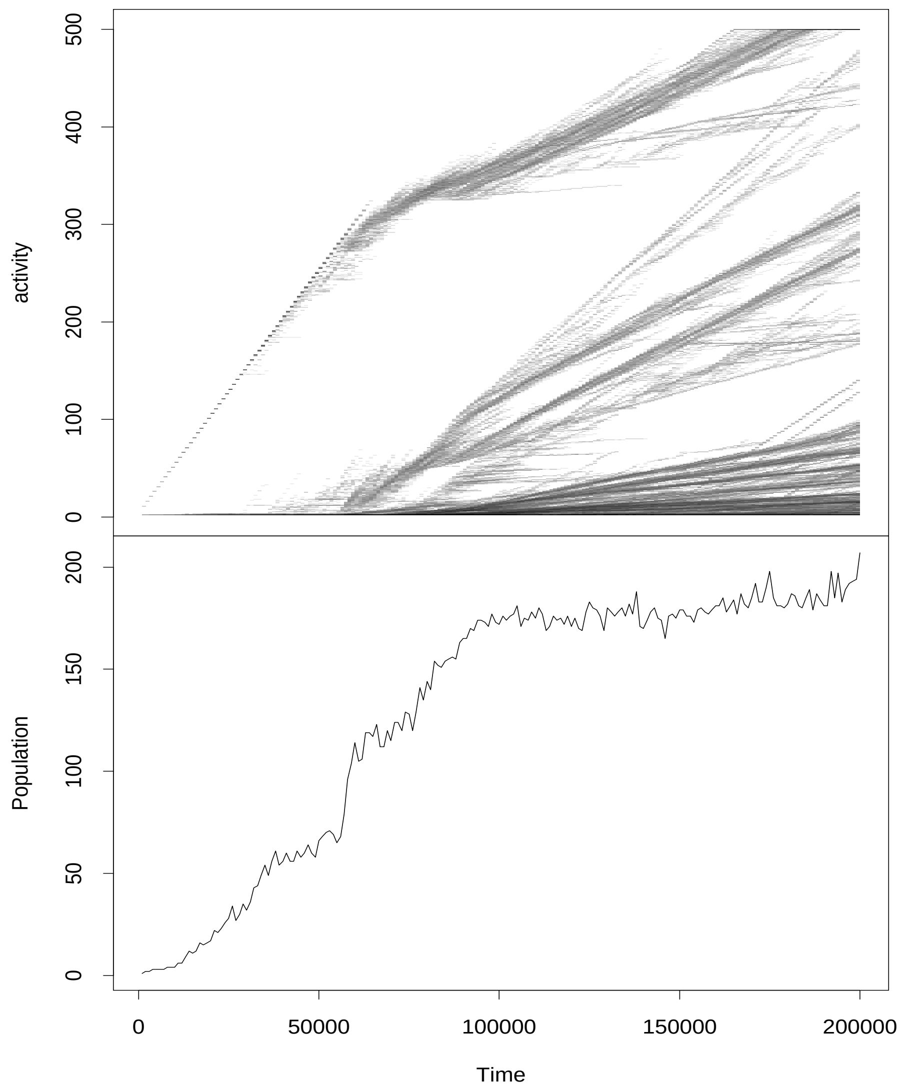

Figure 11: Allele activity waves and population level in scatter run 11.30. A complex combination of many of the phenomena identified in earlier figures.

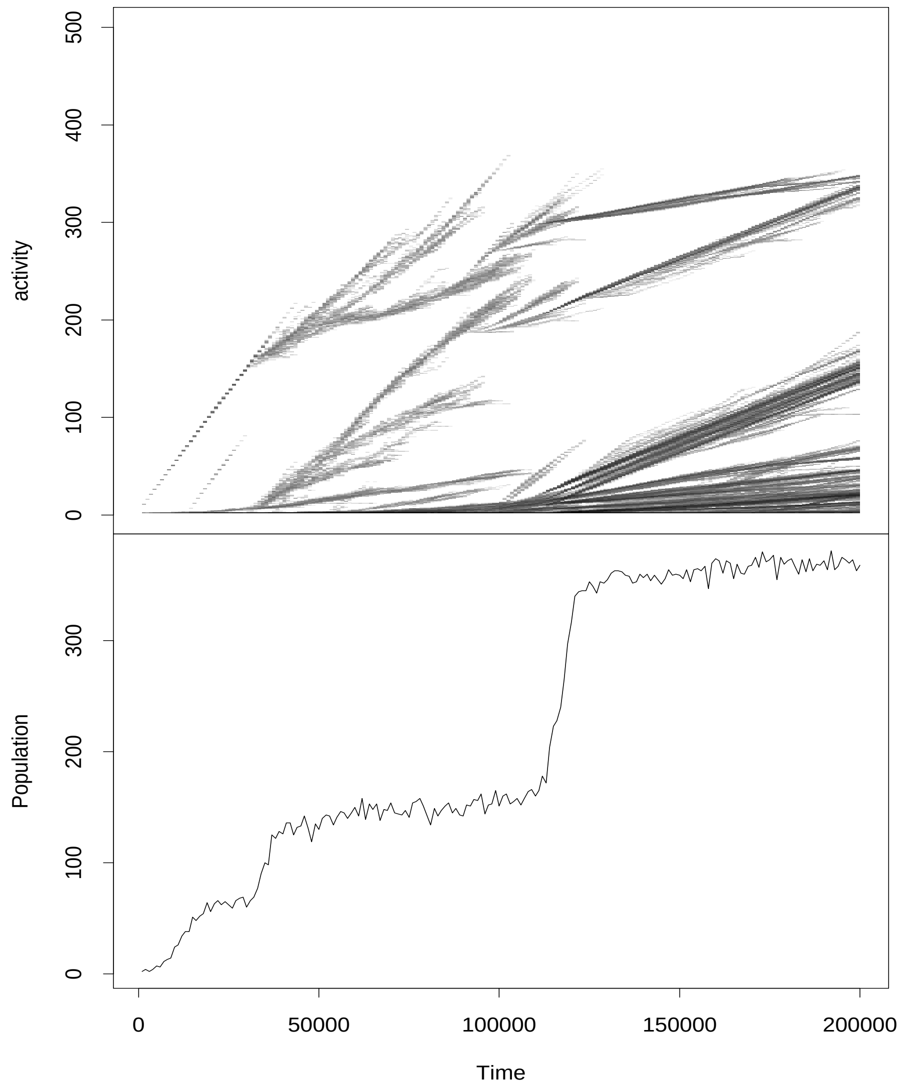

Figure 12: Allele activity waves and population level in scatter run 11.6. A complex combination of many of the phenomena identified in earlier figures.

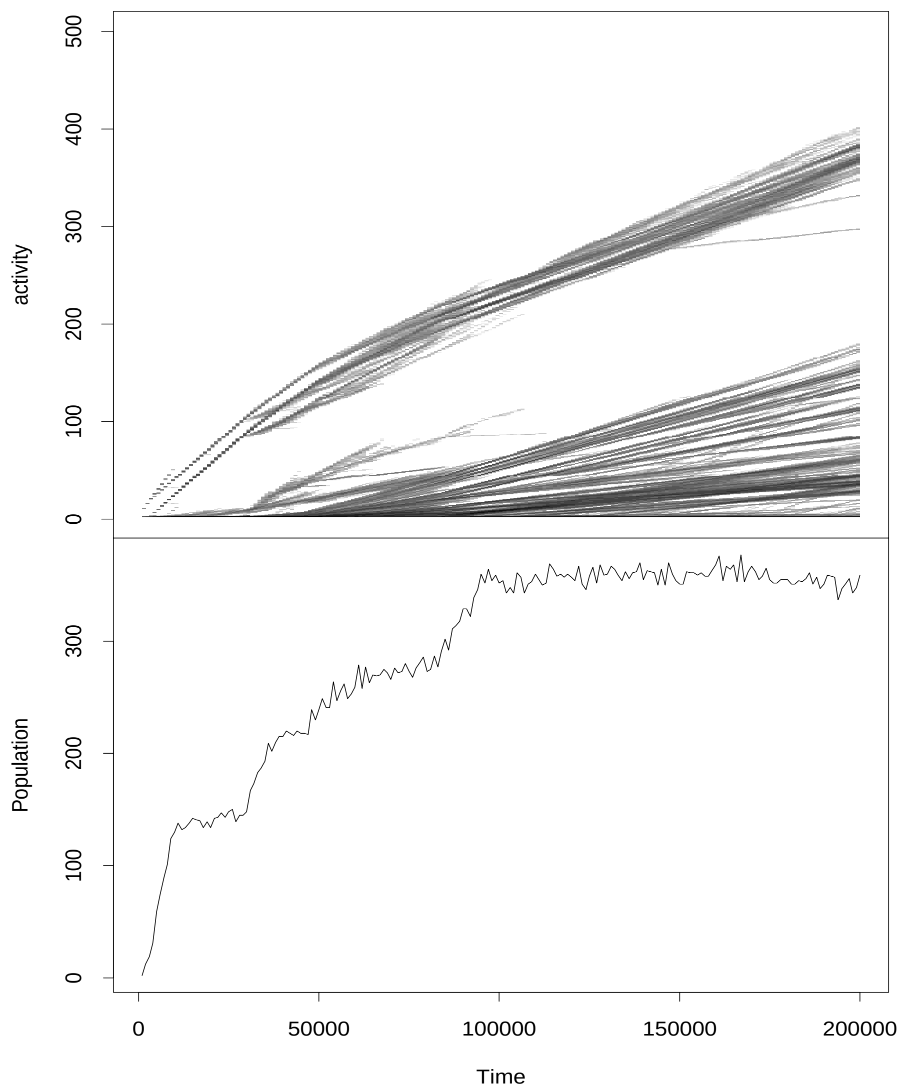

Figure 13: Allele activity waves and population level in scatter run 8.5. Note the parallel waves exhibiting parallel phenomena. Note also the vast number of different waves at different slopes starting about one quarter of the way through the run.

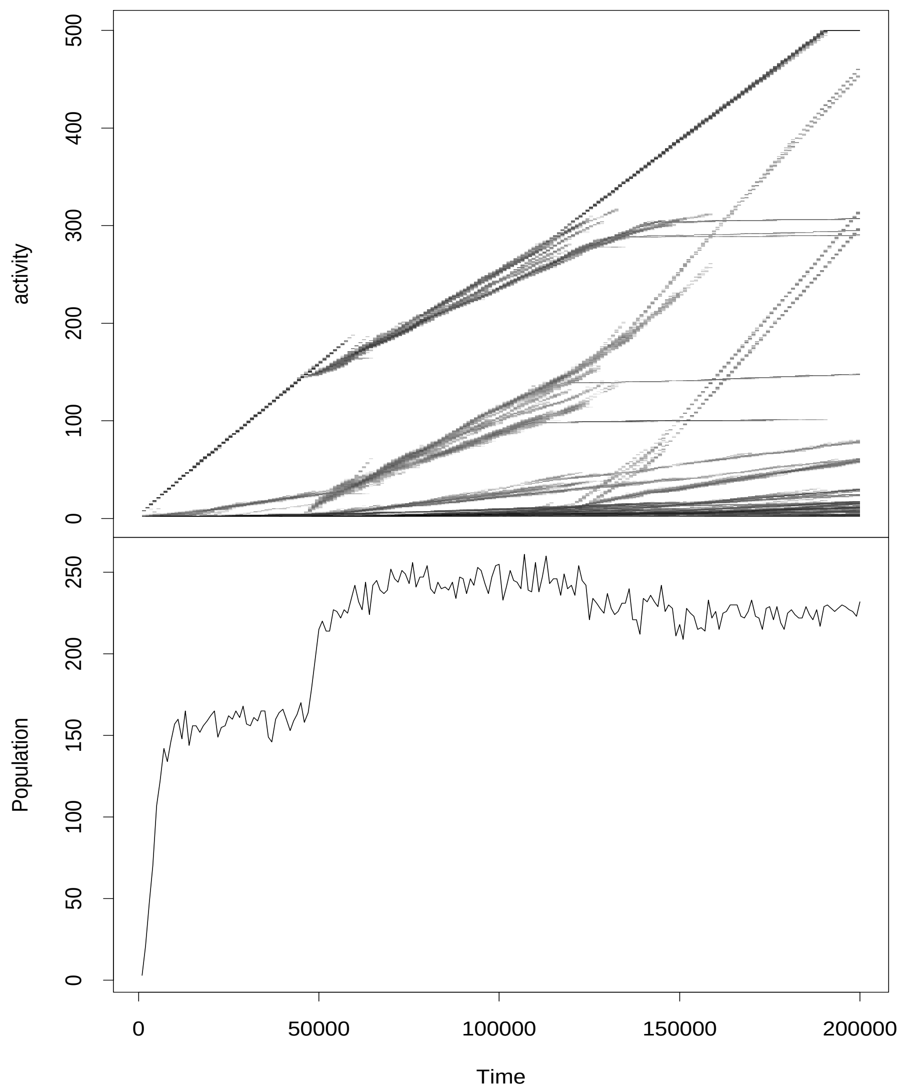

Figure 14: Allele activity waves and population level in scatter run 15.13. A rare example of *shortening* the length of a strategy cycle, when the slope of activity waves increase.