Figures

2.1 Dynamics of the logistic map 36
2.2 Alternative logistic map 37
2.3 Continuous logistic model 38
2.4 The carrying capacity and intraspecific competition as distribution functions 46
3.1 The prisoner's dilemma 67
3.2 The game of chicken 68
3.3 The ecological theater and evolutionary play 75
5.1 The species with highest carrying capacity survives 114
5.2 The "star" locates the strategy at the equilibrium value for x^* 115
5.3 Strategy dynamics on the adaptive landscape for the Lotka–Volterra model with $\sigma_k^2 = 4$ 128
5.4 With $\sigma_k^2 = 12.5$ and $n = 1$, strategy dynamics produces an equilibrium point that is a local minimum 129
5.5 With $n = 2$, strategy dynamics allows for speciation 130
5.6 Low-speed strategy dynamics results in an equilibrium solution 131
5.7 High-speed strategy dynamics results in unstable Darwinian dynamics 132
5.8 With $r = 2.5$, strategy dynamics results in an equilibrium solution for u_1 and a four cycle solution for density 146
5.9 Increasing $r = 2.8$ results in a chaotic solution for the population density 146
6.1 The fitness set, depicted here by the interior of the top shaped region, represents the fitness in habitats A and B as a result of using every possible stratgy 155
6.2 The rational reaction set is given by the solid line 158
6.3 An ESS coalition of two under chaotic density dynamics 192

6.4 When the ESS is strongly dependent on $\mathbf{x}$, the strategy dynamics will also cycle 194
6.5 At a slower rate of evolution, the strategy dynamics becomes smoother 194
6.6 An ESS under non-equilibrium dynamics 195
7.1 At an ESS, $G^*(v)$ must take on a global maximum when $v = u_1$ 201
7.2 A convergent stable system will return to $\mathbf{x}^*$ when $\mathbf{u} = \mathbf{u}_c$ 202
7.3 The solution obtained does not satisfy the ESS maximum principle 203
7.4 An ESS coalition of two strategies as indicated by the open box and asterix 204
7.5 An ESS coalition of one strategy. Regardless of the number of starting species or their initial strategy values, Darwinian dynamics results in the single-strategy ESS 207
7.6 Decreasing the prey's niche breadth from that of Figure 7.5 changes the outcome. When the system is constrained to have a single species, then, regardless of initial conditions, it evolves to a local maximum. This single-species strategy is not an ESS 209
7.7 Darwinian dynamics results in ESS when the system starts with two or more species with sufficiently distinct initial strategy values. However, not all starting conditions need produce this result. For some starting conditions (with two or more species) the system will converge on the single, local, non-ESS peak of Figure 7.6 210
7.8 Adaptive landscape for Bergmann's rule G-function. Because only a positive body size is allowed $G(v, \mathbf{u}^*, \mathbf{x}^*, y^*)$ has a unique maximum 213
7.9 Using $\sigma_b^2 = 10$ results in an ESS coalition with one prey and one predator. There is an illusion that the landscape for the prey dips. It is actually a true maximum as is the predator 216
7.10 Using $\sigma_b^2 = 4$ results in an ESS coalition with one prey and two predators 217
7.11 Using $\sigma_b^2 = 1$ results in an ESS coalition with two prey and two predators 217
7.12 Using $\sigma_b^2 = 0.75$ results in an ESS coalition with three prey and two predators 218
7.13 An ESS coalition of two strategies as indicated by the circle and asterisk 221

7.14 A case where Darwinian dynamics does not result in an ESS solution 221
7.15 A multistage ESS coalition of one strategy 225
7.16 The ecological cycle in this case is a 4-cycle 228
7.17 The adaptive landscape at each of the four points of an ecological cycle. The time step and the value of the G-function at each peak are noted at the top of each graph 228
7.18 A plot of the adaptive landscape at each point of the 4-cycle 229
8.1 Adaptive dynamics can result in a stable minimum that is not an ESS 238
8.2 Using a narrow distribution of strategies about the archetype results in the clumping of strategies at the ends of the distribution 238
8.3 A wider distribution of strategies results in a clumping in the vicinity of the archetype as well as at the left end of the distribution 239
8.4 The two species are at evolutionarily stable maxima but they do not compose an ESS 240
8.5 In this case the strategies clump about a two species archetype denoted by the diamonds 241
8.6 The three-species ESS 241
8.7 By choosing a proper interval for the distribution of strategies, clumping is obtained around a three species archetype that together form an ESS 242
8.8 As the mean strategy approaches the ESS, the variance narrows 244
8.9 Shortly after the simulation starts, only those strategies in the neighborhood of the ESS have a positive fitness 245
8.10 The mean strategy changes with time in a fashion similar to that obtained using strategy dynamics with $\sigma^2 = 0.001$ 246
8.11 A clump of strategies evolves to the ESS 248
8.12 As time goes on, the clump of strategies straddles the ESS as given by $u_1 = 0.6065$ 248
8.13 After reaching the species archetype, the clump of strategies becomes a bimodal distribution 250
8.14 How the clump of strategies approaches the species archetype 250
8.15 With $m = 0.1$ the ESS is a coalition of one strategy 255
8.16 With $m = 0.005$ a single strategy evolves to a local minimum on the adaptive landscape 255
8.17 With $m = 0.005$ the ESS is a coalition of two strategies 256

8.18 Decreasing σ_k^2 can also result in an ESS coalition of two strategies 257
8.19 The four species resulting from the two environmental conditions (E_1 to the left and E_2 to the right). Each figure shows the two co-existing species that have evolved to evolutionarily stable maxima 259
8.20 An adaptive radiation towards a five-species ESS. Sympatric speciation carries the system from a single species up to four species that converge on non-ESS evolutionarily stable maxima 262
8.21 An ESS coalition of five strategies for the Lotka–Volterra competition model 263
8.22 The adaptive radiation of the predator–prey model from a single prey and a single predator species to a non-ESS community of two prey and two predator species 267
9.1 The strategy $\mathbf{u}_1$ is a matrix-ESS 289
9.2 The adaptive landscape is linear for the bi-linear game 289
9.3 A coalition of two pure strategies exists for the game of chicken 291
9.4 The function $G(\mathbf{v}, \mathbf{u}, \mathbf{p}^*)$ takes on a proper maximum at $v = 0.5469$ 297
9.5 The matrix-ESS solution produces the maximum number of children 301
10.1 The solid line represents the fitness in habitat 1 and the curved dashed line the fitness in habitat 2. When the density reaches a level such that the two fitnesses are equal (designated by the square), any further increase in density is divided between the two habitats 307
10.2 The solution obtained in the previous example is found to be convergent stable 314
10.3 The solution obtained satisfies the ESS maximum principle 314
10.4 Strategy dynamics results in an ESS coalition of two strategies 316
10.5 The solution obtained satisfies the ESS maximum principle 317
10.6 When $R < mK_m$ equilibrium C is evolutionarily stable (left panel). When $R > mK_m$ equilibrium B is evolutionarily unstable (right panel) 320
10.7 After two years the cancer cells have evolved to a maximum on the adaptive landscape 323
10.8 After evolutionary constraints have been removed, cancer develops rapidly in the first year 324

11.1 The first panel is the adaptive landscape for the Schaeffer model with no harvest ($E = 0$). The second and third panels illustrate how the adaptive landscape changes with size-restricted harvesting both before and after speciation 357
11.2 Before treatment, the cancer cells are at a local maximum on the adaptive landscape 361
11.3 During treatment the cancer cells evolve to a new, more deadly strategy 362
11.4 After treatment, the cancer cells are again at a local maximum on the adaptive landscape 362