THE CRICKET AND THE ANT:
ORGANIZATIONAL TRADE-OFFS IN CHANGING ENVIRONMENTS

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Abstract

Organizations face trade-offs when they adopt strategies in changing resource environments. The type of trade-off depends on the type of resource change. This paper offers an organizational trade-off theory for quantitative resource changes. We call it the “Cricket and Ant” (CA) theory, because the pertaining strategies resemble the cricket and ant’s behavior in La Fontaine’s famous fable. We derive theorems in this CA theory in First Order Logic, which we also use to demonstrate that two theory fragments of organizational ecology, i.e., niche width theory and propagation strategy theory, obtain as variant cases of CA; their predictions on environmental selection preferences derive as theorems once their respective boundary conditions are represented in the formal machinery.

Organizations, of which even the "fittest" have limited adaptive capabilities and bounded rationality, face the difficulty of having to align with their environment, which in its turn changes continually and is often unpredictable in the longer run. To cope with this problem, organizations adopt strategies, which, given environmental uncertainties and organizational constraints, impose trade-offs. Since organizations can't be proficient at everything, when their environment changes they face a risk of environmental mal-alignment. Organizational ecology, inspired by biological models (Levins 1968), provides a framework for systematic treatment of these trade-offs from a dynamic perspective (Hannan and Freeman 1977). Ecologists study trade-offs from an environmental selection point of view, at the population level. They noticed that an alignment strategy has long-lasting consequences for an organization, because attempts at subsequent strategy changes are severely hindered by *structural inertia* (Hannan and Freeman 1984; Hannan, Pólos and Carroll, 2004). Organizations can be proficient, but they can't readily adapt their potential capabilities when the environment changes, so they might get stuck with an obsolete strategy that was once beneficial.

In organizational ecology, the environment is modeled as a (changing) combination of resources. Different types of trade-offs are then contingent upon different types of environmental change. A first trade-off ecologists studied was either being a *generalist* and moderately efficient at handling diverse resource combinations, or being a *specialist* and being proficient at dealing with one resource combination, but running the risk of failure in case of environmental change (niche width theory, Hannan and Freeman 1977). A second trade-off was either being able to enter new markets (resource combinations) quickly, as a *first mover*, at the expense of being less efficient like the generalist in the former case, or developing efficient organizational routines, and enter the market later as an *efficient producer* (propagation strategy theory, Brittain and Freeman 1980). Each of these two trade-offs has been treated in a theory fragment of organizational ecology, but these two fragments are yet unrelated. A third trade-off, which we want to develop here and is not yet covered by ecological theory, is either reaping as many as possible short term benefits from a beneficial resource period, without creating provisions for adverse times, or to invest in social capital, by developing durable network contacts and supportive institutions to create more favorable conditions when resources become sparse.

These three trade-offs are clearly different, but also seem to have things in common. If we would now attempt to develop a common framework in natural language only, though, we would, as Charles Peirce said, have to "wallow helplessly in a rich mud of conceptions" (Peirce 1878). Thus we follow his suggestion on "how to make our ideas clear," and resort to formal logic to increase rigor and precision. Logic has been applied successfully to fragments of organizational ecology and numerous other theories (Péli et al., 1994; Huang, Masuch and Pólos, 1996; Kamps and Pólos 1999; Péli, Pólos and Hannan, 2000; Vermeulen and Bruggeman 2001; Pólos, Hannan, and Carroll, 2001). In our treatment of organizational trade-offs, each formula will be accompanied by its natural language-counterpart.

A logical formalization consists of two alternating phases, (1) a rational reconstruction of a text or set of ideas, in which a core theory, its key concepts and its logical structure are being sharpened, anticipating (2) a formalization proper, wherein the core theory is represented in a formal language, and logical properties like consistency and soundness are rigorously checked (Bruggeman and Vermeulen 2002). We formalize in standard First

Order Logic, which is well-developed and widely applied (Kyburg 1968).[1] A theory in First Order Logic is consistent if it has at least one model in which all sentences of the theory are true; an inconsistent theory can't be interpreted in any model[2]. Once consistency is established, an automated theorem prover takes as input the negation of a theorem candidate and a set of premises from which it should follow logically. If the theorem prover finds a contradiction, the negated theorem is false, so the theorem is true. If this doesn't work (and typos have been removed), the formalizer is forced to improve the rational reconstruction, and subsequently *prove* the soundness and consistency of the improved theory.

Before starting our formalization, we explain the general conception of environmental change (Section 1), and present the three trade-offs in greater detail (Section 2). For the new Cricket and Ant trade-off, we rationally reconstruct our ideas (Section 3), and then

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[1] Other scholars use *non-monotonic logic*, an extension of First Order Logic (Pólos, Hannan and Carroll, 2001; Hannan, Carroll and Pólos, 2003). An advantage of non-monotonic logic is that it can deal with exceptions, by replacing the universal quantifier ("for all", ∀) by "normally," for empirical generalizations, or by "ad hoc," for model simplifications that aren't part of the substantive theory. Accordingly, conclusions drawn from a premise set containing such quantifiers lose their (potential) universally quantified status, because "for all" is replaced by "presumably". An important reason for us to use First Order Logic is that it can be handled by current theorem provers, whereas non-monotonic logic can't. Our formalization can be transformed into non-monotonic logic by appropriately substituting the above mentioned quantifiers for our universal quantifiers.

[2] A formal theory is a set of sentences in a formal language, such as First Order Logic, with an inference system; the set of sentences is closed under logical deduction, and its theorems are validly inferred from premises according to rules of inference. For sufficiently detailed but still easy to read textbooks on First Order Logic, the reader may consult Gamut (1991) or Barwise and Etchemendy (1990). Our theories have been checked by Otter and Mace, which are freely available on the Web (http://www-unix.mcs.anl.gov/AR/otter/).

formalize the new theory fragment (Section 4). The generalist-specialist theory and the first-mover-efficient-producer theory have been formalized in First Order Logic earlier. Here we will show that when one changes the instances of the actors in the Cricket and Ant theory, as well as the type of resource change, the two other theory fragments are obtained as variant cases (Sections 5 and 6). So our new theory fragment can also be regarded as a "switchboard" to other theory fragments. This is a step towards, although not yet a grand, unification. The main text finishes with a discussion (Section 7), while the technical details are deferred to the appendix.

1. ENVIRONMENTAL CHANGE

In organizational ecology, the environment is conceptualized as a configuration of resources, which a focal population of organizations might exploit. A resource configuration can be seen as a vector in resource space, in which the vector components tell the respective availabilities of the different resources. The resource space can be a socio-demographic space of n social characteristics (the so called Blau-space, McPherson 2003). Having political organizations, the resource space can be a political space of n issues along which voters position themselves (Downs 1957). In economic contexts, the resource space can be a Lancasterian commodity space where products are displayed by n scales along which customers take their preference positions (Lancaster 1966).

To simplify continuous changes of resources, ecologists approximate environmental dynamics by discrete patches, where each patch is a time period with one resource vector; to simplify further, the basic environmental model has two alternating patches, for example a summer and a winter season. Three parameters characterize the pattern of environmental change, *dissimilarity*, *variability* and *grain*. Their values are dichotomous (Figure 1), although their ranges, as well as the number of different patches, can be extended in order to cope with more complex patterns of change, closely approximating continuous change (Bruggeman and Ó Nualláin 2000). Environmental *dissimilarity* tells the magnitude of difference between the two (or more) patches. The bigger this difference, the more difficult it is for organizations to cope with both environmental conditions. Environmental *variability* is about the relative duration of patches; it can tell if either one environmental condition holds most of the time, or if alternating conditions take equal share. If two different patches are about the same duration, variability is *high*, and if one patch is much shorter that the other, representing only a transient period of change that is relatively easy for an organization to sit out, variability is *low*. Environmental *grain* is about the absolute length of patches. In case of *coarse grain*, the average patch length is long. In case of *fine grain*, patches are short on average.

---Figure 1 about here---

2. ORGANIZATIONAL TRADE-OFFS

In a first model (Hannan and Freeman 1977), resource changes are *exogenous* to the population, and the sequence of alternating patches comprises of two *qualitatively* different resource states, E_1 and E_2, for example different customer tastes. Here the trade-off is between organizational niche breadth and performance, through the "principle of allocation" (Levins, 1968; Hannan, Carroll and Pólos, 2003) of some given amount of capacity. Generalist organizations can cope with qualitatively different resource environments. But adaptation to different environments by maintaining a broad niche involves the jack-of-all-trades dilemma: generalists do reasonably well in multiple environments but they excel in none. Specialists bet on a narrow niche (here, one resource environment) and perform there excellently. Depending on the pattern of change, then, specialists or generalists have higher fitness. As a short hand, we write GS for this generalist-specialist trade-off theory. Péli (1997) gave a logical formalization of this so-called niche theory and derived the theory's main conclusions as theorems from the theory's basic assumptions (see also Hannan, Carroll and Pólos, 2003)[3].

In a second model, the external environmental resource offer stays more or less the same but organizations bound free resources as the focal population grows, from an initially empty population till population mass meets the *carrying capacity* of the environment (Hannan and Freeman, 1989; Brittain and Freeman 1980). An example is an empty population at the appearance of a new technology or product; the population grows till the market is saturated. Here, resource changes are *endogenous* and *quantitative*: free resources disappear due to competition within a growing population. The trade-off organizations face is between *r*- and *K*-strategies, named after parameters in an old Lotka-Volterra model (1925). First mover *r*-strategists can proliferate rapidly under conditions of resource abundance, whereas *K*-strategists take their time to invest in development of more efficient routines that enables them to survive in crowded markets. We call this RK theory, of which Péli and Masuch (1997) gave a logical formalization.

In a famous cautionary tale of La Fontaine, an ant spends its summer with hard work collecting food for winter. A cricket lives for the day, playing his violin during the

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[3] Bruggeman (1997) also formalized niche width theory, although based on a slightly different reading of the source texts. In this paper, we stick to Péli's reading.

summer, but suffers from hunger in winter frost. Organizations may face a similar trade-off. In a third environmental model, that we here introduce and was not addressed in organizational ecology, resource changes are again *exogenous*, as in the GS model, but the difference between the two types of patches is *quantitative*. There is an initial period characterized by a substantial external resource supply (a "summer" patch), followed by a second period when external resource supply stops or diminishes to a very low value ("winter"); there may then be an alternating pattern of these two patches as in the GS and RK models. Alternating conjunctural and depression periods in economics exemplify this pattern of resource change. The organizational trade-off is between rapid growth and security. Rapid growth results in a population with many or large organizations with minimal reserves. The slower growth alternative makes possible to spend organizational potential to developing beneficial institutions and social capital through network ties, resulting in a population having less organizational mass (in terms of organization size or number). Building social capital takes time and effort, first to create trust and then to maintain the established ties, which in their turn enforce conformity (Krackhardt 1999) that limits entrepreneurial freedom. In winters of high uncertainty and limited resource supply, the network may support the organizations tied to it, increasing chances of survival. We call this third theory fragment the cricket and ant trade-off, CA for short.

We have now three ways of how environmental resources change and three corresponding organizational trade-offs. The three cases can mix in actuality, but for analytical clarity we address them separately. Our first task is to give an account of population dynamics in case of exogenous and quantitative environmental change, as this is not treated in organizational ecology. We give the environmental selection differences between the Cricket and the Ant strategies in all eight patterns of environmental change depicted in Figure 1. CA is the stepping-stone for the second, main task of the paper, to point out connections between the three trade-off theory fragments by specifying a common formal core for them.

The three population theories overlap in key notions and also in their characterization of environmental change and strategy. This gives an opportunity to merge them into one, in a way that the new general theory gives back the three components (CA, GS and RK) as special theories. Consider the specific assumptions (boundary conditions) of each population theory, respectively, as “switch positions” in a general theory. Setting the switch into GS, RK, and CA positions, the selection predictions of the pertaining component theory should obtain as outputs (theorems) of the general theory. The predictions of GS and RK are given in advance by current theory, whereas the predictions of CA will derive from the new theory.

3. THE CRICKET AND THE ANT

Consider two populations, the Cricket and the Ant, as subpopulations of one larger population, and whose members follow two different strategies respectively. (We refer to the member organizations of these subpopulations as “crickets” and “ants”, respectively.) We want to compare their long term performance from a Darwinian selection perspective, under different patterns of environmental change (Figure 1). Selection’s preference is for (sub)populations with higher organizational mass in the long run, that may turn up in the number or in the aggregated size of the pertaining organizations. In either case, larger mass requires higher growth, which has to be achieved under changing resource conditions. In the CA environmental model, there are high seasons with bountiful resources and low seasons characterized by a lack of resources, called summer and winter, respectively.

Creating strong network ties to cope with resource fluctuations takes time and effort. How well organizations can create them depends on the duration and the resourcefulness of the summer.

Population mass accumulation during summer can proceed in two ways. A population may grow in mass, in terms of the size or number of members (Cricket), or it may grow slower, being composed of less, or relatively smaller, but network-wise better equipped organizations (Ant). However, if the summer is long or resourceful (or both), then even the growth-oriented Cricket population's members can develop some modest assets or some supportive network ties to survive a short winter. Obviously, the crickets' strategy is the best option in case of eternal summers. But when reserves are used up in winters and no other back up is available, organizational numbers fall dramatically, and population mass dwindles.

Business systems in different countries (Whitley, 2002) provide an example for the Cricket/Ant trade-off. Business systems are assessed in economic terms, but their success depends on the underlying institutional arrangements, and also on the existence and the nature of the networks between economic entities. A well-known typology of business systems makes a difference between two broad types, the so called *liberal market economies* (LMEs) and *coordinated market economies,* CMEs for short (Soskice, 2002). Liberal market economies stay close to the text-book type models of capitalism, wherein the market is populated by a large number of individual firms. Market forces are not too much affected by cartels, regulations, and monopolies and the influence of the state and of social institutions is low. Firms are opportunistic ("arm-length" contracting), and industry level cooperation between competitor firms is not typical. Labor force training is task- and firm-specific and takes place mostly within the firms, while employer-employee relations are market based. Company financing is impersonal (stock market based), and it is governed by short term and high risk-taking considerations. Countries of the Anglo-Saxon world exemplify LMEs.

In coordinated market economies, institutions including the state have a strong influence on economic processes. Contracting relations are more stable and firms intend to build on trust and mutual advantages with partners. Industry level cooperation between competitors is typical: industrial chambers regulate market entry and competition, standards are established, and the training of the labor force takes place in educational institutions financed by the industry or by the state. Employer–employee relations feature elements of reciprocity, and trade-unions are also partners, not only antagonists of the employers. The typical way of company financing is based on bank loans. Banks are stakeholders and often shareholders of the firms they finance. Risk avoidance and taking into account long term effects are crucial elements of coordinated market economies. Countries of the “Rhineland capitalism” (Germany, the Netherlands) are typical representatives of CMEs.

How does this setting fit to the Cricket/Ant framework? Now, environmental change comes in the form of economic cycles. “Summer” and “winter” stand for subsequent conjunctural and depression phases. Strong/weak conjunctural periods are modeled by either more or less resourceful summers, during which resource (demand) is high or modest, respectively. In the first case, environmental dissimilarity (the difference between summer and winter conditions) is large, and in the second case it is low. The length of the cycles is captured by environmental grain size. Low variability means that a lengthy conjunctural phase dominates the economic cycle, while high variability means that depressions are about the same length as the conjunctural periods.

An LME exemplifies a Cricket population in the proposed theory. Firms are risk-takers in this business system and opportunistically seize short-term growth possibilities. A CME is the analogue of the risk-averse Ant population. Organizations are less competitive: they trade in a part of their growth potential for safety considerations. Their collective institutional arrangements and network ties confine their set of actions and dampens their growth during conjunctural periods, analogously to the Ant's reserve accumulation during summer. These arrangements, however, may help them to sit out depressions. Our theory will make possible to derive predictions on the relative success of different business systems, in more complex environmental settings which are new to that literature.

4. A FORMAL CRICKET AND ANT THEORY

Environmental change

First, we characterize the temporal patterns of environmental change. We give a set of logical statements (assumptions) on the three environmental parameters: dissimilarity, variability and grain. Most technical details are in the appendix. The symbols applied are explained in Table 1 and the most relevant logical formulae are displayed in Tables 2-3.

---Tables 1-2 about here ---

We address those cases when summers are not shorter than winters, giving the populations under consideration a chance to build networks and institutions or to increase mass. The first assumption (A1, Table 1) states this consideration. The cases when the winter periods are substantially longer than summers are uniform in the sense that the risk-taking Cricket population collapses after running out of resources (except for the case of very fine grained environmental change, treated later on). The second assumption (A2, Table 1) states that low environmental variability means that one environmental patch is much longer than the other. High environmental variability, in contrast, means that summers and winters are by and large of the same duration (A3, Table 1). Assumptions 1 and 2 imply Lemma 1, a simple intermediary theorem that will be useful to derive the theory's more relevant predictions later on:

L1. *If environmental variability is low, then summers are longer than winters.*

$Var(low) \rightarrow dur(S) > dur(W)$

Environmental grain deals with the average durations of the environmental patches.
If grain is coarse, then seasonal durations are long on the average. A4 reflects this fact by stipulating that at least one of the two seasons is long. If grain is fine, neither of the seasons is long (A5, Table 2). Although environmental grain is a dichotomous variable in the organizational ecology literature, with values "fine" and "coarse" (Hannan and Freeman 1989), the present application requires to refer also to cases when environmental conditions are extremely volatile. This "very fine" grain is described by postulating that seasons are short or very short (A6, Table 2). So, environmental grain can have three distinct values: very fine, fine and coarse. This fact, together with A5-6 implies Lemma 2:

L2. *If environmental grain is fine, then some seasons are medium long.*[4]

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[4] The derivation of theorems usually requires a number of premises stating background knowledge (e.g.,

$Grain(fine) \rightarrow dur(W) = medium \vee dur(S) = medium$

Environmental dissimilarity reflects the difference between the seasons' nurturing conditions expressed in terms of resource availability. Resource availability can be high or low in summer. Since resource availability is always very low in winter (A7, Table 2), the summer - winter difference depends only on summer's resource level (Figure 2). High environmental dissimilarity means that resource availability is much higher in summer than in winter (A8, Table 2). Assumptions 7-8 imply Lemma 3:

L3. *Environmental dissimilarity is high, if and only if, resource availability is high in summer.*

$Diss(high) \leftrightarrow res\_av(S) = high$

Otherwise, environmental dissimilarity is low.

--- Figure 2 and Table 3 about here ---

Population mass changes in summer and winter

The crickets try to maximize their growth as long as summer lasts. The ants' concern is safety; they develop network ties and assets to ensure the continuity of operations under poor winter resource conditions. Both Cricket and Ant increase in mass during summer. However, the (sub)population mass at the end of summer depends on the adopted resource allocation strategy. Assumption 9 (Table 3) expresses that the Cricket grows faster during good times. We now represent the trade-off between fast growth and social capital. The

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on inequality and on scales) that we do not mention in the running text, see the appendix.

ants opt for the second, so they can survive on reserves for a long period of time (A10, Table 3). The crickets have poorly developed social capital, but favorable summer conditions may slightly improve their winter chances. Long summers allow to accumulate some reserves; similarly, resourceful, nurturing summers (high resource availability) have the same beneficial effect. If either of the two conditions applies, the crickets' survival period is a bit extended; if non of these conditions applies, then the Cricket population's mass collapses after a very short time in winter (A11, Table 3).

The next formulae spell out the consequences of winter resource conditions on the two populations. If social capital or reserves hold all winter, then the population preserves its mass during winter (A12, Table 3). If reserves do not last for the whole winter, then the fate of the Cricket depends on the length of the period without reserves. If the winter is much longer than reserves allow for, the population collapses: its mass becomes very small (A13, Table 3). But if the winter is only a little longer than the burnout period on reserves, the losses are not fatal, and population's mass is not very much smaller at the end of the winter than its maximal summer mass was (A14, Table 3).

The last piece of information needed to derive theorems on survival advantages of Cricket and Ant populations is a formal characterization of environmental selection. Assumption 15 (Table 3) states that selection's favor is for the population of larger mass at the end of the cycle (i.e., at the end of the winter).

--- Table 4 and Figure 3 about here ---

Theorems

The above set of assumptions now implies environmental selection preferences as theorems (Table 4). Figure 3 gives a visual representation of population dynamics in the eight environmental patterns.[5] The first theorem posits that conditions of low variability are more favorable for the Cricket (Figure 3.a-d). Since in our context low variability means that summers are definitely longer than winters (Lemma 1), Theorem 1 just rephrases the common wisdom that saving is not that important if hard times are transient.

Theorem 1. (from A1-6, A9-12 and A14-15; Table 4: 1-2, 5-6)

If environmental variability is low, then selection favors the Cricket population over the Ant.

$Var(low) \rightarrow Selection\_favors(C,A)$

The La Fontaine tale says that the Ant fares better than the Cricket if winter is long. Winter can be long in absolute terms, or it can be long relative to the summer. Coarse environmental grain means long winter in absolute terms. High variability means long winters in relative terms, i.e., that the winters and summers are similar in duration (A3). If the two effects combine, the Cricket fails (Figure 3e-f):

Theorem 2. (from A1-4, A9-13 and A15; Table 4: 3, 7)

If environmental change is of high variability and the change is coarse grained, then selection favors the Ant population.

$Var(high) \wedge Grain(coarse) \rightarrow Selection\_favors(A,C)$

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[5] The current formal machinery doesn’t detail out the trajectory of populations reaching their maximal or minimal mass. Figure 3 displays one possibility for illustration.

Two environmental change patterns out of eight await explanation. If grain is fine, then the absolute length of winter isn't long. This may give a chance to the Cricket to survive, provided that its members have some minimal reserves. Thus, selection's preference depends on the resourcefulness of the summer. In case of high environmental dissimilarity, the resourceful summer helps the crickets to develop some minimal reserves, and so, to survive and prevail (Figure 3g), otherwise, the Ant is favored (Figure 3h).

Theorem 3. (from A3, A5-12 and A14-15; Table 4: 8)

If fine-grained environmental change has high variability and dissimilarity is high, then selection favors the Cricket population.

$Var(high) \wedge Grain(fine) \wedge Diss(high) \rightarrow Selection\_favors(C,A)$

Theorem 4. (from A3, A5-13 and A15; see Table 4: 4)

If fine-grained environmental change has high variability and dissimilarity is low, then selection favors the Ant population.

$Var(high) \wedge Grain(fine) \wedge Diss(low) \rightarrow Selection\_favors(A,C)$

When grain gets really fine

The term "very fine grain" was introduced as a third, distinct grain category to reflect conditions when seasons are very short (A6, Table 2). This concept is not part of the GS and RK environmental models, only of the CA model. The finer grain size is, the shorter are the environmental patches on the average, so the more frequent the change of environmental conditions. The reason for handling "very fine grain" separately is that otherwise the phrasing of Theorem 4 might run against intuition for certain cases when environmental change is very fast. Figure 3h indicates that the mass of the Cricket should not undercut the mass of the Ant if the seasons (and so the winter) are very short, that is, grain is very fine. In that case, the Cricket doesn't face a winter that is much longer than its survival period on reserves, so it can prevail. This prediction follows as a fifth theorem from our formal machinery.

Theorem 5. (from A6, A9-12 and A14-15)

If the grain of environmental change is very fine, then selection favors the Cricket population over the Ant.

$Grain(very\_fine) \rightarrow Selection\_favors(C,A)$

From here onwards, no more formal theory building is necessary. The task becomes to operate the "switchboard", that is to fine-tune the CA machinery to deduce the conclusions of GS and RK. Again, the emphasis is on the sociological insights: What are the differences between the three addressed population theories? We begin with OE's niche-width theory (GS). We follow Hannan's and Freeman's (1989) description and denotations.

5. GS THEORY

Generalist and specialists in changing resource environments

In GS, two resource environments (E_1 and E_2) follow each other sequentially, like in CA. The eight patterns of environmental change are the same as in CA (Figure 1). But while the difference between the two alternating resource states is quantitative in CA (presence and lack of external resource offer), in GS it's qualitative: E_1 and E_2 represent two different resource configurations. Organizations in the generalist population adapt to both E_1 and E_2

in the sense that they can operate under both conditions (broad niche). The specialist population adapts only to E_1 (narrow niche). The principle of allocation (Hannan, Carroll and Pólos, 2003, see also Section 2) has it that an ability to operate under both conditions takes its toll: it lowers fitness, so generalist organizations have a mediocre performance all the time. On the contrary, specialists perform very well under a narrow range of conditions (E_1) they are specialized to. For them, no resource utilization is possible when E_2 holds sway, and then they have to survive on reserves. Specialist organizations bet on the performance of operations, generalists bet on the continuity of operations.

The predictions of GS on selection preferences is as follows (Figure 4). In the four low variability cases E_1 dominates (Figure 1b), and specialization is the strategy favored by selection. But when environmental variability is high, specialists face beneficial and hostile conditions for approximately the same duration. If the E_2 periods are long, specialists run out of their reserves, just like the Cricket members in CA, and their population collapses. Therefore, generalism is the favored strategy in the two cases when high variability combines with coarse grain. However, if variability is high but grain is fine, then the E_2 patches are not deadly long for specialists. In these cases, selection's preference depends on the dissimilarity between the two environmental states. The bigger the dissimilarity, the more difficult it is for a generalist to adapt to both E_1 and E_2, and this implies lower fitness, according to the principle of allocation. Therefore, high variability and fine grain combined with high dissimilarity are better for specialists, while the same setting with low dissimilarity is better for generalists. The next step is to show that the CA theory implies these predictions as theorems, provided that some modifications are performed.

--- Figure 4 about here ---

Modifications

Environmental change has the same “good times - bad times” character for the specialists in GS as it has for both the Cricket and Ant in CA. The Specialist population behaves exactly as the Cricket: it flourishes when E_1 (summer) holds. E_2 is inaccessible and virtually resource-less for specialists, while it is resourceful for generalists. However, the costs of adaptation to both environmental conditions (lower fitness) slows down the growth of the Generalist population. Note the analogy with the Ant population’s damped growth in summer because of accumulation of social capital and other buffering efforts. Both generalists and ants have a kind of life insurance against environmental change, where the policy costs come in the form of slower growth. The generalist organizations maintain multiple operational routines (Nelson and Winter, 1982), one for E_1 and another for E_2, to be able to cope with qualitative resource changes.

In the pertaining formulae, substitute Specialist (*S*) for Cricket (*C*), and Generalist (*G*) for Ant (*A*) (Tables 2-3). Similarly, substitute E_1 and E_2 for summer (*S*) and winter (*W*), respectively. Up till this point, only notational modifications were made. The only non-notational modification concerns the fact that the Generalist population can grow in both environmental patches (E_1 and E_2), while the Ant can only grow in the summer patch. At the level of formal machinery, this difference means that the Generalist population may change its mass until the end of the second period (E_2) while the Ant reached its maximum mass at the end of the first period (summer) in CA. This modification affects only formula A9; its GS-version is denoted as $\mathrm{A9}^{\mathrm{GS}}$ (Table 3). Moreover, A10 becomes superfluous, since now the Generalist population is active in both periods, so it need not survive on reserves, or on supportive institutions or social capital. These two changes don't affect Theorems 1-4, and we get exactly the predictions on selection preferences of organizational ecology's niche width theory (compare Table 4 and Figure 4).

6. RK THEORY

K- and r-strategists

K- and *r*-strategy organizations have been introduced to organizational ecology by Brittain and Freeman in their propagation strategy theory (1980; see also Hannan and Freeman 1989). *K* and *r* denote, respectively, the carrying capacity of the environment and the intrinsic growth rate of the population. *K*-strategists have competitive advantages over *r*-strategists due to their efficient production on the basis of well-developed routines when the carrying capacity of the environment is approximated, and free resources become progressively scarce. First mover *r*-strategists, in contrast, have low start up costs and an ability to exploit new opportunities quickly, but they perform poorer under high competitive pressure and resource scarcity. Putting it differently, *K*-strategists bet on performance and efficiency, while *r*-strategists bet on rapid proliferation. The relative success of the two strategies depends on the stability of environmental conditions. The *r*-strategists flourish in the short run, while *K*-strategists' investments in routines yield their returns in the longer run--if there is a long run at all, so if the environment is stable or only slowly changing (Hannan and Freeman, 1989, pp. 118-120). When markets change faster than *K*-strategists can reap their returns on skill investments, *r*-strategists fare better. In this theory fragment, the *r*-strategy population's analogue is the Cricket population. The Ant population is the analogue of the *K*-strategy population, whose members now develop production skills instead of social capital.

A difference between the two environmental models is that while CA is about two distinct environmental resource periods, one with and one without resources, RK assumes permanent resource inflow for organizations (e.g., in the form of ongoing customer demand) for the whole observation period. In RK, the two environmental patches are kept apart by the time point when the carrying capacity is reached (Péli and Masuch, 1997). This point splits market history into two phases: an initial p_1 period with free (yet unbounded) resources, and a subsequent p_2 period when free resources have been absorbed by organizations (supply matches or exceeds consumer demand). Putting it differently, resource availability is high in p_1 and low in p_2, while resource inflow (market demand) in absolute terms is by and large stable all the time. Resource acquisition during p_2 resembles to a zero-sum game, where the gain of one organization comes from the losses of others. Environmental dissimilarity here deals with the magnitude of the resource availability gap between p_1 and p_2. The competitive market phase (p_2) ends when some new market opportunities open up that give rise to a new wave of first mover (r-strategy) organizations. This yields a "two-stroke" RK model similar to CA, but whereas in the latter resource availability is determined by external sources, in RK resource availability depends on *endogenous* competitive pressure, which is low in p_1 and high in p_2. Our next step is to derive the theory's conclusions on selection preferences concerning the two organizational strategies by again performing some modifications on CA.

Modifications

To obtain RK theory, denote r- and K-strategy (sub)populations by r and K, respectively. Substitute r for C and K for A in all pertaining formulae in Tables 2-3. Moreover, substitute

p_1 for summer *S* and p_2 for winter *W*. The obtaining predictions of RK theory on selection preferences are listed in Table 5. Recall that the original theory claims that selection favors *K*-strategists if environmental change is slow, and that it favors *r*-strategists when change is rapid. Translating the original predictions (that didn't characterize the environment in terms of variability, grain size and dissimilarity), the expectation becomes that coarse-grained change favors *K*-strategists, while fine grained change favors *r*-strategists (see the logical formalization of RK theory in Péli and Masuch, 1997).

--- Table 5 about here ---

Table 5 shows partly opposing predictions, though: only five conclusions (displayed in bold) out of eight match the expectation. However, the match of the original theory's predictions and ours improves radically by adding one more modification. The original theory (Hannan and Freeman 1989) mentions that the first mover versus efficient producer trade-off takes place in markets with a set of new opportunities (e.g., due to technological or market structure change) that attracts new entrants. In our terms, this means a supporting, resourceful climate that facilitates rapid organizational founding and growth. Resourceful conditions in the early phase imply high environmental dissimilarity between the two phases compared (Lemma 3), to which the original first mover – efficient producer argument should be restricted. Then, the upper row of Table 5 (the low dissimilarity cases, cells 1-4) does not apply, as these conditions didn't exist in the original theory either. In cells 6, 7 and 8 (Table 5), coarse-grained environmental change favors *K*-strategists, and fine-grained change favors *r*-strategists, as the original argument states. One misfit is left (cell 5) to be solved. The next section suggests a solution to this problem by somewhat loosening the constraints of RK.

Revisiting the excluded cases

The environmental conditions excluded in the previous section may occur sometimes in reality, and it would be of interest to generalize RK theory to encompass these cases as well (Table 5: 1-4). Note that the original *r* and *K*-strategist argument takes into account only one environmental parameter, the speed of change (here represented by environmental grain). Our theory also takes into account the influence of the other two parameters, variability and dissimilarity, and suggests that the impact of these two might sometimes overrule grain size.

Let us relax the assumption that the *r* and *K*-strategy dilemma only applies to cases when the opening market is abundant of resources (demand). Now, we revisit the four low dissimilarity cases (Table 5: 1-4) in which our theory contradicts to the original theory in two instances, in cells 1 and 4. Let's begin with cell 4. Since dissimilarity is measured in terms of resource availability differences between market phases, low dissimilarity means that resource availability is not a great deal better during p_1 than during p_2. Resource scarcity has more effect on the rapid-growth oriented *r*-strategists than on the *K*-strategists because the skill-development of the latter depends on internal organizational processes rather than on external resource availability. *K*-strategist's skills also make possible to utilize available resources more efficiently. High variability makes things even worse for *r*-strategists: then, the deadly p_2 phase is not shorter than their growth period p_1 (Figure 1a), giving even more chance for *K*-strategists to prevail. These two effects, together, bring selection's favor to *K*-strategists, just as predicted by our formal model (Table 5: 4).

Cell 1 (Table 5) stands for conditions when environmental variability is low, so the competitive p_2 patch is substantially shorter than the preceding p_1 patch (Figure 1b). This difference between the present and the previous case tips the selection balance in favor of *r*-strategists. The same applies to the last remaining mismatching result (cell 5) with the additional *r*-strategists' advantage that here the abundant external resource supply in p_1 magnifies first mover advantages further (because of high environmental dissimilarity, Lemma 3). Thus, the conclusion implied by our formal RK theory (*r*-strategists are favored by selection) is intuitively justifiable.

7. DISCUSSION

This paper specified a new population dynamics theory (CA) for quantitative environmental resource changes. CA has substantial similarities with two well-established theory fragments from organizational ecology (GS and RK) in terms of environmental modeling and organizational trade-offs. In all these theory fragments, organizational population members face strategic trade-offs between short-term benefits (growth) and long-term security due to social capital (CA), to multiple skills (GS), or to high quality skills (RK). No security measure offers guaranteed survival, though, because expected overall growth in the long run may turn out being slow or even may turn into decline. Thus, the trade-off strategy chosen ultimately depends on how organizational founders perceive their risks. This risk perception might be investigated along the lines of prospect theory (Tversky and Kahneman, 1992; Kahneman and Tversky, 1979) in future research. Ecologists have earlier studied the gestation periods of new organizations (Carroll and Hannan, 2000, p.339). On the basis of detailed micro-studies one could assess how organizational founders perceive future risks, and how their perception influences choices in strategic trade-offs.

The proposed logical theory fragments highlight family resemblances, reflected by the common core, as well as differences, reflected by specific boundary conditions. Table 6 lists some of the differences and similarities between the three component theories. The paper demonstrated that the predictions of CA, GS and RK obtain as theorems when the specific assumptions of the three population theory fragments are instantiated in the logical core machinery. We thereby hope to contribute part of the answer to the more general question: Which kind of organizational strategy is beneficial under which conditions?

--- Table 6 about here ---

The temporal patterns of environmental change are the same in the three theories, but sometimes the changes are quantitative (CA, RK) and sometimes qualitative (GS). Qualitative resource change can also be expressed with quantities, though. Consider the set of relevant environmental resource variables, and denote the cardinality of this set with k. Then, all resource configurations can be expressed with a k-vector, where the resource sorts missing from the configuration are represented with zero components. The disappearance of all resource (quantitative change to winter in CA) corresponds to a zero vector. As quantitative resource change can be reduced to a special case of qualitative change, the Cricket and Ant theory might be seen as a special case of ecology's niche width theory, namely when the level of some vital resource components become low in E_2, and generalists cannot use their routines tuned to E_2; so they can only survive on their presumed higher stocks of reserves. In fact, arguments about niche width and organizational capacity allocation come together in niche width theory. Generalist organizations "hold some capacity in reserve" to ensure reliability of performance when conditions change, while "some of the efficiency resulting from specialization derives from lower requirements for maintaining excess capacity" (Hannan and Freeman 1989, pp. 106). As qualitative and quantitative resource changes can jointly occur, organizational populations may face the Cricket-Ant and the Specialist-Generalist trade-offs but in different times. GS and CA can then be seen as the two marginal cases, when either the composition or the magnitude of resource supply counts, respectively.

The existence of a not-too-high carrying capacity (i.e., one that can be hit during the period of observation) poses another kind of quantitative resource constraint. Carrying capacity plays a role in RK, but not necessarily in CA. In the latter, it is the quantity of environmental resource inflow that changes between the first and the second period (summer and winter). In RK, the external resource inflow (demand) is the same in both periods, but the expanding population absorbs all inflowing resources in the second period (p_2). What organizations experience according to both theories is that resource availability is getting worse. In CA, organizations may prepare for adverse times by developing social ties and supportive institutions, whereas in *RK*, the more competitive *K*-strategists take over the resource share of their *r*-strategy cousins.

Note finally that although the populations in the three theory fragments may interact, two fragments (CA and GS) do not assume interaction between organizations. The Cricket and the Ant (or the Specialist and the Generalist) need not even stay in the same market. Since the driver of selection process, resource change, is exogenous, the same selection outcomes obtain if the compared populations are located in separate but similar environments. In case of *r*- and *K*-strategists, it is population growth that generates resource scarcity, which in turn can be eased by the demise of some organizations. But even RK has a reading that need not assume competitive interaction between the two organization types. Under this interpretation, *K*-strategists' skill elaboration is not about becoming a tough competitor but about becoming more efficient at the exploitation of its own resources. This yields a "pacifist" version of RK in which *K*-strategists do not predate on others.

Can the work performed in this paper be seen as theory unification? Theory unification involves a common conceptual model and theory that give back the component theory fragments as special cases of the general theory. The proposed logical machinery fulfils this requirement to some extent. Substituting CA, GS or RK-specific constraints and parameters to the core-machinery, the respective theories obtain. However, in the presented logical formalization, the corresponding key objects in the three component theories do not merge into one in the context of the general theory. For example, it is usually not the case that the *same* population can bee seen as Ant, Generalist and *K*-strategists, when the focus of analysis shifts between quantitative, qualitative and carrying capacity related aspects of resource supply, respectively (although Generalists and Ants may coincide in certain populations, as we argued above). What the paper demonstrates is that three population dynamics approaches can be captured by one formal core model, which highlights the contingencies of risk strategies in several different environments. Although this is less than theory unification, it can be an important step towards it.

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Table 1.

Logical symbols, proper names, predicates and function symbols

Logical symbols

$\wedge$ - the “and” connective
$\vee$ - the “or” connective
$\neg$ - negation
$\rightarrow$ - “if, ... then”, implication
$\leftrightarrow$ - “if and only if”, bi-implication
$\forall$ - ”for all”, universal quantification
$\exists$ - “there exists”, existential quantification

Proper names

C - the Cricket population
A - the Ant population
S - the “summer” period, the resourceful high season
W - the “winter” period, the resourceless low season
Scale values for mass: *large*, *medium*, *small*, *very_small*
Scale values for durations: *long*, *medium*, *short*, *very_short*
Scale values for resource levels: *high*, *low*, *very_low*

Predicates

Diss(*low*) / *Diss*(*high*) - the dissimilarity between the two seasons is low / high
Grain(*coarse*) / *Grain*(*fine*) - the grain of environmental change is coarse / fine
Pop(x) - object x is a population
Selection_favors(x,y) - selection favors object x over object y
Var(*low*) / *Var*(*high*) - environmental variability is low / high
$x >> y$ - x is much larger than y

Functions

beg(t) - yields the beginning point of period t
dur(t) - yields the duration of period t
end(t) - yields the endpoint of period t
mass(x,t) - yields the mass of x in period t
reserve(x) - the amount of reserves for x
res_av(t) - the resource availability during t

Table 2.

Formulae on environmental change

A1. *Summers are not shorter than winters.*
$\neg(dur(W) > dur(S))$

Variability

A2. *Low environmental variability implies that one of the seasons prevails.*
$Var(low) \rightarrow (dur(S) > dur(W) \vee dur(S) > dur(W)$

L1. (from A1, A2) *If environmental variability is low, then summers are longer than winters.*
$Var(low) \rightarrow dur(S) > dur(W)$

A3. *High variability means that seasons last for the same duration.*
$Var(high) \rightarrow dur(S) = dur(W)$

Grain

A4. *Environmental grain is coarse, if and only if, some seasons are long.*
$Grain(coarse) \leftrightarrow dur(S) = long \vee dur(W) = long$

A5. *If environmental grain is fine, then neither of the seasons is long.*
$Grain(fine) \rightarrow \neg(dur(S) = long \vee dur(W) = long)$

A6. *In case of very fine grained environmental change seasons are short or very short.*
$Grain(very\_fine) \rightarrow dur(W) \leq short \vee dur(S) \leq short$

L2. *If environmental grain is fine, then some seasons are medium long.*
$Grain(fine) \rightarrow dur(W) = medium \vee dur(S) = medium$

Dissimilarity

A7. *Resource availability is very low in winter.*
$res\_av(W) = very\_low$

A8. *High environmental dissimilarity between summer and winter.*
$Diss(high) \leftrightarrow res\_av(S) = high$

L3. (from A7, A8) *Environmental dissimilarity is high, if and only if, summer resource availability is high.*
$Diss(high) \leftrightarrow res\_av(S) = high$

Table 3.

Formulae on population dynamics

A9. *The Cricket population grows large in summer, the Ant population remains small.*
$mass(C,end(S)) = large \wedge mass(A,end(S)) = small$

A10. *The exhaustion period of reserves is long for the Ant.*
$dur(reserve(A)) = long$

A11. *The Cricket has very short winter survival on reserves if the summer is neither long nor resourceful; otherwise, it has a short survival period.*
$\neg(res\_av(S) = high \vee dur(S) = long) \rightarrow dur(reserve(C)) = very\_short \wedge$
$\quad res\_av(S) = high \vee dur(S) = long \rightarrow dur(reserve(C)) = short)$

A12. *Populations preserve their mass if their reserves last all winter.*
$\forall x\ [Pop(x) \wedge dur(reserve(x)) \geq dur(W) \rightarrow mass(x,beg(W)) = mass(x,end(W))]$

A13. *If the winter is much longer than the survival period on reserves, then the population becomes very small by the end of the winter.*
$\forall x\ [Pop(x) \wedge dur(W) >> dur(reserve(x)) \rightarrow mass(x,\mathrm{end}(W)) = very\_small]$

A14. *If the winter is not much longer than the survival period on reserves, then the population's winter mass is not too much smaller than its summer mass.*
$\forall x\ [Pop(x) \wedge \neg(dur(W) >> dur(reserve(x))) \rightarrow \neg(mass(x,end(S)) >> mass(x,end(W)))\ ]$

A15. *Selection favors the largest population at the end of the observation period.*
$\forall x,y\ [Pop(x) \wedge Pop(y) \wedge mass(x,end(W)) > mass(y,end(W)) \rightarrow Selection\_favors(x,y)]$

Model modification for the GS fragment:

A9^{GS}. *The Specialist population grows large by the end of the* E_1 *period; the Generalist population's mass is small at the end of the second* (E_2) *period.*
$mass(S,end(E_1)) = large \wedge mass(G,end(E_2)) = small$

Table 4.
The CA model's predictions for the eight environmental change patterns

	Low Variability		**High Variability**	
	Coarse Grain	**Fine Grain**	**Coarse Grain**	**Fine Grain**
Low Dissimilarity	1. Cricket	2. Cricket	3. Ant	4. Ant
High Dissimilarity	5. Cricket	6. Cricket	7. Ant	8. Cricket

Table 5.

The RK model's predictions for the eight environmental change patterns

	Low Variability		**High Variability**	
	Coarse Grain *slow change*	***Fine Grain*** *rapid change*	***Coarse Grain*** *slow change*	***Fine Grain*** *rapid change*
Low Dissimilarity not resourceful market	1. *r*-strat.	**2. *r*-strat.**	**3. *K*-strat.**	4. *K*-strat.
High Dissimilarity resourceful market	5. *r*-strat.	**6. *r*-strat.**	**7. *K*-strat.**	**8. *r*-strat.**

Table 6.

Resource change in the three models

	CA	GS	RK
Periods	summer, winter	E_1 and E_2	p_1 and p_2 before/after carr.cap.
Resource difference	quantitative	qualitative	quantitative
Resource inflow in 2nd period	not present	present	present
Free resource in 2nd period	not present	present	not present
Remedy of scarcity	buffering/networking (Ant)	adaptation (Generalists)	skill development (*K*-strategists)

Figure 1.

Patterns of environmental change

(a) High Variability

(b) Low Variability

The blocks stand for the temporal patches for which a certain environmental state holds.

Environmental dissimilarity is visualized as tint difference between blocks.

Source: Péli (1977)

Figure 2.

Low and high dissimilarity between summer and winter

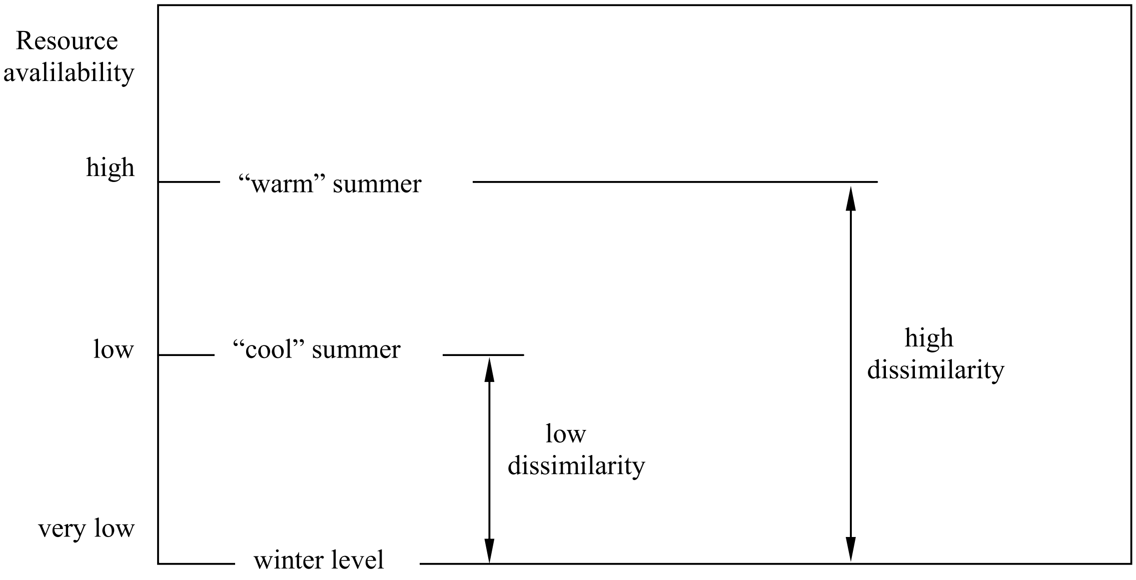


Figure 3.

Population growth and decline during the two seasons (CA)

⋯⋯⋯ The mass of the Cricket population

—— The mass of the Ant population

1. Low variability cases

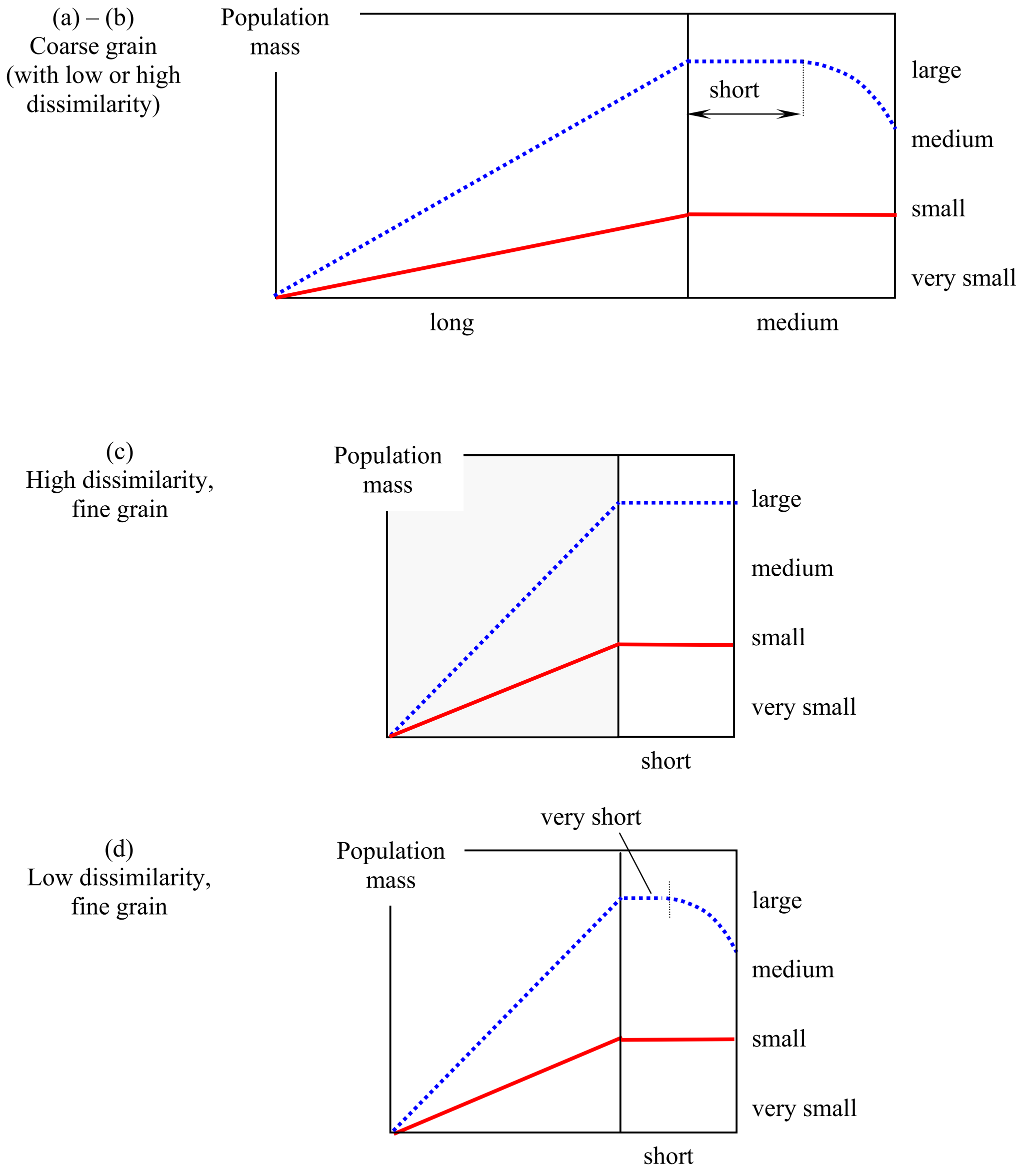
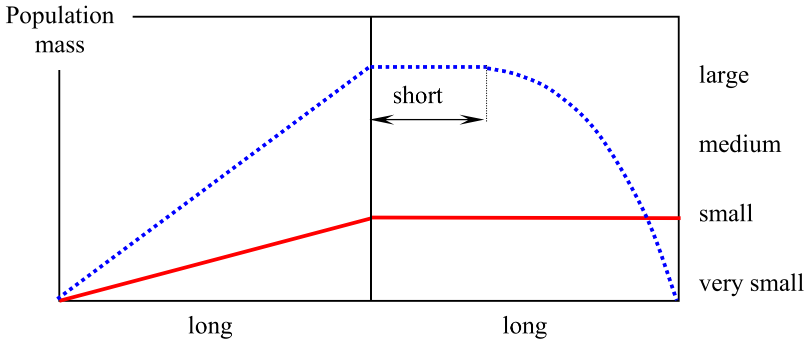


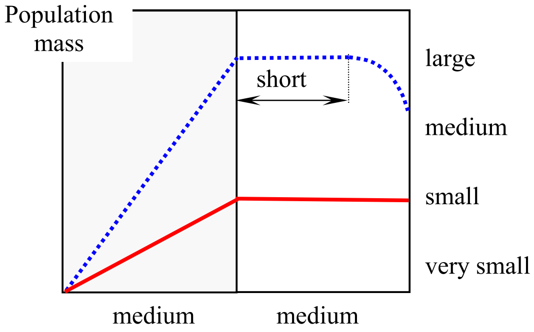
Figure 3. (cont.)

2. High variability cases

(e) – (f)
Coarse grain
(with low or high
dissimilarity)



(g)
High dissimilarity,
fine grain



(h)
Low dissimilarity,
fine grain

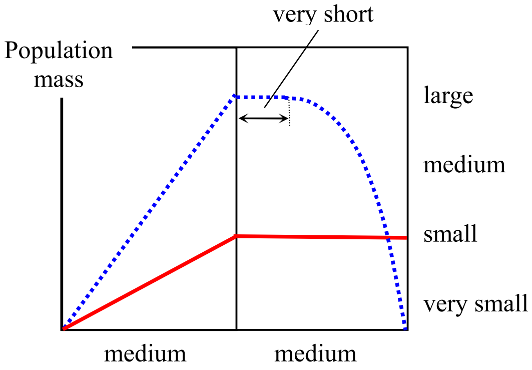
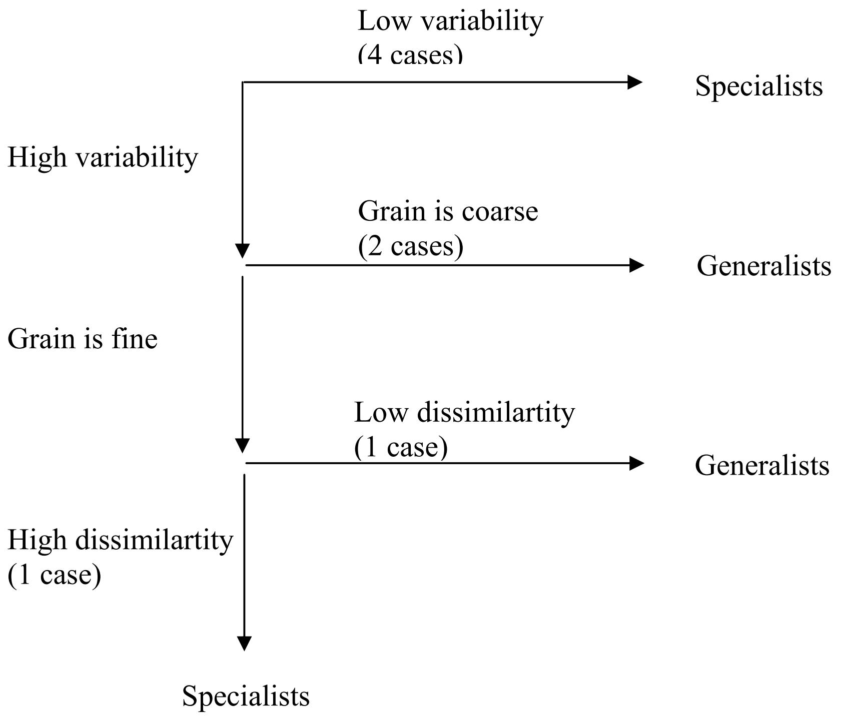


Figure 4.

The GS model’s predictions on selection preferences



Source: Péli (1977)