Chapter 10 Eight roots emerging from a multitude of frameworks

Now that you have learned about the eight qualities which we see in all resilient systems, we'd like to introduce you to a few of the many other attempts to develop systematic tools for inducing ecological resilience. On the surface, these attempts seem different and may appear confusing, but in fact they have all helped us understand and unearth the eight roots of resilience in this book. In this chapter, we will explore in more depth several of the most prominent frameworks and show how they fit with our eight qualities of ecologically resilient systems.

Do we need to understand everything about an ecosystem to predict or induce resilience? Some contend that understanding resilience requires a thorough understanding of the many aspects of social, biological, and ecological systems as they interact. This complexity has spawned a multitude of frameworks for understanding social-ecological systems.[330] This is the approach taken by the Resilience Alliance with their Resilience Assessment Workbook.[331] This tool takes a stepwise approach to describing an Social Ecological System by first defining its boundaries, framing key issues, and identifying critical thresholds: a process referred to as defining "the resilience of what to what." Answering this question appears to be a first step in most assessments.

Our approach seeks not to first define the overall SES. Since resilience is an emergent property of social-ecological systems (SES), the complexity of interactions within each SES make each SES unique and render impossible accounting for every factor which influences resilience now and in the future. One may be able to define a specific component and design it to be resilient (such as reducing the effect of flooding on an electric power grid). However, a comprehensive framework will focus on a few of these influences and cannot define specific activities needed to improve resilience to all present and future disturbances.

Scale is crucial to a deeper understanding of resilience. When you inoculate a log with lion's mane mushroom spawn, you are making an innovation from the scale of the farm, but a transformation from the scale of the log. Likewise building up the soil is building an asset for the farmer, but at the scale of the soil, redundancy is increasing. An asset at one scale is redundancy at another scale. Similarly local self-organizing and ecological integration are similar qualities at different scales. However, resilience at any given scale seems to require that all eight qualities are present.

Most ecological resilience researchers instead have attempted to establish what basic qualities appear in all resilient systems.

[330] Binder, C. R., J. Hinkel, P. W. G. Bots, and C. Pahl-Wostl. 2013. Comparison of frameworks for analyzing social-ecological systems. Ecology and Society 18(4): 26.
[331] Resilience Alliance, 2010. http://www.resalliance.org/resilience-assessment

One of earliest (by Walker and Salt[332]) formulates a set of nine necessary qualities for a resilient world: Diversity, Ecological Variability, Modularity, Acknowledging Slow Variables, Tight Feedbacks, Social Capital, Innovation, Overlap in Governance, and Ecosystem Services.

Carpenter et al. [333] clarified the distinction between the specific "resilience of what to what" and general resilience which confers the ability cope with any disturbance. They went on to posit nine slightly different qualities which enable general resilience: diversity, modularity, openness, reserves, feedbacks, nestedness, monitoring, leadership, and trust. Since Walker is one of the authors of the Carpenter paper, we will assume that this later version subsumes his and Salt's earlier formulation.

Frankenberger et al.'s conceptual framework for community resilience[334] is an influential treatment of resilience from a sociological perspective. This framework posits seven central "community social dimensions." These are preparedness, responsiveness/flexibility, learning and innovation, self-organization, diversity, inclusion and aspirations. Seeing the impossibility of predicting interaction of innumerable complex adaptive systems, others have come up with lists of principles, qualities or indicators correlated with resilience similar those of Frankenberger et al.'s central dimensions.

Rockefeller Foundation has developed a City Resilience Framework which posits seven slightly different qualities of resilient systems: reflective, robust, redundant, flexible, resourceful, inclusive and integrated.[335]

The Stockholm Resilience Center has developed a set of "seven principles that are considered crucial for building resilience in social-ecological systems": maintain diversity and redundancy, manage connectivity, manage slow variables and feedbacks, foster complex adaptive systems, encourage learning, broaden participation, and promote polycentric governance.[336]

Some resilience theorists lump and some split. Others lump and then split. Carpenter et al. split the emergent quality of modular connectivity into several areas. Our interest is in finding the emergent qualities which are necessary to resilience, whether they are lumped or split into various categories.

[332] Walker, B. and D. Salt, 2006. Resilience Thinking. Washington, D.C.: Island Press.
[333] Carpenter et al., 2012, ibid.
[334] Frankenberger et al., ibid.
[335] https://www.rockefellerfoundation.org/report/city-resilience-framework/
[336] Biggs et al., ibid.

Perhaps the most comprehensive review to date is Cabell and Oelofse,[337] which details thirteen categories of indicators shown to be associated with resilience: socially self-organized, ecologically self-regulated, appropriately connected, functional and response diversity, optimally redundant, reflective and shared learning, spatial and temporal heterogeneity, exposed to disturbance, coupled with local natural capital, globally autonomous and locally interdependent, honors legacy, build human capital and reasonably profitable.

Resilience is viewed by some as an emergent quality. Emergence occurs when the merger of components results in a system with properties unknown in any of its components. Resilience is a quality which can be present at all scales. We contend it must be present in component systems to be present at any particular scale. Hence, resilience emerges at a particular scale, only if already present at component scales.

Our approach derives the qualities of resilient system from direct observation and case studies of eight resilient local food systems. We seek not to model the complete complexity of interacting adaptive systems which compose each SES. Nor are we satisfied with simply noting indicators which correlate with resilience. Instead our project is to define the qualities which are foundational to resilient systems. Then we seek indicators which tell us these qualities are present. Below, the eight qualities to emerge from our study are compared to the five discussed above which will be referred to as: Carpenter et al., Frankenberger et al., Rockefeller, Stockholm Resilience Center or SRC, and Cabell and Oelofse.

1. Modular Connectivity.

All prominent frameworks for resilience recognize the importance of connectivity and modularity. Some who are mainly concerned with human systems make social capital a separate category. We see social capital as describing a type of connectivity which occurs in all systems, not just human systems.

Carpenter et al. have a strong focus on modular connectivity. However, they split this quality into several separate areas: modularity, managing feedback, monitoring, openness, and development of trust.

Cabell and Oelofse call the quality appropriately connected. They extoll connectivity, but don't recognize situations where high connectivity leads to low resilience. If the system is not modular or independent, it can't be resilient when disturbance floods though systems.

Frankenberger et al. see the vital importance of social capital, but discuss other aspects of connectivity in less detail and do not discuss modularity.

Rockefeller uses slightly different terminology. Instead of connectivity, they refer to resilient systems as integrated (where exchange of information between systems enables them to function collectively and respond rapidly through shorter feedback loops). Instead of modularity, they use the term robust. (Over-reliance on a single asset, cascading failure and design thresholds that might lead to catastrophic collapse if exceeded are actively avoided.)

[337] Cabell, J. F., and M. Oelofse. 2012. An indicator framework for assessing agroecosystem resilience. Ecology and Society 17(1): 18. http://dx.doi.org/10.5751/ES-04666-170118

Stockholm Resilience Center focuses on managing connectivity and feedbacks, but with less emphasis on modularity than other frameworks.

2. Locally Self-organized.

Frankenberger et al. and Cabell and Oelofse have a strong focus on the locally self-organized quality. Cabell and Oelofse use the term socially self-organized and specifically cite the example of local food systems in the US. They make a distinction echoed in many other frameworks, that locally self-organized networks can be more responsive and adaptable to changing conditions than can larger groups. Top-down initiatives can fail if the timing is wrong, if the needs are misinterpreted, or if there is no buy-in from the stakeholders. Frankenberger et al. and Rockefeller refer to the quality as inclusiveness.

Other frameworks are less specific about the need for local self-organization, but imply its importance in the quality labelled overlap in governance (Walker and Salt), nestedness (Carpenter et al.) and polycentric governance (SRC). These three frameworks all focus on need for governance above the local level to be focused on resilience. Since we see local as a term relative to scale, this distinction is not useful in our framework. Regional and national and world governance are examined at their own scale. All ecosystems are nested since every system is composed of systems. Every resilient system contributes to the resilience of subsystems of which it is composed. Those subsystems are resources or assets to the larger system which must be enhanced and maintained, as we address in the next quality.

3. Building Infrastructure.

Rockefeller is most explicit about the need for physical infrastructure. They use the term robust to refer to well-conceived, constructed and managed physical assets, which enable a system to withstand the impacts of hazard events without significant damage or loss of function.

Cabell and Oelofse emphasize that resilient systems are coupled with local natural capital—the slow variables such as soil organic matter, hydrological cycles, and biodiversity. SRC also notes the importance of managing slow variables, though without emphasis on building up such assets, perhaps because their focus is not primarily agroecosystems.

Frankenberger et al. highlight **c**ommunity assets, which are resources that enable communities to meet the basic needs of their members and reduce vulnerability to shocks. However, the broad definition of assets (including both tangible and intangible assets: social, human, financial, natural, physical, and political capital) makes measurement of this quality difficult in Frankenberger et al.'s framework. Frankenberger et al. proposes two other qualities which are not explicitly stated in other conceptualizations, but are related to building assets: preparedness and aspiration. Preparedness refers to the community resources needed to cope with disturbance. Aspirations are the underlying personal qualities which make people make investments needed to cope with disturbance. Both terms also are defined to include tangible and intangible assets, making measurement difficult.

The other frameworks are not explicit about the necessity of building assets for resilient systems, though the quality seems to be assumed in such terms as reserves (e.g., by Carpenter

et al.) which contribute to recovery from disturbance. Reserves cannot be created without the productive assets needed to create them. Reserves, in our framework, reflect the presence of redundancy (or back-ups) as shown below.

4. Responsive Redundancy or Back-ups.

Redundancy is seen as crucial in all resilience frameworks, though Frankenberger et al. does not explicitly use the term. Cabell and Oelofse use the term optimally redundant. This highlights the crucial qualification that redundancy inevitably increases inefficiency of the system. The presence of reserves, as noted above, reflects redundancy in our framework.

5. Complementary Diversity.

Diversity is extolled by nearly all resilience frameworks. Some frameworks (e.g., Carpenter et al., SRC and Frankenberger et al.) do not address the need for diversity to be complementary or that diversity can undermine resilience. Cabell and Oelofse, in contrast, make this distinction explicit. They also include, as a separate quality, spatial and temporal heterogeneity which is lack of uniformity across the landscape and through time. We see this as a measure of diversity, not a separate quality from diversity.

Though Rockefeller fails to explicitly mention the quality of diversity in their 20114 index, In 2015, their website included diversity as a characteristics of all resilient systems.

6. Conservative Innovation and Flexibility.

Innovation is a necessary quality of resilient systems in nearly all frameworks. Carpenter et al. discuss it under their term openness; Rockefeller under flexible, resourceful and reflective; Cabell and Oelofse under build human capital and reflected and shared learning; SRC under encourage learning; Frankenberger et al. under responsiveness/flexibility and learning and innovation. Many frameworks, however, are not as explicit about the dangers of innovation which does not, as Cabell and Oelofse put it, honor legacy. Legacy is the memory component of the SES. Frankenberger et al. refers to this quality as memory with strong community memory of traditions, practices, past disasters, and changing conditions supporting communities' abilities to draw on experience to prepare for and respond to similar challenges.

7. Ecologically integrated (Working with Nature)

Cabell and Oelofse are the most explicit in recognizing the value of ecological integration when they state that the more intact and robust the regulating ecosystem services are, the more resilient the agroecosystem. They further suggest that more resilient systems are more capable of self-regulation.

Rockefeller's discussion of integration and the importance placed on diversity by all other frameworks make this quality implicit in all the frameworks. Our analysis of local food systems indicates that the quality should be explicitly measured and induced.

8. Reorganizing, reforming, embracing disturbance for transformation.

Cabell and Oelofse mostly clearly see "exposed to disturbance" as a quality of resilient systems. Resilient systems regularly form new systems. Cabell and Oelofse's indicator of temporal heterogeneity also shows recognition of the transformation over time of resilient systems. Frankenburger notes the importance of transformative capacity.

Though innovation within a system is transformative on a smaller scale and is a quality recognized by all as necessary to resilience, most frameworks don't make the leap to recognizing that sometimes the innovation required may be so extensive as to transform the entire system. This limited embrace of transformation is illustrated by Rockefeller's emphasis on reflective systems which notes that resilient systems have mechanisms to continuously evolve, but does not go so far as to say they are periodically totally transformed.

Adaptive cycle and the eight roots of resilience. Transformation and innovation are easily identified as the qualities underlying the omega or dissolution phase transition to the alpha or reorganizing phase. Building assets and redundancy are associated most clearly with the K or conservation phase. Diversity is a result of innovation and transformation and most clearly seen as alpha moves into the r or rapid growth phase. Local self-organizing and ecological integration and modular connectivity are readily apparent in the r phase. However, all qualities must be available to the system throughout the life cycle when needed.

Our work with local food systems indicates that transformation is a quality necessary to resilience and must be explicitly included.

Our eight qualities are compared to qualities proposed by the six other frameworks in the following summary chart.

	Cabell and Oelofse	Carpenter et al	Rockefeller	Stockholm Resilience Ctr	Frankenberger et al.	Walker and Salt
1.Modular connectivity	Appropriately connected.	Modularity openness, feedbacks, monitoring, leadership and trust	Integrated (connected) Robust (modularity)	Manage connectivity Manage slow variables and feedbacks	Social capital	Modularity, Tight Feedbacks
2. Locally self-organized	Socially self-organized; globally autonomous and locally interdependent	nestedness	inclusive	Promote polycentric governance systems (nestedness)	Self-organized inclusive	Overlap in Governance
3. Build Assets			robust		Community Assets preparedness aspirations	Social Capital
4. Responsive Redundancy/Back-ups	Optimally redundant	reserves,	redundant	Maintain redundancy		
5. Complementary diversity	Functional and response diversity; spatial and temporal heterogeneity	diversity		Maintain diversity	Diversity	Diversity
6. Conservative innovation	Builds human capital; honors legacy; Reflected and shared learning	openness	reflective, flexible, resourceful,	Encourage learning	Learning and innovation; responsiveness/ flexibility Memory	Innovation
7. Ecologically self-regulated (works with nature)	Ecologically self-regulated, coupled with local natural capital		integrated			Ecological Variability, Ecosystem Services
8. Embracing disturbance for transformation	exposed to disturbance temporal heterogeneity		reflective	Foster complex adaptive systems thinking	Responsiveness	

What did we leave out? Nearly all of the factors deemed necessary by other frameworks are incorporated in our eight qualities of resilience. A couple are not. Stockholm Resilience Center is the only framework which adds the quality foster complex adaptive systems. Complex adaptive systems do embrace and use disturbance for transformation. However, all living systems are complex adaptive systems, so fostering CAS does not distinguish a resilient from a non-resilient system.

Similarly, "sufficient profit," one of Cabell and Oelofse's 13 indicator categories, does not distinguish between resilient and non-resilient systems. A resilient system will be generating sufficient profit, but profit is not necessarily an output which leads to resilience. Excess profit can certainly lead to non-resilience. Other systems may not be profitable one year due to expenses related to increasing resilience.

Which set of qualities are the most useful? The eight qualities we present each appear to be necessary for resilience in the local food systems we present in this book. Those who arrived at the other sets of qualities likely feel their set fits the systems they know best. The best way to decide between is to attempt to induce resilience in your own local food system or other agroecosystem. In order to do that, we need to operationalize these concepts. We must have specific ways of inducing and measuring each of these qualities. We don't pretend we have the final answers, rather we have tried to define the questions which will lead to particular local answers for a particular system. In the first chapter of this book, we proposed such a set of questions at the scale of the farm, here they are reworded to focus on the community level.

1. How is your community independent yet tightly connected to other communities, markets and government policy systems?
2. How is your community welcoming a diversity of complementary enterprises?
3. How is your community establishing back-ups and redundancy?
4. Are you insuring your community is as locally-oriented as possible? How are you helping your local systems to self-organize to increase resilience?
5. What assets are you building on your community? How do they contribute to your community's resilience?
6. Is your community increasingly working with nature, achieving ecological integration?
7. How do you insure innovation is regularly occurring on your community in a way which conserves the tried and true methods which built it?
8. How is your community embracing disturbance and periodically transforming itself?

In the following chart, we have generated activities and measures at various scales which we hope you will use to test our hypothesis.

If we continue to find these qualities in resilient systems, our basic concept will have been supported, but our work is not complete. Given limited resources, which of these qualities is most important? If all are not necessary in all situations, which should we induce first and which can wait? Are some of the qualities easier to induce in some situations? What determines how easy a quality is to induce? Are low levels of some qualities as effective as higher levels? How much bang for our buck do we get from various intervention to induce each quality? What is the cost-effectiveness of inducing change in each quality?

There are a virtually unlimited set of questions whose answers could help our systems become more resilient to climate change, economic change, technological change, political change or any of a vast set of potential disturbances on our agroecosystem.

The following diagram illustrates a number of ways to think about each factor at different social and biological scales.

Resilient food systems three dimensional matrix: scale, qualities, time								
	modular connectivity	local control, management, ownership	Assets, incl soil, water, increasing	Responsive redundancy	Cooperative, complementary diversity	conservative innovation	integration of natural ecological systems	continual reformation toward more resilience.
Federal Policy System	Cooperative development programs (RCDG)	VAPG, FMPP, LFPP, F2S implemented with ease of access for planning funds for local projects	NRCS support for increasing assets (soil, water catch & conserve, equipment, fence)	BFRDP focused on training a new generation of farmers	Opportunity workshops to encourage diversification of crops and markets	On-farm innovation demonstration trials of tools incorporating traditional methods, tools and products	Workshops to increase use of ecological services (beneficials, cover crops, MIG)	Support for new leader training in farm & cooperative groups.
Regional Network	Bridging contact maintained to all member groups.	Bring contacts which facilitate local control	↑Capability of network to assist local asset increase.	Network recruits new groups from across region.	Accesses new markets, practices for farmer groups	Local traditions celebrated while new ideas embraced	Wilderness reserves maintained	Regular turn-over in governing officials.
Community	Facilitates communication between all members.	Local firms encouraged, outsiders must partner	↑ infrastructure for services.	Community maintains and replaces all needed services.	Increased diversity dedicated to local heritage	Community embraces innovation and new practices as preserve heritage.	↑Area of parks and woodlands	New and young leaders encouraged.
Group of farmers	Farmers trust and value other members of group	LOVA local ownership of processing and marketing	Processsing/market equipment and facilities growing	Group recruits new members	Many different markets maintained for products	Variety of processing methods used as markets change	Support refuges and local heritage products	New processing/ marketing systems and products adopted
Farm and farm family	All systems on farm are independent but connected	Local managers make land decisions	Farm assets, equipment, inventory	Family and friends ready to help manage farm	Variety of systems (e.g., crop/livestock) integrated.	Farm uses old and new tools to produce heritage and new products	Wild refuges maintained on farm	Kaizen, continuous improvement of farm systems
Soils	Feedback tight btw soil and soil cover systems	Local soils need few inputs	Soil health increasing	Soil systems, soil cover reproduce selves	Diversity of soil organisms, and plants maintained.	Soil systems adapt to changing conditions	Native flora, fauna, EM increasingly relied on.	More systems for ↑ SOM, soil depth
Water	Water resource and need have tight feedback.	Local water harvest meets local need	Water capture increasing	Water sources steady to increasing	Multiple water sources available.	Variety of water sources developed/ maintained.	Water systems enhance wilderness	New systems employed to harvest/store local water
Person	Bonding and bridging social capital	Internal locus of control	Maintains equipment, soil, water catchment	Heals quickly, helps others learn	Has variety of approaches, attitudes	Changes approach when need to	Follows natural cycles, eats wild	Regularly tries new patterns, breaks old habits

Eight or five or thirteen or three?

Scientists are renowned for bickering over terminology. Much of the bickering results from pride of authorship and other temporal concerns. Only continued research will clarify which framework is most useful—or lead to creation of new frameworks even more useful than any of these. We have focused on determining the number of qualities necessary to insure resilience. Our qualities can be lumped into broader categories only for heuristic purposes. That is, if it makes understanding them easier, please lump.

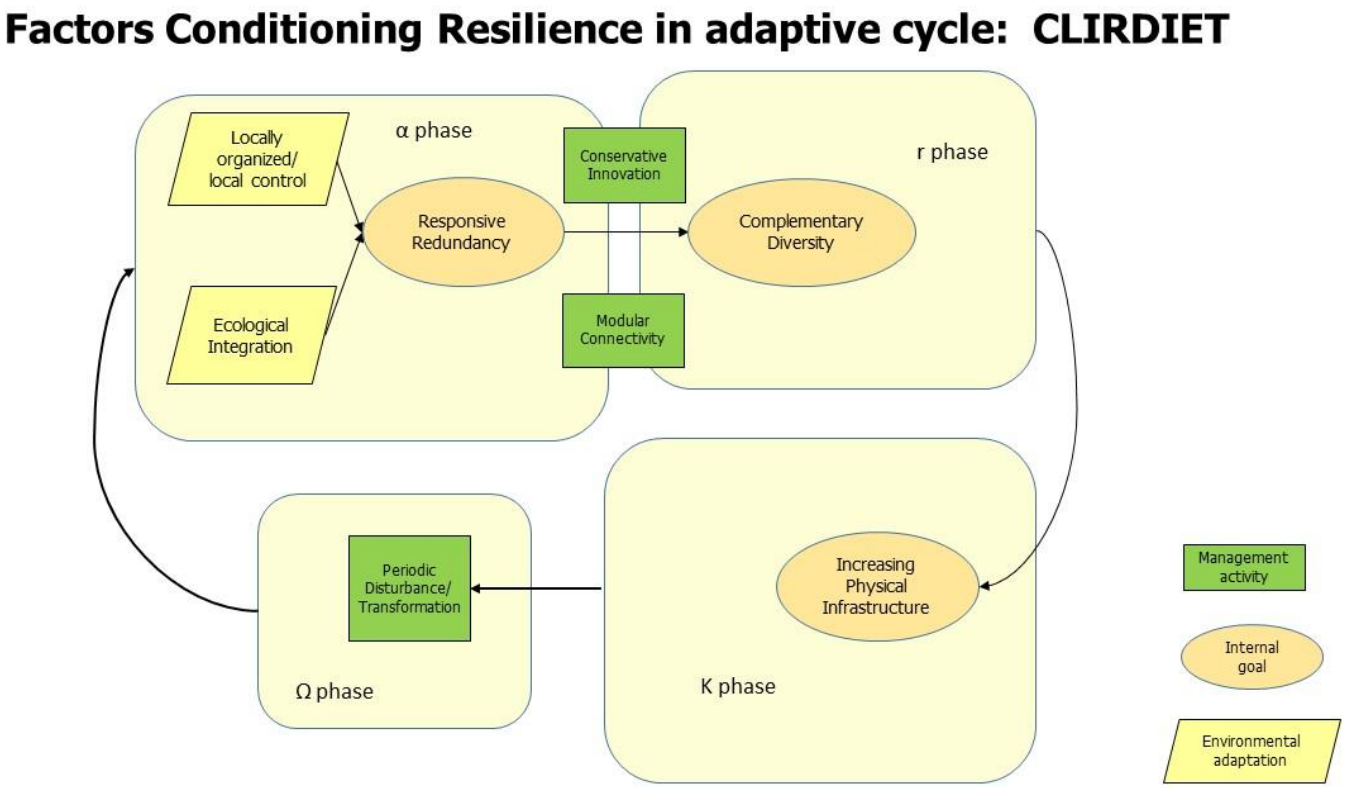
Eight qualities in three categories?

For example, we could argue for lumping our eight qualities into just three categories: **establishing ecologically sound networks, creating new systems and building up resources.**

> **Establishing an ecologically sound network.** Three of the eight qualities of ecological resilience concern the establishment of ecologically sound networks. Modular connectivity, Ecological Integration (Working with Nature) and Local Self-Organization are distinct qualities which emerge in resilient systems at different aspects and scales of the system.
>
> Modular Connectivity emerges in the relationships between all components.
>
> Ecological integration occurs as natural, self-regulating ecological systems merge with those managed more closely by man.
>
> Local Self-organization is created as all components become more tightly meshed in one emergent whole based on local control.
>
> **Creating new systems.** Local self-organization is also closely related to three other qualities.
>
> Conservative Innovation and Periodic Transformation are distinct qualities which emerge independently at each scale but are similar when viewed from different scales. A conservative innovation at one scale can be a transformation at another scale.
>
> Complementary Diversity could conceivably be lumped in this category since it arises from innovation and can lead to transformation.
>
> Innovation, transformation and diversity all show self-organization as different components merge into novel wholes.
>
> **Building up Resources.** Increasing Physical Infrastructur**e** at the scale of the farm may reflect redundancy at other scales. The soil infrastructure is created by the redundancy of many soil organisms. From the community level, the infrastructure of many viable farms is created by the redundancy of each farm.

Adaptive cycle and qualities of resilience.

This lumping of qualities usefully brings us back to the adaptive cycle of all living systems, as illustrated in the accompanying figure.



The qualities subsumed under “Establishing an ecologically sound network” can be seen most readily in the alpha stages of the adaptive cycle—when a system is getting organized and growing rapidly.

The qualities subsumed under “Building up resources” are most evident in the K phase—maturation.

The qualities subsumed under “Creating new systems” are most evident in the omega and alpha phases. Often these phases overlap as an innovation is created which gradually transforms the system by creatively destroying the previous system.

Appreciating the interrelationships of each of the eight qualities becomes easier as you understand each quality in more depth, seeing their interactions at different stages.