

Article

## The Capacity to Endure: Following Nature's Lead

Frank Fogarty <sup>1,\*</sup>, Amy Villamagna <sup>2</sup>, Allen Whitley <sup>3</sup> and Kelly Pippins <sup>1</sup>

<sup>1</sup> Sustainable Development and Conservation Biology Program, University of Maryland, College Park, College Park, MD 20742, USA; E-mail: pippins.k@gmail.com

<sup>2</sup> Department of Fish and Wildlife Conservation, 100 Cheatham Hall, Virginia Tech, Blacksburg, VA 24061-0321, USA; E-mail: amv@vt.edu

<sup>3</sup> Goodwill Industries of Central Texas, Austin, TX 78753, USA; E-Mail: Allen.Whitley@austingoodwill.org

\* Author to whom correspondence should be addressed; E-Mail: fogartyfa@gmail.com; Tel.: +1-352-455-9372.

Received: 6 March 2013; in revised form: 18 May 2013 / Accepted: 27 May 2013/

Published: 6 June 2013

---

**Abstract:** Many businesses today are striving to improve their environmental sustainability for a variety of reasons, ranging from consumer demand for “greener” products to potential cost-savings. For many business decision-makers who lack formal environmental training, the process of identifying facets of their organization that can be improved is unclear and challenging. Inspired by the fields of biomimicry, industrial ecology and organizational ecology, this paper draws on the inherent capacity to endure (CTE) of the natural world and recognizes that ecosystem function can be used as a technical advisor to guide business sustainability. We identified major attributes of ecosystems that both contribute to their CTE and can be easily translated into applications for the business world. Each of these attributes (fitness, functional redundancy, keystone species, waste and efficiency) and their applications are discussed at length. While further work is needed to evaluate their effectiveness and appropriateness for individual firms, we hope they can serve as a starting point for businesses seeking to improve their environmental sustainability.

**Keywords:** sustainability; ecosystem attributes; sustainable business

---

## 1. Introduction

In today's era of increased environmental awareness, we are under pressure to recognize that the current growth and development of modern society often occurs at the expense of the global environment. Ironically, that very growth and development is fundamentally dependent on ecosystem services, the goods and services provided by the environment [1,2]. These include everything from the hydrologic cycle providing water to forests sequestering carbon dioxide and producing oxygen. To address this problem, we must find a way for the built environment and human institutions to harmoniously embrace their relationship to the environment in a way that allows mutual prosperity. Hart [3] addressed this issue by advocating for the shift to a Natural Resource-based View (NRBV) of industry, where businesses recognize the biophysical constraints of the environment and gain a competitive advantage by addressing them more explicitly than their competitors. The framework of Natural Capitalism builds on the theory of NRBV by highlighting the enormous economic value of ecosystem services that is left out of nearly all business and economic decisions [4]. Natural Capitalism asserts that in order to make our economic models complete and improve our relationship with the natural world we must maintain and enhance natural and social capital. Other scholars have focused specifically on business models. The Triple-bottom Line, in which impacts to society, the environment and profit inform business decisions and actions [5], has permeated many business sectors and become a common buzz-word for corporate sustainability [6]. While these modes of thinking have impacted the business world and driven some improvements and innovation, especially for pollution and waste reduction, many other facets of unsustainability remain largely unaddressed and fundamental shifts in business operations have not been realized [7].

In recent decades, several disciplines have emerged that focus on enhancing the efficiency and sustainability of production by emulating nature. Two fields in particular stand out for their integration of engineering and biology to develop sustainable design based on the natural world: biomimicry and industrial ecology. Biomimicry is a design-based discipline in which engineers seek to copy physical features of organisms and ecosystems in an effort to capture the unique, inherent efficiency that results from millions of years of evolution [8]. Velcro, a ubiquitously used hook-and-loop fastening system based on a seed's dispersal mechanism, is one of the more well-known biomimicry examples [9].

In a similar vein, industrial ecology focuses on a much larger scale as it seeks to model industrial collectives or communities after ecosystems in an effort to reduce their environmental impact [10]. The eco-industrial parks of Kalundborg, Denmark are excellent examples where multiple facilities and industries are located in close proximity such that waste streams from one facility can be utilized as inputs to another in an attempt to close as many production loops as possible [11]. Biomimicry and industrial ecology represent just two points along an engineering and development continuum in which nature is used to inspire greater efficiency in the human, built environment.

Building on the ideas of biomimicry and industrial ecology, we have developed a framework of sustainability for businesses modeled after physical characteristics of the environment. The development of the intricate suite of processes, functions, and relationships that simultaneously contribute to the sustainable condition of the natural world has taken millions of years to evolve. By identifying and defining the attributes of this ecologically sustainable system we can begin to understand the lessons it may hold for the business world and how they can be applied to increase

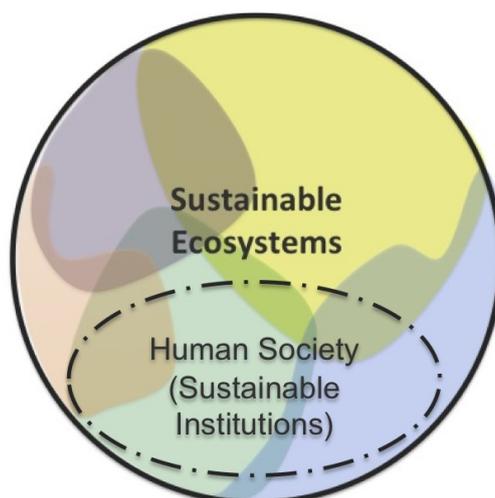
awareness of business sustainability and to enhance recognition of the often overlooked interconnections between the natural world and human institutions.

### 1.1. Defining Sustainability

Before we can identify characteristics of the natural world that can be applied to businesses we must first define sustainability in a business context. One of the simplest definitions of the word *sustain* is “to endure without giving way” [12]. Thus, we can interpret *sustainability* as the capacity to endure. An ecosystem’s capacity to endure (CTE), often referred to as ecological resilience, is inherently dependent on the condition of the environment and the organisms within. A healthy ecosystem can endure disturbances or shocks better than a degraded system [13]. Likewise, business sustainability is resiliency that can be attributed to financial, social, and environmental risk management [14]. By managing for economic efficiency, social equity, and environmental integrity (*i.e.*, the triple bottom line), businesses have the capacity to endure internal and external stresses (*e.g.*, labor strikes and supply shortages, respectively).

Although traditional views of business have considered the built environment and human economy distinct from the natural world, the former are in fact intrinsically linked to ecosystems by their consumption of materials and energy and disposal of waste. Businesses can degrade ecological sustainability by means of pollution or overexploitation but in doing so may hinder their own CTE. Consider the basic example of a timber company. By harvesting all trees at once and degrading soils, that business has diminished the opportunity to harvest from that ecosystem in the future and therefore negatively affected its CTE. Figure 1 depicts a more accurate view of the relationship between businesses and the natural world, in which human society is an integrated subset of broader ecosystems. The figure shows the closed global system as composed of smaller, open and overlapping ecosystems, illustrated by the shapes of various colors and sizes. The dashed border surrounding human society demonstrates that it is an open system embedded within broader natural systems. Using this paradigm, it follows that human institutions can benefit from the organization and structure that lead to the natural world’s CTE and adopt these characteristics as a technical advisor for improving their own sustainability.

**Figure 1.** Human society and the global environment.



## 1.2. The Global Environment as a Technical Advisor for CTE

Despite significant differences between ecosystems, there are common characteristics among them that contribute to their CTE. Our goal is to identify and describe some of those characteristics for enhancing sustainability within the business world. A sustainable business is one that considers the health of the planet as well as their profit margin and in doing so responsibly manages financial, social and environmental risks [14]. Given the complexity of the natural world, every facet of ecosystem function and structure will not be useful to this pursuit. Thus, attributes must meet the following criteria in order to be included in our framework: a) contribute directly to CTE in a clear, definable manner, b) have a clear analog in business, and c) have a neutral or positive impact on the environment when applied to business practices. Our approach is informed by the discipline of organizational ecology, which seeks to understand how environmental and social conditions drive changes in organizations as well as their formation and dissolution [15]. However, our work differs from organizational ecology in several ways. First, much of the literature on organizational ecology has focused on how conditions affect the appearance and disappearance of organizations and organizational forms. Our framework is more concerned with the process and possibility for change within individual organizations (businesses, in our case). Second, rather than focusing on how ecological processes drive change in businesses, we seek to explain how businesses can emulate and integrate lessons from nature to improve both their sustainability and bottom line. Third, we anchor our comparisons between businesses and ecosystems more broadly than organizational ecology. For most of our framework, individual firms are treated as analogs to ecosystems. However, maintaining that comparison is not integral to our approach. Varying the levels of the comparison can be informative and thus some of our attributes treat firms as species. Regardless of the level of comparison, these attributes are informative in their ability to improve a business' CTE.

This work identifies a suite of ecosystem attributes that are characterized as both important to CTE and readily translatable to the business world. We present these attributes and their parallels to the business world in a manner that highlights their utility to firms that are seeking to improve their sustainability. The following ecosystem attributes are described: fitness, functional redundancy, keystone species, and waste and efficiency. While this list is not exhaustive, we feel it summarizes key attributes of sustainability that are relatively straight-forward for businesses to pursue. Each section begins with a detailed description of the characteristic(s) followed by an explanation of its applicability to business operations.

## 2. Ecosystem Attributes and their Parallels in Business

### 2.1. Fitness

In biological evolution, natural selection is the predominant mechanism of change over time. Natural selection can briefly be described as the process by which characteristics are lost or preserved in a population. Traits that enhance the survival and reproduction of an individual in its present environment are likely to be passed on to the offspring of that individual. Traits that are disadvantageous will reduce an individual's chance of survival and therefore the likelihood that such traits will persist in a population. Thus, species fitness is essentially a measure of how well-adapted a

species is to its physical environment and biological counterparts [16]. Species fitness is determined by the suitability of traits within a species among which there is some level of variation. Variation, also referred to as plasticity, within a species enhances long-term fitness as it increases the probability that a group of individuals (*i.e.*, a population) within the species will possess successful characteristics [17]. Given natural selection, these optimal characteristics will presumably be retained in the species population providing the abiotic and biotic environment does not change [18].

The concept of fitness has also been expanded to the discussion of ecosystems. Ecosystems face constraints and stresses induced by changes in their physical surroundings. For example, changes in the local climate can affect the species composition and ultimate structure and function of an ecosystem. The persistence of an ecosystem is generally defined as maintaining some historical level of species diversity and abundance over time where community associations and natural processes are preserved [19]. An ecosystem's ability to persist in the face of change can be seen as a measure of ecological fitness [20]. Ecological fitness can therefore be considered a measure of an ecosystem's CTE.

### Business Fitness

While businesses are capable of setting their own goals for development, they are not free of external selective pressures (e.g., competition, demand, and environmental constraints). The success of a business depends on its ability to meet the demands of consumers and the constraints of the market while maintaining enough profit to persist. Therefore, businesses must actively strive to maximize fitness in the face of selective pressures. Like the natural world, variation and behavioral plasticity is essential to enduring selection pressures. Businesses can enhance plasticity by any number of different strategies and mechanisms. These include targeting new sets of customers or wider audiences, securing multiple suppliers for their inputs and ensuring the long-term viability of these resources (labor, raw materials, capital, modules or parts), having more than one market niche, adopting multiple internal and external communication strategies, and maintaining the ability to develop new products and/or features to order attract new customers. For example, structuring an energy portfolio which utilizes renewable and nonrenewable sources, ensures a continuity of affordable supply while allowing the business to shift the mix (*i.e.*, adapt) depending on how new technologies, demand, and other factors impact price and preference. Unlike ecosystems or species, individual firms can decide to enhance their internal variation and in turn affect their own business fitness. In addition to variation and plasticity, however, is the need to evaluate success and reinvest in effective strategies. This form of internal monitoring, evaluation, and investment mimics the selection and retention processes that we attribute to natural selection.

A discussion of fitness and selection is not complete without some acknowledgement of the timescales for which fitness is evaluated in ecosystems and businesses. The timescales relevant to businesses are much shorter than those of biological evolution, but perhaps shorter than they should be if we acknowledge that the business world is embedded in the natural world (Figure 1). In order to better emulate environmental selection and fitness, businesses will need to look beyond short-term goals and metrics that focus on timescales of quarters or years and consider the impact of their decisions over decades and even centuries. This is not to say that short-term planning should be abandoned entirely, as a business concerning itself only with operations 25 years from now could

easily find itself bankrupt next week. Rather, the ideal shift would be an incorporation of short-, medium-, and long-term goals that allows businesses to ensure their day-to-day profitability in a way that is compatible with environmentally sustainable operations and long-term survival. This sort of strategy would also require businesses to take into account a wider variety of information when making decisions, including resource availability, sustainable and affordable energy sources, diminishing natural sinks for waste products, lasting effects of externalities, and their ability to adapt to shifting trends in consumer demand and technology in order to orient their firms in a viable and enduring direction.

## 2.2. Ecological Redundancy

In the face of changing environmental pressures an ecosystem is able to maintain its integrity in part by capitalizing on the ecological redundancy of its organisms [21]. Every organism within an ecosystem occupies a niche, meaning they hold a specific role in the overall functioning of that ecosystem. The role a certain organism plays is dictated by the current conditions of their environment including both the abiotic factors and the abundance and diversity of fellow community members. Ecological redundancy refers to the ability of multiple species to perform similar functions within the same system [22]. While two or more types of organisms may be able to fill a single niche, the relative ability of those types to perform a given function may vary (*i.e.*, one is more efficient than others) [23]. Chalcraft and Resetarits [24] demonstrated this in their study of functionally redundant predatory fish. Even though several fish species prey on the same species, differences in their preferences for and ability to prey on particular species defines their individual roles in the environment. Furthermore, the specific type of organisms that carry out a specific function will vary with environmental conditions. In a healthy ecosystem with many functionally redundant species, niches tend to be filled by the most adept species for each role [22].

Functional redundancy is critical to CTE because the overlap enables ecosystems to be more resistant to environmental changes (e.g., the decline of single species will not result in complete loss of functionality; [22,25]). Following the loss or decrease in abundance of a specific species or group of organisms, others with a similar functional capacity may replace the loss in ecosystem function by increasing their own density to occupy the open niche. This is not meant to imply that individual species are expendable within an ecosystem. Losses in biodiversity almost always negatively impact the overall ecosystem [25], as no two ecologically redundant species are identical in function and any loss of biodiversity has been linked to a decrease in a system's overall resistance to change [26]. However, ecological redundancy does help explain how the entire, complex ecosystem does not collapse when a single population declines or goes extinct.

### Functional Redundancy in Business

In a similar fashion to ecosystems, businesses can benefit from functional redundancy. We can draw a parallel between ecological niches and the positions, duties, and responsibilities of individual employees within the ecosystem of a business. As mentioned before, an ecosystem does not need a particular species to occupy each specific niche in order to preserve function. Multiple species are capable of occupying most niches and functionality can be maintained (to an extent) as long as niches

are occupied by one of more of these suitable species. Individual positions and duties within a business work in a similar manner. Having a particular employee in a position is not necessarily critical to the function and success of a firm, as long as someone who is competent at the duties of that position is employed. The term “redundant” may hold a negative connotation in the minds of many managers who associate it with a waste of resources and inefficiency, as in paying two people to do identical tasks when one would easily fulfill the need. However, it is important to understand that this is not the implication or goal of functional redundancy. *Business functional redundancy* refers to promoting broader skill sets among employees to ensure that operations are not compromised if an employee is absent from their “niche”. This absence could be due to illness, vacation, or even complete departure from the firm. Having the ability to compensate for the loss by shifting responsibilities to capable, qualified personnel is essential to minimizing the impact of such a loss. Much like a simplistic ecosystem with low diversity may be compromised by the decrease or loss of a single species, a firm operating with minimal functional redundancy will feel the effects of almost any change in available personnel. It is important to note, however, that there will often be some individuals or positions for which functional redundancy is not applicable. These cases and the special consideration they merit are discussed in the next section.

### 2.3. Keystone Species

The stability of many ecosystems depends on keystone species. In these systems, keystone species are defined as having an influence on the structure and diversity of the system that is disproportionate to their abundance [27,28]. The functional role filled by a keystone species will be different from ecosystem to ecosystem but they are all nearly irreplaceable, as ecosystems essentially have no functional redundancy for the critical niches these species occupy. Ecosystems that lose their keystone species can face cascading collapse of their community structure [29]. A classic example is the Sea Otter and its effects on the large kelp forests of the near-shore Pacific Ocean. The otters do not directly feed on kelp, but they are the main predators of herbivorous sea urchins that graze on kelp. When hunting nearly pushed the otters to extinction in the 18th century the entire ecosystem nearly collapsed, as unchecked populations of sea urchins overgrazed kelp and decimated the enormous sea floor habitats they provided [30]. However, keystone species do not necessarily have to be dominant predators at the top of a food chain, as illustrated by the example of burrowing species such as gopher tortoises and prairie dogs that create essential habitat for a wide variety of other organisms. There can even be multiple keystone species within the same system that carry out very different yet equally essential functions. Because of their critical importance to ecosystems as a whole, keystone species have become a major target for many conservation efforts [29].

#### Keystone Employees

Businesses often have a number of key employees who are essential to their continued success. Common places to find keystone employees within a firm are occupying leadership and management niches. However, they are not restricted to senior leadership. Just as keystone species are not necessarily found at the top of the food chain, critical management roles also range from ownership and chief executives down to managers of single departments. The unique insights and experience

possessed by an individual manager may be critical to the proper and efficient functioning of his division or the entire firm. Instances of keystone people may also exist outside of management. Nearly every business employs one or more people who are simply irreplaceable. Their unique abilities and understanding, often coming from a long history within a business or industry, may be nearly impossible to find elsewhere. These employees may possess “tacit knowledge”, intuition or abilities that they are readily able to their work but cannot easily be explained or taught [31]. Examples are an employee with essential technical skills that are specific to the firm, or someone with well-developed relationships with customers, suppliers, or even competitors.

Additionally, a keystone employee’s knowledge of the “big picture” and their understanding of the company’s environmental impact could be tapped as a positive force for increasing business fitness. The role of Chief Sustainability Officer (CSO) in some organizations may fill this niche. Traditionally, department directors and facility managers were responsible for regulating sustainable practices. As the scope of sustainability in business expands, these issues fall beyond the reach of those individuals. CSO’s can help influence sustainable decisions at the corporate level with a strong understanding of the interworking of the corporation and its impact on the environment [32]. These keystone employees are essential to ensuring the incorporation of sustainable practices that benefit their triple bottom line and contribute to CTE. Because of their importance, businesses should seek to identify and “conserve” keystone employees in every level of operations.

#### *2.4. Waste and Efficiency*

In contrast to the current cradle-to-grave product life cycle observed within much of the human-constructed world [33], the natural world has evolved an incredibly efficient system of cycles. In fact “waste,” in the sense of unnecessary excess, does not exist in a healthy ecosystem [34,35]. Generally speaking, all matter is continuously and completely recycled throughout the system leaving little or no excess. For example, the leaves dropped by deciduous trees every autumn decompose, returning organic matter and nutrients to the soil that nourish other plant life.

More broadly speaking, the nutrient and hydrologic cycles in natural systems exemplify the first two laws of thermodynamics, which describe the transformation of materials and energy [36]. The first law of thermodynamics states that matter and energy cannot be destroyed or created by any process [37]. Instead, processes simply transform them from one state to another. The second law of thermodynamics, building on the first, states that all processes move energy and matter towards higher entropy conditions. Entropy, in a simple sense, is defined as a measure of the disorder or randomness of matter or energy [36]. In nearly all situations, lower entropy substances are far more useful than high entropy substances for both biological and industrial purposes due to their homogeneity and structure [38].

In the natural world, the primary input of energy to ecosystems is sunlight, a concentrated, low entropy form that is highly useful to plant life. This energy is initially converted to low entropy molecules like glucose and starch, but these compounds are ultimately metabolized and transformed into higher entropy states (heat and motion) by animals that consume the plants. While individual steps in the cycle may appear to decrease entropy, the overall system moves low entropy sunlight to high entropy heat, thus increasing entropy in the system and adhering to the second law of thermodynamics.

## Waste and Efficiency in Business

In business, waste is often both a monetary cost and a threat to ecosystem health. Therefore, reduction of waste is often identified as a logical and achievable goal for companies looking to reduce their environmental impact [7]. However, based on the laws of thermodynamics a business can never truly get rid of waste. Instead, it can be transformed into inputs for another process, similar to the aforementioned ecological cycles. In some cases, the concept of “zero-waste” may involve the redesign of products to emulate an ecosystem’s cradle-to-cradle approach [33]. Products that are developed under zero-waste restrictions can be easily broken down into re-usable components. Most production processes that create more structured products from raw material involve substantial energy inputs. As entropy increases, the opportunities to reuse or recycle these products decrease, leading to the need for more low-entropy inputs and the increased potential for waste. Therefore, the zero-waste approach targets both the downstream end of a product’s life and upstream manufacturing of products. To facilitate the re-use of materials, businesses may also offer “take-back” programs for environmentally harmful products [33]. In terms of upstream manufacturing, the type of energy inputs and usage are key areas where businesses can minimize waste. Businesses should take into account the diminishing stock of fossil fuels, as their decreased availability will ultimately threaten the viability of any institution dependent primarily on non-renewables. Before this becomes a serious scarcity issue, businesses can search for innovative ways to both reduce their overall energy demand and find renewable alternatives that can replace some of their needs. While increasing production efficiency may be part of the solution for some businesses, other businesses that focus less on production of goods may find energy reduction can be achieved by enhancing the maintenance efficiency (*i.e.*, durability) of necessary materials and equipment [38]. Additionally, businesses generally utilize many material inputs that are not created internally. These may be products of other businesses (engines, tires, paper, *etc.*) or natural resources extracted from the environment (iron, rubber, wood pulp). If businesses are to emulate the way ecosystems cycle materials, they should work towards closing the production loop and avoid creating high entropy products or those that cannot be broken down into reusable forms. Rather than try to process all waste internally, firms could team-up with others to enhance input-output cycles (industrial ecology), as well as incorporate the surrounding ecosystem into their production models (natural capitalism). If sources of natural resources and their finite regenerative rates are considered an irreplaceable part of production, then firms can begin to integrate sustainable rates of usage into their operating plans.

While manufacturing firms may be most interested in reducing wastes in terms of production inputs and outputs, service-based firms may find time a more precious resource that is wasted. Time wasted equates to money wasted. Labor-intensive firms may choose to focus on time-saving activities by offering telecommuting options [39] or high-tech mass transit options that allow workers to start and end their work day during the commute (e.g., Google’s Campus Commuting Options). Telecommuting and mass transit options decrease the collective carbon footprint of the firm while enhancing the quality-of-life of its workers [40]. Likewise, condensed work weeks could reduce energy usage while providing employees a more utilizable period of time off and improving work-life balance [40,41].

### 3. Motivating Change in the Business World

The attributes discussed in the preceding sections are shown in their entirety in Table 1. While every characteristic of the natural world was not reviewed, we find this set to be the most relevant and applicable to businesses and other human institutions. The authors also recognize that while few businesses have adopted all of these attributes, many have already incorporated one or more of them into their business strategies and best practices. For example, Albertsons grocery has two stores in Southern California which are considered zero waste and annually divert more than two million pounds from entering the waste stream. In addition, Whole Foods, The World Bank, and the EPA, to name just a few, run on 100% renewable energy [42]. These are only a few examples of organizations that have accepted or are in the process of understanding and internalizing the tenets of sustainability.

**Table 1.** Capacity to Endure (CTE) Attributes.

<b>Capacity to Endure Attributes</b>	<b>Ecological Example</b>	<b>Business Counterpart</b>	<b>Strategic Actions</b>
Fitness	Natural selection of characteristics that enhance fitness and the capacity to endure; Variation within the species that meets the conditions of the environment are selected and retained within the population [18,43]	Selection by competition, demand, and internal and external environmental constraints	Enhance internal variation and behavioral plasticity by targeting wider market niches, securing multiple input suppliers, adopt multiple communication strategies, and develop new products and/or features to order attract new customers; develop short-, medium-, and long-term goals; increase monitoring and evaluation of business strategy success
Ecological redundancy	Ability of multiple species to perform similar functions within the same system [21–23]	Overlapping job skills and broad employee competency	Cross-train employees to cover multiple positions in the case of sudden unexpected change; Increase training opportunities and workshops
Keystone species	Species with a disproportionately greater impact than its abundance [27,28]	CEO, President, Director, Chief Sustainability Officers and others with tacit knowledge [31]	Promote greater leadership with leadership training opportunities; reward leadership behavior and actions that model sustainability

Table 2. Cont.

Capacity to Endure Attributes	Ecological Example	Business Counterpart	Strategic Actions
Waste and Efficiency	Closed global systems; nutrient and water cycling [34,35]; conversion of carbon and sunlight into energy	Cradle-to-cradle design [33]; renewable energy and material usage;	Select inputs that are biodegradable, recyclable, or reusable; Offer “take-back” programs for harmful products for proper reuse or recycling; decrease resource inputs; shorten the distance between source, production, and delivery; decrease waste production; join with other firms to enhance the utilization of by-products; incorporate resource scarcity and pollution into decisions

A fully sustainable business would embrace its relationship with the natural world, consider the triple bottom line [44,45] in decision-making, and have minimal, if any, negative impact on the environment. However, most decisions are driven by a combination, if not by all, of the following [46]: efficiency, public concern/image, and regulation. For example, a company may increase efficiency in order to enhance cost-savings or to avoid the depletion of a scarce resource. However, sometimes the motivation is voluntary, perhaps to keep up with more efficient competitors, or mandated, such as regulation which is imposed to minimize resource use or waste production. The customer’s perception of a firm and its products plays a large role in their purchasing preference, and therefore can also serve as a strong motivator in decision-making. Many industries today are responding to public concern over environmental impacts and a firm taking steps to improve its environmental sustainability may improve its market share and profit through positive advertising and public perception. These endeavors are largely voluntary but could become almost essential for a company that has endangered its market share through publicized, negative environmental impacts. Regulation is also a key determinant in business-related decision-making. Many changes that improve environmental sustainability are direct reactions to regulation stemming primarily from government mandates (e.g., state-based regulations on vehicle emissions). Firms must comply with these regulations or face penalties such as fines or the revocation of operating rights and licenses. These changes are compulsory and can decrease net profit for a firm. However, this loss of profit may be avoidable if a firm is innovative and proactive in adjusting its operations.

In order to enhance the environmental sustainability of a business it is important to consider how these and other motivators can be used to spark a behavioral change within the organization. Schaltegger *et al.* [47] examined these drivers of business change and how they relate to improving sustainability in laying out their “business case for sustainability.” To achieve their business case, a firm must undertake voluntary changes that provide solutions to environmental or social problems while also providing a clear, non-speculative economic benefit (increased profit, competitiveness,

reputation, etc.). Schaltegger *et al.* [47] also assert that a business case for sustainability will not occur on its own and requires firms to actively adjust their business model to create and manage this condition. Our work complements this approach by demonstrating specific strategies that can be used to create a business case for sustainability. Using the natural world as a technical advisor allows us to identify specific ecosystem attributes that can be adopted by firms and provide both economic and environmental benefits.

#### 4. Conclusions

In this paper, we have discussed the application of ecological attributes to business sustainability and provided a short list of strategic goals to achieve greater business and environmental sustainability. Following the example of biomimicry and industrial ecology, we argue that the natural environment provides the most fundamental model of sustainability and should therefore be used as a technical advisor to develop sustainable practices for human institutions. By extracting sustainable concepts from the environment and applying them in practice to businesses and other institutions, we believe that both the condition of the environment and longevity of the business can be improved. In order to make sustainable institutions a reality, we must first recognize that human society is embedded within the global environment. Because humans have a direct impact on the environment and are in turn limited by its condition, environmental sustainability should be an essential component of long-term business viability.

We believe that a paradigm shift is occurring, evident in the addition of the sustainability vernacular into a variety of topics ranging from finance to management to government. Business decision-makers and managers are under increasing pressure from employers, governments and society to be more sustainable. For example, *Freakonomics* co-author, Stephen Dubner, suggested “that it may be time to start thinking about the U.S. economy not in terms of never-ending growth, but in terms of sustainability” [48]. This indicates that concepts related to those presented in this paper are far-reaching and beginning to influence decision making in a variety of ways.

We realize that some components of this framework may not be practical for all types or sizes of institutions and that these CTE attributes alone may not ensure success. Increasing an organization’s CTE also relies on the proper leadership, as it is up to the decision-makers of an institution to adopt these practices and to be accountable for the impacts of those decisions. We promote the CTE attributes as opportunities to help understand what being more sustainable really means and, ultimately, to achieve greater business and environmental sustainability for human-constructed entities. Future progress toward enhancing sustainability will require an in-depth analysis of its implications from the business perspective. Some of these strategies may not coincide with short-run profit maximization for firms and present a financial risk. Further study is needed to compare the success rates of ‘sustainable’ firms against their conventional counterparts over both the short and long-run. We also suggest that these concepts may be expanded and refined to suit the interests of a broad array of institutions. Thus, the next step may be to evaluate the effectiveness of these attributes when applied to a variety of businesses (e.g., production- vs. service-oriented) and human institutions (e.g., public vs. private) of different sizes. With a little guidance from the natural world, perhaps a company’s sustainability record may soon receive equal consideration to its quarterly profits.

## Acknowledgments

The authors sincerely thank the Smithsonian Institution for its financial support of this project.

## Conflict of Interest

The authors declare no conflict of interest.

## References

1. Costanza, R.; d'Arge, R.; de Groot, R.; Farber, S.; Grasso, M.; Hannon, B.; Limburg, K.; Naeem, S.; O'Neill, R.V.; Paruelo, J.; *et al.* The value of the world's ecosystem services and natural capital. *Nature* **1997**, *387*, 253–260.
2. Daily, G.C. Ecosystem Services: Benefits supplied to human societies by natural ecosystems. *Issues Ecol.* **1997**, *1*, 1–16.
3. Hart, S.L. A natural resource-based view of the firm. *Acad. Manage. Rev.* **1995**, *20*, 986–1014.
4. Lovins, A.B.; Lovins, L.H.; Hawken, P. A road map for natural capitalism. *Harv. Bus. Rev.* **1999**, *May–June*, 145–158.
5. Elkington, J. *Cannibals with Forks: The Triple-Bottom Line of 21st Century Business*; Capstone: Oxford, UK, 1997.
6. Esty, D.C. *A Term'S Limits*; Faculty Scholarship Series, Paper #434; Yale Law School: New Haven, CT, USA, 2001.
7. Hart, S.L.; Dowell, P. A natural resource-based view of the firm: Fifteen years after. *J. Manage.* **2011**, *37*, 1464–1479.
8. Benyus, J.M. *Biomimicry: Innovation Inspired by Nature*; Perennial: New York, NY, USA, 2002.
9. Dickinson, M.H. Bionics: Biological insight into mechanical design. *Proc. Natl. Acad. Sci. USA* **1999**, *96*, 14208–14209.
10. Frosch, R.A.; Gallopoulos, N.E. Strategies for manufacturing. *Sci. Am.* **1989**, *261*, 144–152.
11. Lowe, E.A.; Evans, L.K. Industrial ecology and industrial ecosystems. *J. Clean. Prod.* **1995**, *3*, 47–53.
12. O'Connor, M. *Is Capitalism Sustainable?: Political Economy and the Politics of Ecology*; Guilford Press: New York, NY, USA, 1994; pp. 152–175.
13. De Leo, G.A.; Levin, S.A. The multifaceted aspects of ecosystem integrity. Available online: <http://www.ecologyandsociety.org/vol11/iss1/art3/> (accessed on 25 February 2013).
14. Fisk, P. *People, Planet, Profit: How to Embrace Sustainability for Innovation and Business Growth*; Kogan Page Ltd.: London, UK, 2010.
15. Singh, J.V.; Lumsden, C.J. Theory and research in organizational ecology. *Annu. Rev. Sociol.* **1990**, *16*, 161–195.
16. Orr, H.A. Fitness and its role in evolutionary genetics. *Nat. Rev. Gen.* **2009**, *10*, 531–539.
17. Primack, R.B. *Essentials of Conservation Biology*, 5th ed.; Sinauer Associates: Sunderland, MA, USA, 2010.
18. Hannan, M.T.; Freeman, J. The Population Ecology of Organizations. *Am. J. Sociol.* **1977**, *82*, 929–964.

19. Falk, D.A.; Palmer, M.A.; Zedler, J.B. *Foundations of Restoration Ecology*; Island Press: Washington, DC, USA, 2006.
20. Cropp, R.; Gabric, A. Ecosystem adaptation: Do ecosystems maximize resilience? *Ecology* **2002**, *83*, 2019–2026.
21. Naeem, S. Species redundancy and ecosystem reliability. *Conserv. Biol.* **1998**, *12*, 39–45.
22. Walker, B.H. Biodiversity and ecological redundancy. *Conserv. Biol.* **1992**, *6*, 18–23.
23. Wellnitz, T.; Poff, N.L. Functional redundancy in heterogeneous environments: Implications for conservation. *Ecol. Lett.* **2001**, *4*, 177–179.
24. Chalcraft, D.R.; Reseraris, W.J., Jr. Predator identity and ecological impacts: Functional redundancy or functional diversity? *Ecology* **2003**, *84*, 2407–2418.
25. Naeem, S.; Li, S. Biodiversity enhances ecosystem reliability. *Nature* **1997**, *390*, 507–509.
26. Walker, B.H. Conserving biological diversity through ecosystem resilience. *Conserv. Biol.* **1995**, *9*, 747–752.
27. Paine, R.T. Food web complexity and species diversity. *Am. Nat.* **1966**, 66–75.
28. Paine, R.T. A note on trophic complexity and community stability. *Am. Nat.* **1969**, 91–93.
29. Terborgh, J.; Estes, J.A. *Trophic Cascades: Predators, Prey, and the Changing Dynamics of Nature*; Island Press: Washington, DC, USA, 2010.
30. Estes, J.A.; Palmisano, J.F. Sea otters: Their role in structuring nearshore communities. *Science* **1974**, *185*, 1058–1060.
31. Eraut, M. Non-formal learning and tacit knowledge in professional work. *Br. J. Educ. Psychol.* **2000**, *70*, 113–136.
32. Weinreb Group. Cso Backstory: How chief sustainability officers reached the c-suite. 2011. Available online: <http://weinrebgroup.com/wp-content/uploads/2011/09/CSO-Back-Story-by-Weinreb-Group.pdf> (accessed on 25 February 2013).
33. McDonough, W.; Braungart, M. *Cradle to Cradle: Remaking the Way We Make Things*; North Point Press: New York, NY, USA, 2002.
34. Molles, M.C. *Ecology: Concepts and Applications*; McGraw Hill: Boston, MA, USA, 1999; p. 509.
35. Richards, D.J.; Allenby, B.R.; Frosch, R.A. The greening of industrial ecosystems: overview and perspective. In *The Greening of Industrial Ecosystems*; Richards, D.J., Allenby, B.R., Eds.; National Academy Press: Washington, DC, USA, 1994; pp. 1–19.
36. Daly, H.E.; Farley, J.C. *Ecological Economics: Principles and Applications*; Island Press: Washington, DC, USA, 2004.
37. Beard, R.; Lozada, G. *Economics, Entropy and the Environment: The Extraordinary Economics of Nicholas Georgescu-Roegen*; Edward Elgar: Cheltenham, UK, 2000.
38. Daly, H.E. Economics in a full world. *Sci. Am.* **2005**, *293*, 100–107.
39. Dorf, R.C. *Technology, Humans and Society: Toward a Sustainable World*; Academic Press: London, UK, 2011.
40. Madsen, S.R. The effects of home-based teleworking on work-family conflict. *Hum. Resour. Dev. Q.* **2003**, *14*, 35–58.
41. Northup, H. The twelve-hour shift in the North American mini-steel industry. *J. Labor Res.* **1991**, *12*, 261–278.

42. Herrera, T. How Albertson's achieved zero waste at two grocery stores. Available online: <http://www.greenbiz.com/news/2010/12/01/how-albertsons-achieved-zero-waste-two-grocery-stores/> (accessed on 25 February 2013).
43. Darwin, C.R. *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*; John Murray: London, UK, 1860.
44. Dyllick, T.; Hockerts, K. Beyond the Business Case for Corporate Sustainability. *Bus. Strategy Environ.* **2002**, *11*, 130–141.
45. Hacking, T.; Guthrie, P. A framework for clarifying the meaning of triple bottom-line, integrated, and sustainability assessment. *Environ. Impact Assess. Rev.* **2007**, *28*, 73–89.
46. Van Marrewijk, M. Concepts and definitions of CSR and corporate sustainability: Between agency and communion. *J. Bus. Ethics* **2003**, *44*, 95–105.
47. Schaltegger, S.; Lüdeke-Freund, F.; Hansen, E. Business cases for sustainability: the role of business model innovation for corporate sustainability. *Int. J. Innov. Sustain. Dev.* **2012**, *6*, 95–119.
48. The hidden side of U.S. Economic growth: Is it over? <http://www.marketplace.org/topics/economy/freakonomics-radio/hidden-side-us-economic-growth-it-over/> (accessed on 25 February 2013).

© 2013 by the authors; licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution license (<http://creativecommons.org/licenses/by/3.0/>).