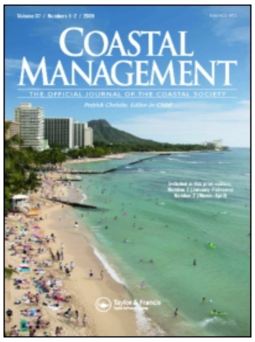

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Michelle Marvier, Peter Kareiva & Emma Fuller

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Mark Plummer's Legacy: Leave No Orthodoxy Unquestioned

Michelle Marvier[a], Peter Kareiva[b], and Emma Fuller[c]

[a]Department of Environmental Studies and Sciences, Santa Clara University, Santa Clara, California, USA; [b]Institute of the Environment and Sustainability, UCLA, Los Angeles, California, USA; [c]Department of Ecology and Evolutionary Biology, Princeton University, Princeton, New Jersey, USA

ABSTRACT
Inspired by Mark Plummer's legacy of questioning conservation and environmental orthodoxy, we challenge several common conservation memes and patterns of thinking. First, we argue that framing conservation messages as crises typically is not an effective strategy. Second, we question conservation regulations that are inflexible and insensitive to costs, uncertainty, and competing values. We instead advocate for experimentation, flexibility, and pragmatism. Third, we suggest that precautionary approaches to conservation regulation are out of step with a rapidly changing world facing uncertain shocks and disruptions. Finally, based on a systematic review of ecosystem change following disturbance, we find simplistic models of ecosystem resilience to be poorly supported by data. Ecosystem change is more the rule than the exception, and while academic ecologists have noted this to be the case, the ramifications of this pattern have yet to be embraced by resource managers. Our goal is to challenge conservationists to question popular conceptual models relentlessly and embrace new information, even when it challenges deeply held assumptions.

KEYWORDS
ecosystem resilience; environmental regulation; fear appeals; precautionary principle

All scientific disciplines include debates and controversies, but few can rival conservation—the application of social and natural sciences to maximize benefits jointly for nature and people (Kareiva and Marvier 2012)—for the passion with which almost any critique of conventional wisdom is scorned (Pimm 2014; Marvier 2014), or for the tendency to make dramatically dire predictions despite huge uncertainty (Ellis 2003). This is not to say that scorn of assaults on consensus views is unfounded or that biodiversity is in good shape. It is simply an observation that debate in this arena frequently veers into the philosophical, and views that challenge widely held beliefs may be painted as heretical, as opposed to being discussed in terms of scientific evidence (Cafaro and Primack 2014).

We argue that several of conservation's deeply entrenched memes and conceptual models may be ill-suited to today's rapidly changing and uncertain world. The conservation patterns of thinking that we question are 1) embracing the notion of "nature on

CONTACT Peter Kareiva pkareiva@ioes.ucla.edu La Kretz Hall, Suite 300, Box 951496, Los Angeles, CA 90095-1496, USA.
Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/ucmg.

the brink" and 2) an overreliance on prohibitive regulation without flexibility and incentives. The conceptual models we question are 1) the management of risk via a precautionary approach and 2) a tendency to manage ecosystems for simplistic notions of resilience that resist, rather than accept and possibly direct, change. We argue that an inflexible regulation that is won via the specter of apocalyptic environmental disasters too often alienates key constituencies and fails to acknowledge the inherent uncertainty regarding the outcomes of conservation interventions. Meanwhile, the precautionary approach can exclude proactive action and experimental or adaptive approaches to uncertain futures. It is our view that society is more likely to maintain biodiversity successfully if it embraces unexaggerated assessments of risk and a serious examination of costs, uncertainties, and diverse stakeholder interests and rights. Based on a systematic review quantifying the rate of recovery following oil spills and disturbances to corals, we suggest that, for integrated human-natural systems, managing for directed change may be more effective than trying to maintain ecosystems in some semblance of an original state. Indeed, instead of resilience what may be needed is "resourcefulness" (MacKinnon and Derickson 2013). Throughout, we touch on examples from around the globe, with the goal of challenging conservationists to question popular conceptual models relentlessly and embrace new information even when it challenges deeply held assumptions.

We draw our inspiration from Mark Plummer, whose intellectual career led him to challenge conventional wisdom without prejudice and seek practical solutions commensurate with the realities of ever-changing nature, poor data, and diverse stakeholder values. He sought flexibility in the Endangered Species Act and rejected unyielding regulation formulated on the basis of purity or principle, rather than practicality. With Charles Mann, Plummer wrote in *Noah's Choice* (1995 p. 215): "Crying no more extinction produces a noble sound, but it does nothing to stop extinction." Like Mark, we argue that, while high ideals are nice, effectiveness is what really matters. At the same time, purely economic arguments will not suffice—human values, which are often messy and contradictory, will shape the future of our world.

Nature on the brink

Conservation was born as a crisis discipline (Soulé 1985) touting one horror story after another about the end of nature, impending environmental collapse, and extinctions. However, critics have drawn attention to unfulfilled prophecies of environmental doom and gloom (Ridley and Ganser 2010). Paul Ehrlich has been a prominent target for this criticism, for opening his 1968 million-selling book *The Population Bomb* with the statement "The battle to feed all of humanity is over," and remarking in 1970 that "sometime in the next fifteen years, the end will come … an utter breakdown of the capacity of the planet to support humanity" (Haberman 2015). Malthusian predictions of environmental collapse and famine have been foretold for over a hundred years and have repeatedly failed to materialize (Ridley and Ganser 2010). To be fair, those predicting ruin may have simply underestimated the long time delays associated with ecosystem collapse. Certainly, while the global food supply has grown enormously over the last 25 years, that growth has come at the cost of marine dead zones and losses of soil that may eventually come back to haunt humanity. That said, the "end" clearly was less imminent than predicted.

Less dramatic prophecies of collapse include the "skies with no birds" mantra of the 1980s, which attributed declining North American songbirds to rainforest deforestation. However, claims of an overall decline of neotropical migratory birds due to tropical deforestation were debunked by careful analyses (James, McCulloch, and Wiedenfeld 1996). In 2006, empty oceans were foretold due to over-fishing (Worm et al. 2006), but a reanalysis of fisheries data later suggested the empty ocean forecast was grossly exaggerated (e.g., Branch 2008).

In our own research careers, we encountered unqualified predictions of extinction for Snake River salmon if four large hydroelectric dams were not removed (Mundy 1999). A full-page ad in the *New York Times* declared, "Without prompt action, wild Snake River spring Chinook salmon, once the largest run of its kind in the world, will be extinct by 2017." Today, in 2016, with the dams still standing, Snake River spring Chinook (*Oncorhynchus tshawytscha*) runs are still tiny compared to historical accounts, but are now far less in danger of extinction than they had seemed to be when the demise of those salmon runs was foretold (Figure 1). Repeatedly, predictions of imminent extinctions or massive declines have been announced, only to be rejected upon closer examination. In no way do we recount these unfulfilled predictions of doom in order to imply environmental degradation and extinctions have not happened—they clearly have. Rather, we seek only to illustrate a common feature of the conservation narrative, which is an overconfidence in the certainty of ecological collapse, when, in fact, uncertainty is the rule.

It should be pointed out that the hyperbole of various messages of imminent doom are balanced on the other side by equally unsubstantiated cheerfulness claiming no environmental harm associated with egregious human assaults upon the environment. For example, gold mining companies in Ghana have tended to dismiss out of hand the concerns of local communities about water shortages, pollution, and health effects associated with mining (Garvin et al. 2009). And even though they may not come to pass, most academic prophecies of doom are inspired by genuine trends of worsening conditions: in the 1960s, many humans were starving, in the 1980s birds were, indeed, in decline in many parts of North America, Snake River salmon runs were disturbingly small in the 1990s, today many fisheries are over-exploited, and species are going extinct.

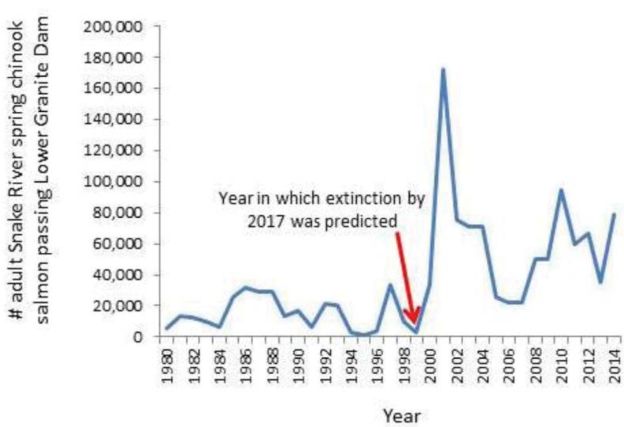

Figure 1. Population fluctuations of run size for spring Chinook salmon (*Oncorhynchus tshawytscha*) in the Snake River. Data from Columbia River DART (2015).

Some erroneous predictions are honest mistakes stemming from a misreading of how natural systems work or from poor or incomplete analysis. However, some of the dire predictions can be attributed to a desire to wake the public from perceived apathy and the belief that an impending catastrophe makes for gripping headlines. For example, a *Seattle Times* report (Bernton 2006) quotes an e-mail among the authors of a paper published in *Science* in which the authors describe their dire projection of fisheries collapse as a potential "news hook to get people's attention." We do not mean to imply that these researchers were misrepresenting their data. Rather, we cite this as an example of how scientists committed to conservation seek news coverage to advance their cause, and, when they do so, are prone to draw attention to dire predictions.

The important question is whether this meme of nature on the brink yields behavioral and political responses that benefit biodiversity and conservation goals. One problem with overstatement is that economic special interests that oppose conservation measures can gain public relations victories by exposing exaggerations about impending environmental disasters (Leiserowitz et al. 2013). Even with that risk, overstatement could still be an effective political tool, if it motivates people to change their votes or behavior (Pacala et al. 2003). The problem is that studies of human behavior do not support the idea that gloomy forecasts inspire people to act.

Messages that emphasize risk as a means of motivating people are known as "fear appeals" (Ruiter et al. 2014). A large body of evidence from the arena of public health messaging (e.g., anti-smoking or HIV-prevention campaigns) suggests that fear appeals can be counterproductive, eliciting risk denial and no behavioral change (Ruiter et al. 2014). Thus, messages that frame environmental threats as life-threatening may have the counterintuitive result of reducing environmental engagement (Fritsche and Häfner 2012). Far more effective are messages that emphasize response efficacy (i.e., that behavioral changes can reduce the risk) and self-efficacy (that the message recipient is able to make the necessary changes) (Ruiter et al. 2014; O'Neill and Nicholson-Cole 2009).

The challenge of crafting effective environmental messages is much greater than the challenge of crafting public health messages. This is because the connection between an individual's behaviors and the risks of, for instance, climate change or biodiversity loss are often perceived to be weak. For example, does it matter whether an individual chooses to take the bus every day when the global number of cars is growing so rapidly? When response efficacy and self-efficacy are perceived to be low, fear appeals commonly result in feelings of helplessness and a greater tendency simply to ignore the message. The public's unwillingness to elevate climate action to a priority may well be, in part, due to a feeling of helplessness.

Because doom-and-gloom scenarios can result in crisis burnout and entrenched apathy, the challenge for the conservation movement is to offer an optimistic and hopeful view that connects with a broad constituency (Vanderheiden 2011). This optimism should, of course, be based on evidence—the goal is not to provide false hope, but a realistic assessment of how changing one's own actions can create a better future. One study asked subjects to respond to a wide variety of images related to climate change. Images depicting potential consequences such as a dried-up lake, starving children, or severe flooding made people feel that climate change was serious but that they were unable to do much about it. In contrast, solution-oriented images such as solar panels, a thermostat, or a cyclist made people feel they could do something constructive (O'Neill and Nicholson-Cole 2009). Effective environmental messages emphasize choice and individual autonomy, rather than punishing bad behaviors. Finally, conservation psychologists remind the creators of environmental messages to recognize that not everyone is motivated by the same values, and it may, therefore, be necessary to frame the benefits of action in a variety of terms, such as financial benefits or benefits to human welfare (Clayton, Litchfield, and Geller 2013).

Regulation, costs, and the false choice of "environment or economy"

Nature conservation and environmental protection often are accomplished by regulation, which means that fines are levied if damage is done, criminal charges are brought for violation of environmental laws, or permits are withheld for activities that range from industrial and residential development to reauthorization of a federal dam. A major criticism of regulation is that the restrictions often fail to account either for the costs or for competing stakeholder interests. For example, in *Noah's Choice*, Mann and Plummer recount how plans to build a road connecting an impoverished Native American community to a hospital and a college conflicted with the habitat needs of an endangered species of carrion beetle. The U.S. Endangered Species Act (ESA) was written such that the costs or competing needs are not factored into decisions to list species as threatened or endangered. The only part of the law that allows for a consideration of costs is the designation of critical habitat. As Mann and Plummer point out (1995, 26), "Always we will choose between aspirations, some more commendable than others, but nearly all worthy of consideration."

Recent years have seen a political swing against prohibitive regulation and in favor of public and private incentives. For the ESA, the creation of policy tools such as Safe Harbor Agreements and Habitat Conservation Plans now incentivize landowners to create habitat and encourage the presence of ESA-listed species in exchange for protection against future restrictions on landowner activities. In addition, the private sector in the form of land trusts has emerged in the last 50 years as a major source of incentives for conservation by paying landowners to practice conservation on their lands. These payments take the form of purchasing easements that restrict specific forms of development while allowing other forms of private benefit. The amount of land protected by easements has grown exponentially over the last few decades (Fishburn et al. 2009) and now exceeds 9.5 million acres in the USA (NCED 2015), which is approximately half the size of the entire state of Maine in area. Private sector and nongovernmental organization (NGO) conservation can be tailored to local conditions and can target specific species and habitats, while still allowing economic activity, with greater precision than national level plans.

There is no question that regulation is necessary for protecting humans and biodiversity from pollution and other forms of environmental degradation. For example, in the case of lead contamination of drinking water, there is a solid scientific understanding of the dose-response curve and strict prohibitive regulations are well justified. Sadly, the recent lead poisoning tragedy in Flint, Michigan illustrates that even with strict prohibitions and clear dose-response curves, people will sometimes make decisions on the basis of narrowly prescribed short-term economic costs that fail to consider long-term human wellbeing (Wines and Schwartz 2016). However, conservation is quite different from pollution and human health, because there exists much greater uncertainty when it comes to predicting how losing a particular population or parcel of habitat will impact biodiversity, ecosystem function, and human wellbeing. We do not know exactly how biodiversity is affected, for example, by the construction of massive solar installations, nor do we know the uncertainty associated with this dose-response curve. If people can choose cutting immediate costs over human health in a relatively straightforward situation like lead in drinking water, then how much more likely is it that people will need incentives and not just prohibitions when it comes to limiting development to achieve conservation? When Mark Plummer critiqued the U.S. Endangered Species Act (Mann and Plummer 1995), he was not critiquing the intent of the act; he was critiquing the feasibility of administering it with private land owners.

Instead of trying to achieve a total ban on economic development—a prohibitively expensive and futile proposition—conservation planners are beginning to recognize that it is more effective to accept that some amount of economic development is a foregone conclusion. The key insight is that working with industry to direct development to areas of lower conservation value can spare areas of high value. Known as development by design, this approach has successfully directed mining and gas exploration away from areas that harbor ESA-listed species or serve as dispersal corridors for wildlife (Kiesecker, Copeland, McKenney, et al. 2010; Kiesecker, Copeland, Pocewicz, et al. 2010). Beyond just directing development to spare valuable areas, development can result in funding via mitigation fees that, in fact, could lead to a greater amount of land protected. By working with industry rather than always against industry, the best habitats are spared and more money is directed toward conservation. The real tension is not between economic development and nature, but rather between economic development that benefits only a few and economic development that extends to groups most in need of employment or income and lacking political power. Clearly in Flint, Michigan and elsewhere, the right of every human to clean water should have trumped the state's concerns for cost-cutting. Because conservation of biodiversity represents, by definition, the long view, it should be on the side of both species and human development. That form of conservation cannot be antidevelopment, but it can be concerned with equitable development.

The precautionary principle and conservation's aversion to novelty and change

The precautionary principle is embraced by the Maastricht Treaty of the European Union, the U.S. Environmental Protection Agency, the United Nations framework convention on climate change, and even the municipal codes of cities like San Francisco (Kelly 2010). The core idea of the precautionary principle is that any new technology must be shown to do no harm before it is adopted. While such a cautious approach seems prudent and reasonable in theory, its implementation can err on the side of being too risk averse and, hence, stifling of innovation. For this reason, even before there was much discussion of the Anthropocene or rapid global change, scholars criticized the precautionary principle (Sunstein 2005; Ludwig, Hilborn, and Walters 1993). The dominant critique has been that overzealous implementation of the precautionary principle can mean that technology of potential great benefit is rejected based on possibly modest risks without regard to enormously positive benefits. The uncertain and rapid pace of environmental change now evident as hallmarks of the Anthropocene adds fresh fuel to the criticism of the precautionary principle. Specifically, instead of invoking uncertainty as a reason for not acting, the uncertain, yet likely dangers of climate disruption require experimentation and innovation.

Throughout human history, there has been a consistent wariness about the innovations of new technology: for example, in the twelfth century, Pope Innocent II banned crossbows for 50 years, and in 1299 Florence banned bankers from using Arabic numerals in their accounts

(Kelly 2010). When evaluating technology, the challenge lies in weighing the costs and risks of adopting the technology, against the costs and risks of not using the technology. An informative example of this quandary was the 1972 Environmental Protection Agency (EPA) ban on the pesticide DDT, and subsequent banning of DDT in many developing countries. While indiscriminate use of DDT in agriculture is harmful, modest use of DDT in households to control malaria-carrying mosquitoes can reduce the incidence of malaria, and the banning of DDT is estimated to have caused millions of new malaria cases and deaths (Attaran and Maharaj 2000). The challenge revealed by this DDT example is one of balance—balancing benefits against inflexible restrictions.

Despite academic criticisms of the precautionary principle, a precautionary stance continues to manifest itself in conservation as everything from resistance to moving species to new locations in response to climate change to shunning genetic engineering in the service of conservation. Related to, but slightly different from, the precautionary principle is the desire to keep things as they have been historically, even when doing so is overwhelmingly impractical. For example, many conservationists see no ecological or biodiversity value in ecosystems that have been transformed by human activity—yet roughly 75% of Earth's ice-free land has been transformed by agriculture and human settlements (Ellis and Ramankutty 2008). These human-altered and novel ecosystems may not represent historically natural systems, but they can harbor large amounts of biodiversity, as in shade coffee systems or low intensity agricultural systems (Daily, Ehrlich, and Sanchez-Azofeifa 2001), or perform valuable ecosystem services, as when nonnative *Phragmites* provides habitat for endangered species and sequesters heavy metals from polluted water (Kiviat 2013). Traditionalists argue that accepting the value of novel ecosystems will diminish the commitment to protect more pristine habitats and undeveloped nature reserves (Murcia et al. 2014). In reality, many of the biggest fans of novel ecosystems are equally committed to protecting wild nature wherever possible (Marris 2011).

A more nuanced view of the plusses and minuses of a precautionary approach would consider the cost of not being precautionary and then suffering an environmental disaster versus the cost of being unnecessarily precautionary when there is no risk and, as a result, stifling innovation. While the costs of a bad side-effect might be estimable, the actual probability of that side-effect or accident is typically very hard to know. Similarly, it is very hard to know if celebrating urban nature actually reduces efforts to project distant wild nature. It is unlikely that science can resolve these sorts of dilemmas. Choices about how to weigh competing risks and costs will always largely be political and public choices.

Resilient ecosystems

The idea of managing for resilience in the face of climate change and other environmental shocks has recently become a dominant theme in both the academic literature and public policy discourse. It is also a focus of business and political leaders, as well as major philanthropic initiatives (Koronowski 2013; Rodin 2013; Clinton Foundation 2014; MacArthur Foundation 2015). Ecologists have been discussing resilience and stability of ecosystems for over 40 years, going back to a seminal paper by C. S. Holling (1973). When theoretical ecologists discuss resilience, concepts of high variability, flexibility, and even potential transformations among multiple stable states are considered (Chapin et al. 2009; Berkes, Colding, and Folke 2008). However, when the idea of resilience is appropriated in the conservation and management literature, it typically reverts to the simple idea of keeping systems—cities, ecosystems, or even human communities—within some basin of attraction such that conditions steadily return to past values. For example, in the World Bank's 2009 report entitled "Climate Resilient Cities" (Prasad et al. 2009), the key indicator of resilience is "the amount of disturbance a society can absorb and still remain within the state of the domain of attraction." Whereas theoretical ecologists may think of resilience in highly dynamic terms, policy makers and resource managers frequently translate it into the expectation of stability (even resistance to change), or a hard-earned recovery to historical conditions.

At first glance, any version of resilience would seem to be a desirable trait or management goal. However, managing for simplistic forms of resilience may, in fact, be misguided in a world that is experiencing rapid directional change. Instead of intervening to push ecosystems back toward a past state, it might be more appropriate to accept the inevitability of change and focus instead on trying to steer that change down pathways that are best for nature and people. It is important to emphasize we are thinking here of local ecosystems; at a planetary level, there are certain limits that should not be crossed at all costs (Rockström et al. 2009).

If Mark Plummer were faced with two contrasting conceptual models—managing for resilience or managing for change—he surely would have asked, "What do the data tell us?" A recent analysis by Maria Dornelas and colleagues regarding changes in species composition in 100 time series revealed that roughly one half of the species present are replaced by other species in as little as 50 years (Dornelas et al. 2014). This would not be surprising if the time series came from sites highly disturbed by logging or urban development —but these data were from relatively undisturbed ecosystems.

An additional line of evidence regarding resilience entails observations of ecosystem recovery following massive perturbations such as oil spills, coral bleaching, clear-cutting of forests, and so forth. We performed a GoogleScholar search for articles regarding oil spills and coral bleaching events. We sought articles that reported quantitative measurements of recovery (or not) from these environmental perturbations. To be included, an article had to provide at least three data points: a control data point (either from a control plot or predisturbance data point), a measurement of the response variable immediately after the disturbance, and a third data point after this initial response variable. Importantly, the last two data points had to be at the same sampling site. When sites were sampled repeatedly over time, we used only the final time point. Once an article qualified for inclusion (see Appendices A and B), we recorded values from tables or, using DataThief software, from figures. The data include measurements of a wide variety of ecological attributes—everything from number of species to biomass to the abundance of a particular species. To make these many different metrics comparable, each perturbation is defined as the change relative to the control. As a measure of the recovery of the system, we used the following metric:

$$\text{Resilience index} = [-\ln(\text{final perturbation} / \text{initial perturbation})] / \\ \text{time elapsed between initial and final measurement of perturbation}$$

There are many ways to measure resilience, and this particular metric is consistent with an engineering approach (Quinlan et al. 2015). Using this formula, whenever the final perturbation is less than the initial perturbation, the resilience index will be positive because in the equation above, we have intentionally taken the negative of ln (final perturbation/initial perturbation). The larger this positive value is the more the perturbation has shrunk and, thus, the greater the resilience. In more mathematical terms, the resilience index is the instantaneous rate at which the perturbation size changes. In many instances, the final perturbation is greater than initial perturbation, which means as time progresses, the system becomes more and more dissimilar to its original state, and the above index is negative. Note that the sign of the index, rather than its absolute magnitude, matters for our question of whether systems generally tend to move back toward or away from predisturbance target values.

Based on a systematic review, we extracted estimates of disturbance for oil spills from twenty-five published studies (Appendix A) that yielded 312 resilience indices and estimates of coral disturbances from fifteen published studies (Appendix B) that yielded 190 resilience indices. With these data, we asked if ecosystems generally recover from damage and move back toward their original state. The answer is not really, or certainly not in most cases. Specifically, most resilience indices were close to zero, meaning that the original perturbation remained constant and neither shrank nor grew over time (Figure 2). Moreover, 44% were actually negative—meaning that the measures moved away from reference conditions. Further exploration of the data revealed that the size of the initial perturbation could not predict resilience scores

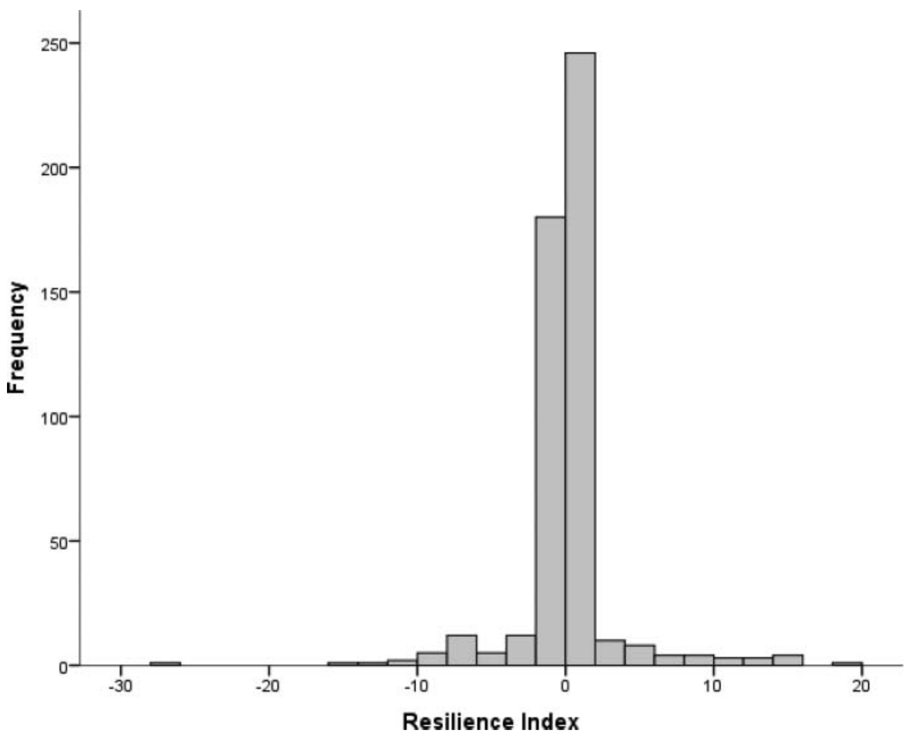

Figure 2. Resilience indices calculated for 502 measures of ecosystem change following oil spill (n = 312) or disturbance to corals (n = 190). The vast majority of studies found a resilience index close to zero, meaning that there was little change following the disturbance. Moreover, 44% of the studies (n = 219) had a negative rather than positive resilience index, indicating that these metrics moved away from the undisturbed reference state after the disturbance ended.

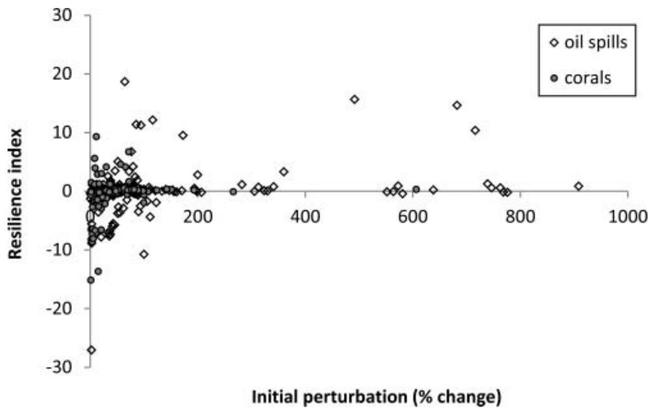

Figure 3. Resilience indices as a function of perturbation size. Each perturbations is measured as the initial percentage change in the metric relative to its reference value (predisturbance or control site). Truncating the x-axis to 1000% percent change caused the omission of 24 additional data points (out of 493 total).

(Figure 3). By no means is this a definitive analysis—but it is one of the few quantitative meta-assessments of the tendency with which systems return to a previous condition.

The distribution of resilience indices reflects that systems often do not return to previous conditions. Instead, many ecosystems experience continued directional change. Given widespread and unrelenting directional change—such as more roads, warmer temperatures, more people, more water extraction for people and their farms, and so forth—simplistic applications of ecological concepts such as resilience or stability lose practical value. It is not just that ecosystems are rarely at equilibrium, but that any underlying equilibrium is itself constantly changing. Thus, trying to hold an ecosystem in some particular state is futile. MacKinnon and Derickson (2013) point out that, while resilience is widely touted as the goal for cities and communities, resourcefulness may be a better trait. The distinction is that resourcefulness is the ability to choose actively a future and take action to move toward that desired future outcome—which may be very different than any past situation. The same might be said of ecosystems. Instead of managing ecosystems to maintain some past property or attributes, it may be more fruitful to accept the inevitability of change and merely try to move ecosystems toward some preferred future configuration.

Pragmatism and flexibility are key to conservation success

We live in a time of accelerated change, enormous uncertainty, and a globally networked world that spreads shocks such as a government debt crisis through everything from food production systems to deforestation. Resource scarcity is placing severe selection pressure on economies and communities. There is no better problem solver than evolution, and we might turn to evolution for insight into how governments and society should respond to environmental crises. Evolution innovates by a combination of mutation, recombination, and selection. Novelty and experimentation are essential to evolution. Unfortunately, multinational and national governments struggle with experimentation. One school of thought argues that the private sector is more adept at innovation and response to surprises than is government. If this is true, then, as we enter a period of unpredictable climate shocks and resource shortages, it may be an argument for more private sector problem solving.

Comparing private sector to government innovation is a challenging research question with no easy answers. However, an interesting analysis that is relevant to environmental problem solving under conditions of huge uncertainty and risk entails a study of early expeditions to the Arctic in search of the Northwest Passage (Karpoff 2001). These explorers had no idea what they would encounter and faced severe environmental conditions. Of the ninety-two expeditions to the North Pole between 1818 and 1909, thirty-five were government sponsored and managed and fifty-seven were private. The difference in outcomes between public and private ventures was striking with six deaths per government expedition compared to only one death per private expedition. Also, one of two government ships was lost, in contrast to only one of four private ships. Looking carefully at the fate and approach taken in each expedition, some patterns emerge. Government expeditions did not adapt—they stuck with standard government-issue uniforms and tents—whereas the private sector expeditions adopted indigenous clothing and built shelters out of snow. Government expeditions were required to use centralized procurement procedures to be outfitted and could not tailor their gear to the Arctic. The incentives for expedition leaders also differed, and often it seemed that leaders of government-sponsored expeditions were afraid to deviate from standard practices. This analysis illustrates the importance of remaining flexible. Rigid adherence to regulation can doom attempts to protect the natural environmental every bit as much as an arctic expedition.

California's current dilemma with managing water in the Delta is a contemporary example of how institutions and the government can lock us into inflexible frameworks that frustrate problem solving (Jacobs and Snow 2015). Here, protection of the ESA-listed Delta smelt (*Hypomesus transpacificus*) is in conflict with agriculture and other water users. The irony is that the ESA-dictated response to the decline of the smelt could completely disrupt water management in California, even if the decline of this species is not directly related to the actions of water users (Jacobs and Snow 2015). The problem arises because the ESA was not designed to deal with directional changes in climatic conditions. If the smelt is declining primarily because of climate change, then what is the point of trying to reverse this decline by restricting water use in ways that yield only marginal benefits for the smelt?

Mark Plummer's legacy of challenging orthodoxy

The hallmark of science is skepticism and a relentless questioning and testing of conventional wisdom and existing orthodoxy. Yet scientists are only human and cannot escape internal biases that act as filters and that shape what evidence they pay attention to and how they synthesize data. Cognitive psychologists and behavioral economists have recently provided an abundance of evidence for how biased attention and social identity can influence the conclusions drawn from data (Fox, Ridgewell, and Ashwin 2009). For example, individuals tend to fall into one of two groups: optimists who, when presented on a computer screen with negative and positive images consistently notice the positive images, and pessimists who, when presented with the same images, consistently notice the negative images. This selective attention might even have genetic foundations (Fox, Ridgewell, and Ashwin 2009). At a higher level of beliefs and attitudes, several studies emphasize that one's peer group has a huge influence on what conclusions a person draws from scientific data—this has been especially well documented with respect to attitudes about climate change (Kahan et al. 2012).

The implications of these findings for conservation science are clear—conservation biologists represent a relatively tight knit peer group who took similar courses as students and, subsequently, read many of the same articles. This has led some to accuse conservation scientists as being unable to face evidence squarely and to champion even something as fundamental as the benefits of biodiversity as a case of confirmation bias and the "tacit agreement among colleagues not to rock the boat of bad reasoning —perhaps out of fear that there is no other way to defend nature and its value" (Maier 2012).

Securing biodiversity and a sustainable planet may be one of the hardest scientific and sociopolitical problems humanity faces. For this reason, conservation scientists must be willing to question orthodoxy. No one was better at this than Mark Plummer. Plummer was criticized (e.g., Rachlinski 1997) for suggesting that, in many ways, the U.S. Endangered Species Act was not working. He challenged the status quo by demonstrating that cost-benefit analyses in the absence of good data are misleading (Plummer 2007). Furthermore, he pointed out the pitfalls of tying conservation to the potentially fleeting economic value of ecosystem services (Plummer 2009). For example, the economic value of a wetland located in Louisiana's Marepus Swamp Wildlife Management Area was high so long as a nearby potato chip factory used the wetland to process its wastewater. However, the wetland's value crashed once the wastewater production outgrew its treatment capacity and the factory switched its output to a conventional treatment system (Plummer 2009).

Critics of current conservation approaches are sometime charged with lacking ethics because they neglect the right of species to exist (Cafaro and Primack 2014). This is a myopic view, because conservation decisions are often a matter of balancing competing ethical values. For example, in conservation, three fundamental rights may come into competition: the right of species to exist, the rights of individual animals, and the rights of individual humans to prosper (Heise 2016). All of these rights can find strong ethical justification. Nonetheless, they do not always align. For example, animal rights activists may protest the killing of non-native pigs on an island that is being done for the purpose of protecting an endangered species (Armstrong 2006). The conflict between multiple moral imperatives is one of the central problems in conservation.

The scientific community should applaud individuals who dare to question conservation's orthodoxy. Progress is made by examining both successes and failures. Mark Plummer had the courage to shine light on some of the shortcomings of current management approaches. He spurred us all to take an honest, hard look at some of our pet policy approaches. Conservation will succeed only if more of us have the audacity to do the same.

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Appendix A. Articles reporting changes in ecological metrics following oil spills.*

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*Note that the two-part series by Colombo et al. was counted as a single publication.

Appendix B. Papers reporting changes in ecological metrics following disturbances to coral reef habitats

Bythell, J. C., Z. M. Hillis-Starr, and C. S. Rogers. 2000. Local variability but landscape stability in coral reef communities following repeated hurricane impacts. *Marine Ecology Progress Series* 204:93–100.
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