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Joshua S Stoll
Christine M Beitl
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How access to Maine's fisheries has changed over a quarter century: The cumulative effects of licensing on resilience

Joshua S. Stoll[a,*], Christine M. Beitl[b], James A. Wilson[a]

[a] School of Marine Sciences, University of Maine, Orono, ME 04469, USA
[b] Department of Anthropology, University of Maine, Orono, ME 04469, USA

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ABSTRACT

We describe how the evolution of the licensing system for commercial fisheries in Maine has progressively limited the ability of both fishers and the State to respond to changing environmental circumstances. Over the twenty-five year period from 1990 to 2014 new licenses were created at the rate of about 0.6 per year. The changes that have occurred have not been the result of a strategic policy agenda that was set to decrease fishers' access, but rather the consequence of multiple decades of policy interventions that have sought to improve the socioeconomic and ecological productivity of individual fisheries. However, the cumulative effect has limited the flexibility of individual fishers and created strong economic interests that are incompatible with shifts towards ecosystem-based management. We use this finding to contribute to the literature on resilience, with a specific focus on the relationship between adaptive management and sustainability.

1. Introduction

1.1. Fisheries as dynamic social–ecological systems

There is increasing recognition that fisheries are complex and adaptive social–ecological systems (Berkes et al., 2003; Chapin et al., 2009b; Folke et al., 2005; Wilson, 2006) that evolve in non-linear ways across time and space (Folke et al., 2004; Gunderson and Holling, 2002). These systems are shaped by interconnected social and ecological processes that exist at multiple and overlapping scales from the ultra-local to the global (Craig and Holling, 2010). This dynamic underscores the need for holistic approaches to marine and ocean governance that account for the linkages between and within the human and natural components of these systems (Chapin et al., 2009a).

Examples of the real-world consequences that arise from being insensitive to the complex and dynamic nature of these systems are widespread (Folke et al., 2004). For instance, the failure to fully understand and account for the fine-scale heterogeneity of the marine environment has repeatedly led to the mismatch between regulatory boundaries and the ecological contours of ecosystems, creating situations in which management strategies have facilitated ecological degradation (Young, 2002). This is evident in the Gulf of Maine, for example, where geographically broad management boundaries for fishing have failed to prevent the serial depletion of spatially explicit subpopulations of Atlantic cod (Ames, 2004) and the local overexploitation of sea urchins from the region's rocky ledges (Johnson et al., 2012). In both cases, the effects of these miscalculations reverberate through the social and economic components of these systems.

Part of the underlying challenge of managing these systems is that acquiring and maintaining 'accurate' information about them is a Sisyphean chore (Wilson, 2002; Wilson et al., 2013). Indeed, the usefulness of information about the form and function of a system at one place, in one moment, often erodes quickly in both social and ecological settings, becoming highly irrelevant and inapplicable at other times or in other places if it is not continually renewed (Levin, 1999). Thus, with the exception of a small number of data-rich situations (e.g., Carpenter et al., 2011), it is difficult to confidently forecast how these systems will respond to socioeconomic or ecological changes (Schindler and Hilborn, 2015; Wilson et al., 1994). This uncertainty is commonly viewed as an impediment to management approaches that are reliant on accurate information to set catch limits and define discrete management boundaries (Standish et al., 2014).

Acknowledging this persistent problem, many scholars have called for a paradigm shift away from management approaches that require definitive information about the social and ecological characteristics of fisheries systems (Briske et al., 2008; Folke et al., 2005; Hughes et al., 2005; Wilson, 2002). Alternative approaches

* Corresponding author.
E-mail address: joshua.stoll@maine.edu (J.S. Stoll).

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include parametric strategies that aim to preserve the life histories of marine species (Acheson and Wilson, 1996); geographic protections that maintain habitat and provide sanctuary to marine species (McClanahan et al., 2006); and community-based institutions that facilitate local responsiveness to threats (Stoll et al., 2015a). While these strategies vary in terms of how they are executed in practice, they are all part of an emerging class of management approaches that aim to build social and ecological resilience (Folke et al., 2005).

In this context, resilience is defined as the capacity of a system to withstand disturbances without fundamentally changing form or function (Adger, 2000; Walker et al., 2004). Examples of disturbances might include extreme weather events (environmental) or shifts in market demand (socioeconomic). Management approaches that foster resilience in fisheries represent a departure from conventional management in that these efforts do not aim to establish particular social or ecological limits, but rather seek to maintain the underlying processes and patterns that drive social–ecological systems so that they can withstand stressors (Chapin et al., 2009b; Wilson, 2006). In doing so, the approach sidesteps the perennial information problem by creating a framework for governance in which imperfect knowledge and scientific uncertainty is inevitable.

The primary goal of this paper is to contribute to the growing body of empirical research on resilience within the context of marine and ocean governance. Our focus in this paper is on the erosion of social resilience, although we recognize that social and ecological resilience are closely coupled in social–ecological systems (Adger, 2000). Here, we describe the evolution of the licensing system for commercial fisheries in Maine since 1977, using it as the basis for a longitudinal analysis of how fishers' access to marine resources has changed over a twenty-five year period from 1990 to 2014. The data reveal changes that reflect, in part, the cumulative effects of fisheries management decisions on fishers' access to marine resources—which, like many (perhaps most) systems of natural resource management, is the outcome of a complex and piecemeal process of negotiating 'solutions' to fisheries-specific problems that arise over time. We argue that the continual decline in access is not the result of a strategic policy agenda that was set to decrease fishers' access, but rather the unintended consequence of multiple decades of policy interventions that have sought to improve the socioeconomic and ecological productivity of individual fisheries. In providing this analysis, we show how the layering of well-intended but myopic species-specific management decisions over time – through a highly adaptive process – have contributed to the decline in resilience of the fishing fleet in Maine over a quarter century. To be clear, our goal in presenting this case is not to implicate policymakers or the legislative process entirely. Any claim of this sort would ignore (at least in part) individual agency (Cote and Nightingale, 2012; Coulthard, 2012; DiMaggio, 1998), discounting the multiple ways that decision-making by fishers may have also contributed to the over-specialization that has occurred (see Steneck et al. (2011)). Although this is a relatively local story, we contend that the process described in Maine has broad relevance to ocean and coastal governance.

Our findings enable us to more fully unpack the relationship between resilience and adaptive management, highlighting the complexity of this connection. In doing so, our aim is to contribute to the growing body of literature investigating the multiple and often hard-to-see consequences of adaptive strategies (Coulthard and Britton, 2015). Here, we specifically focus on the interplay between resilience and adaptive management that has occurred at the legislative level where institutional changes to the licensing system in Maine are negotiated and enacted. We focus at this level of the system because the legislature holds the authority to change the licensing system, but we acknowledge that there are likely underlying power relationships that influence this process. Our intent in using the term "adaptive management" is not to imply that fisheries management or the licensing system itself conforms to a particular process that involves discrete phases of goal setting, management strategy development, implementation, monitoring, and evaluation (Linkov et al., 2006), such as the Adaptive Environmental Assessment and Management framework described by Walters (1986). Instead, we use it in a broader sense to describe the ongoing management interventions that have shaped and reshaped the licensing system, defining the term as the "process by which institutional arrangements and ecological knowledge are tested and revised in a dynamic, ongoing, self-organized process of trial and error" (Folke et al., 2002:20 in Folke et al., 2005). This treatment of the term is consistent with much of the literature on social–ecological systems, which emphasizes adaptability rather than an explicit adaptive process in the formal sense, using it as the starting point to study human responses at different scales ranging from the individual level (Cinner et al., 2008; Coulthard, 2008) to broader institutional scales (Loring, 2011; Moran and Elvin, 2009; Nelson et al., 2007). We also make a distinction between successful adaptation and adaptive management as a form of responsiveness: the former being a process in which feedback informs actors about the success or failure or their actions; the latter being a process in which the absence of feedback can lead to unintended outcomes and slow learning.

1.2. Adaptability as a cornerstone of resilience

Resilience has its roots in the field of ecology (Holling, 1973). However, the concept was integrated into the social sciences shortly thereafter (Vayda and McCay, 1975), and it is now a cornerstone in the theoretical foundation of research on coupled social–ecological systems (Folke et al., 2005, 2010). In the process of becoming a thoroughly transdisciplinary idea, resilience thinking has evolved, shifting away from the perspective that it is simply a measure of the rate at which a system rebounds from a disturbance (Pimm, 1984) to the idea that it is the ability of a system to withstand disturbances without fundamentally changing (Walker et al., 2004). This reorientation has brought increased focus to the social and ecological processes that help systems weather turbulence (Allen et al., 2005; Briske et al., 2008).

The starting point for much of this research is the basic assumption that resilience is a desirable attribute and the goals of management should be to cultivate (or maintain) the resilience of a system so that the social and ecological services of a particular place or process are maintained. Yet resilience is not inherently desirable (Standish et al., 2014). Indeed, there are many cases in which systems that function poorly or are unproductive are highly resistant to change (Filbee-Dexter and Scheibling, 2014). There are also instances in which one part of a system is durable (at the expense of the rest of the system) or the system is resilient to a particular threat, but not well positioned to withstand multiple or unanticipated disturbances (Steneck et al., 2013). Folke et al. (2010) highlight this problem, differentiating between "specific" and "general" resilience. Within this ontology, specific resilience refers to the capacity of a particular part of a system to withstand one type of disturbance, whereas general resilience refers to the capacity of the system to more broadly withstand a range of perturbations. In a similar vein, Standish et al. (2014) bring focus to this issue by drawing a distinction between "helpful" and "unhelpful" resilience. Merging these ideas, we might assert that general resilience is helpful, whereas specific resilience that only buffers against a single threat or protects a particular part of a system is relatively unhelpful in the long-term. The point here is not that there is necessarily a known, desirable state of a system;

rather systemresiliency is maintained by way of sustaining the organizational integrity of its structure.

Contributions like these represent important refinements to resilience thinking as the concept is tested and modified. Yet despite theoretical advancements, the idea continues to be critiqued because it remains difficult to translate into practice (Allen et al., 2005; Rist et al., 2014) and hard to measure empirically (Standish et al., 2014). These critiques do not suggest a wholesale rejection of the concept, but instead highlight the need for further research that adds depth to our understanding of resilience and its underlying attributes. Of particular importance is focus on the organizational structure of systems and how human–natural interactions influence the capacity of these systems to self-organize and maintain their general resilience.

In this paper, we seek to contribute to the resilience literature by focusing on the role of institutional change (e.g., adaptive responses to problems) in cultivating general resilience. We challenge the frequent assertion that adaptive systems – that are regularly tested and revised – invariably facilitate resilience. In this rapidly growing body of research, adaptability is routinely described as one of a short list of mechanisms (Folke et al., 2005; Folke, 2006; Chapin et al., 2009a), along with modularity (Scheffer et al., 2012), diversity (Elmqvist et al., 2003; Mori et al., 2013), and transformability (Walker et al., 2004), that buffer systems against social and ecological disturbances. As a result, it is often used as a proxy for resilience, serving as the theoretical springboard to justify innumerable studies that document adaptive behavior in resource dependent communities (Blythe et al., 2014; Bunce et al., 2009; Coulthard, 2008; Joseph et al., 2013). However, while adaptability certainly has the potential to increase resilience, there is growing recognition among scholars that more attention needs to be given to what Coulthard and Britton (2015 277) call the “full spectrum of consequences that might result from adaptation decisions.”

Our goal in focusing on the interplay between adaptability and resilience is not to suggest that responsive governance systems are not often vital to resilience. Rather by demonstrating how adaptability in management can, in the absence of effective feedback, result in unintended outcomes and undermine general resilience, our hope is to contribute to a more nuanced understanding of the relationship and encourage a more critical examination of what it means to be adaptive and how and when it does and does not foster resilience. To build our case, we focus on institutional changes at the legislative level though we acknowledge that change can take place at multiple levels in a social–ecological fisheries system (including the level of the fisher (Henry and Johnson, 2015)). Here, we treat these institutional changes as cumulative such that the impact of the changes is more than the sum of their parts and the ultimate effect on the system is far different than the impact of each individual action in isolation.

1.3. Management interventions result in cumulative impacts

Many natural systems have been negatively impacted by anthropogenic disturbances, resulting in the loss of ecosystem services. This degradation is often caused by the cumulative and interactive effects of multiple stressors acting upon a system through time, rather than by a particular event or action in isolation (Halpern et al., 2008; Hazen et al., 2013). We see evidence of this pattern in a wide spectrum of natural systems ranging from the human nervous system where the bioaccumulation of toxins can lead to cognitive impairment (Colbern et al., 1993) to marine ecosystems where targeted overfishing in localized areas can unravel entire foodwebs (Frank et al., 2011; Steneck et al., 2011). In these cases, stressors are often innocuous or have seemingly superficial impacts at the outset, but as they build up a system can reach a tipping point that causes it to shift fundamentally. Stressors can also exist at nearly imperceptible but chronic background levels that do not result in system-wide reconfigurations, but nevertheless suppress their productivity (Worm et al., 2006). Understanding and addressing these stressors therefore becomes a necessary step toward building and maintaining functioning systems.

Much of the current research focuses on the negative effects of multiple and temporally compounding stressors on the ecological and biological components of systems. Yet just as cumulative stressors often have negative effects on the natural environment, so too can they erode the integrity of social and economic components of systems (albeit these stressors may be different than those that affect the natural environment) (Murray et al., 2010). In a social context, any number of socioeconomic processes can have cumulative effects, ranging from market dynamics (Stoll et al., 2015b) to regulations (Chan and Pan, 2012; Cinti et al., 2009). In the case of the latter, it is not only the individual regulations that affect social–ecological systems, but also the cumulative effects as new regulations are created and modified over time (Murray et al., 2010).

In documenting the evolution of the contemporary licensing system for commercial fisheries in Maine, we find that it is an account of a system that through the entirety of its history has been evolving as strategies are tested, re-tested, and tweaked. These specific management interventions were attempts by the legislature to be responsive to the difficulties faced by individual fishermen and groups. Most striking is that this process of adaptive management, as we illustrate in this paper, has not been driven by rogue actors working independently or by negligent, out-of-touch policymakers. To the contrary, the licensing ecology of Maine is the result of ongoing efforts to improve the form and function of fisheries in the state. Nevertheless, in examining the layering of species-specific licensing strategies, we find that in certain ways the resilience of the system has declined. This decline, we argue, is in part the result of the cumulative effects of these well-intended but narrowly focused decisions leading to an unintended system-wide effect that may reduce the general resiliency of the system in multiple ways.

1.4. Fisheries as a totemic feature of the contemporary Maine landscape

Maine is the most northeastern state in the United States, with approximately 3,500 miles of tortuous rocky coastline characterized by innumerable bays, coves, tidal marshes, and mudflats that separate land from the Gulf of Maine. Boasting a long and celebrated tradition of commercial fishing, Maine is among the most fisheries-dependent states in the nation with 9,300 state-licensed commercial fishers (not including fishers with federal licenses that are generally needed for fisheries conducted outside the three-mile territorial limit of the states). Although the relative economic importance of fisheries has declined across the state over the last several decades compared to other sectors of the economy, fisheries remain a strong economic driver (>$585 million in 2014) (MDMR, 2015) and an important marker of cultural identity in many coastal communities. This is particularly true for the rural communities of eastern Maine, where 22 of the 177 most fisheries dependent communities in the Northeast United States are situated (Colburn et al., 2010).

Lobster is the most economically important marine resource in the state, accounting for 78% of the overall value of fisheries in Maine in 2014 (MDMR, 2015). This statistic reflects the recent surge in the lobster stock in the Gulf of Maine; however, the iconic crustacean has not always been so dominant (Acheson, 2003; Bolster, 2002), nor is it the only economically important species that fishers depend on today. In fact, only twenty years earlier, the lobster fishery accounted for only 33% of the ex-vessel value of fisheries in the state (MDMR, 2015). Other species of commercial importance include scallops, urchins, marine worms, halibut, sea cucumbers, periwinkles, alewives, soft-shell clams, and elvers. This diversity has historically enabled fishers to shift seasonally in response to natural cycles, periods of low abundance, or low economic demand while maintaining their cultural identity as fishers.

Fisheries in Maine are managed by way of multiple overlapping decision-making bodies that share the unenviable task of governance, trying to both support fishing activities and protect the resources for future generations. The particulars of management differ between fisheries. For example, the state lobster fishery has seven lobster zones, each with its own decision-making body made up of commercial fishers who have the authority to make management decisions that affect their respective area. Each zone also has a representative that sits on the Maine State Lobster Advisory Council. Like the regional bodies, the Council is responsible for making management decisions that have inter-zone implications. Statewide councils also exist in the scallop, elver, and urchin fisheries, while municipality-scale management structures are in place for soft-shell clams and alewives. In all of these cases, the Maine Department of Marine Resources (MDMR) (acting on behalf of the state) plays a combination of roles, supporting the different councils, generating and synthesizing scientific information, enforcing rules and regulations, making management recommendations, and ultimately acting as the final decision-maker.

Fisheries governance in Maine is also influenced by the Maine State Legislature, which has a long tradition of using its statutory authority to influence the direction of fisheries and institutionalize local or state-level rules. The Legislature is unique in that it is the only decision-making body with the authority to alter the licensing system that serves as the framework through which fishers are able to access fisheries. In this way, the licensing system provides an institutional mechanism to constrain participation and thereby effort to some extent. This system is set up such that commercial fishers are required to hold a license to target and harvest particular species (or groups of species). Each year fishers are required to renew their license(s) through MDMR. While this process has not changed, the number, cost, and types of licenses have been regularly changed. We evaluate the cumulative effects of these many legislative changes to the licensing system over the past 38 years. While we recognize that individual fisher decision-making has contributed to the existing structure of the fishing fleet in Maine, we contend that (at least in part) it has been shaped by the licensing structure that has been created.

2. Methods

The research reported here draws on both legislative records and license data for commercial fishers in the state of Maine. This study was conducted as part of an ongoing research project investigating institutional transformability in fisheries in Maine, which started in June 2014. As part of this project, short semi-structured interviews were conducted with more than 350 fishers in eastern Maine. These interviews, coupled with regular engagement with fishers at meetings and in the field, facilitated a level of ethnographic understanding that greatly informed this manuscript. Here, we describe the methods used for the analysis of the legislative and licensing data.

2.1. Legislative history analysis of licensing in Maine

We conducted a historical analysis of the statutes passed by the Maine State Legislature since 1977. To start, we used digital and paper records from the Maine State Legislature Law and Legislative Reference Library to locate original Legislative Document (LD) numbers for all relevant statutes. Using these LD numbers, we collected the statement of fact for each bill as well as the Legislative Record (which includes formal debate by the Maine State House and Senate on the bill) and information included in supplemental studies and reports commissioned by the legislature. We used these data to construct a timeline of the institutional changes to licensing policy in Maine and, while these data do not provide insights about the unstated or underlying power dynamics that motivated change, we were also able to identify the primary justifications used publically in the policy debate to motivate each change. The timeline developed through this process was then used to inform the analysis of fishing portfolios described below.

2.2. Fishing access portfolio analysis: an assessment of the cumulative effect of adaptation

Using licensing data provided by MDMR, we calculated the extent to which fishers' access to commercial fisheries in Maine has changed over a twenty-five year period (1990–2014) as a way to quantify the cumulative effects of the evolving licensing system. The dataset includes 374,970 licenses that were issued to a total of 33,149 individual fishers over the twenty-five year time period. For the purpose of our analysis, we defined 'access' as the relative number of fisheries that a fisher can target given the assemblage of licenses that he or she holds in a particular year. This is notably different from the absolute number of licenses that an individual fisher maintains because several of the license types give fishers access to more than one species. For example, in 1997, the commercial shellfish license gave fishers access to soft-shell clams, surf clams, and mussels. We focused on the portfolio of species that individuals can access rather than on the number of licenses one holds to account for the dramatic proliferation of license types, which increased from 21 in 1990 to 113 in 2014. This includes license types specific for fishers younger than 18 years old and over 70 years old as well as license types for tribal communities, seafood dealers, recreational charter boat operators, and a suite of miscellaneous license types. While some of this growth can be attributed to the creation of subclasses of licenses for particular species (e.g., lobster or scallops), other licenses were divided such that an individual needs to hold two or more licenses to fish for the same set of species that he or she could have targeted in the past with only one license. This deflation in the 'value' of certain licenses could confound a direct comparison of the absolute number of licenses. Instead, to account for this continual subdivision, we weighted licenses based on information from the legislative analysis. We assigned the relative number of species (e.g., an access portfolio) a fisher could access with each license at each time period using the equation:

$$L_{ij}(t) = N_i(t_0) + \Delta N_i(t)$$

$$A_j = \sum_{i=1}^{n} L_{ij}(t)$$

where L is the total number of species a fisher (j) was able to access with a given license type (i) at time (t); N is the number of accessible species for a given license; t_0 is the reference year (1990); ΔN is the difference in the number of accessible species between t_0 and t; n is the total number of licenses held by an individual fisher; and A is the portfolio of species that a fisher can access using all of his or her licenses.

By accounting for the splintering of licenses through time, we were able to calculate how individual fishers' access portfolios have changed. Data for each fisher were then aggregated by year to determine average (mean) changes across the entire state and at county- and town-levels to illustrate spatial variability.

3. Results

3.1. Licensing ecology of Maine: a history of adapting management in response to specific problems

There is a discontinuity between pre- and post-1977 fisheries management in Maine. This is not to imply that contemporary marine resource management is decoupled from the past. Many of the state's rules and norms have historical roots, including the parametric conservation strategies used in the lobster fishery (Acheson, 2003) and the impetus for municipal-level soft-shell clam management (Hanna, 2000). Nonetheless, there has been an apparent shift in the approach to fisheries governance since the MDMR was established in 1977. In the time since, a new licensing regime has emerged that has placed increasing emphasis on access constraint at the individual fisher level. Although licenses in commercial fisheries in Maine date back to at least 1823 (Kelly, 1992), early licenses appear to have sought to limit non-residents from entering fisheries instead of restricting the total number of fishers. In this way, the role of licensing in fisheries has evolved, transitioning from a tool used primarily to limit certain types of people (i.e., non-residents) from entering fisheries to one used to accomplish a wide range of social and ecological goals. One of the main reasons for this evolution was the real and perceived concern that the commercial fishing fleet was over capitalized and fisheries were in decline. Through this transition, licenses have become a ubiquitous part of fisheries that have come to serve as an increasingly dominant feature of the institutional landscape, competing with and in some cases replacing other institutions that have historically acted to constrain access and marine resource exploitation. These licenses, along with other management measures to sustain the productivity of fisheries, have had mixed success (Fig. 1).

The authority to create new fishing licenses is vested in the Maine State Legislature. Prior to 1977, there were five licenses for commercial fisheries in the state: lobster, shellfish, marine worms,[1] scallops, and a general category commercial fishing license to serve as a catch-all for other species not included in the first four licenses or managed by the federal government. Of this initial suite of licenses, the marine worm license is the only one that has not been segmented in some fashion—although it has been amended multiple times. Starting in 1981 and continuing until 2009, multiple license splits occurred, such that by 2014 there were 23 main license types for 16 individual fisheries or group of fish or shellfish (Fig. 2). While both the original scallop and lobster licenses have been subdivided into new subtypes during this time period, the more substantive changes have occurred in the shellfish and general category commercial fishing licenses.

Reasons for these changes ranged from a desire to use licenses to generate revenue to offset the cost of research, enforcement, and management to interest in further developing underutilized fisheries (Table 1). For example, only four years (1981) after the shellfish license was reauthorized, the legislation established a new license for Mahogany clams (110th Session, LD 11). In this instance, the subdivision was motivated by a desire to further develop a targeted fishery for Mahogany clams, which at the time was considered underexploited. The shellfish license was then again subdivided in 1987 with the establishment of blue mussel licenses for hand-raking and dragger vessels (113th Session, LD 1326). At the time, blue mussels had become the third largest fishery in the state (6.3 million lbs), up from 50,000 lbs fifteen years earlier. The rapid growth of this fishery created several problems, including tension with other fishers (in particular marine worm and clam diggers) and the nascent aquaculture sector. In the case of the former, worm and clam diggers were becoming increasing concerned about the direct and indirect impacts that the draggers were having on intertidal resources, whereas in the latter, it was draggers that were concerned that blue mussel farmers could potentially compete with their market. Recognizing these problems, a five-member subcommittee of the Joint Standing Committee on Marine Resources outlined several strategies that the legislature could take to address these issues in a report that was represented to the legislature (Flatebo, 1986). Among the recommendations put forward to solve these problems was the proposal to create a separate license for blue mussel harvesting that was distinct from the shellfish license. The logic behind this idea was that by separating out draggers from other commercial shellfish harvesters, it would be easier to manage the fleet and defray conflict with other sectors. This recommendation, which was eventually accepted and turned into legislation, marked the end of the subdivision process of the commercial shellfish license for twenty years, when a surf clam license was created (123rd Session, LD 554). The details of these changes are less germane to this paper than the general motivations that underpinned them. As evident in this case (and throughout the recent licensing history in Maine) (Table 1), the legislature has been highly responsive, actively working to find solutions to real and perceived social and ecological problems in the state's fisheries. This has resulted in numerous well-intended changes to the licensing system.

3.2. Access to fisheries in Maine: a history of decline

In the midst of ongoing management interventions, the number of commercial fishing licenses issued in Maine increased from 11,645 (1990) up to 17,446 (1996) and subsequently declined through 2014 (13,254). Fishers' individual response to the changing licensing ecology has varied depending on each person's unique personal circumstances (e.g., health, age, alternative job prospects, savings, family connections, and education). We provide three examples of fishers' histories of access to illustrate some of the variation observed in the data (Table 2). These three examples are not intended to represent the entire population, but rather reflect individual-level vignettes that capture three general typologies ranging from specialist to generalist, which is illustrative of the ways that fishers' access to fisheries has changed over time. Fisher A held four licenses in 1990, with access to the suite of species associated with the lobster, scallop, shellfish, and general category commercial fishing licenses. Fisher A subsequently switched between fisheries, dropping the lobster, scallop, and commercial fishing licenses and then reacquiring scallop and commercial fishing licenses again for a short period. Fisher A also acquired a sea urchin license temporarily at the peak of the industry's rapid expansion in the early 1990s. However, like the other licenses, this license was not maintained. The only license that Fisher A maintained over the twenty-five year period was one for shellfish. In contrast, Fisher B did not move between fisheries, maintaining a lobster license continuously since 1997. The third individual increased their access. One year after entering the industry with a shellfish license Fisher C acquired a license to participate in the

[1] Sand and bloodworms are harvested commercially to supply the live bait market. These marine worms are harvested in the intertidal zone in Maine's expansive mudflats.

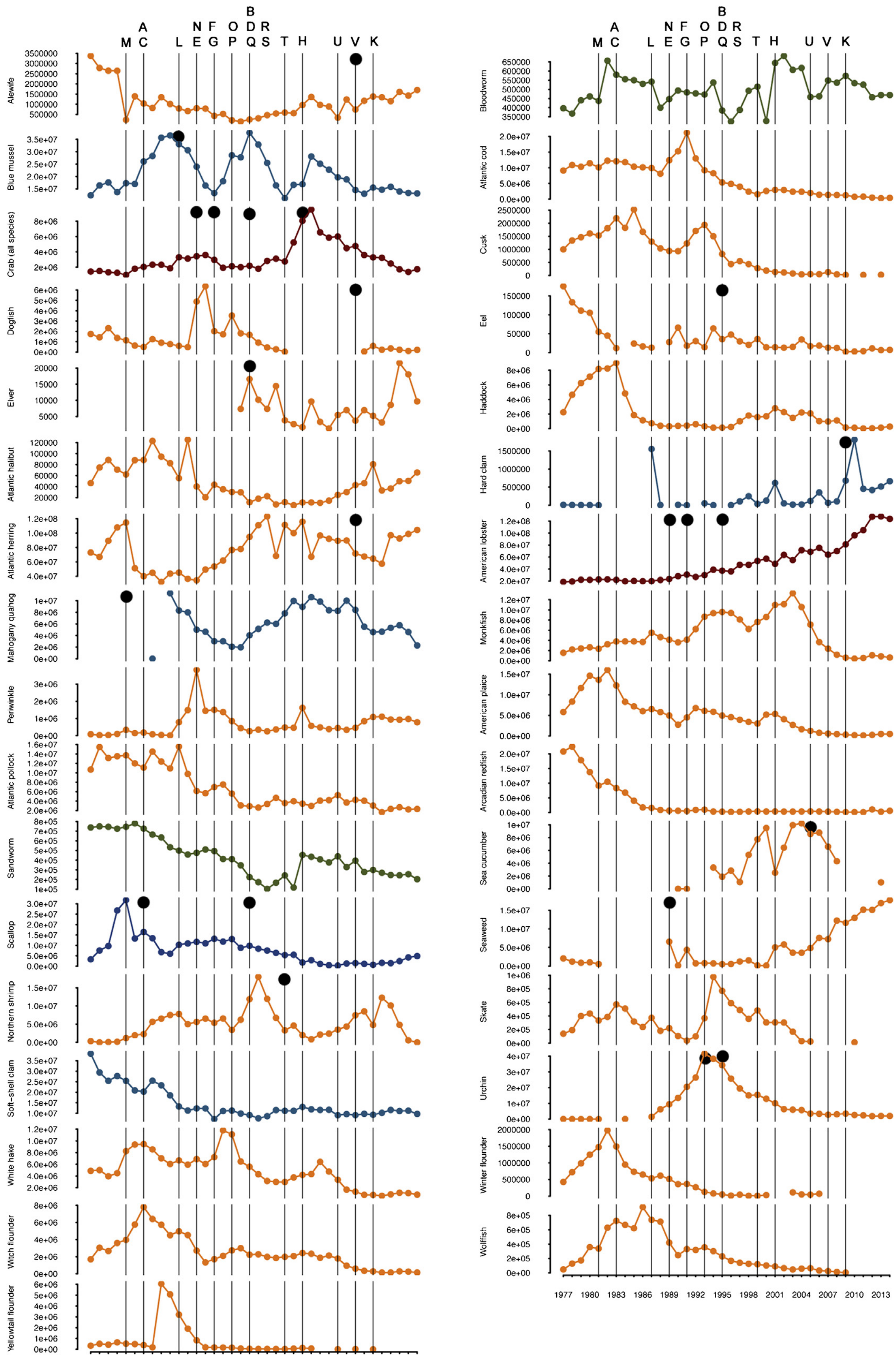

Fig. 1. Landing data for fisheries in Maine from 1977 to 2014. Color of each graph corresponds to license category illustrated in Fig. 2 (i.e., red = lobster/crab, orange = general category, green = marine worm, sky blue = scallop, and teal = shellfish). Vertical lines represent years in which licenses were created. Letters (top) correspond to specific licenses as outlined in Fig. 2. Black circles represent creation of license(s) directly relevant to a given fishery. Species without black circles are those that were licensed at or before 1977. Data source for harvest levels: (MDMR, 2015). *Note*: 2014 data is preliminary. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

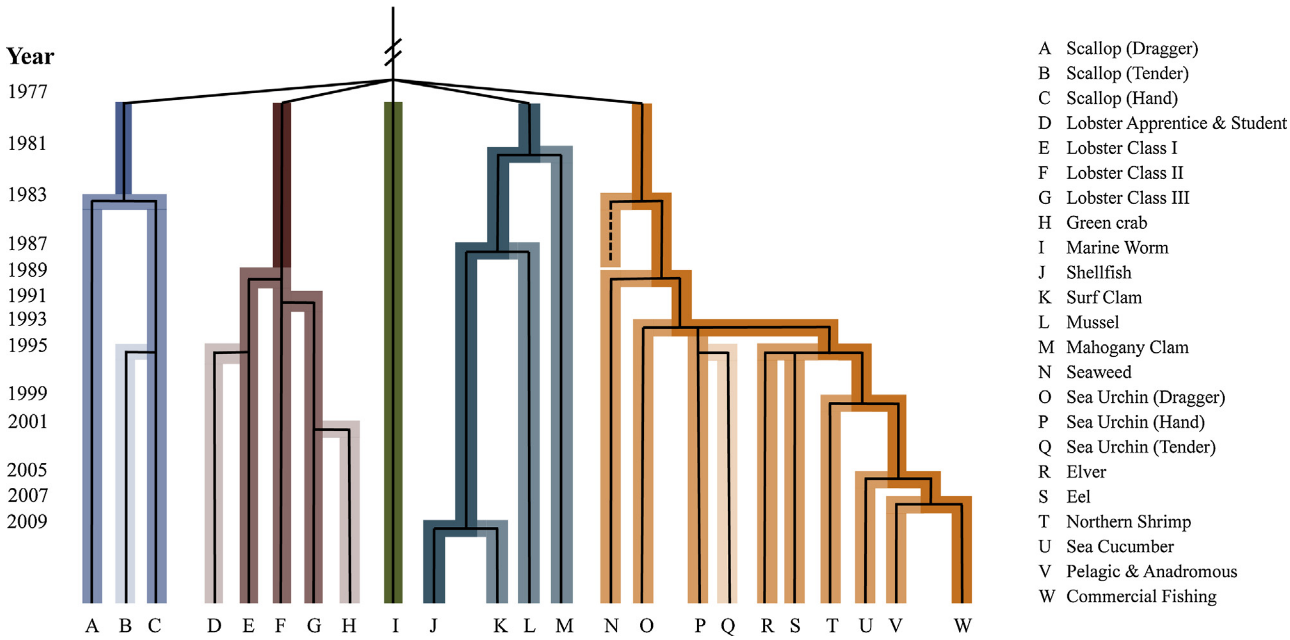

Fig. 2. Evolution of licensing system in Maine. Illustration of historic splintering of commercial fishing license types since 1977 that has led to the existing licensing ecology in Maine. Colors denote initial license types, whereas lighter shapes reflect subdivisions. Bifurcations denote years in which new licenses were created. *Note*: dendogram does not include most licenses for youth under 18 years old (except lobster) or individuals over 70 years old, nor does it take into account licenses for tribal residents.

lucrative elver fishery that occurs in the spring and early summer as juvenile eels migrate into Maine's coastal river systems. Although many fishers' history of access is similar to Fisher B or Fisher C (in that their access has remained stable or increased), access overall has declined.

Viewed in aggregate, there has been an overall pattern of declining access across the state. Fishers' access to fisheries has atrophied significantly, decreasing by 50% over this twenty-five year period, from a mean of 2.87 (1990) to 1.42 (2014) (Fig. 3). In examining this pattern spatially, across the entirety of towns in Maine's eight coastal counties, we find that the decline is particularly evident in the western most, least fisheries dependent counties (Fig. 4).

4. Discussion

4.1. Evolution of the licensing system as a threat to resilience

In this discussion, we consider three ways in which the loss of access to fisheries may erode the resilience of the social–ecological system in Maine's fisheries. We then attempt to reconcile our findings with current theory, by putting forward the idea that adaptability is an inherently path-dependent and myopic phenomenon that is influenced by prior adaptive strategies. In the case presented here, the adaptive process of creating and splintering licenses into increasingly smaller units at the legislative level has continually decreased the effect that these changes have on the system overall. In doing so, we suggest that the ability for adaptive management to contribute to general resilience decreases in these cases, acting instead to address problems concerning specific resilience.

4.1.1. Decreased livelihood diversification leads to economic instability

There is an element of tragic irony embedded in the history of licensing policy in Maine. It is a narrative of well-intended decisions aimed at improving particular fisheries, but that have ultimately decreased fishers' access to marine resources. Despite the fractioning of the management system into more specialized license types, our results indicate that individual portfolios have become less diversified in the past twenty-five years (possibly in the history of commercial fishing in the state). While our results do not speak directly to personal motivations for increasing specialization, they do raise concerns about individual vulnerability and have significant implications for more system-wide processes.

On one hand, reduced access does not necessarily reduce the income potential of harvesters. In fact, specialization can be a strategy to increase wealth. For example, Finkbeiner (2015) observed that fishers in Baja California Sur, Mexico became less diversified during favorable conditions as a means to accumulate wealth by targeting profitable fisheries. On the other hand, decreasing access does change harvesters' relationships with risk at the individual level. Consider a scenario in which there are two harvesters of equal ability. The first one has access to one species and the second one has access to at least two uncorrelated species. We could make this scenario more contextually appropriate by imagining that the harvesters target soft-shell clams and lobster—a combination that is quite common in Maine. If the first harvester only participates in the lobster fishery s/he could conceivably earn more than the second harvester if the latter invests an equal amount of time in the two fisheries since the lobster fishery has been highly productive in recent years. Yet while the first harvester could potentially earn more by being specialized s/he is also more vulnerable to changes in the lobster fishery since s/he does not have an alternative if the lobster fishery becomes unprofitable due to economic, ecological, or regulatory changes. This logic is supported by economic theory and practice that suggest that over the long-term fishers who are not diversified are more vulnerable to socioeconomic and ecological changes (Kasperski and Holland, 2013).

Lack of diversification is particularly problematic for fishers in Maine because unlike in Baja, for example, where individuals continue to have the latitude to switch between fisheries with relative ease to stabilize their income and temper the effects of disturbances, the licensing system in Maine has not only become more splintered, but the institutions in place also make it more difficult for fishers to increase the range of fisheries they target and

Table 1
Summary of primary reasons used to justify the creation of licenses in Maine fisheries since 1977. *Note*: the original shellfish, lobster, scallop, shellfish, and worm licenses are not included in this Table as they were created prior to the establishment of the Maine Department of Marine Resources (DMR).

License	Legislative bill #	Justification(s)	Illustrative quote
Blue Mussel	(113th LD 1326)	To reduce user conflict between fisheries	"Five major issues emerged as a result of the study. These were: (1) concern over the extent and status of the mussel resource. (2) Damage to mussel beds and associated species such as marine worms, herring, clams, and lobsters from dragging activities and mussel culture. (3) Conflicts between fishermen over transferring mussels from wild beds to aquaculture leases. (4) Shortcoming in the current aquaculture lease procedures. (5) Concern that the statutes for shellfish are tailored to the soft-shell clam and are not appropriate for the mussel fishery . . . The subcommittee has developed the following recommendations to address management issues with the fishery . . . Mussel harvesting licenses should be separated from shellfish harvesting licenses." "Because of the [blue mussel] fishery's rapid growth and changing character, conflicts are developed between traditional mussel fishermen, aquaculturists and other fisheries."
Elver and eel	(117th LD 185)	To generate funding for research and enforcement	"I am anti-tax. I am anti-anything you want. I got on this committee and I had to start taking a new look on what was going on. I kept seeing fisheries going down the drain. What do you do to prevent that? Sometimes you have to look ahead, look to the future and say, how can we prevent this fishery from going the way of others? You can put things into place, rather than wait and drag it out. That is one reason for putting a good solid hunk of money up front for science" (Representative Bigl, H-1704).
Green crab	(120th LD 1699)	To control an invasive species	"Delay in the implementation of a green crab licensing requirement could potentially postpone any substantive management efforts for green crab control" (Statement of Fact).
Lobster apprentice and student	(117th LD 1733 and 782)	To train new entrants and to allow youth into the fishery	"The answer to solving the entry problem without a moratorium lies in re-establishing through the state the type of entry regulation which traditionally existed in lobstering communities...An apprenticeship program will do this, without causing the problems a moratorium would. The idea should be to insure that anyone entering the fishery knew the ethics, practices, and practical information that makes a good fisherman" (Commissioner Alder LD 782).
Lobster class I, II, and III	(114th LD 1687)	To make license holders responsible for unlicensed crew	"A holder of a Class II and Class III license will be authorized to hire 1 or 2 unlicensed crew members to assist the license holder under the supervision of that license holder" (Statement of Fact).
Mahogany clam	(110th LD 11)	To develop the fishery	"To establish laws more appropriate for the developing mahogany quahog fishery, a species with good development potential but which is constrained by statutes improperly designed for the objective" (Statement of Fact).
Pelagic and anadramous	(124th LD 1724)	To generate funding for research and management	"The commissioner shall use the fund for research directly related to pelagic or anadromous fishery management and the processing of landing data. The commissioner may authorize the expenditure of money in the fund for research and development programs that address the restoration, development or conservation of pelagic or anadromous fish resources" (Legislative Text).
Scallop (drag)	(111th LD 2173)	To improve enforcement	"This new draft creates a distinction between the methods of scallop fishing in order to facilitate the enforcement of the prohibition on dragging in cable areas" (Statement of Fact).
Sea cucumber	(122nd LD 0602)	To limit access into the fishery and restrict movement in the fishery; To generate funding for research and management.	"The commissioner may not issue a sea cucumber drag license under section 6801-A to any person unless that person possessed that license in the previous calendar year" (Legislative text).
Sea urchin (drag, hand, tender)	(116th LD 140)	To manage harvest and prevent fishers from harvesting lobsters; To restrict non-residents from joining the fishery	" . . . in order to preserve a sustainable resource for immature sea urchins and institutes a log book mechanism by which the DMR can enforce the yield standard and develop a data base of information documenting the amount of urchins harvested, from where, and by whom" (Statement of Fact).
Seaweed	(111th LD 1171)	To collect data about the fishery	"Requiring a permit for seafood harvesting is one way we can learn what is being harvested, from which part of the coast, in what volume. It is one step that could lead to the management plans for the species that is most vulnerable" (Representative Crowley, H-362).
Shrimp	(119th LD 1829)	To generate funding for research and management	" . . . the commissioner shall use the fund in support of issues related to management of the shrimp fishery" (Legislative text).
Surf clam	(123rd LD 554)	To create a cost savings for harvesters	"It creates a new surf clam boat license, which allows vessels engaged in harvesting surf clams to obtain one license to cover all crew" (Statement of Fact).

Table 2
Licenses held by three different fishers (A-C) between 1990 and 2014. License holder A held multiple licenses in the early and mid-1990s, but only maintained a shellfish license after 1998. License holder B acquired a lobster license in 1997 and has continued to renew it. Unlike license holder A, license holder B never held more than one license. License holder C represents a fisher that has an expanded portfolio. License holder C acquired an elver license in 2005 to complement his or her shellfish license.

	1990									2000									2010					
A																								
Commercial	•	•							•															
Lobster	•																							
Shellfish	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Scallop	•			•																				
Urchin			•	•	•																			
B																								
Lobster								•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
C																								
Shellfish															•	•	•	•	•	•	•	•	•	•
Elver																•	•	•	•	•	•	•	•	•

locations. For example, the ability for fishers to move between fisheries in Maine is particularly limited in the most lucrative fisheries in the state (e.g., lobster, scallop, elver), all of which are limited entry programs that constrain entrance or are closed for other reasons. To enter the elver fishery, fishers need to win a lottery that has dismal odds. There is also a moratorium on new licenses in the scallop fishery and the shrimp fishery has been closed since 2013 because the biomass of the fishery has declined. In the lobster fishery, there are long waitlists in all but one zone that make it difficult for new fishers to gain entrance. The unfortunate result is an environment in which fishers are operating with access to few species, limited areas, and reduced potential to diversify. The trend in Maine toward more and more narrowly defined licenses has led to 0.58 new license types added per year over the past 38 years. Of these, five are now limited entry; these fisheries accounted for 82% of the overall value ($) of fisheries in Maine in 2014 (Singer, 2011).

4.1.2. Decreased mobility leads to less abidance

There is no simple solution to the problem of declining access, particularly in a resource-constrained environment where increasing pressure on fish stocks could lead to the depletion of these resources. However, enclosure by way of licensing does not necessarily eliminate the risk of overexploitation or the tendency to continue fishing stocks that might otherwise have been abandoned if there was the opportunity to switch (Sievanen et al., 2005). One potential outcome of the cumulative effects of the licensing system on social–ecological resilience is the emergence of what Porter (1990) calls 'avoidance entrepreneurs.' Avoidance entrepreneurs are individuals that become adept at sidestepping cumbersome rules and regulations.

There is a fairly large body of literature that provides empirical evidence that non-compliance is a problem in fisheries worldwide (Hatcher et al., 2000; Nielsen and Mathiesen, 2003), including locally in the Gulf of Maine (King and Sutinen, 2010). While such rule-breaking represents a perennial problem in fisheries, there is some concern that rule-breaking in Maine may becoming more common. If this is the case, it would be consistent with what has been described in maritime Canada, where non-compliance represents a "routine form of everyday resistance" (Scott 1986:18 in McMullan and Perrier (2002)) that has come about in response to state sanctioned regulations that have been superimposed on informal and local management systems. Examples of rule-breaking in Maine include stories of fishers hauling more than the maximum 800 lobster traps, keeping undersized lobsters, and exceeding state mandated catch limits in the scallop and urchin fisheries. These accounts, to a certain extent, have been corroborated by several recent enforcement actions taken by the MDMR in both the lobster and scallop fisheries.

Multiple factors contribute to non-compliance, including economic necessity and the perceived legitimacy of rules (Nielsen and Mathiesen, 2003). In a system where fishers are increasingly constrained and their occupational mobility is limited (as is the case in Maine), both of these factors are likely to contribute to the adoption of non-compliance practices. Such rule-breaking among a few individuals will not necessarily have a negative impact on marine resources on a broad scale, but fishers' collective shift away from a conservation ethic could undermine the resilience of the system.

Fig. 3. Change in harvesting potential of fishers. Mean access portfolio of Maine fishers from 1990 to 2014. Vertical lines denote the years in which new license(s) were created.

4.1.3. Decreased engagement undermines local ecological knowledge

Decline in access also has the potential to alter the production of local ecological knowledge by fishers (Beitl, 2014; Murray et al., 2010). We can explain this dynamic in the following way. To successfully exploit a fishery, fishers interact with the marine environment in a particular way. The particulars of these interactions are invariably different across fisheries because each fishery requires a different type of gear or occurs during a different part of the year or in a different part of the environment. For example, fishing for lobsters will expose fishers to different components of the marine environment than raking soft-shell clams in the intertidal zone or diving for sea urchins. It is through these direct and variable interactions with the marine

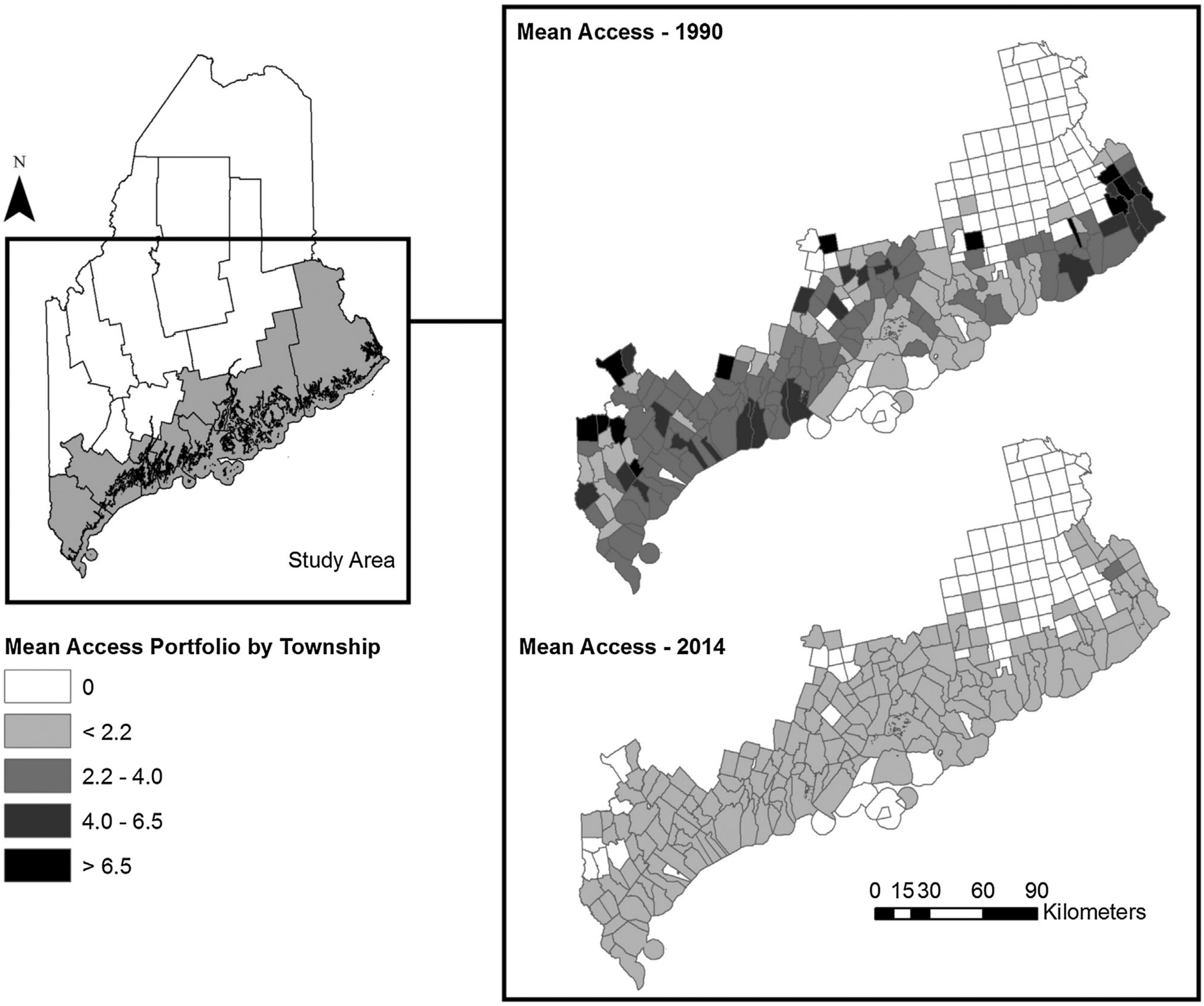

Fig. 4. Change in access portfolios across Maine. Maps define the access portfolios of towns in Maine in the eight coastal counties in 1990 and 2014.

environment that fishers gain local ecological knowledge about the systems within which they operate. Historically, by way of exploiting a diverse range of species, fishers could gain knowledge that was both fine-scale and also holistic (more like the general knowledge of a naturalist than a contemporary scientist is highly specialized). Limiting the ability for fishers to move between fisheries by way of licensing causes a form of specialization. Such siloing would suggest the erosion of ecological knowledge over time and new challenges in the acquisition of broad local ecological knowledge by way of direct interactions.

The potential decline of holistic local ecological knowledge has serious implications for fisheries management, particularly where fine-scale and high-resolution knowledge is needed to understand marine resources and their complex and interconnected dynamics (ignoring the problems of translating private knowledge to the public table). Part of the underlying challenge is that these complex systems are continually changing with time and in space. Thus, useful information about the form and function of one place (at one moment) can be highly irrelevant and inapplicable to other places and vise versa (Levin, 1999).

Many argue that accurate information, by which we mean information gathered by an observer who is aware of the historical context of the social–ecological system and is better able to understand the meaning of observations, can be obtained through alliances with resource users and the private sector (Berkes, 2009; Cinner and Aswani, 2007). Resource users are uniquely positioned to collect these types of information because of their intimate and consistent relationships to the marine environment. This proximity facilitates information acquisition that would be prohibitively costly to fishery scientists and managers. For example, fishermen are increasingly using real-time information about where and when they encounter non-target species to voluntarily impose short-term, fine-scale area closures (Little et al., 2014). In other instances, fishermen are designing and implementing surveys to collect information about the fine-scale recruitment and dispersal patterns of fisheries (Schroeter et al., 2009). With these data, feedback loops can emerge that enable continual learning and facilitate context appropriate adaptation.

The extent to which information rich feedback loops are created and maintained depends, in part, on the extent to which fishers can sustain their interactions with the natural environment. We argue that if these interactions are constrained by the cumulative effects of regulatory entanglement, local ecological knowledge may be lost, thereby threatening general resilience of the system by lowering the collective awareness of the state of the environment.

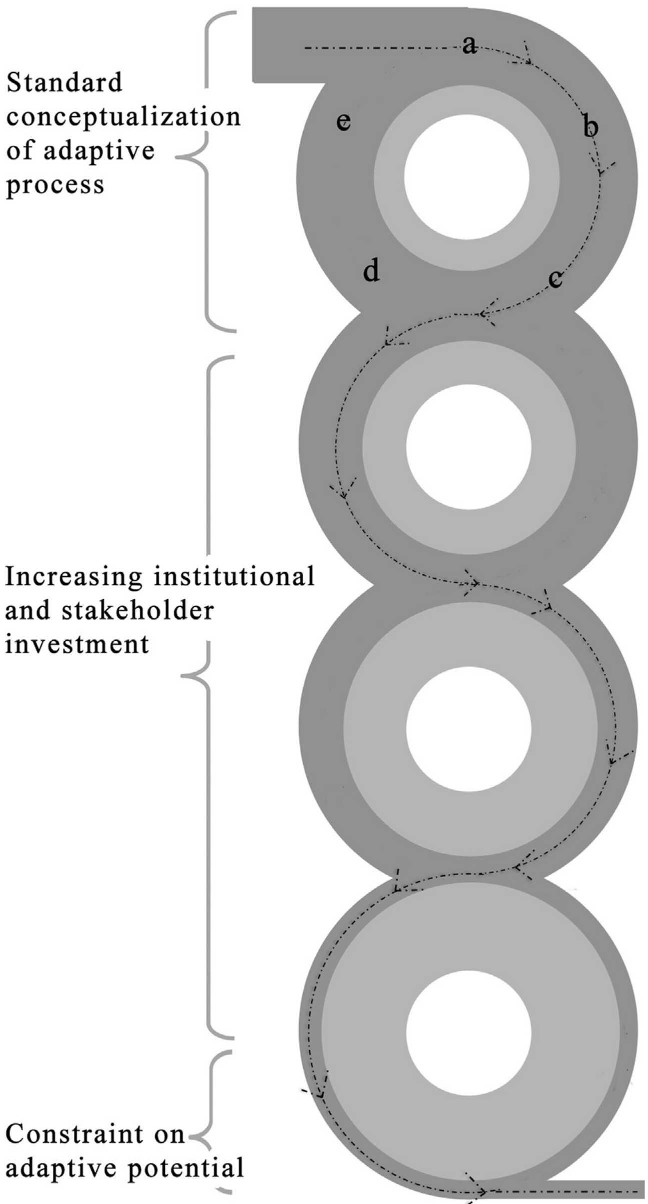

Fig. 5. Bounded adaptation. Top circle provides illustration of adaptive management process as frequently portrayed in literature, with (a) goal setting, (b) development of management strategy, (c) implementation, (d) monitoring, and (e) evaluation (e.g., Linkov et al., 2006). We suggest that over time the ability to influence the general resilience of a system by way of system-level adaptation diminishes as a result of the creation of institutional constraints and the simultaneous investments that stakeholders make in these institutions. We depict this process by way of showing the ratio of dark to light gray decline over multiple phases of adaptation. Dark gray denotes range of possible adaptations while light gray reflects the build up of institutions and investment.

4.2. Toward an understanding of bounded adaptation as an impediment to resilience

By quantifying the decline of fishers' access in Maine over a twenty-five year period, we seek to demonstrate how adaptability in a fisheries context can, in some cases, reduce resilience of fishers and the broader social–ecological system within which they are situated. We begin to make sense of the tension between our findings and conventional wisdom by drawing on a classic metaphor. Ludwig et al. (1993) use the image of a ratchet – with its unidirectional mechanics – to describe how social pressures lead to overfishing. In their conceptual model, productive fishing years resulted in the growth of the commercial fishing sector and its accumulation of social capital and political clout that was then leveraged to sustain subsidies and maintain fishing privileging even as stocks declined, resulting in the eventual overexploitation of the resource. Just as the concept of a ratchet effect works well to capture the dynamics that can lead to overfishing, so too is it applicable to the licensing process in fisheries. The problem is that each license that is created is nearly irreversible – necessary for a ratchet effect. In each instance there is a build up of new special interests and people adapt to the advantages the license confers. Thus, any subsequent proposed change or rationalization of the entire licensing system invariably faces pushback by self-interested actors with existing investments in the status quo.

This dynamic is also evident at the federal fisheries level, where fisheries are managed by multiple overlapping decision-making bodies that share responsibility for working toward what has been described as an "infeasible set of management objectives" (Murawski, 1991) that aim to simultaneously conserve the resources and maximize harvest. These governance bodies are guided by state and federal statutes, but otherwise have had latitude to make whatever context specific rules they deem appropriate. This autonomy, however, has been made narrower by management decisions that these entities have enacted over time. As a result, the adaptive potential of these governing entities has atrophied by virtue of prior adaptive measures that created constraints for future adaptation.

The proposed shift toward ecosystem-based fisheries management highlights the path dependencies that existing management regimes create and how they make the transition to a new management regime difficult. In a constrained budget environment like the US federal government presently faces, moving toward a more holistic approach to management (i.e., ecosystem-based fisheries management) necessarily requires a divestment in single-species research so that more resources can be directed toward process-related research (Ianelli et al., 2011). Even though this may be a trade-off that will improve fishery management outcomes in the long-term, it is one that is not particularly palatable to many fishers (or fishery scientists) in the near-term. The reason for this is that single-species research serves as the backbone of stock assessments, which will suffer from greater uncertainty (which translates into lower fishing quotas). Tensions like this are part of the reason it is more feasible to build upon existing management strategies than to introduce fundamentally new systems. This creates an environment in which fisheries management is tweaked as opposed to broadly revamped.

Such bounded adaptation is consistent with theory on situated rational choice and bounded rationality that acknowledges the ways in which human choices are embeddeded in socioeconomic, political, cultural, historical, and environmental contexts (Cote and Nightingale, 2012; McCay, 2002; Mosse, 1997). In making a case for bounded adaptation, we fully acknowledge the tension between structural determinism and rational choice. DiMaggio (1998) argues that the rise of new institutionalism has brought much needed focus to the ways in which institutions affect actors' behavior. Yet as this field of study has developed, actors' agency has been deemphasized to the point that it has often had to be "smuggled into institutional approaches rather than theorized explicitly" (DiMaggio, 1998). Thus, our point is not that institutions like the licensing system alone bound adaptation, but that they contribute to limited adaptation in a way that can undermine resilience.

Within the context of fisheries, we contend that the result of bounded adaptation is that more complicated, but not necessarily more effective, management strategies often emerge. We see this dynamic particularly clearly in the way licensing policy in Maine is unfolding. The Maine State Legislature and the MDMR are actively exploring legislature that would modify the lobster licensing system, and plans for new licenses for halibut and black sea bass are rumored to be in the pipeline. These adaptations create short-term fixes, but ultimately decrease maneuverability for systemic adaptation that could address fundamental problems like the cumulative loss of access. This dynamic suggests that over time, adaptive strategies in systems like these are prone to shift, slowly transitioning from adaptation that addresses threats to general resilience to adaptation that focuses on specific resilience (Fig. 5). We can consider this paradox of "counterproductive regulations" – a term coined by Grabosky (1995) – a commons problem that (ironically) stems from the institutionalization of rules that were created to solve other commons problems. At the federal level, mechanisms are in place such that the burdens of these compounding regulations are considered (e.g., Executive Order 12866, Executive Order 12898, and in Social Impact Assessments). However, they are rarely the focus of explicit analysis because they fall outside regulators' domain of responsibility. Instead, corrective actions in particular fisheries tend to be made myopically, focusing on specific and isolated problems.

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