



Synthesis

The relationship between adaptive management of social-ecological systems and law: a systematic review

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ABSTRACT. Adaptive management has been considered a valuable approach for managing social-ecological systems involving high levels of complexity and uncertainty. However, many obstacles still hamper its implementation. Law is often seen as a barrier for moving adaptive management beyond theory, although there has been no synthesis on the challenges of legal constraints or how to overcome them. We contribute to filling this knowledge gap by providing a systematic review of the peer-reviewed literature on the relationship between adaptive management and law in relation to social-ecological systems. We analyze how the scholarship defines the concept of adaptive management, identifies the legal barriers to adaptive management, and the legal strategies suggested for enabling this approach. Research efforts in this domain are still highly geographically concentrated in the United States of America, unveiling gaps concerning the analysis of other legal jurisdictions. Overall, our results show that more flexible legal frameworks can allow for adaptive management without undermining the role of law in providing stability to social interactions. Achieving this balance will likely require the reform of existing laws, regulations, and other legal instruments. Legal reforms can facilitate the emergence of adaptive governance, with the potential to support not only adaptive management implementation but also to make law itself more adaptive.

Key Words: *adaptive governance; adaptive management; environmental management; law; legal institutions; legislation; systematic review*

INTRODUCTION

Forty years after its first description by Holling (1978), adaptive management is still considered a valuable approach for dealing with dynamic social-ecological systems (Williams 2011, Westgate et al. 2013, Williams and Brown 2014, Garmestani and Allen 2015, Birgé et al. 2016). It has become increasingly popular among the scientific community, environmental management practitioners, and policy makers for improving decision-making processes involving high levels of complexity and uncertainty (Jacobson et al. 2009, Biber 2011, McFadden et al. 2011, Williams and Brown 2016).

Although the fundamentals of adaptive management have been exhaustively studied in the area of natural resource management (Holling and Sundstrom 2015), its effective practice is still timid (Lee 1999, Craig and Ruhl 2014, Lee 2014, Arnold 2015, Green et al. 2015). Failure of adaptive management implementation is often related to the design of institutions, e.g., the political structure, sets of norms, social values, and standards of behavior shaping human interactions, because they can be too conservative to allow for changes in management (Stankey et al. 2005, Gupta et al. 2010, Herrfahrtdt-Pähle and Pahl-Wostl 2012).

Within this context, there has been increased efforts in recent decades to answer more specific research questions on how to eliminate constraints deriving from legal institutions and create harmony between adaptive management and law (Iles 1996, Doremus 2001, Karkkainen 2005, Ruhl 2005, Ruhl and Fischman 2010, Allen et al. 2011, Craig and Ruhl 2014, Garmestani and Allen 2014, Benson and Schultz 2015, Craig et al. 2017a). Recent contributions have questioned whether adaptive management may need to adapt to law (e.g., Biber 2013), while others have expanded this analysis to encompass the adaptive governance dimension (e.g., Cosens et al. 2017, Craig et al. 2017b, DeCaro et al. 2017a,b). There is a clear need to improve the knowledge of

the impact of legal frameworks on adaptive management implementation (Benson 2012) and understand how adaptive management can be legally operationalized (Lee 2014, McDonald and Styles 2014).

We provide a systematic review with a main focus on the peer-reviewed English language literature discussing the relationship between adaptive management and law. In particular, we seek to do the following: (i) present an overview of the main features of the literature sample; (ii) analyze definitions of adaptive management extracted from the literature sample; (iii) identify within this body of scholarship frequent cited legal barriers to adaptive management; and (iv) examine potential solutions scholars have been suggesting to overcome these legal barriers.

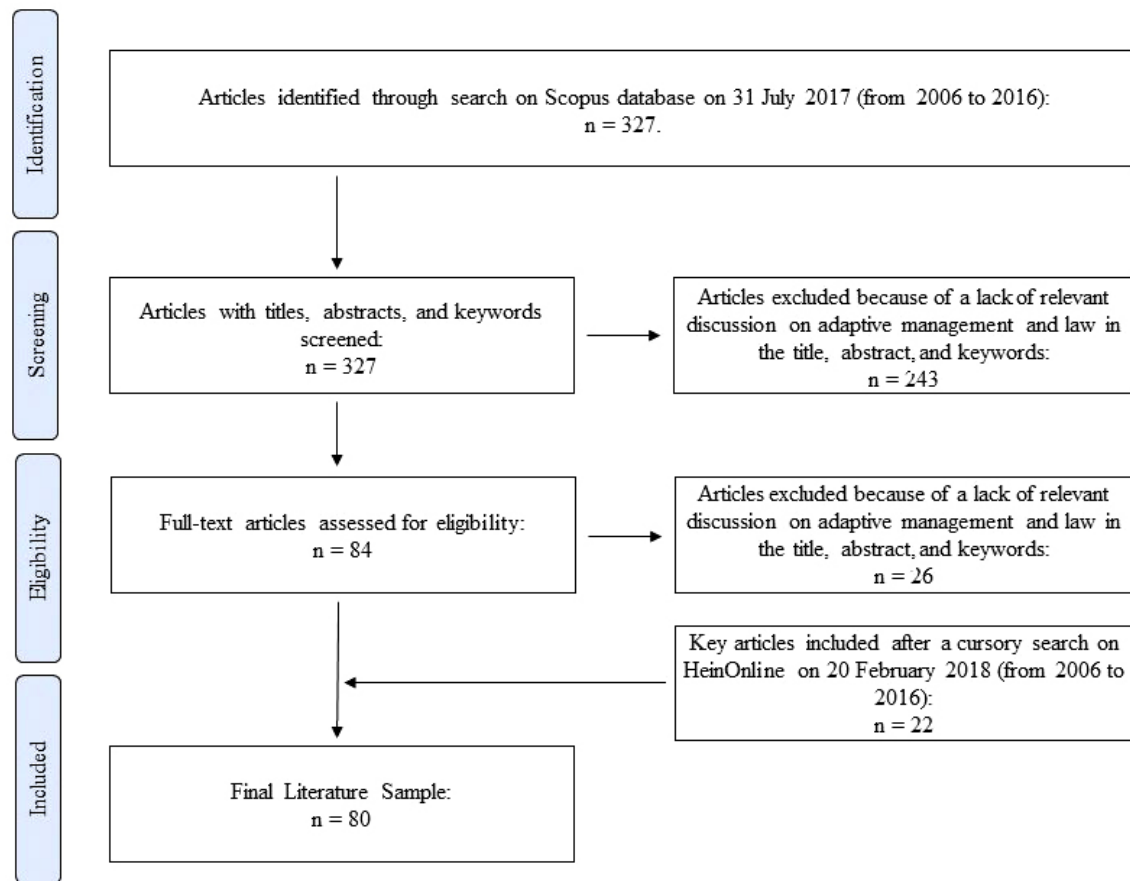
METHODS

Research and review articles in English language journals were obtained and assessed through a systematic review. This approach is common in several research fields, including environmental studies (Plummer et al. 2012a, Carter et al. 2015), and positive outcomes have been observed either with a quantitative or qualitative orientation (Steven et al. 2011, Plummer et al. 2012b, Ballantyne and Pickering 2015, Gallacher et al. 2016, Karpouzoglou et al. 2016). We adopted the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Four-Phase Flow Diagram (Moher et al. 2009) to search and select the literature (Fig. 1), drawing on examples of systematic reviews that have successfully used this structured process (Pickering and Byrne 2014, Ballantyne and Pickering 2015).

First, we created a set of keywords combining “adaptive management” and a group of legal terms (law OR legal OR legislation). For the purpose of this study, law comprises the body of enactments from (i) legislative branches, like constitutional provisions, statutes, and laws; (ii) executive branches, such as rules,

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Fig. 1. Flowchart outlining the protocol adopted in this systematic review based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Four-Phase Flow Diagram (Moher et al. 2009).



regulations, and normative instructions; and (iii) judicial branches, i.e., court decisions providing law enforcement or interpretation (Benson and Schultz 2015).

We ran a search for publications on Scopus, which is known as one of the most comprehensive peer-reviewed literature databases (Falagas et al. 2008, Carter et al. 2015). This source offers a broad coverage of the environmental studies, social sciences, and natural sciences fields (Moore et al. 2014). In addition, although our primary focus was on interdisciplinary peer-reviewed literature, we complemented our literature sample by conducting a cursory search for publications on HeinOnline, one of the world's most popular legal databases because of its vast collection of law journals (Justiss 2011, Gee 2013). Our final sample included 14 nonpeer-reviewed articles and reviews that reinforced the points made by the peer-reviewed literature or added new points. We highlighted in the text when a nonpeer-reviewed publication provided additional insights. We refer to additional points from such journals as "nonpeer-reviewed" in our analysis.

We acknowledge that our search and selection criteria may have excluded relevant publications, including peer-reviewed and nonpeer-reviewed literature available on other sources and, in particular, non-English research articles. The latter is especially worth noting because legal scholars generally have a tradition to

publish in their native languages to target the audience familiar with the legal systems in which they are qualified. However, our synthesis still adds to the current body of research given the lack of any attempt at systematic reviews on this topic, and it may encourage further reviews on the relationship between adaptive management and law using different methods and sources, and within or across specific countries and legal jurisdictions.

To achieve our first research objective, a simple spreadsheet file (Appendix 1) was populated with information from selected publications to map their contextual aspects. The following categories were created: (i) authors and year of the publication; (ii) name of the journal; (iii) geographical context; (iv) main environmental sector or concern; and (v) adoption of interviews or surveys as one of the primary research methods. We included this latter category because we were particularly interested in understanding whether the literature considers the perceptions and contributions of stakeholders about adaptive management and law.

The geographical context of the publications was defined using countries where the case studies were located. If no specific case study was identified, countries used as a context for the theoretical research defined the geographical scope and, if none was applicable, such scope was defined by the countries to which the

Table 1. Categorization of publications by environmental sector or concern, and use of interviews or surveys as a research method.

Main environmental sector or concern	Description	Articles with interviews or surveys	Articles without interviews or surveys
Forestry/Protected Areas	Management of forests and/or protected areas	3	4
Water	Management of water bodies and/or resources	4	14
Biodiversity	Biodiversity conservation and/or management of wildlife, endangered and/or threatened species	1	10
Fisheries	Management of fisheries and/or aquaculture	1	1
Marine/Coastal	Management of marine areas, coasts, and/or estuaries.	0	2
Multiple	No specific sector or concern was identified, or multiple resources were addressed without a discernible emphasis on one	2	38
Total of Articles		11	69

authors were affiliated. Publications having more than three countries were classified as multiple. The classification of the publications according to their environmental sector or concern included (i) forestry/protected areas; (ii) water; (iii) biodiversity; (iv) fisheries; and (vi) marine/coastal. If no specific sector or concern was identified, or more than one sector or concern was addressed without a special weight to any of them, the publication was included in the “multiple” category.

Retrieved publications were then organized within an EndNote library and submitted to content analysis through thematic coding using the NVivo software. Content analysis can be defined as a technique “for making systematic, credible, or valid and replicable inferences from texts and other forms of communication” (Drisko and Maschi 2015:8). The coding involved the identification and recording of passages from selected publications that were linked with a similar theoretical or descriptive idea (Gibbs 2007). Related passages were gathered and labeled under codes, i.e., the name that best represented the idea they shared in common.

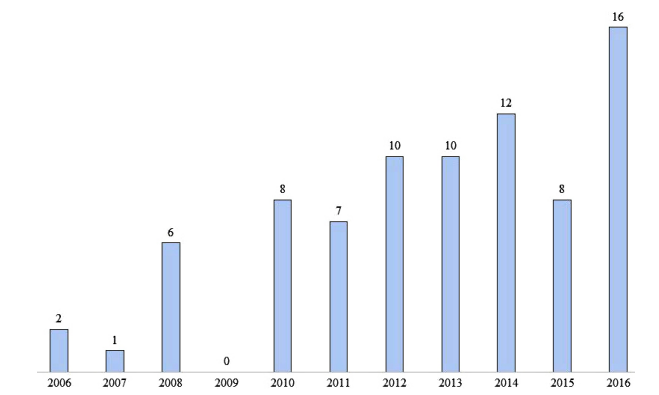
Within NVivo, “nodes” are the containers where coded passages are stored, and this software enables the creation of tree nodes (Richards 1999), which were used to achieve our second, third, and fourth research objectives. To achieve our second research objective, we coded relevant passages where there was a clear intention to define adaptive management, interpret its characteristics, or explain its different forms. With respect to our third and fourth research objectives, we initially used open coding to create subcategories of nodes within the tree nodes. Subcategories were created when passages of selected publications presented or discussed potential or actual legal barriers—or solutions to overcome legal barriers—to adaptive management. When open coding reached a mature stage, we started to revisit the coded passages and regroup the data (axial coding process), in order to refine the organization of the most important patterns and concepts identified during the content analysis (Babbie 2007). Also, we created free nodes to store passages with tangential ideas, and we ran text search queries to identify the occurrences of words and phrases that could help confirming or complementing our findings. Although we recognize that the process of coding does not fully prevent biases (Carter et al. 2015), the adoption of this process helped to increase the reliability and validity, and consequently the accuracy of our analysis (Miles and Huberman 1994, Patton 2002).

RESULTS AND DISCUSSION

Overview of the literature sample

Although we reiterate that our review is not exhaustive, publication dates indicate that the discussion on the relationship between adaptive management and law is likely growing over recent years, especially when compared to the initial four-year period of our literature sample (Fig. 2). Table 1 categorizes the literature sample according to their main environmental sectors or concerns, and the adoption of interviews or surveys as a primary research method. Publications with a lack of emphasis on one specific environmental sector or concern, covering multiple resources, represented half of the sample. Within a singular resource context, water management was the most prominent (18 publications or approximately 22% of the sample). Conversely, fisheries and the management of marine areas, coasts, and estuaries were among the categories with fewer publications. Adaptive management in the context of integrated coastal management (ICM) has faced important challenges (Craig and Ruhl 2010, Jacobson et al. 2014), with few efforts related to its implementation (Smith and Lazarow 2006), and limited research on the identification of crucial mechanisms for its success (Smith and Smith 2006). Although we recognize that publications may have been excluded because of our search and selection criteria, the results of our systematic review indicate that, if framed within underexplored environmental management contexts, e.g., ICM, future contributions to the existing body of literature may potentially improve understanding about the role of law in adaptive management.

Fig. 2. Number of articles by publication date.



Only 11 publications (approximately 14% of the sample) adopted interviews or surveys as a primary research method. However, some of the outcomes are worth mentioning. For example, Koontz and Bodine (2008) interviewed members of the U.S. Bureau of Land Management and the U.S. Forest Service to identify obstacles to ecosystem management implementation, and reported that adaptive management was seen as a challenging component. This overall perception was linked to the existence of legal barriers, which were identified by 17% of respondents (Koontz and Bodine 2008). Some years later, a survey of adaptive management practitioners in the USA revealed that more than 70% of the respondents felt hampered by legal and institutional constraints (Benson and Stone 2013).

Within the publications reviewed, the discussion on adaptive management and law was still highly geographically concentrated in the USA. Publications including only the USA as their geographical context accounted for approximately 64% of the literature sample. These results are consistent with the observations made by Humby (2014) on her literature review on resilience and law published in a nonpeer-reviewed journal, which also found that the USA was, by far, the most frequently studied jurisdiction. Together with the USA, countries with legal systems based on, or influenced by, the English common law system, e.g., Australia, Canada, and South Africa, were regularly used as the geographical context of publications. Although these results possibly reflect bias in our methods that exclude non-English language publications, they may also indicate a predominance of USA, and subsidiarily of other common law countries, in this academic scholarship, especially within the peer-reviewed literature. Further research in developing countries would be of particular interest because these jurisdictions may face challenges to implement adaptive management practices on account of the lack of a strong or well-defined rule of law (Garner 2016). Despite its predominance in developed countries, adaptive management approaches can be designed to serve different social-ecological and economic contexts (Schramm and Fishman 2010, nonpeer-reviewed). Comparative studies would also be insightful because the conclusions from previous research conducted in a specific legal system can also be relevant to other jurisdictions (Green et al. 2015, Curran and Mascher 2016). For example, in the USA, Craig (2010a) suggested in a nonpeer-reviewed publication that state common law public trust doctrines can be used to support adaptive management in the context of climate change. New studies could investigate the feasibility of this suggestion in other common law countries, and what legal tools are available in jurisdictions adopting different legal systems.

The meaning of adaptive management

Adaptive management has no single or static meaning (Raadgever et al. 2008, Schultz and Nie 2012), which often leads to terminological confusion (McDonald and Styles 2014). Selected definitions provided by publications included in this systematic review are presented in Table 2. Adaptive management is a framework designed for managing complex and dynamic social-ecological systems (Thrower 2006, Garmestani et al. 2008, Craig 2010b, Novellie et al. 2016, Ruhl 2016), in which decision making follows a structured and iterative process (Raadgever et al. 2008, Benson and Garmestani 2011, Craig and Ruhl 2014, Green et al. 2015, Fischman and Ruhl 2016, Ruhl 2016) aiming to reduce uncertainties over time (Schultz 2008, Benson and Garmestani

2011, Benson et al. 2013, Craig and Ruhl 2014, Garmestani 2014, Green et al. 2015, Fischman and Ruhl 2016, Fuentes et al. 2016) through monitoring and evaluation of management actions (Angelo 2006, Thrower 2006, Benson and Garmestani 2011, Benson and Stone 2013, Craig and Ruhl 2014, Garmestani 2014, Butler et al. 2015, Green et al. 2015, Chaffin et al. 2016, Fischman and Ruhl 2016, Wiafe 2016). The approach is intended to facilitate learning from management outcomes and, consequently, about the social-ecological systems being managed (Garmestani et al. 2008, Spies et al. 2010, Benson et al. 2013, Cosens 2013, Pratt Miles 2013, Chaffin et al. 2016, Fischman and Ruhl 2016, Fuentes et al. 2016, Wiafe 2016). Such new knowledge allows for the adjustment of previous established objectives and adopted actions (Dwyer 2011, Pratt Miles 2013, Craig and Ruhl 2014, Garmestani 2014, Green et al. 2015, Chaffin et al. 2016, Fischman and Ruhl 2016, Wiafe 2016), reaching the point where the iterative process restarts, following a cycle of continuous management improvement (Raadgever et al. 2008, Craig and Ruhl 2014, McDonald and Styles 2014, Fuentes et al. 2016).

The adaptive management process begins with a set-up phase (Craig and Ruhl 2014, Tan et al. 2015, Ruhl 2016), and the first step involves the definition of clear objectives and goals (Raadgever et al. 2008, McDonald and Styles 2014, Chaffin et al. 2016). These are defined based on available data, which are gathered to assess the current condition and the characteristics of the social-ecological system (Thrower 2006, Dwyer 2011, Holley and Sinclair 2011, Craig and Ruhl 2014, McDonald and Styles 2014). Additionally, detailed monitoring protocols must be produced, describing how the effectiveness of actions and the progress toward defined objectives and goals will be assessed (Schultz and Nie 2012, Borgström 2015, Johnson et al. 2016). Monitoring is considered essential and at the core of adaptive management (Jones 2007, Green and Garmestani 2012, Bjorkland 2013, Butler et al. 2015, Novellie et al. 2016).

The adaptive management process then moves on to its “iterative” phase, during which the defined actions are implemented, and the monitoring efforts gather new data to be evaluated (Nie and Schultz 2012, Craig and Ruhl 2014, Ruhl 2016). Learning from monitoring outcomes allows for improvement of scientific understanding of the social-ecological system (Thrower 2006). It also provides feedback about the adequacy of management objectives and implemented actions, which can be revisited and adjusted in light of new information (Jones 2007, Cosens 2013, Green et al. 2013, Garmestani 2014, Tan et al. 2015, Fuentes et al. 2016).

Adaptive management may be adopted in different forms (Biber and Eagle 2016). Although the traditional distinction between active and passive adaptive management was made by several reviewed publications (Thrower 2006, Garmestani et al. 2008, Benson and Garmestani 2011, Dwyer 2011, Holley and Sinclair 2011, Schultz and Nie 2012, Biber 2013, Craig and Ruhl 2014, Humby 2014, McDonald and Styles 2014, Fischman and Ruhl 2016), another form, which has been often mentioned by the legal scholarship, is called adaptive management lite. The concept was first mentioned by Ruhl and Fischman (2010) on a nonpeer-reviewed review of adaptive management litigation in the USA, and their definition, “a watered-down version of the theory that resembles ad hoc contingency planning more than it does planned

Table 2. Selected definitions of adaptive management extracted from the literature sample.

Definition	Reference
“Adaptive management, a product of the nonequilibrium paradigm, is a theory of ecological oversight and administration that recognizes the utility and necessity of experimentation and flexibility in identifying how complex ecosystems respond to disturbances. Through its continuing evaluation of the repercussions of a preceding action, adaptive management permits action and reaction in the absence of complete information. This affords the decision maker the opportunity to adapt and change tactics to maximize the environmental benefits of a course of action.”	Thrower (2006:873)
“The adaptive management model envisages an initial regulatory approval based on initially available information (perhaps guess-work, estimation or ‘regulatory science’) followed by a period of monitoring and reporting with reassessment of the appropriateness of the initial regulatory action and adjustment or amendment as required in light of new information, and presumably the resolution of previously identified uncertainties.”	Jones (2007:361)
“Although the definitions of adaptive management differ, the term generally includes four elements: (1) the articulation of clear goals and measurable indicators of progress toward achieving those goals; (2) an iterative approach to making decisions and the opportunity to adjust strategies; (3) the continual monitoring of outcomes and impacts; and (4) the explicit acknowledgement and characterization of risks and uncertainties.”	Huang et al. (2011:309)
“Adaptive management at its core is applied understanding about ecosystems drawn from resilience theory. This entails an iterative process of decision making that integrates uncertainty and the inevitability of “surprise” (i.e., non-linear change) into the management process via a learning infrastructure (Benson and Garmestani 2011). Monitoring is an essential aspect of adaptive management, as information from the system (e.g., monitoring data) feeds back into the management process in an iterative manner that allows managers to adapt to changing circumstances associated with managing ecosystems. Thus, management actions are hypotheses to be put “at risk” in an adaptive management framework, and information that allows for learning is generated to improve management decisions (Benson and Garmestani 2011).”	Green and Garmestani (2012:165)
“The term ‘adaptive management’ has been used to describe a process of learning through monitoring ecosystem response to a particular action, followed by incremental change in the action based on what is learned (Lee 1999, Folke et al. 2005, Huitema et al. 2009) and generally applies to management action by a single entity.”	Cosens (2013)
“Adaptive management is an environmental management strategy that is an iterative process of decision making and attempts to reduce the inherent uncertainty in ecological systems via system monitoring (Holling 1978). Adaptive management is proactive, rather than reactive, which makes it a very attractive option for sound environmental management (Garmestani et al. 2008). Adaptive management uses models based upon current information to develop management interventions. The system is then monitored at a rate appropriate to the system of interest, and the results evaluated. From this information, models are improved and management of the system is adapted to the new information in an iterative process.”	Garmestani (2014:735)
“Adaptive management means a decisionmaking process based on the structured and iterative implementation of management measures, with comprehensive monitoring of relevant system indicators, in the attempt to achieve specific management goals or objectives, reduce uncertainty, or increase knowledge about the system that an agency is charged with managing.”	Craig and Ruhl (2014:63)
“Adaptive management is designed to address uncertainty, and is a structured, iterative approach to management that involves hypothesis testing through management action(s), monitoring, and feedback (ie adjusting management parameters).”	Green et al. (2015:334)
“In ideal conception, adaptive management uses an experimental approach in which actions are taken on the landscape followed by monitoring to determine whether the strategy achieved desired results. Through such experimental means, uncertainties can be redressed overtime, while allowing management to proceed based on the best available information.”	Butler et al. (2015:565)
“Adaptive management is supposed to be an iterative process in which decision outcomes are continually monitored and evaluated to determine whether they are achieving objectives. The feedback loops rely on goal establishment, model building, performance standard setting, outcome monitoring, and recalibration. Over time, feedback and adjustments provide flexibility in the face of uncertainty while simultaneously reducing uncertainty through systematic learning (Nie and Schultz 2012).”	Fischman and Ruhl (2016:269)
“Adaptive management involves decision making following a structured, multistep protocol designed to facilitate decision making in dynamic management environments.”	Ruhl (2016:418)
“AM [adaptive management] is the structured implementation of management actions as experiments, followed by monitoring, evaluation and adjustment of management actions as needed to manage ecosystems (Allen et al. 2011, Allen and Garmestani 2015).”	Chaffin et al. (2016:433)
“Adaptive management is a framework for resource conservation that promotes iterative learning-based decision making.”	Fuentes et al. (2016:209)
“Adaptive management is a relatively new concept that incorporates research into conservation action. Specifically, the concept integrates design, management and monitoring to systematically test assumptions in order to adapt and learn. Adaptive management can further be viewed as the process of hypothesizing how ecosystems management should have worked with people, monitoring results, comparing them with expectations and modifying management decisions to better achieve conservation objectives through improved understanding of ecological processes (Lancia et al. 1996; Salafsky et al. 2001).”	Wiafe (2016:2)

‘learning while doing’ (Ruhl and Fischman 2010:426), was explicitly discussed by multiple publications of the literature sample (Ruhl 2011, Green and Garmestani 2012, Schultz and Nie 2012, Benson and Stone 2013, Craig and Ruhl 2014, McDonald and Styles 2014, Meretsky and Fischman 2014, Fischman and

Ruhl 2016, Novellie et al. 2016). This approach is considered “a compromised version of adaptive management” (Green and Garmestani 2012:171), in which management objectives are loosely defined, monitoring protocols are vague, and management actions triggered by monitoring thresholds are not

clearly detailed (Nie and Schultz 2012, Craig and Ruhl 2014, Fischman and Ruhl 2016). This lack of specificities allows natural resource management agencies and other public authorities to skip essential parts of the structured and iterative learning process of adaptive management, and increase their discretion and flexibility within decision making embedded in political controversies, financial restrictions, or scientific uncertainties (Nie and Schultz 2012, Schultz and Nie 2012, Bjorkland 2013, Fischman and Ruhl 2016, Novellie et al. 2016). The rhetoric of adaptive management can be used as a smokescreen to postpone difficult decisions by leaving descriptions of responses to management actions too generic or unspecified (Green and Garmestani 2012, Craig and Ruhl 2014, Meretsky and Fischman 2014, Novellie et al. 2016). For these reasons, adaptive management lite is often seen as open-ended contingency planning, adaptive mitigation, or simply “on-the-fly” management (Schultz and Nie 2012, McDonald and Styles 2014, Meretsky and Fischman 2014, Fischman and Ruhl 2016).

Legal barriers to adaptive management

Adaptive management can face legal barriers (Benson and Garmestani 2011, Benson and Stone 2013, Craig and Ruhl 2014). Laws themselves can create difficulties for critical components of adaptive management (Koontz and Bodine 2008), and specific pieces of legislation are often mentioned as barriers to this approach. An example is the U.S. Endangered Species Act (ESA), which has been criticized for focusing on the protection of individual species, rather than the management of the overall social-ecological system (Koontz and Bodine 2008, Benson 2012), and for leaving little room for experimentation (Schultz 2008, Cosens and Williams 2012). Narrow and prescriptive rules are considered more problematic (Jantarasami et al. 2010, Green et al. 2015, Cheng et al. 2016). On the other hand, process-oriented laws are regarded to offer more opportunities for adaptation (Jantarasami et al. 2010, van Rijswijk and Salet 2012, Garmestani and Benson 2013). Nevertheless, details on how the adaptive management process should occur are practically nonexistent in environmental statutes and regulations (Angelo 2006, Zellmer and Gunderson 2008, McDonald and Styles 2014).

Several aspects of law were highlighted in the literature reviewed as limiting adaptive management approaches. For example, jurisdictional boundaries, regulatory fragmentation, and legal division of landscapes among multiple owners may not match ecosystems boundaries and scales, and this context can restrain adaptation (Thrower 2006, Garmestani et al. 2008, Koontz and Bodine 2008, Craig 2010*b*, Jantarasami et al. 2010, Biber 2011, Cosens and Williams 2012, Cosens 2013, Preston 2013, Arnold 2014, 2015, Chaffin et al. 2014, 2016, Humby 2014, Parlee and Wiber 2014, Green et al. 2015, Curran and Masche 2016). Moreover, although stakeholder involvement and collaborative efforts are essential components for building transparency and legitimacy in adaptive management (Craig and Ruhl 2014), extensive legal requirements for public participation can burden the iterative adaptive management process by creating inefficiencies in decision making (Zellmer and Gunderson 2008, Ruhl 2012, Biber 2013, Craig and Ruhl 2014, Fischman and Ruhl 2016, Biber and Eagle 2016).

Judicial review can also make adaptive management implementation more difficult (Koontz and Bodine 2008, Schultz

2008, Craig 2010*b*, Biber 2011, Green and Garmestani 2012, Nie and Schultz 2012, Ruhl 2012, Schultz and Nie 2012, Craig and Ruhl 2014, Borgström 2015, Biber and Eagle 2016, Fischman and Ruhl 2016). Court decisions can provide check and balance systems, ensuring compliance with the laws produced by the legislative branch, and controlling the discretion of public authorities in charge of executing and enforcing legislation (Cosens 2013, Craig and Ruhl 2014). They also help decision making to be more reasonable and oriented to the public interest, and have the capability of increasing transparency and public participation (Craig and Ruhl 2014). However, legal systems that establish too liberal requirements for standing allow the legal challenge of a wide variety of management decisions, and can result in harmful overlitigation for adaptive management (Dwyer 2011, Craig and Ruhl 2014, McDonald and Styles 2014).

Lawsuits can be costly and time consuming, diverting the attention from improving planning, monitoring, and collaborative efforts (Koontz and Bodine 2008). Excessive opportunities for judicial review can disrupt the iterative process of adaptive management by preventing the adjustment of management actions promptly and on the basis of new knowledge generated (Craig and Ruhl 2014). Natural resource management agencies and other public authorities may be liable for the consequences of their previous decisions (Godden and Kung 2011), and this encourages a management approach more concerned with avoiding legal disputes rather than engaging in experimentation and monitoring (Craig 2010*b*, Bjorkland 2013). Within this context, practitioners end up being inclined to engage in adaptive management lite, rather than truly adaptive management (Craig and Ruhl 2014).

Legal mandates are another frequently reported barrier because they can be inflexible and outdated (Koontz and Bodine 2008, Godden and Kung 2011), and require specific management outcomes, e.g., narrow goals related to the recovery of specific species rather than an ecosystem approach, that discourage adaptive management practices (Benson and Stone 2013). Furthermore, the adoption of an adaptive management approach is rarely an explicit substantive requirement in legal frameworks (Schultz 2008, Benson and Garmestani 2011), and law generally does not establish clear provisions to promote learning and reduce uncertainties through the design of management actions as experiments (Craig and Ruhl 2014).

Another component of adaptive management constantly ignored by law is monitoring; many relevant statutes, such as the U.S. National Environment Policy Act (NEPA), do not mandate it (Thrower 2006, Benson and Garmestani 2011, Benson and Stone 2013, Bjorkland 2013). Although the legislation of many countries has already given attention to monitoring, for example, allowing its inclusion as a postapproval condition of licences and authorizations (Jones 2007), or even requiring responses based on monitoring outcomes (Borgström 2015), those provisions are not frequent (Benson and Garmestani 2011, Benson and Stone 2013). Legal requirements for monitoring would not necessarily lead to useful results for management or guarantee adaptive responses (Chapman 2012, McDonald and Styles 2014), but the absence of enforceable mandates can eventually increase political and budgetary constraints to monitoring (Benson and Stone 2013).

Table 3. Law values hindering the design and implementation of adaptive management.

Law value	Key Reference	Examples	
Stationarity	Craig (2010b)	Godden and Kung (2011)	Stationarity was identified as a feature of water management law in two Australian States, Queensland and Victoria, when dealing with flood events. Both legal systems adopt the 1:100-year flood risk datum as a central standard for management, assuming that climate conditions are relatively stable, and that minor variations are predictable.
		Benson (2012)	Stationarity was described as a concept embedded in the U.S. Endangered Species Act (ESA), which focuses on restoration and recovery rather than resilience and adaptive capacity. The statute takes as a premise that “extinction is not an option,” assuming therefore that social-ecological systems are stable.
		Novellie et al. (2016)	Stationarity was noted in legislation governing the South African National Parks. They argued that the National Environmental Management: Protected Areas Act (NEM: PAA) establishes static goals because it requires a high level of operational detail in management plans and, at the same time, subjects that any changes to plans shall be approved by the highest political level authority.
Certainty	Schultz and Nie (2012)	Nie and Schultz (2012)	Certainty was pointed as an aspect demanded by nonfederal property owners in the USA about what actions are allowed by an incidental take permit issued under the ESA.
		Preston (2013)	Certainty was seen as a feature of the process of imposing conditions related to land-use consents. He cited mining leases as an example in Australia because they guarantee access to a specific mining resource for specified periods to provide businesses with certainty, and this may not take into consideration the ecological sustainability of the whole ecosystem.
		McDonald and Styles (2014)	Certainty was blamed for encouraging a front-end decision-making model in conventional environmental impact assessment in Australia. They argue that decisions about a development and what conditions should be imposed on it are made at the beginning of a project, leaving few opportunities to revisit the approval at a later stage.
Finality	Craig and Ruhl (2014)	Cosens and Williams (2012)	Finality was stated as one aspect addressed by order-based legitimacy, one of the sources of legitimacy relevant for adaptive management implementation. They affirmed that order-based legitimacy also derives from the judicial review of administrative actions, which provides finality through final decisions (<i>res judicata</i>), and consideration of earlier court decisions (<i>stare decisis</i>). Relitigation is discouraged and, consequently, the review of past management decisions is deterred.
		Craig and Ruhl (2014)	Finality was acknowledged as a value of contemporary administrative law in the USA. They observed that there are many requirements for front-end justification of management decisions, undermining the capacity to engage in experimentation and adaptation. Finality can be identified in many agency adjudications in the USA, such as permitting, and even in rule making.
		Borgström (2015)	Finality was considered a rooted value of administrative procedures in the context of a discussion about the capacity of biodiversity conservation law in Finland to support climate change adaptation. She exemplified with old water permits for hydropower plants, which cannot be revised to include new conditions for mitigating impacts on fisheries, as stated in a 2006 Finnish Supreme Court decision.

The results of this systematic review demonstrate that legal barriers to adaptive management are usually related to one or more of the following legal values: (i) stationarity; (ii) certainty; and (iii) finality. These are deeply intertwined, and empirical research has identified how they emerge in the context of adaptive management. Table 3 presents some examples of the observation of these legal values across different legal systems.

Originally coined by Milly et al. (2008), stationarity has been described as a failure of some legal frameworks to recognize the dynamics of social-ecological systems, which are constantly facing change rather than remaining stable (Thrower 2006, Craig 2010b, Spies et al. 2010, Benson and Garmestani 2011, Godden and Kung 2011, Huang et al. 2011, Ruhl 2011, Benson 2012, Garmestani and Benson 2013, Arnold 2014, 2015, Cosens et al. 2014, He 2014, Humby 2014, McCormack and McDonald 2014, McDonald and Styles 2014, Curran and Masche 2016, Novellie et al. 2016). Since the 1970s, many environmental laws have been influenced and shaped by the “equilibrium paradigm,” a belief

that, without human disturbance, ecosystems can eventually reach or maintain a natural stability (Thrower 2006, Benson and Garmestani 2011, Benson 2012, Craig and Ruhl 2014). Under this view, changes in ecological processes are considered predictable (Thrower 2006, Craig 2010b, Benson and Stone 2013, Novellie et al. 2016), occurring within a “fixed envelope of variability” (McDonald and Styles 2014:41), or a “suite of unchanging variables” (Benson 2012).

Legal frameworks tend to incorporate preservation and restoration approaches (Craig 2010b, Schramm and Fishman 2010, Spies et al. 2010, Huang et al. 2011, Benson 2012, McDonald and Styles 2014). Both approaches assume that ecosystems have a desirable and achievable “state of being,” which remains historically constant (Craig 2010b). This perspective is incompatible with the adaptive capacity needed to address relevant environmental management issues, such as climate change (Craig 2010b, Spies et al. 2010, Huang et al. 2011, Ruhl 2011, McCormack and McDonald 2014). By not acknowledging

the complexity and unpredictability of social-ecological systems, legal frameworks based on stationarity can be too rigid for adaptive management (Craig 2010b, Benson and Garmestani 2011, Godden and Kung 2011, McCormack and McDonald 2014, Novellie et al. 2016).

One of the reasons that law has easily embraced stationarity derives from the aim of legal systems to provide certainty to social relations (Thrower 2006, Koontz and Bodine 2008, Ruhl and Fischman 2010, Green and Garmestani 2012, Nie and Schultz 2012, Schreiber 2012, Schultz and Nie 2012, van Rijswijk and Salet 2012, Benson and Stone 2013, Bjorkland 2013, Demange 2013, Green et al. 2013, Preston 2013, Arnold 2014, 2015, Garmestani 2014, Humby 2014, McDonald and Styles 2014, West and Schultz 2015, Camacho and Glicksman 2016, Curran and Masche 2016). Law is essential to ensure the organization of the various societal interactions (Schreiber 2012). Ruhl (2012) highlighted that law's overall purpose "is to produce more order than chaos," thus it is concerned with the creation and maintenance of the social stability for the operation of human activities. For example, the idea that the same rules will be equally applied to all favors economic pursuits (Cosens and Williams 2012). The usual goal of legal frameworks is to always determine an accurate connection between causes and effects, or at least provide a sensation of certainty, and this approach may conflict with the adaptive management imperative of acknowledging the uncertainties of the social-ecological systems (Koontz and Bodine 2008, Green et al. 2015). Moreover, the need for legal certainty may reduce the flexibility required to allow for adaptation in light of new information (Green et al. 2013, Garmestani 2014).

The search for certainty is commonly materialized in law by means of a front-end approach to management, in which decisions are made at the very beginning of the processes, relying on the ability to predict all the environmental and social consequences that an action can generate (Thrower 2006, Jones 2007, Craig 2010b, Benson and Garmestani 2011, Green and Garmestani 2012, Nie and Schultz 2012, Ruhl 2012, Schultz and Nie 2012, Benson and Stone 2013, Craig and Ruhl 2014, McDonald and Styles 2014, Green et al. 2015, Fischman and Ruhl 2016). This front-end style of decision making has become part of the legal foundations of natural resource management, and has been well received not only by the courts and those responsible for the design and implementation of policies, laws, and regulations (Ruhl 2012), but also by environmental and stakeholder groups (Thrower 2006).

Front-end management fosters another law value that is considered by Craig and Ruhl (2014) as the most in tension with adaptive management: finality. Finality implies that legal systems generally create an environment in which management decisions should not only be made upfront, but also seek a final determination (Thrower 2006, Benson and Garmestani 2011, Cosens and Williams 2012, Benson and Stone 2013, Cosens 2013, Garmestani and Benson 2013, Craig and Ruhl 2014, Cosens et al. 2014, Borgström 2015, Green et al. 2015, Fischman and Ruhl 2016). Craig and Ruhl (2014:34) define finality as "the insistence on final resolutions by administrative agencies that will be definitively upheld or rejected by the courts" within the context of the U.S. Administrative Law. They argued that law stimulates agencies to focus on the upfront justification for their actions that can be subjected to judicial review, and to avoid the reopening of

decisions already made, once they are judicially confirmed (Craig and Ruhl 2014).

Finality is essentially a result of a conflict between science and law because the former has in its nature the constant desire to revisit answered questions and constructions of truth, and the latter is more concerned with a scenario of economic stability, which involves decisions capable of putting an end to conflicts (Cosens and Williams 2012, Cosens 2013). As a consequence, this law value may hamper the iterative and structured process adopted by adaptive management, because it is framed for linear decision-making approaches (Benson and Garmestani 2011). Finality discourages experimentation (Craig and Ruhl 2014), and prevents the level of flexibility required to adapt in the face of change or new information (Thrower 2006, Cosens 2013, Craig and Ruhl 2014, Green et al. 2015).

Overcoming the legal barriers to adaptive management

Despite the legal barriers and law values described above, adaptive management has been used, or at least attempted, within many existing legal frameworks not intentionally designed for its adoption (Jones 2007, Schultz 2008). The approach is not necessarily incompatible with current legislation (Schultz 2008, Stuart-Hill and Schulze 2010, Borgström 2015) because many legal mandates have a level of vagueness that allows adaptive management to be an option (Spies et al. 2010, Benson and Garmestani 2011). However, with a "regulatory home," adaptive management implementation can certainly be less problematic (Benson and Garmestani 2011).

In the USA, Fischman and Ruhl (2016) highlighted that agencies and courts would benefit from legislative standards for adaptive management, which are rare in U.S. federal statutes. Similar conclusions were reached by Kwasniak (2010) in Canada, where the Canadian Environmental Assessment Act (CEAA) does not provide a detailed procedure on how to implement adaptive management, and only expressly authorizes the approach in relation to follow-up programs under environmental assessment processes, leaving out other relevant phases, such as project planning and design. Kwasniak (2010) argued that the lack of specifics in the CEAA may have contributed to a Canadian court's misinterpretation of adaptive management principles in the *Penimba Institute for Appropriate Development et al. v Attorney General of Canada and Imperial Oil Resources Ventures Limited* (the "Kearl Mines case"). This case was related to a proposed oil sands mine and, according to Kwasniak (2010), the court's interpretation of CEAA (i) authorized the use of adaptive management to deal with uncertain adverse environmental effects that may prove to be significant and, therefore, (ii) allowed for the adoption of mitigation measures involving uncertainty about their efficacy for dealing with significant adverse environmental effects, and (iii) considered adaptive management as an offset to the precautionary principle, based on statements made on the decision. She then suggested amendments in this statute to clarify the role of the approach in the Canadian environmental assessment process (Kwasniak 2010).

These scholars are not alone as many have been arguing that some kind of reform may be required to improve law so that it is better prepared to deal with the uncertainty of social-ecological systems and manage for resilience (Craig 2010b, Spies et al. 2010, Benson and Garmestani 2011, Benson 2012, Green and Garmestani 2012,

Ruhl 2012, Benson and Stone 2013, Cosens 2013, Garmestani and Benson 2013, Preston 2013, Chaffin et al. 2014, Craig and Ruhl 2014, He 2014, Garmestani 2014, McDonald and Styles 2014, Green et al. 2015, Borgström 2015, Novellie et al. 2016). Accommodating adaptive management into legal systems can be difficult (Ruhl 2012). By moving toward adaptive management, law will inevitably enter into an uncomfortable environment embedded with nonlinear changes and unpredictability (Craig 2010b). The challenge of legal reform must, therefore, be faced with optimism, just like many adaptive management practitioners interviewed by Benson and Stone (2013) have demonstrated. From those who agreed with the existence of legal constraints to adaptive management, 53% were positive about eliminating them through changes in law (Benson and Stone 2013).

Within the literature reviewed, increasing the flexibility of legal frameworks was seen as an imperative for responding to the legal barriers of adaptive management (Thrower 2006, Craig 2010b, Benson and Garmestani 2011, Herrfahrtd-Pähle and Pahl-Wostl 2012, Benson and Stone 2013, Garmestani and Benson 2013, Green et al. 2013, Preston 2013, Craig and Ruhl 2014, Garmestani 2014, He 2014, McDonald and Styles 2014, Borgström 2015, Fischman and Ruhl 2016, Frost et al. 2016, Fuentes et al. 2016, Garner 2016, Jaeckel 2016, Novellie et al. 2016). Innovative ways will have to be pursued to balance the flexibility needed for adaptive management and the stability demanded by law (Thrower 2006, Angelo 2008, van Rijswijk and Salet 2012, Garmestani 2014, Pidot 2015, Cosens and Chaffin 2016, Fischman and Ruhl 2016). Flexible legal frameworks designed to accommodate adaptive management will have to limit the discretion of actors who may be inclined to remain in inertia or deviate from regulatory and management objectives (Craig 2010b, Bjorkland 2013). The task to improve legal flexibility for adaptive management, therefore, must be conducted carefully and responsibly because it can leave room for political and economical interferences that may ultimately compromise the original intention of those who put it into consideration in the first place (Biber and Eagle 2016).

Suggestions related to legal reform have included binding commitments to implement adaptive management under certain circumstances, in order to increase enforceability and legitimacy of the approach (Benson and Garmestani 2011, Nie and Schultz 2012, Bjorkland 2013), and clear provisions related to the implementation phase, by defining parameters to be followed during the various phases of the adaptive management cycle. Establishing such requirements would contribute to reducing litigation (Thrower 2006) because courts would have a legal basis to evaluate and support adaptive management initiatives (Craig and Ruhl 2014).

Possible ways to make broad processes established by legal frameworks more flexible and adaptable can include “in-built review mechanisms or sunset clauses for regulatory objectives or entire statutes, enhanced public participation processes, better mechanisms for dealing with private property rights, and multi-layered and multi-jurisdiction governance arrangements” (McDonald and Styles 2014:40). Furthermore, management objectives can be established with more attention to resilience and adaptive capacity, allowing for flexibility rather than embracing goals based on the stationarity approach (McDonald and Styles

2014). For example, instead of pursuing specific and static volumes or flow regimes, water management law in Australia has shifted its focus to protecting “key ecosystem functions” and “key environmental outcomes” (McDonald and Styles 2014). However, allowing for this flexibility also involves limiting the discretion of those adopting an adaptive management approach, by ensuring that management objectives are not too broad and open-ended that would not enable the measurement of performance (Craig and Ruhl 2014, McDonald and Styles 2014). Legal frameworks must then have and require the definition of goals that are not only flexible, but also clear, specific, and measurable, in order to avoid adaptive management lite practices (Craig and Ruhl 2014, McDonald and Styles 2014).

Legal reform can create or refine monitoring and evaluation requirements (Thrower 2006, Craig 2010b, Schramm and Fishman 2010, Benson and Garmestani 2011, Holley and Sinclair 2011, Benson and Stone 2013, Preston 2013, Craig and Ruhl 2014, McDonald and Styles 2014, Borgström 2015, McDonald et al. 2016). Legal mechanisms can also be designed to increase funding for monitoring (Craig 2010b, Benson and Stone 2013), while an enforceable monitoring mandate would have the potential of stimulating the allocation of financial resources for adaptive management implementation (Benson and Garmestani 2011). Particular attention must be given to establishing adequate time frames in legislation for evaluating, sharing, and reporting the information gathered through monitoring (Schramm and Fishman 2010, Cosens 2013, Craig and Ruhl 2014, McDonald and Styles 2014, Borgström 2015).

Legal tools can be applied to improve the capacity to respond to changes based on the knowledge gained (McDonald and Styles 2014, Borgström 2015). A legal framework designed for adaptive management must provide feedback-loop processes, with opportunities for evaluation and adjustments of management actions in light of new monitoring data. In this sense, laws and regulations can offer staged and tiered processes (McDonald and Styles 2014, Meretsky and Fischman 2014), and design conditional approvals that allow for future modifications or management interventions once predefined triggers/thresholds are reached or verified (Nie and Schultz 2012, Schultz and Nie 2012, McDonald and Styles 2014). Proportionate resource allocation models and decisions rules, such as fishing quotas for harvest control and water entitlements based on resource availability, are another way to provide a regulatory incentive for adaptive management (McDonald and Styles 2014).

Most of the suggestions described above have already been adopted in different jurisdictions, yet the ability to implement adaptive management has not always increased. Flexibility can exist on paper without positive repercussions on practice (Benson and Stone 2013). The fact is that the adaptive management literature still does not provide many specifics concerning the legal framework (Raadgever et al. 2008). As our results show, this does not mean that the level of understanding of the legal constraints related to adaptive management implementation has not grown over the last years, nor that solutions for these shortcomings have not been proposed. Nevertheless, new studies with a focus on thinking about how we can use these recommendations in the real world to improve the law would add valuable contributions. More empirical research is needed on how to assess the capacity of

specific legal frameworks to enable adaptive management, and to make tailor-made and feasible legal reform proposals for particular contexts.

In the USA, the first effort in this direction was made by Craig and Ruhl (2014). They drafted a detailed legislation model, which creates an “adaptive management track” for specific situations as an alternative to the conventional decision-making process of U. S. Administrative Law. Their “Model Adaptive Management Procedure Act” aims essentially to overcome the front-end style of decision making, by preserving finality, public participation, judicial review, and increasing the flexibility of agencies for adaptive management implementation. They proposed a different approach to finality, which would be understood not in view of the administrative process itself, “but rather by the goals that the adaptive management project is trying to achieve” (Craig and Ruhl 2014:42). Instead of a heavy focus on upfront public participation, they suggested multiple (but punctuated) moments for the involvement of the relevant stakeholders as the proposed project or plan evolves over time, combined with reporting requirements at regular intervals. Not every adjustment would trigger the requirements of public notice and comment, because this would undermine the capacity to timely implement the lessons learned. The same logic would be applied to the availability of judicial review.

In a nonpeer-reviewed publication, Biber (2014) engaged in dialogue with Craig and Ruhl (2014), suggesting amendments to their statutory model with the main purpose of improving the balance between the flexibility needed for adaptive management and the level of discretion agencies would have by choosing the “adaptive management track.” For instance, he proposed a review of adaptive management plans at least every six years, in which the agency would have to demonstrate why adaptive management is still required, and how the plan will continue to be effective. This suggestion aims to avoid agencies continuing on the “adaptive management track” *ad eternum* just to skip judicial review and public participation requirements. However, Biber (2014) acknowledged that Craig and Ruhl’s pioneer contribution has many merits, and we believe that their dialogue has the potential to offer relevant insights to other legal systems beyond the context of the U.S. Administrative Law.

The success of any attempt of legal reform to accommodate adaptive management within a specific legal framework will be strongly influenced by the governance structure in place. The term “governance” encompasses the laws, regulations, and other legal instruments, and therefore the legal framework to be reformed, but also comprises informal institutions, such as practices, customs, social norms, power relationships, and the organizations involved in governing the management of a social-ecological system (Cosens and Williams 2012, Cosens 2013, Chaffin et al. 2014, Cosens et al. 2014). Proposals to change the law will necessarily involve a process of resolving trade-offs within a complex social environment of different stakeholders and interests.

For this reason, adaptive management as theorized is more suitable for projects that have a single organization responsible for clear and distinct goals, being only part of the solution for the management of complex systems involving multiple goals that may conflict, multiple scales, and multiple authorities with

overlapping jurisdiction (Cosens 2013, Green et al. 2015). A new body of literature has recently started to identify shortcomings in adaptive management related to governance issues and legal barriers to more adaptive forms of governance (Cosens et al. 2014). In this sense, adaptive governance has been suggested for coupling law and social-ecological resilience (Green et al. 2015). That is, for law to better facilitate adaptive management, there must be a governance structure in place that acknowledges the uncertainty and complexity of social-ecological systems (Chaffin et al. 2014), and recognizes the linkages between the social and ecological subsystems (Green et al. 2013).

In a comprehensive review, Chaffin et al. (2014) defined adaptive governance as “a range of interactions between actors, networks, organizations, and institutions emerging in pursuit of a desired state for social-ecological systems.” The approach has been perceived “as the institutional and societal structures that facilitate adaptive management” (Cosens et al. 2014:2345), and the type of governance that provides the level of flexibility needed for adaptive management (Cosens and Williams 2012). Adaptive governance has broader boundaries, including not only its critical adaptive management component (Chaffin et al. 2014) but also integration, collaboration, and cooperation across the formal and informal institutions, levels of government, and relevant stakeholders (Cosens 2013, Chaffin et al. 2014, Green et al. 2015, West and Schultz 2015). It also involves meaningful public participation in proper moments of decision-making processes (Green et al. 2015, van Buuren et al. 2015, Novellie et al. 2016).

The emergence of adaptive governance is a result of the shortcomings of centralized, top-down and command-control approaches to governance, which have shown failures in dealing with the complexity of social-ecological systems (Chaffin et al. 2014). Adaptive governance advocates for increasing cross-scales interactions and social networks among stakeholders within the governance system, and encourages a focus on matching the scale of governance to the scale of the ecosystem, which was defined by Huitema et al. (2009) as managing at the “bioregional scale” (Cosens and Williams 2012, Cosens 2013, Chaffin et al. 2014, Cosens et al. 2014). In order to implement this approach, adaptive governance calls for polycentricity, i.e., multiple governance units of power at multiple scales, with partially redundant and overlapping authority to act (Cosens and Williams 2012, Cosens 2013, Garmestani and Benson 2013, Chaffin et al. 2014, Cosens et al. 2014, van Buuren et al. 2015, West and Schultz 2015, Cosens and Chaffin 2016, Novellie et al. 2016). Polycentric governance enables decision making to be closer to the social or environmental issue demanding an action, through increasing the capacity for management at the local scale, while retaining a network with the higher scales of the governance system (Cosens and Williams 2012). Although law plays a critical role in supporting those components, it is often an aspect ignored by the adaptive governance scholarship (Green et al. 2015).

CONCLUSION

More than 20 years ago, Iles (1996) warned that more studies on ways to overcome legal barriers to adaptive management were necessary. Our systematic review contributes to ongoing efforts toward the design of legal frameworks that are better fitted to deal with the complexity and uncertainties of social-ecological systems. Research in the USA and other countries with legal

systems based on common law has evolved significantly over recent years, and we also encourage other scholars to accept and join this challenge, particularly those from legal jurisdictions where the discussion on adaptive management and law is not so advanced.

A convergent discourse is that accommodating adaptive management into legal frameworks will likely require some kind of reform of existing laws, regulations, and other legal instruments. Dialogues on specific legislative proposals have begun to emerge in this direction (Biber 2014, Craig and Ruhl 2014, Craig et al. 2017a). Our results show that the peer-reviewed English language literature has evolved to describe several legal barriers to adaptive management, and has also provided suggestions on how to address these obstacles. Adaptive governance has been identified as a way to facilitate adaptive management implementation (Cosens et al. 2014), and the function law plays within this approach has just recently turned into a topic of interest (Green et al. 2015).

The design of legal institutions balancing the flexibility required for adaptive management and the stability demanded by law needs to be more deeply explored to ensure the successful practice of this approach. However, reviews indicate that legal flexibility cannot be a synonym for freedom to act (Biber and Eagle 2016). Investigations on how flexible legal strategies can be designed and implemented will have to consider responsible ways of conferring discretion for those implementing adaptive management approaches.

Although the assessed scholarship has helped to build an overall understanding of the relationship between adaptive management and law, and on how adaptive governance can support this coupling, the specificities of legal systems vary significantly across countries and their different levels of government. Our conclusions cannot be generalized to all jurisdictions. Further research is needed to test these ideas in different legal contexts and social-ecological systems. New studies using other sources, such as non-English publications and a detailed analysis of non-peer-reviewed scholarship will probably offer additional observations to the research questions we pose in this systematic review.

Future contributions could expand this body of research to unexplored legal systems and specific environmental management approaches facing problems with their adaptive management component, such as ICM. Comparative studies have the potential to stimulate learning from past and ongoing experiences of applying different legal frameworks in different jurisdictions. In particular, empirical research built on interviews with stakeholders who are involved with the governance and management of social-ecological systems may provide valuable lessons of how law has been affecting positively or negatively the capacity to implement adaptive management policies and strategies.

Responses to this article can be read online at:
<http://www.ecologyandsociety.org/issues/responses.php/10060>

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Appendix 1. Literature Sample

	Author/year	Journal	Geographical Context	Main Environmental Sector or Concern	Interviews or Surveys
1	Thrower (2006)	Ecology Law Quarterly	USA	Multiple	No
2	Angelo (2006)	Ecology Law Quarterly	USA	Biodiversity	No
3	Jones (2007)	Journal of Environmental Law	USA Australia	Multiple	No
4	Koontz and Bodine (2008)	Conservation Biology	USA	Multiple	Yes
5	Garmestani et al. (2008)	Nebraska Law Review	USA	Multiple	No
6	Schultz (2008)	Environmental Science and Policy	USA	Forestry/Protected Areas	No
7	Raadgever et al. (2008)	Ecology and Society	Multiple	Water	Yes
8	Zellmer and Gunderson (2008)	Nebraska Law Review	USA	Multiple	No
9	Angelo (2008)	Nebraska Law Review	USA	Multiple	No
10	Spies et al. (2010)	Landscape Ecology	USA	Forestry/Protected Areas	No
11	Craig (2010a)	Vermont Law Review	USA	Water	No
12	Craig (2010b)	Harvard Environmental Law Review	USA	Multiple	No
13	Stuart-Hill and Schulze (2010)	Climate and Development	South Africa	Water	No
14	Jantarasami et al. (2010)	Ecology and Society	USA	Forestry/Protected Areas	Yes
15	Kwasniak (2010)	Journal of Environmental Assessment Policy and Management	Canada	Multiple	No
16	Ruhl and Fischman (2010)	Minnesota Law Review	USA	Multiple	No
17	Schramm and Fischman (2010)	Minnesota Law Review	Multiple	Multiple	No
18	Godden and Kung (2011)	Water Resources Management	Australia	Water	No
19	Dwyer (2011)	Macquarie Journal of International and Comparative Environmental Law	Australia	Multiple	No
20	Benson and Garmestani (2011)	Journal of Environmental Management	USA	Multiple	No
21	Holley and Sinclair (2011)	The Australasian Journal of Natural Resources Law and Policy	Australia	Water	Yes
22	Huang et al. (2011)	Climate Law	USA	Multiple	No
23	Biber (2011)	University of Colorado Law Review	USA	Multiple	No
24	Ruhl (2011)	The North Carolina Law Review	USA	Multiple	No

25	van Rijswick and Salet (2012)	Ecology and Society	USA	Multiple	No
26	Ruhl (2012)	Ecology and Society	USA	Multiple	No
27	Schultz and Nie (2012)	The Natural Resources Journal	USA	Multiple	No
28	Nie and Schultz (2012)	Conservation Biology	USA	Multiple	No
29	Herrfahrdt-Pähle and Pahl-Wostl (2012)	Ecology and Society	South Africa Uzbekistan	Water	Yes
30	Green and Garmestani (2012)	Diversity	USA	Biodiversity	No
31	Benson (2012)	Ecology and Society	USA	Biodiversity	No
32	Schreiber (2012)	Marine Policy	Peru	Fisheries	No
33	Chapman (2012)	Science of the Total Environment	USA	Multiple	No
34	Cosens and Williams (2012)	Ecology and Society	USA	Multiple	No
35	Bjorkland (2013)	Environmental Impact Assessment Review	USA	Multiple	No
36	Preston (2013)	Environmental and Planning Law Journal	Australia	Biodiversity	No
37	Benson and Stone (2013)	Ecology and Society	USA	Multiple	Yes
38	Green et al. (2013)	Ecology and Society	Multiple	Water	No
39	Garmestani and Benson (2013)	Ecology and Society	USA	Marine/Coastal	No
40	Cosens (2013)	Ecology and Society	USA	Multiple	No
41	Benson et al. (2013)	Ecology and Society	USA	Water	No
42	Pratt Miles (2013)	Ecology and Society	USA	Multiple	No
43	Biber (2013)	Akron Law Review	USA	Multiple	No
44	Demange (2013)	Pace Environmental Law Review	Multiple	Multiple	No
45	McDonald and Styles (2014)	Journal of Environmental Law	Multiple	Multiple	No
46	Cosens et al. (2014)	Sustainability	USA	Water	No
47	Chaffin et al. (2014)	Ecology and Society	USA	Multiple	No
48	Craig and Ruhl (2014)	Vanderbilt Law Review	USA	Multiple	No
49	Garmestani (2014)	Clean Technologies and Environmental Policy	USA	Multiple	No
50	He (2014)	Asia Pacific Journal of Environmental Law	China	Multiple	No
51	McCormack and McDonald (2014)	Environmental and Planning Law Journal	Australia	Biodiversity	No
52	Meretsky and Fischman (2014)	Conservation Biology	USA	Forestry/Protected Areas	No
53	Parlee and Wiber (2014)	Current Opinion in Environmental Sustainability	Canada	Fisheries	Yes
54	Biber (2014)	Idaho Law Review	USA	Multiple	No
55	Arnold (2014)	The University of Kansas Law Review	USA	Water	No
56	Humby (2014)	The Seattle Journal of Environmental Law	USA	Multiple	No

57	Borgström (2015)	Review of European Community and International Environmental Law	Finland	Biodiversity	No
58	Butler et al. (2015)	Environmental Management	USA	Forestry/Protected Areas	Yes
59	Green et al. (2015)	Frontiers in Ecology and the Environment	USA	Multiple	No
60	Tan et al. (2015)	International Journal of Water Resources Development	Australia	Water	No
61	Van Buuren et al. (2015)	Ecology and Society	Netherlands	Water	Yes
62	West and Schultz (2015)	Ecology and Society	Multiple	Multiple	No
63	Pidot (2015)	Cardozo Law Review	USA	Multiple	No
64	Arnold (2015)	Journal of Environmental and Sustainability Law	USA	Water	No
65	Wiafe (2016)	Springer Plus	Ghana	Biodiversity	No
66	Ruhl (2016)	Journal of Environmental Management	USA	Multiple	No
67	Novellie et al. (2016)	Environmental Science and Policy	South Africa	Forestry/Protected Areas	No
68	Johnson et al. (2016)	Biological Conservation	Laos	Biodiversity	No
69	Jaeckel (2016)	Marine Policy	Australia	Marine/Coastal	No
70	Garner (2016)	Water International	USA	Water	No
71	Fuentes et al. (2016)	Mitigation and Adaptation Strategies for Global Change	Australia	Biodiversity	No
72	Frost et al. (2016)	Aquatic Conservation: Marine and Freshwater Ecosystems	United Kingdom	Biodiversity	No
73	Fischman and Ruhl (2016)	Conservation Biology	USA	Multiple	No
74	Cosens and Chaffin (2016)	Water	USA	Water	No
75	Cheng et al. (2016)	Journal of Forestry	USA	Forestry/Protected Areas	Yes
76	Chaffin et al. (2016)	Journal of Environmental Management	USA	Water	No
77	Curran and Masche (2016)	McGill Journal of Sustainable Development Law	Australia Canada	Water	No
78	Biber and Eagle (2016)	Ecology Law Quarterly	USA	Multiple	No
79	McDonald et al. (2016)	University of New South Wales Law Journal	Australia	Biodiversity	Yes
80	Camacho and Glikzman (2016)	Water International	USA	Water	No