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Into the deep blue sea: Commons theory and international governance of Atlantic Bluefin Tuna

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Abstract: The need to understand how to sustainably govern oceanic fisheries has become increasingly urgent as their contribution to global food security and livelihoods are threatened by declining stocks. Atlantic Bluefin Tuna (ABFT) is a prominent example of the complexities associated with widely distributed oceanic resources, extending in this case to include much of the North-Atlantic and Mediterranean Sea. This distribution has led to limited attention from commons theorists that tend to focus on small-scale social ecological systems. Therefore in order to explore the fit between theories of the commons developed in small-scale systems, we apply the Social-Ecological Systems Meta-Analysis Database (SESMAD) to systematically analyze ABFT governance over a 22 year period. The results, which focus on the effects of resource characteristics, broadly correspond to the expectations of commons theory. Interestingly, however, the addition of resource storage in the form of ABFT ranches appears to be contributing to unsustainable harvests. This stands in contrast to previous findings in the commons literature that storage tends to enhance prospects for sustainable governance. Therefore several alternative hypotheses are developed by comparing and contrasting attributes of ABFT and canal irrigation storage. These hypotheses may be used in future research to evaluate the conditions in which storage enhances prospects for sustainable governance.

Keywords: Atlantic Bluefin Tuna, common-pool resource theory, fisheries, resource storage, SESMAD

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1. Introduction

The governance of oceanic fisheries has long been held as particularly challenging owing to the complexity of regulating the use of mobile, widely distributed stocks across international boundaries and non-territorial waters (Berkes et al. 2006). Most attempts to shift from an open-access regime to a regulated fishery rely upon state-based command-and-control and scientific management techniques that devise harvesting rules in line with conventional notions of maximum sustainable yield. While this approach has often been criticized for failing to resolve fundamental issues related to overharvesting (Ostrom 1990; Dobson and Lynch 2003) and the regeneration of biological populations (Acheson and Wilson 1996; Holling and Meffe 1996), it is not clear that the participatory approaches that characterize the governance of common-pool resources (CPR) at local levels offer a viable alternative. CPR theory is best developed at the level of the individual where it can draw upon formal models of collective action and experimental methods to inform our understanding of the factors that influence choice (Ostrom et al. 1994). As analysis shifts to the system level – in this case, the social-ecological system (SES) – CPR theory provides a more general set of attributes that tend to be associated with long-enduring and sustainable resource governance. However, it remains unclear whether these attributes, developed mostly in the context of small community systems, scale-up to larger systems such as oceanic fisheries. Thus, this study seeks to explore the extent to which theories developed in the study of small-scale systems apply to a widely distributed oceanic resource, Atlantic Bluefin Tuna (ABFT).

ABFT (*Thunnus thynnus)* is a large-bodied fish that inhabit much of the North Atlantic and Mediterranean. Since the late 1960s, it has been governed under the auspices of the International Commission for the Conservation of Atlantic Tunas (ICCAT). ICCAT was created to coordinate decision-making and fishing regulation among member states in pursuit of sustainable yields. ICCAT's management of bluefin tuna has, however, been characterized as an institutional failure because of its inability to implement effective regulations and control extraction rates of its member states (Hurry et al. 2008; Korman 2011). While these studies provide insights into the specific problems that ICCAT faces, few situate their analysis within the broader universe of social-ecological systems (SESs), thereby limiting progress toward a more general theory of sustainability. This study is an attempt to address this shortcoming by drawing upon the SES framework to capture, organize, arrange, and analyze the diverse set of social and ecological factors that affect the performance of ICCAT (Ostrom 2007, 2009). More specifically, we apply an adapted version of the SES framework as described in Cox (2014) to identify the core components and interactions of the SES and code a wide range of potentially influential attributes of these components and interactions. Whereas the other papers in this issue focus more intently on social and institutional attributes of SESs, this paper emphasizes the effects of resource attributes on environmental governance that are often overlooked in the CPR and SES literature (Epstein et al. 2013). As such, it makes two main contributions to the literature: (1) it explores how existing theories concerning the effects of resource attributes in small-scale settings scale up in larger systems and (2) it adds to more general discussions about the effects of resource attributes on sustainable governance of natural resources.

The remainder of the paper is structured in the following way. Section 1 continues by briefly describing the origins of CPR theory, the development of the SES framework, and how the framework can be used to test, refine, and develop theories of sustainability. Section 2 describes the methods employed in this study, while Section 3 outlines important historical developments in the ABFT fishery and the ICCAT governance regime. Section 4 discusses the specifics of the ICCAT case across three snapshots to identify relationships between the state of variables and outcomes in light of CPR theory. Finally, a brief conclusion identifies several hypotheses developed in the analysis of this case and urges additional research on large-scale CPRs.

1.1. Systematic approaches to the study of environmental governance

CPR theory emerged as an alternative to centralized or market-based approaches to environmental governance by refuting predictions of inevitable destruction of commonly owned resources (Gordon 1954; Hardin 1968). Several studies conducted over the last 30 years strongly support the viability of CPR governance regimes (McCay and Acheson 1987; Ostrom 1990; Bromley et al. 1992; Dolšak and Ostrom 2003; Cox et al. 2010), although like its state or market-based counterparts, CPR governance often fails (Acheson 2006; Ostrom et al. 2007). Nevertheless, studies of CPRs have triangulated around a set of empirically derived attributes of successful CPR governance systems, the first synthesis of which included eight mostly institutional attributes that pertain to harvesting, collective-choice, and monitoring and sanctioning processes (Ostrom 1990). Since the publication of that seminal study, the number of “enabling conditions” has grown to more than thirty, having expanded rapidly with the increased salience of environmental issues and the development of the commons literature (Agrawal 2003; van Laerhoven and Ostrom 2007).

The need to organize and study the growing number of relevant attributes in a systematic manner has led to the creation of the SES framework. The SES framework uses a multilevel classificatory system to group the attributes into four main components: resource systems, resource units, actors, and governance systems (Ostrom 2007, 2009). Each of these components is structured as a partially decomposable system with clearly specified relationships among the components. Within this structure, each of the components can be unpacked into a subset of attributes and each of the attributes can be further subdivided into a more specific set of attributes, allowing researchers to capture and examine the structure and performance of a complex SES (see Basurto and Ostrom 2009 for a specific example).

The core unit of analysis of the SES framework is the system, which consists of social, ecological, and institutional components that in turn are defined by attributes at varying levels of specificity (Ostrom and Cox 2010). Influential attributes are separated from other contextual attributes via a variety of quantitative and qualitative methods. Comparative approaches, typically variants of Mill’s (1859) case-based methods, are often used to identify influential attributes or potential causes on the basis of similarities and differences in the attributes of systems and their association with some measure of success. Although this is sufficient for establishing the likely influence of an attribute, the strength of the argument is augmented if there is a plausible or empirically supported mechanism that links the attribute to the observed outcome.

Apart from its ability to systematically describe the structure of an SES and facilitate analysis of its components and attributes, there are several additional benefits that flow from the adoption of the SES framework. First, studies that adopt the framework as an analytical tool and collect data on a common set of potentially relevant attributes allow for a cumulative categorization and integration of knowledge concerning the governance of SESs. Second, it fosters the creation of a common interdisciplinary language among various social and natural scientists. These benefits permit researchers to actively engage in collaborative research across disciplinary boundaries and to share and compare findings across methods and types of SESs.

2. Methods

The ICCAT case, like the other cases presented in this special issue, relies upon methods developed as part of the Social-Ecological System Meta-Analysis Database (SESMAD) project and are described in greater detail by Cox (2014). A mixture of peer-reviewed studies, publicly available data, and the occasional piece of grey literature were used to inform this analysis. Approximately thirty studies were reviewed to code the case into the database. Content analysis of the selected studies was used to (1) identify the important components (e.g. resources, governance systems) of the ICCAT SES, (2) identify the important interactions between these components, and (3) code each of these components and their interactions into the appropriate tables in the database. The selection of core components and coding of their attributes are based upon intersubjective agreement among the authors of a case (Cox 2014). In general, this approach favors validity over reliability.

The SESMAD database, a relational database hosted at Dartmouth College, contains approximately 200 variables relevant to the study of SESs and CPR theory. Information about the components of the SES and their attributes are stored in four main tables in the SESMAD database. The case table contains general information about the SES, which is defined as a system containing at least one (but often more) of the following components: an environmental commons, a governance system, and an actor group. A governance system (GS) is a set of institutional arrangements (rules, governance activities) that are used by one or more actor groups to govern interactions with a resource and each other. An actor group (A) is defined as any grouping of individuals, organizations, or nations that have developed a set of institutional arrangements in order to manage interactions in a specific environmental system, or who alter resource characteristics through extraction or emission. An environmental commons (EC) is a good – whether naturally occurring, such as ABFT, or anthropogenically created in the case of many pollutants – that is directly or indirectly regulated for some purpose. Within the relational database, information on the relationships between these components is stored in an interactions (I) table. Different interactions can be used to represent distinct snapshots that differ with respect to the components involved in interactions, change to one or more attributes of those components, or simply distinct time periods. In effect, a snapshot is a self-contained description of an SES that is bound in time and space and can be used to perform within and cross-case analysis of the effects of SES attributes.

Within the confines of this study, we use two distinct modes of inference to evaluate the correspondence between CPR theory and the ICCAT case. The vast majority of attributes are evaluated in relation to the expectations of CPR theory, which in effect amounts to constructing a theoretical counterfactual and then comparing whether the empirical results correspond to these expectations (Levy 2008). For instance, CPR theory would generally predict that a resource with poorly defined boundaries is likely to be associated with poorer outcomes; thus, empirical evidence is considered to support this hypothesis if the same relationship is found in this analysis. The second, generally more rigorous, approach seeks to isolate one or a small set of SES attributes, and then makes causal inferences on the basis of covariation between an outcome and that attribute. This approach leverages the snapshot design in an attempt to isolate potential causes from other potentially intervening attributes.

3. Timeline of the international commission for the conservation Atlantic tunas

ABFT fisheries have a long history dating back to the seventh century BC when they were harvested by Phoenicians and Romans in the Mediterranean (Fromentin and Powers 2005). This region remained the primary fishing ground until the nineteenth century when new fisheries emerged throughout the Atlantic. While the historical Mediterranean fishery used mostly beach seines and traps, the Atlantic fisheries introduced a variety of fishing methods such as purse seines and longlines that gradually grew to dominate the fishery (Fromentin and Powers 2005). The comparative effectiveness of these fishing methods, as well as an overall increase in fishing effort after World War II, led to considerable declines in ABFT catches that prompted the international community to develop a governance system that could regulate and coordinate resource use in the 1960s. A general outline of the contemporary history of the ABFT fishery can be found in Table 1.

Table 1: Major events characterizing the governance of ABFT stocks given for the resource as a whole, and for Western and Eastern stocks separately due to institutional and biological variations across these two stocks.

	Date	Event
All 1950–2007	1950s	Japanese fishing fleet starts to actively fish in the Atlantic
	1966	Creation of ICCAT
	1969	ICCAT entered into force
	1970s	Growth of Japanese sashimi market
	1971	ICCAT Secretariat permanently based in Madrid, Spain
	1974	Minimum size established for ABFT: 6.4 kg (~age 2)
	1981	Implementation of the two-stock regime: 45° W boundary line was used to separate East and West stock management areas
	2003–2010	Quotas exceed scientific recommendations
	2010	Attempt to list ABFT under CITES
Western bluefin tuna	1970–1980	Development of the Japanese longline fishery in the Gulf of Mexico
	1981	Western ABFT fishery is closed with exception of scientific monitoring quota
	1982	Quota is raised despite lack of improved conditions
	1991	Attempt to have stock listed under CITES
Eastern bluefin tuna	Pre 1950	Small-scale fishing effort dominated by traps
	1940–1963	Large commercial catches in the North Sea
	1970–1980	Growth of purse seines, decline of traps
	1985–1995	Expansion and industrialization of fisheries in the Mediterranean
	1995–	Expansion of ABFT farming in the Mediterranean

3.1. History and governance structure of ICCAT

ICCAT represents an ambitious attempt to govern ABFT, as well as other tuna and tuna-like species in a large-scale oceanic commons. Its origin lies in the introduction of new fishing techniques that expanded the range of exploitation, prolonged the fishing season, and corresponded to declining ABFT catches (Wagner 1996, Hurry et al. 2008). This decline led to a conference of interested parties that culminated with the creation of ICCAT in 1966 when 17 national governments signed the international convention in Rio de Janeiro (ICCAT 2007). ICCAT officially came into effect in 1969, marking the start of a regime that would grow to regulate more than 30 species in the Atlantic Ocean (ICCAT 2007). Since its inception, the number of contracting parties has steadily grown and now includes 48 contracting parties. Eighteen countries joined between 2000 and 2009, a majority of which are from the global south (see ICCAT website, http://www.iccat.int/en/contracting.htm), with Cuba and Benin being the only countries that have formally withdrawn from the convention. Although the individual member states of the European Union have also withdrawn, they are jointly represented by the European Union, which has been a signatory since 1997.

The goal of ICCAT is to cooperatively maintain fish stocks "at levels which will permit the maximum sustainable catch for food and other purposes" (Preamble, ICCAT 2007). While ICCAT does not have regulatory or enforcing powers (Korman 2011), it is entrusted with collecting and compiling statistical data, generating scientific reports, proposing management recommendations based on its findings, and creating an arena for contracting parties to meet and discuss recommendations (ICCAT 2007). The commission meets annually at its headquarters in Madrid, Spain, to discuss statistical reports and recommend management measures (Wagner 1996). These recommendations are not binding for the contracting parties; instead, every party has a right to object to a proposed recommendation within a six-month period (Article VIII, ICCAT 2007). In such a case, if the number of parties who filed an objection is less than the majority, the proposed recommendation will not apply to those parties; and if the number of parties is more than the majority, the recommendation will be withdrawn in its entirety (Article VIII, ICCAT 2007). The existence of these formal vetoes has led to a more informal consensus-oriented system of decision making wherein only those recommendations likely to be universally accepted are promulgated (Hurry et al. 2008).

Several factors provide incentives for this informal, consensus-based approach. The first is that under the formal majority-based voting structure, nations that agreed to abide by recommendations would be operating under different rules than those that did not agree. This two-tiered framework would quickly become unworkable, and great effort is expended prior to adoption of any proposed recommendation to avoid such a scenario. In addition, parties can strike agreements outside of ICCAT with other parties (trade incentives, market opportunities, development funding, etc.) to provide side-payments for agreeing to recommendations. A final factor that may influence parties' willingness to agree to measures that are not in their favor is the lack of enforcement capabilities within ICCAT. Parties may find it politically easier to agree to recommendations and not enforce them than to submit formal objections to proposed measures. In fact, over the 40-year history of ICCAT, only six objections related to three recommendations have been confirmed (Hurry et al. 2008). Parties to the convention are therefore obliged to share information, adopt regulations congruent with recommendations for which they have not filed an objection within the prescribed period, and to enforce those regulations in their territorial waters and on ships flying their flag. The chief benefit of joining the convention, however, is that it provides legal access to the lucrative BFT markets of other signatories, most notably Japan.

The first enacted recommendation took effect in 1974 when a minimum size limit was established (Fromentin and Powers 2005). Since then, many additional recommendations have come into force that limit annual catches, and regulate where, when, and how fishing activities may take place (Porch 2005; ICCAT 2010). One of the most significant changes occurred in 1981, when ICCAT elected to divide ABFT governance into Eastern and Western management units using an effectively arbitrary boundary of 45° W longitude. The rationale for such a decision rested on the clear biological distinctiveness of Eastern and Western stocks and the perceived absence of ABFT in the central North Atlantic (Fromentin and Powers 2005). Although the boundary remains in use, it is now apparent that this assumption was inaccurate and that both stocks frequently cross this boundary (Block et al. 2001, 2005).

A significant political controversy for ICCAT and ABFT governance emerged in 2010 when the United States and European Union jointly supported a motion to list ABFT under the Convention on International Trade of Endangered Species (CITES) (Korman 2011). While the listing was ultimately rejected due to heavy political pressure and lobbying by Japan, the latent threat of potential CITES listing prompted ICCAT to reduce quotas and propose new techniques to strengthen its monitoring process (Korman 2011). Overall, ICCAT's efforts to achieve its management goal and maintain ABFT populations at levels that would allow maximum sustainable catch have not been achieved, and according to a recent official performance review, "there is little doubt that bluefin tuna in the ICCAT area is far from BMSY (maximum sustainable yield biomass) and there are indications that collapse could be a real possibility in the foreseeable future" (Hurry et al. 2008).

3.2. Western bluefin tuna stock

The creation of the two-stock regime in 1981 marked the regionalization of ABFT management with Western stock quotas being assigned primarily to the United States, Canada, and Japan (Webster 2008). Western ABFT catches peaked in the early 1960s, mainly due to the increasing fishing pressure by Japanese fishing boats. After a few years of high catches, the catch declined substantially, leveling off in the early 1980s. Recent spawning stock estimates suggest that Western ABFT is at approximately 35% of the 1970 reference level (ICCAT 2012).

Management decisions related to the Western stock suggest that political bargains and lobbying activities have leveraged scientific uncertainty to determine quotas and dominate ICCAT operations (Safina and Klinger 2008; Webster 2008; Korman 2011). For example, the initial 1981 decision to cut the quota from 6,000 to 545 metric tons was quickly raised to 800 metric tons (Webster 2008). A year later, the quota was quadrupled, with political arguments that the earlier estimates were overly pessimistic (Webster 2008). On the other hand, conservation organizations actively lobby ICCAT member states for more stringent regulations. In 1991, they successfully lobbied the US government to propose a CITES listing for Western ABFT. Although the United States failed to follow through with the recommendation, ICCAT reacted by introducing a documentation program to track the origin of each captured fish and thus reduce illegally caught fish from reaching the market (Webster 2008).

3.3. Eastern bluefin tuna stock

Eastern ABFT stocks as well as catches are considerably larger than their Western counterparts. Furthermore, unlike the Western stock, the Eastern stock is being exploited by at least 15 countries, of which 8 are major quota holders that captured more than 90% of the total catch in 2011 (ICCAT 2012). Recent assessments indicate that the Eastern spawning stock deteriorated markedly during the 1970–2007 period, although recently enacted conservation measures may have reversed this trend (ICCAT 2012). Failure to prevent overexploitation and to stabilize the population has been attributed to illegal, unreported, and unregulated (IUU) fishing that stems from the lack of an effective monitoring and enforcement system (Boustany 2011; Sumaila and Huang 2012).

The Eastern ABFT fishery has experienced increasing industrialization since the 1970s. The first change is characterized by increasing use of purse seines and decline of traps in the ‘70s and ‘80s, followed by a dramatic expansion in the use of tuna farming technologies between 1995 and 2002 (Sumaila and Huang 2012). The two developments are related since purse seines catch live fish that can subsequently be transported to farms where they are fattened and eventually harvested.

4. Coding and analyzing ICCAT as a large-scale SES

In this section, we describe the structure of this case, the snapshots that are coded in the SESMAD database, and then continue by evaluating the correspondence between the results and CPR theory. We conclude by discussing the challenges associated with coding and analyzing this case.

4.1. Structure of the ICCAT case

For the purposes of this study, the ICCAT case is defined by the relationships among the components of the database presented in Figure 1. There are seven core components consisting of three actor groups, three resources, and a governance system. We distinguish, as is the convention in ABFT studies, between Eastern and Western stocks, which differ with respect to breeding grounds and the relative size of the stock. It is generally accepted that the Western and Eastern stocks mix on feeding grounds but do not interbreed (Block et al. 2005; Carlsson et al. 2007; Boustany et al. 2008). The Eastern stock is coded over two separate time intervals, 1985–1995 and 2003–2007. The eight-year gap reflects the increasing use of storage pens, or ABFT farms, which grew gradually in the mid-1990s but expanded tenfold between 1997 and 2003 (Sumaila and Huang 2012). The three actor groups are used to distinguish between (1) contracting parties, which includes all signatories, and those countries that are assigned quotas to the (2) Western, and (3) Eastern stock, respectively. The only governance system that is coded in this analysis is ICCAT, although it is important to note that each party has its own set of national-level fisheries policies and regulations. As can be seen in Figure 1, these components produce three sets of interactions or snapshots. The Western SES is coded as a single snapshot from 1985 to 2007, reflecting the absence of dramatic shifts in state or policy variables during this time interval. The Eastern SES is, on the other hand, coded in two distinct snapshots reflecting the introduction of storage facilities in the late 1990s and early 2000s.

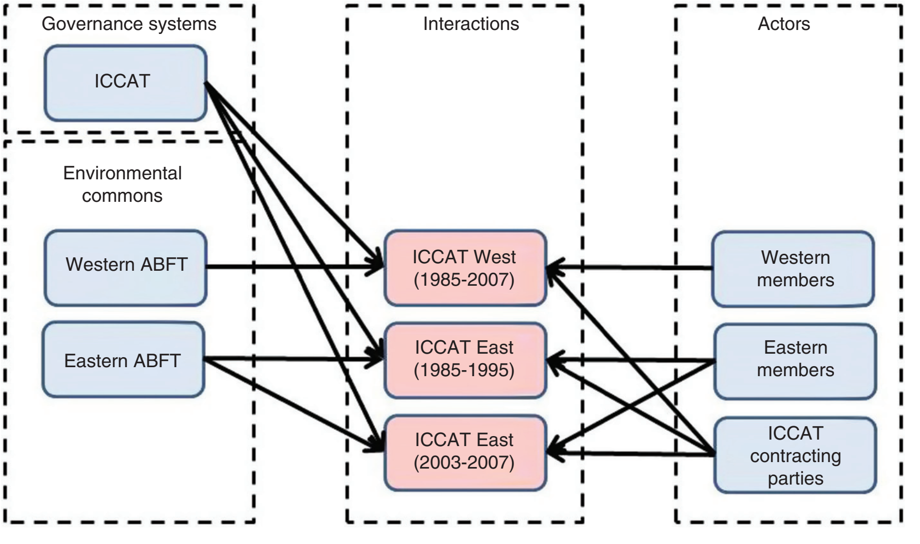

Figure 1: Schematic representation of the ICCAT case.

4.2. Social-ecological outcomes

The effects of ICCAT governance on ABFT stocks and flows are told in a context of considerable uncertainty. Nonetheless, estimated catches (1950–2007) and stock sizes (1970–2007) are presented for each stock in Figures 2 and 3, respectively. Table 2 summarizes this information to report the relative magnitude of stocks and catches in relation to historical peaks, the trend during the snapshot interval, and a qualitative assessment of institutional performance based on these figures. Overall, in two of the three snapshots, ICCAT appears to have maintained stable stocks, with a sharp rise in catches in the latter half of the first Eastern ABFT snapshot. However, in relation to historical peaks, the estimated size of both stocks in 2007 is well below those levels.

The Western spawning stock biomass fluctuated around 20% of its peak between 1985 and 2007, while catches were mostly stable around 10% of their peak. The catches are less concerning than it initially appears, given that peak catches in the 1960s were almost certainly unsustainable (Fromentin and Powers 2005; Webster 2008). ICCAT governance of the Eastern stock is described in two separate snapshots as per the structure of the case described in Section 4. Between 1985 and 1995, the Eastern spawning stock biomass was stable around 70% of its peak, while catches increased dramatically from less than 50%, to more than 90% of the maximum catch. While the stability of the stock coupled with an increase in catches could be described as a successful case of environmental governance, it appears likely that this increase may have contributed to the eventual decline in the stock that occurred in the second snapshot. In this last snapshot, Eastern stock

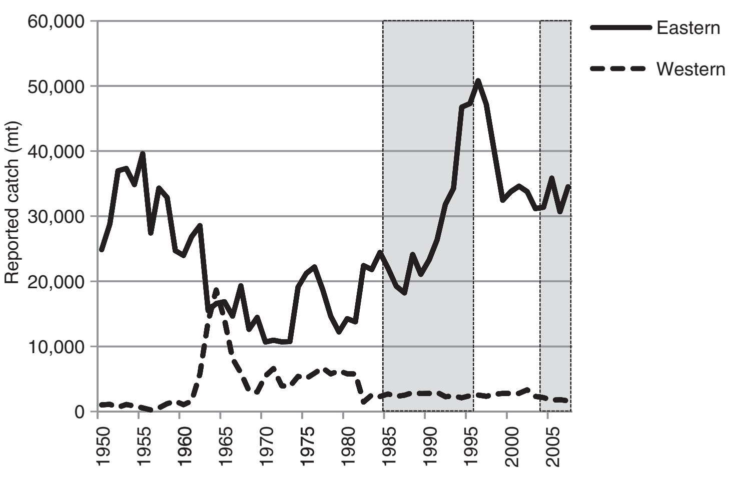

Figure 2: Annual catches for Eastern and Western stocks from 1950 to 2007. Shaded areas are the two time periods coded for the Eastern stock; Western stock is coded from 1985 to 2007. Source: ICCAT (2010).

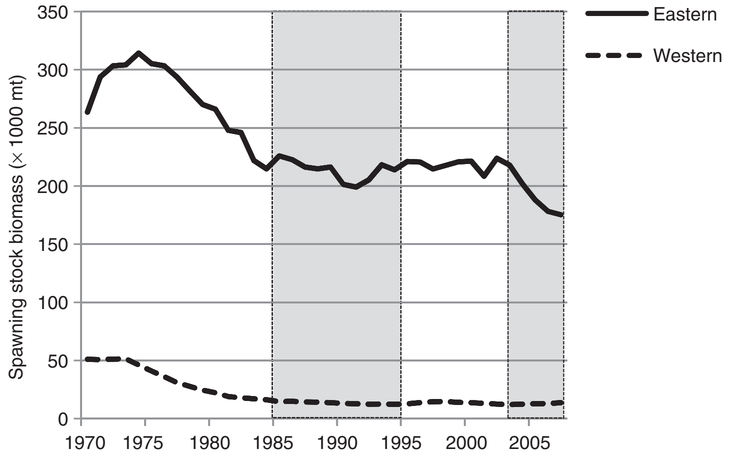

Figure 3: Annual estimates of spawning stock biomass for Eastern and Western stocks from 1970 to 2007. Shaded areas are the two time periods coded for the Eastern stock; Western stock is coded from 1985 to 2007.
Source: ICCAT (2010).

fell to about 55% of its peak, while catches increased slightly from about 61% to 68% of the peak catch.

In general, we can conclude that ICCAT governance of the Western ABFT stock has been successful in preventing further declines in both stocks and catches. However, it has also failed to implement a long-term strategy to enhance stocks to historical levels, resulting in a seemingly sustainable but nonetheless suboptimal outcome. In contrast, the Eastern ABFT stock appeared to be stabilizing in the first snapshot after fairly precipitous declines in the 1970s and early 1980s, but then experienced further declines between 2003 and 2007. The following section shifts attention to the potential causes of these results by drawing upon CPR theory and variables stored in the SESMAD database.

Table 2: Social and ecological outcomes of ICCAT governance as coded in the large-scale common-pool resource database. Trends and governance effect record the relative change from the beginning to the end of the snapshot interval.

Governance outcomes	Western ABFT (1985–2007)	Eastern ABFT (1985–1995)	Eastern ABFT (2003–2007)
Size of stocks	Small	Moderate-Large	Moderate
Stock trend	Stable	Stable	Decreasing
Size of catches	Small	Large	Moderate
Catch trend	Stable	Increasing	Increasing
Governance effect	Remained the same	Remained the same	Worsened

4.3. ICCAT case alignment with CPR theory

Table 3 summarizes a subset of SES characteristics that have received considerable theoretical and empirical attention by CPR theory. These include factors related to the size and composition of groups (Vedeld 2000; Agrawal and Goyal 2001; Poteete and Ostrom 2004; Ruttan 2006), the design principles (Ostrom 1990; Quinn et al. 2007; Cox et al. 2010), and the resource characteristics (Schlager et al. 1994; Acheson and Wilson 1996; Agrawal and Chhatre 2006; Tucker et al. 2007). The section continues by evaluating the extent to which the relationship between outcomes and the state of these attributes in each snapshot correspond to the expectations of CPR theory.

4.3.1. Boundaries

Boundaries are important attributes of an SES as they help to internalize the benefits and costs of governance within a set of appropriators (Giordano 2003; Cox et al. 2010), while also allowing for the coordination of harvesting rules throughout the range of a resource. Boundaries are thus often distinguished between those that mark membership in a group (social boundaries) and those that mark the distribution of a resource (resource boundaries).

Resource boundaries, particularly those that define the Eastern and Western stocks, have been an important issue for ICCAT governance of ABFT since the stocks were first separated for management purposes in 1981. The choice to

Table 3: Comparing the governance of Atlantic bluefin tuna.

Component	Theoretical variable	1st snapshot Western ABFT (1985–2007)	2nd snapshot Eastern ABFT (1985–1995)	3rd snapshot Eastern ABFT (2003–2007)
Actors	Group size	Smaller (3)	Larger (~30)	Larger (~30)
	Heterogeneity	Less	More	More
Resource	Size of resource system	Large	Large	Large
	Boundaries	Unclear	Unclear	Unclear
	Productivity	Lower	Higher	Higher
	Mobility	High	High	High
	Economic value	High	High	High
	Storage	Absent	Absent	Present
Governance	Clarity of social boundaries	Clear	Clear	Clear
	Fuzziness of social boundaries	Rigid	Rigid	Rigid
	Participation of affected parties	Limited	Limited	Limited
	Fit to local conditions	No	No	No
	Nested enterprise	Yes	Yes	Yes
	System-wide monitoring	Limited	Limited	Limited
	National-level monitoring	Less variable	More variable	More variable
	Monitoring by fishers	No	No	No

delineate separate stocks was based on mounting evidence that ABFT consisted of two non-interbreeding stocks that required distinct regulations to achieve the stated goal of maximum sustainable yield. The 45th meridian, however, was chosen as a matter of convenience that corresponds well to their respective spawning grounds but not the annual distribution of these highly mobile fish (Block et al. 2005; Fromentin and Powers 2005; Hurry et al. 2008). The potential effects of incorrect assignment are asymmetric in nature given the order of magnitude difference in population size between the Eastern and Western stocks (Boustany 2011). For instance, incorrect assignment of one metric ton of Western stocks would represent approximately 10% of the total stock, while this same figure would constitute less than 1% of the Eastern stock. At present, there remains considerable uncertainty regarding the level of mixing among stocks (Fromentin and Powers 2005; Hurry et al. 2008; Boustany 2011), and whether the simple but arbitrary boundary rule should be retained, abandoned, or modified.

Membership in ICCAT, as an international body organized under the auspices of the United Nation's Food and Agriculture Organization, is technically open to (1) any government that is a member of the UN, (2) a specialized agency of the UN, or (3) organizations such as the European Union to which states have transferred competence over issues pertaining to ICCAT (ICCAT 2007). ICCAT has also introduced a lower-level membership category, denoted as a cooperating non-contracting party, that provides much of the same benefits and obligations in an attempt to enhance implementation of conservation measures throughout the convention area (ICCAT 2003). Nevertheless, boundaries as to who is, and who is not, a member is quite clear and rigidly defined by a country's contracting or cooperating status. Members of the Eastern and Western group are equally clear and defined by the assignment of quota for a given stock in a given year. It must be noted that membership in ICCAT does not, in and of itself, define rights to harvest ABFT in the design principle sense (Ostrom 1990; Cox et al. 2010), but it does define the ability to trade captured fish with contracting parties, most notably Japan.

4.3.2. Congruence between rules, local conditions, and contributions

Congruence between rules and the social-ecological context of a resource, and the users of that resource, has often been identified as an important factor in the success or failure of environmental governance (Ostrom 1990; Acheson et al. 1998; Folke et al. 2007). As a whole, ICCAT could be said to sacrifice alignment with local conditions in favor of symmetric implementation (i.e. quotas) of ICCAT conservation measures (ICCAT 2003). The use of quotas – which is the dominant policy instrument utilized by ICCAT – has been criticized by some scholars who argue that the regeneration of many marine resources are chaotic in nature and better suited to alternative regulatory instruments (Acheson and Wilson 1996). While there is considerable formal flexibility for ICCAT members to design context-specific regulations, the emphasis on consensus decision making means that once recommendations are adopted, members who have accepted them are constrained within the terms of their quota assignment, size restrictions, and restricted areas, leaving little room for meaningful adaptation. The United States, for instance, had adopted more stringent size restrictions for commercial catches than required by ICCAT, but would not be sanctioned for the reverse. Notwithstanding the potential misfit between rules and the resource, this issue is overshadowed by the lack of enforcement of those rules (Hurry et al. 2008).

4.3.3. Participation of affected parties

The design principles – a core part of CPR theory first developed in Ostrom (1990) and supported in a more recent meta-analysis (Cox et al. 2010) – are quite clear that user participation, if not direct provision of rules and monitoring by resource users, are often important for successful environmental governance. The ICCAT case violates this principle by situating rule making at the international level and monitoring at the national level for each of the contracting parties, with little direct input from resource users. While there is evidence that some users have been able to organize and lobby governmental participants, and more recently conservation and technical organizations have participated in ICCAT processes, their influence appears to be limited.

4.3.4. Monitoring and sanctioning

Continual monitoring and sanctioning have been found to be one of the key aspects of successful resource management in both marine and terrestrial systems at the local level (Basurto 2005; Gibson et al. 2005). In the case of ICCAT, both monitoring and sanctioning capabilities are greatly restricted. While ICCAT conducts limited fishing fleets as well as resource capture and distribution monitoring through fish observers and catch-reporting mechanisms, it does not have any enforcing or sanctioning powers, with the exception of trade restrictions that have never been applied (Hurry et al. 2008; Korman 2011). Instead, ICCAT relies directly on member states to enforce the agreed-upon rules and to perform most monitoring activities. In a sense, this type of self-monitoring resembles the classic allegory of the fox guarding the henhouse, at least with respect to countries that by virtue of choice or constraints are unable or unwilling to devote sufficient resources to monitoring.

Overall, this governance structure has been recognized to greatly impede the proper functioning of ICCAT (Hurry et al. 2008; Sumaila and Huang 2012). In the independent review of the commission, Hurry et al. (2008) point out that ICCAT's failure to achieve its management objective partially results from a lack of political support of member states to fully implement and enforce agreed-upon rules. This situation, according to some of the more recent analyses, has led to a proliferation of illegal fishing activities, especially in the Mediterranean (WWF 2006; PEW 2011). PEW (2011) has estimated that the quantity of ABFT international trade in 2010 was approximately 140% higher than ICCAT's adjusted quota for the same year. Moreover, incomplete or fraudulent reporting of catches and a lack of government oversight and control has been reported for several Mediterranean countries (ICIJ 2011).

While the apparent inadequacy of the current monitoring and enforcement system is evident, there has been no visible reaction within ICCAT to deal with this problem, in spite of numerous recommendations by academic and non-governmental institutions. Furthermore, it seems that effective monitoring and sanctioning mechanisms are equally relevant in local and international contexts. However, the second-order dilemmas might be more challenging to overcome at the international level given the sovereign character of each member state. It has also been suggested that ICCAT could benefit greatly by devising monitoring protocols that actively encourage fishers to monitor the behavior of their peers (Korman 2011).

4.3.5. Nested governance

Nested governance is commonly found to be an important factor in the successful governance of natural resources where physical boundaries or some other characteristic of the good require that management activities are coordinated across scales (Ostrom 1990; Cox et al. 2010). Nested governance serves a variety of roles in a polycentric system (Ostrom et al. 1961; Ostrom 2010), but in general allows a governance system to better match rules or levels of public goods provision to local conditions while ensuring that the actions of multiple groups align in such a way as to promote the sustainable exploitation of a stock.

The presence of nested governance in the ICCAT case was virtually guaranteed by the international nature of the ICCAT governance regime, which views coordination as one of its primary aims (ICCAT 2003) and where the rights of states supersede the rights of an international body. In general, the ICCAT regime adopts a nested approach on the basis of governance functions. Scientific analysis of stocks and catches, the determination and assignment of quotas and system-wide rules, is conducted at the international level and coordinated by the ICCAT secretariat (Korman 2011). Member states are responsible for the implementation of regulations, monitoring, sanctioning, and collection of data for harvesting that occurs within their national waters, and for ships flying their flag in international waters. In theory, regulations can and do vary across states, but the fact that these regulations must fit within the context of their assigned quotas (and other rules) severely constrains the ability of states to design rules that fit their particular conditions and capacities. For example, traditional fishery regimes often employ closed seasons, assigned fishing grounds, limit harvests to certain types (i.e. size, age, sex) of a resource, and apply bans on harvesting in certain areas to conserve their resource (Johannes 1978; Schlager 1994), all of which are difficult to align within the confines of a quota system. Furthermore, variability across states in terms of the availability of resources to effectively and efficiently perform the required tasks means that levels of monitoring and data collection vary; and even developed countries lack the ability to fully monitor fishing in their territorial waters (Korman 2011). Notably absent from the system of nested governance are the fishers themselves, who could make major inroads into the monitoring problems given appropriate incentives (Korman 2011).

4.4. The peculiar effects of storage: tuna farming

The most interesting finding from this study is the co-occurrence of declines in Eastern tuna stocks alongside a significant growth in the availability and use of storage technologies. The farming of ABFT is characterized by the live capture of wild fish that are then raised in captivity until they reach a certain size and are sold at market (Klinger et al. 2013). This contrasts sharply from other forms of live fish storage such as aquaculture, where fish are hatched and grown in captivity for eventual harvest; and stock enhancement, where fish are hatched and grown in captivity before they are released into a natural aquatic environment. Since 1993, farmed tuna were subject to the same reporting requirements of fishing fleets, wherein all trade required that the tuna be accompanied by a document reporting details of its location and flag of capture. By the end of the study period, it became increasingly clear that such a system was inadequate to effectively monitor these facilities (Hurry et al. 2008), and in 2010 a more comprehensive catch documentation program was introduced (ICCAT 2010). Nonetheless, an important theoretical question remains as to why the introduction of storage facilities to the SES coincided with a decline in Eastern ABFT stocks. This finding stands in contrast to a long-standing and generally supported hypothesis in CPR theory that storage helps groups to resolve problems of overappropriation (Schlager et al. 1994; Agrawal 2003).

At a minimum, we can conclude that the introduction of storage to the SES has done little to resolve problems of overappropriation, and may in fact be a direct contributor to the observed decline in Eastern stocks. While we could take this evidence to reject the hypothesis that storage increases the likelihood of sustainable governance, it seems more likely that the effects of storage, like many SES attributes, are contingent upon more specific attributes or subtypes of storage, and attributes of the broader SES environment in which they operate. This finding broadly corresponds to the shift from CPR to SES theory, wherein the search for enabling conditions has transformed into the search for the effects of SES attributes across varied SES contexts (Young 2002; Ostrom 2009). Nevertheless, we can safely say that storage itself is not sufficient for the sustainable governance of natural resources.

In order to explore possible explanations for the effects of storage in this snapshot, we draw upon SES theory to suggest that the unexpected results are a function of contextual differences between the tuna fishery and the canal irrigation systems where this hypothesis was developed. For example, there are several obvious and significant differences between the storage of an abiotic resource such as water, and a living biotic resource such as tuna, which requires regular maintenance and food inputs as part of its storage function. Therefore, in what follows, we contextualize Eastern ABFT and canal irrigation storage with respect to the attributes of storage facilities and the broader social-ecological context. Then, we seek to uncover possible explanations as to why tuna storage facilities have failed to reduce pressure on Eastern ABFT stocks by comparing the state of selected attributes across the two SESs. These are summarized in Table 4, and are broadly broken down into attributes of the environment and storage facilities.

Table 4 indicates at least two potentially salient differences between the environments in which canal irrigation and ABFT storage operate that may be responsible for the variation in the effects of storage. First of all, the simplest possible explanation for the divergent results is that a hypothesis developed in the context of an irrigation system does not apply in the context of a fishery. More specifically, this suggests that the outcomes are different because the problems faced by irrigation water users differ in kind from those faced by fishers. While this may be the case, it is not an entirely satisfying theoretical answer as it does not provide any indication as to the mechanism that underlies the different effects of storage in fishery and irrigation systems. Second, we would be remiss if we failed to consider the possibility that differences are a function of the relative size of resource systems. The largest irrigation case examined had a total command area of 300 hectares (Schlager et al. 1994), as compared to more than 10 billion hectares for the Atlantic Ocean. Even accepting that ABFT are not present throughout this range, and that storage is confined to coastal areas, their wide spatial distribution poses a considerable and costly challenge for monitoring (Agrawal and Goyal 2001). Moreover, the presence of multiple jurisdictions that vary with respect to the enforcement or capacity to enforce ICCAT regulations may allow opportunistic individuals and groups to situate storage in favorable settings where enforcement is absent or weak.

Table 4 also shows how the characteristics of canal irrigation storage systems and those used in the Eastern ABFT fishery have at least one interesting similarity, in addition to several potentially influential differences. First of all, both rely upon an exogenous (i.e. natural) supply of a resource to stock their respective storage facilities, which are then stored for future consumption. Although this appears to

Table 4: A comparison of the attributes of resource storage and the environment in canal irrigation systems and the Eastern ABFT fishery.

Attribute	SES	
	Canal irrigation	Eastern ABFT fishery
Environmental		
Sector	Irrigation water	Fishery
Size of resource system	Small	Large
Storage facilities		
Inputs	External	External
Property rights	Mostly common	Private
Economic benefits	Indirect	Direct
Variable costs and risk	Lower	Higher

rule out exogenous inputs as a cause of the divergent results, it is possible that the sustainability-enhancing effects of storage depend upon interaction between the source of inputs and the sector in which they operate. In the case of canal irrigation, attempts to "close the loop" or develop an endogenous supply of a resource are logically impossible, but many aquaculture systems close the loop via captive reproduction (Zohar 1989; Brummett 1995; Sumaila and Huang 2012). While recent developments have demonstrated that captive reproduction of ABFT is possible (Mylonas et al. 2007); prospects for a commercially viable closed-loop system remain somewhat unlikely in the near to medium term (Locke 2008). Moreover, studies have shown that even if a closed loop aquaculture system is developed, it does not necessarily translate into lower fishing pressure or net environmental benefits (Naylor et al. 2000; Pauly et al. 2002).

The two storage systems also vary in terms of the property rights that are assigned to stored units, the structure of economic benefits and costs, and the ways in which these facilities affect uncertainty concerning resource flows. Whereas Schlager et al. (1994) describe storage facilities where stored units are owned collectively by a group of potential appropriators, the ABFT stored in farms for fattening are held privately. Discussions about the effects of property rights on sustainability have broadly settled on the conclusion that government command-and-control and common-property systems are equally prone to succeed or fail, although typically for different reasons. Common-property failure is often linked to characteristics of communities in which groups are unable to devise and implement rules due to the absence of clear boundaries, social capital and presence of cultural differences (Acheson 2006). Private-property failures, on the other hand, are linked to profit maximization, rational discounting of future returns, uncertainty, and the economic situation of owners (Acheson 2006) – the first three of which are almost certainly present in the context of Eastern ABFT storage.

For instance, tuna have direct economic use value, whereas the value of irrigation water is generated indirectly as an input for agricultural production processes. When water is abundant, stored units of irrigation water may possess zero immediate use value, while in periods of drought its use value could be immense. The most significant implication of this is that the marginal benefits of consuming a stored unit of irrigation water fluctuates dramatically according to temporal availability, while the marginal benefits of consuming stored tuna is considerably more stable. When this is combined with fairly significant variable costs in the form of fish feed (Volpe 2005) and the risk of fish mortality in the storage facility (De Stefano and Van Der Heijden 2007), it appears to generate a situation favoring profit maximization, rational discounting, and risk, if not uncertainty, regarding future returns. Finally, the variable costs of storing a fixed quantity of irrigation water over a period of time are considerably lower, and with a few exceptions (i.e. high evaporation rates) associated with lower levels of risk.

While we cannot provide a definitive answer as to why storage appears to be contributing to the decline of Eastern ABFT stocks, the preceding discussion appears to lead in a few distinct directions. First, private property rights generate a different set of motives than common property that when combined with the costs, benefits, and risks associated with tuna storage appears to do little to reduce pressure on Eastern ABFT stocks. The absence of an endogenous supply of resource units certainly exacerbates this problem, but even if the loop is eventually closed, studies suggest that it rarely has an appreciable effect on capture fisheries (Naylor et al. 2000). Finally, the introduction of storage when combined with the large size of the resource system has added an additional layer of complexity for monitors that non-compliant harvesters can and have used to their advantage. Although tuna captured by the purse seine fleet are included in quota assignments, trade statistics suggest that the Mediterranean fleet systematically underreports the quantity of tuna transferred to storage facilities (PEW 2011). To date, however, ICCAT has been unable to develop and implement a strategy to effectively detect specific instances of illegal transfers between the purse seine fleet and tuna ranches and between tuna ranching facilities.

4.5. Methodological challenges

The complexity implied by an SES approach for the study of environmental governance is a common problem for scholars seeking to define causes among a large range of attributes whose effects may vary according to the presence, absence, or magnitude of other attributes (Agrawal 2003; Poteete et al. 2010). Whereas these problems are a feature of both small- and large-scale SESs, secondary analysis and coding of large-scale systems introduce additional problems of method that were evident in the analysis of this case. The source of most of these problems rests in some combination of (1) the availability of data, (2) assigning values to attributes in the context of heterogeneity, and (3) the loss of heterogeneity important to the case in favour of relative homogeneity across multiple cases.

The omission of resource users as a component of the ICCAT SES was the most significant issue to arise in the coding of this case, and was driven by the scarcity of information about the groups and individuals that harvest ABFT in the Atlantic Ocean and Mediterranean Sea. Aside from discussions of compliance problems (ATRT 2005; Hurry et al. 2008; PEW 2011), few details emerge about the characteristics of users or their interactions and role in national-level management regimes. The absence of users was not taken lightly given their prominence in the commons literature (Ostrom 1990, 2009), and the fact that environmental outcomes inevitably flow through the choices made by this important group. In fact, an attempt was made to code the attributes of resource users, which resulted in a table composed almost entirely of missing data, ultimately leading to the decision to omit them entirely. In retrospect, it seems almost inevitable that the emphasis on large-scale systems would at times lead to the omission of user groups, but it remains unclear what effect this omission portends for the analysis of large-scale SESs.

The choice to adopt a relational database approach for this project was explicitly situated in a desire to capture important heterogeneities across actors, resources, and governance systems (Cox 2014) that may have differential effects on important outcomes of interest for a case or set of cases. Inevitably, however, data constraints when combined with trade-offs between depth and breadth led to the aggregation of actors into groups based on some underlying shared characteristic. In this case, aggregation was facilitated by important differences across stocks (Fromentin and Powers 2005), the stock-based governance system, and the assignment of quota for those stocks to member countries. This grouping, while theoretically appropriate, required that coding take into account heterogeneities within these groups. Thus, the Western members (which effectively consist of Canada, the United States, and Japan) were easily coded as having a fairly high economic status and low economic heterogeneity, while Eastern members (consisting of Western and Eastern European nations as well as North Africa) were coded as having a moderate economic status with high levels of economic heterogeneity. An alternative grouping, based on geography, for instance, would have produced different measurements pointing to potential problems of method driven by the specification of the components of a case. Moreover, the snapshots that are used to mark important differences in the structure of an SES generate valuable benefits for counterfactual inference but may mask the effects of long-term or stochastic processes (i.e. Pierson 2003). For instance, we were able to leverage this design feature to isolate storage from other attributes and infer that storage is responsible for the decline of Eastern ABFT stocks. However, it is also plausible that the decline reflects a long-term unobserved trend, or a threshold response to some stressor or combination thereof. In any case, the best a snapshot can achieve is some form of pseudo-isolation wherein some but not all threats to validity can be controlled.

Finally, some important attributes of the snapshots are lost when data is taken from the literature and entered into the SESMAD database. As an example, tuna from the Eastern stock grow faster and reach sexual maturity earlier than the Western stock (Fromentin and Powers 2005), but the difference is not captured in the database due to the presence of coding thresholds designed to capture heterogeneity across multiple types of SESs. Furthermore, the details concerning types and attributes of tuna storage facilities are not present in the SESMAD database, which simply records whether storage is present or absent, whether it is used, and whether the facilities are natural or artificial. Ultimately, the compromise between specificity and generalizability remains an important problem for any study of SESs. But projects that combine case-based analytic approaches while also accumulating cases for large-n analysis are more likely to produce a strong body of generalized and specific knowledge.

5. Conclusion

The future of Eastern and Western ABFT stocks remains unclear. Are they in a state of dangerous decline (Hurry et al. 2008; Safina and Klinger 2008; MacKenzie et al. 2009; Collette et al. 2011; Juan-Jordá et al. 2011), or are they on a pathway to eventual recovery (ICCAT 2012)? These contrasting positions are not uncommon, but their joint prevalence is nonetheless surprising in that they are derived more or less from the same set of publicly available data. This analysis does not fully answer the fundamental question concerning the long-term sustainability of ABFT fisheries whose answer continues to elude ICCAT and scholars who have dedicated their careers to better understand this fish species, the people who use it, and how to effectively govern its use. In fact, the single most interesting contribution of this study is external to this case and consists of a set of testable hypotheses for commons scholars surrounding the effects of storage in natural resource settings. Why does the addition of storage appear to be exacerbating, rather than ameliorating, the exploitation of ABFT despite long-standing predictions to the contrary (Schlager et al. 1994)? Is it simply that storage has a different effect in large systems or in fisheries? Perhaps the effects of storage in fisheries depend upon the development of a closed-loop system, different property rights, or perhaps the perceived effect of storage in this case is simply standing in for one or more other factors that have been omitted in this study. In any case, the answers to these questions cannot be found in the ICCAT case but rather in the accumulation of evidence from multiple cases and multiple methods of inquiry (Poteete et al. 2010) that undoubtedly includes a large-n database on similar large-scale commons.

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