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REVIEW

The Historical Dynamics of Social–Ecological Traps

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Abstract Environmental degradation is a typical unintended outcome of collective human behavior. Hardin's metaphor of the "tragedy of the commons" has become a conceived wisdom that captures the social dynamics leading to environmental degradation. Recently, "traps" has gained currency as an alternative concept to explain the rigidity of social and ecological processes that produce environmental degradation and livelihood impoverishment. The trap metaphor is, however, a great deal more complex compared to Hardin's insight. This paper takes stock of studies using the trap metaphor. It argues that the concept includes time and history in the analysis, but only as background conditions and not as a factor of causality. From a historical–sociological perspective this is remarkable since social–ecological traps are clearly path-dependent processes, which are causally produced through a conjunction of events. To prove this point the paper conceptualizes social–ecological traps as a process instead of a condition, and systematically compares history and timing in one classic and three recent studies of social–ecological traps. Based on this comparison it concludes that conjunction of social and environmental events contributes profoundly to the production of trap processes. The paper further discusses the implications of this conclusion for policy intervention and outlines how future research might generalize insights from historical–sociological studies of traps.

Keywords Social–ecological traps · Path dependency · Agricultural involution · Gilded trap · Dryland poverty trap · Lock-in trap

INTRODUCTION

Many current environmental problems, such as pollution, degradation, and resource overuse, are unintended consequences of human action. Degradation of environmental resources on which livelihoods depend is seldom intended as such, but is an outcome of the cumulative effect of people's individual behavior. "The tragedy of the commons" (Hardin 1968) is a classical metaphor that is used to capture the type of social dynamics leading to environmental degradation. The tragedy stands for instances when people fail to solve "dilemmas of collective action." These are often situations in which the use of communally owned natural resources is non-exclusive, which means that the individual gains of using these resources exceed the individual's share of the collective costs (De Swaan 1996). As long as there exists a difference between individual gain and collective costs, the rational course of action for individuals is to increase exploitation until the resource is depleted. The metaphor, and its underlying assumptions, has been fiercely criticized for its disregard of context. Ostrom's work, for example, shows that not all situations in which natural resources are commonly shared necessarily lead to degradation (Ostrom 1990). Case studies from different places in the world show that people can overcome collective action dilemmas. This means that collective action dilemmas suffer from different levels of rigidity: in some cases tragedies are unavoidable, while in others people do find ways (intentionally or unintentionally) to overcome the dilemma. Contemporary studies therefore try to identify the conditions that hamper or enable effective common property management (Agrawal 2003).

It is within this body of work that several recent studies began to pay more attention to the different levels of rigidity of collective action dilemmas that produce environmental degradation. A leading metaphor in these studies is the idea of "social–ecological traps" (Enfors et al. 2008; Stockholm Resilience Centre 2011; Steneck et al. 2011). The image highlights the unusual degree of rigidity of the interaction between social and ecological processes leading into "trap situations" once thresholds have been crossed

(Carpenter and Brock 2008; Scheffer 2009). These studies consequently focus attention to the different levels of controllability of these types of processes, and explain rigidity through the identification of causal mechanisms that link people and their environment across scales (Barrett and Swallow 2006; Barrett 2008). The multi-scalar analysis that is typical for studies of social–ecological traps usefully highlights the complexity of social–ecological systems and consequently the difficulties involved in collective management of such systems. What is currently missing in these studies is a systematic analysis of the historical origin and temporal sequence of events that produce social–ecological traps. Time and timing play a role but only as background conditions; they are not analyzed as causes that produce social–ecological traps (see also Johnson 2004). This is somewhat remarkable since both classic and contemporary social science studies clearly highlight the causal force of timing, through the conjunction of events, in the production of rigid social processes (Mahoney and Rueschemeyer 2003).

The objective of this paper is to address this knowledge gap through means of a systematic comparison of history and timing in four studies of social–ecological traps: agricultural involution in rural Java (Geertz 1963); the gilded trap in the Maine lobster fisheries (Steneck et al. 2011), the dryland poverty trap in Makanya, Tanzania (Enfors 2012), and the lock-in trap of the Western Australian agricultural region (Allison and Hobbs 2004). An empirical underpinning of the formal, abstract understanding of the dynamics of traps (e.g., Carpenter and Brock 2008) is necessary not only to understand the pathways into traps, but also to inform how governance can recognize, and possibly prevent or resolve, social–ecological traps. The question that this paper sets out to answer is therefore if and how the timing of historical events contributes to the emergence and persistence of social–ecological traps?

In answering this question the paper proceeds as follows. It will first introduce the concept of path dependency and explain how it will be used to analyze the historical–temporal dynamics of social–ecological traps. Second, it presents four within-case studies of the social–ecological traps just mentioned. Geertz' study has admittedly not yet been recognized as a study of a social–ecological trap, but this paper shows how it represents a study of social–ecological traps *avant la lettre*. The third section of this paper consists of an analysis and comparison of the case studies. The comparison is followed by a discussion and conclusion, which highlights how knowledge of timing and conjunctures can generate new insights for studies and policies trying to address social–ecological traps.

THE TRAP IS THE PROCESS

As a way into theoretical and conceptual background of this study it is useful to take a closer look at the actual workings of trap devices, such as fish traps. Although fish traps in general all work in the same way by making escape difficult through having so-called chambers, they come in a bewildering worldwide variety (Von Brandt 1972, pp. 93–104). One of the differences between fish trap devices is whether animals are trapped immediately and suddenly in a chamber, as for example, in crab traps (see Fig. 1), or whether they are trapped gradually with movement through a series of chambers, as for example, in fyke nets or weirs (see Fig. 2).

This difference in the actual working of traps can also be recognized in studies that use traps as metaphors. Most studies consider social–ecological traps as a condition from which people (almost) cannot escape. These are synchronic studies that explain the rigidity of social and ecological conditions at one particular point in time, namely after entrapment is final. The analysis invokes the image of traps that suddenly capture, such as the crab traps mentioned earlier. Instead of considering the trap metaphor as a condition, this paper conceptualizes it as a process and pursues a diachronic study of social–ecological traps. The concept of social–ecological trap in this paper thus always refers to the process of entrapment; the trap is the process, not the outcome. Traps as process best resembles the fish traps that catch fish gradually by forcing them to move through a series of chambers.

Since Heraclitus sociologists and philosophers have argued for the conceptualization and analysis of social reality as processes (Whitehead 1967 [1925]; Dewey 1922; Elias 1994 [1939]) to better account for non-optimality, inefficiency, variety, and non-linearity of social reality. A focus on process allows consideration of the dynamic of social interaction in time as causal mechanism in analyses of social–historical development. An instructive example of this idea can be found in a chapter of Elias' book *What is Sociology* (1978) where he likens social processes to "games" in order to illustrate how the interdependency between people can act as a main cause (or mechanism) in processes of structural change. The examples of simple games played by two players, and highly complex ones played by many players on different levels, are used to argue that the course of these games can never be fully controlled by any of the players involved. As the games come to include more and more players (that is, if the interdependency between people grows in processes of social interaction), the potential of the individual players to control the game decreases.

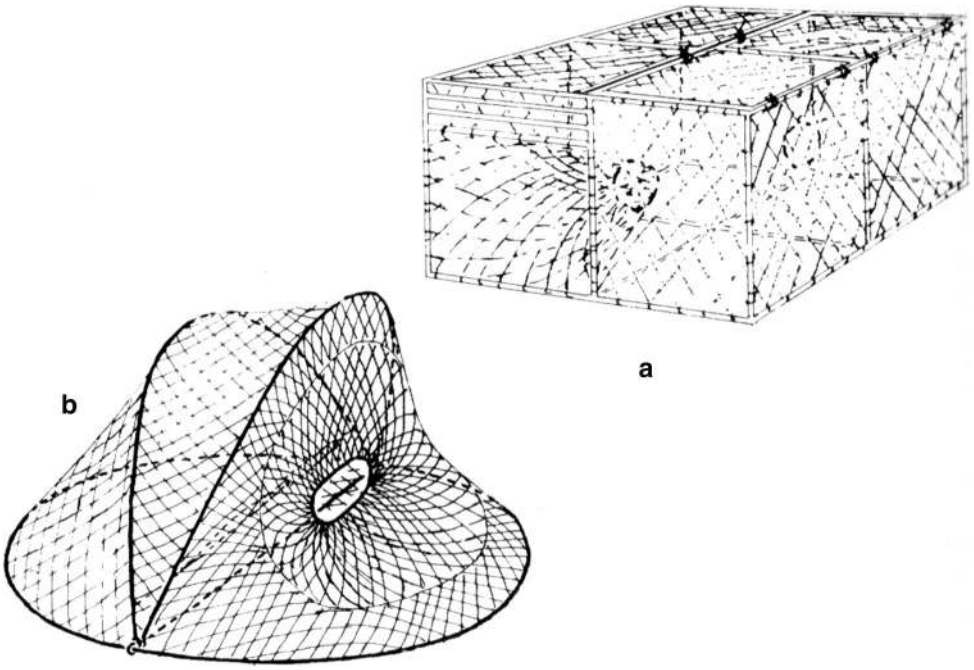

Fig. 1 Crab nets (Von Brandt 1972, p. 100)

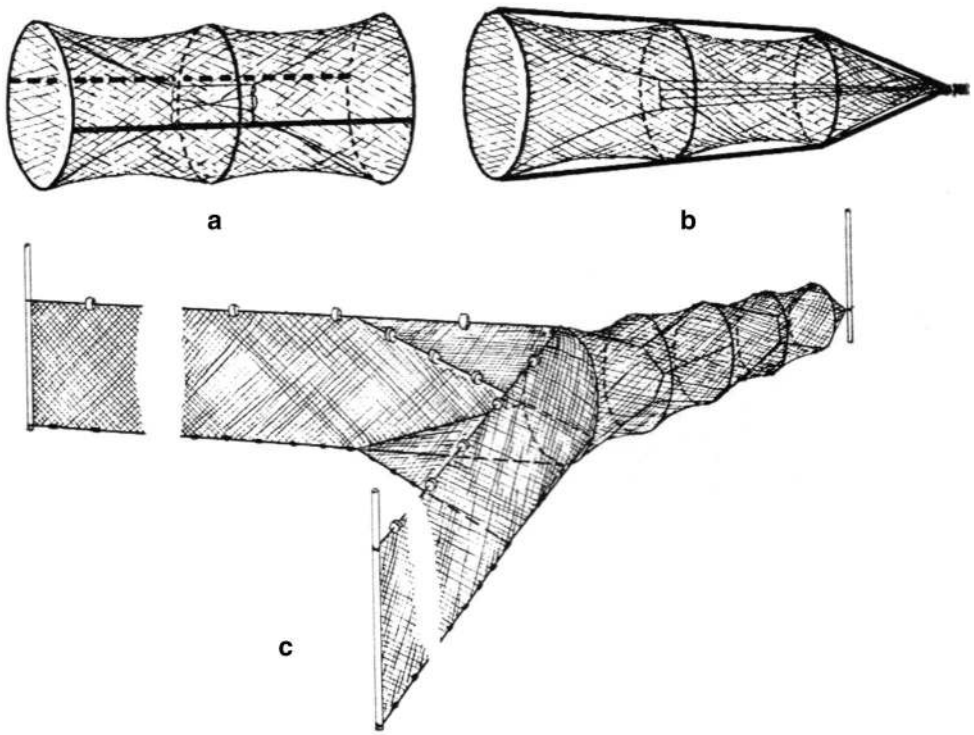

Fig. 2 Fyke nets (Von Brandt 1972, p. 101)

> Here the game gains relative autonomy from the plans and intentions of any of the individual players who create and maintain the game by their actions. […] the course of the game itself has power over the behavior and thought of the individual players (Elias 1978, pp. 75–76). [The] game process, which comes about entirely as a result of the interweaving of the individual moves of many players, takes a course which none of the individual players has planned, determined or anticipated. On the contrary, the unplanned course of the game repeatedly influences the moves of each individual player (Elias 1978, p. 95).

Elias' game metaphor insightfully captures some essential features of social–ecological traps. First of all, social–ecological traps are unplanned and unintended

processes that come into existence from the interweaving of human actions and environmental changes. Second, the process of entrapment should be attributed a causal force of itself, semi-autonomous of individual actions. Third, to be able to analyze the causal force of social–ecological traps, one needs to focus on the interdependent interactions between people and their natural environment, but also on the interdependency between episodes or phases within longitudinal social processes.

An analytical concept that can live up to these theoretical and methodological requirements is path dependency. For Mahoney (2000) a path-dependent process refers to the reproduction, or persistence, of certain phenomena in the absence of the forces that were responsible for the original production of these phenomena. According to Pierson (2000, p. 235) self-reinforcing feedback is the causal mechanism that creates path dependency.

> Each step along a particular path produces consequences, which make that path more attractive for the next round. As such effects begin to accumulate, they generate a powerful virtuous (or vicious) cycle of self-reinforcing activity (Pierson 2000, p. 253).

Ideal-typically, path-dependent processes can be characterized by a sequence of several distinct phases (Mahoney 2001). "Antecedent conditions" refer to factors in the past that determine the options available existing in later situations. During a "critical juncture" a particular option is chosen from among these multiple options. This choice triggers self-reinforcing mechanisms, e.g., institutionalization or habituation, which causes the "structural persistence" of the phenomenon. In turn, structural persistence triggers so-called reactive sequences (Mahoney 2000), which consist of a series of reactions and counter-reactions of the actors involved to the prevailing (structurally persistent) phenomena (e.g., poverty, inequality, environmental degradation, etc.). It is important to point out that the mechanisms that produce reactive sequences are not self-reinforcing mechanisms (or positive feedback) but "reactive mechanisms" who are marked by a tendency to transform or reverse the structural persistence of phenomena (see also McAdam et al. 2007). Studies of path dependency show that critical junctures, i.e., moments in time when multiple options exist, often come into existence through unintentional and unanticipated conjunctures of diverse social and ecological events.

Using Mahoney's ideal–typical structure it becomes possible to more systematically address the temporal sequence of social–ecological traps (Fig. 3), and to systematically compare these. The method used for the within-case analysis is process tracing, which is a type of social science analysis that historically links an outcome with the key events or processes that have produced it (Falleti 2006). The purpose with process tracing is thus to establish a causal chain between an independent and a dependent variable (George and Bennett 2005, p. 206), i.e., to highlight causal linkages between events in particular historical sequences (see also Goldstone 1991, pp. 50–62). The comparison between these within-case studies serves to analyze the influence of history and temporality for the establishment of social–ecological traps. To this aim the cases will be compared on two grounds: (a) the nature of the process by which a social–ecological trap reproduces itself, i.e., the mechanisms that produce self-reinforcing and reactive feedback; and (b) the historical sequence of ecological, economic, and political events, i.e., causal conjunction, and how it triggers self-reinforcing and reactive feedback.

FOUR TRAPS

The first case study of a social–ecological trap that will be analyzed with Mahoney's ideal–typical representation of a path-dependent process is Clifford Geertz' classic anthropological study *Agricultural Involution* (1963). This historically detailed study is highly interesting for the purpose of this paper since it describes how, from 1619 until 1950, the conjunction of ecological and social processes on Java, Indonesia, set into motion a gradual, deterministic process that got people trapped in poverty. Geertz' study is not only qua subject relevant; it also contains a highly useful methodology, which lends itself well for the objective of this paper. Geertz can be considered as one of the first social scientists that relied on process tracing for his analysis. Although he did not call his method process tracing—in fact he called it doing history backwards—it resembles it strongly as the following demonstrates: […]

> beginning with a picture of the general situation at a later period, […] we can try, first, to figure out how the situation characteristic of this later period could have been produced and then, second, we can see whether the […] historical evidence supports the notion that it was in fact so produced. Such a procedure amounts, admittedly, to doing history backwards. But it is doing history, not deducing logically the past from the present. It is moving from a known result to an analysis of a factually much less fully outlined process which seems to have brought the result about, in order to clarify that process and give it a more concrete content. (Geertz 1963, pp. 70–71).

As the following will show Mahoney's ideal–typical model can be used successfully to reinterpret Clifford Geertz' study of agricultural involution in Java, Indonesia.

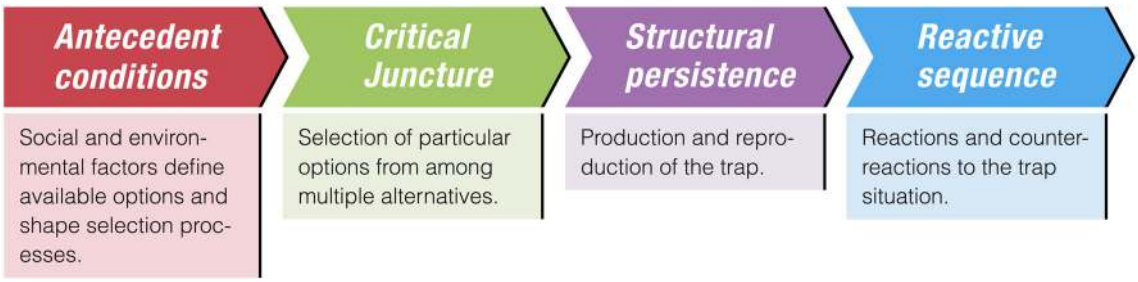

Fig. 3 The ideal–typical structure of a social–ecological trap (adapted from Mahoney 2001, p. 113)

The other three case studies, however, differ in some respects from the ideal–typical representation of a path-dependent process. But a closer look at each of the cases is needed before the usefulness of the concept of path dependency, and the differences and similarities between the cases can be discussed.

Agricultural Involution in Java, Indonesia, 1830s–1950s

> In land tenure, in crop regime, in work organization, and in the less directly economic aspects of social structure as well, the village, "hemmed in on all sides by a crystallized pattern" (to quote Goldenweiser again), faced the problems posed by a rising population, increased monetization, greater dependence on the market, mass labor organization, more intimate contact with bureaucratic government and the like, not by a dissolution of the traditional pattern into an individualistic "rural proletarian" anomie, nor yet by a metamorphosis of it into a modern commercial farming community. Rather, by means of "a special kind of virtuosity," "a sort of technical hairsplitting," it maintained the overall outlines of that pattern while driving the elements of which it was composed to ever-higher degrees of ornate elaboration and Gothic intricacy. (Geertz 1963, p. 90)

Geertz' book offers an historical explanation for the persistent poverty situation in the 1950s of rural families on Java. More precisely, it tries to answer the question why rural families on Java kept on intensifying their already highly productive wet rice cultivation instead of expanding it, or modernizing their farming styles.

The antecedent conditions that limited the possible development trajectories for Javanese rural families lie in the characteristics of wet rice cultivation, which existed since time immemorial. Wet rice cultivation on so-called *sawahs* was then and now typical for Java, while swidden agriculture was practiced in most other parts of Indonesia. A typical feature of wet rice cultivation is its extraordinary stable output. At least when rice is cultivated under irrigation, since irrigation makes it becomes possible to replenish the nutrients that were lost during the cultivation process.

> Given maintenance of irrigation facilities, a reasonable level of farming technique, and no autogenous changes in the physical setting, the sawah […] *seems virtually indestructible* (1963, p. 33).

With irrigation infrastructure in place it becomes possible to intensify the wet rice production seemingly indefinitely through either fine-tuning water supply or the perfection of cultivation techniques (e.g., using seed nurseries, pre-germination, frequent weeding, double or triple cropping, etc.). Geertz remarks that, once in place, the intensification of existing plots has a much greater marginal productivity compared to the establishment of new sawahs (Idem, pp. 31–37). The latter option requires a huge investment in preparatory labor that is not immediately productive. The elastic productivity of the sawah

> it seems almost always possible somehow to squeeze just a little bit more out of even a mediocre sawah by working it just a little bit harder (Idem, p. 35)

together with high start-up investments in labor and capital create a typical "sunk-cost effect" (Janssen and Scheffer 2004). The Javanese simply have "too much tied up in [the sawahs]" (Geertz 1963, p. 36).

However, the sunk-cost effect alone is not a sufficient explanation for the persistent poverty in which farmers on Java were caught. Geertz argues that there are two other factors, which come together and reinforce the strategy of intensification. The first factor concerns the Dutch colonization of Java that developed in three stages—the East India Company (1619–1799), the Culture System (1830–1870), and the Corporate Plantation System (1870–1942). During these stages the Dutch superimposed a plantation economy upon the Javanese subsistence economy. The capital flows of these economies were kept strictly separate, which meant that the Javanese farmer did not have access to markets beyond the immediate, regional markets

for food crops. In this "dual economy" (Idem, p. 48) labor and land necessary for the production of cash crops—sugar, indigo, coffee, and tobacco—were subtracted from the subsistence economy. The Javanese farmers made up for these losses in land and labor through even more intensification of wet rice cultivation. The second factor that Geertz identifies is population growth. From the beginning of the nineteenth century the Javanese population begins to grow from 7 million people in 1830 to almost 42 million in 1930,[1] which meant that any productivity increase through intensification of rice cultivation was almost immediately usurped by the growing number of people. In other words, the labor intensity per piece of land grew, which increased the output per area, but output per head diminished or remained constant.

Geertz marks out the 1830s as a critical juncture, since it is here that

> the Javanese economy could have made the transition to modernism, […], with more ease than it can do today (Idem, p. 82).

From 1830 three factors begin to conjunct: (a) the elasticity of wet rice production on sawahs together with its sunk-cost effects; (b) the lack of alternative economic opportunities through political oppression, i.e., no access beyond the regional subsistence economy; and (c) explosive population growth. Together they produce a process which Geertz famously calls "agricultural involution," and which can be considered an early description of a social–ecological trap:

> the overdriving of an established form in such a way that it becomes rigid […] tenure systems grew more intricate; tenancy relationships more complicated; cooperative labor arrangements more complex – all in an effort to provide everyone with some niche, however small (Idem, p. 82).

In other words, involution refers to the rigidization of social and ecological interactions, which then become a trap and substantially limit human agency.

Using the ideal–typical structure of a social–ecological trap it can be speculated that agricultural involution on Java formed an important trigger for the Indonesian struggle for independence before and after the Second World War. Interpreting the struggle as a reactive sequence makes sense since it was the explicit aim of the Indonesians to end colonial rule since they felt it kept people trapped in poverty situations. Although Geertz did not analyze the struggle for independence in this way, he did single out the colonial system as an important factor for the impoverishment of the Javanese rural population (Fig. 4).

[1] Today there are 135 million people living on Java.

The Gilded Trap in Maine Fisheries 1890s–2010s

> A gold-rush mentality, cheating, ineffectiveness of the rules, political opposition, and stock decline follow each other in an ever-more desperate downward spiral. (Acheson and Gardner 2011, p. 1014)

The metaphor of the *gilded trap*—coined by Steneck et al. (2011)—describes a situation in which fishers in the Gulf of Maine, USA, have almost exclusively come to rely on the lobster fishing. The authors show that nearly the whole regional economy in Maine depends on the availability of lobster. Alternative income sources, e.g., fishing other species or performing other type of work, are limited, while at the same time the pressure is high to earn incomes to pay off debt. Fishers are thus trapped in a lucrative (hence "gilded") lobster fishery, which involves high risks due to the likelihood of collapse of the lobster population in the near future. The marine ecosystem in the Gulf of Maine has been subject to intense fishing pressure, which not only reduced the number of fish species in the system, it also created conditions with low predation levels in which lobster populations thrived to the extent that they now dominate the marine ecosystem.

Although the authors do not explicitly refer to path dependency, they provide some historical information that can be used to the different phases of the trap process. Moreover, several other authors have provided detailed analyses of the history of fisheries and fisheries management in New England[2] (Hennessey and Healey 2000; Acheson 2003, 2011; Layzer 2006; Apollonio and Dykstra 2008; Acheson and Gardner 2011) that can also be used for this purpose. The antecedent conditions from which the gilded trap originated are a coastal marine ecosystem that had been overfished since the beginning of the twentieth century. Fishing effort was particularly high during from the 1950s to the 1970s when fishers were modernizing their vessels and when there was open-access fishery in the Gulf of Maine. Critical junctures in the history of the gilded trap can be located in the beginning of the 1980s when foreign fleets are successfully banned from American waters through the installment of the Exclusive Economic Zone (EEZ) and the Fisheries Conservation and Management Act (FCMA). Part of the FCMA was the creation of the New England Fisheries Management Council (NEFMC), a regional council whose goal is to sustainably manage the New England marine ecosystems. Moreover, bottom trawl surveys revealed the precarious situation of the groundfish stocks. This period makes for a critical juncture because here the fishers and the US government had the opportunity

[2] New England is a region in northeast USA consisting of the states Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut.

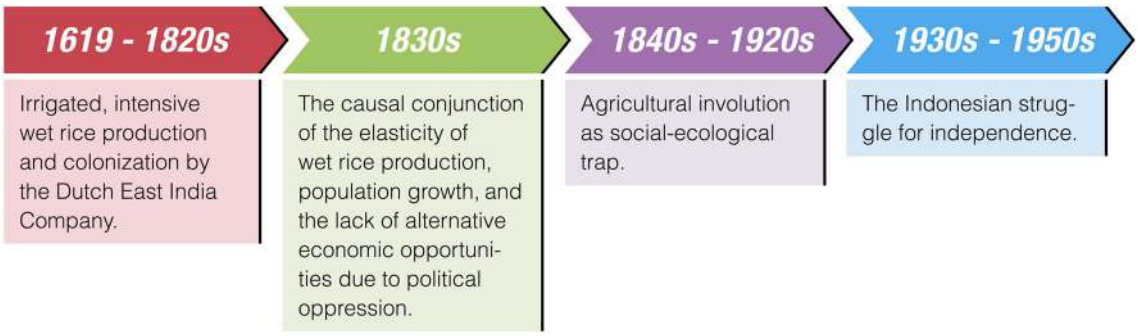

Fig. 4 Agricultural involution

to take matters in their own hands. They secured exclusive control over offshore fish stocks, developed a management infrastructure, all in the awareness that stocks were dwindling. But interests and hopes were contradicting. People from the government and fishing sector saw the exclusive U.S. jurisdiction over the offshore fishing grounds as a way to ban foreign fishing and to vitalize and modernize the domestic fleet, while marine scientists, environmentalists, and civil servants hoped that the new management structure finally would regulate fisheries and protect stocks (Healey and Hennessey 2000; Layzer 2006). The combination of these two contradicting messages—modernization and expansion of the fisheries while at the same time introducing limitations—created a "rush for permits" (Apollonio and Dykstra 2008, p. 31): 1200 fishing licenses were issued in 1977, while in 1979 the number increased to 2191—a growth of 83 % (Acheson 1984). These events are critical because they triggered the already mentioned effect of sunken investments, i.e., fishers investing in their operation and wanting a return on their investments. In the case of fishing they include both economic and social costs, i.e., investments in physical structures and equipment, as well as human capabilities acquired through expenditures on knowledge, social relations, innovation, building up trust and a "good reputation" (David 2007). The sunk-cost effect was that the Maine fishery intensified, i.e., it caught more fish per unit (e.g., hour or boat), which subsequently triggered a classic "race for fish" and illegal fishing (Acheson and Gardner 2011). The intensification of cod fishery allowed the lobster and sea urchin populations to grow since they became subjected to lower predation pressure (Fig. 5).

The reinforcing feedback between the race for fish and the growing lobster populations became structurally persistent from the 1980s into the 1990s. When coastal cod stocks became extinguished fishers begin to target more distant offshore stocks cod and other predatory finfish. This allowed the lobster populations to expand even into low quality habitats.

With groundfish populations dwindling—due to the increased fishing effort and lobsters becoming more abundant—fishers from the 1990s onwards increasingly target lobsters, also since lobster prices are relatively good. The lobster fishing is successful; the catch per unit increases steadily despite more intense fishing effort (Steneck et al. 2011, p. 906). Furthermore, through a combination of traditional local co-management arrangements and a strong conservation ethic lobsters fishers avoid illegal fishing that plagues other types of fishing in Maine (Acheson 2003). The growing importance of lobster fishing signals a switch in fishing style from an offshore, diverse fishery to a predominantly inshore, specialized fishery. In Mahoney's framework this switch can be considered the beginning of a *reactive sequence* produced by the gradual depletion of groundfish and the growing abundance of lobster. Although the lobster fishing is a way to offset the demise of the cod and haddock fishery, it does not offer the Maine fishers a sustainable alternative livelihood in the long run. Steneck et al. argue that during the 2000s the fishers are caught in the gilded trap: a radically simplified and vulnerable marine ecosystem and a highly specialized, overcapitalized fishery with limited alternative income sources. They point out that the abundant lobster is susceptible to disease, which in extreme cases can decimate the population, leaving the fishers with no alternative income. The outcome of such an ecological collapse could very well be that fishers cannot repay their debts and go bankrupt. This will of course cause much social and economic upheaval and unrest. The gilded trap has not yet closed, but escaping it will require fundamental changes, including recognition of the risks that threaten the lobster fishery and a restructuring of marine governance arrangements (Steneck et al. 2011, pp. 909–910).

The Dryland Poverty Trap in Makanya, Tanzania, 1950s–2010s

> These changes [increase in dry-spell frequency, population growth, institutional change] would probably have been manageable one by one, but combined, they resulted in a reduction in the overall

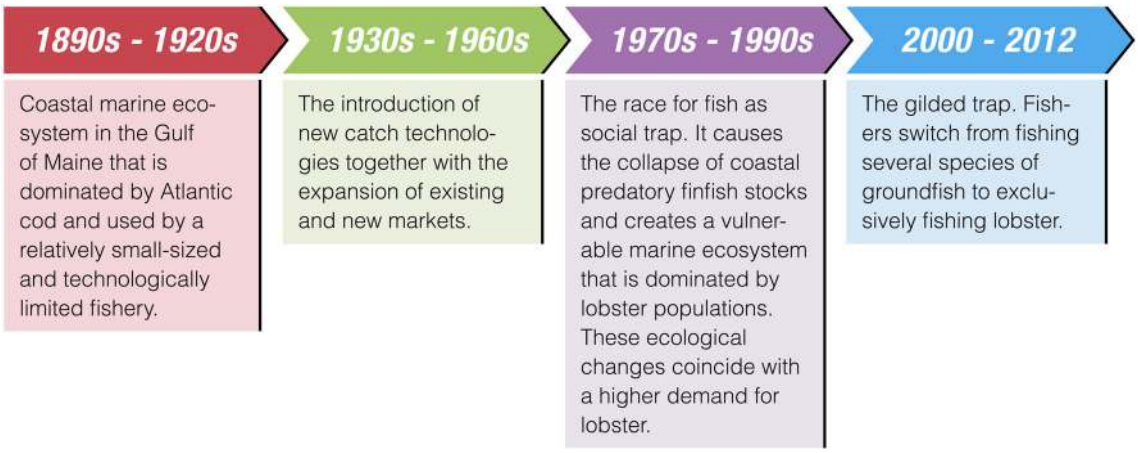

Fig. 5 The gilded trap

> adaptive capacity among farmers in the agro-ecosystem. (Enfors 2012, p. 56)

The literature on so-called "poverty traps" has grown in recent years (e.g., Barrett 2008), but often these studies do not explicitly account for the ways in which characteristics and changes in natural environments contribute to the rigidity of traps. Recent studies on the poverty traps of rural livelihoods in Makanya, Tanzania are exceptions to this rule (Enfors and Gordon 2007, 2008; Enfors et al. 2008; Enfors 2012). These scholars have tried to understand why ecosystems that these livelihoods depend on are being degraded, why efforts to raise crop yields fail and why, consequently, many people in Makanya find themselves in a situation of chronic poverty. How did this situation come into existence historically? The following analysis draws heavily from studies cited above, and especially from Enfors (2012), which reviews this literature.

The antecedent conditions that have a crucial influence on the development of the dryland poverty trap in Makanya are the soils in this semi-arid region, and the limited, bimodal rainfall. The soils are generally low on nitrogen and organic matter, which limits productivity (Idem, p. 7). Families work on small-scale farms producing maize for own consumption, and vegetables as cash crop. People also keep livestock, often as a way to invest financial surplus. To improve productivity farmers added nutrients to the soil after the cultivation according to an annual cropping cycle with an extended fallow period (Fig. 6).

This way of working changed drastically after the 1960s under the influence of several inter-related events and processes. During this time the Tanzanian population began to grow leading to a higher demand for food. Farmers responded by changing from an annual to a double cropping cycle to increase their output. The consequence of this change was that the nutrient levels of the soils could not be restored and productivity gradually declined. To make up for these losses farm families began to depend more heavily on commonly owned natural resources, e.g., fodder, wood, and vegetables from the rural landscape. These changes coincided with Tanzania becoming an independent state under President Nyerere. During this political regime shift land was nationalized, and traditional local land use arrangements were abandoned. The nationalization was followed by policies of "villagization" under the "ujamaa program." These policies replaced older institutional arrangements and in so doing created an institutional vacuum since the new leaders and rules lacked the legitimacy and trust from the rural population (Scott 1998). The result was a de facto open-access situation which led not only to overuse of common pool resources, e.g., grasslands and forests, but also their clandestine appropriation, i.e., grassland was turned into de facto privately owned farmland (Enfors and Gordon 2007). As the following will show, these political changes form the critical juncture after which a situation of rural poverty becomes structurally persistent. If these changes would not have occurred, i.e., if local institutional arrangements had remained intact, common property resources may have been more or less sustained and provided people with resources to fall back on in times when agricultural yields faltered.

Under the influence of the diminishing of common property (from 61 to 43 %) and its overuse, families again turned back to farming their land more intensively. From this point in time—the 1980s—the poverty situation becomes *structurally persistent*. Families can no longer offset declining yield with use of ecosystem services, which meant that they started to usurp previously accumulated capital and other assets, such as financial revenues, cattle, or properties. These assets were being used to buy food, which meant that they could no longer be used to compensate for the lack of moisture and nutrients in the

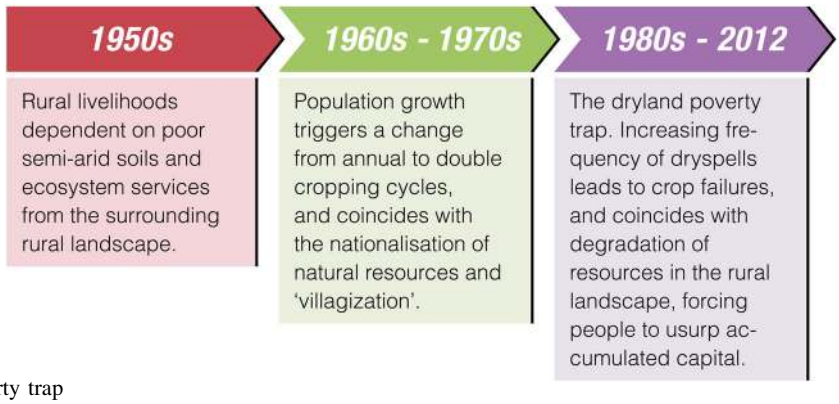

Fig. 6 The dryland poverty trap

soil. The vicious cycle of: (a) low yields leading to less food, (b) leading to farmers usurping their assets, (c) resulting in a lack of farm investments, is aggravated by the increasing frequency of dry spells during the rainy season from March to June. In conclusion Enfors (2012, p. 56) argues that the dryland poverty trap came into existence through the

> convergence during a relatively short time period during the 1960s and 1970s of the increase in dry-spell frequency, the population growth, and the drastic changes in institutions for natural resources management.

It proved to be difficult to identify a reactive sequence from the literature on the dryland poverty trap, which is why it is missing from Fig. 4. Reasons for this omission could be that the studies cited did not have the objective to investigate reactive mechanisms, or that the trap is so persuasive and persistent that it precludes any actions that can possibly lessen its grip.

The Lock-in Trap of the Western Australian Agricultural Region 1900–2003

> This state we have labeled "lock-in" which, in economics, describes an industry that has so much "sunk-costs" that it may continue to degrade the resource it relies upon until the capital is totally removed. (Allison and Hobbs 2004, p. 15)

This case study describes changes in land use in the agricultural region in Western Australia (WA). Results of the study have been published in Allison and Hobbs (2004). Today the region is characterized by broad acre agriculture, which uses more than 90 % of the total land use in the area. These farms are based on large-scale cropping of oilseeds, cereals, and pulses. Historically the area used for broad acre used to be much smaller, but it grew so large through the removal of native vegetation, which currently amounts to less than 10 % of the total land area. Allison and Hobbs argue that the farmers working in the region are trapped, due to a combination of reduced economic returns and declining yields. How did this situation come into being? (Fig. 7).

Prior to the end of the nineteenth century the region was not used for (commercial) agricultural use; it was covered by forests, woodlands and scrubs and very rich in biodiversity. Southwestern Australia has a Mediterranean climate, with a wet winter and dry summer. The soils are typically sandy and nutrient poor but also include lateritic soils rich in iron and aluminum. This situation gradually changed with the settlement of farming families beginning in the 1880s. From this time to the Second World War the agricultural area grows from a small 3 to 50 % of the total area. The establishment of farms and expansion of agricultural area, through the removal of native vegetation, was politically supported primarily through the construction of railroads. Legal regulation, such as the Homesteads Act (1883) and Land Act (1898) allowed families to claim and own property. The agricultural expansion slows down during 1929–1945 when the Great Depression and Second World War result in declining commodity prices. This period also coincides with several droughts.

The end of the Second World War makes for a sharp break with the previous period—*a critical juncture*. Technological and scientific developments in agricultural production (e.g., fertilizers, machination, etc.) coincide with low prices for inputs (e.g., fuel, labor), and government regulation that is prioritizing the expansion and intensification of agricultural production through farm amalgamation and subsidies. It is here that history could have taken a different turn. Just as in many other governments of high-income countries, agricultural science and extension, farm unions and farmers actively pursued to "modernize" agriculture. This so-called "modernization project" (Van der Ploeg 2006) includes: (a) mechanization, i.e., the substitution of human labor with the work of machines, which greatly improves possibilities for the expansion of agricultural production; (b) intensification, i.e., increasing the output per production unit (e.g., hectare or animal); and (c)

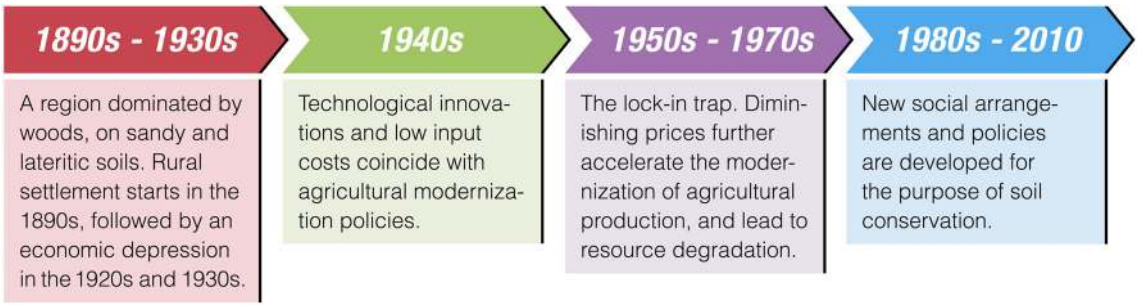

Fig. 7 The lock-in trap

specialization, i.e., the process whereby farmers only produce one type of commodity (Hardeman and Jochemsen 2012). As Piore and Sabel point out in their book "The Second Industrial Divide" (1984) the modernization of farming and industries was not the only possible development trajectory. Just after the Second World War many farms and firms were still organized through so-called craft labor and flexible production processes. However, these sources for an alternative trajectory became quickly marginalized when the above-mentioned agricultural modernization became *structural persistent*. Land was turned into farmland with increasing speed; it grew from 50 to 90 % of the total area in WA agricultural region. Allison and Hobbs argue that during this period of structural persistence that lasted from the 1950s until the 1970s farmers of the region got "locked in" since farm modernization transformed the region's ecosystem. The removal of vegetation changed the region's microclimate and hydrological cycles causing water tables to rise, leading to salinity, flooding, soil erosion and degradation and lower biodiversity. To offset these negative effects and maintain productivity scientists, extension officers, and farmers initially searched for solutions in technological fixes, i.e., investments in fertilizers or new crop varieties. Technology use is often subject to self-reinforcing tendencies because farmers (just as other people) consider prior investments when making decisions and tend to stick with prior choices because they do not want to lose the capital they invested (such as knowledge, social networks, labor, etc.)—the "sunk-costs effect" (Janssen and Scheffer 2004). Or, alternatively, perhaps a farmer at an earlier stage has started to use a high-yielding variety that ripens uniformly and can be harvested all at once. In order to enjoy the benefits of a uniform and all-at-once yield she needs to use modern harvesting technology. These are "compatibility effects" (Van der Ploeg 1991, pp. 214–218; Scott 1998, p. 267).

There were other factors as well that contributed to the rigidization of farm modernization. Since the 1960s wool and wheat were overproduced, which led to a structural drop in price of these commodities on global markets. Moreover, the region experienced severe droughts from 1969 to 1979. All in all these events put farmers under continuous pressure to produce more to cope with rising costs of production as well as declining economic returns. Under these pressures farmers started to try out alternative solutions during the 1980s–2010s. New social arrangements developed such as the *Australian Conservation Foundation* (1988) and *Land Care* (1990) that included both farmers and environmentalists, and aimed to reduce salinity. Furthermore, different policy programs began to actively target the environmental problems coming from farm modernization, such as the *National Soil Conservation Strategy* (1983), *Conservation Through Reserves Program* (1970s), and the *National Plan for Salinity and Water Quality* (2000). Using Mahoney's scheme these initiatives can very well be understood as a reactive sequence that follows upon the structural persistence of farm modernization and environmental degradation. Whether or not farmers in the agricultural region of WA indeed are able to free themselves from the "lock-in" trap remains a question.

DISCUSSION: TRAPS COMPARED

As Pierson (2004, p. 21) remarks path dependence refers to developmental trajectories that are inherently difficult to reverse, or change. There seems thus a logical connection between path dependence and social–ecological traps from the start. But the affinity goes deeper. All four cases of traps exhibit the causal components typical for a path-dependent process: (a) the particular conditions that started the trap (the antecedent conditions and critical juncture), and (b) the general process through which the trap reproduces itself (structural persistence) (Mahoney 2001). These two components together constitute the causal role that history plays in producing trap situations (Pierson 2004). It is important to consider in detail how it was possible to locate the beginning of the trap process at a specific point in time, i.e., why the trap solidified at a particular point in time rather than earlier or later. Systematically addressing this question helps to avoid the problem of infinite regress, and avoids turning analysis of path dependency in a "just-so story."

The problem of infinite regress means that there is always some earlier causal factor in a historical process, so which reasons can analysts use to identify this first historical set of causes in a path-dependent process (Pierson 2004, p. 89)? Pierson (2004) suggests that the first causal component (the antecedent conditions and critical juncture) can be recognized through its relative openness compared to the later historical sequence after a critical juncture. One way to locate this openness is using counterfactual reasoning (Weber 1949 [1904]) to identify a phase in the history of a social–ecological trap where a trap would not have developed if certain events or causal factors were not present. Using counterfactual reasoning it is possible to identify antecedent conditions in all four cases. Geertz explicitly locates a critical juncture in agricultural involution in the 1830s when three factors conjunct: (a) the elasticity of wet rice production on sawahs together with its sunk-cost effects; (b) the lack of alternative economic opportunities through political oppression, i.e., no access beyond the regional subsistence economy; and (c) explosive population growth. As Geertz remarks, "before this point in time the Javanese peasants could have transformed their livelihoods *with more ease than* [they] *can do today*" (Geertz 1963, p. 82). In the case of the New England fishery, for example, the US government and fishers had the opportunity just after foreign fleets were banned from the GOM to prevent the gilded trap by immediately imposing limits on fishing effort and access to the fishery. At this point in time more than one outcome (a trap) was possible. This openness quickly disappeared, however, when contradicting aims of fisheries management during that time—modernization and expansion of the fisheries while at the same time introducing limitations—created a rush for permits and expansion of fishing power. Likewise, Enfors also highlights conjunction as a critical juncture during the 1960s and 1970s when an increase in dry-spell frequency, population growth, and institutional change starts the entrapment of small farmers in Makanya. She also highlights that things could have been different in the beginning of a path-dependent process when she talks—albeit in abstract—about alternative development trajectories in social–ecological systems (Enfors 2012, p. 53). It proved to be most difficult to locate antecedent conditions and a critical juncture in the case study of the Western Australian Agricultural Region. Secondary literature on agricultural and industrial development in high-income countries (Piore and Sabel 1984; van der Ploeg 2006; Hardeman and Jochemse 2012) suggests a critical juncture just after the Second World War when these countries had the opportunity and will to modernize their agricultures.

The second risk with accounts of path-dependent processes is that they easily turn into "just-so" stories.

> It just happened that this happened first, then this, then that, and it is not likely to happen that way again (Goldstone 1998, p. 833).

To prevent this one needs to move beyond the outcomes of single case studies and try to generalize. Scholars of historical sociology do this through the identification of causal mechanisms. Pierson (2004, pp. 30–40), for example, identifies three types of mechanisms that produce path dependency: institutional density and design; authority and power asymmetries; and the complexity and opacity of collective action. Mahoney (2000, p. 517), on the other hand, distils from the literature four different types of explanations of path dependency: *utilitarian, functional, power*, and *legitimation.* The study in this paper adds to these lists social–ecological mechanisms that highlight how specific natural conditions interact with human resource use. Perhaps this point can be best illustrated with Geertz' agricultural involution. In his analysis he emphasizes the ecological qualities of the *sawahs* to explain why the Javanese peasants continue to opt for the intensification of cultivation as a response to increasing pressures from institutional and demographic change. An almost reverse situation is found in rural Tanzania (the dryland poverty trap) and Western Australia (the lock-in trap) where the biological and physical conditions of the soils in both regions limit possibilities of farmers.

The ultimate objective with historical analysis and the identification of causal mechanisms is of course to elucidate how traps can be prevented or reversed. One clear outcome of the comparative study in this paper is that the *how* depends crucially on the *when*, i.e., how traps can be prevented and resolved depends on their rigidity—i.e., the specific phase they are in. Possibilities for human intervention can possibly be improved when taking account of the opportunities and restraints of historical processes. It should, in other words, adapt to the temporal dynamics of the trap process, e.g., possibilities for agency and management are greater just before a critical juncture than later down in the sequence of a path-dependent process (Gelcich et al. 2010).

Notwithstanding the usefulness of these insights, more research is needed to further generalize findings. First of all, it is still unclear how and to what extent human agency is instrumental in either the establishment or the prevention of tragedies and traps. The comparison in this study cannot differentiate very well between structural factors and proximate factors (Geist and Lambin 2002), probably since the case studies presented here are referring to very different time scales. As a general rule, a study focusing on the short-term is better equipped to identify proximate factors, such as social actions of specific individuals, than studies of the long-term. The reverse holds true for structural conditions. This problem is somewhat inherent to

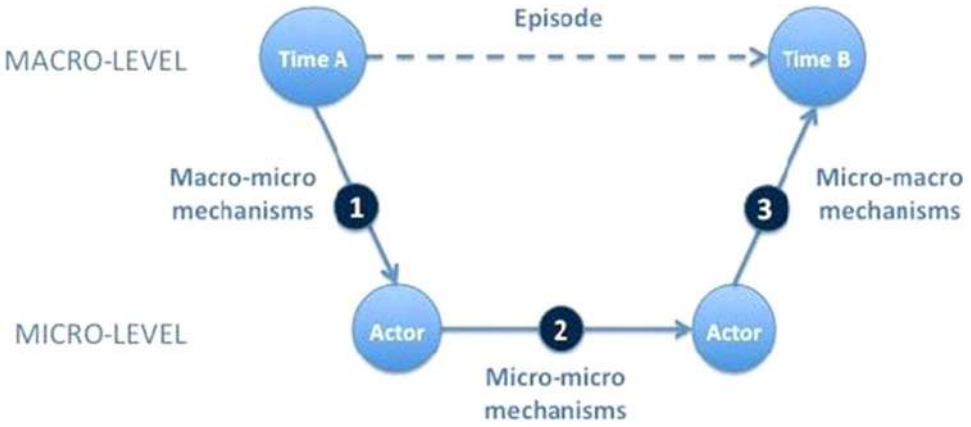

Fig. 8 Schematic representation of the temporal relations between macro and micro social processes (adapted from Coleman 1990, p. 8; Hedström and Ylikoski 2010, p. 59)

current conceptualizations of path dependency; it is frequently criticized for being either too deterministic (Huber and Stevens 2001), too contingent (Schwartz 2004), or both (Thelen 1999, 2003). A possible solution to these problems seems to lie in what Mills (2000 [1959]) has called the "sociological imagination"—understanding the intersecting of biography and history—and that would require an analysis on different timescales. Path-dependent sequences are a macro-level property, i.e., collective outcomes that are not reducible to (the sum of) single entities at the microlevel (Hedström and Ylikoski 2010). Causally explaining these trajectories therefore requires a description of social interactions in time and space, and how these are interdependent with the macro-sociological, path-dependent trajectory in which they are embedded. As the debate on path dependency shows, not explicating this interrelation will run the risk of reinforcing the macro–micro dichotomy and all the drawbacks associated with it (Giddens 1984). One possible way of showing how different types of mechanisms both reproduce and change path-dependent trajectories is through the so-called Coleman's boat (Fig. 8). Coleman's boat clearly shows that legacies of past interactions between people and their natural environment shape the structure of opportunities currently existing (macro–micro mechanisms, see Fig. 8). It also refers to how present interactions shape (both stabilize and transform) conditions for future interaction in the trajectory (micro–macro mechanisms, see Fig. 8).

A full awareness of these intersections between history and biography can help to accept and locate the limits of human agency and management, but without leaping back to structuralistic and deterministic analysis. The literature on traps refers to this macro–micro interdependency as "nested traps" (Platt 1973) or "fractal (poverty) traps" (Barrett and Swallow 2006), but focusses exclusively on hierarchical system scales, and does not include timescales.

The last issue that needs more study is the difference between so-called self-reinforcing and reactive mechanisms, and their respective roles in path-dependent processes. Mahoney (2000) makes this distinction to highlight that self-reinforcing mechanisms induce further movement in the same direction that over time become more difficult to reverse. The importance of this type of mechanisms in producing path dependency and trap situations is beyond doubt. A clear example of a self-reinforcing, or positive feedback mechanism is the *sunk-cost effect* that featured in agricultural involution, the gilded trap as well as the lock-in trap of the Western Australian agricultural region. The importance and role of reactive mechanisms is, however, debated (see Pierson 2004; Schwarz 2004). According to Mahoney (2000) reactive mechanisms are chains of temporally ordered and causally connected events, where each event in sequence is both a reaction to the antecedent event and a cause of a subsequent event (see also Platt 1973, p. 647 on the "invisible chain"). The difference with a self-reinforcing pattern is that in a reactive process events do not reinforce early events, but on the contrary, reactive sequences backlash processes that transform and reverse early events and thereby set into motion a chain of (counter) reactions. Needless to say, history also here has a crucial and causal effect upon future developments. The case study comparison highlights several reactive sequences. Although Geertz does not argue this, the Indonesian independence war can be understood as a reactive sequence triggered from the structural poverty situation of the Indonesian population. Likewise, the institutional and policy changes during the 1980s in Australia that target the erosion and salinization of farm land, can be understood as a reactive sequence triggered by the rigidity and counterproductivity of farm modernization starting from the 1950s. For the dryland poverty trap no reactive sequence could, however, be identified. It seems that the occurrence of reactive sequences depend much on human agency. It would be highly informative to closer study these sequences because they can perhaps highlight the circumstances, which allowed people to overcome the rigidity of social–ecological traps.

CONCLUSION: HISTORY MATTERS

Traps and tragedies are members of the same family (Platt 1973). They point towards a range of problems that can be understood as unintended outcomes of collective social behavior. One of the most pressing global problems of this kind is degradation of resources and the environment on which communities dependent for their wellbeing. Both metaphors are used to describe and explain this problem, and typical for both is their overtly deterministic quality; they result in inevitable, unpleasant, and sometimes lethal, endings.

But there are also some crucial differences. The tragedy of the commons is a simple model based on a utilitarian sociology of human behavior and static social and ecological conditions. The only things changing in Hardin's example are the size of the herd and the gradual impoverishment of the pasture (Hardin 1968). Traps are a great deal more dynamic. Platt (1973) already pointed at the variety of traps depending on the number of people involved, but also highlighted that that history matters:

> Which pattern [cooperation or conflict] is obtained seems to depend critically on the outcome of the first few plays (Platt 1973, p. 645).

While Platt still assumed people to be primarily utility maximizers, scholars nowadays use his concept to understand outcomes of complex human-environment interactions featuring much more realistic conceptualizations of human and social behavior as the case studies in this paper highlight.

The objective of this paper has been to show that the concept of traps indeed has the potential to account for the historical dynamics of collective action dilemmas. These types of dilemmas often suffer from strong path dependency (see Pierson 2004, pp. 31–34) as the application of the concept on the four different case studies made clear. Nevertheless, most studies of social–ecological traps are still not historical enough, i.e., they continue to treat history and timing as just one more background variable in the analysis. Indeed, history matters, but how remains unclear. To address this hiatus, the paper has systematically compared the historical sequences of four different social–ecological traps with the analytical concept of path dependency. The comparative analysis shows unmistakably the causal importance of conjunction (in time) of social and ecological events. Typically these conjunctions can become "critical junctures" which subsequently trigger the structural persistence (or rigidization) of certain social–ecological dynamics. A logical conclusion from this observation would be that human intervention (e.g., management or governance) need not only to adapt to scale but also to time.

To conclude, this paper should be considered as a first effort to explicate history's role in the establishment of social–ecological traps. Many questions of course remain about the causal interrelation between structural and proximate factors, or the precise contribution of reactive sequences in the establishment and/or prevention of traps. But hopefully there is no doubt after reading this paper that history is more than just "one damned thing after the other." Knowing the effects of timing and history is of crucial importance not only for understanding but also possibly preventing and solving social–ecological traps.

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