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SPECIAL FEATURE: ORIGINAL ARTICLE

Networks of Action Situations in Social-Ecological Systems Research

# Understanding the governance of sustainability pathways: hydraulic megaprojects, social–ecological traps, and power in networks of action situations

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## Abstract

To enable sustainability pathways, we need to understand how social–ecological systems (SES) respond to different governance configurations, considering their historical, institutional, political, and power conditions. We advance a robust methodological approach for the integrated analysis of those conditions in SES traps. Our advancement consists of a novel combination of the networks of action situations approach with an agency-based polycentric power typology and the concept of discursive power. We test the approach by building on previous research on the Doñana estuary–delta SES (Guadalquivir estuary), which is characterized by a rigidity trap in the context of ecosystem and water governance. Specifically, we focus on a recent hydraulic megaproject involving deep dredging in the Guadalquivir estuary, finally canceled due to its broad negative socioeconomic and environmental repercussions. According to our analysis, certain governance, institutional, and informational mechanisms currently prevent further SES degradation in Doñana. However, key governance actors are caught in a lasting coordination failure prone to mutual defection strategies owing to power dynamics and discursive-institutional inertia. Although seemingly stable due to counteractive mechanisms among actors, this situation is at continuous risk of being unbalanced by powerful actors promoting large SES interventions such as deep dredging. Such interventions bear the systemic risk of strong suppression of SES functions, and a regime shift to a lock-in trap. This overall undesirable situation might be escaped through transformative policy designs that take into account meso-level mechanisms, such as discursive power and its role in non-decision-making, pragmatic inaction, and inefficient investment and infrastructure.

**Keywords** Water resource governance · Sustainability pathways · Social–ecological traps · Agency-based power · Discursive power · Networks of actions situations

## Introduction

Sustainability pathways have become more urgent than ever to safeguard our life-support systems (Coloff et al. 2021; Folke et al. 2021; UNEP 2021; Ely 2022). Understanding

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the role of governance in change processes towards sustainability is critical at both empirical–theoretical (how does current change happen) and normative (how change ought to happen) levels (Berkes 2007; Patterson et al. 2017; Turnheim et al. 2018; Donges et al. 2021; Pickering et al. 2022). However, despite growing attention in the last decade, the understanding of the role of governance and its underlying processes remains underdeveloped (Muñoz-Erickson et al. 2016; Patterson et al. 2017; Kellner 2021; Orach and Schlüter 2021; Muiderman et al. 2022; Rocha et al. 2022). In particular, interventions to foster sustainability pathways must reflect on how social–ecological systems (SES) respond to different governance configurations, considering their local arrangements of actors, institutions and power, and historical legacies (Clark and Harley 2020).

Here we contribute to fill the gap in the literature regarding the role of governance and its underlying processes in fostering change towards sustainability, with a particular focus on SES traps (Holling et al. 2002; Carpenter and Brock 2008). We define governance broadly as the processes through which actors create the conditions for social coordination, resource allocation, sharing power and making policy (based on Folke et al. 2005). SES traps are processes of involution of social–ecological interactions (Boonstra 2016), driven by strong feedback loops "with negative outcomes for people and/or ecosystems" (Cumming 2017). We deal with two SES traps: the rigidity trap (Herrfahrdt-Pähle and Pahl-Wostl 2012; Enqvist et al. 2016; Stedman 2016; Méndez et al. 2019) and the lock-in trap (Allison and Hobbs 2004; Boonstra and de Boer 2014). Rigidity traps are characterized by a mutual reinforcement of power, politics, and profit through the recurrent application of command-and-control approaches (Holling and Meffe 1996) for resource and ecosystem management. Eventually, these features hinder potential for change, diminish SES resilience (i.e., the capacity of a SES to absorb change and disturbance and avoid a regime shift to undesirable sets of processes and structures), and promote strong dependence on limited sets of resources (Gunderson et al. 1995; Holling and Meffe 1996; Walker and Salt 2006; Cox 2016). In a lock-in trap, the economic sectors bear high sunk costs and so risk degrading SES functions and the resource base until capital is totally removed, thus dramatically diminishing economic returns, resource yields, and overall potential for socioeconomic change (Allison and Hobbs 2004). We assume that the rigidity and the lock-in traps exist in an evolutionary continuum, whereby if the former is pushed enough against resilience thresholds, it can enter a self-reinforcing dynamic leading to a lock-in trap and so suppresses the potential of change toward more favorable situations (based on, e.g., Gunderson et al. 2017; Reyers et al. 2018; Dornelles et al. 2020).

A general goal of SES traps studies is to understand the causal mechanisms underlying the degree of rigidity or lock-in of social situations producing environmental or resource degradation (e.g., Steneck et al. 2011; Méndez et al. 2012; Enfors 2013; Haider et al. 2018). In the past decade, increasing focus has been directed to analyzing the role of historical, discursive, political, and power phenomena in the emergence and persistence of traps (e.g., Beier et al. 2009; Chapin et al. 2010; Méndez et al. 2012; Wrathall et al. 2014; Enqvist et al. 2016; Laborde et al. 2016; Baker et al. 2018; Graziano et al. 2019; Schlüter et al. 2019). However, within current research, there is still a lack of systematization of the interweaving influence of such phenomena over historical configurations and their outcomes (Méndez et al. 2019). Advances are still challenged by the intractable nature of different power forms (Boonstra 2016; Morrison et al. 2019; Avelino 2021). A methodological engagement with the effect of power as a property of both actors and structures vis-a-vis historical, institutional (Boonstra 2016; Dewulf et al. 2019) and discursive (Méndez et al. 2019) dynamics can help uncover richer sources of resilience and transformative capacities in entrapped SES.

In this article, we explore a methodological approach to integrate historical, institutional, discursive and power factors for enhanced explanations of the governance configurations of SES traps. Specifically, we combine three different concepts: (1) the "Networks of Action Situations (NAS) approach" (e.g., McGinnis 2011a; Kimmich and Villamayor-Tomás 2019; Möck et al. 2019; Basurto et al. 2020; Kimmich et al. 2022 this issue); (2) the "polycentric power typology" (Morrison et al. 2017, 2019; Mudliar 2020); and (3) "discursive power" (Clement 2010). To test the approach, we build on a long-term social–ecological research program in the Doñana region, an estuary–delta SES (Guadalquivir estuary, SW Spain). The Doñana SES is stuck in a rigidity trap characterized by path dependence, strong command-and-control management of water resources, the historical loss of key SES functions, a pronounced development vs conservation paradigm, and lack of mechanisms to facilitate learning from management failures and environmental crises (Méndez et al. 2012, 2019; see also perspectives from, e.g., Martín-López et al. 2011; Fernández-Delgado 2017; Green et al. 2017). Our proposed approach is tested on a recent hydraulic megaproject in the Guadalquivir estuary (henceforth "estuary megaproject"), and as such, brings an entirely new analytical effort to the Doñana research program. As we show below, the megaproject constituted a large intervention bearing a substantial risk of pushing the Doñana SES to a lock-in trap, thus hindering sustainability pathways. Although finally canceled, important lessons can be derived from the megaproject using counterfactual reasoning (Boonstra and de Boer 2014): what if deep dredging, a disturbance of catastrophic magnitude, had been implemented? Why and how did it take almost two decades for it to be canceled? Under which governance configuration would it

have operated? Given the above context, our exploratory aims were:

- Methodological aim: to advance a novel approach that integrates rigorous institutional and power analysis via combining three conceptual components: the NAS approach, the polycentric power typology and discursive power.
- Research aim: to refine the explanatory mechanisms underlying Doñana's rigidity trap, to assess the risk of a lock-in trap and the prospects for fostering a sustainability pathway.[1]

Next, we describe our methodological approach, including our unit of analysis (estuary megaproject), the conceptual components used and the methods employed to operationalize such components. We then present our results in narrative form, followed by our discussion and conclusions.

## Methodological approach

### Unit of analysis: the estuary megaproject—the port awakens

The research presented here constitutes a third iteration of the Doñana long-term social–ecological research program, which follows an iterative adaptive inference protocol (based on Holling and Allen 2002; see details in S1). As described above, our unit of analysis is the Guadalquivir estuary megaproject: a major hydraulic intervention for improving the maritime access to Seville's inland port, promoted by the Port Authority in 2000 as part of its broader 2020 Strategic Plan. After several years of shallow dredging, the estuary megaproject proposed, among other measures, deeper dredging of the Guadalquivir estuary (Fig. 1) to allow for heavy-ship navigation, based on the assumptions that (1) the best development alternative for the port was to increase freight traffic and to make the port accessible for larger and higher tonnage ships (e.g., deeper draft vessels), thus improving its connection to the Trans-European Transport Network (SPA 2013); (2) this infrastructure development would be key for socioeconomic development at provincial level (e.g., generation of thousands of jobs; increasing cruise tourism) (Vargas and Paneque 2015; Donadei 2020).

However, deep dredging posed large negative socioeconomic and environmental impacts (Vargas and Paneque 2015), as identified through a study led by the Spanish Research Council (CSIC study hereafter; CSIC 2010). This study showed poor environmental and ecological conditions in the estuary (e.g., biochemical pollution; high organic matter content and turbidity; non-stratified water body leading to habitat reduction and decreased potential for fishing activities). Two main conclusions from the study were (1) overall resource optimization for both the socioeconomic and conservation sectors is not possible—especially in the current scenario of climate change; (2) the cumulative impacts from deep dredging could worsen the environmental situation and socioeconomic prospects (CSIC 2010). Moreover, the assumption of socioeconomic development resulting from new infrastructures and enhanced maritime tourism and trading has been convincingly argued as very speculative (Sancho-Royo and Del Moral 2014, 2015; Vargas 2014; Vargas and Paneque 2015). The megaproject was finally canceled by the Spanish Supreme Court in 2019.

A key insight from previous research provides the basis for our current approach in this iteration. Doñana's SES "stability landscape" (Walker et al. 2004) is characterized by the path-dependent rigidity trap (current domain) plus the lock-in trap and a sustainability pathway (alternative domains) (Fig. 2). The fast development of irrigation and rice agriculture between the 1950s and the 1980s reduced the original marshland surface area by ~ 80% (Fernández-Delgado 2017). This process of natural capital destruction could have driven the Doñana region directly into a lock-in trap (Allison and Hobbs 2004). Instead, a rigidity trap with higher potential for change materialized due to the creation of the Doñana National Park in 1969, thanks to the innovative action of an international coalition of institutional entrepreneurs (Fig. 2) (Méndez et al. 2012)—also envisaged as a process of "ecological diplomacy" (Camprubí 2020). In this conception, the estuary megaproject appears as a disturbance posing (again) a risk of a regime shift to a SES lock-in trap, which has less potential for change due to high sunk and trajectory-shifting costs (Fig. 2).

### Conceptual components

#### Networks of action situations: a systems-based application

The action situation is a core component of actor-centered, pluralistic institutional analysis frameworks focused on understanding the micro-level of natural resources governance problems (Anderies et al. 2004; Hagedorn 2008; Pahl-Wostl et al. 2010). Here, we conceive an action situation as an analytical component, in the rational-choice tradition of the Institutional Analysis and Development (IAD) framework (Ostrom 2005), as the social space where: (1) policies or institutions are designed or developed by actors engaged in strategic interactions at multiple levels (operational, collective-choice and constitutional); (2) the patterns

[1] This research has been designed to inform the development of the policy analysis task of eLTER Research Infrastructure (https://elter-ri.eu/).

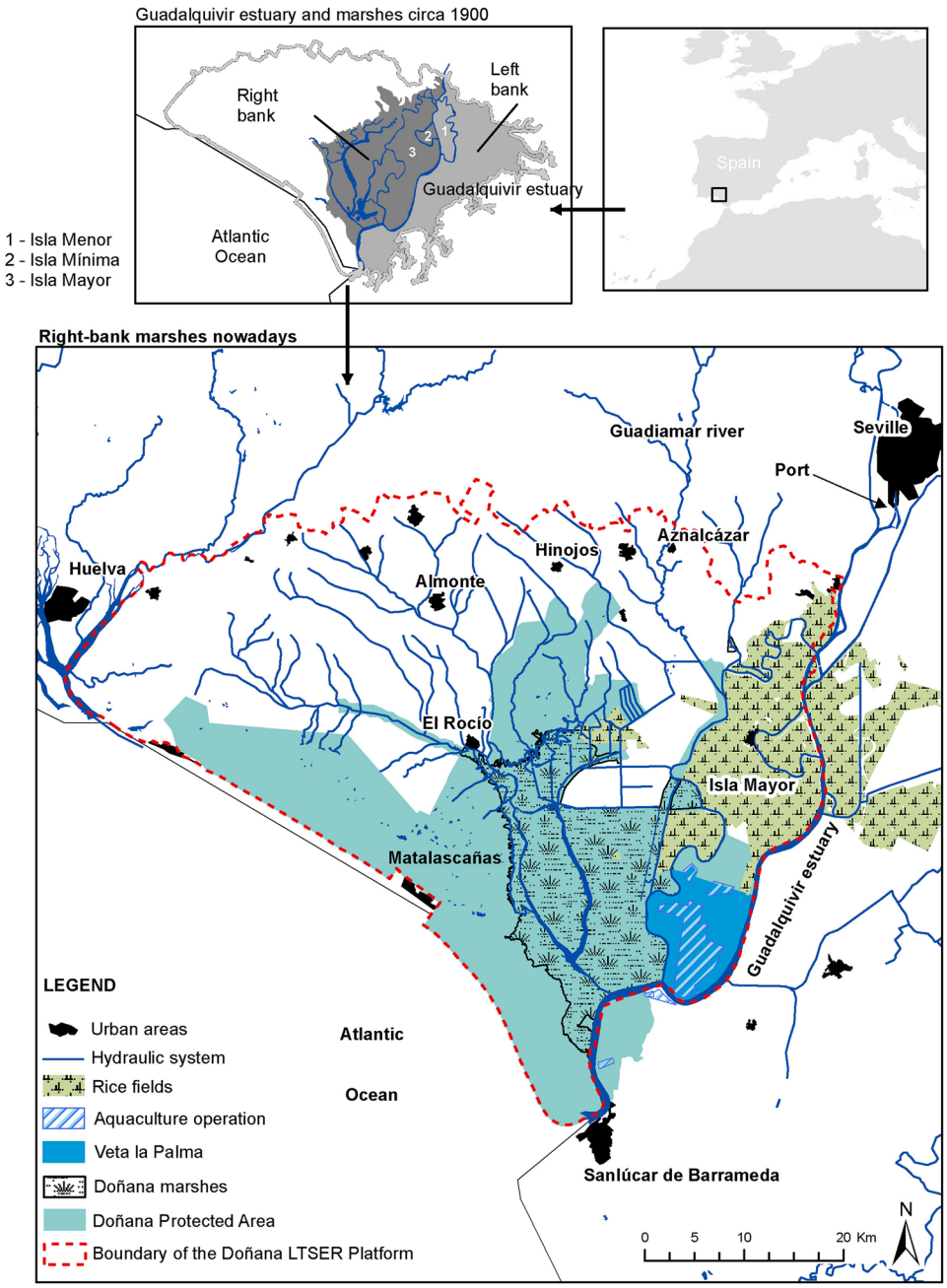


**Fig. 1** Geographical location of the Doñana social-ecological system and the main elements characterizing our unit of analysis (estuary megaproject) (modified from Méndez et al. 2019, under a Creative Commons CC BY-NC 4.0 International License)

of interactions, plus the decisions made and actions taken, shape certain internal or external outcomes associated with different payoffs for the different participating actors; (3) such outcomes feedback into the action situation and its context, potentially changing them and shaping future dynamics (based on Ostrom 2005; McGinnis 2011b). The action situation is a strong analytical device for seeking explanations within place-specific settings, addressing their biophysical, institutional, and cultural conditions (Ostrom 2005).

Recently, scholars have started to apply a relational perspective by applying a network of action situations (NAS) approach to analyze how and when situations affect each other, thus stretching the explanatory power of the action situation component (McGinnis 2011a; Möck et al. 2019; Kimmich et al. 2022 this issue; Srigiri and Dombrowsky 2022). Formally, a network of action situations (NAS) constitutes an array of action situations differing in, e.g., degrees of proximity, function, and the game into which they theoretically fit (McGinnis 2011a; Kimmich 2013). More generally, four types of links across the NAS can be distinguished (Kimmich 2013; Hoffmann and Villamayor-Tomas 2022 this issue): biophysical transactions; information; institutions; and actors involved. The application of the NAS approach involves two initial steps: (1) the definition of a "focal action

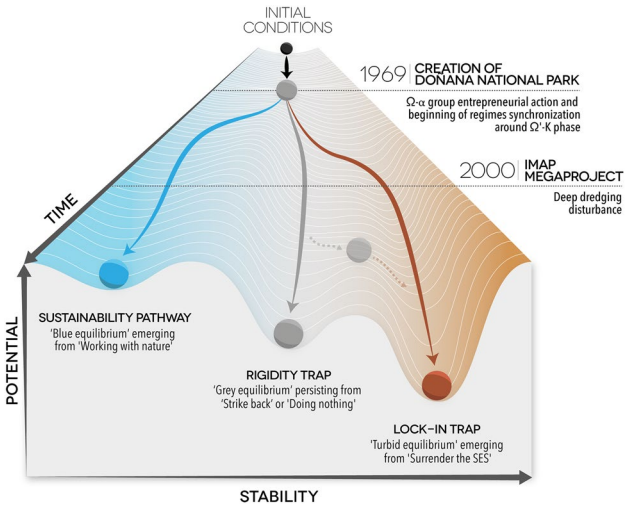


**Fig. 2** Landscape of stability domains of the Doñana social-ecological system (SES) (inspired by figure in Bennett et al. 2021), including: the rigidity trap (grey trajectory; intermediate potential for SES change) as the current domain, and the lock-in trap (brown trajectory; lowest potential for SES change) and sustainability pathway (blue trajectory; highest SES potential), as alternative domains. The creation of Doñana National Park appears as an event that prevented the fall to a lock-in trap in 1969 and resulted instead in the realization of a rigidity trap; the estuary megaproject appears as a counterfactual event that might have led to a lock-in trap. Design credits: Sistèmika (Silvia Jiménez Izquierdo and Sonia Rodríguez Martínez)

situation" (FAS) and the "adjacent action situations" affecting it; (2) the identification of the strategic games that might be at play, thus helping to unravel the foundational structure of dilemmas, conflicts, or coordination problems (Kimmich and Villamayor-Tomás 2019). The NAS-linked game models help to understand outcomes (e.g., equilibria) which would otherwise remain unexplained (McGinnis 2011a; Kimmich 2013).

Here, we used the micro-level NAS approach keeping a meso-micro analytical tension to connect logically with the Doñana research program. The latter works at meso-level, aggregating institutional, discursive, and power mechanisms to explain processes and outcomes at SES level (e.g., SES traps), and deals with the macro properties of path dependence. Indeed, both emergence from bottom-up interactions and systems-to-micro effects are crucial to understand causality in SES (Schlüter et al. 2019). Path-dependent SES traps constitute an emergent phenomenon that results from micro-level actor interactions embedded in macro- or system-level trajectories (Boonstra and de Boer 2014). To that end, Boonstra and de Boer (2014; based on Elias 1978) propose game concepts to capture the essential features of path-dependent SES traps. Over time, player interactions shape the course of a game, each course gaining in autonomy over initial player choices in an unanticipated way, and which then repeatedly influences the future moves of individual players (Boonstra and de Boer 2014).

### A power typology

Power, both endogenous and exogenous to actor-centered phenomena, is increasingly being analyzed to understand its role in resource and environmental governance (Clement 2010; Theesfeld 2011; Epstein et al. 2014; Kashwan 2016; Morrison et al. 2017; Bennett et al. 2018; Brisbois et al. 2019; Cole et al. 2019; Mudliar 2020). Here, concerning the analysis of power relationships and dynamics, we drew on two conceptualizations: "discursive power" (Clement 2010) and the "polycentric power typology" established by Morrison et al. (2017, 2019; see Table 1). The discursive power notion was introduced into the IAD framework by Clement (2010) to systematize the analysis of how power shapes the decisions of actors located in action situations, factoring in the political-economic context. From a discursive power perspective, discourses hold a capacity to reinforce or undermine the credibility and legitimacy of institutions, and so are constitutive elements that can confer/drain power to/from institutions (i.e., discourses have power on their own) (Clement 2010). In a dynamic two-way interaction, discourses can mobilize power and function as drivers of policy and institutional dynamics, with actors' values, interests, and beliefs

**Table 1** Polycentric power typology (Morrison et al. 2017, 2019; Mudliar 2020), including discursive power (Clement 2010) as a fourth type

| Type of power | Description |
|---|---|
| Power by design | Power written in rules and incentives. Formal authority with capacity to make rules, allocate resources, undertake structural adjustment, redesign markets and administrative structures, to tax, and regulate resource use and externalities. Includes legal power, political power and administrative power |
| Pragmatic power | Discretion associated in implementing rules. Includes cooperation as well as false compliance, feigned ignorance, tokenistic behavior, non-decision-making, inability, and reluctance of formal government to implement policies, and lack of compliance |
| Framing power | Actors construct frames to manipulate, persuade, induce, sanction, and coerce the contest of top-down decisions and present them as illegitimate to subvert, disrupt, and avoid formal rules |
| Discursive power | Discourses exercise power by influencing how actors perceive reality and by constituting their interests and preferences. They also exercise power by limiting the range of institutions and policy options perceived as possible and acceptable |

built in. In turn, power dynamics are shaped by the political–economic context and the pre-existing institutional practices in which they are embedded (Clement and Amezaga 2013).

The polycentric power typology allows for a closer examination of the power-laden conditions and various power sources enabling actors to fulfill their interests and achieve their goals (Morrison et al. 2019). Using that typology (Table 1), we sought to complement our use of discursive power in previous research (Méndez et al. 2019) with agency-based theories of power. By combining these two conceptualizations of power with the NAS approach, we sought to explore the role of power in explaining strategic interactions among actors. In our view, whilst discursive power allows the capture of power phenomena not easily attributable to a specific group of actors, the polycentric power typology allows the capture of actors' agency and, notably, their capacity to influence the way environmental problems are framed and thus to change/reinforce discourses. Here, the strengths of the polycentric power typology were leveraged in the context of a command-and-control paradigm. This paradigm was inherited from previous authorities, and it continues to imbue the current multiple governing authorities operating at different levels in Doñana.

### Methods: operationalizing the conceptual components

To operationalize our conceptual components, we followed two main steps. First, we collected information to build a historical profile of the estuary megaproject between 2000 and 2019. This was done through a critical review of (1) key primary sources for direct evidence and historical data, and (2) secondary sources for interpreted evidence and context found in similar research (see sources consulted in S2). Second, we performed our core analytical task by probing the historical profile and concurrently constructing a qualitative narrative for reporting our results. To maintain a systems perspective and meso–micro tension in our exploratory exercise, we decided a priori to identify and apply game-theoretic logics to the core FAS situation (micro-level), and to perform a more descriptive analysis of its adjacent NAS dynamics (meso-level). Third, drawing on discursive power and the polycentric power typology, we analyzed power relationships over the whole NAS, letting the required meso–micro tension to arise ex post. Analysis and narrative construction proceeded through a cyclic recursive process of information collection, interpretation, and inference (Yin 2018). Our focus was on (1) interactions within and between action situations, and how and why such interactions might influence SES outcomes, and (2) the risk of regime shift to a lock-in trap and the prospects for a sustainability pathway at Doñana SES level. Our procedure borrowed from the analytic narrative approach (e.g., Levi 2004), in that it specified how the narrative was assembled, and contributed to explanation on a par with game-theoretic language and the empirical material against which the proposed games were evaluated (Mongin 2018).

## Results

Our narrative first presents the identified Focal Action Situation (FAS), its linked Network of Action Situations (NAS) and the initial conditions of the analysis. The narrative then provides an analysis of the games that best approximate the strategic interactions among FAS actors and their interweaving with NAS dynamics. The narrative finishes with the power analysis using the polycentric power typology and discursive power.

### Focal action situation, linked network of action situations and initial conditions—the lock-in menace

The FAS was composed of three main organizational actors at operational level (i.e., directly affecting or affected by the estuary megaproject): Port Authority ($A_1$), Rice Growers ($A_2$) and Nature Stewards ($A_3$) (Fig. 3). Nature Stewards encompassed actors with similar interests in preserving healthy ecosystem processes and functionality in the Guadalquivir estuary (e.g., fisheries sector), the Doñana marshes (e.g., National Park) and Veta la Palma (e.g., sustainable aquaculture operation) (see Fig. 1 for geographical location and S1 for further description). Those actors are represented here mainly by the World Wildlife Foundation (WWF) and in key governance structures such as the Doñana Participation Council. The FAS was then linked to a NAS composed of six main action situations. Closer to the FAS, at collective-choice level, we identified three specific action situations: water planning ($AS_{wp}$), knowledge generation ($AS_{kg}$) and governance ($AS_{govc}$). At a higher constitutional level, we identified three broader action situations operating top-down: government ($AS_{gov}$), ruling ($AS_{rul}$) and supranational authority ($AS_{sup}$). See Fig. 3 for detailed descriptions.

Analysis concentrated on the period 1985–2000. In 2000, the estuary megaproject proposed four major measures (SPA 2013):

1. The construction of a new lock through enlarging the old lock that connected the estuary and the commercial quay.
2. Deep dredging of the estuary to increase its depth (from 6.5 to 8 m on average) and width (from 60 to 90 m on average) along the whole course of the navigable canal.
3. Maintenance of the deep dredging for 20 years.

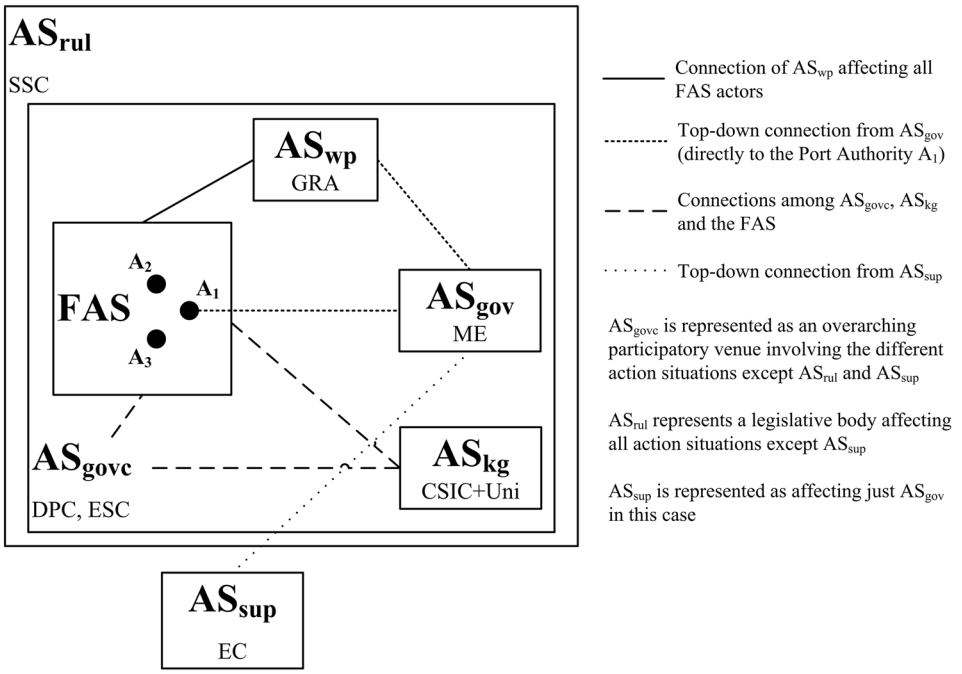


**Fig. 3** Focal Action Situation of the estuary megaproject, linked Network of Action Situations, main interrelationships and actors' descriptions

**FAS** A1, A2, A3 — **Focal Action Situation** – Main actors:
- Port Authority ($A_1$): state body in charge of Ports' development, planning and management, and promoting and regulating trade activities
- Rice Growers ($A_2$): key socioeconomic sector focused on rice cultivation and storage, no processing industries, farmers operating as a Rice Federation, within Cooperatives for common grain storage and under Integrated Farming standards
- Nature Stewards ($A_3$): encompass actors with a similar interest to preserve healthy ecosystem processes and functionality in the Guadalquivir estuary, the Doñana marshes and the Veta la Palma aquaculture lagoons. Represented here mainly by WWF and through the Doñana Participation Council

**ASgovc** DPC, ESC — **Action Situation, governance** – Main actors Doñana Participation Council (DPC) and the Estuary Scientific Commission (ESC): the DPC is a regional government body in charge of ensuring compliance with conservation and environmental legislation and planning within and around Doñana's protected areas. Reports about activities in other sectors affecting conservation, public use and water quantity/quality. Advises scientific research programs. Role of ESC described in main text

**ASkg** CSIC+Uni — **Action Situation, knowledge generation** – Main actors CSIC and universities (CSIC+Uni): in our case, in charge of filling key gaps in the knowledge base used to support the 2003 Environmental Impact Assessment decision — most notably the impacts of deep dredging on biodiversity and ecosystems

**ASwp** GRA — **Action situation, water planning** – Main actor Guadalquivir River Authority (GRA): a state body with formal authority to allocate resources, develop new infrastructure, undertake infrastructural adjustments and regulate resources use within the Guadalquivir River Basin. Depending to a great extent on the central government Ministry of Environment

**ASgov** ME — **Action Situation, government** – Main actor central government Ministry of Environment (ME): formal authority to enact environmental policies and legislation for water resources, biodiversity, climate change, forests, energy, demographics, etc. Direct management over the Hydraulic Public Domain, thus overseeing River Authorities

**ASrul** SSC — **Action Situation, ruling** – Main actor Spanish Supreme Court (SSC): highest legal authority on jurisprudence in Spain, in charge of deciding about annulment, review appeals and lawsuits against members of state bodies

**ASsup** EC — **Action Situation, supranational government** – Main actor European Commission (EC): executive of the European Union (EU), with formal authority to initiate EU's legislation (e.g., directives) that must be transposed by member states and taking action against states failing to comply with EU law

4. Auxiliary infrastructure (e.g., new bridges, port infrastructure, road and rail communication network).

For our analysis, the relevant measures were (1) the new lock, named "Sea Gate," and (2) the "deep dredging measure" (DDM; never implemented). These measures are

now subsequently contraposed to (1) the status quo "shallow dredging measure" (sqSDM; subcontracted by the Port Authority for maintenance since 1985), and (2) a potential sustainability pathway.

Before 2000, the FAS actors seemed to have co-existed in a quite stable pattern of strategic interactions. This stable state was characterized by a local use of water resources that (arguably) did not imply net short-term deterioration of overall quality, nor an excessive withdrawal by any single actor that significantly reduced availability for others. We argue that this was due to existing infrastructure, governance and institutional mechanisms that contributed (and still contribute) to the minimization of impacts and the de-escalation of conflictive situations. Key mechanisms included (based on Del Moral 1991; González-Arteaga 2005; Méndez et al. 2019; See also SES boundaries in S1):

- A massive hydraulic-irrigation infrastructure that allows for command-and-control water management across sectors.
- The coordination of estuary water intakes required for rice cultivation with (1) salinity wedge control through managed freshwater discharges from upstream and headwaters dams, and (2) maintenance shallow dredging.
- The aquaculture operation, which has the ability to control water quality through sluice gates and internal recirculation.
- The protection of the Doñana marshes both legally and physically through surrounding natural levees and artificial embankments equipped with sluice gates.
- Governance bodies such as the Doñana Participation Council, through which conflicts, if not resolved, are at least made explicit and liable to closer inspection.
- No destabilizing large megaprojects or developments in a region already saturated by hydraulic infrastructure and that was probably close to its limits in terms of agricultural economic yield.

Subsequently, three pertinent insights were gained. First, the FAS stable state characterized water resources/wetlands governance and the rigidity trap in Doñana to a large extent pre-2000, and it currently remains the status quo, as DDM was never implemented. We thus conjecture that: pre-1985 the three FAS actors were (and still are) enmeshed in a rather regularized pattern of expectations and strategic interactions posing no immediate risk of large irreversible socioeconomic impacts or environmental degradation in the short term. Second, in 1985, sqSDM gave the Port Authority a first-mover advantage and increased the probability of DDM, thus setting the initial conditions to destabilize the FAS state. Third, in 2000, DDM posed a looming systemic risk at SES level, jeopardizing a stable situation with higher potential to achieve a sustainable pathway in a less costly way than (counterfactually) a world where DDM had been implemented—probably leading to a lock-in trap. We termed this situation "grey equilibrium" (see game-based description below). Prompted by these insights, we applied our game-theoretic NAS approach and power analysis.

## Focal action situation games and network of action situations dynamics—a knowledge hope

### A pattern of uncooperative behavior (2000–2010)

We merged the estuary megaproject's historical profile with our description of NAS dynamics, to show such dynamics vis-a-vis key influencing events and linkages (Fig. 4). We identified three relevant cycles characterizing NAS dynamics (we describe the most important linkages; for further details see Fig. 4):

1. A governance cycle (2000–2007) that originates in $AS_{govc}$, triggered bottom-up by the prescriptive report of the Doñana Participation Council rejecting the estuary megaproject ($\delta_2\iota_1$, $AS_{govc}$), and the participatory decision to create the Estuary Scientific Commission ($\delta_4$, $AS_{govc}$). The cycle closed with the commissioning of the CSIC study ($\delta_5$, $AS_{kg}$).
2. A government cycle (2010–2014) that originates in $AS_{gov}$, triggered by the publication of the CSIC study ($\delta_6\iota_2$, $AS_{kg}$), which set into motion national ($\delta_7$, $AS_{gov}$) and supranational ($\delta_9$, $AS_{sup}$) governmental reactions in response to the study plus formal complaints from Nature Stewards (e.g., $\delta_8$, FAS).
3. A final ruling cycle (2015–2019) triggered by the inclusion of DDM in the two subsequent Guadalquivir River Water Plans of 2013 ($\delta_{10}$, $AS_{wp}$) and 2016 ($\delta_{14}$, $AS_{wp}$), both of which entailed sentencing against such inclusion by the Spanish Supreme Court in 2015 ($\delta_{13}$, $AS_{rul}$) and 2019 ($\delta_{16}$, $AS_{rul}$), respectively.

The entry point for our analysis was the informational-institutional linkage $\delta_6\iota_2$ created between $AS_{kg}$ and the FAS through the 2011 CSIC study (Fig. 4). With such linkage absent, the FAS, between 2000 and 2010, seems to fit a one-shot game of conflict. Here defection and free riding on estuary water resources were the chosen behaviors of the Port Authority, and such behavior was passively supported by the River Authority through its water planning functions, $AS_{wp}$ (Fig. 4). The game approximates a prisoner's dilemma where the Port Authority sets an action course (defection strategy) to its own advantage, choosing to maximize economic targets irrespective of the strategies of the Rice Growers and Nature Stewards. Between 2000 and 2010, those two actors also had their own defection strategies—which, to the best of our knowledge, they still have in 2022. Rice Growers had

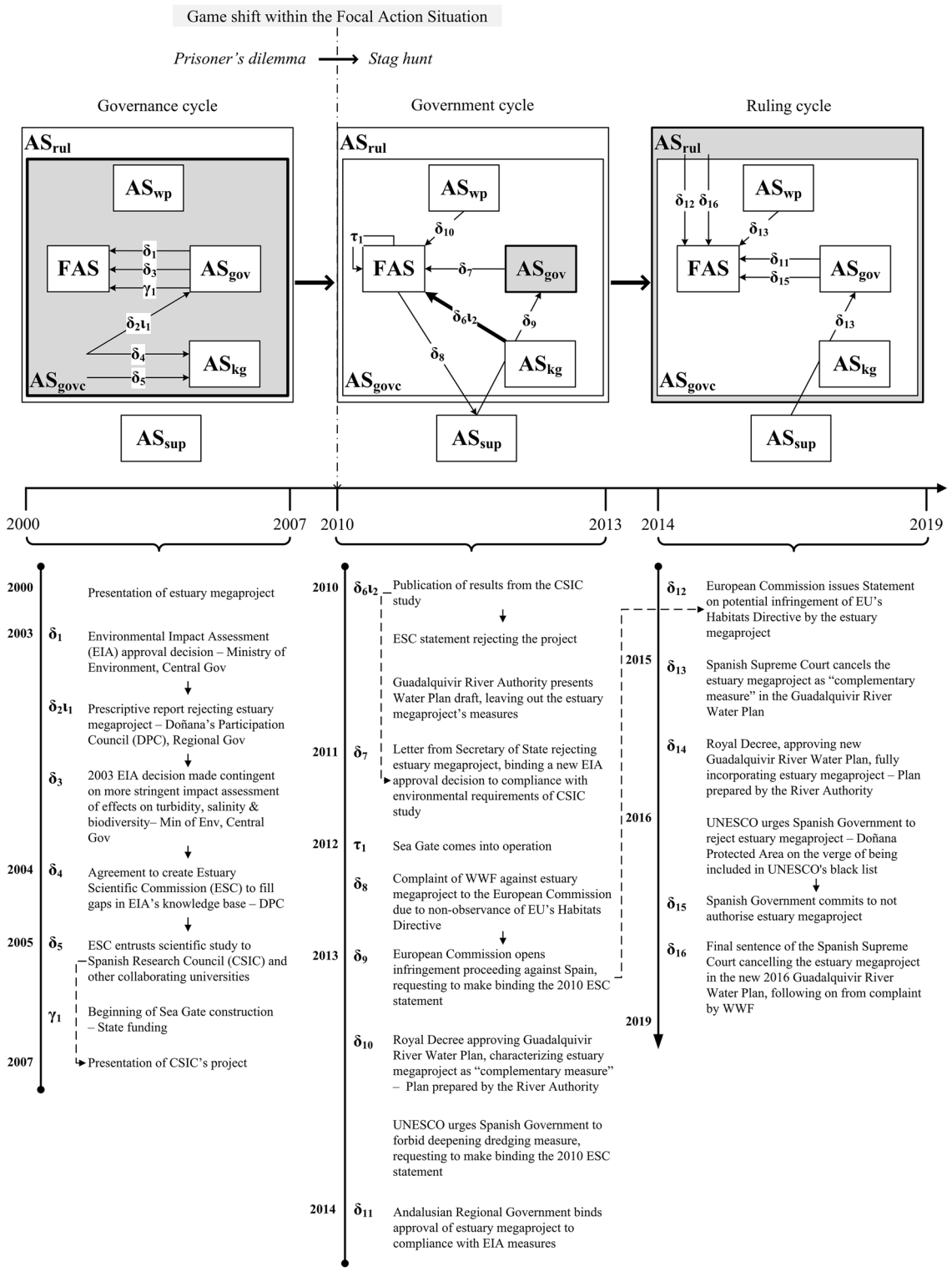


**Fig. 4** Dynamics of the Network of Action Situations of the estuary megaproject vis-à-vis the megaproject's historical profile. Such dynamics evolved between 2000 and 2010 through three relevant cycles (governance, government and ruling) and resulted in a major shift in the underlying rules of the game within the Focal Action Situation after 2010

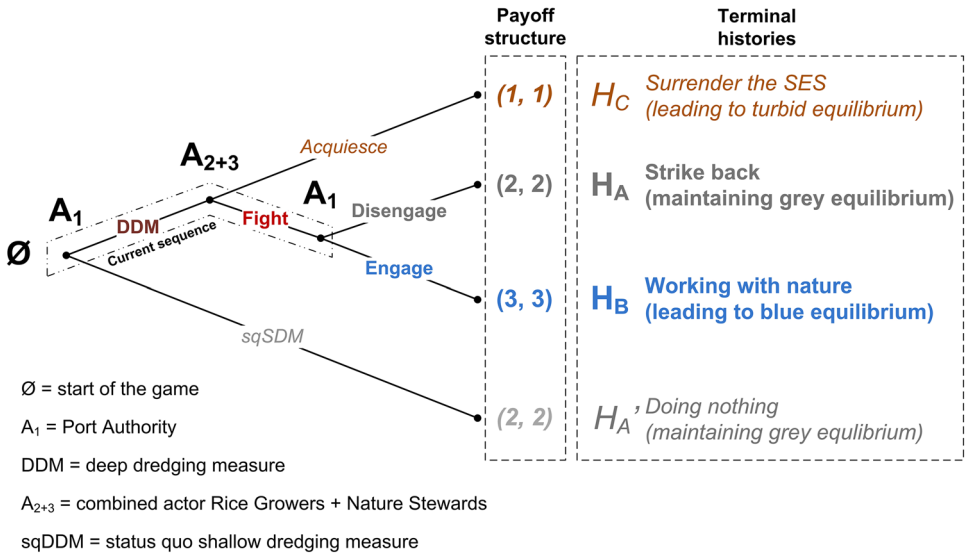


**Fig. 5** Stag-hunt game model of the Focal Action Situation in extensive form. The game progresses from the start of the game (Ø) to four terminal histories describing the sequential structure of actors' decision-making. The differing preferences of actors are represented by the structure of their payoff functions for each of the terminal histories, which can be characterized by three outcome equilibria: turbid equilibrium (achieved by the Nature Stewards "surrendering the SES"), grey equilibrium (maintained by the Port Authority "striking back") and blue equilibrium (characterized by all actors "working with nature")

a strong lobbying power to achieve the construction of an alternative hydraulic megaproject granting water resources upstream of the Port or from other basins. Nature Stewards had the capacity to isolate wetlands and the aquaculture operation from the biophysical conditions in the estuary via engineering means (e.g., sluice gates, see S1).

In this situation, the prospects for cooperation and keeping the status quo "grey equilibrium" were limited. But the relevance of this analysis does not lie in how well the situation adjusts to a prisoner's dilemma, but in how the estuary megaproject appears to have concurrently induced three things. First, the launch of the megaproject caused the (somewhat hidden) "grey equilibrium" to emerge in 2000. Without the megaproject's launch, such an equilibrium might have gone unnoticed for either the playing actors or any external observer. Second, the realization of that equilibrium induced an unstable prisoner's dilemma, making the Port Authority's overall development strategy highly vulnerable. The other two players became rapidly aware of the risk posed by the Port Authority's first-mover advantage, and the Nature Stewards in particular chose to fight back throughout the NAS governance cycle (Fig. 4). Third, this fightback stance made possible the CSIC study, which then induced a game shift in 2011.

In 2011, the CSIC study ($\delta_6\iota_2$, $AS_{kg}$, Fig. 4) and additional studies questioning the assumptions of socioeconomic growth underlying the estuary megaproject changed the underlying rules of the game. We argue that, in 2011, the FAS actors entered a coordination game resembling a stag-hunt (assurance) game (Fig. 4, game shift) (see, e.g., Mielke and Steudle 2018). As we show below, the stag hunt continues to reflect the prisoner's-dilemma situation (i.e., propensity to defect from the "grey equilibrium"), but it also reflects two other equilibria that would have not materialized in the absence of a knowledge input such as the CSIC study. The latter shifted a situation dominated by imperfect information and possible payoffs from the actor's defect strategies, to a more informed situation with the potential to achieve a higher equilibrium dominated by risk—but also more rewarding if considering overall socioeconomic welfare at SES level. However, as we show next, this situation was characterized by a coordination failure among actors—a failure that, to the best of our knowledge, still characterizes the situation in 2022.

### An escapable coordination failure (2011–2019)?

We reflect on our argument about the game shift using an extended-form game model (Fig. 5; shift also marked in Fig. 4). To simplify our causal interpretation, we combined Rice Growers and Nature Stewards into a single actor $A_{2+3}$, but diagnosed separately their different interests, behaviors, and influence over SES outcomes. The differing preferences of actors are represented by the structure of their payoff functions (Fig. 5), for which there seem to be three outcome equilibria. Each equilibrium results from a respective terminal history describing the sequential structure of decision-making from the start of the game Ø (Fig. 5):

- "Strike back" ($H_A$): the Port Authority chooses to "disengage" from the rest of actors, hence precluding the finding of a coordinated SES-level solution. Such a choice thus means a proactive role in keeping the status quo "grey equilibrium" which shows intermediate payoffs (2,2) associated with past prisoner's-dilemma-like strategic interactions. This equilibrium situation keeps open the possibility of "fight" responses from both the Nature Stewards (hard responses) and Rice Growers (lukewarm responses, due to their plan B megaproject). In game-theoretic terms, actors continue their uncooperative behavior and "choose" to hunt hare to secure a more certain gain, i.e., the "grey equilibrium" is payoff dominant. This equilibrium also reflects on a terminal history in which the estuary megaproject was never put forward, i.e., "doing nothing" beyond sqSDM ($H_A$').
- "Working with nature" ($H_B$): the Port Authority chooses to "engage" with the other actors to find a coordinated solution at SES level. This choice, therefore, means a potential collective bet to coordinate the achievement of a "blue equilibrium" showing the highest payoffs (3,3). This equilibrium situation would arise from new strategic interactions emerging in the FAS and spreading to, or facilitated by, its linked NAS, to secure a robust sustainability outcome and pathway. Here, we do not discuss in detail the governance configuration or policy instruments required for the "blue equilibrium," but use it as a likely future scenario in which we speculate that all actors would be better off—although not without taking certain risks. Indeed, if the actors coordinate, they "choose" to hunt stag and seek riskier long-term gains at SES level: the "blue equilibrium" is, therefore, risk dominant.
- "Surrender the SES" ($H_C$): the Nature Stewards choose to "acquiesce" to the estuary megaproject and DDM is implemented. This choice thus means a below sub-optimal "turbid equilibrium," potentially showing the lowest payoffs for all actors (hunt precluded). Based on existing evidence (see main text and S1), we assume that in this equilibrium situation: the purported socioeconomic benefits of the estuary megaproject are highly speculative and are not achieved; the Rice Growers manage to lobby effectively for a new megaproject granting their required resources but in doing so create similar allocation issues elsewhere; the estuary ecosystems become highly degraded; and the protected wetlands remain disconnected from their natural dynamics; therefore, failing to achieve their original hydro-ecological functions.

The peripheral terminal histories $H_C$ and $H_A$' reflect on counterfactual decision events, with $H_C$ representing an unlikely, but still possible scenario. For our explorative research here, two central histories, $H_A$ and $H_B$, are the most relevant, as they reflect on the actual sequence of decision events and the likeliest potential outcomes of the stag-hunt game (Fig. 5). These two outcomes are both Nash equilibria: players choosing to hunt stag and move towards the "blue equilibrium" risk that other players choose not to cooperate and hunt hare (risk dominance); non-cooperating players maintain the "grey equilibrium," foregoing potential payoffs of successful stag hunts whilst securing a lower payoff (payoff dominance) (Skyrms 2008). Therefore, in terms of best response strategies, the decision sequences leading to $H_A$ and $H_B$ are "strategies from which no one finds it unilaterally convenient to deviate" (Conte and Paolucci 2002, p.52).

As argued above, the FAS, between 2000 and 2011, was configured around the "grey equilibrium," stabilized by a series of governance and institutional mechanisms that certainly come with advantages to prevent further SES degradation. The "grey equilibrium" is, however, characterized by a fragile stalemate among actors underlain by a sub-optimal payoff structure that, with a sufficient disturbance level (e.g., DDM), can develop into a below-sub-optimal outcome ("turbid equilibrium"). Such a shift could lead to a tighter and more reactive command-and-control of water resources for two reasons. On the one hand, the shift might entail higher risks and uncertainties posed by uncharted biogeochemical and physical conditions in the estuary. On the other hand, the "turbid equilibrium" would have resulted in an asymmetric social dilemma in water appropriation. Such a result would see a shift from non-consumptive to consumptive water use by the Port Authority, due to the net quantity subtraction implied in increased freshwater discharges from headwater dams to control for the quality (e.g., salinity and turbidity levels) required by the other actors. The Rice Growers, however, were already lobbying for their own alternative megaproject (defect strategy) for provision/allocation from upstream waters (Vargas 2014). If materialized, such a megaproject would probably have created subtractability problems and new dilemmas with upstream actors. For the Nature Stewards, the impacts would have been mixed. For example, concerning the Doñana marshes, DDM would have entailed a higher uncertainty for the decision to fully reopen them to natural dynamics (see S1). In relation to the estuary's ecosystems, it would have been disastrous (see CSIC study). Regarding the aquaculture operation, it would have entailed a medium risk, due to its capacity to recirculate water inside the operation to control for quality (see S1).

If looked at through a purely rational-choice game-based lens, the sub-optimal and stalemate "grey equilibrium" seems to emerge, with actors interacting, yet unconscious of their overall (tragic) strategic situation. Since 2000, FAS actors seem to have been interacting as if their interests were aligned to produce a stable equilibrium with regularized gains from uncooperative behavior. Through the lens of a stag-hunt game, which factors in the CSIC study as

an informational input reducing overall uncertainty in the system, it is striking the persistence of the Port Authority in resolutely maintaining its defect strategy, a strategy potentially leading to the "turbid equilibrium." Considering the poor socioeconomic prospects of the estuary megaproject, the knowledge provided by the CSIC study and the Supreme Court's rulings, the Port Authority appears as though it was behaving irrationally. This seemingly irrational behavior was compounded by the existence of the nearby more competitive and accessible seaport of Cádiz, and by probable high sunk and maintenance costs derived from DDM (e.g., regular deep dredging, corrective measures for large environmental impacts). If finally built, the megaproject's infrastructure would have more than likely become unfit for purpose and inefficient, i.e., a white elephant, even more so in a context of accelerating climate change (see, e.g., Zittis et al. 2019), e.g., leading to an uncertain water supply–demand ratio upstream and potentially reduced volumes in the headwater regulatory reservoir system.

In our view, the current trajectory of the game is highly dependent on the two available choices for the Port Authority to either "disengage" or "engage" as described above. If the Port Authority disengages, not yielding to the evidence of the negative impacts of deep dredging after the ruling cycle, nor seeking alternative coordinated solutions for the Port's function contributing to overall socioeconomic welfare, it might proactively be putting itself on a collision course—approximating, e.g., a chicken game—with the other two actors, especially with the Nature Stewards. The latter would probably not change their strategy, as they currently have precedent legal and knowledge-based mechanisms to prevent harmful interventions entailing systemic risks. If these mechanisms were to fail in the future, due to no further "fight" responses from the Nature Stewards, and the "deep dredging" measure was to be implemented due to a choice to "acquiesce" (i.e., full realization of "surrender the SES" terminal history), then all three actors would fall into a massive coordination failure. Such a failure is characterized by a below-sub-optimal payoff structure in which actors are worse-off environmentally, probably leading to economic loss and requiring a complex readaptation of expectations and strategies.

Understanding or even predicting how the game might end, and informing how to escape the current coordination failure, requires a more nuanced explanation of the Port Authority's seemingly irrational behavior potentially leading to the "turbid equilibrium," i.e., an apparent odd game outcome. Below, we show how the polycentric power typology and insights from previous research drawing on discursive power cast some "rationality" to the Port Authority. Further, those types of power contributed to a more refined explanation of the current situation in terms of the inertia of the current stalemate "grey equilibrium" within the FAS and the risk of regime shift from a rigidity to a lock-in SES trap.

## Enter power into the analysis—the rise of hydraulics

Our power analysis was guided by questions concerning the Port Authority's persistence of DDM and the River Authority's tolerance of such a measure. The Port and the River Authority wielded power by design, backed by their respective national government mandates to promote maritime trading and water use planning. Formal authority operationalizes resource allocation, infrastructure development, infrastructural adjustments, and regulation of resource use. The critical issue is that both Authorities executed their mandates despite general disproof and lack of support for the estuary megaproject. Thus, a more nuanced interpretation points to a discretionary use of legal and administrative backing, i.e., pragmatic power. The Port Authority's pragmatic power stemmed from misdirected power-by-design, through feigning ignorance of the megaproject's negative forecasted impacts. The behavior of the River Authority was clearly marked by a non-decision-making attitude, running counter to EU regulations that are superordinate to the Authority's planning competencies (inclusion of DDM in two subsequent Water Plans, $\delta_{10}$ and $\delta_{14}$, $AS_{wp}$; Fig. 4). The inclusion of DDM as a "complementary measure" in the River Authority's 2013 Water Plan ($\delta_{10}$, $AS_{wp}$; Fig. 4) is striking, as such measures must be conducive to "good environmental status," a key aim of the European Union's Water Framework Directive. Paradoxically, DDM would have surely needed its own "complementary measures" to counteract the large socioeconomic and environmental impacts foreseen by the CSIC study (Vargas and Paneque 2015). The Port Authority also showed framing power in using questionable grounds to characterize the estuary megaproject as a panacea for socioeconomic development and in presenting the "complementary measure" issue as a "procedural defect" (Diario de Sevilla 2015; El Mundo 2015). This might be seen as an attempt to disrupt formal rules, such as the new knowledge requirements for the Environmental Impact Assessment ($\delta_7$, $AS_{gov}$; Fig. 4). We found no evidence of use of framing power on the part of the River Authority, but the question remains of whether it was acting in collusion with the Port Authority. Why was the Sea Gate built before DDM was implemented (i.e., why the cart was put before the horse)? Were both the "complementary measure" and the Sea Gate acting as Trojan horses?

Our analysis above illuminated "how" both authorities operationalized their persistent (Port Authority) and tolerant (River Authority) behaviors but answering "why" provided us with a more robust explanation. Why such behavior given the mounting evidence that DDM would not bring about the argued benefits? Why not change the approach and search for

alternative solutions? Why bring into play the agent-based power sources identified above? Based on previous research, we argue that discursive power was both overarching and funneled through those power sources, albeit differently for each Authority. In Doñana, previous research evidences a hegemonic hydraulic mission discourse operating from the political–economic context at national level (e.g., Méndez et al. 2019). This discourse operates through two meso-level mechanisms: (A) it mobilizes discursive power top down, imbuing institutional arrangements across multiple levels, and (B) it signals increasing-returns mechanisms that prompt bottom-up strategic reactions from actors at lower levels. We assessed that (A) influenced the River Authority more markedly, further explaining its tolerant behavior, and (B) influenced the Port Authority, leading it to become heavily invested in potentially inefficient large infrastructure. We reason as follows.

In our analysis, discursive power seems to be acting as an overarching frame. Since the beginning of the twentieth century, the hydraulic mission discourse has defined Spanish water policies to a large extent, steering regional socioeconomic development in a particular direction, and relying on large public hydraulic infrastructure and irrigation agriculture (Swyngedouw 1999; Saurí and Del Moral 2001; López-Gunn 2009; Font and Subirats 2010; Castán-Broto 2015; Swyngedouw 2015; Vargas and Paneque 2015; Kimmich and Villamayor 2019; Donadei 2020). Key features of such a discourse are: increasing water provision (supply side) through state intervention via economic planning and modernization; massive public funding of large hydraulic infrastructures; passive concern for both water quality and hydrological system conditions; low water prices for final users under the assumptions of net returns on investments to national wealth; hegemony of technocratic elites and civil engineering corps; and the paradigm of nature as an object to be dominated and modified (Saurí and Del Moral 2001; Swyngedouw 2015; Vargas and Paneque 2015).

Discursive power, imbued by the above features of the hydraulic mission discourse (mechanism A above), legitimated, in this case, the use of pragmatic power by the River Authority, i.e., misdirected power-by-design. From a different angle, the estuary megaproject would have been improbable without discursive power persistently structuring the perception of reality of both the River and Port Authorities. Indeed, the latter appears as the last in a row of socioeconomic actors responding to opportunities and constraints deeply embedded in upper level institutional arrangements, which, in turn, were infused by cognitively powerful ideas stemming from the hydraulic-mission discourse. Such a discourse constrained the Port Authority's choices and its course of action; hence, it was perhaps not behaving irrationally, but manifesting a logical strategic behavior that was embedded within larger structural and discursive forces (based on Schwartz 2004, unpublished manuscript). Indeed, mechanism B above constitutes the continuation of the hegemonic hydraulic-mission discourse to signal massive increasing returns downstream. It thus induces large hydraulic interventions such as the estuary megaproject, for example, through:

1. *Large setup costs (i.e., the inertia of sunk costs)* arising after the spending of public funds for the construction of the Sea Gate (€163 million; Vargas and Paneque 2015). This created a high payoff for further Port Authority investment in the estuary megaproject as a single option for the estuary's future. In other words, such setup costs could not be recovered unless the full estuary megaproject had been fully implemented through the execution of DDM.
2. *Learning effects*, due to the knowledge gained in the recursive operation of the estuary's navigable canal (e.g., combining shallow dredging and light ship traffic since 1985), leading to higher efficiency and higher returns from continuing the same type of operation over time.
3. *Adaptive expectations*, whereby the increasing prevalence of the selected choice created a self-reinforcing mechanism, thus increasing its prevalence (1985–2019).

## Discussion

Several key insights can be derived from our results. We have evidenced how the dynamics of meso-level mechanisms (discursive power, signaled increasing returns) in the Doñana SES interweave with micro-level FAS strategic interactions and agency-based (polycentric power typology) forms of power. Hydraulic-mission discursive power seems to be imprinted in the rationality of central actors in Doñana's water governance, showing the capacity of hegemonic discourses to influence actors' agency-based pragmatic power. This pragmatic power, in turn, has materialized in water policies and planning, showing how feigned ignorance and non-decision-making can increase the likelihood of large interventions posing risks of high environmental deterioration and suppression of key SES values. Our research thus contributes to fill a key gap in action-situational institutional analysis, which currently fails to accurately capture inaction and non-decisions, thus missing related forms of power imbalances at play—even when incorporating "politicized" variables such as discursive power (Brisbois et al. 2019).

In Doñana, key power fronts at local level seem to recurrently counteract each other over time. Despite the existence of formal bodies with actual capacity for central coordination (such as the Doñana's Participation Council or the Guadalquivir River Authority), they seem unable to direct

governance to escape the current stalemate ("grey equilibrium") situation or the system-level rigidity trap. This creates a space where any actor with a first-mover advantage might grab power and intervene within the SES, potentially leading others or all to be worse-off, and thus decreasing overall SES welfare. But more relevant for our case, any actor moving first, supported by forceful discourses and institutional arrangements, seems to get immediately counteracted by other actor(s) supported by the very same mechanisms. While this power-counteraction mechanism seems to neutralize large perturbations in the short-term, nothing truly prevents the weakening of current governance controls, the results of which might lead to the authorization of larger, riskier interventions. As we have shown above, the inertia of increasing-returns mechanisms and the hydraulic mission discourse is sometimes sufficient a risk (e.g., Sea Gate and "complementary measures"). Further, this power-counteraction mechanism is impeding coordination to trigger a sustainability pathway—i.e., precluding increasing returns from sustainability coordination effects. Interestingly, past research in Doñana has shown how this mechanism can be productively filled, whether through entrepreneurial action to (1) develop rice agriculture (1950s–1980s), or (2) as a counteraction to create the Doñana National Park (1969), potentially preventing the fall into a lock-in trap (Méndez et al. 2019; see Fig. 2). Therefore, Doñana's power-counteraction mechanism constitutes a double-edged sword: it can enable agency from an actor coalition to prevent a locked-in situation (but stabilizing rigidity), but can also block collective agency (i.e., coordinated collective action) from all relevant actors to pursue a SES sustainable outcome. Our insights resonate with recent understanding on discursive-institutional inertia mechanisms underlying the dominance of actors' groups in water governance (Williams 2019; see also Méndez et al. 2022). Furthermore, our insights align with research showing how the passivity of authorities can be a cause of water resources degradation and entrenchment of rigidity traps, and how such passivity can effectively be counteracted by social movements inducing individual agency (Enqvist et al. 2016).

Our meso-micro analytical tension, which deals with the macro-level properties of the path dependence notion used in previous Doñana research, led us to a final key epistemological insight with normative implications. In path dependence logics, to sustain a certain path, whatever the scale of analysis and/or mechanisms identified, at least *one* of these mechanisms (e.g., contextual factors, positive/negative externalities) must act to decrease the relative attractiveness of alternative paths (Arrow 2000; Kay 2005; Vergne and Durand 2010). Premature assessments based solely on, e.g., a rational-expectations standard alone, and obviating contextual (institutional, discursive, power, etc.) conditions, might end up concluding local irrational behaviors, cognitive biases or small-random historical accidents. This, in turn, might result in not getting the incentives or the rules right (Bowles 2009), which then leads to a wider misaligned institutional fit for resolving problems at SES level (Epstein et al. 2015) or framing innovative policies to trigger a sustainability pathway. In Doñana, as our results show, two meso-level mechanisms (discursive power and increasing returns), aggravated by the power-counteraction mechanism argued above, still serve to decrease the attractiveness of sustainable alternatives at present. Therefore, we must go beyond micro-level institutional analysis to adequately inform the design of policy instruments which trigger collective action towards more sustainable outcomes (e.g., high "blue equilibria").

Indeed, power imbalances might have macro- or meso-level contextual or historical origins and be "congealed" in current institutional arrangements that purposive actors use as vantage points (Kashwan 2016), thus operating "below the radar of institutional analyses" (Ingalls 2017). It would therefore be advantageous to work at the intersection of post-structuralism and rational-choice institutionalism to understand how people self-organize to overcome governance challenges (Bennett et al. 2018), by, e.g., seeking philosophical middle ground (Clement 2010). Cox (2019) argues for a focus on the dynamics and disparities of power and authority, codified through "the language of institutions" (e.g., property rights), and making best use of institutional path dependence (e.g., historical institutionalism à la North 1990). According to Cole et al. (2019), we need "combined" frameworks systematizing the analysis of "hidden" structures of power and human agency. Instead of viewing them as an analytical contingency, such structures are significant, as they can shape or be shaped via collective action and can enable or prevent change (Cole et al. 2019; Méndez et al. 2019). An epistemological connection between power-centric and actor-centric institutional approaches can indeed be very productive in gaining insights on the interconnections between macro- and micro-level processes and outcomes (Knight 1992). Here, we have shown how interpretations from game-theoretic micro-level analyses of strategic interactions and agency-based power relationships can be strengthened by logically connecting with previous meso-level analyses which combined post-structural power, and rational-choice and historical institutionalism (Méndez et al. 2012, 2019).

## Conclusions

Understanding the governance of sustainability pathways in SES traps is imperative, since the wrong configuration might lead from escapable to inescapable states (e.g., from a rigidity to a lock-in trap). It is critical to understand how historical, institutional, discursive and power factors interweave

and can create or hinder governance configurations more favorable to fostering sustainability pathways. Here, we have contributed to such understanding through a novel combination of the NAS approach, the polycentric power typology and the concept of discursive power. We have shown how certain institutional (e.g., forceful legal frameworks) and informational (e.g., new knowledge generation) mechanisms within a NAS can result in a governance configuration that prevents further SES degradation. However, underlying these apparent robust governance configurations, key actors can be caught in lasting coordination failures and fragile sub-optimal equilibria situations prone to mutual defection strategies. While if persisting over time such strategies might seem irrational, they become more explicable in the presence of meso-level mechanisms involving power dynamics and discursive-institutional inertia. These situations are constantly at risk of being unbalanced by powerful actors promoting large SES hydraulic and technocratic interventions, backed also by the inaction of tolerant authorities. Such interventions bear systemic risks of governance falling to below sub-optimal equilibria situations, characterized by a strong suppression of SES functions and values, and the high sunk- and trajectory-shifting costs of a lock-in trap.

Coordination failures among water governance actors in SES must be pushed to higher equilibria—termed here "blue equilibria"—situations, more conducive to enable collective action for fostering sustainability pathways. Those situations present greater risks for all actors involved, as they might require relinquishing economic maximization goals and power grabbing at all levels. Instead, mutually agreed solutions to resource use problems must be favored, including the establishment of regional development goals and biophysical limits to resource use. Determining the conditions for fostering such situations and minimizing risks for the actors involved is a matter of further prospective research on the transformative potential of specifically tailored policy mixes. However, based on our results, we can be certain that inaction and non-decision making can perpetuate a rigidity trap which lacks the flexibility and learning capabilities that ward-off the risk of falling to undesirable situations such as a lock-in trap. An integrated NAS-power approach such as the one presented here, which combines action-situation institutional analysis with discursive and agency-based power forms, has shown to be well equipped to inform policy and institutional designs through the targeting of richer sources related to meso- and micro-level causality of actors' behaviors and collective-action dilemmas. Such policy and institutional designs could thus be more effective in inducing new baseline governance configurations more prone to working with nature and nurturing sustainability pathways at SES level.

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**Data availability** The authors confirm that the data supporting the findings of this research are available within the article and its supplementary materials.



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