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Responding to coastal problems: Interactive knowledge development in a US nature restoration project

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ABSTRACT

Coastal decision-making is impacted by global climate change and region-specific changes related to population growth, economic activities and the natural environment. This results in complex and interdependent problems. Addressing these problems requires the involvement of decision-makers, researchers and other societal actors in knowledge production. However, such means of knowledge production are poorly understood when it comes to coastal regions. Using a conceptual framework that makes a distinction between project arrangements and knowledge arrangements, this paper analyses interactive knowledge development in a nature restoration project on the US West Coast. The project adopted a collaborative approach, and involved diverse organisations in developing knowledge for reaching its restoration solutions. The case study analysis results in seven causal mechanisms. The mechanisms are divided into two groups. One group discusses processes that affect interactive knowledge development, such as the need for public support. The other group explains how interactive knowledge development functions, for example through facilitation and the creation of safe environments for researchers and regulators. Through identifying these mechanisms, this paper contributes to an improved understanding of interactive knowledge development in coastal regions.

1. Introduction

Coastal regions face various environmental and spatial problems. In seeking solutions to these problems, decision-makers have to deal with all kinds of uncertainties, ranging from knowledge uncertainties related to global climate change (Hanger et al., 2013) to the competing interests of nature protection, expanding cities and economic activities (Cicin-Sain and Knecht, 1998; Kay and Alder, 1999). Responding to these issues in coastal decision-making processes requires the involvement of researchers, decision-makers and stakeholders in knowledge production (Tribbia and Moser, 2008; Schmidt et al., 2012; Hanger et al., 2013; Clarke et al., 2013). A critical assumption is that their involvement is essential in coming to robust solutions for the coastal region. The involvement of actors outside the research community in producing knowledge is essential for knowledge uptake (van Koningsveld, 2003), for identifying effective solutions (Clarke et al., 2013) and for anchoring these solutions within society (Schmidt et al., 2012). The aim of this paper is to increase understanding of such knowledge production in coastal regions.

The involvement of researchers, decision-makers and stakeholders is necessary to produce socially robust knowledge: knowledge that is relevant in the context of its application (Gibbons et al., 1994; Nowotny et al., 2001). Relevant criteria such as legitimacy, credibility and salience (Cash et al., 2003) also emphasise the need to involve actors outside the research community. Indeed, the latest perspectives on knowledge production and uptake in coastal decision-making highlight the need to include a diversity of actors in knowledge production (Bruckmeier, 2012; Bremer and Glavovic, 2013; Clarke et al., 2013). Nevertheless, research shows the difficulty of organising such interactive modes of knowledge production. For example, Bruckmeier (2012) reports limited attention to knowledge integration in three Swedish EU research projects. Tribbia and Moser (2008) discuss a disconnect between scientists and decision-makers in California's coastal zone management. Clarke et al. (2013) conclude that a more collaborative coastal governance structure is required for sustainable decision-making and knowledge generation in Australia. These cases demonstrate

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the difficulties in reaching interactive modes of knowledge production between researchers, stakeholders and decision-makers.

This paper focuses on processes for interactive knowledge production in coastal projects. To date, coastal-related research on this topic has focused on research partnerships (McFadden and Schernewski, 2012; Schmidt et al., 2012), coastal policies (Bremer and Glavovic, 2013; Clarke et al., 2013) or the relationship between climate science and decision-makers (Tribbia and Moser, 2008; Shaw et al., 2013). Coastal projects represent a distinct domain for understanding the production of socially robust knowledge as projects seek multi-million dollar solutions with a lifespan of several decades. Solutions concentrate for example on nature restoration, coastal protection or waterfront expansion. Consequently, projects have to respond to the global and regional changes in their area, and this requires socially robust knowledge. Research shows that this becomes a challenging process if the project organisation adopts a hierarchical approach towards other organisations (Seijger et al., 2013). Although collaborative settings are deemed necessary for effective coastal science–policy interfaces (Bremer and Glavovic, 2013; Clarke et al., 2013), there remains a gap in the literature on how interactive knowledge development functions in such a collaborative setting.

The objective of this paper is to understand the role of interactive knowledge development in a collaborative coastal project. The central question is how does a process of interactive knowledge development function in a collaborative coastal project? Collaboration refers to the way organisations jointly manage a project. Interactive knowledge development is defined as a participative form of knowledge production in which knowledge is shared and developed by using the perspectives of key stakeholders (researchers, decision-makers, stakeholders) involved in the complex problem being studied to develop relevant solutions for the problems defined in the project (Seijger et al., 2013). This paper analyses interactive knowledge development in a large-scale nature restoration project – the South Bay Salt Pond Restoration Project – located in South San Francisco Bay. The project aims to restore 60 km^2 of former industrial salt ponds to nature while providing flood control and public access. The project organisation adopted a collaborative approach, giving significant attention to the involvement of researchers, stakeholders and regulators. This resulted in interactive knowledge development in seeking restoration solutions.

The remainder of this article has four sections. Section 2 outlines the methodology applied. Section 3 presents the results of the analysis of our restoration project case study, and these results are placed in a wider scientific context in Section 4. Section 5 presents the main conclusions of this study.

2. Methodology

As argued by van de Ven (2007), there is a knowledge production problem in the limited use of research knowledge. In response, we analyse the process of interactive knowledge development to arrive at socially robust knowledge. Rather than focusing on knowledge transfer (Carlile, 2004; Vinke-de Kruijf et al., 2012) or distinct types of knowledge (Edelenbos et al., 2011; Maiello et al., 2013), we argue that the process of knowledge production itself holds important clues for creating socially robust knowledge. This revolves around questions of who is involved, in which phases and what is their contribution? These questions relate to various phases in the process of knowledge production for environmental decision-making: formulating the problem (Hommes et al., 2009); identifying methods and using them to generate knowledge (van Buuren and Edelenbos, 2004; Norgaard et al., 2009); and interpreting the results (Eshuis and Stuiver, 2005; Lane et al., 2011).

2.1. Conceptual framework: project arrangements and knowledge arrangements

In studying interactive knowledge development in a project environment, we apply the framework developed by Seijger et al. (2013) to analyse project arrangements and knowledge arrangements. With the use of this framework, we are able to analyse, through a longitudinal approach, how knowledge is interactively produced within an evolving project setting. Here, we summarise the main elements of the framework presented in Seijger et al. (2013). The framework builds on the policy arrangement approach of Van Tatenhove et al. (2000). A policy arrangement is defined as 'the temporary stabilisation of the content and organisation of a policy domain' and is analysed in terms of four dimensions:

- Actors and their coalitions;
- The division of resources among actors that lead to variations in power and influence;
- The rules of the game in operation, both in formal procedures and informal routines of interaction;
- Discourses, that entail the views and narratives of the actors involved.

Seijger et al. (2013) adapted the policy arrangement approach to study interactive knowledge development within a project by analysing the project arrangement and the knowledge arrangement. The *project arrangement* focuses on the overall project goals: how problems are defined, solutions are proposed and decisions are taken. The *knowledge arrangement* focuses on the process of knowledge development to find solutions for the problems defined in the project arrangement.

The four dimensions of a policy arrangement apply to *both* the project arrangement and the knowledge arrangement. Indicators for the four dimensions are shown in Table 1.

The project and the knowledge arrangements have distinct scopes. The project arrangement focuses on the overall project goals; the knowledge arrangement on the dynamics of interactive knowledge development for a particular solution. In a knowledge arrangement, four main activities define the process of interactive knowledge development (van Buuren et al., 2004; van de Ven, 2007):

- Problem formulation – the scope of the problem is determined and research questions are formulated by the actors involved to address that problem;
- Methods and techniques to be used – discussions focus on methods, techniques, models and theories to be used in data collection;
- Interpretation of results – results are interpreted after which conclusions are drawn;
- Choice of solution – a solution is chosen to solve the problem under study.

Table 1
Indicators of the project arrangement and knowledge arrangement.

Dimension	Indicator
Actors	Actor involvement, actors' relationships, actors affected, actor coalitions
Resources	Time, money, information
Rules	Access rules, allocation of responsibilities, legislation and policy rules, interaction rules
Discourses	Project rationale, the project solutions, nature restoration

Both arrangements can be studied longitudinally in order to analyse how a project develops over time, and how knowledge is developed for solutions. Insights are gained both on project decisions that impact interactive knowledge development, and on the functioning of interactive knowledge development.

2.2. Method

Our goal was to gain empirical insights into interactive knowledge development in collaborative coastal projects. A case study approach was selected as this enables an in-depth analysis of complex, uncertain and multidimensional phenomena in their context (Flyvbjerg, 2006), a description that fits our subject. While a case study can achieve high internal validity, it is less appropriate for investigating a large range of cases (Flyvbjerg, 2006; Gerring, 2007). Nevertheless, generalisation to a broader class of cases can be achieved through careful case selection (Flyvbjerg, 2006; Gerring, 2007).

The findings of this paper rely on four sources of data: semi-structured interviews (19), observations of meetings (6), field trips (5) and project documents (numerous). Annex 1 provides more information on these sources. The interviews were qualitatively analysed in three rounds through a template-coding approach (Miles and Huberman, 1994; Crabtree and Miller, 1999; Seijger et al., 2013). In the first round, text fragments were coded on the basis of the indicators in the conceptual framework. In the second round, all the coded fragments were further categorised. In the third round, links between the various categories and indicators were explored. Based on this coding process, causal mechanisms can be derived that explain interactive knowledge development in the coastal project. Findings were triangulated both within and across sources to increase the internal validity of this study.

3. Interactive knowledge development in South Bay Salt Pond Restoration Project

San Francisco bay covers an area of 1 200 km^2 and is located in California between the mouth of the Sacramento-San Joaquin river system and the Pacific Ocean. The sea level has been rising with 2 mm/year between 1897 and 2006.[1] San Francisco Bay is heavily modified since the 1850s due to hydraulic mining, land reclamation, waste disposal, and farming (Nichols et al., 1986). The South Bay is one of the four sub-systems of San Francisco Bay.[2] The South Bay floor is dominated by mud-sized sediments, and has been accreting sediment (11million m3) between 1983 and 2005 (Barnard et al., 2013). The shoreline is prone to flooding due to extensive groundwater pumping in the adjacent region. This pumping led to subsidence ranging from 1 m near the southern shoreline up to 4 m in San José (Poland and Ireland, 1988).

We selected the South Bay Salt Pond Restoration Project (SBSPR project) for our analysis as it represents a typical case (Gerring, 2007) of a collaborative, coastal project. We consider this case as typical in that various levels of governmental organisations (federal, state, local) collaborate with non-governmental organisations to restore the salt ponds. Further, organisations share resources and make decisions on a consensual basis. During the period of data collection, between September 2012 and March 2013, knowledge was interactively developed for a new set of restoration solutions. Interactive knowledge development actually started in 2010 and, hence, the knowledge arrangement covers the period 2010–2013. However, to understand the origins of these restoration solutions, as well as the functioning of the project organisation, we consider the project arrangement to cover the period from land acquisition in 2003 until 2013 (see also Table 2).

Section 3.1 provides an analysis of the project arrangement in terms of the four dimensions outlined earlier. The analysis starts with the project history, the formal project discourse and the actors that are mobilised by this discourse. It continues with the structuring impact of environmental regulation on the planning process, the various sub-discourses, and how collaboration serves as an interaction rule in dealing with these sub-discourses. Section 3.2 discusses the knowledge arrangement. The four dimensions of the two arrangements are summarised in Table 3. Section 3.3 then presents the mechanisms that explain interactive knowledge development in the SBSPR project.

3.1. Project arrangement South Bay Salt Pond Restoration Project

In 2003, 66.8 km^2 of salt ponds in San Francisco Bay were purchased from Cargill for USD 100 million. The State of California contributed USD 72 million, the US federal government USD 8 million, and four private foundations USD 20 million. Since the 1850s, 83% of the original South San Francisco Bay marshland has been lost to dyked habitat (~60%, mostly salt ponds) and bay fill. This dramatic loss of tidal mudflats and marshlands is problematic: marsh-dependent fish and wildlife stocks have dwindled, risks of local flooding have increased and the water quality decreased. The South Bay Salt Pond Restoration (SBSPR) project is responsible for the restoration of three salt pond complexes covering 60.7 km^2 in the South Bay (see Fig. 1). The formal discourse of the SBSPR project is ‘to restore and enhance wetlands in South San Francisco Bay while providing for flood management and wildlife-oriented public access and recreation’ (discourse, Table 3).

The project area comprises three salt pond complexes which are managed by state and federal landowners. CDFW[3] owns and manages the Eden Landing complex, and USFWS the Ravenswood and Alviso complexes. The SCC supervises the project and oversees the two landowners. The project management team (PMT) is the key decision-making body of the project. The PMT consists of governmental and non-governmental agencies who jointly manage the project (see Fig. 2 and the actors in Table 3). The project has a time horizon of 50 years, and all the restorative actions should be completed by 2058 (resources, Table 3). The first restorative actions focused on creating tidal and pond habitats, trails and viewing access points.

The existing environmental legislation is a key ‘rule’ in the project arrangement as it provides a framework for project planning (legislation, Table 3). The project has to comply with federal and state environmental regulations (NEPA and CEQA respectively[4]) given the federal and state landowners. The plans, proposed in a NEPA/CEQA procedure, are impacted upon by various acts. Permits have to be obtained under acts that might cover proposed actions (i.e. Endangered Species Act, Clean Water Act, Migratory Bird Treaty Act). The potential environmental impacts of the project are evaluated in an Environmental Impact Statement/Environmental Impact Report (EIS/EIR). During the phase 1 planning, the PMT developed a programmatic EIS/EIR[5] (responsibilities, Table 3). The EIS/EIR evaluated three restoration scenarios with a

[1] Measured by the San Francisco tide station near the Golden Gate bridge. Data were obtained from the NOAA website http://co-ops.nos.noaa.gov/sltrends/sltrends_station.shtml?stnid=9414290 (website accessed on December 3rd, 2013).

[2] Other sub-systems are San Pablo Bay, Central Bay and West-central Bay.

[3] Such acronyms are explained in Fig. 2.

[4] NEPA = National Environmental Policy Act, CEQA = California Environmental Quality Act.

[5] Phase 1 restoration alternatives were also evaluated in this EIS/EIR.

Table 2
SBSPR project phases and their relationship to the conceptual framework (^{p} = part of project arrangement, ^{k} = part of knowledge arrangement).

2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Interim stewardship plan $^{(p)}$: change management of industrial salt ponds to prepare them for nature restoration												
	Phase 1 planning $^{(p)}$: programmatic restoration including an adaptive management plan, phase 1 restoration actions											
						Building phase 1 restoration actions						
						Phase 1 studies: informed by the adaptive management plan						
							Phase 2 planning $^{(p,k)}$: restoration alternatives					

Table 3
Main elements in the project arrangement and knowledge arrangement dimensions of the SBSPR project.

Dimension	Project arrangement phase 1 planning (2003–2008)	Project arrangement phase 2 planning (2010–2013)	Knowledge arrangement Alviso phase 2 (2010–2013)
Discourse	Restore and enhance wetlands in South San Francisco Bay while providing for flood management and wildlife-oriented public access and recreation	Do no harm to flood impacts and ensure progress towards the 50–50 managed pond – tidal marsh habitat equilibrium	Tidal marsh restoration where there is a backside levee
Actors	Formal project management structure (see Fig. 2)		Executive project manager, USFWS, consultant team, City of Mountain View
Rules (legislation)	Environmental regulations (NEPA-CEQA structure planning process)		Charleston Slough mitigation permit[a] and environmental regulation
Rules (interaction and responsibilities PMT)	PMT meets twice a month: responsible for developing a restoration plan	PMT meets once a month: responsible for implementing restoration actions	PMT meets once a month: responsible for developing restoration alternatives
Resources (time and money)	Project has fifty years to complete implementation (2008–2058), full project budget is spent when planning for phase 2 ends		No strict deadline, costs for Alviso ~ USD 300,000
Resources (information)	Bayland Habitat Goals Report	Phase 1 studies, programmatic EIS/EIR	Programmatic EIS/EIR, phase 1 studies, research summaries, information from City of Mountain View

[a] The permit is only relevant to the Alviso pond complex.

fifty-year period: no action, 50–50 tidal-pond habitat and 90–10 tidal-pond habitat.

Two key decisions have been made in the programmatic EIS/EIR that affect phase 2 planning. The first was to acknowledge the uncertain outcomes of the project given the fifty-year time horizon. As a result, the project does not work towards a defined end-state. Rather, the project adopts a phased approach, and relies on researchers and adaptive management to adjust management decisions and the future restoration of the salt ponds. A lead scientist, positioned within USGS, is part of the PMT and is responsible for the link between project managers and researchers. Studies in the science programme (totalling 4.8 million USD[6]) address key uncertainties that were identified during phase 1 planning in the adaptive management plan (information, Table 3). Researchers work for various types of organisations, ranging from a university as UC Davis to a research organisations as USGS to a private company.

The second key decision that affects phase 2 planning was to consider restoring 50% of the tidal marshes as the minimum. This decision was informed by the Baylands Ecosystem Habitat Goals report (1999) (information, Table 3). That report led to a hard-fought consensus between researchers and resource managers in the bay area. The report provided guidance on two topics: the types of habitat to consider, and the minimum amount of marsh restoration. The SBSPR project adopted their findings and, consequently, a 50–50 split between tidal and pond habitats became the lower boundary for restoration in the programmatic EIS/EIR (information, Table 3). This constraint was maintained in phase 2.

The actors interpret the three objectives of the formal project discourse differently. The PMT considers nature restoration to be the prime goal of the project, for which flood control is a prerequisite, and public access should be compatible with wildlife and restoration efforts. This is reflected in the narrow discourse for phase 2 where the two guiding principles are 'to do no harm relative to flood impacts, and to progress towards the 50–50 managed pond – tidal marsh habitat equilibrium' (discourse, Table 3). The sequence of actors joining the PMT also reflects this priority: flood control agencies joined the PMT in August 2004, whereas a public access organisation did not formally join the PMT until 2012. In addition to these unequal priorities, there are multiple perspectives within each sub-discourse. In terms of nature restoration, conflicts exist as to whether the salt ponds should be restored as marsh or as pond habitat.[7] In terms of flood control, large areas of the Alviso and Eden Landing complexes need improvement before the salt pond levees can be breached for tidal restoration. Here, the project is reliant on the willingness and procedures of regional flood agencies and the USACE to improve flood control. Public access is only planned in areas where the expected impact on nature will be small. This conflicts with various public access organisations such as The Bay Trail that want to maximise public access opportunities. The PMT developed a collaborative style in an attempt to accommodate these perspectives.

This collaborative style is a formal PMT consensus-based interaction rule.[8] Non-governmental organisations (the private foundations and the CCP) initiated this collaborative style. Prior to the land acquisition, the private foundations were already pushing the dealmakers to organise a transparent and inclusive process

[6] SBSP overall project costs (20 Aug 2012).

[7] Although the project addresses the historic loss of marshland, pond habitat is also needed for the migrating and overwintering birds that have become regular visitors to the salt ponds since the 1900s.

[8] Memoranda of Understanding in 2003, 2004, and 2009 state that 'The Parties agree to seek consensus among themselves prior to taking actions that may significantly impact the Project'.

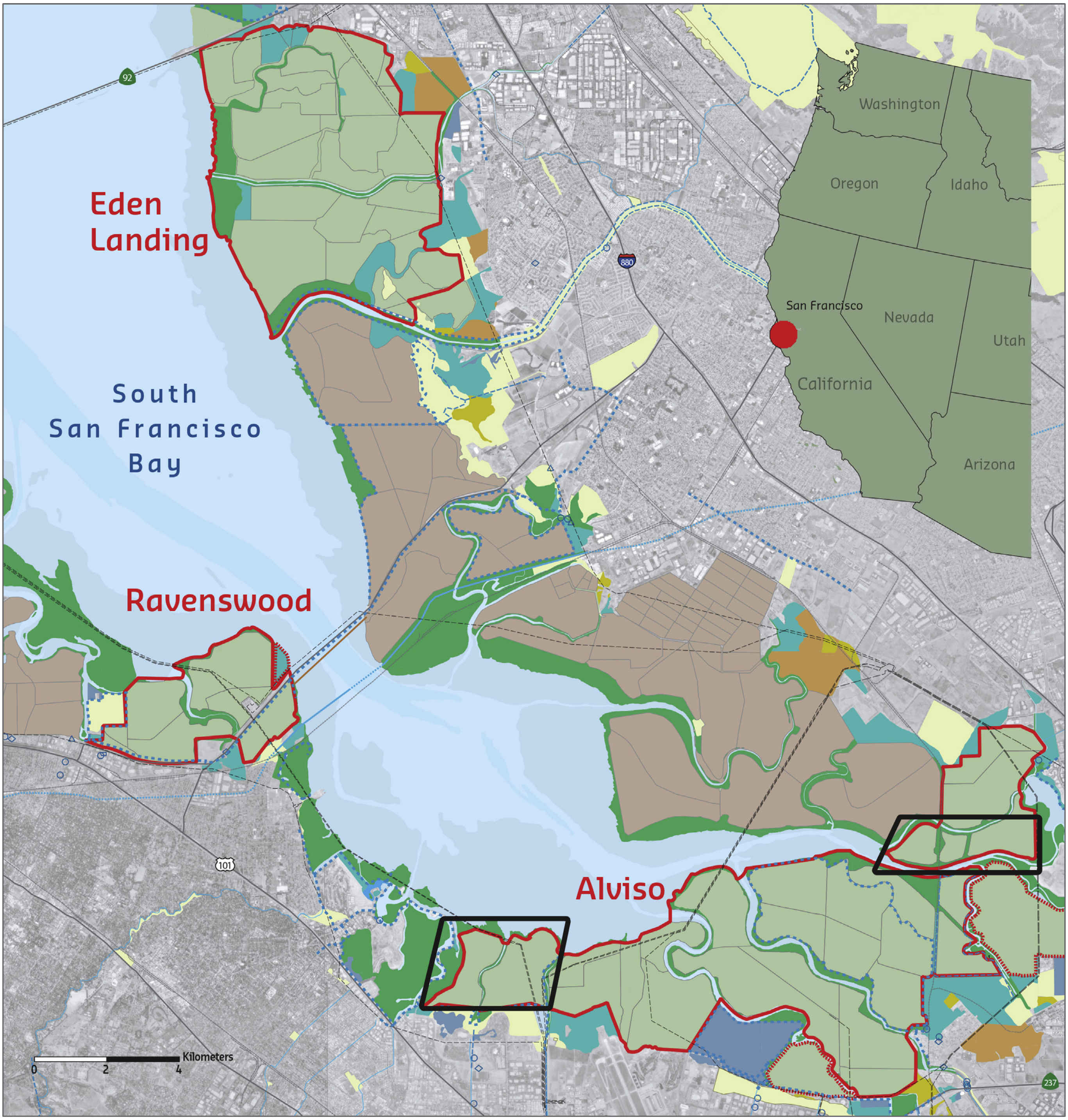

Fig. 1. The three salt pond complexes: Eden Landing, Ravenswood and Alviso in South San Francisco Bay (total 60.7 km^2). The black quadrangles mark the areas that are considered for restoration in the Alviso phase 2 knowledge arrangement (Section 3.2.): the Mountain View ponds (left) and Island ponds (right).

once they acquired the land. The public support that would arise from such a collaboration would be crucial for the future of the project as public support and funding are coupled. Californians vote for tax measures, so-called state bonds, which require a majority vote to be accepted. These state bonds cover more than half of the project costs[9]. Thus, without this public support, funding for the project would be heavily impacted, especially as new state bonds were needed after phase 1 construction work is finished. The foundations insisted that the SCC supervise the project and oversee the two landowners. Further, the private foundations introduced the CCP to the dealmakers. The CCP has participated in the PMT since 2003 and is responsible for outreach, conflict mediation and facilitation. In 2003, the CCP developed a collaborative project management structure that remains largely in place for phase 2 of the project.

[9] SBSP overall project costs (20 Aug 2012).

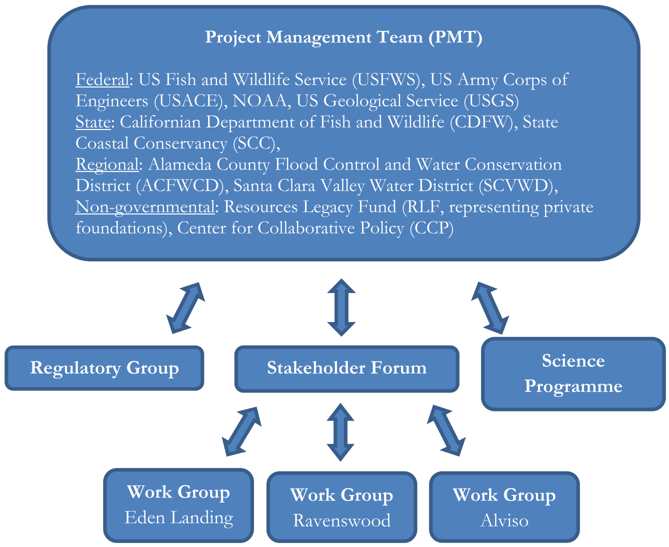

Fig. 2. Organisational project structure: SBSPR project. The figure omits the Executive Leadership Group. This group has not met in recent years as there have not been any major conflicts or challenges that have required addressing by the executive leaders of the governmental organisations.

Collaboration primarily occurs at two levels, among PMT members and between the PMT and other groups. The monthly PMT meetings are where all the organisations meet (interaction, Table 3). In these meetings, members inform each other and take decisions. Each organisation has specific responsibilities and areas of expertise. In the meetings, PMT members provide updates on topics under their responsibility (i.e. public outreach, science programme, finance, progress in pond complexes). As members value and respect each other's expertise, there is not necessarily much discussion on each topic. Alongside this collaboration within the PMT, the PMT collaborates with stakeholders, regulators and researchers through frequent formal and informal meetings. Nevertheless, maintaining the project's collaborative capacity is not easy. For example, many PMT members regard collaboration with others as difficult due to conflicting interests, organisation-specific procedures and limited responsibilities. One respondent saw the collaborative capacity of the PMT weakening due to shrinking state budgets and a fading project memory: successors of PMT members do not share the initial project spirit, and tend to forget the project has three objectives: restoration, flood control and public access. Instead, they tend to focus on their own interests.

Table 3 summarises for the project arrangement the primary elements of each dimension during phase 1 and phase 2 planning.[10] Changes occurred in the arrangement's four dimensions between the two planning phases. A change in the core responsibility of the PMT steered the changes: during phase 1 planning they had to develop a programmatic plan for restoration, whereas in phase 2 they had to implement restorative actions. This resulted in a narrower discourse in phase 2 planning. The financial resources also dried up once the phase 1 restorative actions are carried out. Therefore, there is no budget for phase 2 construction, and no strict deadlines placed on phase 2 planning. To summarise, the PMT's approach to salt pond restoration is to restore them through a collaborative and science-driven process, by building upon decisions made in the phase 1 planning phase.

[10] The period between phases 1 and 2 is excluded from Table 3 as this consisted primarily of applying for permits and construction activities that did not affect phase 2 planning.

3.2. Alviso phase 2 knowledge arrangement

Our analysis of phase 2 planning[11] revealed two distinct knowledge arrangements with different discourses. First, knowledge was developed in the science programme to reduce the uncertainty in planning and management of the SBSPR project. Supervised by the lead scientist, 15 principal investigators, each with their own research team, analyse issues that could potentially halt the restoration work such as mercury contamination or changes in fish and bird populations. Second, knowledge is developed for the phase 2 restoration alternatives under two guiding principles: solutions should do no harm to flood impacts, and should ensure progress towards the 50–50 pond-tidal marsh habitat. The latter resulted in a focus on tidal marsh restoration. We chose to study interactive knowledge development for phase 2 of the Alviso pond complex. Of the three pond complexes, this provided the best opportunity to study interactive knowledge development as there was considerable interaction between the PMT and other organisations. In the other pond complexes there was either little interaction between the PMT and other organisations (Ravenswood), or the production of phase 2 alternatives were postponed (Eden Landing).

3.2.1. Links between project arrangement and knowledge arrangement

The Alviso phase 2 knowledge arrangement is closely linked to the project arrangement. Both arrangements are subject to the same project management structure, with the same rules and resources (see Table 3). Knowledge is developed for various restoration ideas as environmental regulations demand the development of three alternatives. Various restoration actions have been discussed for two sets of ponds, covering 5.3 km^2, in the Alviso complex: the Mountain View ponds and the Island ponds (see Fig. 1). The alternatives include actions in response to the three project goals including breaching the salt pond levees for tidal restoration, establishing ecotone transition areas, improving levees and establishing trails and viewing platforms. The City of Mountain View became a restoration partner due its own marsh restoration requirements for Charleston Slough, adjacent to the Mountain View Ponds (actors and rules, Table 3).

Table 4 provides an overview of important events in this knowledge arrangement. The remainder of this section discusses the findings in terms of the four interactive knowledge development activities identified in Section 2.1 (problem formulation, methods and techniques, interpretation of results, choice of solution).

3.2.2. Problem formulation

The topic requiring knowledge development for Alviso phase 2 is the possibilities for achieving the three project objectives: nature restoration, flood control and public access. Research questions were not formulated as such for this process. The problem formulation was guided by the programmatic EIS/EIR and the two guiding principles for phase 2: no harm to flood impacts and progress towards the 50–50 pond – tidal habitat equilibrium. These guiding principles were translated into 'tidal marsh restoration where there is a backside levee[12]' (discourse, Table 3). During the design

[11] Knowledge was also developed during phase 1 planning on various topics: the adaptive management plan, restoration scenarios in the programmatic EIS/EIR and possible phase 1 restoration actions. These topics are excluded from this analysis as this section focuses on phase 2 planning and the related knowledge development.

[12] If solid levees are present at the landside of the salt ponds, then the bayside levees of these ponds can be breached for tidal marsh restoration. Salt ponds between the Mountain View ponds and Island ponds lack a solid backside levee, and were therefore excluded from phase 2 restoration (see also Fig. 1). A parallel project, the South San Francisco Bay Shoreline Study, explores feasible options for flood control in this area.

Table 4
Key events in the Alviso phase 2 knowledge arrangement.

Date	Event	Purpose	Characterising interaction	Interactive knowledge development activity
May 2010	Design workshop	What to consider for Alviso phase 2	Among PMT members	Problem formulation
Oct 2010–Nov 2011	First set of meetings with stakeholder forum, researchers and regulators	Present results of design workshop and obtain feedback	Consensus and preparation by PMT, then others	Interpretation of results
Sept 2011	Request for Services for Phase 2 consultants	What to consider for Alviso phase 2	SCC and City of Mountain View	Problem formulation
June 2012	Opportunities and Constraints Report (OC Report)	Explore opportunities and constraints	Consultants and SCC, review by some PMT members and by City of Mountain View	Interpretation of results
Sept–Nov 2012	Second set of meetings with stakeholder forum, researchers and regulators	Present results of OC report and obtain feedback	Consensus and preparation by PMT, then others	Interpretation of results
Feb 2013	Alternatives Report	Compare the alternatives and select three for environmental review	Consultants and PMT	Choice of solution

workshop, the PMT explored various phase 2 restoration options. Many ponds were rejected either because they were identified as pond habitat in the programmatic EIS/EIR or because there were issues linked to mercury or flood control. A major finding of the design workshop was that only two sets of ponds were suitable for tidal restoration: the Island ponds and the Mountain View ponds.

3.2.3. *Methods and techniques*

The methods used to develop knowledge for the Alviso phase 2 restoration alternatives mostly relied on expert opinions. The PMT reduced the number of options through a design workshop and a multi-criteria analysis. Consultants developed qualitative descriptions of the opportunities and constraints offered by these options. In an alternatives report, these options were evaluated using a multi-criteria analysis. Scientific studies, mostly conducted under the science programme, informed the Alviso alternatives. The PMT established a deliberated method to involve stakeholders, researchers and regulators in knowledge production for phase 2. This method involves making only small steps in the phase 2 planning process, and then presenting the same message to the various groups and gathering their feedback in two sets of meetings. Similar to the two levels of collaboration in the project arrangement,[13] the deliberated method manifested itself on two levels: within the PMT and in meetings between the PMT and other actors. Methods are discussed and decided upon within the PMT. The meetings with the other groups are carefully prepared, with PMT members discussing the topics for the meeting, the kinds of questions they want to ask and how to frame certain issues.

3.2.4. *Interpretation of results*

An Opportunities and Constraints Report was developed primarily by the consultancy team and the executive project manager. The report identified the opportunities and constraints arising from the options discussed in the design workshop, while taking into account the feedback from the first set of meetings with stakeholders, researchers and regulators. The report's contents were reviewed by several PMT members (USFWS, SCC, lead scientist, SCVWD) and the City of Mountain View. Comments focused on both the implications of the scientific studies for the restoration alternatives, and location-specific considerations such as mercury contamination and levee strength. Changes in the restoration alternatives reflect the knowledge developed: levee improvements would be required in an adjacent flood basin, trails and an interpretive platform were added, and the nesting islands and ecotone transition areas were modified.

In 2012, the PMT discussed the opportunities and constraints in separate meetings with researchers, regulators and stakeholders. Researchers were asked to provide input for Alviso phase 2. This resulted in fewer breaches in the Island ponds, and changes to the sizes and shapes of nesting islands in the Mountain View ponds. Regulators were asked for input on allowable strategies for creating ecotone areas from dredged material. However, the regulators asked questions about the restoration alternatives, and gave little feedback on allowable strategies. Stakeholders were able to ask questions about the restoration plans and many questions had a clarifying character. Generally, the stakeholder forum approved the plans with the notable exception of the planned restoration of Charleston Slough. Here, a bird protection organisation (Audubon) criticised plans to restore this area to tidal marsh. In addition to the meetings, findings in this knowledge arrangement are communicated in multiple ways. Various reports are posted on the project website (memo design workshop, Opportunity and Constraints Report, updated maps). More informally, the executive project manager discussed findings in personal meetings with various actors: the consultant team, regulators, USFWS staff, concerned stakeholders and the City of Mountain View.

3.2.5. *Choice of solution*

An agreed solution for Alviso phase 2 had not been identified by the time of our data collection in 2012. The PMT later selected three alternatives for the Alternatives Report (February 2013) that will be evaluated in an EIS/EIR procedure.

To conclude, the degree of interaction among the organisations involved varied across the four interactive knowledge development activities. The PMT directed the problem formulation, the selection of methods and techniques and the solution choosing process. During the interpretation of results stage, other actors could share their knowledge. Researchers contributed new knowledge on restoration alternatives with their studies and observations from field visits. Stakeholders were less significant in terms of contributing knowledge in this phase as they had already shared their knowledge in earlier stakeholder forum meetings. By involving the regulators, the project ensured that only permissible restoration

[13] Collaboration refers more generally to how organisations interact with each other in the project arrangement, whereas the deliberated method refers specifically to interactive knowledge development. The discussion on possible funding strategies with the stakeholder forum (November 15, 2012) amounts to collaboration. In the same meeting, as part of interactive knowledge development, stakeholders provided input for phase 2 restoration alternatives (see Section 3.2.4).

actions would be developed. Involving all these groups was not easy: scientists felt neglected during the first round of meetings in 2011 and developed a highly critical approach to the PMT; stakeholders represented multiple interests that had to be continuously addressed; and regulators were reluctant to engage early in the planning process.

Having discussed the project and knowledge arrangements, we derive in the next section the causal mechanisms that explain the process of interactive knowledge development for restoration alternatives for Alviso phase 2.

3.3. Causal mechanisms explaining interactive knowledge development in SBSPR project

From the analysis of the project and knowledge arrangements, we can derive causal mechanisms that are rooted in the empirical data of this case study. These mechanisms show how elements of a causal process contribute to the process of interactive knowledge development in the SBSPR project. By describing both these elements, as well as their effect on the process of interactive knowledge development, the mechanisms improve understanding of interactive knowledge development in an evolving project setting. As causal mechanisms reflect the causal processes responsible for the observed outcomes, they specify the spatial and temporal context in which they operate (Hedström and Ylikoski, 2010; Beach and Pedersen, 2013). The mechanisms are derived on the basis of our template-coding approach (see Section 2.2). The mechanisms are numbered for referencing purposes within this paper and do not signify a dominance of one mechanism over the other. Mechanisms 1–3 outlined below operate within the project arrangement and have an effect on the knowledge arrangement, whereas mechanisms 4–7 operate within the knowledge arrangement. The arrangement dimension in which each mechanism originates is highlighted in italics.

Mechanism 1. Public support – The need for public support results in a process of interactive knowledge development.

The case studied shows that public support was of the utmost importance for the project by fostering funding and project progress. The project management team adopted a collaborative approach *(interaction rule)* to ensure support from communities and organisations in the bay area. This collaborative approach was translated into a deliberate and transparent method of interactive knowledge development for Alviso phase 2. Deliberation occurred at the PMT level and also between the PMT and other groups. Documents of meetings and intermediate reports are posted on the project website, resulting in a transparent process.

Mechanism 2. Project memory – The project memory of actors structures the roles of others in a process of interactive knowledge development.

Individual PMT members *(actors)* of CDFW, SCC, USFWS and CCP were involved from the land acquisition in 2003. They carried the project through the planning phase, saw the rise of the adaptive management plan and the phase 1 studies and then supervised construction activities. As such, they have intimate knowledge of the possibilities in future restoration of the salt ponds. This affected their relationships with the consultant team that was hired for phase 2. As a newcomer to the project, the consultants added details under the PMT's directions.

Mechanism 3. Resources – Resources narrow the scope for interactive knowledge development.

In the case studied, the programmatic EIS/EIR (*information*) supported the option of establishing tidal marshlands, and other resources (limited *time* and *money*) prioritised the type of solutions sought for Alviso phase 2. This resulted in a retrenchment from a formal equal discourse (restoration, flood control and public access) to tidal restoration where a backside levee was present. In rejecting other options, PMT members referred to these limited resources when explaining their decisions.

Mechanism 4. Type of knowledge – The type of knowledge supports a process of interactive knowledge development.

In this case, the restoration alternatives for Alviso phase 2 were understandable by non-experts (*actors*). Stakeholders, researchers and regulators commented on the qualitative results in the form of maps and descriptions. Further, contributions by organisations such as Audubon, a bird protection organisation, were easy to incorporate when a set of alternatives were developed for the Alternatives Report.

Mechanism 5. Creating a 'safe environment' – A safe, confidential, environment results in extra valuable knowledge.

In this project, researchers needed a meeting with the PMT, independent of other stakeholders, in which they could share knowledge that was not strictly based on their findings. Regulators met one-on-one with the executive project manager, and shared more information than they would in a meeting with other actors. The PMT created these 'safe environments' (*interaction rules)* on purpose so that actors could share more knowledge than they would in public. In this way, the PMT received valuable knowledge that they might otherwise lack. This helped the PMT in developing good and allowable alternatives for Alviso phase 2.

Mechanism 6. Professional facilitation – Professional facilitation smoothes the process of interactive knowledge development.

The CCP had no formal responsibilities in the project, and focused on its tasks of facilitation and conflict mediation. During phase 2 meetings, the CCP facilitated dialogues *(interaction rules)* between decision-makers, researchers, stakeholders and regulators. The CCP ensured that each meeting was carefully prepared, that each voice was heard, that the scope of a discussion was clear and that vague expressions were clarified. This resulted in better understanding among the actors involved in the meetings.

Mechanism 7. Diverse perspectives – Including diverse perspectives broadens support among the actors involved.

In the case studied, the method of deliberately involving *actors* early and frequently in the process ensured that concerns were detected early. During the various meetings, criticisms were explored and potential drawbacks were discussed. This resulted in changes in some of the restoration alternatives, for example in the proposed nesting islands. The meetings offered distinct platforms for discussion between the PMT and stakeholders, researchers, and regulators leading to a shared understanding.

The mechanisms discussed above are closely connected (see also Fig. 3). Mechanisms in the first group (1–3) connect the project arrangement to the knowledge arrangement. These mechanisms *affect*, or have an effect on, the process of interactive knowledge development. Mechanisms in the second group (4–7) operate within the knowledge arrangement. These mechanisms e*xplain*, or provide more detail on, the process of interactive knowledge development. In addition, the mechanisms have either an enabling (1, 4–7) or constraining (2, 3) impact.

4. Discussion

The causal mechanisms represent the key findings of our analysis. The uncovered mechanisms enrich the current understanding of interactive knowledge development in coastal regions. The entire set reveals how mechanisms coexist and influence interactive knowledge development. The mechanisms are rooted in a collaborative coastal project that integrates knowledge from researchers, stakeholders, regulators and decision-makers. As such, this paper suggests how to integrate the knowledge held by such

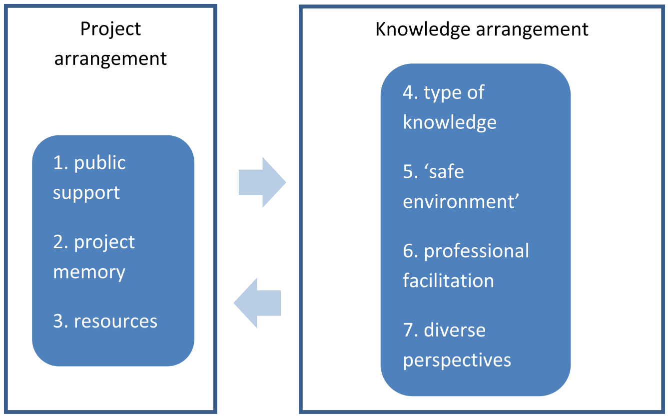

Fig. 3. Characteristics of the project and knowledge arrangement that influenced interactive knowledge development in the South Bay Salt Pond Restoration project.

diverse groups for various management purposes such as: sustainable coastal zone management (Bruckmeier, 2012; Bremer and Glavovic, 2013; Clarke et al., 2013), adaptation to climate change (Tribbia and Moser, 2008; Schmidt et al., 2012) or adaptive management (Walters and Holling, 1990; Folke et al., 2005). The mechanisms highlighted represent diverse processes that influence interactive knowledge development: the availability of resources (mechanisms 1 and 3) the contribution of actors (mechanisms 2, 5, 6 and 7) and the type of knowledge developed (mechanism 4).

Two mechanisms illuminate relationships that have not been previously reported in scientific literature on interactive knowledge development for environmental decision-making. The first mechanism is the strategy of actively creating safe environments. This results in additional knowledge from researchers and regulators that would otherwise have been difficult to obtain. This mechanism seems to contradict with the idea of a common space in which stakeholders, decision-makers and researchers convene together to share and develop knowledge (Schmidt et al., 2012). The second mechanism is the strong link established among public support, funding and interactive knowledge development. As discussed earlier, drivers, or arguments for interactive knowledge development, are often referred to in abstract terms such as sustainable development, broadly accepted solutions or adaptation to climate change. This case study adds an additional driver: public support as a catalyst for funding.

In this paper, we used the conceptual framework of project arrangements and knowledge arrangements (PAKA) (Seijger et al., 2013). This framework served our research interests, and by applying it in a longitudinal approach, the framework effectively unravelled the process of interactive knowledge development in the project domain. A different, but related framework has been developed that supports an analysis of joint knowledge production projects (Hegger et al., 2012a). This so-called JNP framework provides seven success conditions for joint knowledge production. Both frameworks have been published recently, thereby showing the significance of understanding interactive modes of knowledge production. To enhance conceptual understanding of such knowledge production in a project domain, we compare the two frameworks with each other in the remainder of this section. The frameworks share similar conceptual foundations: they perceive the production of knowledge as a social process, rely on the policy arrangement approach (van Tatenhove et al., 2000) and study interactive knowledge development within a project domain.

The frameworks differ in three aspects. First, the JNP framework derives success conditions from literature, whereas the PAKA approach roots mechanisms in real-life projects. The mechanisms and success conditions overlap (i.e. in terms of actor involvement, problem formulation), but also focus on different aspects such as reward structures (Hegger et al., 2012a, 2012b) or the type of knowledge developed (Seijger et al., 2013; this paper). Second, the JNP framework consists of a single arrangement whereas the PAKA approach has two types of arrangements. By distinguishing project arrangements and knowledge arrangements in the PAKA framework it becomes possible to analyse how the project environment affects the process of interactive knowledge development. This results in additional insights, for example on project drivers of interactive knowledge development or on project-level actor relationships. (Seijger et al., 2013; this paper). Third, the frameworks cover different purposes of knowledge production. JNP assesses the success of research programmes that aim to produce policy-relevant knowledge whereas PAKA assesses knowledge production for solutions that are constructed within coastal projects. These different purposes, and the different foci of the two frameworks, suggest that the production of socially robust knowledge differs between science–policy interfaces and implementation projects.

5. Conclusions

To address the need to produce socially robust knowledge for coastal solutions that respond to global and regional changes, this paper's aim was to understand the role of interactive knowledge production in collaborative coastal projects. The analysis of the South Bay Salt Pond Restoration (SBSPR) project has contributed to a thorough understanding of interactive knowledge development by focusing on the interplay between the project and knowledge arrangements, and by deriving and developing causal mechanisms that influence the process of knowledge development.

The SBSPR project shows that establishing a collaborative project and a process for interactive knowledge development does not guarantee an all-encompassing solution for complex problems in coastal regions. The initially equal goals of nature restoration, flood control and public access were reduced in the Alviso complex to tidal restoration where adequate flood controls were present. An existing lack of adequate flood controls served as a rigid boundary condition that restricted the possible solutions for restoring nature in Alviso phase 2. Collaboration failed to overcome such boundaries in phase 2 planning.

Moreover, the case study highlights how difficult it is to organise interactive knowledge development. Every actor requires careful handling in a lengthy process, and it took almost three years to develop alternative restoration options. The study identified seven mechanisms that both affect and explain the process of interactive knowledge development in this project. This set of mechanisms reflects a novel step in understanding interactive knowledge development: a step that enriches current understanding by making explicit the elements, structure and effects of a causal process in interactive knowledge development.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.ocecoaman.2013.12.011

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