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ORIGINAL ARTICLE

A game-structuring approach applied to estuary management in South Africa

J. H. Slinger · S. W. Cunningham · L. M. Hermans · S. M. Linnane · C. G. Palmer

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Abstract A game-structuring method is applied in a contested, real-world setting of estuary management in South Africa. The key activities undertaken in applying the six step game-structuring method are described and artefacts developed in the process are provided. Participants were readily able to identify strategic outcomes and payoffs in the case. Conversely, identifying actions in a well-timed sequence proved difficult. Choices to focus the discussion of actions on real-world biophysical and infrastructural interventions proved necessary for successful method application. The implications for method design and the challenges of using the game-structuring method as a mediating intervention form the subject of reflection.

Keywords Problem structuring methods · Water management · Environmental negotiation

Mathematics subject classification 90 · 91 · 93

J. H. Slinger · S. W. Cunningham (✉) · L. M. Hermans
Policy Analysis Section, Faculty of Technology, Policy and Management,
Delft University of Technology, Delft, The Netherlands
e-mail: s.cunningham@tudelft.nl

S. M. Linnane
Centre for Freshwater and Environmental Studies, Dundalk Institute of Technology,
Dublin Road, Dundalk, Co. Louth, Ireland
e-mail: Suzanne.Linnane@dkit.ie

C. G. Palmer
Unilever Centre for Environmental Water Quality, Institute of Water Research, Rhodes University,
Box 94, Grahamstown 6140, South Africa
e-mail: Tally.Palmer@ru.ac.za

1 Collaboration or contestation?

South Africa implemented a pioneering National Water Act in 1998. The law guarantees access to water for basic human needs and for the purposes of ecological sustainability. Other uses, in excess of basic need and sustainability, are subject to allocation processes designed to promote equitable and sustainable development. The law is an international exemplar of equitable and sustainable policy for water management and represents a departure from the previous riparian system, whereby water rights were allocated to land ownership along rivers (Thompson et al. 2001). However, there are several obstacles to the effective implementation of the law. The law mandates a procedural system for resolving water dispute, with a process of mediation and negotiation ordered by the minister of water affairs as last resort in dispute resolution. Further, the Constitution of the Republic of South Africa (1996) established three spheres of government, with distinct functions—the national, provincial and local spheres. This systematic application of the subsidiarity principal means that the provincial and local spheres acquired new, decentralized functions. A full-fledged system of local representation and national cooperation is still developing (Thompson et al. 2001). Further, common pool management is hindered by a history of apartheid (Beall et al. 2005), and the perception among the public of a corrupt government (Hauck and Sweijd 1999).

In 2011, the situation of Groot Brakrivier, a small town in the Western Cape of South Africa (Fig. 1), exemplified at small scale the nationwide situation of paralysis and concomitant failures in service delivery (Palmer et al. 2013) and provided the context within which a novel game-structuring approach aimed at facilitating social negotiation could be applied and tested for the first time. The application of the game-structuring method is described in this paper and its utility as mediating intervention is evaluated.

The town of Groot Brakrivier is situated on an estuary, known locally as the Groot Brak Estuary or the Great Brak Estuary. (The word "brak" is Afrikaans, and means a body of brackish water). An island stands between the town and the sea, housing a population of elderly, long-term residents who have built their homes in the floodplain of the estuary. The island and the town are subject to both drought and flood. The estuary is periodically shielded from the sea by a berm, a bar of sand which blocks the incursion of salt water. Heavy flows of fresh water are needed to restore the connection between the estuary and the sea, and like many estuaries, ecological health depends upon the exchanges of salt and fresh water (Allanson and Baird 2000, p. 340). Both the estuary and sea are important for local recreation, tourism, and fishing livelihood.

Groot Brakrivier is characterized by a 25-year long history of contestation about the management of water releases to the downstream estuary from a dam constructed 3-km upstream of the town in 1989 (CSIR 1990; Slinger et al. 2005). The water in the dam was envisaged to be able to supply the industrial water requirements of the petrochemical industry in the region, the future domestic water needs of the Mossel Bay metropole, 35 km from Groot Brakrivier, as well as addressing the water requirements of the downstream estuary. Following an initial environmental impact assessment (CSIR 1990), monitoring and regular publically

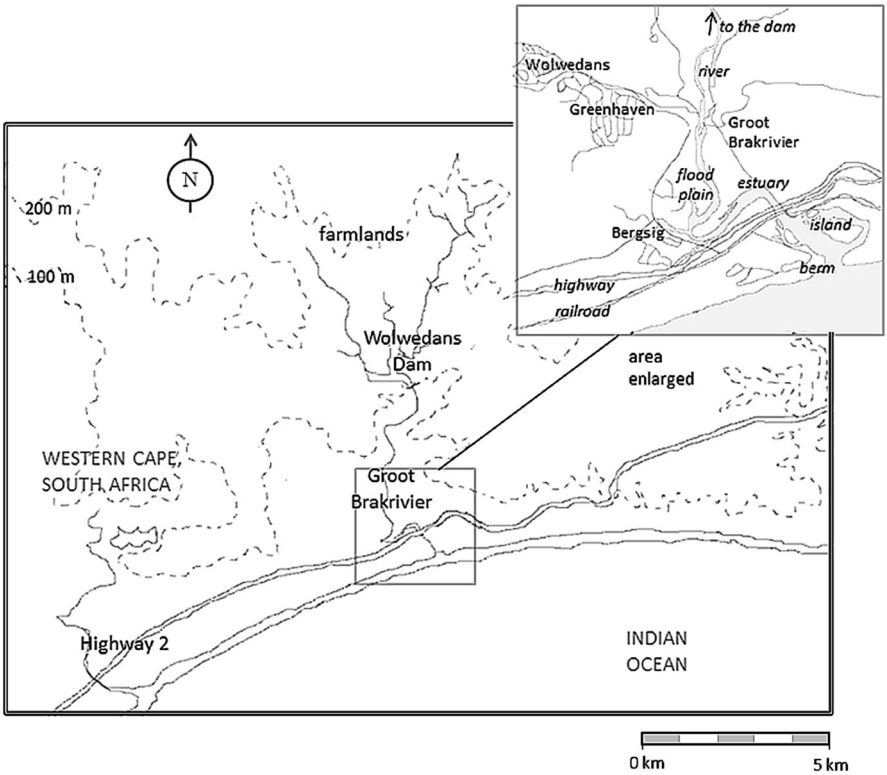

Fig. 1 Groot Brakrivier and environs

informed revision of the operational management of the dam occurred over some 20 years under the auspices of the Great Brak Environmental Committee (Slinger et al. 2005).

However, in 2010/2011, the situation was at an impasse. Although a study to determine the freshwater flow requirements of the downstream estuary was undertaken (Department of Water Affairs 2008), a decision by the national Department of Water Affairs (now department of Water and Sanitation) regarding the amendment or ratification of the annual freshwater allocation to the environment (in this case the estuary) was still pending. In the meantime, a period of severe drought (2009/2010) led to the allocation of a national infrastructure grant to construct a desalination plant to ensure the security of supply of freshwater to the Mossel Bay petrochemical industry and metropole residents. The drought led to the estuary not receiving any water from the dam in contravention of existing agreements. The situation was further exacerbated by catastrophic river flooding of Groot Brakrivier and island in 2011. In short, a long standing situation of collaborative engagement on a contested water resource could be characterized as "stuck" at the time of this study.

This situation provided the motivation for a broad, transdisciplinary intervention within the ongoing societal negotiation process related to the use of water from the

upstream dam (Palmer et al. 2013). The intervention involved establishing a chronology of decision making from 1985 to the present day during a workshop attended by officials and advisors who were directly involved with decision making on the Great Brak system in the past (Taljaard et al. 2012). Validating the chronology and extending it to the present day semi-structured interviews with eight local and regional officials were conducted in November 2011. A further 69 members of the local community were interviewed to deepen understanding of the present situation, particularly the use of the estuary by local residents (Greter and van den Hurk 2012). A narrative chronology of the Great Brak, its water and society was produced (Linnane and Slinger 2012).

It is within the context of extensive system knowledge of the functioning of the Great Brak estuary, the water system, the local and regional stakeholders, the use that the coastal community makes of the estuary, and the deeply contested decision-making environment that the game-structuring workshop intervention is undertaken. The purpose of this paper is to clarify the role of a game-structuring workshop as a component of an extended system of intervention. Additionally, the paper clarifies the workshop design choices to provide guidance to others who may be facing similar design issues. These clarifications also help in establishing the reliability of the data collected. Throughout, the case is used to exemplify a successful game-structuring exercise, as a concrete case is often far more instructive than an abstract methodological specification. As a final note, the paper reflects on the suitability and limitations of a particular class of problem structuring methods. Such reflections may be of broader use to methodologists, or to particular domain experts encountering similar issues of natural resource management.

Following a description of the game-structuring method (Sect. 2), the application to the Great Brak case is detailed (Sect. 3). Choices made in applying the method are highlighted and artefacts from the game-structuring process are provided. The implications of the case for the participants and Groot Brakrivier itself are then evaluated and reflected upon (Sect. 4). Then, we conclude in Sect. 5 by highlighting future research requirements for methods focusing on highly contested social environments.

2 The game-structuring method

As noted, the Groot Brak intervention involved a mixed methodology. Part of this methodology involved conducting a game-structuring workshop intended to reveal the complexities of the decision-making context surrounding the estuary. We build upon an existing problem structuring method to better explore the case (Cunningham et al. 2014). The researchers hypothesized that participants in the workshop could easily identify the standard components of a game, as specified in the technique, and that these components would aid in structuring, understanding and mediating the problem.

The methodology adopted is a hybrid methodology which builds upon a number of existing problem structuring methods. It uses common game elements which are found in multiple techniques, including the analysis of options, conflict analysis,

exchange modelling, hypergame analysis, and the theory of moves (Howard 1971, Coleman 1972, Bennett 1977, Fraser and Hipel 1984, Brams 1994). These game elements are then coupled with an explicit participatory modelling framework which is explicitly developed for engagement with stakeholders, following Voinov and Bousquet (2010). Franco and Montibeller (2010) also consider issues of facilitated modelling.

In the following methodology section, we note the six main steps of the technique. Some of these steps are conducted directly with workshop participants, while others are part of an extended methodology. Our specific choices in this regard are discussed further in Sect. 3, where specific results are presented, and specific design choices are made clear. First, however, we set out each of the steps, and describe particular issues which need to be addressed in each of the steps.

The first step involves identifying the players. This step is performed in part as an ethnographic study where an extended list of the affected stakeholders is considered. Expert consultation is also used, for instance, to better understand the legal and institutional frameworks operating in the region. This process, in general, of establishing the full decision-making context is known as describing the arena of the problem (Hermans and Cunningham 2013). Project goals are also established in this step. Cunningham 2014 offer some guidance as to which goals are available, and how these goals might be established. Listed goals include enabling learning, developing technical requirements, and anticipating political action. [See for instance Bueno de Mesquita (2010), which describes heresthetics—the practice of predicting and intervening in strategic games.] Intermediate goals between these three include process and stakeholder management, and also negotiation and arbitration of potential favourable outcomes.

Step two involves analysing the system and its context. This entails a substantive process of developing an understanding of systems functioning. This step is also the subset of problem structuring methods (cf. Eden and Ackermann 1998). See for instance (Wang et al. 2003) for a thorough systems analysis as a precursor to a full game analysis of a (water) policy setting. It is also necessary during step two to assess strategic vulnerabilities—whether from external events, or deliberate actions taken by other players.

In this paper, systems understanding and strategic vulnerabilities were derived from existing research activities outside of the game-structuring intervention. These encompassed expert consultation, ethnographic studies, interviews, stakeholder engagement, document analysis, systems modelling and spatial analysis. A scientific workshop (in addition to a participatory workshop) was also held. The interviews generally lasted longer than 1 h, and were semi-structured in character. The interviews were conducted with several needs in mind—"snowballing" to establish a list of future contacts, determining the needs and vulnerabilities of the community, establishing sources of strategic action and conflict, and eliciting information to gain better insight into the context of the problem.

The group of researchers and graduate students was active in Groot Brakrivier as part of an international exchange and research project involving coastal and water management (Palmer et al. 2013). The workshop was nested within existing research activities, including expert consultation with other water officials and

engineers, interviews with industrial interests, and a study of water use in the local population. This extended analysis involved interviewing 69 local citizens as well as eight corporate and government actors (Taljaard et al. 2012). A mixed analysis involving both spatial–geographical as well as anthropological elements was performed using a geographic information system (Greter and van den Hurk 2012; Taljaard et al. 2012). The systems analysis drew upon an extensive body of knowledge of the estuary ecology, water quality, hydrodynamics and the river hydrology, as well as 25 years of experience in the management of the estuary as recorded in a series of management reports (CSIR 1990, 2003). The current system understanding was synthesised in a recent ecological flow requirements study for the Great Brak estuary (Department of Water Affairs 2008). This knowledge base and the ongoing activities provide a sense of the extended intervention of the analysis. The game-structuring analysis was not performed in isolation of other research activities, but instead drew upon the existing and deep system understanding of the participants.

The extended analysis revealed several sources of potential vulnerability in the system, which was discussed briefly by participants. The severity of recent incidences of both drought and flood (CSIR 2011) in the mild, maritime climate was seen as indicative of the onset of long-term climate change by many citizens. Regardless of climate change, local development has encroached on low-lying lands making the incidence of flood damage an ever present likelihood (CSIR 2011). The region is subject to both periodic drought and disastrous flooding, as a result of the interannual, seasonal wet–dry climate (CSIR 1990; Department of Water Affairs 2008). The town and surrounding region suffer water stress resulting from natural variability of supply, and a wide variety of conflicting demands on the river and estuary about which the town is built. These include local and regional demands for water for domestic, agricultural and industrial purposes; water to flush sediment from the mouth of the estuary and so to reduce the risk of (back)flooding; water to maintain the ecological health and water quality of the estuary; and water to sustain tourism and recreation.

Step three involves the development of strategic outcomes, as indicators of potential game outcomes. Here, we are using the meaning of outcomes as possible strategic futures as described by Howard (1987). Howard's focus on strategic futures rather than futures created by external events or contexts is unusual, but not without precedent in the literature. See for instance Rhyne (1981). Unlike Howard (1987), but in keeping with Dewar et al. (1993), the outcomes of the game are envisaged before the range of possible actions is deliberated. One of the created outcomes should be dedicated to the status quo outcome, or how things may progress if no action is taken to deviate from existing paths. The status quo is an important benchmark for setting future goals and expectations (Li et al. 2004).

Step four involves the analysis of payoffs for the various actors. Payoffs are stakeholder-specific valuations of outcomes of interest, which are ultimately derived from the particular system under study. An understanding of system functioning derived from step two is, therefore, necessary here. In many systems, it is permissible to entertain mixtures of outcomes. This step requires assessing the ordinal utilities of each of the outcomes developed in step three. This is performed

on behalf of each of the key players of the game, possibly using role-playing and/or surrogates where pay-offs may be estimated by other informed participants. A simple rank ordering of the *n* outcomes from least preferred (rank one) to most preferred (rank *n*) is sufficient. More elaborate treatment of utility is possible, if respondents display a lot of inter-group and between-group reliability in assessing the preferences.

Step five involves using a planning approach model to develop possible actions. A planning approach involves thinking first of outcomes and only later of actions. Accordingly, this step requires evaluation of all the outcomes from step four to determine a range of possible actions for each of the players. The participants identify which sets of actions are necessary to create each of the potential future outcomes. Participatory methods for framing policies in pursuit of desirable futures are the main focus of back-casting efforts—see for instance (Quist and Vergagt 2006). It is important at this stage that the participants remain agnostic about whether a player would or would not take a particular action; all should be listed. Entirely new actions may be proposed during this stake to hedge losses, or to shape and promote positive outcomes for a particular player.

Step six entails offering further mediation. Social dilemmas involve players being trapped in sub-optimal outcomes because of a lack of communication, cooperation, or external mediation. Analysts or facilitators can help by describing the space of possible win–win solutions, a process called integrative negotiation (Thompson 2011). For other literature on the practice of effective negotiation, see Fisher et al. (1991). For more normative theories of negotiation, see Sibenius (1992). Further distributive negotiations (Thompson 2011), where players discuss the relative division of rewards from cooperation, may then occur. Various other game-structuring techniques make further analytical assumptions about rationality and game equilibria and may be employed as warranted (Howard 1971; Fraser and Hipel 1984). Although only limited mediation occurred in this paper, the effects of mediating activities undertaken later by participants are reported.

3 Game-structuring applied to the Great Brak case

In the following section, we describe and specify the key activities undertaken in applying the six step game-structuring method to the case of the Great Brak, highlighting choices made in applying the method, and providing artefacts built from the process where suited.

3.1 Workshop set-up

The workshop participants were selected on the basis of (1) their involvement in advising on the allocation of water from the dam located immediately upstream of the town of Groot Brakrivier, or in studying the Great Brak estuary and its societal use, (2) their presence in the Great Brak area at the time of the workshop, (3) their familiarity with the interests and perspectives of a range of involved actors, from municipal managers, ecologists, local farmers and schoolchildren to industry

representatives (through the 77 interviews conducted in the area), and (4) their willingness to participate in testing a novel approach to environmental management.

The participants included two natural scientists and an older coastal engineer from the Council for Scientific and Industrial Research (CSIR), three graduate students, and four academic researchers in policy, water and coastal management, and aquatic science. When required, the ten participants were divided into groups of two, in order to better share ideas, and so as to have a relatively compact set of outcomes. In retrospect, the workshop would have run very differently, and been tuned to very different outcomes, if a wider variety of stakeholders were engaged. We reflect further on this point in the conclusions.

The workshop was held on two successive evenings, in two sessions of 2 h on 17 and 18 November 2011. The timing of the workshop was determined primarily by the availability of the workshop participants. During the day, the exigencies of the SANPAD project required the workshop participants to be in different locations in the environs of Groot Brakrivier, making evening sessions the only viable option. The workshop was held in a beach-side condominium. Given the relatively intimate setting, and the comparatively few participants, it was sufficient to capture the main ideas of the participants in notes. Communication and feedback to participants were primarily verbal. Nonetheless, the use of other media (computer and paper-based) could have been suitable, and might have enhanced the experience. Two sessions were necessary because calculations had to occur between Steps four and five, and to retain the attention of the (tired) participants. The first session ended after the discussion of outcome rankings in Step four.

3.2 Step 1: Identify the key players

Participants were requested to identify the key players involved in the allocation of water from the dam and the management of the Great Brak estuary. After a lively discussion of the wide diversity of actor interests and perspectives, participants agreed to nominate five players, which are archetypes or composites of diverse actors with shared interests. The liveliness of the discussion stemmed from either long-term experience with stakeholders in the estuary (on the part of the CSIR scientists and engineers) or the first-hand experiences gained through interviews and ethnographic activities (academic researchers and graduate students). An implicit social contract was adopted which permitted—and even encouraged—younger members of the group to speak.

The first player, the Locals, is envisaged as encompassing long-term residents of the community, as well as seasonal vacationers. The community of Locals may be subdivided further according to age, socio-economic status, livelihood, and regional ties. The second player, the Developers, includes the local municipality, as well as commercial and landed interests. The Developers may be subdivided further by public or private concerns. Participants nominated Water Affairs as the third player. This actor represents water governance interests, and may be subdivided further by their coordination effort across spheres of South African government—national, provincial and local. The Industrialists player represents the major users of water for non-domestic and non-agricultural purposes. This includes a processing plant which

requires substantial quantities of water for processing regional reserves of natural gas. The fifth player, the Environmentalists, was also nominated. Environmentalists may be subdivided further by the nature of their environmental concerns. They may be motivated primarily by recreational, livelihood, scientific, or community-oriented concerns.

The process of identifying the key players in terms of their shared interests was conducted en plénière under the leadership of the facilitator, so that each participant could hear the other participants' views on actors' interests and perspectives and fully grasp the resulting characterization of the key players.

The facilitator played some role in developing a consensus about which actors to take forward for further modelling. The facilitator had previous experience in game theoretic formal modelling, where simple, brief, explicit assumptions are favoured. This certainly played a role in structuring and ultimately reducing some of the complexity of the arena. This step was also useful for time management purposes, because the workshop design itself scales in time according to the number of key actors selected. The drawbacks and limitations of this are further considered in the conclusions.

Participants generally had little difficulty in conducting this broad characterization, but felt some initial discomfort in assigning the local municipality (Groot Brakrivier) with commercial and landed interests in the Developers player. However, the interests of the local municipality were deemed to coincide with those of the commercial and landed interests in relation to the allocation of water from the dam, making the characterization of such a representative group feasible.

3.3 Step 2: Gather information

In this implementation, gathering information and system structuring activities were held entirely outside of the game-structuring activity. The fuller context of this multi-methodology intervention is discussed in the previous section. This previous information gathering activity primarily served as context for the game-structuring workshop. Lest this sound like a relatively minor input to the workshop, as researchers we were collectively very concerned about getting the system assumptions correct. Game-structuring methods typically leave the system, and its outputs, underspecified. The formal modelling activity leaves these system outputs unspecified so to better focus on the interactive and strategic character of decision making. As an adjunct to problem structuring, however, this places additional responsibility on the analyst to get the system setting correct. We reflect on these challenges in the following section on discussion and reflection.

3.4 Step 3: Discuss and define outcomes

Participants were invited to generate and describe future outcomes concerning the estuary using an informal variant of the nominal group technique per group of two, and to describe the states of the system under these outcomes. Participants were explicitly requested to draw primarily upon their system knowledge to envisage logically consistent yet socially "unthinkable" or "undesirable" future states, so as

Table 1 Synopsis of the future outcomes

Outcome name	Outcome description
Status quo	Represents the system today, and projects this into the future
Ghost town	Prolonged drought causing one or more large employers to leave the area
Cess pool	Heavy local and regional water demands result in inadequate flushing of the estuary
Children frolic	Ecologically sound use of water from the dam, increased tourism
Dutch design	Engineered safe housing on the island and low-lying areas by building dikes and sustaining walls
Maldives on the Brak	Seawater is pumped into the estuary at the cost of ecological integrity

to loosen societal bounds to their thinking and encourage out-of-the-box outcomes. Six utopian and dystopian outcomes were created and then discussed and coined en plénière. No particular adaptations of the methodology were needed.

The facilitator encouraged consideration of a wide variety of possible outcomes. In particular, participants were encouraged to develop outcomes which span the space of strategic possibility. We argue that some groups naturally foreclose possibilities arguing that the outcomes may not be socially or politically feasible. Nonetheless, foreclosing these possibilities is counter productive since outcomes, even if never reached through strategic action, play a very important role in shaping and structuring further action. Spanning outcomes are deliberately encouraged so as to open the space for future discussion and negotiation (see step five below). In addition, a selection of spanning outcomes is very helpful for triangulating more moderate or intermediate values. Also see (Bueno de Mesquita 2010) for more about developing a spanning scale for evaluating a full range of desirable and undesirable outcomes.

This activity of encouraging divergent thinking is similar in some respects to creativity exercises, and also to scenario analyses. However, it also bears significant differences, since the purpose of the constructed scenarios is not to uncover wildcards, or to develop strategies which are robust to a variety of unforeseen futures. Instead the role of the outcomes is to clarify potentially very different desirable and undesirable outcomes for the estuary, and to clarify how these threats and promises might serve as a commitment to future action.

The six outcomes are summarized in Table 1, and discussed individually below. Although, not immediately apparent to the participants, the understanding emerged that differences in the outcomes arise from differing priorities placed on human development, industrial activity, and environmental concerns. It is noteworthy that one of the outcomes—Maldives on the Brak—had never previously been considered as a potential future state owing to the implication that one would engineer for a loss of ecological integrity.

A status quo outcome, representing the state of the system today, was included. In particular, the status quo retains a large petro-chemical company as the major employer in the region and the continued growth of the Mossel Bay metropole. The status quo determines the minimum satisfactory payoffs for all key players.

The ghost town outcome describes a situation where one or more major employers leave the area. A secondary cause of the outcome is prolonged drought, with insufficient water available by any means. This results in a reduction of local and regional economic activity through knock-on or multiplier effects. Both local and regional de-population occur, as job seekers move elsewhere.

The cess pool outcome depicts a failure of common pool governance. Heavy local and regional demands on the water result in lower levels in the dam and insufficient flushing flows to the estuary. Untreated sewage and nutrient-rich waste enter the estuary from the town and island, resulting in algal blooms and unacceptable water quality. Tourism and recreational use of the estuary suffer. This outcome highlights the role of water as an enabling resource. With insufficient water, any number of future outcomes—whether industrial, social, safety, or ecological—are effectively foreclosed.

The children frolic outcome involves a sustainable, ecologically motivated and sound use of water from the dam. It is accompanied by investment in environmental education and tourism, with Groot Brakrivier functioning as a show case, and generating eco-tourism revenue. Extended exploration of this outcome revealed that this outcome mostly entailed a process of social learning and whereby the people of the Groot Brak and visiting tourists learned about, and enhanced their relationship with, the estuary. Very different would be a scenario which involved restoring and maintaining the estuary at a state prior to the dam, and to extensive exploitation.

The Dutch design outcome explored the potential to engineer safe housing on the island and low-lying areas by building dikes and flood-resistant structures. By loosening constraints on the maximum volume of water that can be released from the dam, the outcomes both increase the protection from flooding when a flood is imminent, and enhance the efficacy of water releases for the ecology. Thus, the water could be used elsewhere in the system, for different ends or purposes.

The Maldives on the Brak outcome involves re-engineering so that seawater is pumped continuously at a low rate into the estuary. This reduces the requirement of the estuary for freshwater to flush the mouth open and maintain the connection with the sea. The outcome creates a safe and aesthetically pleasing living environment, but these changes sacrifice the ecological integrity and biogeographic uniqueness of the estuarine ecology.

3.5 Step 4: Discuss payoffs

Each group of two participants was then assigned a key player and invited to rank sort the outcomes. This was done as a means of understanding the societal interests involved. Participants were knowing assigned key players. Two different and competing goals were at work. On the one hand, by assigning participants the actors they worked most closely with, the design could ensure a more accurate rating of outcomes. On the other hand by assigning participants very different players, with whom they were not familiar, the process of learning could be enhanced. Our choice here was primarily to enhance learning, rather than to attempt precise specifications of preferred outcomes. We reflect on the consequences of this choice further in the conclusions.

Here, the system knowledge and actor knowledge are drawn together. The ranking is done from the perspective of their particular assigned player. So for instance, the perceived interest of Industrialists may be very different from that of the Locals. The ranking is performed such that each outcome is assigned a unique ranking by each group for their player, and such that a higher score indicates a more favourable ranking. The two participants assigned to each player developed a consensus opinion about the rankings and then shared their reasoning with the group.

We choose the "Developers" key player and the "Cess Pool" outcome for further discussion. A sample strategic conversation concerning the ratings went like this:

Participant 1 The Cess Pool outcome would not be very good for the Developers—they would like it much less than the status quo.

Participant 2 True, but they would like it more than the Ghost Town outcome. Occupancies would drop, and land values would decrease substantially under the Ghost Town outcome.

Participant 1 Do you think they would be willing to invest to remediate such a situation?

Participant 2 I think they would be happy if the national government pays, but would not like to have higher local taxes. Especially if the actions do not benefit new housing projects directly.

Participant 1 Ok then, but would you rate Dutch Design even worse than Cess Pool?

Participant 2 Yes. Projects like that would benefit small home owners and long-term residents much more than newer municipal development plans. Worse still such dikes might block commercial development along the waterfront.

Further discussion regarding values could potentially be assisted by the use of objective hierarchies (Keeney and Raiffa 1993), although particular method was not used in this engagement. The result of the ranking exercise is shown below in Table 2. The first session of the workshop closed with the determination of the outcome rankings.

Analysis of the outcome rankings was undertaken in the period between the two workshop sessions and was discussed with the participants by the facilitator at the

Table 2 Outcome rankings

	Locals	Developers	Water affairs	Industrialists	Environmentalists
Status quo	3	4	2	5	3
Ghost town	5	1	5	1	4
Cess pool	1	3	4	3	1
Children frolic	6	5	6	2	6
Dutch design	4	2	1	4	5
Maldives on the Brak	2	6	3	6	2

outset of the second session. In this case, there may be clear alliances created by scale, caused by those who take the national interest, those who take the regional interest, and those who are concerned for local interests. An assessment of inter-subjective rankings was not possible given the design of two participants per player and a consensus rating. However, statistical techniques such as rank correlation can be used to assess intra-subjective ratings between groups. Principal components analysis, one such possible technique, was applied providing additional insight into the data.

3.6 Step 5: Define future moves/actions

The second workshop session commenced with a discussion en plénière about the analysis of the outcomes and their rankings, and then moved on to defining the actions permitting each outcome. This proved difficult for the participants who tended (1) to confine their description of actions to those they considered wise for the key actors, (2) to persist in trying to sequence potential actions in time, rather than just describing actions that key actors are capable of taking within the biogeophysical and infrastructural system. After extensive discussion, this issue was resolved by assigning a limited set of actions to each of the key players.

Selection of actions by participants is not predicated on whether the actions are constructive, or otherwise in the interests of resolution. The method instead treats actions as naturalistic, emerging naturally from the context of the case, and the capabilities of the players. This assumption about action is deeply held, and originates with the Theory of Games itself (von Neumann and Morgenstern 1944). Von Neumann and Morgenstern begin with the assumption that any game has a fixed structure, and then provides recommendations for strategic play within that structure. Then, the authors also consider the possibilities for communicating or colluding outside the structure of the game. Thus, for von Neumann and Morgenstern, even cooperation begins with a natural structure for contestation.

This original and naturalistic framework for understanding action pervades the game-structuring techniques—all the techniques involve developing a fixed structure of moves (Howard 1971; Coleman 1972; Bennett 1977; Fraser and Hipel 1984). The theory of moves is somewhat different, since it encourages developing an entirely new suite of actions which break the rules of the game (Brams 1994). Nonetheless, even the theory of moves begins with a fixed structure of action which must then be further modified. We reflect further on this matter in the conclusion.

Here again, in the structuring of actions, the facilitator played a strong role. The facilitator has previous experience in developing game theory models. In formal modelling, the choices of actions are kept relatively few, and are selected for clarity and for expository purposes. Having relatively limited choices of action is also very necessary since the method does not scale well to the combinatorial possibilities inherent in each actor having multiple possible choices. This strong structuring of actions has its benefits, in enabling participants to conceive a wide variety of possible actions, and also to introduce their own conceptual analysis of actions in the future. It also introduces dangers or limitations, which are more fully discussed below.

The set of Locals have two options—to stay living in their houses in the floodplain, or to move to higher ground or other regions. The Developers can restrict their building options to better accommodate extreme conditions, or can continue to expand their activities with relative freedom. The Department of Water Affairs has two separate sets of two options. The first concerns whether to invest additionally in flood risk management, or to maintain the current infrastructure. The second is to allocate the recommended environmental allowance to the estuary, or to block further action in this regard. The Industrialists can use municipal water, or they can desalinate their own water. The Environmentalists can retain the existing structure and functioning of the ecological system (preserve), or participate in the radical re-engineering of the estuarine ecology.

In conventional game-structuring approaches, the step of developing actions comes earlier in the analysis process, where it precedes the establishment of possible future outcomes. In an interactive and joint application, following the conventional sequence could make an open debate uncomfortable or impossible, and could lead to positional bargaining rather than interest-based or principled negotiations (Fisher et al. 1991). Discussing possible outcomes—positioned in a somewhat distant future—is likely to offer a more fruitful basis for further discussion. This occurs because sometimes actors can work towards common causes even if their respective interests in these common causes are very different (de Bruijn et al. 2010).

These options are presented in Table 3. Here the options table is abbreviated for conciseness. We show only the Pareto-optimal outcomes which are of primary interest for further mediation. (Identification of Pareto-optimal outcomes is discussed more fully in the next step.) The full table containing all possible outcomes contains over 128 different profiles of moves—there are 64 possibilities given all the moves of the actors, and we also considered a set of variants under extreme climate change. Although there are 128 combinations of moves possible on the complete table, many of the move profiles are effectively indistinguishable from one another. This allows the profiles to be mapped to the six outcomes developed earlier plus the status quo option. Despite this, further discussion of developments under climate change—particularly for the cess pool, children frolic, and ghost town outcomes—is well warranted.

Deriving the table required considerable work with the workshop participants, as well as considerable introspection of the findings of the discussion after the workshop. The authors speculate that appraisal of possible moves is a hard problem in general for problem structuring participants. We reflect on this further in the conclusions.

3.7 Step 6: Mediation of the game

Identifying the space of win–win solutions requires the sequential elimination of dominated solutions—solutions which make one player worse off without demonstrably improving the outcomes for another. These optimal or "efficient" solutions form a basis for further discussion whether the analyst/facilitator seeks the common good, or is strategizing on the sole behalf of one of the players. Other

Table 3 Options table

	Children frolic	Dutch design	Maldives on the Brak
Locals			
Stay	x	x	
Move			x
Developers			
Restrict		x	
Expand	x		x
Water affairs			
Invest		x	
Maintain	x		x
Allocate	x		
Block		x	x
Industrialists			
Municipal	x		x
Desalinate		x	
Environmentalists			
Preserve	x	x	
Re-engineer			x

authors also endorse seeking a space of win–win possibilities when mediating a game (Brams and Taylor 2000).

The general tenor of the discussion is to eliminate solutions which are in no one's best interest. Solutions which cannot be eliminated must, therefore, be favoured by at least one of the players. Rather than intervene on behalf of one player at the cost of another, we maintain all these solutions for further integrative negotiation. The process of finding dominated and undominated outcomes is fully described in the game theory literature. The discussion by Gintis (2009) is exceptionally lucid. Straffin (1993) provides a very clear example of arbitration, including identifying the full space of possible solutions, and identifying the Pareto efficient frontier. The discussion is limited in its generality, however, because it only considers two players.

Consider the following discussion of the respective merits and demerits of three solutions which cannot be easily eliminated from the list of potential outcomes. The Children Frolic outcome involves extensive allocation of water from the dam for environmental purposes. In particular, the periodic flushing of the berm from the estuary to maintain a natural seasonal flow is expensive in terms of water usage. Extensive water conservation measures may be needed to enact this outcome. In contrast, the Maldives on the Brak outcome is very problematic for the environmental advocates since it entails continuous pumping of sea water into the estuary, sacrificing the ecological integrity of the estuary. In fact given the very limited room for negotiation and arbitration, a mixture of Maldives on the Brak and Children Frolic may be the most likely long-term outcome of the problem. However, the Maldives on the Brak solution is particularly troublesome for the environmental advocates.

Identifying the Pareto-optimal outcomes is only the first step in the mediation process. Certainly, it is useful in necessary in envisaging a more constructive future. In this case, additional mediation happened outside of the workshop, when a set of process management recommendations derived from the case were later delivered as part of the overall intervention strategy. Negotiation and arbitration approaches proved helpful in later mediation (Straffin 1993), as did process management techniques (de Bruijn et al. 2010). The results of the game-structuring workshop were an integral part of delivering these recommendations to a wider audience. We could also foresee using the theory of moves, or negotiation approaches to intervene (Brams 1994; Brams and Taylor 2000).

This concludes a discussion of the specifics of the case and the first application of the game-structuring method. In the next section, we offer some thoughts on the validity of the workshop that also entails evaluating the workshop from the perspective of the participants themselves. We discuss limitations of the method, and also evaluate the current developments in the case (up till early 2013) as a necessary postscript to the investigation.

4 Discussion and reflection

Structuring a game and establishing the roles of actors and the rules of decision-making processes with the people involved in these processes are challenging. As Voinov and Bousquet (2010) state, the challenge of working with participants calls for non-traditional approaches. One cannot simply put representatives from different contested corners in one room and ask them to structure their strategic interactions and to put their cards on the table.

General experiences show that it is difficult to ensure analytically meaningful results when working with stakeholders, even when producing relatively simple products such as a stakeholder analysis grid. Indeed, appropriate validation and evaluation of participatory modelling exercises remain a difficult issue (Shadish et al. 2002). The analyst or facilitator intervenes in the research setting, making naive experimental validation efforts difficult or even impossible to apply (Guba and Lincoln (1989). We evaluate our game-structuring intervention using a fairly pragmatic approach, by first evaluating the experiences of the participants, next reflecting on the application of the game-structuring method, and the limitations of the method, and finally exploring the relation with developments in the Great Brak situation (Thissen and Twaalfhoven 2001).

4.1 Evaluating the experiences of the participants

The workshop participants varied in their experience of the game-structuring exercise. All indicated that they enjoyed generating and rating the utopian and dystopian outcomes. They were able to draw upon their existing system knowledge and use it in thinking in a novel way about how the Great Brak estuary and society would react in response to different future stimuli. However, the oldest and most experienced member of the group claimed to have learnt little from the workshop,

but rather to have had his understanding of the situation reaffirmed. This aligns with reported experiences of senior participants in other problem structuring settings. The graduate students viewed the whole workshop as a rich learning environment. A number of other participants were able to identify particular learning. A natural scientist came to appreciate that, through no choice of her own, she was involved in a process of extended societal negotiation rather than holding a neutral scientific advisory position.

Another natural scientist was intrigued by the game-structuring method, questioning her own presuppositions regarding the environmental health of the estuary. She later identified further potential applications of the game-structuring method to coastal management situations in South Africa in which fora for community interaction were being formed, but where there was no shared understanding of the desirability of different outcomes to the involved actors, and where there was no agreed plan of action.

Participants in the game-structuring workshop expressed a deep concern that the issues discussed during the workshop could easily be abused in ongoing debates regarding water allocation. In the real-life situation, workshop participants are most certainly locked into a fixed set of positions. They found it potentially dangerous that the opinions expressed in the safe environment of the game-structuring workshop differed from their official positions.

Participants widely enjoyed the creation of outcomes. This undoubtedly is an advantage for the technique as it contributes to greater engagement in the workshop. On the other hand, the technique demonstrates that even relatively analytical users have difficulty identifying potential moves in the workshop. On the one hand, this may not be all bad, since moves encourage positional bargaining, and are not necessary for identifying a space of win–win solutions. On the other hand, this demonstrates that there may be a greater need for problem structuring techniques designed to assist decision makers in analysing their moves, and the moves and capabilities of other players.

4.2 Evaluating the application of the game-structuring method

As previously noted, two very different interventions were possible in this case. We chose an intervention which worked more closely with scientists, engineers and researchers. Our design intended to maximize learning, and was expressed in the pairing of participants, and in the assigned roles for evaluating payoffs and outcomes. A very different approach would have sought out a variety of different stakeholders, attempting a diverse base of opinion. An approach with diverse stakeholders might have been used to establish social or economic requirements for further technical intervention in the estuary. Both designs have their merit given the respective goals of the intervention.

In previous sections, we noted the challenges in establishing a fixed structure of moves for the game. Game theory analysts have traditionally distinguished between well-formed games, and poorly formed games caused by participants changing the rules and agreeing to form coalitions and covenants. These are the two classic branches of game theory known (rather confusingly) as non-cooperative and cooperative game theory (von Neumann and Morgenstern 1944). Non-cooperative

play assumes games with a fixed set of rules, and cooperative assumes games where participants are willing and able to communicate, potentially coordinating moves, and pooling resources.

As analysts and facilitators we were both challenged by and troubled by the necessity of structuring the game using non-cooperative concepts. It was not clear that there was a single, fixed structure of play involving Groot Brak. Confining the discussion to actions on the biogeophysical and infrastructural environment proved helpful. Somewhat paradoxically, we believe that the additional complexity of introducing conditional moves conditioned on the actions of other players might have resulted in a discussion which was even closer to the social setting of the estuary. In turn, this may have better enabled the discussion and development of strategy on the part of the participants. Further by assuming a fixed structure of play, we as analysts seemed to condemn players to their role environmental dilemma.

In this light, it may be helpful to develop new problem structuring methods more fully appropriate for understanding cooperative games. Such an approach might embrace group behaviour, and the formation of coalitions, and the establishment of common interest. The initial sketches of how this might inform problem structuring methods are beginning to emerge. Wang et al. develop a cooperative framework for modelling water allocation (Wang et al. 2003). Bryson (2004) proposes a narrative, but no less valuable approach when he proposes to work with stakeholders to develop a dialogue in pursuit of the common good.

The role of information—that is, the ability of actors to send and receive signals which are of strategic significance in the play of the game—was seminally discussed by Harsanyi (1967). Information plays an implicit role in both the metagame and hypergame concepts (Bennett 1977; Howard 1987). However, both these game-structuring methods make particularistic assumptions about the nature of information in a game. It may be better instead to let the specifics of the case determine what information is present and accessible to all the players. We found that knowledge of the players regarding the needs, values and concerns of other players was relatively high. In particular, participants were able to consistently value the payoffs to others. Participants were well engaged in discussing outcomes and in adopting alternative perspectives. Thus, the game was not purely a hypergame in the sense of Bennett (1977).

As analysts, we were sensitive to, and concerned with, the ethical implications of being outsiders to the case, and making recommendations to a situation in which we did not have an extended societal stake (Palmer et al. 2013). Our own stance was sympathetic to both environmental and local interests, which we believed we could best support as researchers by providing a full-fledged portrayal of the extended game. Wherever possible we sought win–win outcomes whereby all could benefit, although we were sensitive as outsiders to making policy recommendations that we would not be tasked to complete, nor would affect us directly.

4.3 Limitations of the technique

The technique is limited by the number of potential players considered. As noted, a more comprehensive design with a fuller list of players makes unreasonable

demands on the time of workshop participants. Nonetheless, the outcomes are sensitive to potential wildcard stakeholders, not considered, which may have very divergent interests. Some degree of confidence can be ascribed, however, by noting the convergence in rated outcomes caused by adding new players, or withholding existing players, to the game.

The technique is also limited in terms of the number and quality of outcomes being considered. The number of outcomes could potentially be grown, or bootstrapped, over multiple interventions. The quality of outcomes is still of concern because the specified outcomes may or may not be system feasible. Certainly, the outcomes as described do not strongly specify necessary interventions on the system as a whole. The method could, therefore, be strengthened by combining it with more system-oriented or design-oriented techniques.

The technique requires a fair amount of prior knowledge of game theory, and game theoretic modelling. This necessary prior knowledge is a both a positive, and a negative of the technique. On the positive side, it may be that the game structuring required of the facilitator is also a beneficial activity in assisting participants to better understand their strategic setting. On the negative side, the facilitator may be driving outcomes according to their prior beliefs or pre-conceptualizations. On the balance, and especially when considering learning outcomes from the intervention, it is better to have a facilitator which deliberately drives the selection of actors, moves and outcomes towards challenging or strategically problematic issues.

4.4 Culmination of the case

In the Great Brak case, a ground-breaking decision was made by the national Department of Water Affairs early in 2013 at national level to approve the environmental water allocation to the downstream estuary. This represents a first, yet significant step, in ensuring the long-term ecological health of the estuary and alters the position of the various stakeholders in the social negotiation process. However, it would be "contextually naïve" (Ackoff 1979) to assume that our workshop in its isolation served to arbitrate such a step in a complex and on-going game. This game-structuring workshop was situated within a broader, transdisciplinary intervention and in an ongoing societal negotiation process (Linnane and Slinger 2012). However, the timeliness of the intervention and the influential role of certain of the participants cannot be gainsaid.

5 Conclusion

In this final section of the paper, we propose further research given the outcomes of the game-structuring workshop, and our conclusions regarding the applicability of the method.

The experience with a participatory approach to game-structuring not only suggests promise but also signals a clear need to address further questions. We state some of the questions here.

A first question is: What are the differences between various participatory methods to structure decision environments? For instance, is a game-structuring intervention as described here, fundamentally different from a participatory stakeholder analysis as described for instance by Eden and Ackermann (2004) and Bryson et al. (2002)? The procedures are different, but does this also lead to different contributions to problem solving? Are there differences in the applicability of one approach rather than another to a particular setting? And are there differences between 'stand-alone' decision structuring interventions and those included as part of a larger problem structuring effort that also includes attempts at system structuring? Potentially, game-structuring interventions have considerable effect, as they modify the social setting in which they are placed, making their evaluation a concern of continued research. This requires more work on the evaluation of real-live problem structuring interventions, in line with that of White (2006).

Furthermore, there are questions related to the applicability of participatory game-structuring approaches in a true conflict situation. Game structuring seems most needed in contested problem situations, yet at the same time, these are very difficult situations in which to work, especially when the aim is to clarify the decision environment. In our case, we worked with a small subset of participants, separated from the full set of actors involved. This allowed us to start from a deep, and more shared conception of the system environment and it allowed a free discussion of sensitive issues, among likeminded people in a fairly safe environment. Further research into participative and coercive problem settings is needed to determine the utility of game-structuring approaches.

The paper presents a published account of the first "live" test of game-structuring methods in a water management setting. We assumed that a set of game elements (players, actions, payoffs and outcomes) would be present, relevant, and accessible to experts and active participants in the case, and we also found this to be the case. This raised new questions concerning the facilitated discussion of payoffs, outcomes, and actions in complex problem settings. The paper contributed to a new fusion of existing analysis of options methods with participatory modelling methods. We hope the revisiting of an older literature (which is still relevant in light of current applied work) can assist in the broader discussion occurring on problem structuring methods (cf. Franco and Montibeller 2010). Part of this discussion, we hope, will entail consideration of players, and the role of game-structuring elements in the full characterization of a messy problem situation.

We believe such a case is helpful because it deepens insight into social processes in an important setting, adds to the growing roster of successful problem structuring applications, and provides some guidance to others who may face similar workshop design issues. The application reveals a rather important distinction between methods aimed at problem structuring which seek to explicate the system characteristics of the problem, and those which seek to explicate actors, their interests, values and capabilities. We find considerable commonality across a variety of game-structuring methods and consider it promising work for the future to continue to compare and contrast these methods, and to question their normative and epistemological underpinning. The family of game structuring methods

includes, but is not limited to, analysis of options, conflict analysis, hypergame analysis and the theory of moves.

This case demonstrates a substantive difference between techniques primarily used for managing together with stakeholders, and techniques primarily used for managing stakeholder relationships among themselves. This is part of an apparent and natural evolution of problem structuring techniques to work within a plural, or multi-actor environment. This contribution confronts some of the challenges of working within such a socially complex environment. Problem structuring activities aim to establish a commitment for (joint) action. To this end, problem structuring methods "work with rather than 'on behalf' of groups (Ackermann 2012)". Yet, gaining more insights into these processes may help various actors get involved, enlighten them, and facilitate further progress. Therefore, structuring problem situations in complex decision environments requires methods that not only offer structure, but also tact and specific procedures.

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