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The Mangal Play: A serious game to experience multi-stakeholder decision-making in complex mangrove social-ecological systems

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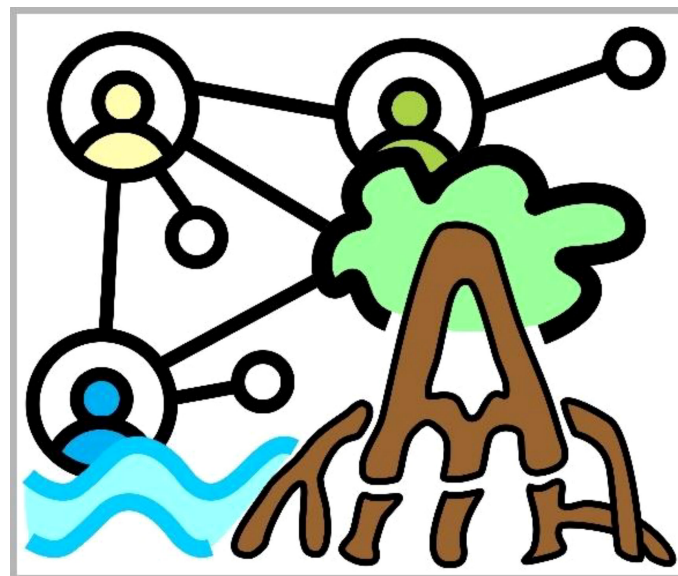
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In order to achieve collaborative action in nature conservation and natural resources management, stakeholders have to understand and acknowledge other stakeholders' interests, values, world visions and objectives and they have to overcome the problem of irrational decision-making through innate opposition discourses. In this paper we developed the Mangal Play, an experiential learning method to have participants adopt the role of a particular stakeholder in an imaginary mangrove forest social-ecological

system (SES). The Mangal Play is a serious game, more specifically a role-play, aimed at promoting oral dialogues between 20 stakeholders involved in governance, fisheries, aquaculture, agriculture, forestry, tourism, transport, conservation and communication sectors. By providing tools to lecturers and scientists to execute it in a public or classroom setting, the Mangal Play stimulates a decision-making process while accepting compromise and distinguishing bottom-line issues from negotiable positions, and instructs about the behaviour of complex real-world systems in a safe learning environment. We exemplify how social network analysis can serve to visualise the outcome and further develop the Mangal Play. In this way we hope to help stakeholders take into account diverse positions in a rational decision-making process.

KEYWORDS

role-play, stakeholder, policy-making, social network analysis, mangrove management, adaptive management, game-based learning, gamification



GRAPHICAL ABSTRACT

Frontiers in Marine Science Community Case Study

1 Introduction

Managing social-ecological interactions or human-nature interactions is a complex, multi-actor endeavour, which

Abbreviations: MC, Master of Ceremony; SES, Social-Ecological System; SNA, Social Network Analysis.

requires communication, collaboration and coordination among a wide range of stakeholders (Bodin et al., 2020; Reed, 2008). Understanding and acknowledging other stakeholders' interests, values, world visions and objectives is key to achieve collaborative action in nature conservation and natural resources management. An opposition to the discourses held by others may complicate decision-making, as people tend to look at the world from a particular perspective (Rose, 2014), to filter the intrinsic complexity of environmental problems. In doing so, confirmation bias and peer pressure may cripple

effective environmental decision-making – hence the necessity to be aware of other stakeholders' perspectives and expectations (Levine et al., 2015).

An extensive body of literature has argued that stakeholders' capacity to create and maintain social networks is key to natural resource governance (Berardo et al., 2014; Berardo and Lubell, 2016; Bodin et al., 2019; Mancilla García and Bodin, 2020). Being able to analyse the relationships among stakeholders and understand their position, importance, and contribution in management networks is an emerging challenge for natural resource management (Dandy et al., 2014; Mancilla García and Bodin, 2018; Hamilton et al., 2019). It is important to identify stakeholders who can drive environmental management towards more collaborative, effective, and legitimate processes (Barnes et al., 2016; Morrison et al., 2019). The intertwined social and ecological components of any environmental management issue have been conceptualised as a social-ecological system (Folke et al., 2005; Ostrom, 2009), hereafter abbreviated as 'SES' (or SESs in plural).

Mangrove SESs, consisting of (sub-)tropical intertidal forests and the human communities depending on them, have not been spared from controversial management and governance decisions, despite the increased recognition of their importance. Controversial mangrove management and governance include political patronage in mangrove-to-aquaculture conversion in Sri Lanka (Foell et al., 1999), mangrove forest reclamation for oil palm plantations in Malaysia (pers. obs.), the replacement of feral water buffaloes in India by high breed cows (Dahdouh-Guebas et al., 2006a), the slaughtering of feral water buffaloes found to forage in Indian mangroves because of their alleged impact on mangrove regeneration (Dahdouh-Guebas et al., 2006b), the construction of a new local airport on a regionally significant mangrove patch in the Maldives (Curnick et al., 2019) or the deforestation of mangroves to construct villas and jetties in the United States of America or Australia (pers. obs.). Some of these may in turn have potential effects on carbon sequestration, or on aquatic microbial communities (Sousa et al., 2006). Many examples are limited to the immediate vicinity of mangrove forests, but environmental management and governance decisions may also cause major impacts inland or upstream that eventually affect more distant mangroves such as river damming schemes in Kenya, Sri Lanka or Cambodia (Dahdouh-Guebas et al., 2005; Baird, 2016; Santos et al., 2021). Power imbalances, leading to the manipulation or the neglect of less powerful stakeholders, often hamper sustainable – mangrove – management (Pielke, 2007). In order to reorient mangrove management decisions towards more sustainable and participatory processes, we argue that 'mangrove stakeholders' would need to be included in decision-making. Role-plays (as so-called 'serious games') open a reflective pathway for inclusion as they enable to simulate real-world stakeholder interactions, and to play out different decision scenarios and their consequences.

Serious games have been used in the context of real-world decision-making where they are becoming increasingly popular (McEwen et al., 2014; Madani et al., 2017). They are not designed solely for entertainment purposes, but as a tool to educate, train and inform users (Madani et al., 2017). Becker (2021) disambiguates such teaching and learning using games as follows:

- “a **game** includes both serious games and games for learning”;
- “a **serious game** is a game designed for the purposes other than or in addition to pure entertainment”;
- “a **game for learning** is a game designed specifically with some learning goals in mind”;
- “**game-based learning** is the process and practice of learning using games”;
- “**game-based pedagogy** is the process and practice of teaching using games”; and
- “**gamification** is the use of game elements in a non-game context”.

Serious games focus on problem solving, require assumptions, workable simulations and should reflect natural non-perfect communication (Susi et al., 2007). They can also be used as a teaching strategy, as way to foster social and societal learning among students (Madani et al., 2017; Ameerbakhsh et al., 2019). There is also some evidence that incorporating serious games such as role-plays in STEM education (Science-Technology-Engineering-Mathematics) increases students' engagement and motivation (Cobo et al., 2011). In this study, we focus on role-plays as a teaching strategy because of the importance outlined below, all of which is valuable in the future life of students becoming researchers, managers and policy-makers.

Role-play simulations and role thinking have been used in a wide variety of disciplines and contexts: (conservation) conflict situations (Green and Armstrong, 2011; Redpath et al., 2018), fisheries management (Ruiz-Perez et al., 2011), water management (Stanitsas et al., 2019), climate change adaptation (Rumore et al., 2016), the Convention of Biological Diversity (Schnurr et al., 2015), and also by many impact assessment teachers (Sanchez and Morrison-Saunders, 2010). Serious games exist in a variety of formats (Table 1), and can be used in different environmental management contexts (e.g. Dieleman and Huisinigh, 2006; Redpath et al., 2018; Stanitsas et al., 2019; Garcia et al., 2022).

Role-plays, an active learning method, have been proposed as a teaching strategy since the 1970s (Champagne and Hines, 1971). As learners engage in critical thinking – through taking up a particular role, reflecting on the role of others and making decisions on how to advance through the scenarios – they actively engage in their learning process (Rao and Stupans, 2012). We summarise how role-playing and other forms of serious gaming can enable participants and constitute learning

TABLE 1 Selection of serious games/role plays used in environmental management and biodiversity conservation, to illustrate the diversity of contexts in which these games are used.

Serious game	Context	Source
Board games		
Nexus	Water management	Stanitsas et al. (2019)
Climate Change Survivor	Climate change	Madani et al. (2017)
Dice games		
Paying for Predictions	Climate change adaptation	Stanitsas et al. (2019)
Card games		
Learning Sustainable Development Game	Sustainable development	Madani et al. (2017)
Computer/Video games		
Simulation games		
FishBanks	Fisheries management	Dieleman & Huisingh (2006); Ruiz-Perez et al. (2011)
Computer quizzes		
Build a Prairie	Pedological game	Stanitsas et al. (2019)
Quizzes by TROPIMUNDO	Thematic awareness-raising Kahoot quizzes	Zoom on Tropical Biodiversity by TROPIMUNDO: https://create.kahoot.it/share/zoom-on-tropical-biodiversity-by-tropimundo/b37aa04f-f624-4a02-bee7-7e8c5eeae7a Water by TROPIMUNDO: https://create.kahoot.it/share/water-by-tropimundo/36a4f9d1-3ca6-43fb-80c7-3574cdd6c61a
Sandbox games		
SimEarth	Planet building	Stanitsas et al. (2019)
Role-playing videogames		
AtollGame		Dray et al. (2006)
Live strategy games		
CoPalCam	Conflict management (in palm oil production & management)	Garcia et al. (2022)
Conservation conflict game	Conservation conflict	Redpath et al. (2018)
Live role-plays		
Mangal Play	Multi-stakeholder decision-making in complex mangrove SESs	This study

outcomes of the Mangal Play (modified from Agell et al., 2015; Creutzig and Kapmeier, 2020):

- a) to have oral dialogues;
- b) to identify problems, find information and propose solutions;
- c) to develop the ability to argue, relating explanations and evidence;
- d) to facilitate the expression of diverse positions;
- e) to let the experience change opinion and make decisions in a responsible and informed way;
- f) to facilitate the manifestation of values and attitudes related to the problem;
- g) to be able to accept compromise and to distinguish bottom-line issues from negotiable positions; and
- h) to learn about the behaviour of complex real-world systems consisting of feedback loops, non-linearities,

accumulations, and time delays by testing policies in a safe learning environment.

The overall objective of the present community case-study paper is to introduce the Mangal Play, a live role-play simulation game aimed at experiencing multi-stakeholder decision-making in marine sciences exemplified by the complex mangrove SES. To our best knowledge, and following serious gaming review articles recently published (Madani et al., 2017; Stanitsas et al., 2019), this is the first serious game publication on mangrove forests and mangrove SESs. The specific objectives of this community case study paper are (i) to provide a step-by-step description of the Mangal Play, (ii) to provide tools to enable other lecturers and scientists to execute the Mangal Play in a public or classroom setting, (iii) to exemplify its application and illustrate feedback elements, and (iv) to evaluate its learning outcomes and points of further consideration. We used this experiential learning method to have participants (students)

adopt the role of a particular stakeholder in an imaginary mangrove forest SES.

2 Context (setting and population) in which the Mangal Play is set

Mangroves are complex SESs which are situated in an intertidal setting along coastal areas, where pressure on the land is high, as human populations also tend to concentrate along coastlines. Moreover, mangrove SESs often encompass and link to other SESs (e.g. coral reef, seagrass bed, beach and coastal forest SESs) (Dahdouh-Guebas et al., 2020; Glaser et al., 2012). Apart from activities taking place in the landscapes adjacent to the mangroves, also those occurring far inland play

a crucial role (e.g. inland deforestation and subsequent sedimentation processes, inland river diversion). The only way to capture such interconnection is by looking at the mangrove SES. However, since there is no mangrove SES without a mangrove forest or ecosystem, the Mangal Play will involve more actors involved directly with mangrove ecosystem goods and services than with far inland activities.

Building on our long-standing expertise in mangrove ecology, ethnobiology, vegetation and landscape dynamics, restoration ecology, mangrove management and governance (cf. Dahdouh-Guebas et al., 2021 and references therein) and because of the model SES that the mangrove SES represents (*loc. cit.*), we chose the mangrove forest as the ecosystem setting (Figure 1). ‘Mangroves’ are plants that grow in tropical, subtropical and warm temperate latitudes along the intertidal land–sea ecotone, in bays, estuaries, lagoons and backwaters.

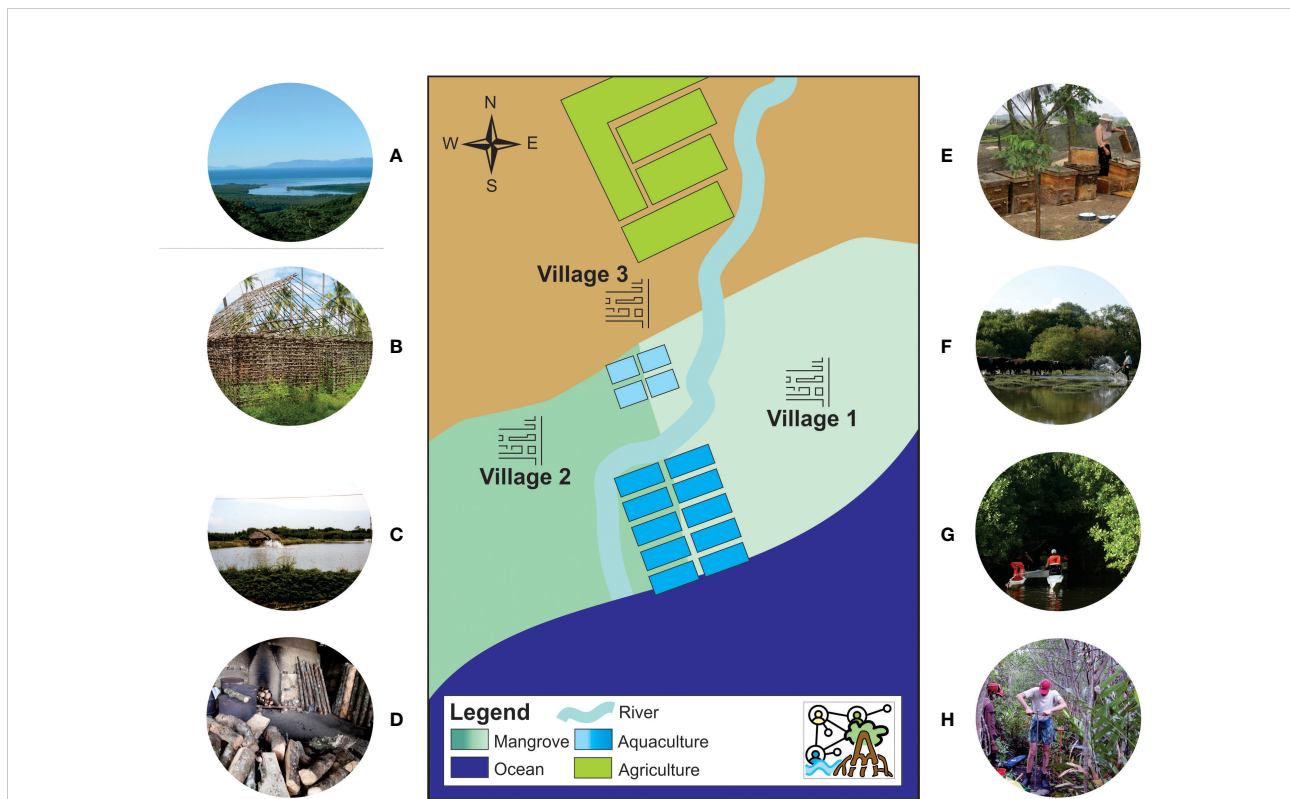


FIGURE 1

Map of The Mangal Play's mangrove forest SES. Photographs provide real-life views from mangrove areas around the world on which the Mangal Play is inspired. Links with stakeholders are indicated by their abbreviations from Table 2. (A) View of a mangrove estuary (Daintree River National Park, Australia, 2006); (B) Mangrove village with houses made of mangrove wood (Gazi Bay, Kenya, 2003), LOG; (C) Shrimp aquaculture pond (Pambala Chilaw Lagoon, Sri Lanka, 1999), AQUA-S, AQUA-L, AQUAWORK; (D) Fuelwood trade in mangroves (Matang Mangrove Forest Reserve, Malaysia, 2017), CHARCOAL, LOG; (E) Bee-keeping in mangroves (Zhanjiang Mangrove National Nature Reserve, China, 2009), BEE; (F) Feral water buffalo herding (Kalametiya Lagoon, Sri Lanka, 2004), HERDSMAN; (G) Tourism in mangroves (Grand Cul-de-Sac Marin Natural Reserve, Guadeloupe, 2009), BOAT, HOTEL, TOURIST; (H) Scientific research in mangroves (Chilaw Lagoon, Sri Lanka, 2006), SCIENTIST. Photo credits: (A, C–F) Farid Dahdouh-Guebas, (B) Griet Neukermans (Dahdouh-Guebas et al., 2020), (G) Jonathan Avau (Avau et al., 2011), (H) Daglas Thisera. N.B. All figures and supplementary online tools have been branded by the Mangal Play logo representing a mangrove tree attached to a social network and integrating as its stem the Cyrillic letter **А** (little yus), which we chose as the ‘Mangial’ currency (see Section 4.2.2 Phase IV) and which resembles ‘m under A’, i.e. the first two letters of ‘mangal’ or ‘mangrove’.

TABLE 2 Overview of the stakeholders involved in the Mangal Play's SES.

Stakeholder	Abbreviation	Location	Country	Profession type	Collar	References
The Government*	01_GOV	Outside	Domestic	Governance	White	Borges et al. (2017)
The domestic small-scale aquaculture owner	02_AQUA-S	Inside	Domestic	Aquaculture	White	Dahdouh-Guebas et al. (2002), Ahmed & Glaser (2016)
The foreign large-scale aquaculture owner	03_AQUA-L	Inside	Int'l	Aquaculture	White	Dahdouh-Guebas et al. (2002); Hamilton (2013)
The aquaculture worker	04_AQUAWORK	Village 1	Domestic	Aquaculture	Blue	
The artisanal fisherman dealing in fish, crabs and lobsters	05_FISHMAN	Village 1	Domestic	Fisheries	Blue	Crona (2006); Santos et al. (2017); Berkström et al. (2019); Ndarathi et al. (2020); Zu Ermgassen et al. (2021)
The artisanal fisherwoman dealing in shrimps	06_FISHWOMAN	Village 2	Domestic	Fisheries	Blue	Ndarathi et al. (2020); Zu Ermgassen et al. (2021)
The dynamite fisher	07_DYNAMITE	Village 1	Domestic	Fisheries	Blue	Palmer and Finlay (2003)
The fish monger	08_MONGER	Village 2	Domestic	Fisheries	Blue	Ndarathi et al. (2020)
The charcoal company	09_CHARCOAL	Village 3	Domestic	Forestry	White	Satyanarayana et al. (2021)
The tree logger	10_LOG	Village 1	Domestic	Forestry	Blue	Satyanarayana et al. (2021)
The boat driver	11_BOAT	Village 3	Domestic	Transport	Blue	Avau et al. (2011), Satyanarayana et al. (2021)
The bee-keeper	12_BEE	Village 2	Domestic	Agriculture	Blue	Hamza (2013)
The Mangrove Boardwalk Women Group	13_BOARDWALK	Village 2	Domestic	Tourism	Blue	Satyanarayana et al. (2012)
The cattle herdsman	14_HERDSMAN	Village 3	Domestic	Agriculture	Blue	(Dahdouh-Guebas et al. 2006a; 2006b)
The agriculturist	15_AGRI	Village 3	Domestic	Agriculture	Blue	Richards and Friess (2016)
The hotel owner	16_HOTEL	Outside	Domestic	Tourism	White	Avau et al. (2011)
The tourist	17_TOURIST	Outside	Int'l	Tourism	White	Spalding and Parrett (2019)
The local environmental NGO	18_NGO	Outside	Domestic	Conservation	White	Dahdouh-Guebas et al. (2002); Friess et al. (2022)
The scientist	19_SCIENTIST	Outside	Int'l	Conservation	White	Numerous papers and personal experience
The media*	20_MEDIA	Outside	Domestic	Communication	Blue	Amir et al. (2020); Dahdouh-Guebas et al. (2020)

Location indicated the Village where the respective stakeholder lives, with 'Inside' denoting stakeholders living within the borders of the map shown in Figure 1 area but not in one of the villages, and 'Outside' a living location outside the borders of the map. Possible classifications of the stakeholders include whether they are domestic or international (Country), which profession type they fall under and whether they are white-collar or blue-collar workers as a metaphor for the working class. The asterisk * denotes a stakeholder who does not have voting rights in the Mangal Play. The references represent a non-exhaustive list of sources in which the stakeholder exists in real life.

These plants and their associated organisms constitute the 'mangrove forest community' or 'mangal', and together with their dependent human population they form the mangrove SES (definition adapted from Dahdouh-Guebas et al., 2021). Present in >120 countries and territories (Spalding et al., 2010), mangrove SESs constitute a geographical and population setting to which hundreds of millions of people can relate directly.

The 'Mangal Play', short for the mangal role-play, materialises in the context of a fictive mangrove forest SES (Figure 1), which (i) offers processes, functions, goods and services of use to three local communities that live within or adjacent to the mangroves, (ii) hosts various human subsistence and commercial activities, (iii) welcomes domestic and international visitors, and (iv) is under the decisional influence of various decision-makers. The inspiration to establish three - fictive - mangrove-connected communities was research-based, taken from our

fieldwork in Mexico, Honduras, Jamaica, Martinique, Guadeloupe, Colombia, Brazil, Mauritania, Senegal, The Gambia, Ghana, Togo, Benin, Cameroon, Democratic Republic of Congo, South-Africa, Tanzania, Kenya, Madagascar, India, Sri Lanka, Bangladesh, Thailand, Malaysia, Singapore, China and the Philippines. However, it was also strategic in terms of game play (See Section 4.2.2 Phase II).

Mangal Play's actors and stakeholders, hereafter interpreted *sensu lato* and simply referred to as 'stakeholders', are empirically inspired and most of them are drawn from scientific literature and/or contemporary news items (Table 2). The in-simulation objective of the Mangal Play is to vote on adopting or rejecting a government bill proposed for enactment, which affects one or more stakeholders. Voting is preceded by interactions between stakeholders, may be subject to different participatory methodologies, and may be re-taken under different local or global scenarios, as detailed in Section 4.2.2.

3 Key programmatic elements of the Mangal Play

3.1. Mangal Play stakeholder outlines

The 20 stakeholders in the Mangal Play (Table 2) must abide by a minimum number of rules, all of which are taken from existing scenarios from mangrove countries around the world. These rules are synthesised as the stakeholder outlines below and serve as a basic introduction to the stakeholders. Important to note is that these stakeholders can be classified per location in the map, per profession type, and per collar class (Table 2). To highlight potential interactions, henceforth we will refer to our 20 stakeholders by their uppercase abbreviations.

01_GOV – The Government, enforces the regulations (e.g. can decide about penalties and fines) and patrols the area. The GOV is composed of 7 departments. (a) The governmental Department of Education and Research, issuing permits to study and research and establishing the research permit fees for SCIENTIST; (b) The governmental Department of Forestry (e.g. Dahdouh-Guebas et al., 2000a), responsible to manage all forests, including mangrove forests, issuing logging permits and

establishing the logging permit fees, deciding how many people are allowed in the forest, and with the capacity to limit the number of LOG, SCIENTIST and/or TOURIST in the forest; (c) The governmental Irrigation Department (e.g. Dahdouh-Guebas et al., 2000b; Satyanarayana et al., 2013), responsible to manage everything within 500 m of riverbanks, including mangrove forests and deciding on hydrographical works, incl. dams to protect upstream agricultural areas from seawater intrusion; (d) The governmental Department of Land Management (e.g. Dahdouh-Guebas et al., 2006b), responsible for land use/land cover (LULC) attribution, and deciding which LULC class to convert into another, e.g. forest to aquaculture (AQUA-S or AQUA-L) or to agriculture (AGRI), production sectors to harbours (involving AQUA-S, AQUA-L, LOG, CHARCOAL), etc.; (e) The governmental Department of Tourism, responsible for all tourism activities by foot or by BOAT and establishing TOURIST fees, incl. discounts for domestic tourists and extra taxes for foreign tourists; (f) The governmental Port Authority, responsible for managing and developing the harbour and seeking to expand harbour activities (incl. maintaining and expanding access routes – both terrestrial and marine – to the harbour); and finally (g) The governmental Department of Finance, responsible for the financial resources (treasury) and

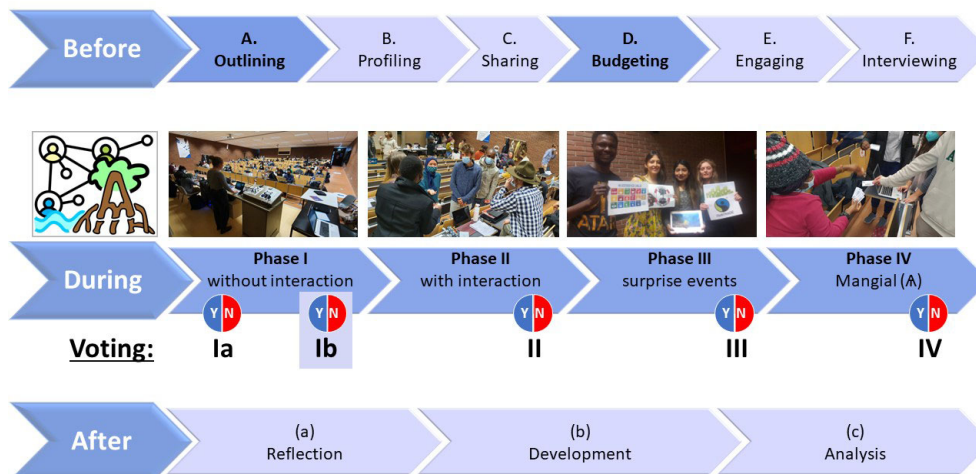


FIGURE 2
 Flow-chart of the different stages before (6 steps: A, B, C, D, E and F), during (4 phases: I, II, III and IV with voting breaks indicated as Yes/No pie-charts) and after (3 debriefing tasks: a, b and c) the Mangal Play. The stages in dark blue constitute a bare necessity to organise the Mangal Play without any preparation; its duration is expected to last ca. 5 hours. The stages in light blue are needed when there is time for preparation before and/or assessment after the Mangal Play, such as in a classroom setting. Preparation can be limited to anything between a few hours (when the Mangal Play is organised as a single-day workshop) and a few weeks (in an interactive course with a sequential build-up), whereas a *posteriori* assessment involves anything between 1 hour (workshop) to a few days (course). See Sections 3.2.1, 3.2.2 and 3.2.3 for detailed descriptions. Photographs illustrate the four phases of the live action organised with MSc. students of 6 scientific disciplines (Biology, Organism Biology and Ecology, Bio-Engineering, Environmental Science and Management, Marine and Lacustrine Science and Management and Tropical Biodiversity and Ecosystems) at Université Libre de Bruxelles (ULB) and Vrije Universiteit Brussel (VUB), Brussels, Belgium. More specifically the photographs illustrate (from left to right): the presentation of the bill proposed for enactment by the Prime Minister of the GOV in Phase I, free-flow interactions between participants constituting the stakeholders CHARCOAL and LOG in Phase II, stakeholder NGO organising loud protest against the bill in Phase III, and currency transactions in Phase IV. Photo credits: Farid Dahdouh-Guebas.

setting out eligibility criteria and requirements for imposing/awarding taxes, tax waivers, loans, etc.

02_AQUA-S – The domestic small-scale aquaculture owner (e.g. Dahdouh-Guebas et al., 2002), located at the landward area on the border between Village 1 and Village 2, has only aquaculture ponds and is dependent on catching gravid female shrimps in the wild for which it may collaborate with FISHWOMAN. It recruits many AQUAWORK and seeks to expand aquaculture activities at the expense of mangrove forest or AGRI fields.

03_AQUA-L – The foreign large-scale aquaculture owner (e.g. Dahdouh-Guebas et al., 2002), located at the seaward area on the border between Village 1 and Village 2, has both aquaculture ponds and a hatchery and is not dependent on gravid female shrimps caught in the wild. It recruits few AQUAWORK and seeks to expand aquaculture activities at the expense of mangroves.

04_AQUAWORK – The aquaculture worker (e.g. Ofori et al., 2022) lives in Village 1, helps defending the interests of Village 1, works in one of the two aquaculture farms (AQUA-S or AQUA-L), whoever pays more, and helps in defending the interests of the aquaculture sector (in part or in full).

05_FISHMAN – The artisanal fisherman dealing in fish, crabs and lobsters (e.g. Crona, 2006; Ndarathi et al., 2020; Manyenze et al., 2021; Zu Ermgassen et al., 2021), lives in Village 1, and helps defending the interests of Village 1, goes around fishing by foot or by paddled canoe from BOAT drivers, consumes and/or sells catches to MONGER or other stakeholders, including BOARDWALK, HOTEL and TOURIST, and helps in defending the interests of fisherfolk (in part or in full).

06_FISHWOMAN – The artisanal fisherwoman dealing in shrimps (e.g. Feka et al., 2011; Ndarathi et al., 2020; Zu Ermgassen et al., 2021) lives in Village 2, and helps defending the interests of Village 2, goes around fishing by foot, consumes and/or sells directly to other stakeholders, including MONGER, BOARDWALK, HOTEL and TOURIST and helps in defending the interests of fisherfolk.

07_DYNAMITE – The dynamite fisher (e.g. Palmer and Finlay, 2003) lives in Village 1, and helps defending the interests of Village 1, goes around fishing by making use of motorised vessel from BOAT drivers, consumes and/or sells directly to other stakeholders, including MONGER, BOARDWALK, HOTEL and TOURIST, and helps in defending the interests of fisherfolk.

08_MONGER – The fishmonger (e.g. Ndarathi et al., 2020; Zu Ermgassen et al., 2021) lives in Village 2, and helps defending the interests of Village 2, buys fish and shellfish from FISHMAN or FISHWOMAN and re-sells it, may decide to buy a lot from one or fewer items from many FISHMAN and FISHWOMAN, and helps in defending the interests of fisherfolk.

09_CHARCOAL – The charcoal company (e.g. Chapin III et al., 2009; Hugé et al., 2016; Satyanarayana et al., 2021), located

in Village 3, manages a forest concession as an agreement with GOV, manages all decisions with respect to nursing, planting, thinning and clear-cutting, works together with community-based natural resource management (CBNRM) initiatives for nursing and planting (e.g. by BEE, BOARDWALK or NGO), hires LOG to do the thinning and clear-cutting in the forest, makes and sells all types of fuelwood, and helps in defending the interests of the forest and of the fisherfolk as long as it matches their single-resource management.

10_LOG – The tree logger (e.g. Dahdouh-Guebas et al., 2000a; Satyanarayana et al., 2021) lives in Village 1, and helps defending the interests of Village 1, is an experienced full-time tree logger, but may shift to a job in aquaculture, agriculture or the service sector (AQUA-S, AQUA-L, BOAT, AGRI, HOTEL). LOG may diversify income by also focussing on non-timber forest products (NTFPs) such as honey produced by BEE, helps in defending the interests of the forest, and may follow the guidelines or bend the rules set out by GOV.

11_BOAT – The boat driver (e.g. Satyanarayana et al., 2021) lives in Village 3, and helps defending the interests of Village 3, owns motorised boats and paddle canoes, works for any stakeholder in need of a boat (AQUA-S, FISHMAN, FISHWOMAN, DYNAMITE, CHARCOAL, LOG, BOARDWALK, HOTEL, TOURIST).

12_BEE – The bee-keeper (e.g. Hamza, 2013) lives in Village 2, and helps defending the interests of Village 2, owns bee hives and produces honey as a part-time job, seeks other part-time jobs (e.g. in AQUA-S, AQUA-L, FISHMAN, FISHWOMAN) and helps in defending the interests of the forest.

13_BOARDWALK – The Mangrove Boardwalk Women Group, located in Village 2 and helping to defend the interests of Village 2, manages a mangrove boardwalk ecotourism initiative, guides TOURIST around in the natural mangrove habitat (e.g. in collaboration with NGO or SCIENTIST), the production sectors (e.g. visiting AQUA-S, AQUA-L, CHARCOAL, BEE, HERDSMAN) or the villages, makes curios and souvenirs, cooks mangrove-based food such as fish, crabs and lobsters (purchased from FISHMAN, FISHWOMAN, DYNAMITE, MONGER), accommodates visitors in traditional mangrove houses and helps in defending the interests of the forest, incl. community-based reforestation.

14_HERDSMAN – The cattle herdsman (e.g. Dahdouh-Guebas et al., 2006a; Dahdouh-Guebas et al., 2006b) lives in Village 3, and helps defending the interests of Village 3, has his cattle browse mangroves in Village 2 or Village 3 and helps in defending the interests of the forest.

15_AGRI – The agriculturist (e.g. Dahdouh-Guebas et al., 2005) lives in Village 3, and helps defending the interests of Village 3, and exploits large lands for cultivation of economic crops.

16_HOTEL – The hotel owner (e.g. Avau et al., 2011; Spalding and Parrett, 2019) attracts TOURIST for meals or overnight stays, organises TOURIST activities, incl. trips to

ecotourism initiatives (e.g. the natural mangrove habitat in collaboration with NGO or SCIENTIST, or visits to the production sectors from AQUA-S, AQUA-L, CHARCOAL, BEE, HERDSMAN).

17_TOURIST – *The tourist* (e.g. Avau et al., 2011; Spalding and Parrett, 2019) may be very decided or undecided in what to visit and how much to pay for it and will be influenced by publicity in MEDIA and stakeholder discourses that make sense (from virtually all stakeholders).

18_NGO – *The local environmental NGO* (e.g. Mangrove Action Project <https://mangroveactionproject.org/> in the real world) protects the interests of nature and environment and opposes any permanent land conversion.

19_SCIENTIST – *The scientist* (e.g. Hugé et al., 2022) performs scientific research, visits the area with students, studies the mangrove SES and may stay in a local village (cf. BOARDWALK) or in a HOTEL.

20_MEDIA – *The media* (e.g. Wu et al., 2018; Dahdouh-Guebas et al., 2020) aims at reaching as many stakeholders as they can, as frequently as they can, picks up facts or rumours and makes them public through websites, social media, newspapers (articles), oral announcements, etc. If the SCIENTIST provides a view, MEDIA will always present it unaltered.

3.2. Sequential build-up of the role-play

The Mangal Play can be executed with or without preparation (Figure 2). Below we will explain the Mangal Play's sequential build-up with preparation, while keeping in mind that the role-play without preparation corresponds to a subsection of it (Figure 2). Three periods corresponding to before, during and after the role-play can be recognised, the steps of each of which are detailed below.

3.2.1. Before the Mangal Play

The period before the Mangal Play consists of six steps aiming at preparing a minimum of 20 participants for live interaction. This minimum number is set to ensure that all stakeholder categories are represented by at least one participant.

- A. *Outlining*. Each participant or group of participants is briefed about the setting of the role-play and is assigned by the Mangal Play's Master of Ceremony (MC) one of the 20 stakeholder roles (see Section 4.1). If the number of participants is higher than 20, different participants will thus together form and must thus collectively act as the stakeholder to which they are assigned. To simplify, henceforth we will refer to the 20 stakeholders regardless of the number of participants they are composed of; in other words, the number of

stakeholders is always 20. Each stakeholder is given the Mangal Play stakeholder outline detailed in Section 4.1.

- B. *Profiling*. Each stakeholder has the task to develop the relatively simple outline into a detailed behavioural stakeholder profile with (i) a point-wise narrative of their discourse¹, including principles and attitudes, and (ii) their vulnerability², adaptability³, resilience⁴ and transformability⁵ incl. limits to them. This profiling exercise must be done by each stakeholder without interaction with other stakeholders. In addition, it

1 A **discourse** is a specific ensemble of ideas, concepts and categorizations that are produced, reproduced and transformed in a particular set of practices and through which meaning is given to physical and social realities (Hajer, 1997). For instance, your discourse may be that animals and humans are equal and have rights and therefore no-one should eat animals. Your principles & attitudes should be included in your discourse narrative and are used in the literal sense of the words, i.e. a **principle** is a guide for behaviour, and an **attitude** is a settled way of thinking or feeling about something, which characterises a person. So you may e.g. live by the principle that you do not eat meat, and your attitude is such that you feel strongly about animal rights.

2 The **vulnerability** is the degree to which a system is likely to experience harm due to exposure to a specified hazard or stress. (Chapin III et al., 2009).

3 The **adaptability**, synonymous with adaptive capacity, is the capacity of human actors, both individuals and groups, to respond to, create and shape variability and change in the state of a system. (Chapin III et al., 2009).

4 The **resilience** is the capacity of a system to absorb disturbance and reorganise while undergoing change so as to retain its essential core function, structure, identity and feedback [loops] (Walker et al., 2004; Dahdouh-Guebas et al., 2021). Resilience contains four aspects: Latitude, Precariousness, Resistance and Panarchy. Latitude and Precariousness are (three-dimensional representations of) respectively the maximum amount a system can be changed before losing its ability to recover, and how close the current state of the system is to a limit or threshold. (Walker et al., 2004). Resistance is the ease or difficulty of changing the system; how "resistant" it is to being changed. (Walker et al., 2004). Finally, Panarchy represents the mosaics of nested subsystems that are at different stages of their adaptive cycles, with moments of interaction across scales. (Chapin III et al., 2009). For a detailed explanation of the adaptive cycle heuristic, we refer to Dahdouh-Guebas et al. (2021).

5 The **transformability** is the capacity to create a fundamentally new system when ecological, economic or social (including political) conditions make the existing system untenable. This can be done by introducing new components and ways of making a living, thereby changing the state variables, and often the scale, that define the system. (Walker et al., 2004).

must not be influenced by what participants, from prior knowledge in their everyday lives, know is right or wrong in a certain situation but must be done as if they were the real-life stakeholder. The detailed behavioural profile must not contradict the stakeholder outline (see Section 4.1). At this point we do emphasize, however, that in more complex SESs people may also belong to more than one stakeholder. For example, fishing can be seasonal or depend on conjuncture/economic situation such as supply or demand and price fluctuations.

- C. *Sharing*. The detailed behavioural profiles are then distributed to all stakeholders. Each stakeholder needs to become one with their own outline and profile and prepares for live confrontation while taking good note of the profile of the other 19 stakeholders.
- D. *Budgeting*. Each participant is asked how he/she would allocate an imaginary budget of 100% over the 20 stakeholders. This information will be used during the Mangal Play (Phase IV). To collect this information, we prepared an online form as well as a spreadsheet to be filled manually (Table 3; Appendix S1). Instead of asking this information from every participant, participants constituting a single stakeholder can also be requested to discuss among them (*i.e.* within stakeholder) and to propose the budget allocation as a stakeholder.
- E. *Engaging*. The GOV will reveal the bill for enactment to the SCIENTIST and recruit this stakeholder to prepare a short presentation providing an impartial scientific assessment and possible scenarios for the future of the mangrove SES. Bills can vary in nature from those targeting a specific sector represented by part of the stakeholders directly or indirectly, to those targeting all stakeholders.

A non-exhaustive list of GOV bills proposed for enactment is given below and is preceded each time by a fact that may help to explain why the bill is proposed:

- **Fact:** The international demand for aquaculture produce is larger than the current supply which means that the economy has not been exploited to its full potential.
Bill: All aquaculture owners will be allowed to expand their shrimp ponds into agriculture or forest lands provided governmental permits are granted.
- **Fact:** There is a water shortage.
Bill: Dams and locks will be built to serve rice fields through an irrigation network.
- **Fact:** Lagoon, estuarine and offshore fish stocks fall.
Bill: The status of the mangrove forest(s) will be changed to MPA. All extraction of animals and plants

will be prohibited, except for charcoal production in designated areas.

- **Fact:** The existing national harbour has become too small to fully serve and exploit international trade.
Bill: A government-private joint-venture will establish a provincial deep-water harbour at the river mouth in mangrove areas currently exploited for charcoal production.

During the role-play only one bill is selected at a time, but if time permits several role-play simulations can be organised consecutively. With the exception of step E Engaging, this does not change the other steps before the Mangal Play.

F. *Interviewing*. The MEDIA may or may not interview stakeholders about their professions and lifestyles.

If Mangal Play is executed without preparation the number of steps before the Mangal Play can be reduced (Figure 2).

3.2.2. During the role-play

When the live role-play simulation starts, participants must act as stakeholders (not as students or scientists or activists, unless they are assigned that role) and they must do so according to their detailed behavioural stakeholder profile, in case Mangal Play is organised with preparation, or according to their stakeholder outline, if it is organised without preparation. In addition, participants must be aware of the behavioural profiles or outlines of the fellow-stakeholders, so that they can contradict or corroborate and rebut appropriately during the live debates. Stakeholders must also be clearly identifiable (Appendix S3).

During the live role-play the assembly of all stakeholders, except for GOV and MEDIA, will act as the legislature voting in favour or against a **bill proposed for enactment**. Whereas the voting method may be adapted, we propose voting by way of an adapted Nominal Group Technique, a group-based qualitative method to elicit judgement from stakeholders (Hugé and Mukherjee, 2018). For the purpose of the Mangal Play we have developed an online voting tool using Kahoot! The latter is a global online learning platform that aims at empowering everyone, including children, students, and employees, to unlock their full teaching and learning potential (<https://www.kahoot.com/>). We used this free platform to collect votes in favour or against the bill proposed for enactment and to enable the Mangal Play stakeholders to justify their vote (Table 3). We emphasize that in Kahoot! stakeholders should (nick)name themselves by their abbreviated stakeholder name (see Table 2). In case the number of participants that can login are limited by the Kahoot! account, two parallel voting surveys can be run in Kahoot! (e.g. login stakeholders 02 to 10 in one of them and 11 to 19 in the other). Ballot sheets are provided for cases in which no online voting can be organised (Appendix S4).

The live role-play contains the following four phases.

Phase I. The bill proposed for enactment is read out by the GOV without explanation and is followed by vote (Phase Ia).

TABLE 3 Overview of the online tools and resources, what/when they are for (see also Section 4) and where to find them, listed in order in which they are needed chronologically before, during and after the Mangal Play.

Which tool?	What is it for?	When to use it?	Where to find it?
Kahoot!	Imaginary budget allocation per participant or per stakeholder	Preparatory step D before the Mangal Play	https://create.kahoot.it/share/mangal-play-budget/f66a9268-caa8-4dfc-97b7-86cc91d62b40
Budget spreadsheet	Budget allocation	In preparation of Phase IV of the Mangal Play	SOI Appendix S1
Sociomatrix spreadsheet	Tracking interactions	During the Mangal Play (all phases)	SOI Appendix S2
ID Tags	To identify Stakeholders	during the Mangal Play (all phases)	SOI Appendix S3
Ballot sheets	To vote on paper	Phases I, II, III and IV	SOI Appendix S4
Kahoot!	To vote online	Phase Ia of the Mangal Play	https://create.kahoot.it/share/mangal-play-bill-a-voting-round-phase-ia/26581606-5c58-4f01-8453-d41926281009
Kahoot! Report	Analysis after the Mangal Play	After Phase Ia	As a downloadable file on the Kahoot! site after closing vote Ia
Kahoot!	To vote online	Phase Ib of the Mangal Play	https://create.kahoot.it/share/mangal-play-bill-a-voting-round-phase-ib/b302e5af-7f22-424e-8985-33ccb546cc78
Kahoot! Report	Analysis after the Mangal Play	After Phase Ib	As a downloadable file on the Kahoot! site after closing vote Ib
Kahoot!	To vote online	Phase II of the Mangal Play	https://create.kahoot.it/share/mangal-play-bill-a-voting-round-phase-ii/6133ca0a-9d27-472c-b796-5eeb261bfa1d
Kahoot! Report	Analysis after the Mangal Play	After Phase II	As a downloadable file on the Kahoot! site after closing vote II
Unforeseen circumstances	Fully-fledged example of unforeseen circumstances	Phase III of the Mangal Play	Appendix 1
Kahoot!	To vote online	Phase III of the Mangal Play	https://create.kahoot.it/share/mangal-play-bill-a-voting-round-phase-iii/d51e4292-7f07-4a27-af59-58f8062d3929
Kahoot! Report	Analysis after the Mangal Play	After Phase III	As a downloadable file on the Kahoot! site after closing vote III
Bank bills in A currency	Mangal Play Phase IV	Phase IV of the Mangal Play	SOI Appendix S5
Cash-flow spreadsheet	Cash-flow profiling	Phase IV of the Mangal Play	SOI Appendix S6
Kahoot!	To vote online	Phase IV of the Mangal Play	https://create.kahoot.it/share/mangal-play-bill-a-voting-round-phase-iv/1ead7f36-a20c-4aca-8f5d-50462a9caf07
Kahoot! Report	Analysis after the Mangal Play	After Phase IV	As a downloadable file on the Kahoot! site after closing vote IV
Filled sociomatrix spreadsheet example	Preparation for SNA	After the Mangal Play	SOI Appendix S7
SNA Tutorial	Visualising the Mangal Play SNA and calculate SNA indices	After the Mangal Play	SOI Appendix S8

We emphasize that in the online voting tool Kahoot! stakeholders should (nick)name themselves by their abbreviated stakeholder name (see Table 2) so as to avoid any confusion at analysis stage after the role-play. SOI, Supplementary Online Information.

Note that GOV and MEDIA do not retain voting rights, GOV because it is presenting the bill and MEDIA because it plays an influencer role. Then, the SCIENTIST is called upon by the GOV to present the impartial scientific context and possible scenarios for the future of the SES, after which another vote is taken (Phase Ib). Both these votes have in common that they take place without *a priori* interaction between stakeholders, but differ in that they were taken without resp. with justification/clarification by GOV and SCIENTIST. This serves to highlight the importance of clarifying policy decisions to local communities, which may or may not be corroborated by differences in voting. The two voting rounds in Phase I can also be reduced to one if no explanation of the bill is needed.

Phase II. Stakeholders are now allowed to interact and ask questions to other stakeholders about how they view the bill. The GOV and SCIENTIST will rebut. This can be moderated,

organised in free-flow or a combination of both. When moderated, all stakeholders will hear all questions and answers from all other stakeholders, whereas in free-flow, stakeholders will not be able to follow all conversations and will have to rely on the MEDIA for public news coverage. It is from this phase onwards that the power of stakeholder coalition based on location, country, profession type and/or collar (Table 2) can be fully explored and exploited. Phase II is concluded by vote II.

If there is a post-Mangal Play period in which debriefing and analyses of the role-play is planned, then during the role-play each stakeholder must keep track of all interactions with other stakeholders (this constitutes ‘ties’ in Social Network Analysis (SNA) terms). They keep track of the direction of these interactions (‘Sending’ and/or ‘Receiving’ questions and answers) which then allows us to estimate reciprocal relations

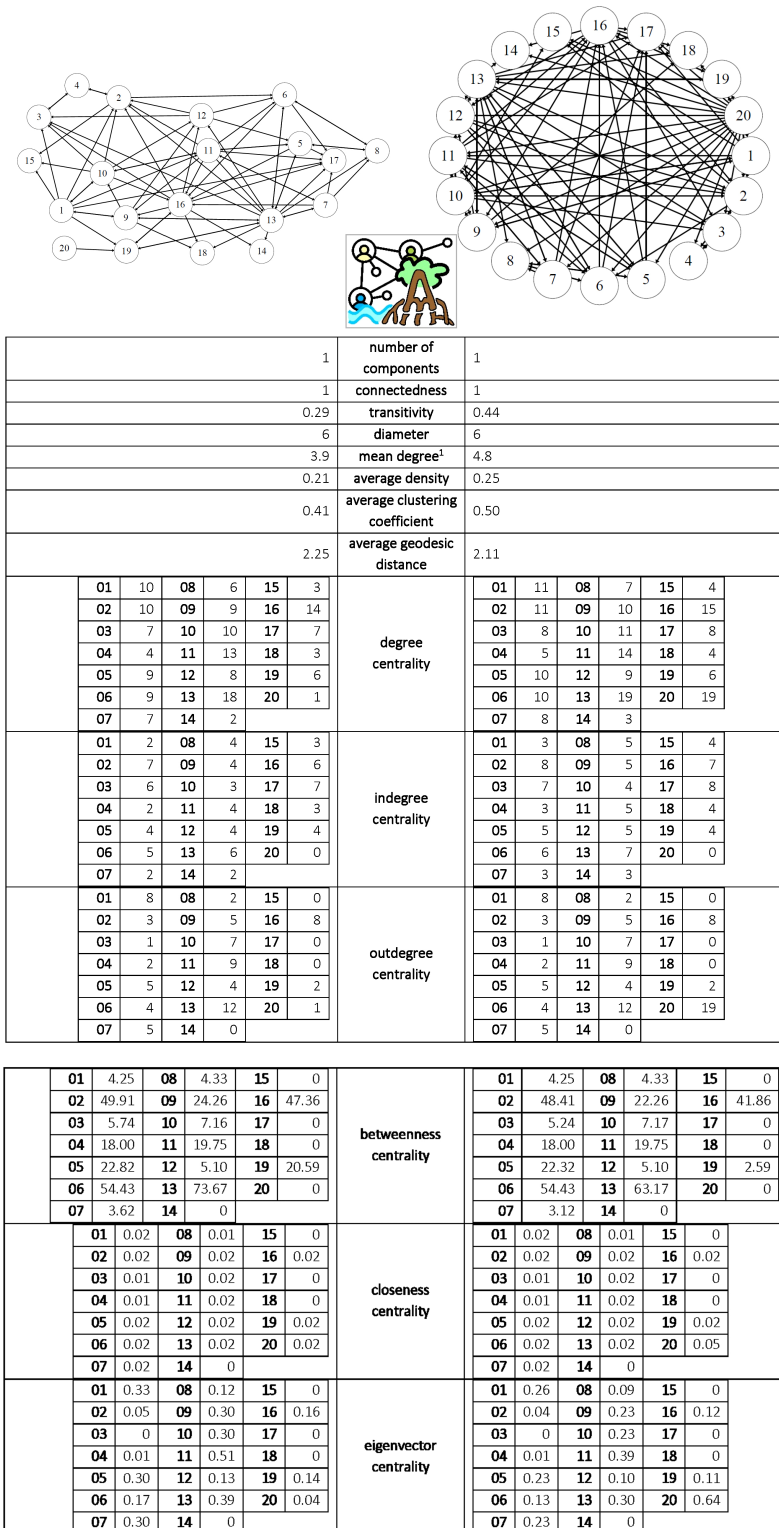


FIGURE 3
Theoretical social networks with directed ties based on the potential interactions described in Section 4.1, and with indices described in the Analysis task of Section 3.2.3. (Left panel and column) Network with web layout with 20_MEDIA interacting with 19_SCIENTIST alone. (Right panel and column) Network with circular layout with 20_MEDIA interviewing each and every other stakeholder. The centrality indices are for individual stakeholders and show each of them by number (following the same numbering as in Table 2). We refer to Appendix S7 for the relational data and sociomatrix corresponding to this social network and to Appendix S8 for definitions of the SNA indices.

by identifying tie directionality. They also are asked to record how many times they interacted with the same stakeholder (which then gives us the opportunity to weight the tie and identify close relationships). In addition, the Phase of the Mangal Play in which the tie was established must be indicated. We recall at this point that no interactions are allowed before the role-play starts except between GOV and SCIENTIST and between MEDIA and any other stakeholder. To keep this track-record, a sociomatrix spreadsheet was prepared along with a clear definition of what an interaction is as well as instructions to complete the spreadsheet (Appendix S2).

Phase III. Any unforeseen circumstances or surprise events may be introduced by the Mangal Play's MC at this stage, e.g. free-riding, rent-seeking, or power relations such as the use of direct and/or indirect influence, the threat of harm, the power of rewards, etc. This is a temporary phase in which the MC confronts participants with a surprise reality-check or a series of unfortunate events that they may have been unaware about while preparing to act as an exemplary stakeholder (see Appendix 1 for a fully-fledged example). This third phase will be concluded by vote III.

Phase IV. In this final phase an additional stakeholder is introduced, namely the imaginary Banca de Manglar (hereafter abbreviated as BANK), which introduces a budget of 1 million Mangial (M), an imaginary currency of the Mangal Play. To avoid any confusion and to keep it simple, this currency is deliberately unlinked to any existing currency, and only banknotes of 5000 M are introduced (Appendix S5). This phase serves to force each stakeholder to yield on promises made during negotiations in the previous phases. The amount that is allocated to a given stakeholder is the average that all participants allocated to that stakeholder following the formula:

$$SH_j = \frac{\sum_{i=1}^n P_{ij}}{n} \quad (\text{Eq. 1})$$

$$\sum_{j=1}^{20} SH_j + SH_{\text{BANK}} = 1,000,000 \quad (\text{Eq. 2})$$

where SH_j is the amount stakeholder j receives, P_{ij} is the amount that participant i allocated to stakeholder j before the Mangal Play (as a proportion in Step D; the amount will thus be calculated as a proportion of 1,000,000), n is the number of participants constituting the 20 stakeholders, and SH_{BANK} is the amount the BANK stakeholder receives. If participants were asked to allocate the budget as a stakeholder, then $n = 20$. The sum of all the stakeholder amounts determined using Eq. 1 will result in a total amount that is less or equal to 1 M M, and the rest of the budget will go to the BANK, as exemplified in the budget allocation spreadsheet (Appendix S1). All incoming and outgoing money transfers must be encoded in a cash-flow spreadsheet (Appendix S6). Phase IV is concluded by vote IV,

after which all banknotes are collected and recorded per stakeholder.

The role and operation of the BANK requires a bit more explanation. The BANK will be operated by the MC or by the GOV participant(s) in charge of the Department of Finance, who will thus leave the GOV to assume the new BANK stakeholder role. We emphasize that the stakeholder outline of the new BANK entirely corresponds to that of the GOV Department of Finance. Therefore, there should be no complications in role-playing for the participant playing the BANK. When any of the 20 stakeholders approaches the BANK to ask for loans the BANK is expected, first, to ask the stakeholder to present a (long-term) business plan in a few brief points. This may include for example how the money will be used (infrastructure, expansion, etc.), whether they have the necessary permits for this expansion (permit for land expansion, clear-felling, etc.), whether they have the necessary skills, what the risks are, etc. Second, the BANK expects to be asked for a reasonable amount for the loan (as a suggestion, the max. the amount of money received by that stakeholder when money was introduced in the role-play). The BANK is free to reduce or even refuse the loans if the above two points are not well developed.

To conclude the Mangal Play, the GOV is given the last word to amend the bill based on all the interactions that took place. Just for closure and for fun the stakeholders can be asked to vote a final time, namely on the re-election of the GOV before calling it a day. This vote can be done by hand.

Finally, if there is no post-play period, the Mangal Play organisers can organise a Focus Group Discussion to debrief the lessons learnt during the role-play, focussing on elements (a) Reflection and (b) Development (see Section 4.2.3), but orally.

3.2.3. After the Mangal Play

After the final vote each stakeholder (i.e. each collective of participants) is given three assignments:

- Reflection:* to write a critical 1 page point-wise assessment/reflection on the lessons learnt, and more specifically what could have influenced the votes and what alternatives could have resulted in a different voting outcome;
- Development:* to provide feedback to develop or improve the Mangal Play;
- Analysis:* to visualise the social network corresponding to the Village in which the stakeholder was living using vertices and edges and to characterise it using the SNA indices incl. number of components, diameter, mean degree, average density, betweenness centrality, closeness centrality, eigenvector centrality, clustering coefficient among others. Stakeholders classified as 'Inside' or 'Outside' under Location in Table 2, make a

so-called non-village SNA. We provided a filled example of the sociomatrix spreadsheet (Appendix S7), prepared a tutorial to analyse it using R Statistic and to generate the corresponding social networks (Appendix S8), and visualised it in Figure 3.

Finally, the Mangal Play organisers can visualise the entire stakeholder network. A final joint meeting or separate meetings with individual stakeholders or participants can be organised for a final debriefing of the Mangal Play to cross-check the learning outcomes (see Section 2).

4. Discussion

The Mangal Play has proven to be instrumental in teaching courses in marine sciences in general, and those integrating ecological as well as management and governance issues in particular. We have organised the Mangal Play seven times from 2016 till 2021 involving in total approximately 450 participants from >40 countries, many of which have mangroves, in groups ranging from less than 30 to more than 130. We recognise that preparation, moderation and time management (Figure 2) may be the most challenging implications of organising the Mangal Play, but in our experience, these have never formed a barrier in the organisation of the role-play. Whereas preparation is straightforward when following the aforementioned procedures, moderation in Phase II of the Mangal Play and time management in all Phases requires discipline and clear communication with the participants.

Judging from written participant feedback on the Mangal Play's serious game simulation, the lessons learned from the Mangal Play are threefold:

- It was a welcome exercise in oral rebuttal and debate;
- It generated respect for and appreciation of the conditions of other stakeholders;
- It is an eye-opener for the complexity of decision-making, which in some cases resulted in policymaking-aversion (*i.e.* some participants playing GOV disliked the massive efforts GOV had to make in order to content all stakeholders to the extent that the Mangal Play reportedly ensured that they would never enter into politics). Yet, learning to distinguish what is bottom-line (no go) and what can be negotiated remains a relevant exercise and learning outcome.

The implications of the Mangal Play for policy and practice include points (a) to (h) already indicated in Section 2, particularly in the educational contexts that we tested repetitively. In a policy context, implications such as the ability to argue, to make decisions in a responsible and informed way

and to accept compromise and to distinguish bottom-line issues from negotiable positions should be paramount. However, in real life there a danger exists of sticking blindly to own (political) discourses. The Mangal Play should enable individuals shy away from such stubborn attitude in a learning environment in which there is no (political) opposition or consequence.

Future applications may complexify the Mangal Play to make it even more realistic and include in a non-exhaustive way:

- **Present more than one bill in series or in parallel.** Bills are usually very specific and some stakeholders feel more concerned or are more involved in one bill as opposed to another. Running multiple bills in serial Mangal Plays has the advantage of increasing the sense of involvement among stakeholders. Running multiple bills in parallel or in the same Mangal Play has the advantage of increasing the negotiability using trade-offs between bills.
- **Add a 'high court' as a stakeholder to solve disputes between stakeholders.** Some stakeholders made agreements with others but then breached the agreement or broke their word. Introducing a legal institution may help resolve conflicts. However, the main disadvantage of conflict resolution is that it is a time-consuming activity.
- **Introduce also banknotes smaller than 5000 A.** The Budgeting step (see Section 4.2.1 and Phase IV) may result in some stakeholders only having a single banknote of 5000 A. Unless they obtain additional funds, they can only invest it in one activity. Being able to split it into smaller banknotes increases their margin of involvement, but it will definitely complexify the collection of banknotes at the end of the role-play.
- **Reveal the budget allocation of each stakeholder to all stakeholders.** Currently, each stakeholder receives their budget in Phase IV, but they are unaware about the budget that other stakeholders received. The advantage of not knowing other stakeholders' budgets is that they have to find out by interaction, whereas the advantage of knowing may provide a shortcut to go and negotiate with the wealthiest stakeholders.
- **Enable more time for interaction in general and after introduction of the money in particular.** As indicated previously, time is a limiting factor. If the Mangal Play is scheduled to last for 5 hours, each phase takes on average no more than 45 minutes, which was perceived as too little by some stakeholders that had to manage lots of interactions.
- **Authorise stakeholder switches or accumulation of multiple stakeholder roles.** In more complex SESs people may belong to more than one stakeholder (for instance within the CHARCOAL workers *sensu* Satyanarayana et al., 2021) or switch role depending

on season or economic conjuncture (for instance FISHMAN and AGRI as in [Omodei Zorini et al., 2004](#); or FISHMAN and FISHWOMAN as in [Ndarathi et al., 2020](#)).

However, this will undoubtedly constrain time even more. Specific conceptual and methodological constraints and their solutions resulting from own experience and from written participant feedback, have been detailed in Section 6.

5. Conceptual and methodological constraints and solutions

We developed tools to organise Mangal Play using pen and paper to enable the experience easily and cheaply, but we also developed online voting and analysis tools where participants can be connected to the Internet ([Table 3](#)). SNA analysis using R was probably the biggest challenge for participants due to its difficulty for first-time users, but this analysis software being open-source and widely used around the world largely balanced this difficulty.

A few methodological constraints were encountered. The first one was ‘lack of time’, resulting in feelings of lack of closure with respect to discussions, negotiations or transactions that were on-going when the time to vote arrived. This is difficult to overcome and can be reduced as much as possible by repeatedly communicating how much time remains, which can be done by displaying a count-down clock. Another way to overcome this in a classroom setting is to extend the Mangal Play over two days one week apart and break in Phase II. This creates ample time for the participants to interact.

The second methodological constraint included the differential way in which different stakeholders were or at least “felt” concerned by the bill proposed for enactment. This can be solved by the MC giving ideas for interactions to different stakeholders. In fact, Phase III with the fully-fledged example of surprise events (see [Appendix 1](#)) serves this very purpose and should make stakeholders realise that they have more negotiation power than they might have believed initially.

A third constraint that is more conceptual in nature was clarity and exemplification of what constitutes an interaction. As a solution, the instructions to fill the sociomatrix and relational data ([Appendix S2](#)) clarify that an interaction must be active. An interaction can therefore be a question that a stakeholder receives or asks, a discussion with someone, an interview, an exchange of data, information, goods, services, funds, etc., whichever medium is used (letter, oral, e-mail, social media, barter and trade, etc.). Simple posts on social media for instance, cannot be taken as interactions unless there is an open letter directly addressing a question or request to one or more stakeholders. The MEDIA saying something about some

stakeholder regardless of whether it is true or false can therefore not be taken as an interaction. Finally, interactions cannot be deleted, reversed or altered, meaning that once an interaction has taken place, it cannot be “undone” even if the interaction was not supposed to have occurred in the first place. This can best be paralleled by referring to the example of sight or hearing: once someone has seen or heard something, one cannot “unsee” or “unhear” it anymore.

Finally, to study the differences between the repeatedly played Mangal Plays (see Section 5), in-depth social-network analysis, statistical comparisons and, first and foremost, comparison with a reference situation to which to compare the fictive plays by classroom participants is required. We announce a follow-up paper in which in-depth analysis is performed and in which we will report the similarities and dissimilarities between the Mangal Play in a classroom setting and in a mangrove field setting involving real stakeholders (*i.e.* a real fisherman, a real wood logger, a real beekeeper, etc.).

Author contributions

FD-G: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Visualisation, Supervision, Project administration, Funding acquisition, Writing – original draft, Writing – review & editing. TN: Methodology, Software, Validation, Investigation, Resources, Data curation, Visualisation, Supervision, Writing – review & editing. JH: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Supervision, Writing – review & editing. YD-G, LM: Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – review & editing. DN: Methodology, Investigation, Data curation, Supervision, Writing – review & editing. AH: Investigation, Resources, Data curation, Supervision, Writing – review & editing. SA, MM: Writing – review & editing. NK, BS: Investigation, Writing – review & editing. MG, CM, IS, MV: Validation, Writing – review & editing. MP: Investigation, Validation, Data curation, Supervision, Writing – review & editing. HR: Methodology, Software, Validation, Investigation, Resources, Visualisation, Supervision, Writing – review & editing. KP: Investigation, Supervision, Writing – review & editing. KV: Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Visualisation, Supervision, Writing – review & editing. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fmars.2022.909793/full#supplementary-material>

SUPPLEMENTARY DATA SHEET 1

The supplementary material is provided as a ZIP file including [Appendix 1](#), as well as the eight Supplementary Online Information (SOI) files listed in [Table 3](#) ([Appendices S1, S2, S6 and S7](#) as a MS Excel spreadsheets, and [Appendices S3, S4, S5 and S8](#) as PDF files).

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