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Matching Ecosystem Functions with Adaptive Ecosystem Management: Decision Pathways to Overcome Institutional Barriers

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Abstract: Environmental management strategies aim to protect or repair ecological assets (ecosystems, species) so that their ecological and social values can be preserved. However, creating an effective strategy is difficult because multiple government departments are involved and because water and land use legislation and policy instruments are often fragmented. A key obstacle that is often overlooked is the spatial mismatch between ecological processes and institutional organisation (i.e., legislative framework and government departments). Successful management depends on the ability to cultivate resilient ecosystems through institutional reforms that take into account the complexity of ecosystems while supporting cross-sectoral and scale-dependent decision-making within the science–policy interface. Here, we use a case study approach to illustrate how collective strategic decisions can be made to manage a valued ecosystem situated within an urban matrix. We used a three-step framework to guide our approach and commenced by identifying a range of adaptation measures (i.e., management interventions) and the actors responsible. For each adaptation measure, we then investigated (i) mismatches among ecosystem and institution scales and levels; (ii) institutional barriers; and (iii) the role of actors in decision making. We use this information to identify 'decision pathways': i.e., a flexible decision-making platform that assists stakeholders to make strategic short- and long-term decisions. Key insights included the discussion of policy and practical experiences for ecosystem management at different levels and the necessary conditions to provide better alignment between jurisdictional an ecosystem scale to guide decision makers accordingly. We detail the institutional and jurisdictional changes that must be implemented across all levels of governance to protect and support the resilience of environmental assets. 'Short-term' decision pathways were preferred among actors and cross-level cooperation at jurisdictional level provided an adequate fit with the ecosystem scale. 'Long-term' decisions require substantial change of the institutional framework to enable the implementation of adaptive management. Although challenges at institutional and jurisdictional scales remain, decision pathways promote adaptive ecosystem management through a better fit of jurisdictional and institutional roles/policy and ecosystem-scale processes.

Keywords: ecosystem resilience; wetlands; collective decision-making; trans-disciplinary cooperation; scale; level; cross-scale dynamics

1. Introduction

Ecosystems are naturally complex, and considerable uncertainty exists about their ability to maintain natural function while exposed to anthropogenic stress [1,2]. Ecosystem management plans aim to prevent the gradual degradation of essential functions or the rapid transition from a 'healthy state' to an 'unhealthy state' [3–5]. Management is particularly complicated where the natural system is embedded within a human or social system, i.e., social ecological systems (SES), because the anthropogenic setting also experiences its own changes and feedbacks on the ecosystem [6–9]. This is especially the case when the social system consists of a set of societal drivers (e.g., institutional controls, population, technology, etc.) and a complicated institutional organisation that protects the ecosystem [10].

Given the complexity of SESs, it is not surprising that most governance and legislative frameworks struggle to protect them. Factors contributing to the poor success rate of management plans include the institutional fragmentation of environmental policies (e.g., separation of land use from water planning) and their enforcement by different organisations. Another key obstacle is the poor alignment of the decision-making process within the institutional domain and the influential ecological and social processes [11,12]. For example, while ecosystems are organised in a hierarchy of spatial scales (e.g., patch, catchment, basin, region), the management of ecosystems typically operates at a single organisational level that is driven by compliance with often rigid legislative frameworks [13,14]. Furthermore, it is common for jurisdictional boundaries to be poorly aligned with ecologically meaningful delineations, such as a catchment boundary [15,16]. A common situation is an urban ecosystem that encompasses multiple local councils or water regulators. In instances where management does occur at multiple spatial levels (e.g., site, landscape), successful management is contingent on the timely transfer of information among spatial levels and requires cooperation of management authorities that operate at different spatial scales [17]. Another unexpected but potentially important problem is the ability for national or state level mandated policies to negatively impact on local-level decision-making (e.g., climate adaptation [18] and governance [19]). Lastly, mismatches often exist between the compliance of organisations to mandated legislation and the resources needed to support the successful implementation of on-ground management actions; this is particularly an issue for local scale ecosystem management departments [20] or departments with conflicting interests [21].

Solutions to improve our ability to protect ecosystem functions in SESs include knowledge co-creation and collaborative governance that facilitate the sharing and integration of diverse sources and types of knowledge [22]. The management-as-learning approaches include the dynamics in a transition due to both internal and contextual factors [23–27] while fit-for-purpose governance strategies focus on dynamic perspectives and strategies [28–30]). Stakeholders that operate at multiple spatial scales are able to link ecological and social conditions with the institutional framework. To be successful, such a framework needs to contain clear linkages between management triggers associated with critical and undesirable ecosystem changes (e.g., loss of species, change in water depth) and legitimate actions for ecosystem rehabilitation or adaptation [18,31,32]. Knowledge co-creation and collaborative governance to achieve adequate adaptive management (flexible management decisions while recognising uncertainty) is not only challenged by the degree of institutional flexibility and uncertainty of ecosystem responses [33–36], but also by fragmented departmental arrangements with complex water and land use policies which lead to a lack of necessary cross-departmental cooperation [23,37]. If practical limitations (barriers) to the implementation of adaptive management are recognised and institutional constraints are better understood across various spatial scales (both legislative framework and organisations responsible for ecosystem management), ecosystem outcomes can be improved [38–40].

Timely and targeted management intervention is also critical to successfully managing and protecting SESs. Typically, management is characterised by small, incremental steps with protracted time lags occurring between the condition of an ecosystem (function) and management intervention [41,42]. Far too often, the timing of on-ground actions is determined by institutional

and political constraints rather than scientific evidence, which leads to sub-optimal environmental outcomes [39,43,44]. Ideally, the decision-making space within the institutional domain should be flexible enough to respond to the dynamic nature of complex ecosystems and socioeconomic systems [45]. Moreover, these decisions need to provide mechanisms to achieve the targets of the environmental protection policy, such as the EU Water Framework Directive and the Environmental Protection Acts in the USA and Australia [46–48]. Determining optimal decisions among stakeholders across spatial scales of ecosystem management and jurisdictional boundaries could optimise the decision-making process of stakeholders.

This study shares policy and practical experiences on ecosystem governance at different levels and discusses the necessary conditions for results-oriented stakeholder engagement, and to guide decision makers accordingly. We focus on how to improve management of SESs by investigating how collective strategic decision-making can be used to identify scale mismatches and barriers that prevent the implementation of adaptive ecosystem management. The merit of the pathways approach minimizes regret and enhances flexibility for decision-making and has been widely applied [49,50]. We adapt a three-step framework to guide the process and illustrate our method using a groundwater-dependent wetland in an urban matrix that is threatened by a drying climate. We start by identifying a range of adaptation measures (i.e., management interventions) and the actors responsible. We then use this information to investigate three research questions:

1. What mismatches exist across jurisdictional and ecosystem scales, and which actors must be involved in the processes of identifying institutional constraints when adaptive ecosystem management needs to be implemented?
2. What barriers exist between jurisdictional and institutional scales that prevent the implementation of adaptive management to support ecosystem function?
3. What time frames for decision pathways are considered and how do actors collaborate to implement each flexible arrangement?

Our decision pathways create a flexible decision-making platform that assists stakeholders to make strategic short- and long-term decisions that anticipate future disturbances to the ecosystem and institutional domain.

2. Methods

2.1. Clarification of Terms

Within an SES, many interactions take place at different scales. We define "scale" as the spatial or temporal dimension used to measure and study the interactions of our case study area and "level" to the specific unit/domain within a scale [49]. We present the following definitions for human-environment interactions at different scales and the different levels of each scale [17]:

- Ecosystem scale: biophysical phenomena that take place in different areas (region, landscape, patch [51]);
- Jurisdictional scale: administrations or actors that are involved in managing the ecosystem and where decisions are made (national, state, localities);
- Institutional scale/framework: policies, legislation and regulation for the conservation of the ecosystem and the division of jurisdictions;
- Temporal scale: decisions taken by administrations or actors that follow the political and policy cycle with outcomes of environmental management decisions (<5 years, short time scale) or outcomes that follow ecosystem processes (>10 years, long time scale) [52];
- Cross-level: interactions among levels within a scale, for example, between local and state actors with the jurisdiction scale;
- Mismatch: the problem of fit involving jurisdiction and institutions that do not map coherently onto to the bio-geophysical phenomena of the ecosystem, either in space or time [53];

- Governance: the ways and means employed by actors to make collective decisions, choose collective goals, and take action to achieve those goals;
- Decision pathway: cross level interaction within the jurisdictional domain to allow the implementation of adaptation measures that match the biophysical levels of the ecosystem. We make two distinctions on the temporal scale of decisions: those that only depend on cross-level jurisdictional cooperation on a local level are identified as 'short-term' decisions, whereas 'long-term' decisions require across-level collaboration of jurisdictions.

2.2. Case Study Description and the Actors Involved in Conservation

Our case study was Forrestdale Lake, a wetland in Perth, Western Australia (See Figure 1) that has undergone a marked reduction in water depth through time associated with climate change and urban development [54]. The wetland has lost some key ecosystem functions (e.g., breeding habitat for migratory bird species) and a previous analysis showed that the institutional framework (environmental policy, legislation, and management plans) is inadequate to mitigate declining water levels in the lake [55]. Various actors (Table 1) are involved in the conservation of the wetland, and their tasks are set according to the legislative framework aimed to maintain individual biophysical processes (Supplementary Materials, F1). Decision-making takes place by different administrations at the jurisdiction scale which therefore have the power to change the institutional framework accordingly [55].

Table 1. Overview of the actors (stakeholders) involved in the conservation of the wetland.

Actor.	Administration	Task	Jurisdiction
Armadale local government	City council	Land division, drainage, and irrigation	Local
Department of Parks and Wildlife	Conservation authority	Conservation of biodiversity, wetland buffer zone, fire management, and public access	Local and Sate
Department of Water	Water regulator	Ground- and surface water allocation and monitoring	Local and State
Water Corporation	Water utility	Groundwater abstraction for drinking water, maintains large drains	Local and State
Urbaqua	Research institute	Groundwater modelling research in local catchment area	Local
Friends of Forrestdale	Community and local conservation group	Monitoring birds, revegetation and rehabilitation of the wetland buffer zone	Local
Commonwealth Government	Federal environmental department	Responsible for species protection according to Environmental Protection and Biodiversity Act	National

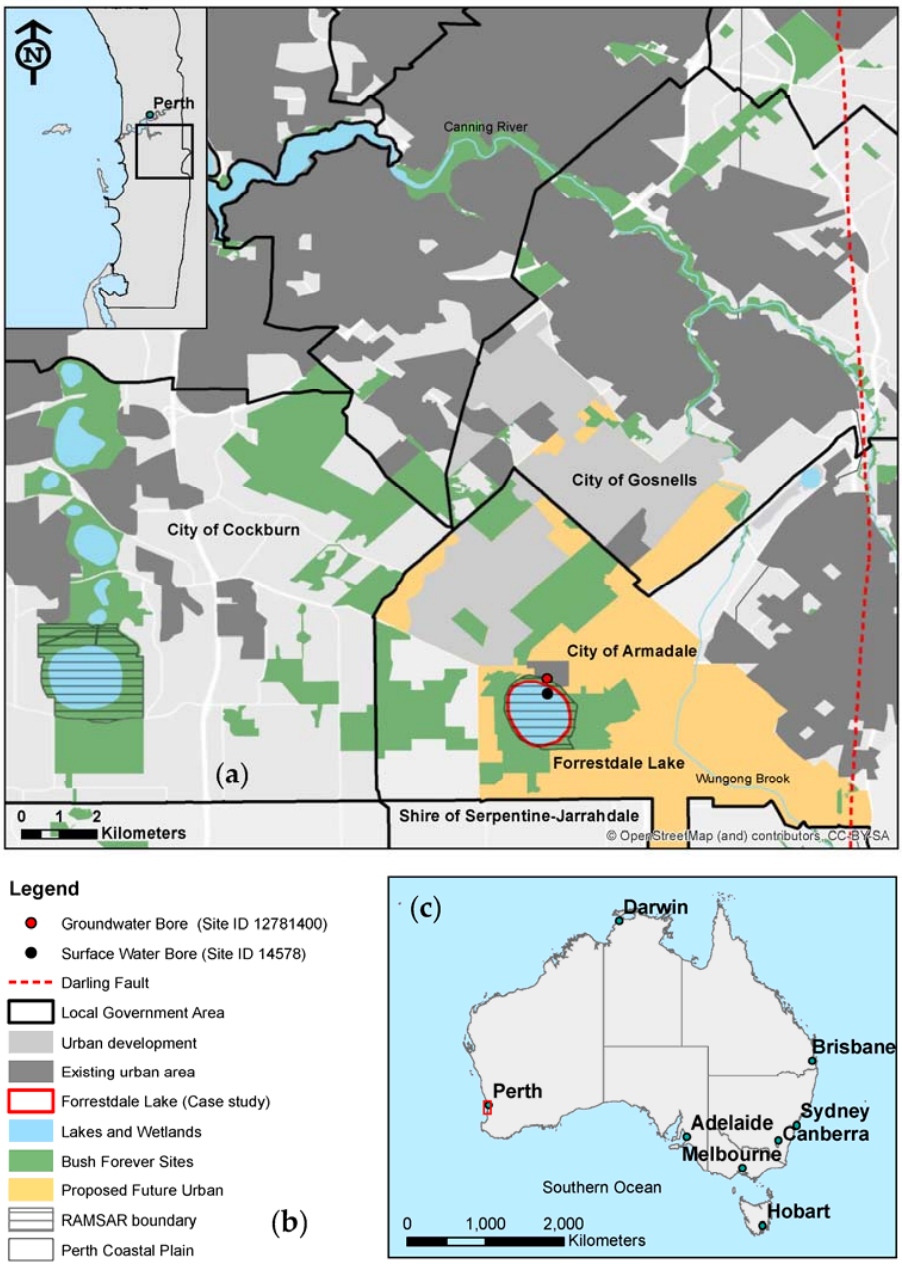

Figure 1. (**a**) Location of Forrestdale Lake (32°09′30″ S, 115°56′16″ E) with multiple management authorities responsible for the conservation different aspects of the ecosystem (Map projection: GDA94). Groundwater is regulated by the Department of Water; Wetlands, Bush Forever, and Ramsar Sites are managed by the Department of Parks and Wildlife; Urban development is regulated by Local Government Area the City of Armadale; and Forrestdale Lake is supported by community group Friends of Forrestdale; (**b**) Legend; (**c**) Location of the case study area in Australia.

2.3. Research Design and Data Collection

As the dynamics of cross-scale and cross-level interactions are affected by the interplay between institutions at multiple levels and scales, we used a method that included knowledge co-production, collaboration, and negotiation across scale-related jurisdictions and institutions to facilitate the complex decision-making process in the management of the ecosystem. We adapted a framework created for strategic delta planning [30] that was applied for the implementation of adaptation pathways in the Netherlands and the United Kingdom [50]. The framework is characterised by a funnel-shaped

decision process in which stakeholders and the decision space is gradually reduced with a widening scope through three steps: agenda setting, plan formulation, and implementation (Figure 2). Central to this approach are the dynamics of stakeholders who have clear tasks that can be investigated in a case study situation. The three-step approach also provided a structure that enabled us to investigate our three research questions. The analytic techniques included document analysis of the environmental history; a literature review of key environmental planning documents, three semi structured workshops, each 2.5–3 h in length with 5–6 actors (two representatives specific to their jurisdiction or personal expertise); and analysis in a systematic qualitative framework to determine scale mismatches, barriers to implementation, and decision-making.

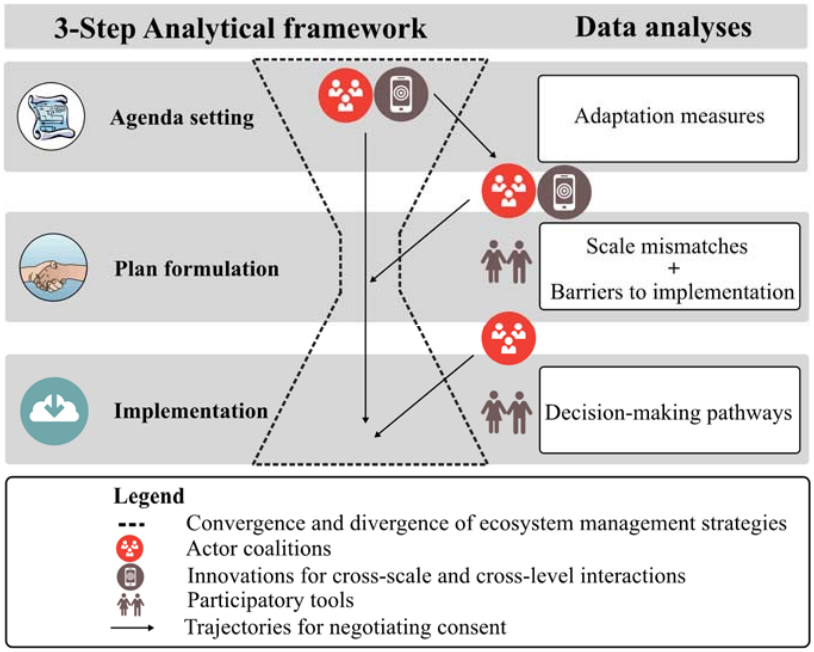

Figure 2. A stylised framework for strategic decision-making and ecosystem management across scales and levels (adapted from [30]). Step 1—agenda setting—determines the adaptation measures, i.e., the on-ground actions that can protect or repair the ecosystem, based on previous research. Step 2—plan formulation—identifies scale mismatches and barriers to the implementation of adaptation measures. Step 3—implementation—identifies the decision-making pathways to improve ecosystem scale fit. Actor coalitions, participatory tools and innovations across scales are shown.

In Step 1—agenda setting—the analytic techniques included document analysis of environmental history and the qualitative analysis of the workshop field notes and transcripts [55]. We gathered together relevant stakeholder groups, socio-ecological objectives of the wetland and proposed adaption measures to cope with declining water levels and deterioration of the ecosystem's biophysical processes (Supplementary Materials, Tables S1–S4). To determine the institutional framework of Forrestdale Lake, we conducted a literature review of key planning documents and relevant scientific literature (Supplementary Materials 2).

In Step 2—plan formulation—our first aim was to provide an overview of mismatches among the jurisdictional, ecosystem, and institutional scales as part of the plan formulation stage. For this, we extended the matrix with adaptation measures and asked stakeholders (Tables S5–S9).

a. Which actor(s) is/are responsible for the execution of each adaptation measure at the jurisdictional scale;
b. At which ecosystem level an adaptation measure has the largest impact at the ecosystem scale;

c. Which policy or legislation needs amendment and at which level does such decision take place; and
d. Which limitations/barriers arise when adaptive measures are implemented?

Interview transcripts and field notes were qualitatively analysed in five steps and identified for each adaptation measure: (1) the actor and its level within jurisdictional scale; (2) the biophysical process it targets and at what level within the ecosystem this has effect; (3) the main policy/law that needs amendment and at what level this operates within the institutional scale; (4) the interaction among actors and institutional arrangements; and (5) the barriers that arise for the implementation of each adaptation option according to a theoretical framework [24,56]. We distinguished barriers (research question two) from an interaction perspective which is characterised by content, the structure of how actors are organised, and from a legal perspective that is characterised by the flexibility to adapt legislation (Table 2). We summarised the case study area in relation to the interaction and legal perspectives in the Supplementary Materials (Table S10).

Table 2. Overview of characteristics of flexible arrangements and the barriers from an interaction and legal perspective; adapted from [56].

Interaction Perspective (i.e., among Actors)	
Characteristics	*Barriers*
Flexibility of content	Conflicting time frames and interests
Flexibility of the process	Obscure distribution of responsibilities between actors
Flexibility of the structure	Unclear distribution of costs and future benefits
	Lack of trust between participants
Legal perspective (i.e., legislation, policy)	
Characteristics	*Barriers*
Flexibility of content	The perceived need for legal certainty
Flexibility to adjust arrangements	The need to protect individual rights, procedural guarantees and rights

In Step 3—implementation—to determine how actors differentiate the temporal scale in the decision-making process (research question three), we identified which actors took decisions to implement adaptation measures with occurring scale mismatches or provided other actors (not involved in the workshop) required for decision-making to implement each adaptation measure. Then, we analysed the actor coalitions of all three workshops at three stages—agenda setting, plan formulation, and implementation—in the decision-making process. We present these multiscale decisions as decision-pathways and make two distinctions on a temporal scale: short-term and long-term decisions. Adaptation measures that show a mismatch with the institutional scale are identified as 'long-term' decisions as legislation or policy changes require time beyond the political cycle (5–10 years). Decisions that only depend on cross-level jurisdictional cooperation are identified as 'short-term' decisions and can be realised within the political cycle (<5 years).

3. Results

3.1. Jurisdictional, Ecosystem, and Institutional Mismatches

Our first aim was to provide an overview of mismatches among the jurisdictional, ecosystem, and institutional scales as part of the plan formulation stage (Supplementary Materials, Tables S11 and S12).

From our analyses, we find that mismatches occur across all three scales (Figure 3). Firstly, jurisdictional scale mismatches lead to different actors that are concerned with the wetland's conservation and a lack of a coordinating actor that can align decisions over multiple jurisdictional

levels. An example from our workshop is the State Conservation Authority that is responsible for meeting the ecological requirements, while the Water Authority complies to groundwater abstraction limits that the Conservation Authority cannot amend when these are over-allocated. The jurisdictional organization across levels is a direct result of the institutional framework. For each institutional category, there is a jurisdiction and an appointed decision-making jurisdiction (e.g., national/state parliaments, state planning institute). This range is diverse and includes land-use, water regulation (e.g., abstraction and allocation limits), water resource planning, regional biodiversity and maintaining hydrological and bushland corridors (e.g., wetlands and wetland buffer zones).

The close interaction of jurisdictional and institutional scale is not always a limiting factor for the conservation of the wetland ecosystem. As the health of the wetland is determined by hydrological and ecological processes within the lake, immediately surrounding the lake (e.g., riparian buffer), as well as further afield (e.g., regional aquifer), there is a need for close cooperation across all jurisdictional bodies responsible for land and water management. In our case, the State Conservation Authority considers taking this role to ensure that plan formulation simultaneously takes place at multiple jurisdictional levels. This ensures that the interests of local level actors (local council and community) are aligned with their jurisdiction. These actors depend on the plan formulation to align their interests, which are the responsibility of actors on the state level. An example is the application of ecological criteria that involve the protection of the wetland buffer zone. The local council, community, and State Conservation Authority collaborate to limit weeds, rehabilitate vegetation, and remove waste that decreases the fire risk.

Jurisdictional fragmentation also leads to a mismatch with the ecosystem scale and its individual biophysical processes that are supported through adaptive management (Supplementary Materials, Table S13). For example, protecting flora species is in the interest of local government and community while this is the jurisdiction of the State Conservation Authority, although local government, the community and the State Conservation Authority collaborate to remove weeds and limit access to the wetland and thus enable cross-level matches with the biophysical processes at the ecosystem scale, in this case for flora species conservation.

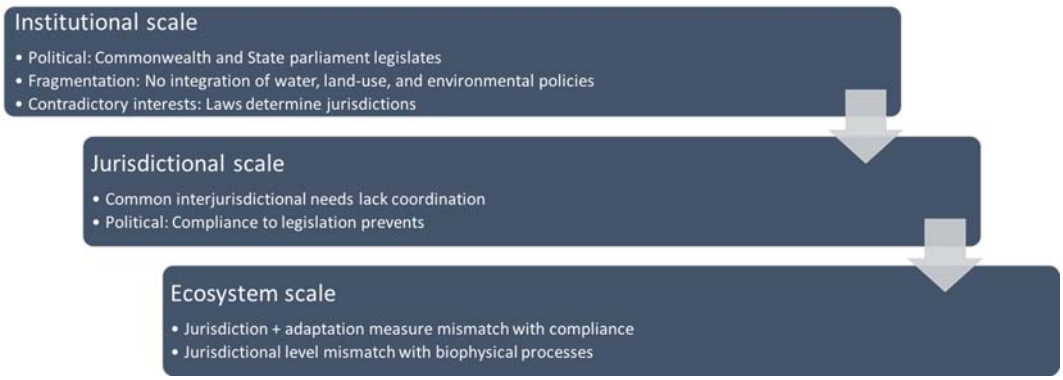

Figure 3. Mismatches across three different scales and the main causes or effects.

The third finding focuses on mismatches between jurisdictional and ecosystem scales that are often a result of institutional fragmentation originating from the institutional scale. National or state-level policies at the institutional scale often mismatch with the ecosystem scale and its biophysical processes. For example, the reduction of groundwater abstraction could improve water levels in the wetland but requires the amendment of state level legislation to reduce allocation limits. When an actor pumps water to supply surface water into a wetland (local action), the major hydrologic process controlling water level in the lake relate to the regional aquifer (large spatial scale). This means that local scale action does not repair the low water levels, which are impacted at a large spatial scale.

3.2. Adaptive Management and Its Barriers across Scales

Our second research question involved an analysis of barriers that exist for flexible adaptive management across jurisdictional, institutional and ecosystem scales. We list these barriers from an interaction and a legal perspective that were obtained from the stakeholder workshops (Supplementary Materials, Tables S14 and S15). From an interaction perspective, cross-level collaboration within the jurisdictional scale is aimed to minimise mismatches between jurisdictional and ecosystem scales (Figure 4). The focus of actors is on cross-level cooperation. While all actors mentioned that cross-level collaboration does not remove the institutional and jurisdictional scale mismatches, each actor complies with the institutional framework that aims to regulate specific resources such as: land resources, water resources, groundwater abstraction, public open spaces or species conservation.

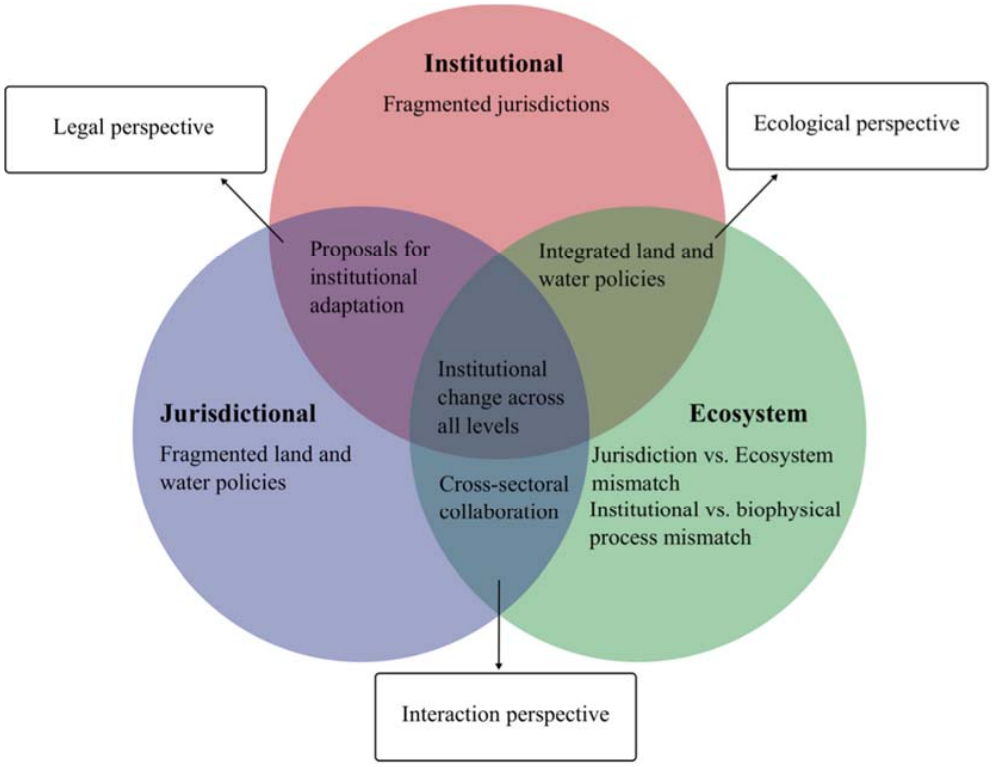

Figure 4. Mismatches across three different scales and perspectives, with the main barriers for each scale mismatch and overlapping areas that indicate the perspectives to match between two or (in the centre) all three scales.

From a legal perspective, cross-level collaboration within the jurisdictional scale is limited due to the institutional framework that mandates the role of each actor. The hierarchy of institutional levels (from local management plans, state land-use and water policies, and national biodiversity law) prevent cross-level collaboration among actors. There are two reasons for minimised cross-scale interactions:

a. The institutional framework includes the protection of individual rights of people, but also a common right to the conservation of ecosystems. This leads to conflicting interests when adaption measures are implemented;
b. Local level actors are prevented from implementing adaptive management due to their jurisdiction that is determined by state-level institutions. This means that actions to improve ecosystem conservation by a local government are limited as result of state planning and water policies. For example, a local government cannot demand restrictions of groundwater use by individuals (arranged in state groundwater policy), despite this action supports adequate water levels in the wetland.

In Figure 5, we conceptualise the institutional barriers and the process stakeholders followed to explain the flexible arrangements in the case study area, which ends with decision-making as a main obstacle to change the institutional framework.

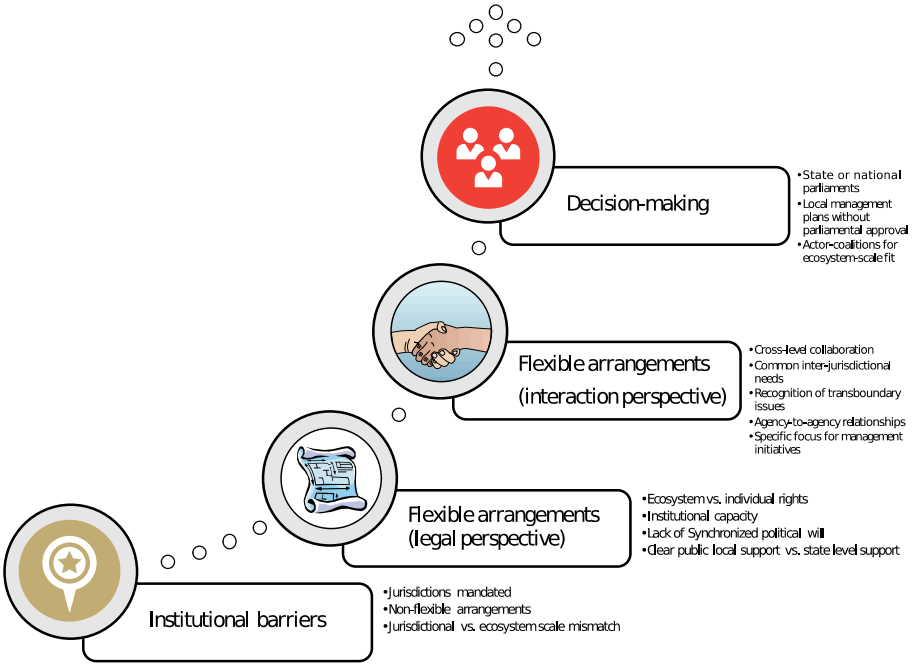

Figure 5. The process from identifying institutional barriers to decision-making which resulted from stakeholder interactions.

3.3. Actor Roles and Decision Pathways for Ecosystem Management

To answer the third research question, we identified which actors took decisions to implement adaptation measures with occurring scale mismatches (Supplementary Materials Table S16). We found that agenda setting, plan formulation and implementation take place across all jurisdictional levels (Figure 6). In cases when the decision-making actor is unclear, cross-level cooperation at the jurisdictional scale leads to emerging discussions about who is responsible for taking decisions to implement an adaptation measure. In general, these actor coalitions support cross-level cooperation at the jurisdictional scale. A state-level actor (water utility) was included to promote cross-level and cross-scale interactions for adaptation measures such as water regulation, water savings and drainage infrastructure (Figure 7). Actors regard institutional changes as politically dependent events that require complex decisions with national and state-level actors (e.g., water department and water utilities). Currently, compliance to the existing institutional scale prevents the implementation of adaption measures by local actors.

Figure 6. Actors form different coalitions for each adaptation measure that enhances jurisdictional and ecosystem fit. Local and regional level jurisdictions provide plan formulation to integrate their different policies.

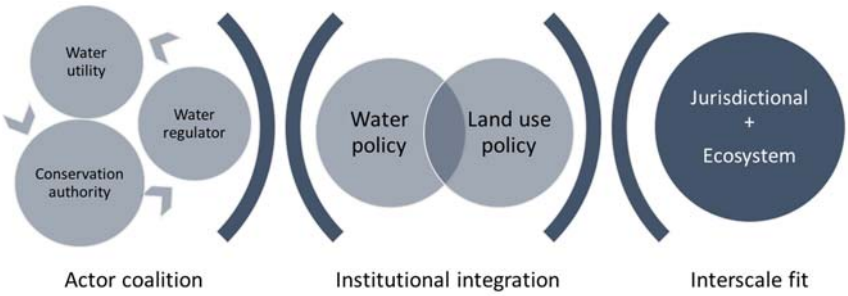

Figure 7. The inclusion of a new actor in an actor coalition provides discussions about institutional integration for increased ecosystem fit of adaptive actions.

Cross-level interactions within the jurisdictional domain allows the implementation of adaptation measures with ecosystem fit across biophysical levels (Supplementary Materials, Table S17). Stakeholders preferred to implement adaptation measures that required no change to the institutional framework at national or state level; rather, actors matched the jurisdictional level of an actor with an adaptation measure, so that a single actor could decide (Figure 8). Actors may group together during plan formulation to create a dynamic cross-level decision-making process, without taking into account the mismatch with biophysical processes at the ecosystem scale.

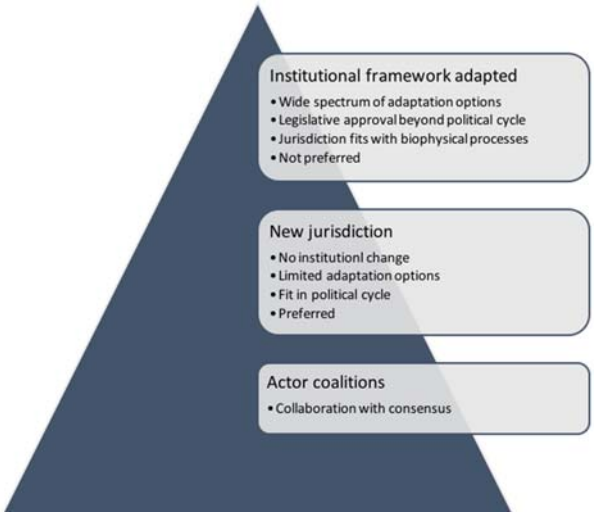

Figure 8. The hierarchical structure for the selection of adaptation measures, which depends on the preference of working with the current institutional framework.

The last finding from the analyses of our workshops fills the gap of consolidating the consensus and plan formulation with a clear indication of making decisions. In Figure 9, we conceptualise the cross-level and cross-scale interactions to provide ecosystem fit and the time scale for decisions. We refer to these as decision pathways and build on the previous results of actor coalitions, the barriers, and flexible arrangements. The concept shows how actors can collaborate and when decisions require institutional changes or when improved collaboration across the jurisdictional scale is sufficient.

The five decision pathways are represented for the implementation of adaptation measures:

1. Local level actors in a shared jurisdiction implement adaptation measures according to agreed objectives (example in Section 3.1);
2. Local level actors that negotiate plan formulation with actors that operate at a single level to support the implementation on local level (example in Figure 6);

3. Local level actors that negotiate plan formulation with actors that operate multiple levels to support the implementation on local level (example in Figure 7);
4. Local level actors reach consensus for agenda setting on both individual rights and adaptation measures to improve ecosystem conservation and propose a plan for institutional amendments (explained in Figure 8);
5. Pathway 5 includes a 'new' actor in actor coalition to increase jurisdictional and ecosystem fit. This includes more flexibility in the contents, interaction, structure and process of decision-making at national or state level (explained in Figures 6–8).

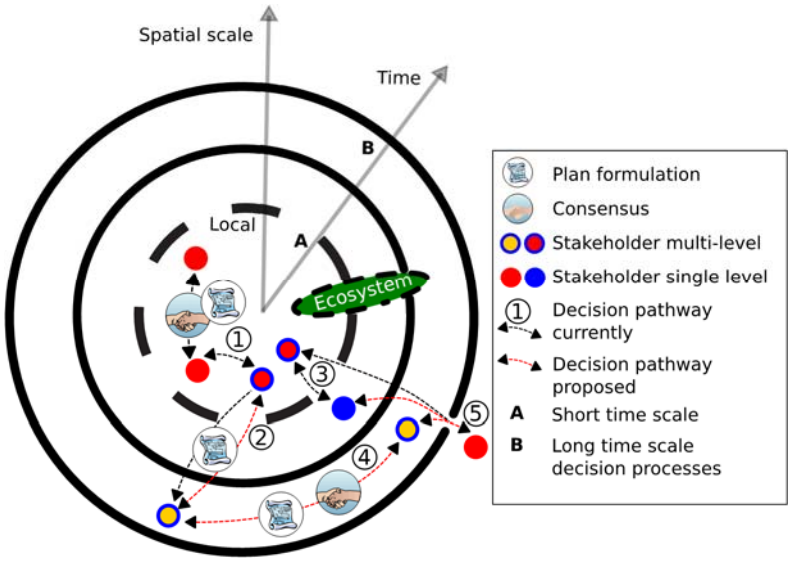

Figure 9. A conceptualisation of decision-making across spatio-temporal scales that follows five different decision pathways to implement adaptive ecosystem management. Agenda setting, plan formulation and implementation take place across both jurisdictional and ecosystem scales, and decisions pathways are either short-term (zone A) or long-term (zone B).

4. Discussion

4.1. Temporal and Spatial Arrangements Applied to Ecosystem Conservation

A key issue limiting the effective implementation of adaptive measures for our case study wetland was jurisdictional and institutional fragmentation and the mismatch between ecosystem scale biophysical processes and institutions. Mismatches were discussed with participating actors across the jurisdictional/institutional scales and were followed with cross-level interaction within the jurisdictional scale. Cross-level collaboration among jurisdictional levels that takes into account hierarchy, different sectors, government, and academia was recommended in previous research [57–59].

Actors at the jurisdictional scale often face conflicting institutional barriers [31], and in our case study area we found that cross-sectoral collaboration is challenged due to compliance with complex policy and legislation [23,60,61]. As in our case, adaptive environmental management depends on decisions that are taken across multiple levels at jurisdictional scale. Our results show that multiple levels of actors have distinct jurisdiction and therefore have to comply to different sets of policy or law. Compliance occurs at different institutional levels and includes water resources planning, land-use planning, and ecosystem conservation. To reach agreement for collaboration by different actors, compliance to the institutional framework must be taken into account, although compliance to the institutional framework does not necessarily mean that the actor's adaptation measures match with the appropriate biophysical level of the ecosystem. Often institutional scale limits the actions by actors to meet compliance with ecological targets at landscape scale [7,62]. Therefore, actors focused on

integrating diverse levels of the institutional framework that enables better cross-scale (ecosystem and jurisdiction) to implement adaptive ecosystem conservation across multiple ecosystem scales [63–65].

The relationship of analytical levels of human choice and geographic domains is a well-described phenomenon [22,53]. In our case study area, ecosystem management requires actors to negotiate to apply ecological criteria. These criteria depend for example on the protection of the buffer zone that will deliver multiple benefits to the wetland such as provision of habitat, and corridors to assist the movement of wildlife and reduce disturbance [66,67]; however, this action is currently not being implemented due to a fragmented institutional framework. Local level actors require state or national level endorsement when jurisdictional and institutional mismatches occur [68]. Actors in our case study area improved their management plan by getting around barriers (flexibility in the content, cross-level collaboration). Recent studies show that water policies (e.g., groundwater abstraction limits) depend on higher level institutional level policies, but also require choices among local level actors to provide adaptation measures that benefit the ecosystem [69–71].

4.2. From Adaptive Governance to Decision-Making for Adaptive Ecosystem Management

Adaptive management moves from a focus on efficiency and lack of overlap across actors at the jurisdictional scale to a focus on diversity, redundancy, and multiple levels of jurisdiction that include local knowledge and local action [72]. We determined the barriers that exist across multiple levels of jurisdiction and compared this with the levels of ecosystem scale, following previous research [23,24,56]. In contrast to the findings of other studies, we found that barriers mainly arise from a fundamental question about who is responsible for an ecosystem and who needs to make a decision. This becomes more relevant when actors focus on biophysical processes of the ecosystem that may not match with their jurisdiction. Simply, the actor lacks the jurisdiction to decide on adaptive management to support a biophysical process. For example, when a local council seeks to remove weeds to provide habitat for migratory birds, their lack of jurisdiction limits their ability to take the actions necessary at regional (or larger) spatial scales (e.g., illegal hunting) to protect populations of migratory bird species. Caution must be taken regarding the broad-scale applicability of our results, since institutional frameworks may differ from country or among case study locations. Four criteria for adaptive governance are explained [73] and we recommend including public participation, an experimental approach to resource management, and management at the ecosystem scale to overcome barriers in decision-making.

Numerous decisions must be made throughout agenda setting, plan formulation and implementation phases of any ecosystem management plan. A clear overview of necessary cross-level collaboration has been illustrated by our conceptual representation of decision making. Despite the well-described cross-level and cross-scale interactions in the literature [17], the dynamics of multiple actors are highly complex. The interplay of jurisdictions could lead to improved decision making due to the interplay of multiple disciplines and perspectives. Our study revealed that decision-making takes a similar approach during all stages of a management plan (i.e., consensus, plan formulation, and implementation) and is a non-linear process that takes place simultaneously at multiple levels of governance (jurisdictional scale). Other studies also highlight that the interactions among actors are influential in determining how adaptation processes will occur. The identification of existing and new feedback processes is critical to effective decision-making within the jurisdictional-institutional landscape [74,75].

Decision pathways offer alternative ways to improve collaboration and the implementation of an ecosystem management plan. Also, they reflect debates or disagreement about environmental governance. The debate in our case study focused on the competing rights of individuals (e.g., people) and a common resource that needed protection (e.g., the wetland). Decisions are taken at different levels of governance [30,76,77], although, each actor faces different challenges [78]. Regulatory actors usually have only jurisdiction for a portion of the resources in the wetland ecosystem and often the institutional mandates are conflicting (e.g., groundwater use vs. water availability in the wetland). A final consideration relates to political land administrative collaboration since the wetlands are shared

by two or more administrations or land owners (e.g., the riparian vegetation). In our case study, actors were challenged with trade-off situations that could arise during decision-making, such as legal consequences (e.g., individual rights to abstract groundwater upheld by courts) and inadequately protecting common resources, such as groundwater for ecosystems [63,79,80]. The environmental preferences of the involved actors determined the environmental outputs of the decision-making process. We found that multi-level governance comprising many cross-level actors yields higher environmental outcomes (e.g., management interventions) compared to monocentric governance [81]. Unless political and administrative cooperation (jurisdictional scale) can be achieved the rich array of ecosystem resources and ecological processes will continue to be exploited. We consider that the concept of decision pathways can clarify the decision-making space and improve the fit between policy delivery (adaptive management), jurisdiction and the ecosystem being managed.

From a broad perspective of resilience literature, institutional frameworks are often incremental and non-flexible whereas ecosystems can change abruptly [3,14,31,82]. We found that the political time scale to take decisions is generally much shorter than the biological timescale which constrains adaptive management, since the institutional and jurisdictional systems are viewed as a boundary condition [83]. By focusing research on those boundaries and how to move them, greater implementation of emerging approaches to adaptive ecosystem management and resilience may be achieved as pointed out in previous research [84–87]. Adaptive management provides a way to manage uncertainty with adaptation pathways and jurisdictional or institutional organisation [37,88,89]. The difficulties involved in negotiating these issues place significant importance on management abilities and the role of governance and institutions to provide resilient ecosystems. Decision pathways provide a tool to facilitate the inclusion of ecosystem organisation with institutional organisation through different decision pathways.

5. Conclusions

We aimed to clarify the decision-making pathways with policy delivery (adaptive management) and jurisdictional fit to the ecosystem. We developed the concept of decision pathways to promote adaptive ecosystem management through a better fit of jurisdictional, institutional and ecosystem scales. Consensus, plan formulation and negotiation across institutional levels is required to ensure that adaptation (intervention) measures match ecosystem organisation. The identification of barriers is a starting point for involved actors to determine which adaptation measures can be implemented within the current institutional framework. The decision pathways show two different temporal scales that depend on jurisdictional and institutional fit to the ecosystem. Short-term decisions require no substantial changes to the institutional framework and depend on multi-level collaboration to fit jurisdiction scale with ecosystem scale. Long-term decision pathways require institutional changes and multi-level collaboration. In this interactive spectrum, scientists need to responsibly navigate science–policy interactions, so that optimal solutions are translated to normative choices within the political spectrum. Challenges remain to identify temporal scale effects for decision-making as a result of a complex human-nature system that depends on financial resources, the political climate, or other trade-off situations with individual or common rights. Attempts to create adaptive management procedures that are a better fit with biophysical processes could overcome slow institutional changes that are often limited by narrow political and bureaucratic goals.

Supplementary Materials: The following are available online at http://www.mdpi.com/2073-4441/10/6/672/s1, Figure S1. Conceptual overview of the case study; Tables S1–S3. Structure of the workshop conducted in previous research; Table S4. Overview of all adaptation measures; Tables S5 and S6. Overview of the workshop structure for this study; Tables S7–S17. Data obtained from the stakeholder workshops. Tables S1–S4 Literature review of policies, legislation and actors.

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