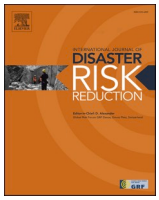
International Journal of Disaster Risk Reduction 57 (2021) 102185

Contents lists available at ScienceDirect

International Journal of Disaster Risk Reduction

journal homepage: http://www.elsevier.com/locate/ijdrr



Cross-scale interactions in flood risk management: A case study from Rovaniemi, Finland

Aleksi Räsänen [a,b,*]

[a] Department of Geography, Norwegian University of Science and Technology, NO-7491, Trondheim, Norway
[b] Ecosystems and Environment Research Programme, Faculty of Biological and Environmental Sciences, and Helsinki Insitute of Sustainability Science (HELSUS), P.O. Box 65, FI-00014, University of Helsinki, Finland

ARTICLE INFO

Keywords:
Adaptive cycle
Cross-scale interactions
Flood defense
Flood risk management
Panarchy
Structuration

Abstract

Cross-scale interactions affect resilience in a wide array of social systems such as flood risk management, but it has been argued that studies of such interactions remain limited. Based on qualitative interviews, quantitative surveys, and policy document analysis, I employed the panarchy framework in an analysis of temporal changes and cross-scale interactions in flood risk management at the local and regional scale in Rovaniemi, in Finnish Lapland. The results revealed that administrative co-operation in flood preparedness has functioned well in Rovaniemi in recent decades and few changes have been made to it. Nevertheless, flood defense measures have been the subject of a persistent and dynamic conflict, which has been locked in a polarized phase. Among local residents' approaches to flood risk management, there have been few changes in preparedness, although administrative actors have emphasized communication and self-preparedness in recent years. I discuss how the cross-scale mismatches have contributed to hinder the flood risk management, sharpen the conflict over flood defense measures, and keep the local residents' level of preparedness low.

1. Introduction

There has been a shift from technical flood protection towards more integrated flood risk management (FRM), which includes land use planning, structural measures, and measures for enhancing preparedness, response, and recovery [1–3]. In the European Union (EU), this shift is evident in the Floods Directive (Directive 2007/60/EC), which stresses a diversified approach in FRM instead of focusing solely on technical measures [4]. In connection with FRM, there has been a rise in the number of studies linked to flood resilience [2,3,5,6]. Resilience can be defined in many different ways [6–8]; in a commonly used definition, resilience describes a system's ability to withstand and persist change without shifting to an alternative state [7–9]. Therefore, resilience does not imply only resisting changes or shocks such as floods e.g. with technical measures but also absorbing, coping with and adapting to the changes [2,6,10].

In a governance perspective, the concept of resilience-based or adaptive governance has been put on the research and policy agenda [11–16]. One of the focus areas in adaptive governance are interactions across administrative, social and geographic scales. These include for example matching governance arrangements with the focal ecological system (such as river basin), and interaction, coordination, and co-operation across administrative and social scales [11–16]. There can also be scalar mismatches; for example, flood defense measures can be beneficial for a specific community but detrimental for a river basin [17], and conflicts between authorities and local residents are not uncommon [1].

FRM is increasingly conducted with adaptive governance principles, with the EU Floods Directive being a prime example of adopting a multilevel governance and river basin approach [14]. For instance, in Finland, the key actors in FRM are regional authorities, consisting of environmental administration and fire and rescue services [18]. On the national scale, FRM planning is coordinated by the Ministry of Agriculture and Forestry [18] while the EU Floods Directive sets the minimum common framework for Finland and the other EU member countries [4,14]. At the local scale, individuals and municipalities are responsible for flood protection on their own properties [18].

Multiple diagnostic frameworks can be used in FRM and flood resilience studies. On the one hand, frameworks such as policy arrangements approach [19,20] and multipattern approach [21] can be applied especially when analyzing changes in policies, but their usefulness is limited in analyses of processes and interactions on multiple

* Department of Geography, Norwegian University of Science and Technology, NO-7491, Trondheim, Norway
E-mail address: aleksi.rasanen@helsinki.fi.

https://doi.org/10.1016/j.ijdrr.2021.102185
Received 30 September 2020; Received in revised form 18 February 2021; Accepted 9 March 2021
Available online 17 March 2021

scales. On the other hand, there are resilience-based frameworks suitable for analyzing the state of FRM and changes in it [22–28], but scalar conceptualizations are included only in part of them [27,28]. It has been suggested that the adaptive cycle framework and in particular its extension panarchy could be used in analyses of cross-scale interactions across temporal trajectories [15,29,30]. The adaptive cycle framework was originally developed for analyzing ecological system dynamics including phases of growth, conservation, release and reorganization [29]. In panarchy, multiple adaptive cycles, that are located on different scales, are interacting with each other [29]. Although the adaptive cycle framework has been applied in a wide variety of social and ecological systems, it has been criticized because of its restricted sensitivity towards sociopolitical factors, such as power and agency, which should be accounted for when studying management and governance systems, such as FRM [31,32].

Nevertheless, there have been different conceptualizations of the adaptive cycle that apply social science theories [33–35], which could be implemented when examining such systems. These include Giddens's structuration theory [34], actor network theory [35] and institutional theories [33]. However, the adaptive cycle conceptualizations applying social science theories have not been used widely in analyses of cross-scale interactions. In addition, more generally, it has been argued that empirical studies of cross-scale interactions remain limited [11,27,30,36], in particular in relation to resilience against natural hazards such as floods. To address these two gaps, I analyze cross-scale interactions in FRM by utilizing the panarchy framework and Pelling and Manuel-Navarrete's [34] conceptualization of the adaptive cycle which incorporates Giddens's [37] structuration theory.

I draw on the results of mixed methods research including qualitative interviews, quantitative surveys, and an analysis of policy documents to study changes in FRM carried out by administrative actors and local residents across local and regional scales in the city of Rovaniemi, in Finnish Lapland. Rovaniemi is an ideal setting for applying the panarchy framework due to a long-lasting conflict over flood defense measures and recent changes in FRM [38,39]. I ask what kind of temporal changes and cross-scale interactions there have been in the FRM in Rovaniemi and how the interactions have affected FRM conducted by different actors at different scales.

2. Adaptive cycle and panarchy

The adaptive cycle model was originally developed to outline typical dynamics in ecological systems but has since been used in a wide variety of ecological, social, and socio-ecological systems [40]. The cycle consists of two loops, each of which is divided into two phases [29,40]. The growth (r) and conservation (κ) phases together form the relatively slow front loop of the cycle during which the system grows and stabilizes, while the release (Ω) and reorganization (α) phases together form a fast progressing back loop of collapse and restructuration. The adaptive cycle is visualized on two axes: connectedness, i.e. controllability (x-axis) and potential for change (y-axis). Two different traps can be found in the adaptive cycle: the poverty trap and the rigidity trap. The poverty trap is a collapsed system in which the cycle is in the r phase, no capital, resources, or energy exists to progress to the κ phase [29], whereas the rigidity trap can occur during κ phase. Typical examples of a rigidity trap are hierarchical and bureaucratic totalitarian social systems. Although there is high potential for and a high degree of connectedness in the system during the rigidity trap, the system is highly regulated and alternative solutions are suppressed, thereby making the system maladaptive to changes [29].

To analyze governance systems and social structures, Scheffer, Westley, Brock and Holmgren [41] and later Pelling and Manuel-Navarrete [34] combined the adaptive cycle framework with the structuration theory of sociologist Anthony Giddens [37]. At the core of Giddens's structuration theory is the duality of structures: structures both enable and constrain the agency of humans, while also being continuously reproduced through differing forms of human agency. According to Giddens [37], three types of structures can be distinguished, albeit only in analytical terms: structures of signification, domination, and legitimation. Structures of *signification* refer to discourses and symbols, and communication is used to interact with those structures. Structures of *domination* are linked to political and economic institutions, and are restructured by means of power. Structures of *legitimation* are formed by legal institutions that are regulated by norms, and a key way of interacting with those structures is the use of sanctions.

When the duality of agency and structure was integrated into the adaptive cycle by Pelling and Manuel-Navarrete [34], power dynamics evident in governance systems could be taken better into account. In that framing, the original adaptive cycle axes of connectedness and potential were rephrased as social structure/institutional forms (x-axis) and the agency of social capital (y-axis) (Fig. 1a). At the same time, the different phases of the cycle were renamed (Fig. 1a). In the polarized phase (r), the agency of the system is characterized by prominent competition in the interests of different actors and networks, and few social structures facilitate the competition. In other words, divergences in policy options become notable in this phase, and there might be conflicts over, for example, how FRM should be conducted and which kind of flood defense measures should be implemented. The movement to the institutionalized phase (κ) happens through negotiation or imposition, and eventually specific agents aligned with social structures become dominant and suppress the alternatives. In this phase, specific forms of governance become dominant, but these forms may either persist or collapse during a disaster situation [42], such as a flood. The potential of transition to the scattered phase (Ω) is thus dependent on the adaptive and transformative capacity of the system [e.g. [43]. The scattered phase is characterized by diffuse and diverse forms of agency, and there is room for searching for alternative forms of governance, whereas the existing structures have failed and have not been reinforced by the agency of any actor. Hence, there is a lack of formal governance (i.e., there is anarchy) [42], and no one is in charge of FRM, for example. When moving towards the mobilized phase (α), specific value constellations become prominent and compete for dominance. In the mobilized phase, specific interest groups emerge and there are competing structures for governing social systems and risks that those systems are facing. While transiting to the polarized phase, cohesion of actor networks and associated social structures is constructed within the sociopolitical context, and actor groups become fewer while interest discrepancies become more prominent.

When various adaptive cycles at different scales are combined into an interacting overall system, a panarchy is formed [29,40]. In social systems, scales can be individual, community, regional, national, and global [30]. There are various types of interactions between the cycles [11], but two that are usually mentioned and analyzed in the literature are "remember" and "revolt" [29,30,40] (Fig. 1b). In the remember interaction, the κ phase from the larger and slower adaptive cycle initiates a reorganization or mobilized phase (α) in the faster and smaller adaptive cycle. A typical example is the provision of external (e.g. national or international) resources and knowledge structures that may strengthen local FRM after a flood but that can also perpetuate existing social inequalities if power asymmetries within the locality are not fully acknowledged [42]. In the revolt mechanism, a shock in the smaller and faster cycle will launch a similar process and Ω in the larger adaptive cycle, and one example is a sudden natural hazard (such as flood) at the local scale that may renew the organizational structures across scales [42].

3. Materials and methods

3.1. Study area

The City of Rovaniemi (66°30′N, 25°44′E; 80 m a.s.l.) is located at the confluence of two major rivers (Kemijoki and its tributary

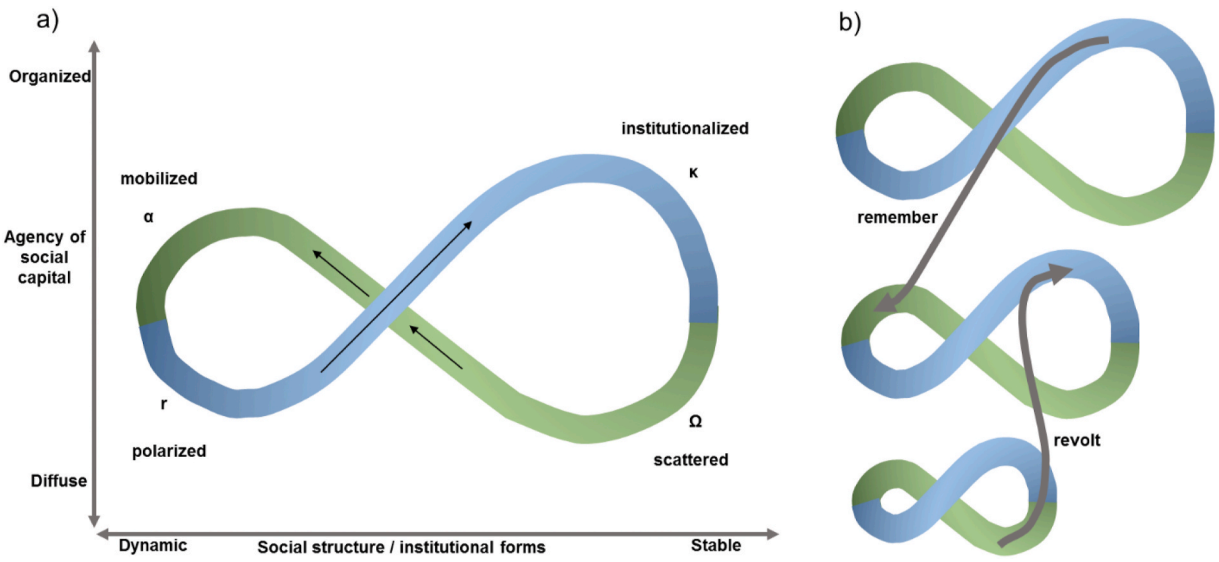


Fig. 1. a) The adaptive cycle consisting of four phases (r, κ, Ω, and α) formed by a front loop (blue) and a back loop (green). The nomenclature follows Pelling and Manuel-Navarrete [34]. b) Multiple adaptive cycles on different scales form a panarchy, with two main feedback mechanisms: remember and revolt [29]. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Ounasjoki). It is the administrative center of Finnish Lapland and has approximately 60,000 inhabitants. It is among the 21 potentially significant flood risk areas in Finland. The River Kemijoki basin is the second largest river basin in Finland, and drains 51,527 km^2. The average flow of the Kemijoki at Rovaniemi downstream of the confluence is 524 m^3s^{-1}, with an average maximum flow of 2463 m^3s^{-1} during spring flooding [44].

In Rovaniemi, the largest flood risks are in the residential suburb of Saarenkylä, which is located partly on a low-lying island between the rivers and partly on the mainland. The distance to city center is 3 km and there are approximately 7500 inhabitants, of whom 800 and 2900 live in the risk zone of 100-year and 1000-year return period floods respectively [44].

In Rovaniemi, all of the floods that have caused significant damage have occurred during spring, when the snow melts, usually with a flood peak in May. The most recent larger floods occurred in 1993 and 2020, with a return period of 20 years and a maximum flow of 4207 and 4147 m^3s^{-1}, respectively. However, in these floods, only a few buildings and roads suffered from damages. The most recent major floods were in 1859 and 1910, and there have been smaller floods that caused damage in 1943, 1966, 1967, 1973, and 1981. In 1859, the entire island was below water, and it has been estimated that the floodwater was 2 m above the 1993 flood with a return period of 250 years [44].

During each spring, regular meetings between FRM actors are held. In these meetings, it is discussed how the flood forecast looks like, how flood risk should be communicated and what kind of preparedness measures (e.g. how dams and floodgates are operated, is there a need to rent flood defense equipment) should be conducted [18]. The main actors in FRM in Rovaniemi include the regional environmental administration, and fire and rescue services. The regional environmental administration coordinates institutional interplay in flood preparedness and is the leading expert in FRM. Fire and rescue services lead the actions during flood response, with the support of the City of Rovaniemi, the volunteer fire brigade, defense forces, and the police. The City, private companies, and local inhabitants are responsible for flood protection on their own properties. The City is also responsible for land use planning. Another key actor in the FRM, is Kemijoki Oy, a company that operates the dams and, together with regional environmental administration, plans the spring discharge [18].

The objectives and measures for FRM are listed in six-year FRM plans, with the plan for 2016–2021 published in 2016 [44]. Measures include risk reduction measures such as land use planning, flood defense measures such as dams and dykes, preparedness measures such as flood forecasts, and actions during and after floods. The preparation of these plans is coordinated at the national scale by the Ministry of Agriculture and Forestry. At the regional scale, the main parties involved in the preparation of the FRM plans are the Regional Council of Lapland and the regional environmental administration [18].

Since the 1950s, several hydropower dams have been constructed on the River Kemijoki, with two major reservoirs and one heavily regulated lake upstream from Rovaniemi. It has been estimated that with the operation of the dams, the water height during flood situations could be reduced by 0.5 m [45].

3.2. *Description of methods*

I used mixed methods [46], including qualitative interviews, quantitative surveys, and policy document analysis to (1) examine the FRM by regional and local administration as well as by local residents, (2) analyze the interactions across geographical scales, and (3) corroborate evidence from multiple sources about changes in the FRM.

To gather information on how FRM had progressed at the local and regional scales, and what kind of changes there had been among the different actors, 18 semi-structured interviews (16 face-to-face, 1 by phone, 1 written response) were conducted in Rovaniemi between June 8, 2017 and July 10, 2017. One of the interviews involved three interviewees and the remaining ones involved only one interviewee. The interviewees comprised regional and local administrative actors (10 interviews), civil society actors (4 interviews), and residents in flood risk areas (4 interviews). Relevant administrative and civil society actors were identified prior the interviews. Local residents were recruited by sending invitations to a local homeowner association and other civil society organizations and using the snowballing method [47]. In total, there were 16 male and 4 female interviewees with an approximate average age of 63 years (not all interviewees revealed their exact age). The interviews were transcribed verbatim, but some filler words were removed during transcription. The material was then analyzed using ATLAS.ti software (ATLAS.ti GmbH, Berlin, Germany) using qualitative content analysis [48]. The data were first read and re-read, then coded, and thereafter general patterns in the codes were collated. The codes were related to how flood defense measures and FRM actions at different time steps were described, what kinds of measures were taken by

different actors, and what kinds of interactions there were between the actors. During the analysis and coding, I concentrated on the descriptions of how FRM had changed over the years and which moments had been considered decisive. Additionally, I examined how the different moments and phases were described by the interviewees.

To assess whether there had been changes in the residents' opinions on flood risk areas with regard to both FRM and actions regarding FRM, data from two household surveys carried out in the suburb of Saarenkylä in Rovaniemi were analyzed. The first survey focused on flood risk communication and was carried out during July 2009. Invitations together with survey questionnaires were posted to 1678 households. Some of the results of the survey have been reported earlier [49,50]. The second survey was carried out in November 2017 and concentrated on FRM and community resilience. In total, 1220 invitations were posted, and the invitation letter included a link to an online survey. In 2009, 325 responses were received (response rate 19.5%), and in 2017, 104 responses were received (response rate 8.5%). In the 2009 survey, there were 163 female and 158 male respondents, with average age of approximately 54 years (the respondents chose from six age groups when responding). In the 2017 survey, 31 women and 72 men responded to the survey, and their average age was 57 years. Some of the questions used in the 2009 survey were replicated in the 2017 survey. The themes of the questions included flood awareness, preparedness and worries, opinions about FRM measures and actors, and the use of flood-related information. The differences in the survey answers were compared by using non-parametric Mann-Whitney U-tests.

To supplement the information gained from the interviews and to gather information about changes in the FRM at the administrative scale, I analyzed key policy documents. The documents comprised the FRM plan for the Kemijoki basin area for the years 2016–2021 [44], its appendices, written feedback from authorities, civil society organizations and individuals, responses to the feedback from the FRM working group, minutes of the working group meetings, and an earlier vision statement relating to FRM and the River Kemijoki development [51]. Moreover, I reviewed other material, including proposal for the FRM plan for the years 2022–2027 and the minutes of the working group meetings, Rovaniemi municipal government meetings and Board of the Regional Council of Lapland meetings, as well as materials related to regional land use plan [52].

4. Results

Three different processes could be delineated in the FRM in Rovaniemi. Two of the processes were related to formal FRM conducted by

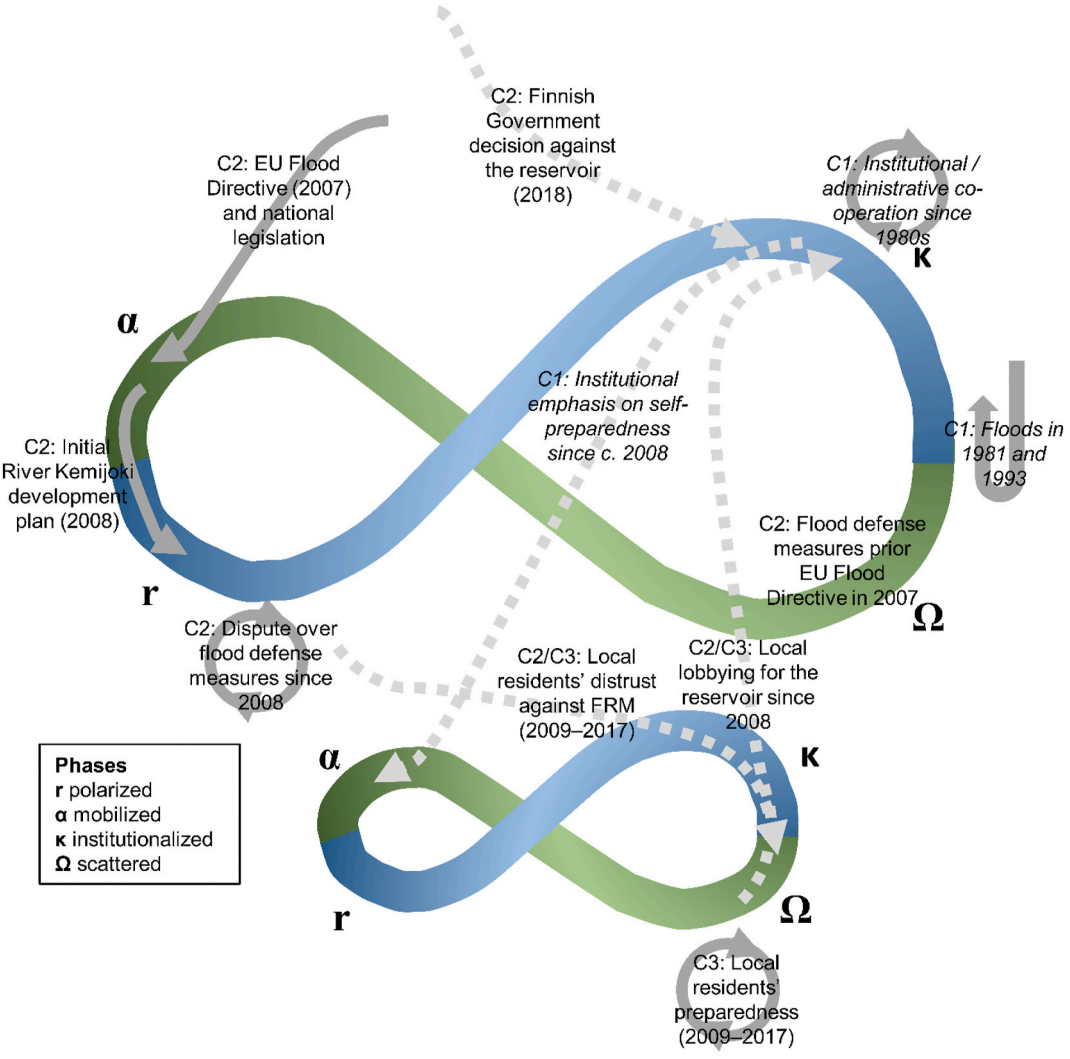


Fig. 2. The panarchy of flood risk management in Rovaniemi. Adaptive cycles at two different scales exist: a larger administrative cycle and smaller cycle of local residents' preparedness (C3; Section 4.3). At the administrative scale, two different adaptive cycle processes exist: administrative co-operation in flood preparedness (C1, shown in italics; Section 4.1) and work on flood defense measures (C2, shown in regular font; Section 4.2). Cross-scale mechanisms that have not progressed are shown with dashed arrows.

authorities at regional and local scale, while the third process was related to FRM carried out by residents in the flood risk areas.

4.1. Administrative co-operation in flood preparedness and response

The floods in 1981 and 1993 were experienced as shocks, which prompted more institutionalized flood preparedness. Hence, there was progress in flood preparedness measures during the 1980s and especially during and after the 1993 flood. The 1993 flood could be described as not big enough to cause any drastic change in the adaptive cycle: the institutional phase persisted although some reorganization was done before, during, and after the flood (Fig. 2). Most importantly, the 1993 flood resulted in the initiation of a tradition of annual flood meetings between the different administrative FRM actors, including the regional environmental administration, fire and rescue services, the City of Rovaniemi, and the dam operating company, Kemijoki Oy.

During the interviews, all of the actors said that the administrative interplay had worked well in recent decades and there had not been any tension in their everyday co-operation. They also informed that each spring preparations were made to protect the city and its residents against possible floods. The 1993 flood also made other kind of changes in everyday administrative-level flood preparedness. Some actors described how learning had happened before, during and after the 1993 flood, examples being how the sewage treatment system works during a high flood and where the water needs to be pumped and stopped with each water level so that damages are prevented.

In 2005, a major flood hit the village of Kittilä, 80 km upstream from Rovaniemi on the Ounasjoki River. As Kittilä is located in the same Kemi River basin as Rovaniemi, many of the same FRM actors were involved. Although the flood caused major damage in Kittilä, with an overall cost of approximately EUR 6 million, it hardly affected the FRM at the regional scale and therefore did not have any effects on the FRM (or adaptive cycle) in Rovaniemi. Some interviewees even described how Rovaniemi would have been better prepared than Kittilä, e.g. due to floodgates, pumps, and knowledge of the sewage treatment systems, and that the extent of the damage would have been smaller in Rovaniemi, thus highlighting the institutionalized and well-managed flood preparedness and response in Rovaniemi.

Since the major flood in Kittilä in 2005, the institutionalized phase in administrative flood preparedness has continued and there have been only minor changes in how the work is carried out. The interviewees highlighted that the changes had been positive and that the level of administrative preparedness was higher than it had been earlier (e.g., 20 years earlier). Some interviewees described that the discussion about floods for instance in the form of FRM plans has helped in concentrating on flood preparedness.

Some interviewees argued that more effort had been put into flood risk communications than previously: Rovaniemi had been chosen as a pilot area for flood risk communication in the period 2008–2010, and a plan had been made for improvements in flood communications. Some interviewees maintained that the flood-risk communication project had had little tangible impact, although in general there had been progress in flood risk communication over the years.

Nowadays, the role of local inhabitants in self-preparedness is emphasized more in flood risk communications (Fig. 2). For example, the state has not covered flood damage costs since 2014, and every household is expected to take responsibility for ensuring that it has adequate insurance cover. Other changes in the FRM include deepened institutional interplay, with one example being the establishment of National Flood Center in 2014. Some interviewees also highlighted that one improvement is more realistic flood forecasts and maps, as there has been technical development in the models.

With regard to the annual administrative co-operation in flood preparedness, it is evident that FRM is locked in the institutional phase, as there have been few changes in recent decades and as the work has been highly organized (Fig. 2). However, there have been more changes with regard to the desired flood defense measures, and I discuss these in more detail in Section 4.2.

4.2. The adaptive cycle in flood defense measures

The launch of the EU Floods Directive in 2007 (Directive 2007/60/EC), followed by the passing of the Finnish Flood Risk Management Act in 2010 (No. 620/2010), initiated a move towards the institutional phase of the adaptive cycle at higher administrative scales. The change also functioned as a remember mechanism, which initiated a mobilized phase in the FRM for Rovaniemi and Lapland (Fig. 2). As a result, floods in Central Europe acted both as a shock at a lower scale as well as a revolt mechanism, leading to more institutionalized FRM in the EU. This, in turn, mobilized FRM at lower scales.

In Rovaniemi, the new flood legislation awakened the local and regional actors, and initiated a more systematic approach in the search for optimal flood defense measures. The flood defense measures were not systematically planned prior the EU Floods Directive of 2007, and the work so far could be described as scattered (Ω phase), although annual administrative co-operation in flood preparedness had been institutionalized as detailed in Section 4.1 (Fig. 2).

In September 2007, the Rovaniemi municipal government took the initiative to implement an initial River Kemijoki development plan, concentrating on FRM and published in 2008 (Fig. 2). Some interviewees described that all possible flood defense measures were discussed during the work and the majority of the actors made a decision that the most efficient flood defense measure would be a new reservoir that could reduce flood heights by 1.5 m and would be constructed upstream from Rovaniemi, at an established protected Natura 2000 site. Not all actors agreed and therefore the discussion was locked into a polarized phase. This phase has since continued, although there have been other changes in the FRM, as discussed in Section 4.1 (Fig. 2).

The reservoir plan had first been launched in the 1960s, and later ruled out by the Supreme Administrative Court of Finland in 2002. However, following the court's decision, the primary purpose of the reservoir was changed from electricity production to flood defense, and there were some adjustments in the plan, related for example to the size of the reservoir. However, the proponents and opponents of the reservoir plan remained the same. The City of Rovaniemi, the Regional Council of Lapland, and many inhabitants in Rovaniemi have been in favor of the reservoir, while regional environmental administration, environmental civil society organizations, and many upstream dwellers have been against it. Interviewees from both sides argued that the conflict was merely about principles and not about facts, since the conflict had persisted for decades.

The development of the official FRM plan for 2016–2021 [44] was carried out between 2012 and 2015. Many interviewees described how the working group was organized such that the proponents of the reservoir formed the majority. The detailed work on the FRM plan was described as confrontational, as the members of the group had diverging opinions on flood defense measures. The prioritized measure was the reservoir, but some of the actors, including the regional environmental administration, did not agree with the decision. The flood dykes in Rovaniemi were chosen to be a supplementary measure to ensure that the FRM would be approved by the Ministry of Agriculture and Forestry. The decision to build dykes was opposed by the City of Rovaniemi, and nothing further happened to the implementation of that measure. The target in the FRM plan was set so that 250-year return period floods could be managed, although in other FRM plans in Finland the target was set to 100-year return period floods. The higher target was chosen so that the construction of the reservoir could be legitimized, as major damage caused by 100-year return period floods could be prevented by using other measures too.

The Ministry of Agriculture and Forestry did not fully approve the plan, and left the decision about the reservoir and 250-year target open, as the decision would be made simultaneously with the decision about

the regional land use plan. The regional land use plan was prepared at the same time as the FRM plan and was finalized in 2016. Since the plan included the zoning of the reservoir into a Natura 2000 area, a Natura 2000 derogation decision had to be approved by the Finnish Government.

In January 2018, the national government decided against the derogation (Fig. 2), but the City of Rovaniemi and local residential associations appealed the decision to the Supreme Administrative Court of Finland. In April 2019, the court enforced the government's decision, meaning that the planned reservoir will not be built. The preparation of a FRM plan for the years 2022–2027 started in 2019, and in the proposed plan, flood dykes were included but the reservoir was not. Due to the seemingly well-functioning co-operation about flood defense measures during the 2022–2027 FRM plan development, it is reasonable to suggest that adaptive cycle in flood defense measures is moving from the polarized phase to the institutionalized phase, and that some of the flood defense measures will be implemented in the near future (Fig. 2).

4.3. Low level of preparedness among local residents

The local residents in the suburb of Saarenkylä in Rovaniemi have taken few preparedness measures by themselves, and there have been few changes in their preparedness or their degree of concern since 2009 (Table 1). In 2017, only 25% of the survey respondents reported that they were insured against floods, while 32% reported that they were not insured. The remaining 43% were uncertain about their insurance status. Nevertheless, from the survey results, there were indications that flood awareness in Saarenkylä had increased and that flood risk maps and flood forecasts were used more widely in 2017 than in 2009 (Table 1). However, the level of opposition against flood dykes had increased during the eight years between the two surveys. Furthermore, there was less appreciation of the FRM work undertaken by regional environmental administration, which had been a keen supporter of the dykes and against the reservoir. There were fewer changes in the appreciation of other FRM actors and other flood preparedness measures (Table 1). Overall, the respondents considered that the different actors had been unsuccessful in handling flood matters. The most important precautionary measures were thought to be flood risk communication, the regulation of watersheds (which could include existing regulations and new dams and reservoirs), and zoning. When respondents in the 2017 survey were asked about the specific flood defense measures, 73% of them thought that the reservoir should be built and 41% though that dykes should be built, while 17% were opposed to the reservoir and 51% were opposed to the dykes.

Two pieces of information could be summarized from the surveys and the interviews held with local inhabitants. First, the levels of opposition against flood dykes and distrust of regional environmental administration were high and had increased during the eight years between the surveys, suggesting that the conflict over flood defense measures had also had an impact on the local residents' opinions of FRM (Fig. 2). A polarized situation between the local residents was evident too, as some interviewees and respondents expressed that they were strongly against the reservoir in their interviews and their open answers in the survey. Second, the efforts made in flood risk communication had increased general awareness of floods but had had little effect on flood preparedness.

With regard to the adaptive cycle, it can be reasoned that FRM is locked in a scattered phase (Fig. 2) due to the low level of preparedness; in other words, the agency of local residents is not organized and the situation has stayed stable. Despite the institutional phase in administrative FRM and efforts to emphasize self-preparedness, there are few indications of a remember mechanism between the two scales. Lastly, in Saarenkylä, many residents and members of the local homeowners association have been strong proponents of the reservoir and have actively lobbied for it. This can be seen as a "revolt" attempt to renew FRM at the administrative scale (Fig. 2).

Table 1
Average values of the local residents' answers to different survey questions in 2009 and 2017, and P-values of Mann-Whitney *U* test. The questions were 4-point Likert-scale question, where 4 was "highly probable"/"greatly worried"/"well"/"important"/"well prepared"/"agree." In the two last questions, a 5-point scale was used with options ranging from "Often" to "I haven't visited."

Question	2009	2017	P-value
How probable you think that a 50-year flood will occur in Saarenkylä during your lifetime?	2.70	2.58	0.323
How probable you think that a 250-year flood will occur in Saarenkylä during your lifetime?	2.20	2.10	0.348
How worried you are about the floods of Kemijoki and Ounasjoki concerning your home?	2.62	2.43	0.072
How worried you are about the floods of Kemijoki and Ounasjoki concerning Saarenkylä?	2.88	2.77	0.254
How worried you are about the floods of Kemijoki and Ounasjoki concerning Rovaniemi?	2.60	2.48	0.222
How have the following matters been taken care of in Saarenkylä?			
General awareness regarding floods	2.30	2.64	0.001
Implemented flood preparedness measures	1.85	1.81	0.388
Flood prevention plans	2.09	2.09	0.923
Resident co-operation in flood prevention	1.59	1.58	0.547
Resident co-operation during flood	1.69	1.60	0.28
How do you feel the following parties have handled flood matters?[a]			
The city of Rovaniemi	2.16	1.93	0.514
Voluntary rescue organizations	2.48	2.24	0.582
Rescue workers	2.67	2.42	0.309
Regional environmental administration	2.47	2.01	0.003
Kemijoki Oy	2.54	2.23	0.142
How important do you consider the following precautionary measures are?			
My own precautionary measures	3.07	2.86	0.027
Regulation of watersheds	3.67	3.63	0.754
Floodbanks and other protective measures	3.49	2.96	<0.001
Zoning	3.54	3.38	0.035
Pre-flood communication	3.66	3.65	0.897
Flood warnings	3.70	3.59	0.46
How do you feel about your current level of preparedness for floods?	1.98	2.13	0.222
How do you feel about your neighborhood's level of preparedness for floods?	1.96	1.97	0.91
If precautionary measures were taken in Saarenkylä, what would you think about the following statements?			
They would prevent major flood losses.	3.22	2.86	0.002
They would create a sense of security.	3.34	3.02	0.002
I would allow a floodbank/dyke to be built on my property.	2.52	2.10	0.003
I would be willing to participate in the construction costs of the floodbank/dyke.	1.83	1.70	0.173
I would be willing to give up a view for a floodbank/dyke.	2.56	2.11	0.001
I would be willing to give up ecological values for precautionary measures.	2.86	2.67	0.225
Have you visited the hydrological forecasts page on the website of Finland's environmental administration (www.environment.fi/waterforecast)?	1.46	2.17	<0.001
Have you visited the flood mapping page on the website of Finland's environmental administration (www.ymparisto.fi/tulvakartat)?	1.40	2.21	<0.001

[a] In 2009, the question was "How do you feel the following parties have handled flood matters before floods?"

5. Discussion

I have delineated two adaptive cycles at the local or regional administrative scale and a third adaptive cycle concentrated on the flood preparedness of local residents (Fig. 2). The three conceptualized cycles are differently dynamic. While the cycles in administrative flood preparedness and local residents' preparedness have stayed relatively stable, there have been more changes in the cycle in flood defense measures. Furthermore, there have been cross-scale interactions and mismatches e.g. in the form of (supra)national legislation, communicative emphasis on self-preparedness, and residents' lobbying. Next, I will discuss the three cycles, the cross-scale interactions and insights in relation to resilience in more detail.

5.1. Adaptive cycles at the local or regional administrative scale

The two parallel adaptive cycles at the local or regional administrative scale show the vagueness of single-scale adaptive cycles. Although the administrative actors in both adaptive cycles are mostly the same, the relationships between actors are strikingly dissimilar. Administrative interplay in flood preparedness is cooperative, but the actors have had strong and differing opinions on the needed flood defense measures. The elusiveness of adaptive cycles has been discussed before in a partly similar manner. Moen and Keskitalo [53] have shown how there can be several panarchies within a system, while Rawluk and Curtis [54] have discussed how the perception of the adaptive cycle can differ between stakeholders, and Maclean, Ross, Cuthill and Witt [31] have argued that the key properties of social systems do not necessarily fit into specific scales of the panarchy but they may be divided across the scales.

When looking at the both administrative adaptive cycles in more detail, the FRM process have been locked: co-operation on flood preparedness and response has been locked in the institutionalized phase, and implementation of flood defense measures has been locked in the polarized phase (Fig. 2). Both phases are linked to traps in the original formulation of the adaptive cycle: in the institutionalized phase, there is a risk of the rigidity trap, while in the polarized phase, there is a risk of the poverty trap. It seems that neither of these traps exists in Rovaniemi.

First, in the case of FRM co-operation, it can be suggested that there is no trap at all, as the situation is positive and FRM actors appeared to be satisfied with the administrative co-operation in flood preparedness. Still, this view is challenged by the fact that none of the main FRM actors is well appreciated by the local residents, and appreciation has not improved during the last decade (Table 1). This may imply that, in the opinion of local residents, their views have been suppressed in the FRM decision-making.

Second, although the everyday co-operation in flood preparedness functions well, the implementation of flood defense measures has contradictorily been halted due to conflicts, not due to lack of resources or possibilities to continue. Hence, the situation could be conceptualized either as frozen in a polarized phase [41] or as a discrepancy trap: there could be possibilities to implement specific measures, but discrepancies in policy options have made progress almost impossible.

5.2. Social structures and cross-scale interactions

With regard to the different structures formulated by Giddens [37], some insights can be suggested in relation to the adaptive cycle and panarchy framework and cross-scale interactions in FRM. In relation to the flood defense measures, the proponents of the reservoir succeeded in constructing a discursive hegemony (i.e., hegemony in the structures of signification) at the regional scale, which possibly also strengthened local public opinion in favor of the reservoir and against the dykes. This was seen especially in the fact that opinion against dykes and distrust of regional environmental administration had statistically significantly strengthened (Table 1).

However, in order to proceed from a polarized phase to an institutionalized phase, some social structures should dominate over others, and often dominance at several scales and in several forms of social structures is needed [34]. When looking at the national scale of different social structures, the picture is different from the regional scale. There seems to be a stronger focus on nature conservation, which is shown e.g. in the decision against the reservoir by the Finnish Government (structure of domination) dependent on the popular vote in parliamentary elections. Also the laws relating to nature conservation and environmental protection (structure of legitimation) have been strengthened in Finland over the years, making the development of areas with high conservation value more difficult than before [38]. This was reflected when Supreme Administrative Court of enforced the government's decision. In this perspective, the decision by the government and later by the court was expected. The reservoir was planned to be constructed at a protected Natura 2000 site and the reservoir would have been detrimental in an ecological river basin perspective. Even though it would have reduced flood risks in Rovaniemi, it would have altered the river flow patterns and deteriorated water quality [44]. Indeed, while many local actors supported the reservoir due to safety against floods and economic development, others opposed it due to nature conservation. Similar arguments against flood defense measures have been visible also in other FRM conflicts [1].

Furthermore, Finnish national FRM legislation has emphasized a diversified approach to managing floods instead of sole structural measures [10]. Despite this, the FRM plan for the years 2016–2021 [44] relied heavily on one structural measure (the reservoir) even though other FRM measures were also included in the plan. The diversified FRM approach with multiple different measures was more visible in the 2022–2027 plan proposal, reflecting the shift from flood defense to FRM. Therefore, national scale structures of legitimation initiated changes in regional scale structures but there was a time lag in the implementation.

The mismatch (or 'structural contradiction' in Giddens's [37] vocabulary) between local public opinion and national public opinion, and a related mismatch in other social structures may lead to new difficulties in implementing policies and measures, such as the dykes, and thus may create new types of discrepancy traps. A probable development is that dykes will be constructed, the adaptive cycle in flood defense measures will move into the institutionalized phase, the two adaptive cycles on the local or regional administrative scale will merge and administrative co-operation will function well also in terms of flood defense measures. However, administrative will to construct the dykes is contradicted by local residential opinion against the flood dykes, as according to many, dykes will change the townscape and water would permeate through soil to residential areas even if there were dykes. Therefore, it may be that the FRM will be hampered by cross-scale mismatch between administrative actors and local residents. In other words, there is a risk for a rigidity trap and a conflict "below the surface". There might also be an enduring conflict between different administrative actors because also some administrative actors have been heavily opposing the dykes. This dispute may potentially hamper the administrative co-operation in flood preparedness and response that has functioned well (Fig. 2).

The above-discussed cross-scale linkages highlight that the remember and revolt mechanisms are only some examples of the many possible interactions across scales. This is backed by the research by Bui, Jones, Weaver and Le [55], who emphasized the complexity of interactions and the finding that remember and revolt can both be initiated either top-down or bottom-up. However, the remember and revolt mechanisms were applicable during the analysis of some of the cross-scale interactions. As pointed out in Section 4.2, there was an evident remember mechanism between international and/or national and regional scales in the form of FRM legislation, which sparked FRM planning and discussion about flood defense measures at the regional scale from 2007 onwards (Fig. 2). Nevertheless, similar to the analysis by Bui, Jones, Weaver and Le [55], this mechanism was more linked to regulating than remembering, due to the strong role of legislation. In turn, the active lobbying for the reservoir by some of the local residents and the homeowners association can be seen as a revolt attempt (Fig. 2) but it failed due to cross-scale mismatches as discussed above. Similarly, even the lack of self-preparedness can be seen as an unintentional revolt attempt because it had mobilized the local and regional administration to make changes in the FRM and communication so that either the residents could be protected or the residents themselves could make changes in their preparedness.

5.3. Cross-scale interactions and resilience

Some observations can be made when evaluating resilience against floods at the local and regional scale. First, administrative co-operation in flood preparedness has worked effectively, been stable and developed

slightly over the years, which may indicate that there could be high resilience against floods. However, no major floods have affected Rovaniemi during the past century, thus emphasizing that the high level of administrative preparedness is merely speculation. Although the administrative co-operation functioned seemingly well during the larger flood in 2020, the flood was still relatively minor in historical perspective and in relation to modeled possible major floods. Therefore, it cannot be judged, what would have happened when preparing and responding to a major flood. Besides, as discussed in Section 5.2, there are cross-scale mismatches in FRM relating to flood defense measures, which are eroding the overall FRM [e.g. 11, 12]. Hence, there is reason to question whether the levels of resilience and preparedness will be high if a major flood occurs.

Second, the well-functioning administrative co-operation is contrasted by the low level of preparedness among local residents which is evidenced by the adaptive cycle locked in scattered phase (Fig. 2). Previously, it has been suggested that communication and the versatility in the provision of information could help to increase the level of preparedness also in situations in which there are higher levels of awareness than preparedness [49,56,57], such as in Rovaniemi. However, evidence from the two surveys does not reinforce such a claim and instead suggest that there is a cross-scale mismatch between administrative governance and residents' actions. Despite the fact that there has been a pilot study of flood risk communication [49,50], as well as continued effort to enhance communication, there have been no statistically significant changes in preparedness measures, although awareness had improved in in the study area (Table 1). Instead, the results of the 2017 survey revealed that own precautionary measures were seen as slightly less important than in 2009, and this change was statistically significant. The limited changes in flood preparedness can be related to general mistrust against FRM conducted by administrative actors, especially in terms of flood defense measures (Fig. 2), and lack of recent major floods.

The overall situation seems to suggest that flood resilience in Rovaniemi could be strengthened by acknowledging cross-scale dynamics [11,30], for instance by better coordination of FRM planning between national, regional and local scales. Previous research has emphasized the need for simultaneous implementation of bottom-up (e.g. local initiatives for FRM) and top-down (e.g. legislation related to FRM) processes, as well as acknowledgement of cross-scale interactions as a prerequisite to generate solutions that are beneficial for FRM [58, 59]. In Rovaniemi, local and regional actors were trying to plan a reservoir with detrimental impacts for the river basin, and they were not willing to understand the impossibility of the reservoir in ecological and legal perspective, including national and supranational legislation. Thus, in the future FRM in Rovaniemi, communication and coordination between the scales and actors should function better. This could include clearer communication between local residents and authorities about what kind of solutions can be implemented in FRM. Furthermore, FRM with greater participation of various stakeholders could decrease disputes [1,5,60]. This could include, for example, participatory and communicative workshops for different actors, including local residents [61]. In addition to better communication and participatory approaches, it seems that transformations in values and beliefs of local and regional actors, including local residents and some authorities, is required to achieve such FRM in Rovaniemi that is both supported by the residents and sustainable in river basin perspective [59].

6. Conclusion

I analyzed temporal changes and cross-scale interactions in FRM in Rovaniemi, Finland by utilizing the panarchy framework mixed methods. According to the results, few changes have occurred in the well-functioning administrative co-operation in flood preparedness and response, and in local residents' preparedness that has remained low despite authorities' increased emphasis on self-preparedness. There have been more changes in a conflict related to flood defense measures that was initiated when the defense measures were started to be planned after national and EU-level flood legislation in 2007. Some local and regional authorities and local residents actively lobbied for a reservoir, which was selected for further planning, but later, national government and court ruled it out due to detrimental ecological and river basin impacts. In its part, the conflict has kept the local residents' preparedness low and increased their mistrust against authorities. The results show how (supra)national legislation has steered FRM at the local and regional scale but at the same time facilitated a conflict and opposition against authorities. The case study highlights the need to consider cross-scale interactions in FRM and for better interplay between different actors to achieve sustainable and legitimate FRM.

Declaration of competing interest

The authors declare no conflict of interest.

Acknowledgements

This paper is a deliverable of the Nordic Center of Excellence for Resilience and Societal Security (NORDRESS), which is funded by the Nordic Societal Security Programme. I am grateful to Haakon Lein, Sirkku Juhola, and Gunhild Setten for their comments when planning the research. The household survey in 2009 was carried out by the Finnish Environment Institute, and I thank Juha Aaltonen and Pia Rotko for kindly providing the data.

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