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Rapid Characterisation of Stakeholder Networks in Three Catchments Reveals Contrasting Land-Water Management Issues

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Abstract: Catchments are socio-ecological systems integrating land, water and people with diverse roles and views. Characterising stakeholder networks and their levels of influence and interaction within catchments can help deliver more effective land and water management. In this study, we combined stakeholder analysis and social network methods to provide a novel stakeholder-mapping tool capable of identifying interactions among the land and water management communities across three contrasting study catchments. The overarching aim was to characterise the influence of different stakeholders involved in catchment management based on the perceptions of participants from four key stakeholder groups (Environmental Regulators, Water Industry Practitioners, the Farm Advisor Community, and Academics). A total of 43 participants identified 28 types of specific catchment management stakeholder groups with either core or peripheral importance to our three case study catchments. Participants contributed 490 individual scores relating to the perceived influence of these different stakeholder groups and categorised whether this influence was positive, negative or neutral for the management of catchment resources. Local Government, Farmers and Environmental Regulators were perceived to have the greatest level of influence. Social network analysis further determined which stakeholders were most commonly connected in all of the study catchments and hence formed the core of stakeholder networks in each catchment. Comparing outputs from the analysis of three contrasting river catchments, as well as between participants from four key stakeholder groups allowed identification of which stakeholders were more central to the catchment management networks. Such analyses could help facilitate effective communication within land and water management stakeholder networks by targeting highly connected opinion leaders or promoting peer learning via distinct catchment subgroups.

Keywords: socio-ecological systems; land and water management; participatory stakeholder engagement; social network analysis

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1. Introduction

Global demographic, economic and climatological changes are increasing demand for natural resources, which in turn impacts on ecosystems' ability to function sustainably and remain resilient to shocks and disasters [1]. Society is faced with the complex task of balancing the often opposing demands for water, food and energy security of a growing global population while at the same time protecting biodiversity and mitigating impacts from climate change [2]. Aquatic, riparian and coastal ecosystems host some of the most diverse biodiversity and supply critical ecosystem services for human health and well-being [3], but they are increasingly threatened by habitat alteration, water pollution, overfishing, exotic species introduction, fragmentation and flow regulation [4]. Water resources are also highly vulnerable to climate change and by 2050 around 50% of the world's population could be living in countries experiencing water stress [5]. Due to hydrological connectivity, river catchments often integrate multiple pressures [6], which makes them less resilient to change and reinforces the concept of the catchment being the most appropriate scale for holistic land and water management [7]. Catchments integrate land, water and people with diverse roles, views and function as socio-ecological systems; thus, effective catchment management must recognise the importance of stakeholder networks and their influence and interactions in order to ensure long term sustainability that benefits people and catchments.

Managing the breadth of water use and users within a catchment is a complex task, which often necessitates a role for social, political, and economic institutions of a country [8] and is further complicated for trans-boundary river basins. Thus, fragmentation of stakeholder networks can arise from shifts in local jurisdiction and in turn lead to less integrated decision-making despite high levels of awareness of shared water management issues across the catchment [9]. Different stakeholder typologies (e.g., regulators, water industry practitioners, landowners) within a catchment may also express varying preferences on water management decision-making, depending on their knowledge, values and connections to the landscape [10]. Hence, there is a growing call for more stakeholder-focused approaches to water resource management to balance the varied and sometimes opposing demands on water resources towards more adaptive and integrated decision-making [11,12].

Stakeholder analysis seeks to identify stakeholders (individuals, groups, or organisations) who can affect or be affected by decision-making in a system. It can analyse differences among stakeholders, such as their involvement in the decision-making process, as well as investigate relationships among them [13]. Stakeholder analysis is also used to understand the diverse range of potentially conflicting stakeholder interests [14,15]. In social network analysis, actors in a social network are depicted as nodes and links are established to other actors, allowing the analysis of the relations between nodes to identify the most influential actors (in contrast to those at the periphery of the network). Both stakeholder analysis and social network analysis have been demonstrated as useful tools in natural resource management [16]. In terms of water management, stakeholder and social network analysis have been used to analyse the structure of water governance networks [17], identify their spatial scale mismatches [18] and highlight opportunities for cooperation within them [19], or to analyse catchment stakeholders' interests and spheres of influence [20]. Stakeholder network analysis has also been used to find ways to improve fishery commission management [21], mitigate impacts of climate change on water management [22], and identify the social stability risk of large hydro engineering projects [23]. One of the main drawbacks of common stakeholder mapping techniques is that they tend to identify the 'usual suspects' and there is a danger that this may lead to the under-representation of peripheral stakeholders [24]. Engaging stakeholders involved in water management for social network analysis and stakeholder analysis offers potential to facilitate effective knowledge exchange among stakeholders in a network, capitalising on important expertise and highlighting differences in how stakeholders perceive and value other groups [25]. This presents a gap in the research where novel techniques may be developed for ameliorating conflicts, fairly representing diverse interests and preventing further marginalisation of under-represented groups.

Here, we combine stakeholder analysis and social network methodologies to elicit perceptions from four key stakeholder typologies involved in water management across three diverse study catchments. Using this approach, the overarching aim of this study was to characterise how influential different stakeholders were perceived to be with respect to catchment management. We used the data from participants' self-reported social networks to provide further insight into the co-occurrence of stakeholders (i.e., how often groups were named together by one participant), allowing core and periphery analysis of which groups had the greatest co-occurrence. This approach represents a novel and rapid methodology for characterising stakeholder networks at the catchment scale and could be used as a complementary methodology for enhancing other stakeholder mapping techniques that are commonly topic-driven rather than catchment-centric.

Each actor (or node) in a network can perceive a network structure subjectively, or as a cognitive social structure [26]. Such a network can also be constructed objectively with empirical data to compare with subjective perceptions of the network; however, cognitive social structures are data in their own right, giving insights into insider actors' views.

Therefore, the objectives were to: (1) Assess whether participants representing four key stakeholder groups perceive the importance of stakeholder influence in line with the existing governance structure of Scottish catchment management; (2) Determine which stakeholders are more central to a catchment management network and which are perceived as peripheral; (3) Quantify which stakeholders are perceived to have the largest impact, as well as the most positive or negative influence on the water environment; (4) Compare self-reported social networks between the four participant groups and the three contrasting river catchments.

2. Materials and Methods

2.1. The Case Study Catchments

Three catchments from across Scotland (UK) were selected on account of their diverse and contrasting geomorphologies, land cover types, stakeholder communities, and land and water management pressures (Figure 1). The River Spey is in the north-east, the South Esk in the east, and the River Ayr catchment in the south-west of Scotland. The catchments vary in size from ~600 km^2 (South Esk and Ayr) to just under 3000 km^2 (Spey). The River Spey and South Esk catchments are dominated by moors and heathland, followed by sparsely vegetated land in the mountainous areas of the Spey (23%) and arable land in the Esk catchment (31%). Dairy production is a key local industry in the Ayr catchment with pasture accounting for 39% of the land cover. In general, the uplands of the three catchments are dominated by rough grazing, commercial forestry, and sporting estates (e.g., shooting and angling), while the lowlands accommodate arable land and improved grazing.

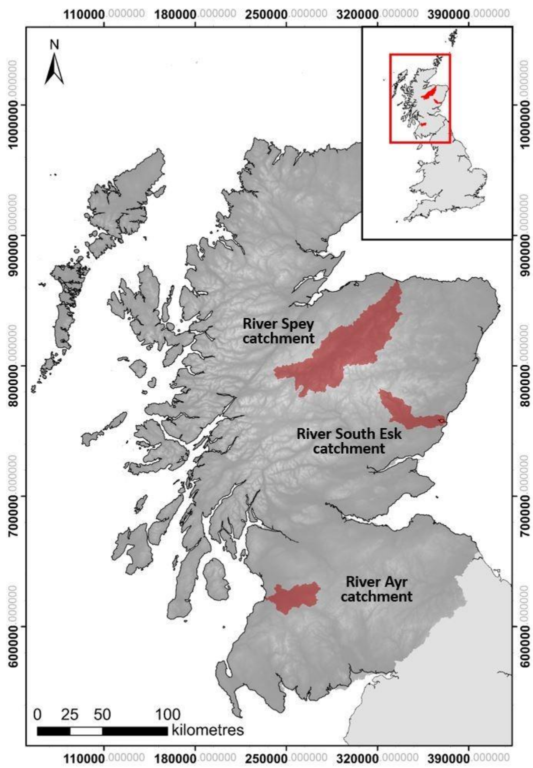


Figure 1. Location of the three study catchments in Scotland, UK.

The Ayr catchment is characterised as an agricultural (and particularly a dairy) catchment, while the Spey is more of a recreation-focused catchment partly within a national park, whilst the Esk has a mixture of farming (particularly arable), forestry and recreational land uses. Tourism and angling represent important local industries, with whisky production also being significant, particularly in the Spey. The river Spey and South Esk are important sites for conservation NGOs and the Scottish nature conservation agency, as both are designated a Special Area of Conservation for Atlantic salmon, freshwater pearl mussel, and otter, and the Spey forms part of the EU Natura 2000 network [27].

There are competing pressures on water resources in all three catchments due to the, often competing, demands of different stakeholders in the catchments. An estimated 20% of the mean annual water flow of the Spey River is diverted to large hydropower schemes in nearby catchments. Competing demands of stakeholders on the remaining water resources in the catchment come from local hydropower plants, increasing domestic water demands and irrigation needs, as well as a growing food and drink manufacturing industry [28]. In the South Esk catchment both ground and surface waters are at risk of nitrate leaching from soils. It has, therefore, been designated as a nitrate-vulnerable zone, and hence farmers must adhere to additional management restrictions to reduce nitrate leaching in the catchment. Point source pollution from wastewater effluent discharge, diffuse pollution from agriculture, and water abstraction for arable farming are the major pressures on this catchment system [29]. Livestock rearing, tourism, and wild salmon angling are important local economies, which impose contrasting demands on the catchment. The Scottish environmental regulator has declared the catchment a "priority catchment for diffuse pollution" and has worked with local farmers to avoid breaches of local regulation to protect human health at the designated public bathing water beaches on the Ayrshire coast.

2.2. Sample Selection and Design of Engagement Exercise

In each of the three study catchments, three to five individuals were recruited from four key stakeholder groups: environmental regulator staff (n = 12), water industry staff (n = 9), catchment scientists (n = 11) and farming representatives (n = 11). A total of 43 stakeholders carried out the engagement exercise in 2017 and contributed their local knowledge on catchments within which they worked: 15 contributed to the River Spey catchment analysis, 13 to the South Esk and 15 to the Ayr catchment. The four stakeholder groups were chosen via a preliminary desk-based exercise ranking their interest in and influence on land and water management decisions. Criteria for selection of participants were: (i) Experience in their respective catchment, e.g., an individual was required to have worked for at least a year in the catchment, or written a publication or report linked to the catchment; (ii) Expertise on land and water management issues. Participants were initially selected through a desktop study with additional stakeholders identified through recommendations from the initial cohort.

All the data collection was carried out as part of a PhD project at the University of Stirling in Scotland, UK [27]. The engagement exercise presented here was part of a larger conceptual modelling exercise in which participants were asked to rank ecosystem services in their catchments, identify various pressures on their river catchment, as well as name which remediation measures were already in place. After that, participants were asked to list all stakeholder groups (herein referred to as stakeholders) that have an influence on catchment management within their catchment of interest. Participants were not given a list of possible stakeholder typologies but were asked to recall stakeholders from memory, which helped to inform analysis of which stakeholders were omitted. After completing their list, participants were asked to state whether they considered each stakeholder to have a small, medium or large influence on the management of the catchment and whether that perceived influence is positive, negative or overall neutral.

2.3. Data Analysis

The results from the survey were collated into two matrices; one matrix that captured each participant's perceived size of each stakeholder typology's influence (either a 1, 2 or 3 for small, medium or large influence, respectively), and another matrix depicting the perceived value of each stakeholder typology's influence (either a 1, 2 or 3 for negative, neutral or positive influence, respectively). As participants were not given an a priori list of stakeholders to select from, the large number of elicited stakeholder typologies (71) were collated to reduce it to a number of 28 typologies. This was to ensure the stakeholder networks were legible by grouping together similar stakeholders, such as several NGOs, small local businesses and diverse industry. Any stakeholder group that was named by only a single participant was omitted from the analysis. Both matrices (perceived size of the influence and perceived value) were imported to UCINET 6 for social network analysis [30]. As the data was collected as a 2-mode valued network we used 2-mode Centrality to calculate the degree score. A 2-mode Categorical Core/Periphery Model was used to separate stakeholders into a core and periphery and a Conversion Projection method was used to turn the 2-mode data into a 1-mode affiliation matrix. A two-way ANOVA was carried out using SPSS version 28 to compare responses (mean degree scores, mean no. of responses, mean perceived influence and mean proportion of negative ties) among the different stakeholder groups and catchments [31].

3. Results

The 43 participants identified a combined total of 28 different stakeholder typologies. As stakeholders were identified by multiple participants, 490 individual scores were collated. On average, each participant named 11 stakeholder typologies and the exercise took around 15 min per respondent. Most of the stakeholder typologies received positive scores in terms of their perceived influence on the case study catchments (305), followed by neutral (125) and negative (60). Similar numbers of stakeholders were identified as having a medium (193) or large (191) influence with less having a small influence on the catchment (106). The Devolved Government (2.67 ± 0.15), Farmers (2.57 ± 0.13), and the Environmental Regulator (2.48 ± 0.12) had the greatest mean size of perceived influence (Figure 2).

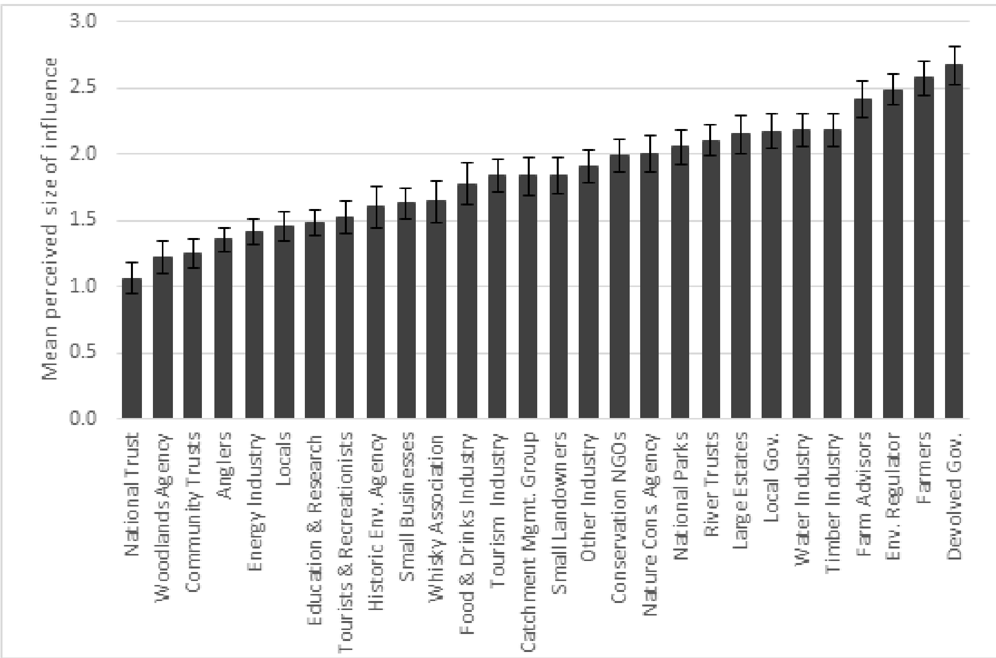


Figure 2. Ranked mean size of the perceived influence (1 = small, 2 = medium, 3 = large perceived influence) of the elicited stakeholders on catchment management in the study catchments (±1 standard error).

The Environmental Regulator was elicited most frequently (42 times), followed by River Trusts (31), Local Government (29), Water Industry (29), Timber Industry (29) and

Farmers (28, Figure 3). Neither the UK Government nor the European Commission were mentioned by the participants more than once and so were not included in the analysis. Small Businesses (0.45), Energy Industry (0.36) and Farmers (0.32) had the greatest proportion of perceived negative influence. When combining responses for negative and neutral influence, Small Businesses (0.82), Farmers (0.79), Large Estates (0.79) and Other Industry (0.77) scored highest. Participants belonging to different stakeholder typologies named a comparable number of stakeholders (Table 1). Participants responding for the South Esk catchment named the fewest mean numbers of stakeholders (around 10), whereas it was around 12 in the Ayr catchment and around 13 in the Spey catchment.

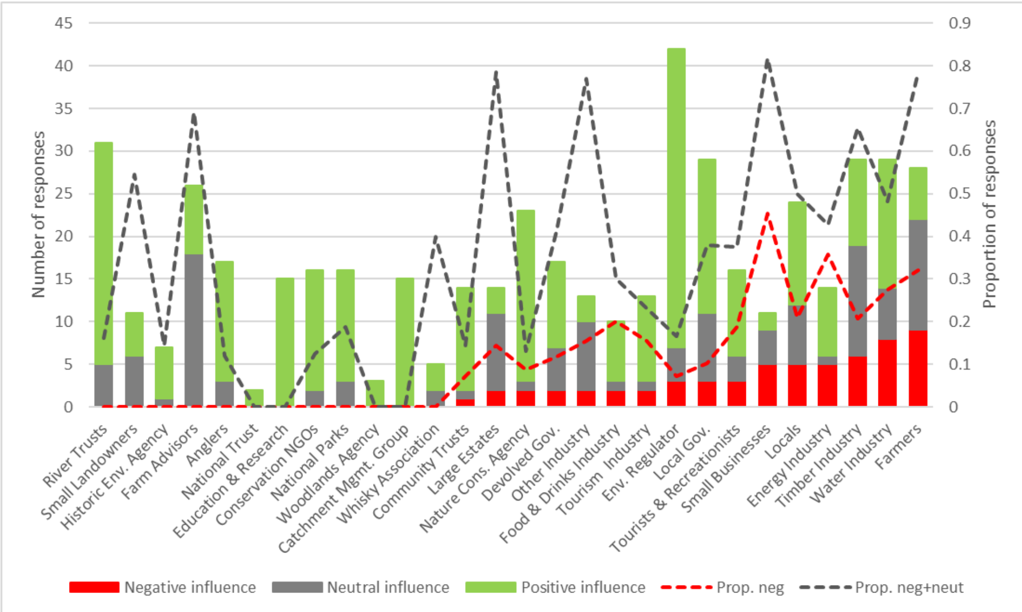


Figure 3. Number of responses of perceived negative, neutral or positive influence of the stakeholders named by participants, ranked by perceived negative influence (*N* = 43, stacked bar graphs); and proportion of responses that were negative (red) or negative and neutral (grey, dotted line graphs).

The network analysis determined the stakeholders that were most commonly connected in all of the study catchments and hence had the greatest degree score (node size) and those which formed the core of the stakeholder network (Figure 4; pink nodes). The Environmental Regulator had the largest degree score (2.52), followed by Farmers (1.81) and River Trusts (1.60), which were closely followed by Water Industry (1.58), Timber Industry (1.58), Local Government (1.56), and Farm Advisors (1.56). The Devolved Government and Nature Conservation Agency both had a degree score of 1.19. These nine stakeholders were classed within the core and the remaining 19 stakeholders were classed within the periphery (Core/Periphery correlation coefficient = 0.9211). The stakeholders with the highest degree scores within the periphery were Locals (0.88), National Parks (0.84), Large Estates (0.81), Conservation NGOs (0.79), and Catchment Management Groups (0.70; see Appendix A degree scores of all stakeholders). Ties (connections between stakeholder nodes) depict co-occurrence of stakeholders in participant responses. The greatest ties are among the core stakeholders; however, there are also moderately high ties between National Parks and the Environmental Regulator and River Trusts, Conservation NGOs and the Environmental Regulator and Farm Advisors, Catchment Management Groups and Local Government and the Water Industry, the Tourism industry and several stakeholders, and Large Estates and the Timber Industry, the Environmental Regulator and several other stakeholders.

Table 1. Mean number of responses, mean degree, perceived influence, and proportion of perceived negative influence and negative and neutral influence of the three contrasting catchments and four key water management stakeholders (±1 standard error). None of these statistics were significantly different between catchments or stakeholder groups (significance of differences between the means at 0.05 level).

	Ayr Catchment	South Esk Catchment	Spey Catchment	Catchment Scientists	Farm Advisors	Environmental Regulator Staff	Water Industry Staff
Mean number of responses	11.53 (±0.90)	9.92 (±1.34)	12.53 (±0.98)	11.27 (±1.36)	11.18 (±0.88)	11.55 (±1.22)	11.44 (±1.68)
Mean Degree	1.02 (±0.10)	0.87 (±0.13)	1.15 (±0.09)	1.03 (±0.13)	0.95 (±0.10)	1.06 (±0.11)	1.03 (±0.18)
Mean influence	2.45 (±0.09)	2.46 (±0.11)	2.58 (±0.08)	2.58 (±0.09)	2.38 (±0.14)	2.55 (±0.08)	2.48 (±0.10)
Proportion of perceived negative influence	0.04 (±0.02)	0.04 (±0.02)	0.02 (±0.01)	0.02 (±0.01)	0.06 (±0.02)	0.02 (±0.01)	0.03 (±0.02)
Prop. of perceived neg. and neutral influence	0.11 (±0.01)	0.08 (±0.02)	0.11 (±0.02)	0.11 (±0.02)	0.10 (±0.02)	0.10 (±0.03)	0.10 (±0.02)
Core/Periphery fit (correlation)	0.912	0.889	0.897	0.864	0.861	0.902	0.872

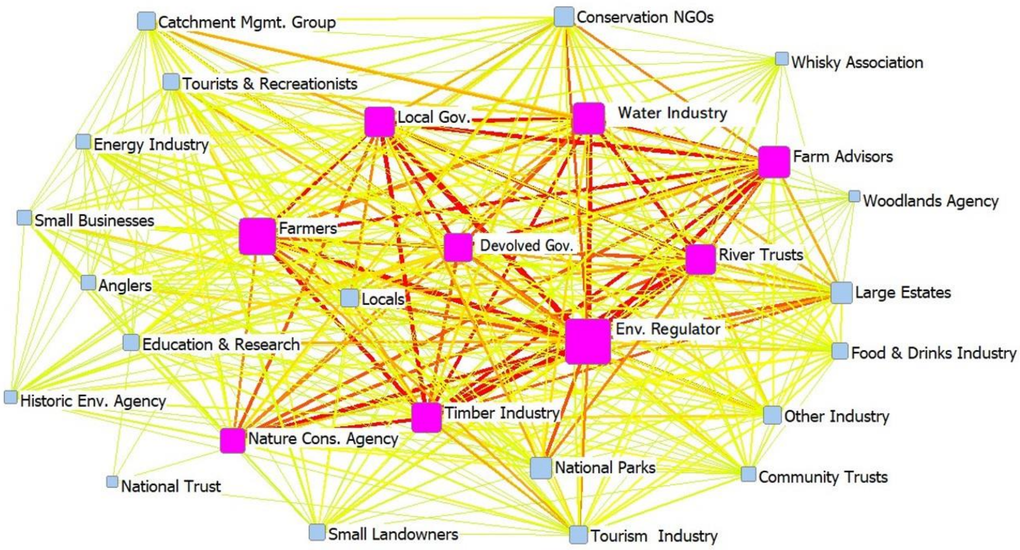


Figure 4. One-mode network of the stakeholder typologies, with node size depicting degree score and node colour showing the core (pink) and periphery (blue). Core/Periphery fit (correlation) = 0.9211. Ties depict co-occurrence of stakeholders from participant responses and tie strength is visualised both by line thickness and colour, with green depicting low tie strength (max. = 192).

The core stakeholders from the Ayr catchment were identical to the Esk's eight nodes, but also included the Nature Conservation Agency (Figure 5). Responses from the Spey catchment identified ten core stakeholders. This included seven that were also selected in the Ayr catchment, but not the Devolved Government and Farmer nodes, unlike the core groups in both the Esk and Ayr catchments. The analysis also included three groups in the Spey network's core that were lacking in the other two catchments: Large Estates, Conservation NGOs and National Parks. The Whisky Association was only named in the Spey catchment and National Parks were named in the Spey and Esk, but not in the Ayr catchment. The Ayr was the only catchment where the Environmental Regulator did not have the greatest degree score, with Farmers scoring slightly higher.

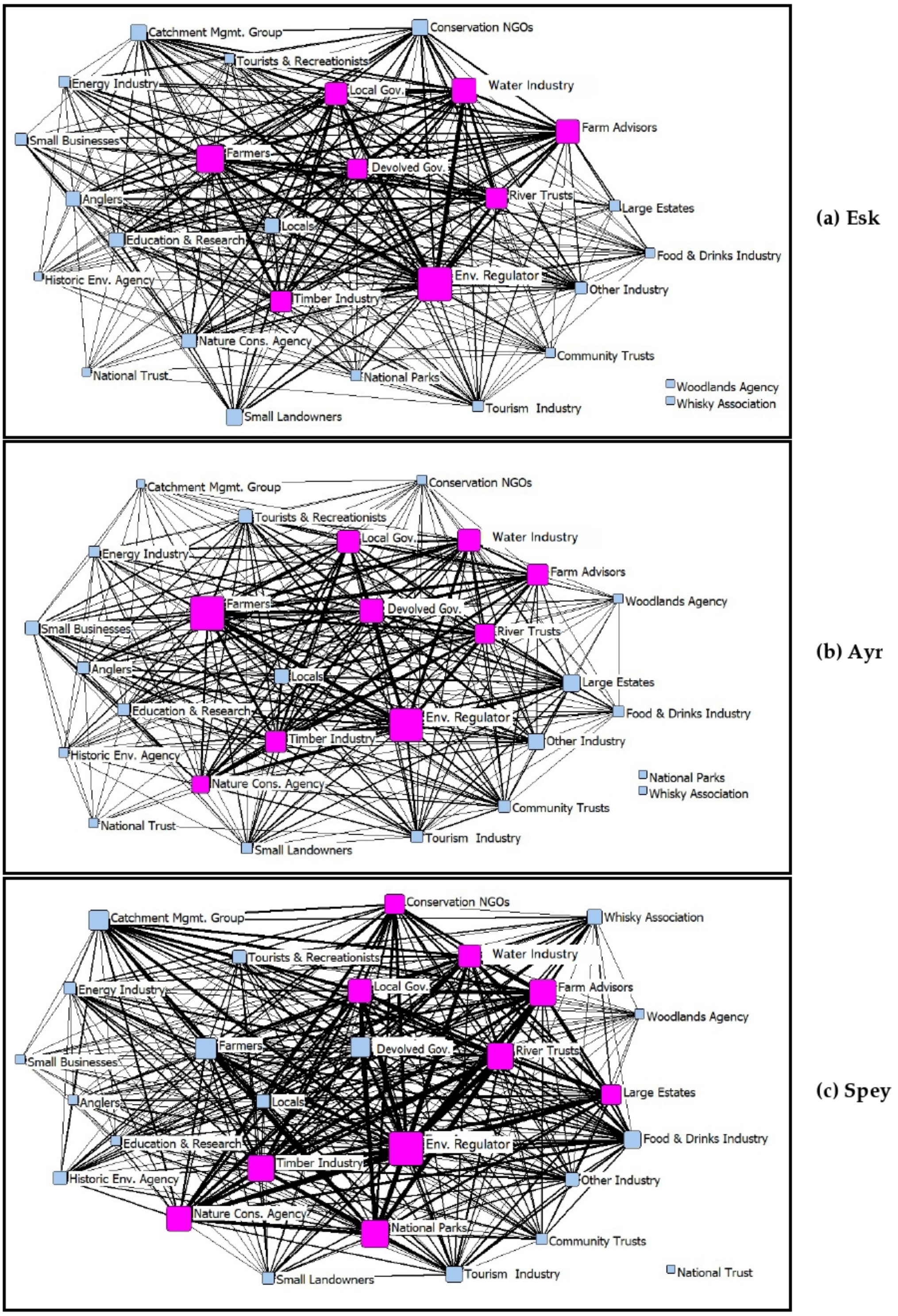


Figure 5. One-mode networks from the (**a**) South Esk, (**b**) Ayr and (**c**) Spey catchments. Node size depicts degree score and node colour the core (pink) and periphery (blue). Core/Periphery fit (correlation) = 0.889 (South Esk), 0.912 (Ayr) and 0.897 (Spey).

When comparing the core/periphery analysis between the four stakeholder typologies that the participants belonged to, networks of the Water Industry Staff had the greatest number of nodes within the core (11), followed by Environmental Regulator Staff (9), Catchment Scientists (8) and Farm advisors (6) (Figure 6). Stakeholder nodes that were classed as being within the core across all four participant typologies were the Environmental Regulator, Local Government, River Trusts and the Timber Industry. The Water Industry, Farm Advisors and Farmers were classed as being within the core by three of the four participant groups. The Devolved Government, the Nature Conservation Agency and National Parks were classed within the core by two participant groups and Conservation NGOs, the Food and Drinks Industry and Large Estates by one. Farm Advisors were the only participant group where a stakeholder (Farmers) had a greater degree score than the Environmental Regulator.

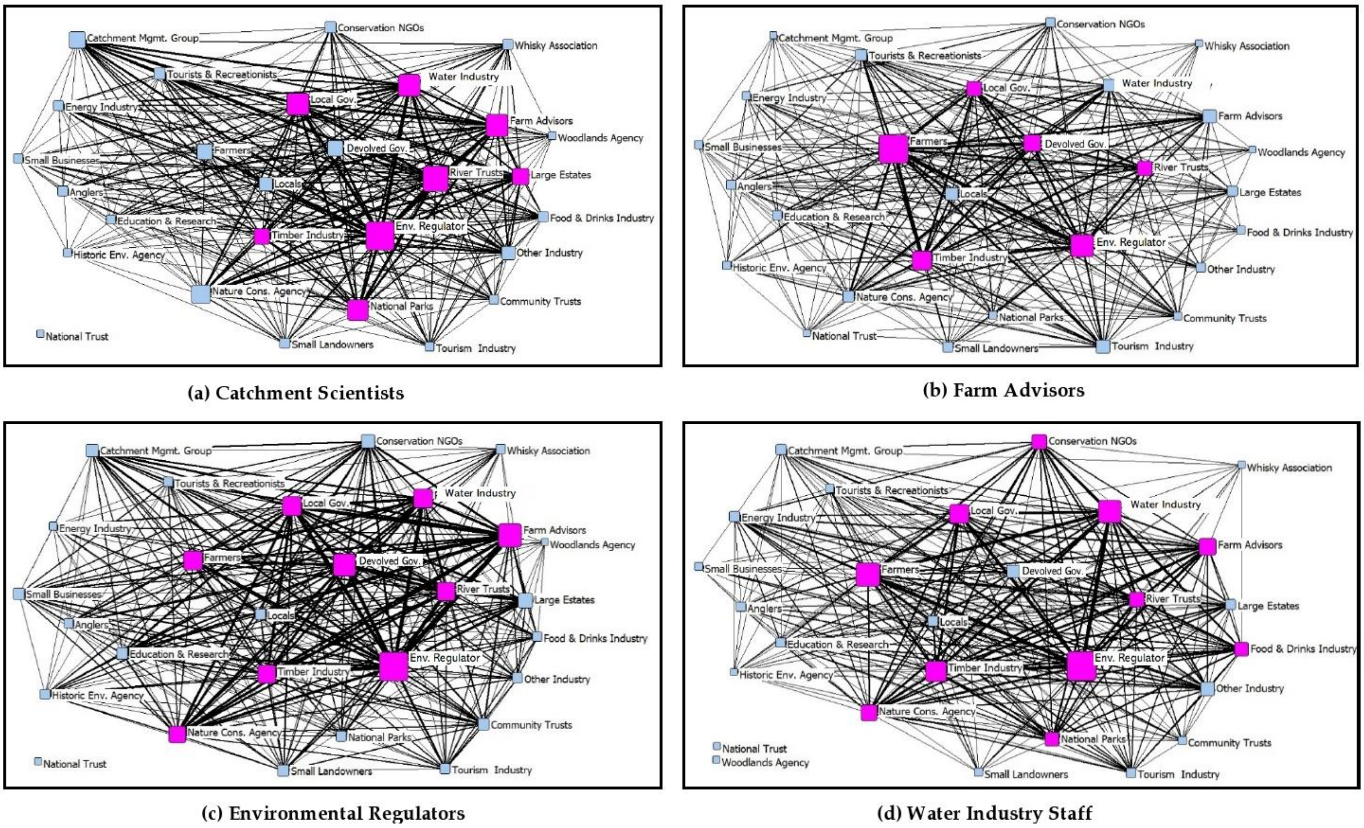


Figure 6. One-mode networks from the (**a**) Catchment Scientist, (**b**) Farm Advisor, (**c**) Environmental Regulator and (**d**) Water Industry Staff stakeholders. Node size depicts degree score and node colour the core (pink) and periphery (blue). Core/Periphery fit (correlation) = 0.864 (Catchment Scientists), 0.861 (Farm Advisors), 0.902 (Environmental Regulators) and 0.872 (Water Industry Staff).

Figures 7 and 8 show all participant's responses, i.e., which stakeholders they listed and whether they perceived that group's influence on their catchment as small, medium, or large, and whether they thought this influence was overall positive, neutral, or negative. Three and twelve participants identified National Parks as a relevant stakeholder in the Esk and Spey catchments, respectively, but none for the Ayr catchment. Respondents in the Spey catchment chose negative ties half as often as those in the other two catchments and Farm Advisors responded with the greatest numbers of negative ties out of all the participants, two and three times higher than Water Industry Staff and three times greater than Environmental Regulator Staff and Catchment Scientist (Figure 8 and Table 1).

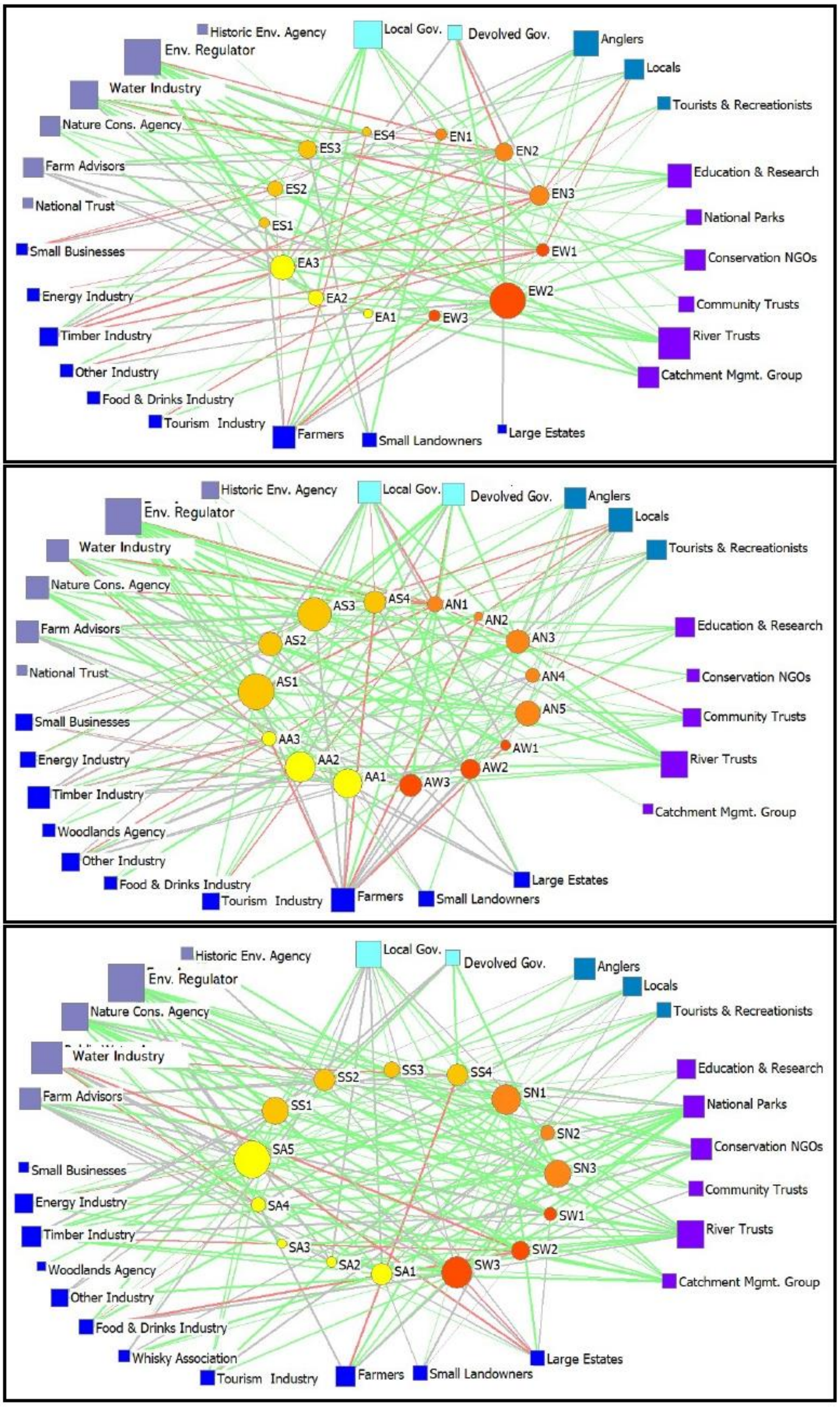
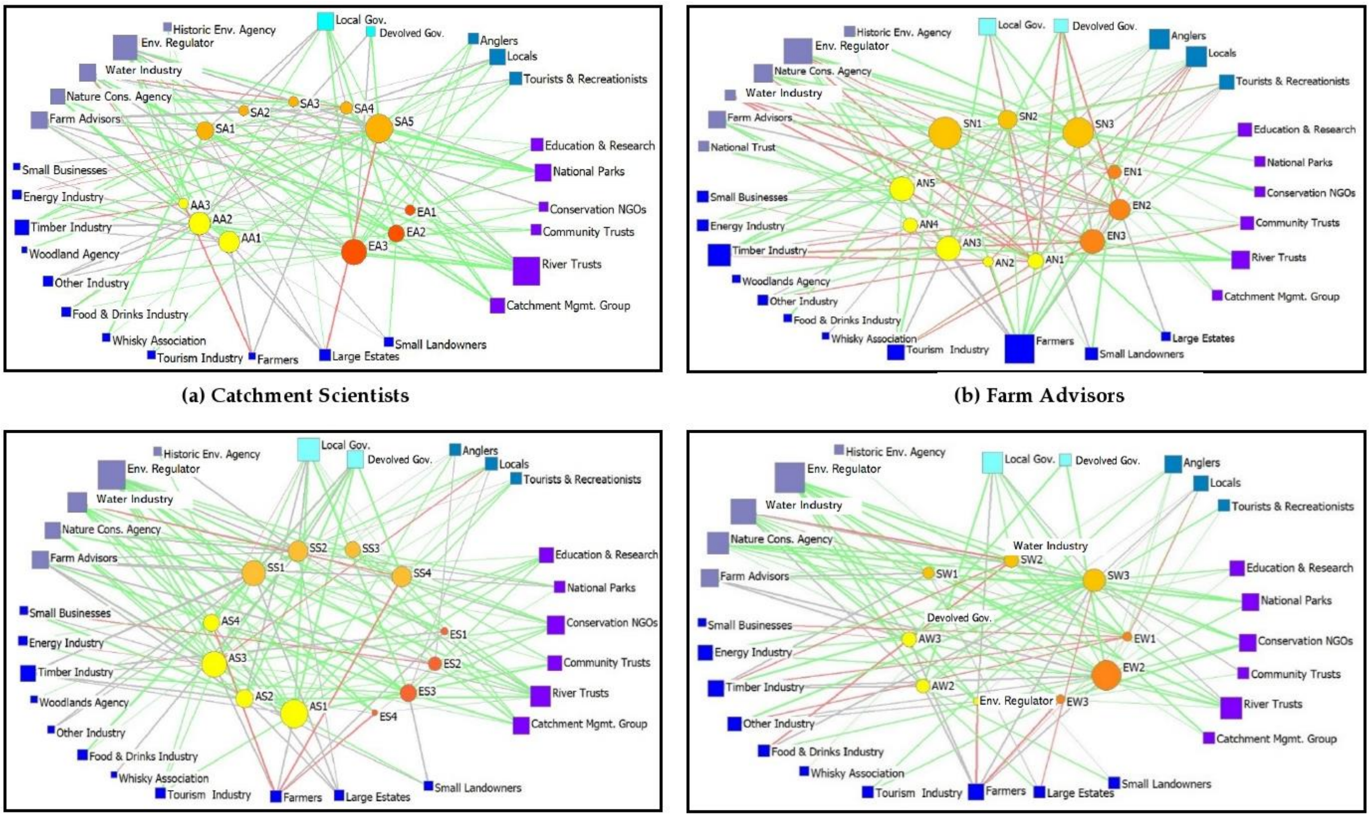


Figure 7. Two-mode networks of the (**a**) South Esk, (**b**) Ayr and (**c**) Spey catchments. Depicting responses of stakeholder typologies (squares, coloured to distinguish government (turquoise), public bodies (grey), private business (blue), other stakeholders (purple) and individual actors (cyan)) by individual participants (circles, yellow (Catchment Scientists; i.e., EA1–3), amber (Environmental Regulators; i.e., ES1–4), light orange (Farm Advisors; i.e., EN1–3) and dark orange (Water Industry staff; i.e., EW1–3)) with tie strength depicting a small, medium or large influence on the catchment and tie colour showing a negative (red), neutral (grey) or positive influence (green). Node size depicts degree score.



(a) Catchment Scientists **(b) Farm Advisors**

(c) Environmental Regulators **(d) Water Industry Staff**

Figure 8. Two-mode networks from the (**a**) Catchment Scientist, (**b**) Farm Advisor, (**c**) Environmental Regulator and (**d**) Water Industry Staff stakeholders. Depicting responses of stakeholder typologies (squares, coloured to distinguish government (turquoise), public bodies (grey), private business (blue), other stakeholders (purple) and individual actors (cyan)) by individual participants (circles, yellow (Catchment Scientists; i.e., EA1–3), amber (Environmental Regulators; i.e., ES1–4), light orange (Farm Advisors; i.e., EN1–3) and dark orange (Water Industry staff; i.e., EW1–3)) with tie strength depicting a small, medium or large influence on the catchment and tie colour showing a negative (red), neutral (grey) or positive influence (green). Node size depicts degree score.

4. Discussion

We combined stakeholder analysis and social network methods to provide a novel stakeholder-mapping tool capable of identifying important distinctions between interactions among the land and water management communities across three contrasting study catchments. The methodology used a participatory approach to identify the perceived importance of key stakeholders and how connected they were, and in turn helped to understand which stakeholders were considered core versus peripheral with respect to catchment management. Stakeholder mapping exercises are often undertaken without direct stakeholder input and, therefore, may reflect researcher biases with regard to who they believe has the most influence rather than the perceptions of the stakeholders themselves [24]. The catchment-scale stakeholder mapping approach reported here, therefore, represents a stakeholder-driven framework for identifying key players in catchment management. By reporting on perceived influence of stakeholders across three different catchments accommodating varying management issues we provide a framework that is transferable, simple, engaging and rapid to carry out for each of the participants.

The differences between land use among our three case study catchments corresponded well with how Farmers, the National Park and other stakeholders were represented in the stakeholder maps, indicating that the methodology can differentiate between catchments. When using this methodology in practice for catchment management, a much smaller number of participants would likely give good insight into the stakeholder network. Here, we wanted to be able to statistically compare responses among the stakeholder typologies in each catchment and hence elicited responses from at least three participants for each group. The networks depicting only results from one stakeholder typology are based on as little as nine responses, but still have high Core/Periphery fit correlation scores. When adapting this methodology, initially, responses from an even smaller number of key stakeholders could be analysed to inform whether more responses are needed (if variance between responses is high), or whether a major core stakeholder has not been invited to participate. This makes the methodology a useful stakeholder mapping exercise, which can complement an existing portfolio of stakeholder mapping tools in stakeholder identification and in investigating their relationships [32].

4.1. Contrasting Catchments and Their Stakeholder Typologies

The number of participants mentioning National Parks as a relevant stakeholder corresponded to the catchments located within a National Park. A majority of the area of the Spey catchment is within the borders of the Cairngorm National Park, while the South Esk has only a small area in the park, and the Ayr is located outside of any national parks. The Nature Conservation Agency, and the Conservation NGOs were also more influential here and part of the core in the River Spey catchment. This correlates with significant landownership of NGOs in the catchment area and habitat provision for endangered species, such as capercaillie, Scottish wildcat and golden eagle [33]. A stakeholder only mentioned by participants in the Spey catchment was the Whisky Association, which corresponds to the large number of Whisky distilleries located along the River Spey [34]. The Environmental Regulator was elicited most often overall, which reflects their central role within catchment management issues, such as diffuse pollution and flooding. The stakeholders with the largest numbers of perceived negative influence were also associated with the two main sources of pollution to watercourses: wastewater inputs and diffuse pollution from agriculture [35]. These results suggest that the methodology was able to identify differences in underlying issues in land and water management in the study catchments.

4.2. Perceived Magnitude and Value of Stakeholder Influence

The Devolved Government, Farmers and the Environmental Regulator were perceived to have the largest influence on catchment management, which was consistent across the three study catchments. This highlights, again, the central role of the Environmental Regulator in enforcing land and water management in Scotland. Although much of the legislation protecting water resources comes from the EU, water is a particularly critical resource for all sectors of the Scottish economy, such as for manufacturing, energy, agriculture, food and drink and tourism, and the Scottish Government acknowledges this through their 'Hydro Nation' agenda [36]. Farmers are also central to catchment management in Scotland due to their use of water, as well as due to diffuse pollution from agricultural land, which continues to represent a wide-scale and persistent problem in many regions of Scotland [37]. Farmers also had amongst the greatest proportion of perceived negative influence and perceived neutral and negative influence. This measure was added to the results as several participants voiced that they felt uncomfortable about ascribing the term 'negative' to any stakeholder, which sometimes then led them to select the 'neutral' option. Thus, a minor modification for any future survey using this approach would be to ask whether the influence of each stakeholder was positive, neutral or negative concerning a specific measurement, such as 'Ecological Status', which is well-defined under the EU Water Framework Directive and key stakeholders would be very familiar with such terminology. When comparing negative ties in each of the catchments, participants from the Spey catchment identified half as many negative ties than those in the other two study catchments. This may link back to greater cooperation and understanding among stakeholders in this particular catchment or lower levels of conflict as was identified in our previous conflict hotspot research in the study catchments [38]. Others have highlighted the role of negotiation and joint learning in helping to foster the bridging of social capital between farmers and government officials, which in turn increased shared views on conservation goals [39]. The Spey catchment was also the only study catchment where Farmers were not classed as a core stakeholder. This may reflect the smaller influence of agricultural land management in the catchment, causing less negative impacts on aquatic quality resulting in fewer perceived negative ties. The Spey catchment has a large proportion of sparsely vegetated mountainous areas (23%), moors and heathland (29%), smaller proportions of pasture (9%) and arable land (2%) than the other two study catchments [38].

Farm Advisors were up to three times as likely as other participants to select negative ties and none of the Farm Advisor participants perceived Farmers as having a negative influence on catchment management. Farm Advisors are likely to have differing attitudes on what constitutes a 'good farmer' relative to other catchment stakeholders as they are more understanding of farmers' landscape values, while they also assist them to comply with the increasing environmental legislation [40]. As society's expectations of the farming community change from that of supporting food security and animal welfare issues to inclusion of broader social and environmental goals [41], farmers may not be necessarily opposed to specific practice changes to protect environmental quality, but may be resistant to challenges to their identity of what makes a 'good farmer' [42]. Although there is also some scepticism from farmers regarding diffuse pollution control programmes and their efficacy in Scotland [43], there may be a shift in how the quality of riparian environments contribute to what constitutes a 'good farmer' [44].

Another cause of tension among stakeholders with regard to land and water management may extend to opposing views on how their own and other stakeholders are being perceived [15] and be more complex than simply accommodating differing attitudes about land and water management in general. When stakeholders are required to work together, negative stereotyping, distrust and scapegoating may arise, causing conflict and threatening the social harmony of collaborative systems [45]. Adapting the approach used here in one-to-one interviews for the context of a group discussion could present an opportunity for stakeholders to articulate their views in a non-confrontational and abstract setting, as well as reflect on how accurately the data represents stakeholder networks in their catchments [46]. In doing so it could promote discussion of otherwise implicit attitudes, build shared mutual understanding and facilitate future cooperation [47]. The UK leaving the EU and being able to devise their own agri-environment schemes may be an opportunity to involve stakeholders in their design and to allow farmers to embed their understanding of landscape stewardship and their landscape values [48]. Other stakeholder engagement exercises, such as stakeholder Delphi analysis and fuzzy cognitive mapping could also benefit from using 'insider knowledge' from key stakeholders, such as is presented here, instead of relying on desktop study to select stakeholder participants [49].

4.3. Omission of Stakeholder Groups in Responses

A notable difference in expected and elicited results was that neither the UK Government nor the EU Commission was mentioned by more than one stakeholder across all three catchments. Identifying which stakeholders are missing from studies such as this, in addition to those that are well recognised, can inform on which stakeholders may be disenfranchised or marginalised, but may also provide insight into disparities between an academic view of stakeholder networks versus what key stakeholder groups experience on the ground. If marginalisation was identified during initial stakeholder mapping exercises, focusing on opening two-way dialogue with stakeholders who would otherwise be considered peripheral, or 'radical transactiveness', would benefit the stakeholder analysis [50]. In this case, however, stakeholders that are often identified as high-influence and high-interest, or 'key players' in stakeholder mapping exercises were omitted by participants [24]. Due to the UK Department for Environment Food and Rural Affairs often closely liaising with the Scottish Government, they were expected to be perceived as relatively influential. The lack of responses for the EU Governance structure were particularly counter-intuitive given their role in proposing and administering relevant legislation relating to land and water management, such as the EU Water Framework Directive, the EU Bathing Water Directive, the EU Floods Directive and EU Climate Change targets.

The omissions in responses may be methodological. When asked which stakeholders had influence on catchment management in their respective catchments, this may have implied influence would have to be through direct actors, rather than indirectly through legislation. The Environmental Regulator implements most of the EU Directives and is the designated competent authority; hence, stakeholders in the catchment may perceive them as the stakeholder that influences their catchments through regulation and enforcement. Had the methodology encouraged more hierarchical thinking in participants, the UK Government and EU Commission would likely have been mentioned more often; however, such a methodology may have overly focused on participants' knowledge of the stakeholder network rather than allowed insight into their day-to-day experiences within their catchments. When engaging participants for stakeholder mapping, surveys also often make use of a pre-prepared list of stakeholder groups to choose from, which does not supply the information of who might have been left out [51]. The methodology provides insight into the procedural interactions among land and water stakeholders, which may show that these higher-level institutions are at arm's length when it comes to catchment management in practice. Stakeholder analysis in the Swiss water supply and wastewater sector showed clear dominance of local actors, while regional, and especially national actors, were perceived as less important [52]. Including Scottish Government staff as participants would have likely included the UK Government and EU Commission in the responses as they would have more direct links between each other. The composition of participants will, therefore, influence results, so initial selection of participants needs to have a clear aim in mind. In our example, we focused on participants directly involved in land and water management and chose not to include legislators.

4.4. Degree and Core and Periphery Analysis

Stakeholders that had the largest degree score and which formed the core of the network were from across all sectors; thus, showing no bias towards any specific sector. The stakeholder nodes that were classed as being within the core across all four interviewed stakeholder typologies and across all three study catchments may be assumed as particularly relevant for catchment management across the country (Environmental Regulator, Local Government, River Trusts and the Timber Industry). Key players in these elicited stakeholder networks included legislators and land managers similarly to Reed et al. [24] in their example of a stakeholder mapping exercise applied to flooding. Our results also included River Trusts, public bodies, agencies and private businesses, which may illustrate the heterogeneity and complexity of focusing on integrated catchment management networks as opposed to a single water management issue. Integrating peripheral stakeholders into participatory catchment management can help to achieve more equitable development outcomes where people are marginalised, but may also aid behaviour change of poorly networked stakeholders, which may be of particular interest if they are likely to participate in illegal behaviours [53].

Numbers of times stakeholders were mentioned and co-occurrence of stakeholders were used in our study to determine nodes and ties in the one-mode networks. Although social network analysis would allow a whole host of other social network analysis tools, this would also require a much more rigorous data collection to ensure each node and tie in the network was identified [52]. Hence, our methodology has the benefits of a rapid survey with broad but still in-depth insights into stakeholder networks. The methodology could be adapted to include elicitation of hierarchical level of stakeholders or interest, as well as influence to make it more comprehensive. Other additional criteria, such as identifying stakeholder roles, may also be beneficially added to techniques such as the one presented here [54]. Alternatively, this methodology could be used as a complementary tool for enhancing other stakeholder mapping techniques or as a preliminary methodology for full social network analysis. For example, the methodology could be used as a rapid scoping exercise, with benefits exceeding a simple desktop study, to identify which stakeholders to involve in any stakeholder participation exercise. Likewise, it could provide a framework to help catchment co-ordinators identify likely stakeholders of interest for catchments of a particular typology without the need for further elicitation or participation. Increased understanding of stakeholder networks can improve stakeholder communication, make implementation more effective and make citizen science initiatives more successful [55]. It could inform who to target for consultation in 'active involvement' exercises suggested under the WFD or determine who to involve as stakeholders in a Citizens' Jury to inform decision-making on complex science-policy problems [56]. The approach could have also benefited from focus groups or workshops to facilitate open debate and exchange of the findings from this study with different stakeholders, which may help inform their land and water management decision-making and increase understanding and cooperation between stakeholder groups.

5. Conclusions

Combining stakeholder analysis and social network methods provides a novel and rapid tool to investigate stakeholder interactions, in our case, concerning catchment management. Comparing outputs from the analysis of three contrasting river catchments, as well as between participants from four key stakeholder groups allowed identification of which stakeholders are more central to the catchment management networks as opposed to which are seen as to act more along the periphery and to quantify perceived stakeholder influence on the water environment, as well as whether that influence was perceived to be mostly positive, neutral or negative.

Social network analysis into how information flows between the core and peripheral stakeholder groups identified here may help provide more effective communication within Scottish land and water management stakeholder networks. For example, communications may be targeted to highly connected opinion leaders to leverage their influence, or communication may be facilitated between distinct subgroups to promote peer learning [53]. Future research into social networks could test the hypothesis whether a more centralised network structure may be more effective at coordinating catchment management, or whether relying on a single dominant node within the core may lead to conflicts and lack of cooperation between other nodes. Our catchments seem to show a mixture of those two approaches as the Environmental Regulator dominated, but the other core nodes were also well-connected, which may give them both the advantages of being able for rapid top-down mitigation of specific and easily identifiable threats to the system, whereas broader connectivity may allow more effective management of other more indirect or less easily measurable threats [57].

Applying 'fully articulated' social-ecological network analysis to a catchment socio-ecological system presents an innovative avenue to further investigate not just ties between social network nodes, but also relationships in ecological networks and social-ecological ties [18]. Such research could give insights into how collaboration among users of shared catchment resources leads to successful management [58], or which social-ecological patterns are likely to facilitate adaptations and transformations [59]. The social factors that provide resilience within catchment management, such as flexibility, social organization, learning, and agency could also be explored with social-ecological network approaches [60]. This may give vital insights into the social dimensions of resilience in catchments to help understand likely impacts of land management changes or climate change and help to make catchments more resilient against future change.

There is a need to translate interdisciplinary research on catchments into informed decision-support tools to allow policy makers, communities, and individual stakeholders to make better informed decisions. Including these in existing structures, such as the Water Framework Directive River Basin Management Cycles, or agri-environment funding cycles, and building upon positive pre-existing relationships, such as catchment management groups, may be the best approach to ensure effective stakeholder participation and develop strong partnerships among stakeholders [61].

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Appendix A

Table A1. Degree, mean perceived influence, and proportion of perceived negative influence, and combined negative and neutral influence of the 28 elicited stakeholders.

	Degree	Mean Perceived Influence ± st. Error	Proportion of Perceived Negative Influence	Prop. of Perceived Neg. and Neutral Influence
Farmers	1.81	2.57 ± 0.13	0.32	0.79
Environ. Regulator	2.51	2.48 ± 0.12	0.07	0.17
Water Industry	1.58	2.18 ± 0.12	0.28	0.48
Large Estates	0.81	2.15 ± 0.14	0.14	0.79
Timber Industry	1.58	2.18 ± 0.12	0.21	0.66
River Trusts	1.60	2.10 ± 0.12	0	0.16
Community Trusts	0.47	1.24 ± 0.11	0.07	0.14
Nature Cons. Agency	1.19	2.01 ± 0.14	0.09	0.13
Small Businesses	0.47	1.63 ± 0.12	0.45	0.82
Small Landowners	0.51	1.84 ± 0.14	0	0.55
Historic Env. Agency	0.28	1.60 ± 0.16	0	0.14
Farm Advisors	1.53	2.41 ± 0.13	0	0.69
Locals	0.88	1.45 ± 0.11	0.21	0.50
Local Gov.	1.56	2.17 ± 0.13	0.10	0.38
Devolved Gov.	1.19	2.67 ± 0.15	0.12	0.41
Tourists and Recreationists	0.60	1.53 ± 0.12	0.19	0.38
Anglers	0.58	1.35 ± 0.09	0	0.12
Energy Industry	0.51	1.41 ± 0.10	0.36	0.43
Other Industry	0.67	1.90 ± 0.13	0.15	0.77
Food and Drinks Industry	0.49	1.77 ± 0.16	0.20	0.30
National Trust	0.07	1.06 ± 0.11	0	0
Education and Research	0.56	1.48 ± 0.10	0	0
Conservation NGOs	0.79	1.99 ± 0.12	0	0.13
National Parks	0.84	2.05 ± 0.13	0	0.19
Woodlands Agency	0.12	1.22 ± 0.12	0	0
Tourism Industry	0.63	1.83 ± 0.12	0.15	0.23
Catch. Mgmt. Group	0.70	1.83 ± 0.14	0	0
Whisky Association	0.23	1.64 ± 0.16	0	0.40

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