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Towards effective conservation and governance of Pontocaspian biodiversity in the Black Sea region

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Using social network analysis to assess the Pontocaspian biodiversity conservation capacity in Ukraine

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Abstract

Social networks, defined as sets of relationships between stakeholder organizations, are important determinants of constructive actions for biodiversity conservation. Such actions are achieved through cooperation between various stakeholders, exchange of information, and joint planning and implementation. Here we used a mix of qualitative and quantitative social network analysis methods to investigate the inter-organizational network of stakeholders in Ukraine, and the implications of network properties for the conservation of Pontocaspian biodiversity. Pontocaspian biota contains unique and endemic fauna, which are threatened by anthropogenic impacts, making effective conservation measures an urgent priority. We identified a well-connected, centralized network in Ukraine. However, the strong network has not resulted in effective conservation of Pontocaspian biodiversity. Suboptimal conservation action stems from the subordinate role of Pontocaspian species in the inter-organizational interactions, likely due to lack of knowledge regarding Pontocaspian taxa. Social variables, such as funding scarcity and legal constraints, further limit the effectiveness of biodiversity conservation actions. We conclude that the current landscape of stakeholders in Ukraine is well placed to rapidly improve conservation actions if supplied with improved information and recognition of conservation needs of Pontocaspian taxa, combined with improved financial and legal conditions.

4.1 Introduction

Pontocaspian biota comprises endemic flora and fauna which evolved in the isolated anomalohaline (brackish) lake systems in and around the Black and Caspian Sea basins over the

past two million years (Kostianoy and Kosarev 2005; Krijgsman et al. 2019). This biota includes mollusks, crustaceans, and fish, as well as planktonic groups such as dinoflagellates and diatoms (Grigorovich et al. 2003; Marret et al. 2004). Within their native range, the diversity and abundance of Pontocaspian species are subject to anthropogenic pressures, such as habitat destruction, introduction of invasive alien species and pollution (Grinevetsky et al. 2016; Lattuada et al. 2019; Velde et al. 2019). The Ukrainian territory covers an important part of Pontocaspian habitats (Fig. 4.1). In Ukraine, Pontocaspian species richness and abundance are in decline and require effective conservation actions (Anistratenko and Anistratenko 2018; Bloesch et al. 2006; Wesselingh et al. 2019). Legal instruments for the conservation of Pontocaspian biota are confined to few taxa (Anistratenko 2009; Dumont et al. 1999; Munasypova-Motyash 2009a, b) and scientific information regarding the majority of Pontocaspian species is scarce and restricted to individual stakeholder organizations (ECODIT LLC 2017).

This study is part of the Horizon 2020 'Pontocaspian Biodiversity Rise and Demise' (PRIDE) program. The PRIDE program (http://www.pontocaspian.eu/) was designed to generate scientific knowledge on Pontocaspian biodiversity, inform decision-making, and guide effective conservation policy. Effective collaboration between stakeholder organizations, defined as high levels of information exchange and coordination of joint actions is essential for adequate implementation of biodiversity conservation measures (Binning et al. 1999; Briggs 2001; Durham et al. 2014). Different types of stakeholders such as academic organizations, policy makers, non-governmental organizations, public sector and conservation managers need to be involved and act at different levels of biodiversity conservation. This involvement ranges from the delivery of scientific information, to the enforcement of rules and regulations and actual implementation of conservation measures (Durham et al. 2014). Scientific information, knowledge and management experiences are at the heart of these processes (Lee 1999; Salafsky et al. 2002). Therefore, effective collaboration to address environmental issues largely depends on knowledge sharing and implementation in conservation policy (Cash et al. 2003; Francis and Goodman 2010; Pullin and Knight 2001). Recent studies indicate that defining and understanding the different types and roles of stakeholders and their professional relationships - including the exchange of information – are a requirement for optimal conservation planning and the protection of biological diversity (Isaac 2012; Mills et al. 2014; Paletto et al. 2015).

A commonly used tool to analyze and visualize relationships between stakeholders is a Social Network Analysis (SNA), which models the statistical properties of a social network (Wasserman and Faust 1994). Social networks define the relationships between stakeholder organizations, capturing the scale of information and knowledge sharing, as well as joint actions and decision making between network members (Barnes et al. 2016; Ernoul and Wardell-Johnson 2013). Social networks are therefore critical to facilitate biodiversity conservation and effective management of natural resources (Bodin et al. 2006; Bodin and Crona 2009). Empirical studies on the relationships between the structural characteristics of a network and the outcomes for biodiversity conservation

identify which properties of a network are beneficial for conservation. For example, well-connected networks allow for the effective exchange of information and facilitate the definition and prioritization of biodiversity conservation challenges (Abrahamson and Rosenkopf 1997; Sandström and Carlsson 2008; Weimann 1982). Decision making is facilitated when one or few institutions take a central position in a network (Leavitt 1951). Furthermore, bi-directional knowledge and information exchange between producers and users is positively correlated with increased social and environmental impacts of scientific research (Fazey et al. 2013). Similarly, strong connections and frequent interactions among stakeholders are indicative of high levels of trust, and are necessary to communicate complex biodiversity related information (Crona and Bodin 2006; Newman and Dale 2005). In summary, a structurally strong network that enables effective exchange of information between different types of stakeholders has the potential to enhance collaboration and achieve optimal conservation of biodiversity.

High levels of information sharing alone, however, may not suffice because networks may exist in which not all actors hold shared ideas and goals, making its functioning less effective (Ernstson et al. 2008; Mizruchi and Galaskiewicz 1993). Additionally, power relations among stakeholder organizations are important determinants of network outcomes (Markovsky et al. 1988). Different stakeholders have different interests and power, potentially resulting in more powerful actors using their favorable positions to their own advantage (Adger et al. 2005). Moreover, social variables such as funding schemes and funding availability, governance arrangements, stability and functioning of organizations, personal attitudes and willingness to collaborate further influence the functioning of the network (Cowling and Wilhelm-Rechmann 2007; Fuhse and Mützel 2011; Knoke and Kuklinski 1991). The extent to which the exchanged information in an existing network influences conservation policy depends on its content, relevance and legitimacy (Reed et al. 2014; Stringer and Dougill 2013). Often, the information and scientific knowledge shared with policy-makers is difficult to interpret, or may be contested depending on how knowledge is produced, translated or transformed as it is shared (Reed et al. 2013; Stringer and Dougill 2013). According to Reed et al. (2009), Prell et al. (2009) and Hauck et al. (2015) the combination of SNA methods and the qualitative analysis of stakeholders' knowledge, referred to as the mixed-methods approach, allows for triangulation between the network structure, social variables, and their outcomes for conservation action. The mixed-method is an adequate approach to link the structure of the social relationships expressed in the network to individual stakeholders, and the context in which the relations exist (Fuhse and Mützel 2011; Herz et al. 2015).

Here, we combine the results of SNA with qualitative analysis of stakeholder knowledge to understand the structure and functioning of the network, and the outcomes of network properties for the conservation of Pontocaspian biota. We aim to a) quantify the Pontocaspian biodiversity related information sharing network using SNA; b) examine the content of the network interactions using a qualitative approach; c) identify social variables that influence collaboration; and d) outline areas for improvement for effective conservation of Pontocaspian biodiversity in Ukraine.

Table 4.1. Stakeholders included in the study and their respective stakeholder categories. "Acad" represents academic institutions, "Gov" - governmental, "NGO" – non-governmental and "Pa" – protected areas, under 'Category'.

ID	Abbreviation	Category	Organization name	Department/Service
1	IZAN	Acad	I.I. Schmalhausen Institute of Zoology of the National Academy of Sciences of Ukraine (NASU)	Department of Invertebrate Fauna and Systematics
2	IHB	Acad	Institute of Hydrobiology of the NASU	
3	IMB	Acad	Institute of Marine Biology of the NASU	
4	KHS	Acad	Kherson Hydrobiology Station of the NASU	
5	KSU	Acad	Kherson State University	Faculty of Biology, Geography and Ecology
6	ONU	Acad	Odessa National University	Faculty of Biology
7	YN	Acad	Southern Scientific Research Institute of Marine Fisheries and Oceanography	
8	KNU	Acad	Taras Shevchenko National University of Kiev	Department of Ecology and Zoology
9	US	Acad	Ukrainian Scientific Center of Ecology of the Sea	
10	KSRA	Gov	Kherson State Regional Administration	Department of Ecology
11	MAPF	Gov	Ministry of Agrarian Policy and Food	Department of Agriculture
12	MENR	Gov	Ministry of Ecology and Natural Resources of Ukraine	Department for Protection of Natural Resources
13	MSRA	Gov	Mykolaiv State Regional Administration	Department of Ecology
14	OSRA	Gov	Odessa State Regional Administration	Department of Ecology
15	CRS	NGO	Centre for Regional Studies	
16	NECU	NGO	National Ecological Centre of Ukraine	
17	WWF	NGO	World Wide Fund for Nature in Ukraine	
18	BSBR	Pa	Black Sea Biosphere Reserve of the NASU	
19	DBR	Pa	Danube Biosphere Reserve of the NASU	
20	KSRP	Pa	Kinburn Spit Regional Landscape Park	
21	LDNP	Pa	Lower Dnieper National Nature Park	
22	NPBS	Pa	National Park "Biloberezhia Sviatoslava"	

4.2 Methods

4.2.1 Stakeholder identification and prioritization

Twenty-nine stakeholder institutions directly or indirectly involved in Pontocaspian biodiversity research and conservation were identified through online research and exploratory consultations with PRIDE partner institutions in Ukraine for inclusion in the study. We define a stakeholder as a person or group who influences or is influenced by the Pontocaspian biodiversity related research, following Durham et al. (2014). Stakeholder roles were assessed through online inquiries of their activities and subsequent interviews. Stakeholders that lacked any activities or interest in Pontocaspian biodiversity were subsequently omitted from the study, resulting in a final list of 22 institutions (Table 4.1, Fig. 4.1). These institutions were assigned to four stakeholder categories based on their function and responsibilities: Academic (Acad), governmental (Gov), non-governmental (NGO), and protected areas (Pa).

Figure 4.1. Map of the study area. The black stars on the map represent the stakeholder institutions (IDs in Table 1). Green areas indicate major Pontocaspian habitats.

4.2.2 Data collection

Quantitative and qualitative network data were acquired through semi-structured, in-depth interviews with the heads or vice-heads of institutions using a questionnaire (Appendix 4.1). Interviews of 1-3 hours in length were conducted between May and July 2017. A 'whole network analysis' approach was employed, in which each stakeholder was questioned about each of the other 21 stakeholders using a standardized questionnaire. All interviews were audio recorded.

Qualitative data

Data on the content of interactions among stakeholder organizations was collected using two qualitative questions, first asking the interviewees to describe their professional relationships with the other stakeholders, and second specifically asking whether the interaction involved Pontocaspian biodiversity (See Appendix 4.1 for the full interview protocol). If the interaction did not involve Pontocaspian biodiversity, the protocol was to move on asking about the next stakeholder from the list of stakeholders (Table 4.1). If the interaction involved Pontocaspian biodiversity related topics, the interviewees were asked to rank the strength of reported interaction using a table of strength definitions developed as part of the questionnaire (Table A4.1.1). Once a Pontocaspian biodiversity related link was established, stakeholders were asked to report if the interaction was perceived to be sufficient or insufficient to achieve the desired level of collaboration and information exchange. Not all stakeholder institutions were easily reached or willing to answer

the interview questions, resulting in some missing data. We used the imputation-by-reconstruction method (Stork and Richards 1992) to deal with missing data (see Appendix 4.1 for details).

Quantitative data

We used the frequency of contact as a measure of strength (weight) of relational links following Prell et al. (2009), Paletto et al. (2015) and Giurca and Metz (2017). Five weight categories (0 to 4) were used ranging from no contact (0) to very frequent contact (4). We defined strong relationships as the weights higher than or equal to 3. Only formal connections were considered in the network because the informal, personal contacts could not be confirmed. The values given to the strength of confirmed relationships between pairs of stakeholders did not always match. In the cases of bi-directional information exchange, tie values were left as reported by the stakeholders. In the case of unidirectional information transfer, however, the lowest tie value was selected. Answers to this question allowed for the generation of a weighted, directed, information and knowledge transfer network.

4.2.3 Analysis

Qualitative analysis

For qualitative data analysis we used the established methods of Ryan and Bernard (2003) and Bradley et al. (2007), and applied an inductive approach. This means that the themes of interaction were determined based on acquired data and not on theoretical knowledge or assumptions. Transcribed interviews were carefully examined and read multiple times to understand the context of the network. The themes in the transcribed text were identified based on repetitions (Bogdan and Taylor 1975). A 'constant comparison' method was used to refine the dimensions of determined themes and to identify new themes (Glaser et al. 1967). The identified themes for both the content of confirmed relational links and perceived sufficiency of relationships were counted, and their relative importance was determined based on the order of frequency. Identified themes of interaction were grouped in three categories based on similarity: 'communication relations' – linkages between actors primarily used for transmitting information; 'collaboration relations' – the ties between actors consisting of joint action; and 'authority/power relations' – relational links, which indicate the rights of organizations to issue commands and obligations of other organizations to obey.

Social network analysis

For readability, we provide all SNA term definitions in Appendix 4.3. Basic network characteristics, such as number of actors and relational ties, graph density, and network centralization index were calculated using the CRAN R package 'igraph' (Csardi and Nepusz 2006), which was also used to visualize the sociogram. Mean shortest distance, a measure for average distance between actors in the network, was calculated using the CRAN R package 'tnet' (Opsahl 2009) because the 'igraph' package does not take edge weights into account when measuring the shortest distance. The

network centralization index was calculated based on degree centrality scores of individual nodes. Measurements of density and centralization were converted to percentages for visual representation.

Centrality of individual nodes was measured through the degree centrality and betweenness centrality measures (Freeman 1978). We regarded the central stakeholders as those with centrality scores higher than or equal to the third quartile threshold, following the methods of Grilli et al. (2015), Paletto et al. (2015), and Yamaki (2017).

Brokers were identified based on the combination of quantitative and qualitative data. Quantitatively, we regarded brokers to be the stakeholders with high betweenness scores, which also accounted for low Burt's constraint values. Qualitatively, we searched for evidence of brokerage from the network narratives following the definition of Fazey et al. (2013), whereby brokerage implies involvement in the mobilization of information, deliberation between different types of stakeholders and potentially the mediation through working groups to address conservation issues. We used only strong ties (≥ 3) to identify brokers as they reflect regular contact.

Finally, we used a null-model approach to examine the degree of 'homophily' in the network (Newman 2003). We tested whether densities within and between stakeholder groups (defined by the stakeholder category) were significantly higher or lower than random expectation. We randomly assigned nodes to the stakeholders proportional to the true network and subsequently assessed the stakeholders within and between group densities. This was replicated 1000 times, and the resulting 1000 stakeholder group density values were ranked from low to high. Observed within and between group densities were then compared to the randomized results. If the actual density values were outside the 95% confidence interval of the random distribution, we regarded the true within or between group densities to be significantly higher (top 2.5%) or lower (lower 2.5%) than expected by random chance.

4.3 Results

In total 82% of the network data was gathered, with 18 out of 22 institutions interviewed (16 face-to-face and 2 through an electronic questionnaire). Three out of the four remaining institutions were formally contacted, but did not respond and did not complete the electronic questionnaire. One institution could not be reached during the fieldwork period

4.3.1 Network structure

The quantitative results revealed a well-connected information-sharing network with a total number of 191 confirmed, directed relational ties out of 462 potential ties, resulting in a network edge density of 41% (Table 4.2). The Pontocaspian biodiversity conservation network was centralized on few central stakeholders (degree of centralization 38 %), and none of the stakeholders occupied an isolated position in the network (Fig. 4.2). On average, each organization had 17 relational ties (including both incoming and outgoing ties). The majority of the information sharing links were strong (61%; weight ≥ 3) reflecting regular contacts (Table 4.2). The mean distance between any

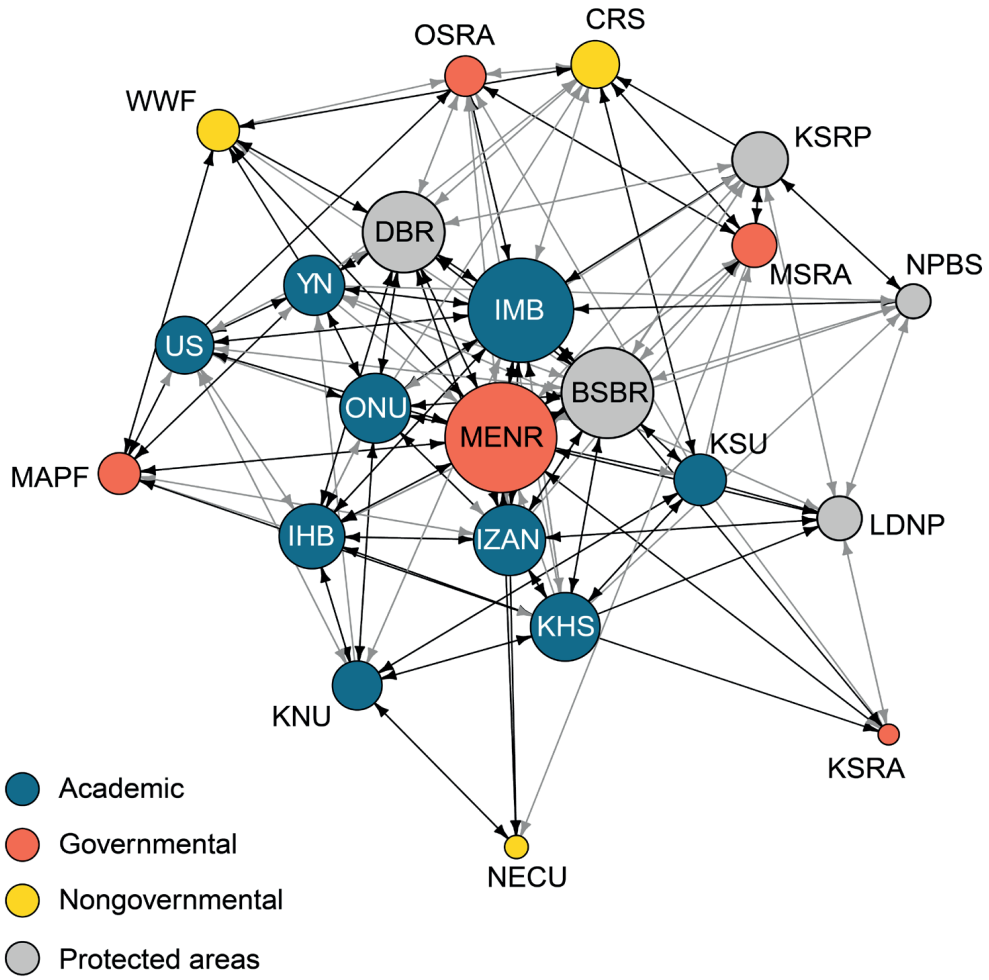

Figure 4.2. Sociogram of the information transferring network of stakeholder organizations involved in Pontocaspian biodiversity conservation and planning. Nodes represent organizations (see Table 4.1 for full names). The size of the nodes corresponds to the node strength. Arrows represent relationships between the nodes and show the direction of relevant information transfer. Black arrows (ties with value ≥ 3) represent strong relationships and gray arrows (ties with value < 3) represent weak relationships.

two actors was 1.5. In-degree and out-degree were very closely correlated (rho = 0.78), so the exchange of information was reciprocated, with stakeholders sending information to many institutions also receiving information from multiple sources.

Table 4.2. Network statistics.

Network data	Values
Total No. actors	22
Total No. ties	191
Mean degree	17
Density (%)	41
Degree of centralization (%)	38
Tie Reciprocity (rho)	0.78
Strong/weak ties (%)	61/39
Mean shortest distance	1.5

4.3.2 Relational content

From the network narratives, we identified 13 themes of stakeholder interactions (Fig. 4.3, Table A4.2.1). These interactions included 'communication relations', e.g., exchange of data and management experiences; 'collaboration relations', e.g., joint research and conservation planning; and 'power relations' e.g., directing action and scientific supervision. Most stakeholders indicated to have multiple kinds of interactions with other stakeholders (Table A4.2.2). For example, organizations collaborating in joint conservation projects also exchanged ecological and environmental information, as well as opinions. Similarly, organizations involved in commercial fishing exchanged information regarding living water resources, and shared management experiences (Table A4.2.2). Few stakeholders only engaged in the exchange of information and did not collaborate with each other. For example, Kherson Hydrobiology Station regularly reported to the Ministry of Ecology and to the regional administrations on study results, but did not engage with them in joint actions. Similarly, protected areas exchanged information and opinions among each other, but hardly collaborated with each other. Out of the identified 191 relational links, 67 links had a single theme of interaction, 72 links had 2 themes of interaction, 43 links had 3 themes of interaction, 8 links had 4 themes of interaction and remaining 1 link had 5 themes of interaction. The links with more relational content were significantly stronger than links with less relational content ($p < 0.001$, Fig. A4.2.1).

Only one theme, namely 'Sturgeon conservation' was identified to directly target the Pontocaspian species. Interviewees mentioned this theme 3 times (Fig. 4.3, Table A4.2.1). The other themes did not directly address Pontocaspian biodiversity, but Pontocaspian species were incidental to the interactions. For example, shared data on ecosystem functioning and dynamics (theme 'Ecological data'), assessments of water parameters (theme 'Environmental data'), advice on restoration projects (theme 'conservation planning'), and joint fieldwork and research (theme 'Research'), were reported by the interviewees to occasionally involve Pontocaspian habitats and/or species. We did not include a standard question on the definition of Pontocaspian species in our questionnaire, but the network narratives indicated that stakeholders had slightly different ideas on what Pontocaspian species and habitats comprise. In some cases, interviewees avoided specifying in

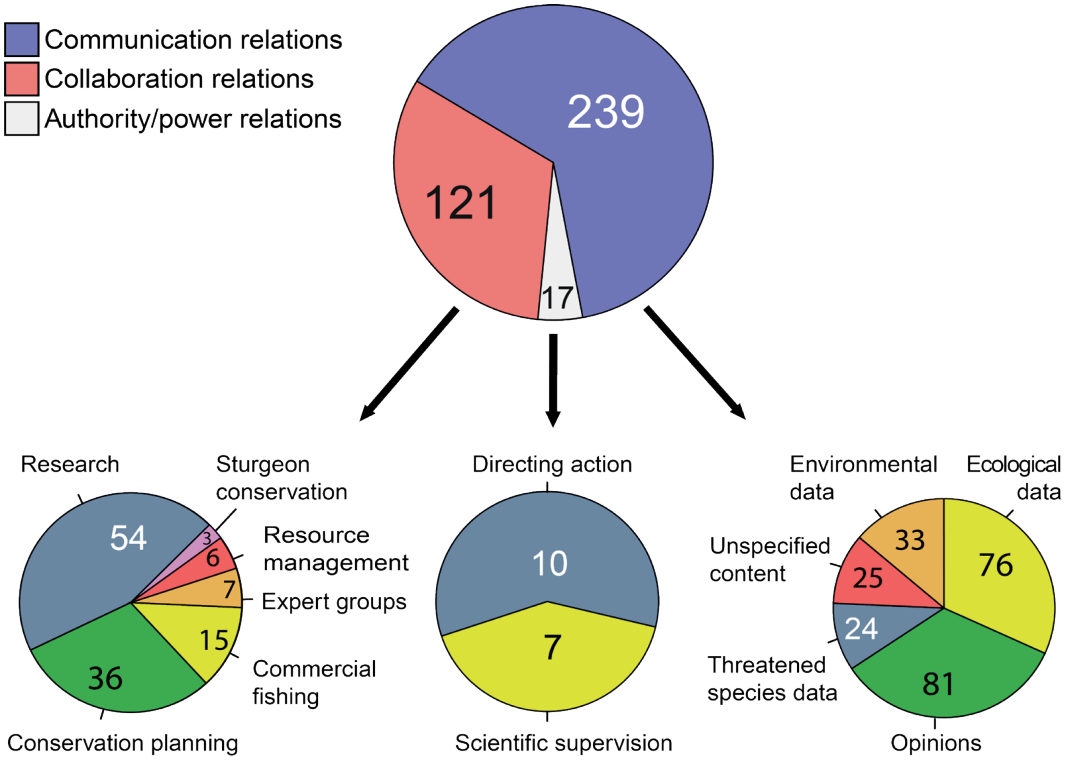

Figure 4.3. Categories and themes of stakeholder interactions. Values in pie charts represent absolute numbers. See definition of themes in Table A4.2.1.

which context Pontocaspian biodiversity related data was exchanged (Fig. 4.3, Table A4.2.1, collated within the theme 'Unspecified content')

4.3.3 Perceived sufficiency of interactions

A total of 42 relational links (31% of 137 links for which the sufficiency was indicated by interviewees) were reported to be insufficient, i.e. below the desired intensity of collaboration and information exchange (Table A4.2.3). Insufficient collaboration was mostly attributed to 'budget constraints' (18 times) and 'legal limitations' (15 times). 'Budget constraints' referred to either a general lack of funding or unfavorable funding schemes, which restricted the participation of stakeholders in a project. 'Legal limitations' referred to inconsistency in conservation policy, which resulted from contradictions in national laws. 'Lack of interconnection' and 'Employee turnover' were minor factors limiting the collaboration (Table A4.2.3). Interestingly, most of the 'insufficient' relational links were strong links ('budget constraints' – 13 strong vs. 5 weak, and 'legal limitations' – 8 strong vs. 7 weak links), suggesting that regular stakeholder contacts within the network were not necessarily indicative of sufficient collaboration.

Table 4.3. Node-specific measures. Values between brackets under 'Degree centrality' represent the in-degree and out-degree measures respectively. In bold are values higher than, or equal to the third quartile threshold (lower or equal to the first quartile threshold in case of 'Burt's constraint'). Numbers between brackets under 'Qualitative data' represent the frequency of respective themes characterizing the incoming and outgoing ties.

	Quantitative data				Qualitative data		
Abbr.	**Degree centrality**	**No. ties strong/ weak**	**Betweenness centrality**	**Burt's constraint**	**Communication relations**	**Collaboration relations**	**Authority/ power relations**
MENR	**32 (17, 15)**	20/12	**110**	**16**	47 (30, 17)	18 (12, 6)	6 (0, 6)
IMB	**28 (14, 14)**	23/5	**108**	**21**	48 (20, 28)	16 (8, 8)	4 (0, 4)
BSBR	**28 (13, 15)**	17/11	**46**	**25**	38 (18, 20)	14 (7, 7)	2 (2, 0)
DBR †	**24 (12, 12)**	16/8	16	28	31 (13, 18)	20 (9, 11)	3 (3, 0)
IZAN	**21 (9, 12)**	14/7	12	28	21 (10, 11)	13 (5, 8)	1 (0, 1)
ONU	**21 (10, 11)**	14/7	12	28	21 (9, 12)	15 (10, 5)	0
IHB	19 (9, 10)	14/5	7	29	28 (9, 19)	15 (6, 9)	1 (0, 1)
KHS	19 (7, 12)	14/5	**20**	**26**	24 (7, 17)	13 (6, 7)	1 (1, 0)
YN	19 (8, 11)	10/9	5	34	33 (11, 22)	18 (8, 10)	1 (1, 0)
US	19 (9, 10)	9/10	7	36	20 (7, 13)	13 (6, 7)	2 (2, 0)
KSRP	18 (9, 9)	7/11	12	42	23 (9, 14)	7 (3, 4)	3 (3, 0)
KNU †	15 (7, 8)	10/5	10	29	15 (7, 8)	8 (4, 4)	0
CRS †	15 (9, 6)	7/8	18	33	22 (14, 8)	6 (3, 3)	0
KSU	14 (5, 9)	10/4	**20**	28	6 (5, 1)	11 (3, 8)	1 (0, 1)
OSRA †	14 (9, 5)	5/9	1	42	16 (14, 2)	9 (5, 4)	1 (0, 1)
LDNP	14 (8, 6)	6/8	3	33	13 (8, 5)	8 (4, 4)	2 (2, 0)
MAPF	13 (7, 6)	7/6	4	36	12 (8, 4)	10 (7, 3)	1 (0, 1)
MSRA	13 (7, 6)	8/5	15	**27**	19 (12, 7)	6 (3, 3)	2 (1, 1)
NPBS	12 (7, 5)	4/8	0	69	17 (10, 7)	4 (2, 2)	2 (2, 0)
WWF	11 (6, 5)	9/2	**20**	31	9 (6, 3)	12 (5, 7)	0
KSRA	7 (5, 2)	3/4	0	44	8 (7, 1)	3 (3, 0)	1 (0, 1)
NECU	6 (4, 2)	5/1	7	38	7 (5, 2)	3 (2, 1)	0

† Institutions that could not be interviewed for which relationships were imputed.

4.3.4 Stakeholder centrality and brokerage

Node level statistics identified central stakeholders (Table 4.3). Three out of nine academic institutions had a very high number of relational ties ('degree centrality' score higher than or equal to the third quartile threshold ≥20). The Ministry of Ecology had the most connections in the network and was the only governmental organization with a high degree centrality score. None of the NGOs accounted for high degree centrality values. The Black Sea Biosphere Reserve and the Danube Biosphere Reserve represented two out of the five protected areas with high connectivity. The ratio of strong to weak ties (for individual stakeholders) was diverse throughout the network. All central stakeholders had more strong ties than weak ties.

We identified four organizations with structurally favorable positions to act as brokers in the network, displayed through their high betweenness centrality (higher than or equal to the third quartile threshold ≥20) and low Burt's constraint values (lower than or equal to the first quartile

threshold ≤27). These organizations were the Ministry of Ecology, the Institute of Marine Biology, the Black Sea Biosphere Reserve and the Kherson Hydrobiology Station (Table 4.3). However, qualitative data showed that only the Ministry of Ecology and the Institute of Marine Biology were actually involved in brokering behavior, such as mobilization of information and resources, deliberation between different types of stakeholders, and coordination of research and conservation action (Table A4.2.2, themes 'Expert groups', 'Scientific supervision', and 'Directing action'). For example, the Ministry of Ecology was reported to form expert groups composed of representatives of various stakeholder categories to discuss progress towards the implementation of the national conservation agenda and to facilitate strategic planning (theme 'Expert groups'). Furthermore, the Ministry of Ecology was involved in directing and coordinating the actions of several scientific institutions (e.g. the Ukrainian Scientific Center of Ecology of the Sea) and all the protected areas (theme 'Directing action'). The Institute of Marine Biology was a scientific supervisor for several protected areas (e.g. the Danube Biosphere Reserve, the Kinburn Spit Regional Landscape Park, and the National Park "Biloberezhia Sviatoslava") and acted as a bridge between them which were otherwise disconnected or weakly connected (Table A4.2.4, 'Pa-Pa' – 10 weak links).

Black Sea Biosphere Reserve and Kherson Hydrobiology Station, although structurally well positioned, did not take advantage of this to initiate Pontocaspian biodiversity related conservation action. These organizations were hosting academic institutions and protected area representatives to do research on their territories, and reported the study results to the Regional Administrations (Table A4.2.2), resulting in their many, and potentially bridging ties (Table 4.3). However, no evidence was found that these organizations initiate any collective action with regard to Pontocaspian biodiversity conservation to utilize their favorable positions, perhaps due to the low priority for Pontocaspian species conservation and lack of funding.

4.3.5 Stakeholder group connectivity

Academic institutions had significantly higher within group density value than expected by random chance (Table A4.2.4). They were also strongly connected to each other (35 strong vs. 12 weak connections) indicative of regular contact. When in contact, the academic organizations exchanged data and experiences, and engaged in face-to-face interactions such as joint research and conservation planning. Links among academic organizations were mostly constrained by lack of funding necessary for research and collaboration (Table A4.2.4). This latter also limited cooperation between academic sector and protected areas as the academic institutions could not afford regular fieldwork within protected areas. Academic institutions and non-governmental organizations were significantly less connected with each other than expected by chance, reflecting comparatively little exchange of information and collaboration between these groups. When in contact, academic institutions and NGOs rarely met face-to-face and mostly interacted via the 'communication relations' (Table A4.2.4). For example, Centre for Regional Studies (CRS) was found to be requesting and receiving scientific information from the Institute of Marine Biology, Odessa

National University, Kherson State University, and Southern Scientific Research Institute of Marine Fisheries and Oceanography on yearly or biannual bases, but no collaborative relation was found between them. CRS used the requested information for preparing reports on state of environment and for providing consultancy to the central, regional and local authorities (http://www.crs.org.ua/en/about.html). Besides the lack of funding, unfavorable policy regulations impeded the desired levels of collaboration between academic organizations and other stakeholder categories. For example, Odessa National University and Southern Scientific Research Institute of Marine Fisheries and Oceanography reported having difficulty conducting an inventory of aquatic species within the protected areas due to a disagreement between the Ministry of Agrarian Policy and the Ministry of Ecology on common study methodology. Policy regulations also obstructed collaboration efforts between NGOs and the protected areas, and among governmental organizations (Table A4.2.4).

Most stakeholder groups had considerably more 'Communication relations' than 'Collaboration relations' (Table A4.2.4), which may indicate that the exchanged information did not always result in conservation action in Ukraine. Governmental organizations were the only ones with equal amount of information exchange and collaborative action. However, governmental organizations were collaborating among themselves only on topics related to commercial fishing and management of aquatic resources; but not on topics related to joint conservation planning (Table A4.2.4). Some stakeholders were involved in specific interactions. For example, WWF in Ukraine was a beneficiary in the project 'Life for Danube Sturgeons' focusing on saving the sturgeon species (https://danube-sturgeons.org/). To implement the project, WWF collaborated with the governmental organizations, such as the Ministry of Ecology, and the Ministry of Agrarian Policy; and a single protected area, namely the Danube Delta Biosphere Reserve (Table A4.2.2).

4.4 Discussion

Pontocaspian biodiversity is in need of effective conservation action, which requires the coordinated involvement of institutions including governmental organizations, NGOs, the academic sector and protected areas. In our analysis, we found that the Pontocaspian conservation network in Ukraine has structural properties capable of allowing optimal conservation action. Institutions within the network are well connected (high network density) and tend to have strong connections to many partners, with whom they collaborate and regularly exchange information (Tables 4.2 and 4.3, Fig. 4.2). The two most central stakeholders in the network, such as the Ministry of Ecology and the Institute of Marine Biology exploit their structurally favorable positions and act as brokers, by mobilizing information and resources and deliberating between different types of stakeholders (Tables 4.3 and A4.2.2). These are, according to network theory, characteristics of a well-functioning network (Crona and Bodin 2006; Fazey et al. 2013; Leavitt 1951). Yet, from our interview results and recently published studies, it is evident that the conservation status of Pontocaspian biota in Ukraine is sub-optimal (Anistratenko and Anistratenko 2018; Dumont et al. 1999; Wesselingh et al. 2019). This is primarily caused by the fact that Pontocaspian biodiversity does not drive the

inter-organizational interactions in Ukraine (Fig. 4.3, Table A4.2.1). Instead, the primary focus is on the conservation of the flagship species, notably sturgeons, leaving the majority of Pontocaspian taxa absent from the conservation agenda. The general lack of knowledge on Pontocaspian species identities and ecology (with the exception of sturgeons) is a likely cause of their observed subordinate role in the organizational interactions. Furthermore, the optimal functioning of the structurally adequate network for biodiversity conservation is challenged by social variables such as limited funding availability and lack of consistency in conservation policy.

4.4.1 Network relations and challenges to optimal Pontocaspian biodiversity conservation

Stakeholder organizations in Ukraine are in close contact, but rarely discuss or act on issues related to Pontocaspian species (Fig. 4.3, Table A4.2.1). Typically, stakeholder interactions target Pontocaspian flagship species, such as sturgeons; commercially important species, including few Pontocaspian species such as the gobies; and alien invasive species (Fig. 4.3, Table A4.2.1, themes - 'Sturgeon conservation', 'Commercial fishing' and 'Ecological data'). Few other Pontocaspian species, such as some bivalve species, were mentioned as part of the theme 'Threatened species data' (Fig. 4.3, Table A4.2.1). Themes listed under the 'Collaboration relations' category mostly exclude Pontocaspian species with the exception of sturgeons. However, these themes do target the Pontocaspian habitats, including coastal areas and the lower stretches of the rivers (Fig. 4.1), indirectly affecting biological communities occupying these habitats. The minor role of Pontocaspian species in organizational interactions is likely a result of low level of knowledge regarding Pontocaspian species, including a lack of clarity on species identities. Recent research on Pontocaspian mollusk taxonomy and autecology supports this observation by showing that many of the Pontocaspian mollusk species have disputed identities, multiple synonymies and are data deficient in the IUCN Red List Databases (Wesselingh et al. 2019).

In addition to knowledge gaps, utilization of exchanged information in conservation planning is suboptimal and needs to be studied further. From the interviews, we learned that information exchange between the academic sector and governmental organizations and between protected areas and governmental organizations occurs on mandatory bases. However, the advice and recommendations that are exchanged, are not always taken into consideration and do not always translate in conservation action, even when stakeholders are strongly interlinked (Table A4.2.4). Additionally, we found that regional administrations, central governmental bodies, the academic sector and NGOs operate at a variety of scales and sometimes independently, complicating conservation efforts. For example, the regional administrations involved in biodiversity conservation were separated from the Ministry of Ecology in 2010. As a result, the actions of the regional administrations are no longer centrally coordinated and controlled, reported as 'Legal limitations' among 'Gov-Gov' interactions (Table A4.2.4). Regional administrations are not decision makers, but execute with disparate views on biodiversity conservation targets. Effective biodiversity

management and species conservation requires coordinated actions from different institutions to be based on the best available knowledge and recommendations (Binning et al. 1999; Briggs 2001).

Optimal functioning of the studied network is restricted by funding availability (Tables A4.2.3 and A4.2.4). Project-based collaboration on conservation of Pontocaspian biodiversity is limited in Ukraine (Fig. 4.3, Table A4.2.1) and the exchange of information mostly occurs due to organizational mandates or voluntary actions and supporting attitudes of organizations. Academic institutions suffer most from the lack of funding, which often translates into weak connections (Table A4.2.4). From the stakeholder narratives, we learned that weak connections rarely result from conflicting views or lack of acquaintance, but rather from lack of funding. For example, few academic organizations can financially afford to carry out fieldwork within protected areas more than once a year. Limited available funding to study the Pontocaspian species and their absence from the global biodiversity databases such as the IUCN Red List of Threatened Species reduces the interest of NGOs to collaborate on topics related to these taxa. Consequently, NGOs focus on obtaining funding on the flagship species conservation and have a relatively marginal position in the network (Tables 4.3 and A4.2.4).

In some cases, the criteria for grant applications further limit access to funding for Pontocaspian biodiversity projects. For example, Universities are excluded from projects funded by the National Academy of Sciences of Ukraine (NASU), and organizations under NASU are not eligible to take part in projects funded by the Ministry of Education and Science. Similarly, grants from regional administrations are mostly aimed at organizations within the region. International small grants are mostly available to NGOs, or NGOs plus a regional administration. The European Union 'LIFE Program' projects (https://ec.europa.eu/easme/en/life) are aimed at organizations registered in EU and usually involve one, or few institutions from Ukraine as associated beneficiaries, e.g. involvement of WWF in Ukraine in a sturgeon conservation project (Table A4.2.2). Cross-Border Cooperation (CBC) projects (https://www.euneighbours.eu/en) are the only ones, which frequently combine different types of stakeholder organizations, such as academic institutions, NGOs and protected areas. While the term 'Pontocaspian' is largely absent in the formulations of CBC projects, these projects target Pontocaspian habitats such as the lower Danube river and the Black Sea coastline. CBC grants, however, limit stakeholder participation to local or regional parties. For example, the programs on Black Sea conservation allow participation of only those organizations, which are located in the Odessa, Kherson and Mykolaiv regions. Similarly, grants on the conservation of the Danube Delta target only organizations from the Odessa region. In summary, available funding schemes in Ukraine limit the participation of multiple stakeholders from different administrative regions with unparalleled ecological knowledge and experiences to collaborate and act together, which is a necessary precondition for optimal conservation. This has previously been recognized as a challenge for research and conservation action in Ukraine by an independent panel of experts and national peers, and recommendations have been developed for

improvement through increased availability of grants to all types of stakeholder organizations from a centralized state fund (Chang et al. 2017).

The lack of consistency in biodiversity conservation policy ('Legal limitations') is another factor that hampers adequate collaboration and Pontocaspian conservation action (Tables A4.2.3 and A4.2.4). 'Legal limitations' refer to uncoordinated action of regional administrations, and to some of the national laws in Ukraine which are contradictory and create confusion among conservation organizations. For example, fish, mollusks, as well as water resources in general are under the control of the Ministry of Agrarian Policy and Food (MAPF), whereas protected areas are under governance of the Ministry of Ecology (MENR). Laws made by MAPF that regulate research methodologies and set standards to assess commercial fish and mollusk species richness and population densities are not implemented by the Ministry of Ecology. Therefore, academic institutions contracted by the MAPF face restrictions in conducting research within protected areas (Table A4.2.4). Interviewed stakeholders are aware of the contradicting national laws and MENR is taking a leading role in resolving the legal inconsistencies and coordinating the efforts to reach better alignment of laws and regulations.

4.4.2 A strong social network is in place to improve Pontocaspian conservation

We argue that the key structural characteristics of the studied network, such as high number of connections and reciprocated ties, high network centralization, and clearly defined broker institutions, are favorable for effective biodiversity conservation actions (Tables 4.2 and 4.3). The content of interactions (Fig. 4.3, Table A4.2.1) and the social variables, such as the funding and policy frameworks (Table A4.2.3), seem to be more consequential for biodiversity conservation outcomes than the network structure itself. According to network theory, centralized networks are highly beneficial in the initial phase of the conservation process to disseminate information, mobilize and coordinate resources, and to make simple decisions (Leavitt 1951; Olsson et al. 2004). Decentralized networks with multiple stakeholders holding many relational ties are more suitable to solve complex long-term conservation challenges (Crona and Bodin 2006; Leavitt 1951). In Ukraine, our results together with the reviewed literature suggest that there is a long tradition of research on Pontocaspian biodiversity but the translation of research outputs into effective biodiversity conservation actions is relatively novel (Anistratenko 2009; Cuttelod et al. 2011; Munasypova-Motyash 2009a, b). A 'centralized network' such as we find in the current phase is well placed to overcome this hurdle, making the existing network structurally suited to implement an improvement in Pontocaspian biodiversity conservation actions.

The two identified broker organizations in the studied network (Table 4.3) are very important stakeholders, considerably influencing the functioning of the network, and need to be involved in long-term Pontocaspian biodiversity conservation and planning in Ukraine. Furthermore, the qualitative data indicates that WWF in Ukraine is involved in the conservation of Pontocaspian flagship species, such as the sturgeons, through the enforcement of conservation laws and awareness

raising activities (Table A4.2.2). Besides the identified interactions in the studied network, WWF in Ukraine operates a large network of young volunteers and students, and closely collaborates with different entities such as fishery patrol inspectors and state border guards in Odessa. Therefore, WWF in Ukraine has the potential to rapidly spread new knowledge throughout the network and beyond, if supplied with information. WWF in Ukraine, together with two identified broker institutions, which are the Ministry of Ecology and Institute of Marine Biology, can play a critical role in the initial phase of Pontocaspian biodiversity conservation action, through organizational capacity building, and awareness raising to expand the current scope of conservation initiatives beyond flagship species. However, the factors hampering conservation efforts must be addressed to create conditions in Ukraine, which can support collective actions. In summary, the observed structural properties of the network suggest that improving the content of interactions through resolving taxonomic uncertainties and raising awareness of non-flagship species, combined with addressing the limiting social variables, such as funding scarcity and contradicting laws will enable a rapid improvement in effectiveness of Pontocaspian biodiversity conservation actions.

4.5 Conclusion

We identified a strong stakeholder network for Pontocaspian biodiversity conservation in Ukraine. Yet, indications of Pontocaspian biodiversity decline have not resulted in strong, concerted conservation actions. Overall, it emerged that Pontocaspian taxa play a minor role in inter-organizational interactions. Academic institutions and the protected areas study specific aspects of Pontocaspian biodiversity, but research outputs are not always related to, or translated into, environmental policy and biodiversity conservation planning priorities. Funding scarcity, legal limitations and taxonomic uncertainty of Pontocaspian biota emerged as key contributing factors leading to the observed sub-optimal conservation outcomes. With the current stakeholder landscape in Ukraine, it can be expected that improved taxonomic definitions of Pontocaspian species and better understanding/awareness, combined with increased research funding and more consistent conservation policy will quickly translate into increased conservation actions. The maintenance of the existing network in Ukraine is, however, a critically important pre-condition for such actions.

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Appendices

Appendix 4.1. Interview protocol, survey questions and missing SNA data.
Appendix 4.2. Network findings.
Appendix 4.3. SNA term definitions.

Appendix 4.1. Interview protocol, survey questions and missing SNA data.

Interview protocol

Network data was acquired through semi-structured, in-depth interviews with the heads or vice-heads of institutions using a questionnaire (see survey questions below). Qualitative data regarding the overall, tie-focused descriptions was collected using a general question: "Do you have professional acquaintance/links with [stakeholder organization named here from table 4.1]?" If the answer was positive, follow-up questions were asked, allowing interviewees to narrate the content of the interaction: "How would you describe your interaction with this stakeholder? What matters/topics do you discuss when you are in touch?" These questions were asked in general terms, without referring to Pontocaspian biodiversity. After the narrative, a specific question was asked addressing Pontocaspian biodiversity related information exchange: "Do you exchange scientific data, information, knowledge, opinion or advice regarding Pontocaspian biodiversity with this stakeholder organization?" In cases of short or unclear answers, the interviewees were asked to explain the link in more detail and provide examples of interaction. We were particularly interested in Pontocaspian biodiversity, so if the answer to this question was negative, we stopped asking regarding this particular stakeholder, and moved on asking about the next stakeholder organization from the list of identified 22 organizations. Subsequently, the interviewees were asked to rank the strength of the reported Pontocaspian biodiversity related interactions using a table of strength definitions developed as part of the questionnaire (Table A4.1.1). Once the Pontocaspian biodiversity related relational link was established, its perceived sufficiency was addressed through the question: "Do you consider your contact with this stakeholder sufficient or insufficient to achieve effective collaboration and information exchange?" In case of insufficiency, a follow-up question was asked: "If the contact is insufficient what is the reason you are not in contact more often?" Not all stakeholder institutions were easily reached or willing to answer the interview questions, resulting in some missing data. We used the imputation-by-reconstruction method (Stork and Richards 1992) to deal with missing data (see 'missing SNA data' section below for details).

Survey questions

Background

1. Organization name?
2. Name of the person interviewed ?
3. Position of the person interviewed?
4. Location?
5. Date?

Relationships for social network analysis (SNA)

6. Do you have Professional acquaintance/links with [stakeholder organization named here from the list of selected 22 organizations]?
7. How would you describe your interaction with this stakeholder? What matters/topics do you discuss when you are in touch?
8. Do you exchange scientific data, information, knowledge, opinions or advice regarding the Pontocaspian biodiversity with this stakeholder organization?
9. From the table below, how strong would you classify your professional acquaintance/links with this stakeholder?

Table A4.1.1. Tie strength definitions.

Weight	Strength	Definition
0	Absent	We are never in contact with each other.
1	Very weak	We have been in contact at some point in the past and foresee contact in the future.
2	Weak	We are in contact incidentally, e.g. if we have joint projects or if we need specific knowledge, services, support or expertize from each other. However, the rate of interaction is low and irregular.
3	Strong	We are in contact regularly, on a monthly or quarterly basis.
4	Very Strong	We are in contact very often, on a daily or weekly basis.

10. Do you consider your contact with this stakeholder sufficient or insufficient to achieve effective collaboration and information exchange?

10a. If the contact is insufficient what is the reason you are not in contact more often?

Missing SNA data

Missing interview data complicates the social network analysis (Barnes et al. 2016; Dean Jr and Brass 1985; Monge et al. 1983; Prell et al. 2009). Ignoring missing values was demonstrated to have considerable negative effects on the structure of the network leading to significant loss of information (Huisman 2009). Huisman (2009) showed that in directed networks with small amounts of missing data (20-30%), reconstruction provides more representative results than ignoring missing values. The reconstruction method assumes the link between a respondent and a non-respondent to be as reported by the respondent (Stork and Richards 1992). Two preconditions have to be met when using the imputation-by-reconstruction method. Firstly, respondents shall be similar to non-respondents. Secondly, the description of the relational links provided by the respondents shall be reliable. The similarity of respondents and non-respondents shall be verified in two ways: in terms of individual level traits (e.g. legal status) and in terms of the number and strength of links they receive (Stork and Richards 1992). The reliability of the responses can be measured through the confirmation rate. Confirmation rate is the proportion of links described similarly by both stakeholders involved. If respondents and non-respondents

are similar and the confirmation rate is high, it can be assumed that the respondent's description of the link accurately characterizes the relationship between respondent and non-respondent (Stork and Richards 1992). In this study, 82% of the links was gathered and 18% was missing, therefore below the 20% threshold. Out of the four institutions that could not be interviewed one is academic, one governmental, one non-governmental and one a protected area; therefore non-responding institutions are similar to responding institutions in terms of individual level traits. The confirmation rate was 88% and Chi-squared test revealed no significant differences in the distribution of the weights of received relationships between the respondents and non-respondents (p-value = 0.78). Therefore, the imputation-by-reconstruction method was adopted.

Appendix 4.2. Network findings.

Table A4.2.1. Identified themes of stakeholder interactions and their descriptions. 'Frequency' reports the number of mentioning of identified themes by the interviewees. The numbers in brackets reflect how many times the theme was associated to strong vs. weak relational links.

Category	Theme name	Theme description	Frequency (strong/ weak)
Communication relations	Opinions	Exchange of opinions, consultations and recommendations on current work, plans and initiatives; exchange of project management experiences.	81 (50/31)
	Ecological data	Exchange of data and knowledge directly or indirectly related to Pontocaspian communities. For example, data on ecosystem functioning and dynamics to which Pontocaspian species are incidental; data on invasive species, which potentially harm Pontocaspian species; data on species distribution and population genetics, which sometimes involve Pontocaspian species; assistance with species identification.	76 (49/27
	Environmental data	Exchange of information on the state of environment. For example, exchange of study results on the sea and fresh water parameters, pollutants and water resources.	33 (22/11)
	Unspecified content	Exchange of Pontocaspian biodiversity related information reported by an interviewee without specifying the context or the content of interaction. For example, 'if we need specific data we are in touch', 'sometimes our interests overlap'.	25 (11/14)
	Threatened species data	Exchange of information on the state of threatened species, including the red list species; providing consultations.	24 (12/12)
Collaboration relations	Research	Joint fieldwork, lab work and publications, which sometimes involve Pontocaspian species and habitats. Hosting the fieldworks and lab works, providing the necessary equipment and/or space for work and receiving the generated results.	54 (47/7)
	Conservation planning	Collaboration and joint conservation planning, e.g. agreeing on actions; developing and working in joint nature restoration projects; providing scientific support for different conservation activities.	36 (22/14)
	Commercial fishing	Joint planning and regulation of matters related to commercial fishing. For example, rules, methods, mode of fishing, limits, and quotes.	15 (9/6)
	Expert groups	Participation of experts in working group meetings and discussions, which are facilitated by the Ministry of Ecology to solve the coastal lake, river and Black Sea related problems, which sometimes concern Pontocaspian habitats.	7 (4/3)
	Resource management	Joint planning and agreeing on the procedures, limits and standards of use of different biological resources.	6 (2/4)
	Sturgeon conservation	Collaboration, planning and data exchange through the projects on charismatic Pontocaspian species, such as the sturgeons. For example, 'Life for Danube Sturgeons' (https://danube-sturgeons.org/).	3 (3/0)
Authority/power relations	Directing action	Giving directions of work and research, and asking for the generated study results or reports on outcomes, which sometimes involve Pontocaspian species and habitats.	10 (5/5)
	Scientific supervision	Developing and providing research standards and methodology.	7 (6/1)

Table A4.2.2. Number of mentioning of interaction themes by individual stakeholders. Values between brackets represent No. times the theme characterized the incoming ties and No. times the theme characterized the outgoing ties.

	Communication relations					Collaboration relations						Authority/power relations	
Abbr.	**Opinions**	**Ecol. data**	**Environmental data**	**Unspec. content**	**Threat. species data**	**Research**	**Conserv. planning**	**Commerc. fishing**	**Sturgeon conserv.**	**Expert groups**	**Resource managem.**	**Directing action**	**Scientific supervision**
MENR	22(11,11)	8(7,1)	7(6,1)	2(1,1)	8(5,3)	1(1,0)	7(6,1)	3(2,1)	1(1,0)	2(1,1)	4(1,3)	6(0,6)	0
IMB	20(7,13)	21(8,13)	1(1,0)	2(2,0)	4(2,2)	10(3,7)	6(5,1)	0	0	0	0	0	4(0,4)
BSBR	9(5,4)	15(6,9)	6(3,3)	6(3,3)	2(1,1)	9(5,4)	3(1,2)	2(1,1)	0	0	0	1(1,0)	1(1,0)
DBR	13(5,8)	12(4,8)	2(1,1)	2(2,0)	2(1,1)	7(3,4)	10(4,6)	2(1,1)	1(1,0)	0	0	2(2,0)	1(1,0)
IZAN	6(3,3)	11(5,6)	0	1(1,0)	3(1,2)	10(4,6)	3(1,2)	0	0	0	0	0	1(0,1)
ONU	6(3,3)	14(5,9)	0	1(1,0)	0	13(9,4)	0	0	0	2(1,1)	0	0	0
IHB	13(4,9)	4(4,0)	0	11(1,10)	0	12(5,7)	2(0,2)	0	0	1(1,0)	0	0	1(0,1)
KHS	4(2,2)	11(3,8)	5(1,4)	1(1,0)	3(0,3)	9(4,5)	2(1,1)	2(1,1)	0	0	0	0	1(1,0)
YN	4(2,2)	7(3,4)	12(3,9)	1(1,0)	9(2,7)	6(5,1)	1(0,1)	11(3,8)	0	0	0	1(1,0)	0
US	6(3,3)	5(1,4)	4(1,3)	3(2,1)	2(0,2)	3(2,1)	3(1,2)	2(1,1)	0	5(2,3)	0	1(1,0)	1(1,0)
KSRP	9(4,5)	8(3,5)	4(0,4)	2(2,0)	0	5(2,3)	2(1,1)	0	0	0	0	2(2,0)	1(1,0)
KNU	7(3,4)	3(2,1)	1(0,1)	4(2,2)	0	8(4,4)	0	0	0	0	0	0	0
CRS	5(2,3)	8(6,2)	4(3,1)	3(1,2)	2(2,0)	0	6(3,3)	0	0	0	0	0	0
KSU	2(2,0)	2(2,0)	0	2(1,1)	0	8(3,5)	3(0,3)	0	0	0	0	0	1(0,1)
OSRA	8(6,2)	4(4,0)	1(1,0)	0	3(3,0)	0	5(3,2)	0	0	0	4(2,2)	1(0,1)	0
LDNP	3(3,0)	3(1,2)	3(2,1)	3(1,2)	1(1,0)	4(2,2)	3(1,2)	1(1,0)	0	0	0	2(2,0)	0
MAPF	1(1,0)	3(2,1)	5(3,2)	1(1,0)	2(1,1)	1(1,0)	1(1,0)	5(3,2)	1(1,0)	2(1,1)	0	1(0,1)	0
MSRA	5(4,1)	7(4,3)	6(3,3)	0	1(1,0)	0	3(1,2)	0	0	0	3(2,1)	1(0,1)	1(1,0)
NPBS	8(3,5)	2(2,0)	2(2,0)	4(2,2)	1(1,0)	2(1,1)	1(0,1)	1(1,0)	0	0	0	1(1,0)	1(1,0)
WWF	3(2,1)	1(1,0)	1(1,0)	0	4(2,2)	0	8(4,4)	1(1,0)	3(0,3)	0	0	0	0
KSRA	3(2,1)	3(3,0)	1(1,0)	0	1(1,0)	0	2(2,0)	0	0	0	1(1,0)	1(0,1)	0
NECU	5(4,1)	0	1(1,0)	1(0,1)	0	0	1(1,0)	0	0	2(1,1)	0	0	0

Table A4.2.3. Identified themes of insufficient interactions and their descriptions. 'Frequency' reports the number of times a theme was mentioned, with strength of representing links in parentheses.

Name	Description	Frequency (strong/weak)
Budget constraints	Organizations cannot achieve the desired levels of interaction due to the general lack of funding for research and conservation initiatives; and/or due to the unfavourable funding schemes, which restrict the participation of different types of stakeholder organizations in a project.	18 (13/5)
Legal limitations	The desired levels of interaction cannot be achieved due to the lack of consistency in conservation policy, which results from the contradicting national laws and complicates collaboration and exchange of information.	15 (8/7)
Lack of interconnection	The desired levels of interaction cannot be achieved because one of the stakeholders abstains from having more contact.	6 (1/5)
Employee turnover	The desired levels of interaction cannot be achieved because of the staff turnover and the loss of established contacts.	3 (2/1)

Table A4.2.4. Stakeholder group relations. Values in brackets under 'Category' report the number of ties within or between stakeholder groups. An * indicates significant difference from random expectation at 5% level according to the null-model test.

Category (No. ties)	Density (%)	No. ties strong / weak	Reasons for insufficient interaction (No. mentioning)	Themes of interaction (No. mentioning)
Pa-Pa (14)	70	4/10	Budget constraints (1)	Communication relations (Total 19) Opinion (7) Unspecified content (7) Pontocaspian species data (4) Environmental data (1) Collaboration relations (Total 3) Research (3)
Acad-Acad (47)	65*	35/12	Budget constraints (11)	Communication relations (Total 55) Pontocaspian species data (22) Opinion (21) Unspecified content (8) Environmental data (3) Threatened species data (1) Collaboration relations (Total 36) Research (28) Conservation planning (3) Expert groups (3) Commercial fishing (2) Authority/power relations (Total 2) Scientific supervision (2)
Gov-Gov (10)	50	6/4	Legal limitations (5) Lack of interconnection (1)	Communication relations (Total 8) Opinion (4) Environmental data (3) Pontocaspian species data (1) Collaboration relations (Total 8) Resource management (6) Commercial fishing (2)
NGO-NGO (2)	33	2/0	NA	Communication relations (Total 1) Opinion (1) Collaboration relations (Total 2) Conservation planning (2)

Category (No. ties)	Density (%)	No. ties strong / weak	Reasons for insufficient interaction (No. mentioning)	Themes of interaction (No. mentioning)
Acad-Pa (43)	24	29/14	Budget constraints (5) Legal limitations (4) Lack of interconnection (2)	Communication relations (Total 48) Pontocaspian species data (19) Opinion (12) Environmental data (8) Threatened species data (6) Unspecified content (3) Collaboration relations (Total 34) Joint research (21) Conservation planning (7) Commercial fishing (6) Authority/power relations (Total 4) Scientific supervision (4)
Gov-NGO (12)	21	8/4	Employee turnover (2)	Communication relations (Total 14) Opinion (6) Threatened species data (4) Environmental data (2) Pontocaspian species data (2) Collaboration relations (Total 9) Conservation planning (5) Expert groups (2) Sturgeon conservation (2)
Gov-Pa (19)	21	10/9	Lack of interconnection (3)	Communication relations (Total 28) Opinion (13) Pontocaspian species data (9) Environmental data (6) Collaboration relations (Total 8) Conservation planning (8) Authority/power relations (Total 8) Directing action (8)
Acad-Gov (28)	15	13/15	Legal limitations (2) Budget constraints (1) Employee turnover (1)	Communication relations (Total 44) Opinion (12) Pontocaspian species data (12) Threatened species data (11) Environmental data (6) Unspecified content (3) Collaboration relations (Total 13) Conservation planning (5) Commercial fishing (4) Joint research (2) Expert groups (2) Authority/power relations (Total 3) Directing action (2) Scientific supervision (1)

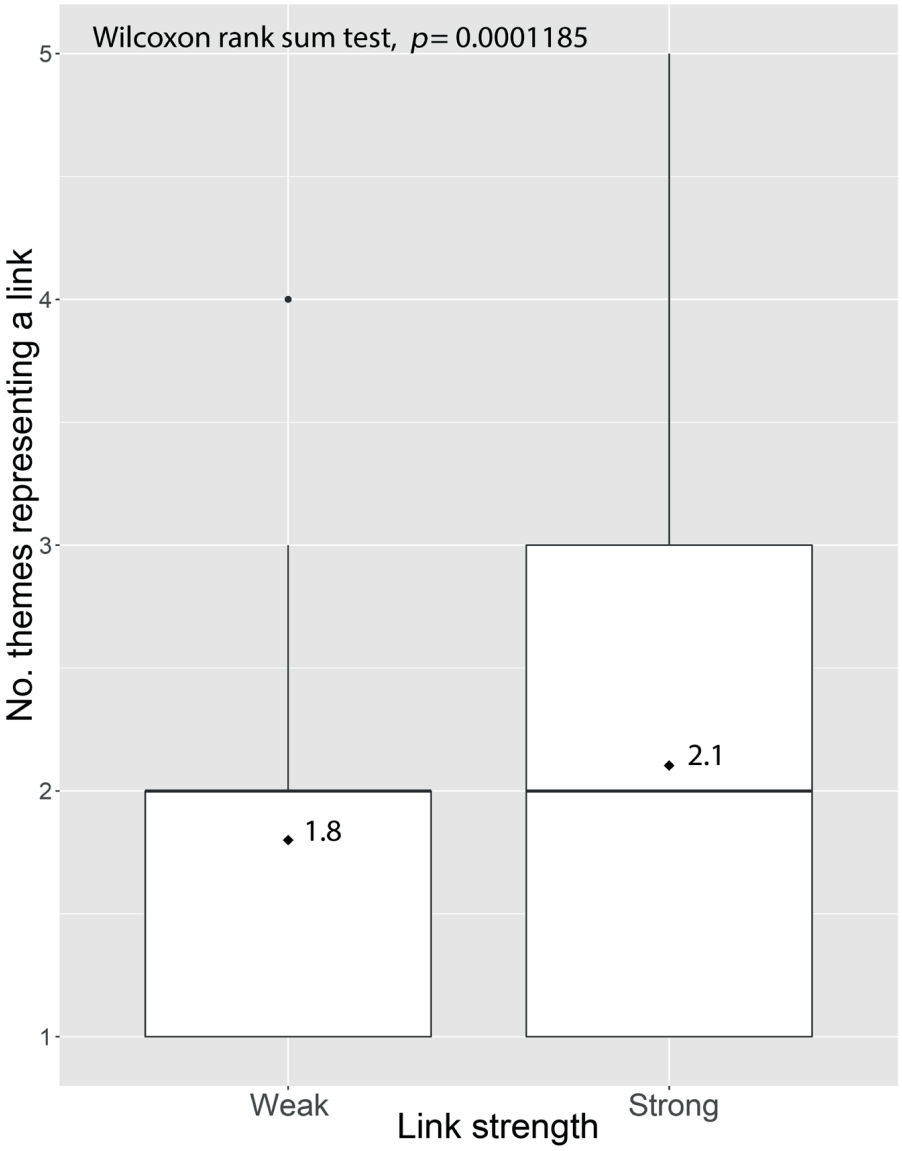

Figure A4.2.1. Boxplot on number of themes representing a link and the strength of the link. Horizontal lines in the boxes represent the median values. Diamonds represent the mean number of the themes.

Appendix 4.3. SNA term definitions.

Betweenness centrality - a measure, developed to assess the extent to which a node is among other nodes in a network i.e. how many times a certain node connects the other two nodes that are not directly connected (Freeman 1978). Betweenness centrality takes the intermediary nodes into consideration and is calculated based on the shortest path among the nodes (Opsahl et al. 2010).

Broker - a node with high betweenness centrality (Freeman 1977) and/or low Burt's constraint score (Burt 1992; Lee 1999; Therriault et al. 2004), which both, receives but also sends many relational ties out to the other stakeholders (Wasserman and Faust 1994) and serves as a bridge between the disconnected or weakly connected stakeholders. Betweenness centrality locates the brokers with respect to all the other actors in the network. Burt's constraint however, is a local measure of brokerage based on the triadic closure principle. A triad is any three nodes in the network with any type of relationship (Davis and Leinhardt 1967). If the tie is absent between two neighboring nodes in a triad, then the triad is incomplete and has a structural hole in it (Burt 1992). A node connecting two disconnected nodes in an incomplete triad has a power to broker. Brokers have low Burt's constraint score, meaning that their behavior is not constrained by the other disconnected nodes in a triad (Burt 1992). High constraint on the actor means that it is involved in many complete triads and is constrained to act as broker.

Burt's constraint - a measure, developed to assess the extent to which an actor's behavior is constrained by the other actors in a network, based on a triadic closure principle. Actor can have a Burt's constraint value ranging from 0, if it is involved in many incomplete triads, to 1, if it is involved in many complete triads (Burt 1992). Lower the actor's Burt's constraint score, lesser its behavior is constrained by other nodes in the network.

Confirmation rate - proportion of relational links described similarly by both nodes involved (Stork and Richards 1992).

Degree centrality - the number of connections that a particular node has with all the other actors in a network (Freeman 1978). In a directed network, the degree of a node is measured through a combination of in-degree and out-degree values. The in-degree value of a node is the number of the actors that have an incoming link to it, and the out-degree value is the number of outgoing links from the node (Kleinberg 1998). In weighted networks node strength represents an extension of degree centrality to the sum of tie weights and integrates information about connectivity and the weights of links (Barrat et al. 2004; Newman 2004; Opsahl et al. 2008).

Directed network - a network, in which the edges have a direction, as such a message or resources are sent from a sender to a receiver (Shannon and Weaver 1949).

Edge - a relational link between actors, also known as arc or tie (Wasserman and Faust 1994).

Network centralization - a measure of the extent to which certain actors are more connected in the network than the others (Freeman et al. 1979; Wasserman and Faust 1994). A centralized network is one in which only one or few actors are having the majority of ties. Such a network has

a high overall centralization score. If actors are not very different from each other in their degree of connectedness, the overall centralization score is low, so the network is decentralized. The network centralization index can be calculated based on 'degree centrality' scores of individual nodes, and indicates the relative dominance of single actors in the network (Freeman et al. 1979).

Network density - also referred to as the graph density, is a measure of the proportion of the relational ties that are actually present in a network. It is calculated by dividing the number of existing ties by all the possible ties in a network (Scott 1991). Density can have a value ranging from 0, if all the ties are absent, to 1, if all the possible ties are present (Scott 1991; Wasserman and Faust 1994).

Network homophily - a selective linking between actors based on specific attributes, such as the category of institution (Newman 2003). Stakeholders are more likely to form strong connections with similar stakeholders than with stakeholders from other categories as they have higher mutual understanding (Prell et al. 2009).

Node - representation of actor in a network, also referred to as a vertex or point (Wasserman and Faust 1994).

Node centrality - a measure of a particular actor's involvement in the network, represented through the degree and betweenness centralities. The more relational ties an actor has, and more times it connects the other nodes that are not directly connected, the more central it is.

Shortest distance - a minimum number of steps that the nodes are away from each other in a network. In weighted networks the tie weights shall be taken under consideration (Opsahl et al. 2010).

Sociogram - a two-dimensional picture showing relationships between the actors where the actors are represented by the nodes and the relationships between them are represented by the edges (Moreno 1953).

Theme - a recurrent unifying concept or a statement about the content/subject of the inquiry (Bradley et al. 2007).

Triad - any three nodes in a network with any type of relationship (Davis and Leinhardt 1967). A triad is complete if all three actors in it are connected to each other, and incomplete if a tie is absent between two neighboring nodes in it (Burt 1992).

Weighted network - a network in which the edges carry values that can be used as a measure of the strength of the relationship (Wasserman and Faust 1994).

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