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GENERAL INTRODUCTION

Biodiversity decline is one of the greatest challenges that humankind is facing today and broad consensus exists on the urgent need of global, large-scale interventions for nature conservation. The current rate of biodiversity loss is unprecedented in the history of the earth (Barnosky et al. 2011). The global wildlife population has fallen by 68% in the last 40 years as a result of human activities (WWF 2020), and almost 75% of the earth's surface has been altered (Kotiaho and Halme 2018). This already has alarming consequences, threatening our economy and social development (World Economic Forum 2020). The cost of inaction is expected to grow even more in the future (OECD 2019). Despite the recognition of dire effects of biodiversity loss, the conservation efforts and interventions of different governments, institutions and stakeholders are still fragmented and lack the coordination and financial means to address the current biodiversity crisis (Díaz et al. 2019; OECD 2019). Ideally, biodiversity and its values to humankind should be recognized and mainstreamed as part of other challenges such as climate change, food security, and circular economy (CBD 2020; Díaz et al. 2019). A prerequisite for this is a well-coordinated, inclusive and integrated governance system that takes the responsibility, and accepts the costs of an effective nature conservation plan (OECD 2019; Waldron et al. 2013). In addition, the available scientific knowledge should be mobilized and additional knowledge generated to help shape such a strategy and monitor its progress.

A legal base for such a large-scale, effective conservation regime already exists, since the signing of the Convention on Biological Diversity (CBD 1992) in Rio de Janeiro by 150 countries. According to the Fifth Global Biodiversity Outlook, which is a periodic report of the CBD, by 2020 partial progress has been made towards the achievement of some of the Aichi Biodiversity Targets. However, the business-as-usual scenario promises further loss of biodiversity and ecosystem services calling for an urgent need for the transformative changes necessary to attain the 2050 Vision for Biodiversity (CBD 2020). European Union (EU) has already agreed and adopted such a transformative post-2020 global framework at the 15th Conference of the Parties (COP) to the CBD, by setting out an EU Biodiversity Strategy for 2030 (European Commission 2020). This Strategy aims to "ensure that Europe's biodiversity will be on the path to recovery by 2030 for the benefit of people, the planet, the climate and our economy, in line with the 2030 Agenda for Sustainable Development and with the objectives of the Paris Agreement on Climate Change" (European Commission 2020).

Fresh and brackish water ecosystems are particularly vulnerable and may well be the most endangered ecosystems on earth (Dudgeon 2012; Dudgeon et al. 2006; Reid et al. 2019; Sala et al. 2000). This is firstly due to high species richness in freshwater ecosystems (Dudgeon et al. 2006; Lundberg et al. 2000), and secondly, due to the concentrated human developments around fresh and brackish water ecosystems (Dudgeon 2012; National Research Council 2000; Vitousek 1997). Brackish environments are transitional zones between marine and freshwater ecosystems, such as the estuaries, lagoons and coastal ponds, which are characterized by the instability of their chemical and physical properties, most importantly the salinity conditions (Cognetti and Maltagliati 2000). These ecosystems are less species-rich compared to marine and freshwater ecosystems (Barnes 1989), but they are highly productive and important ecosystems in terms of their functions, physical and chemical properties, and the animal and plant life that they support (Matthews 1993).

Pontocaspian (PC) ecosystem is a prominent example of brackish water ecosystems. PC biota comprises endemic aquatic ecological communities and species that are confined to the north-eastern part of the Black Sea Basin (BSB) and the entire Caspian Sea (Krijgsman et al. 2019). This biota includes vertebrates such as the charismatic sturgeon species and the Caspian seal (Pusa capsica) but also lesser-known invertebrate groups, e.g., crustaceans, mollusks and annelid worms, and planktonic groups such as diatoms and dinoflagellates (Grigorovich et al. 2003; Marret et al. 2004; Starobogatov 1970). Scientific knowledge on PC species population trends is limited. However, PC habitats in the Black Sea and Caspian Sea Basins are known to have experienced major modifications by human activities, such as habitat fragmentation, pollution and introduction of invasive alien species. This resulted in strong decline of PC species in various places throughout their native range (Lattuada et al. 2019; Markovsky 1953, 1954a, b, 1955; Popa et al. 2009; Velde et al. 2019). Outside their native range, some of the PC species are amongst the 'worst' invasive species, rapidly spreading throughout European and American inland waters (Ketelaars 2004; Reid and Orlova 2002; Ricciardi and MacIsaac 2000), causing large-scale ecological and high economic impacts (Benson and Boydstun 1995; N'Guyen 2016; Pimentel et al. 2005). This calls for a global need for effective PC biodiversity management within, as well as beyond its native range. This thesis deals with the challenges towards effective conservation of PC species in their native range.

Biodiversity change, either positive or negative, is caused by the direct and/or indirect drivers of change (Díaz et al. 2015). Some direct drivers are of natural origin, e.g., earthquakes and tsunamis, some of the droughts and floods. Others have an anthropogenic origin, for example intensive agriculture, overfishing and introduction of invasive alien species (Díaz et al. 2015). Indirect drivers refer to the ways in which people, organizations and societies interact with each other and with nature (Díaz et al. 2015; Salafsky et al. 2002). Examples of such drivers are environmental laws and policies, conservation awareness, conservation governance systems, as well as institutional alignments. Globally, five major direct drivers of biodiversity decline have been identified, namely (in order of importance) changes in land and sea use, overexploitation, climate change, pollution, and invasive alien species (Díaz et al. 2019).

Direct and indirect drivers of PC biodiversity change in their native range are poorly known due to the taxonomic uncertainties, transient boundaries of PC habitats and lack of knowledge on the status and trends of PC populations (Sands et al. 2020; Wesselingh et al. 2019), coupled with the complex socio-political context within which PC biodiversity conservation is embedded (see below). Thorough, global threat analysis studies, like those conducted for freshwater ecosystems, are lacking for brackish PC habitats and species. Anthropogenic threats driving the global freshwater biodiversity decline have been reviewed by Dudgeon et al. (2006) who identified a) overexploitation, b) water pollution, c) flow modification, d) destruction or degradation of habitat and e) invasion by exotic species, as five direct anthropogenic drivers of population decline and range reduction of freshwater species worldwide. With the advancements of human society, however, which in geological terms is referred to as 'Anthropocene' (Crutzen 2016), new and/or previously unrecognised threats have emerged. Reid et al. (2019) updated our knowledge of such emerging threats to freshwater biodiversity by documenting 12 threats that either intensified since Dudgeon et al. (2006) published their work, or are entirely novel. As PC habitats range from marine to freshwater settings in the BSB, threats documented by Dudgeon et al. (2006) and Reid et al. (2019) are relevant and may inform PC biodiversity conservation planning. However, a comprehensive understanding of the specific threats to the unique, brackish PC biodiversity is necessary to inform the PC biodiversity conservation planning.

Direct threat analyses studies that have been conducted in the PC habitats have been focused on either individual countries (Aliyeva et al. 2013; Stanica et al. 2007; Tudor et al. 2006; Varnosfaderany et al. 2015) or selected target species (Burada et al. 2014; Dmitrieva et al. 2013; Poorbagher et al. 2017). However, PC habitats have a patchy distribution and cross the national boundaries, while the PC taxa encompass diverse and very different taxonomic groups such as vertebrates, invertebrates and algae. Therefore, PC ecosystems could benefit from a large-scale, transboundary studies on individual and cumulative effects of human pressures, similar to that conducted by Lattuada et al. (2019) for the Caspian Sea basin. These authors assessed the Caspian Sea basin-wide individual and combined effects of critical anthropogenic pressures on the local ecoregions and found that both cumulative and individual pressure scores were unevenly distributed across the Caspian Sea. They identified the most important individual pressures to be invasive species, chemical pollution and poaching. Similar studies for the PC areas in the BSB are limited to individual PC habitats, see e.g., Burada et al. (2014); Son et al. (2020); Stanica et al. (2007) and Tudor et al. (2006).

Biodiversity conservation is a complex socio-political process involving different dimensions and interests of various stakeholders and end users; as such, the response to the current PC biodiversity crisis can only be a product of human action and organization (Brechin et al. 2002; Durham et al. 2014). Effective PC conservation planning must therefore include social, political and ecological considerations (Ban et al. 2013). Most biodiversity hotspots, including the PC region, are socially and politically dynamic and challenging environments involving countries with diverse histories, economic and political situations, cultures, languages and priorities. PC areas, like most coastal environments in the world, are an important resource for local communities. Therefore, interventions of conservation programs, often produce adverse social impacts and exacerbate the local ecological problems (The World Bank study team 2014). Besides the local fisheries and fisherman in the PC areas, whose livelihoods directly depend on fishing, there are a number of other stakeholder groups including the local agrarian communities, business sectors, such as touristic agencies and recreational centers, the military and the local researchers and conservation planners (CEP 2002; ECODIT LLC 2017; The World Bank study team 2014). Understanding the local stakeholder landscape, their needs and interactions, as well as the additional social variables such as their conservation awareness, attitudes towards nature conservation, motivation to collaborate or participate in conservation actions and their financial status, are critically important to inform conservation planning and management interventions.

The Danube Delta shared between Romania and Ukraine in the north-western BSB, is a prime PC hotspot (chapter 2). With its PC habitats, transnational location and complex socioeconomic and political characters the Danube Delta is an excellent model system for the wider PC region to understand challenges of effective PC biodiversity conservation. The Danube Delta includes the lower stretch of the Danube River, its 3 branches – Chilia, Sulina and Sf. Gheorghe, Razim-Sinoe Lake complex and the adjacent Black Sea coastal ecosystems in Ukraine and Romania (see chapter 2). The delta is internationally recognized as Europe's largest water purification system and an important wildlife habitat (Baboianu 2016). The management of Danube Delta is, however, embedded in highly complex social and political systems, that involve different interests of various stakeholders and different levels of governance (The World Bank study team 2014). For example, Danube Delta as a 'Waterflow Habitat' is a designated Ramsar site in Ukraine and Romania. Additionally, within the UNESCO Man and Biosphere Program, it is declared as a "Danube Delta transboundary Biosphere Reserve Ukraine and Romania". Furthermore, the Danube Delta is protected and managed through the Danube River Protection Convention (1994) and Bern Convention (1979). Additionally, natural resources in Danube Delta are highly sought after by the local inhabitants who live in small villages and rely on direct exploitation of natural resources (Gastescu 2009; The World Bank study team 2014). The unemployment rates within Danube Delta are higher than that of average country-wide rates in both Ukraine and Romania (Koyano 2008). Therefore, conservation planning within the Danube Delta is a challenging task, and the conservation interventions often result in conflicts with local communities and stakeholders (The World Bank study team 2014).

Ukraine and Romania that share the responsibility for effective conservation of species and ecosystems within the Danube Delta (ICPDR 2015, 2020) have different socio-political and economic backgrounds that may affect the outcomes for PC biodiversity conservation. Romania is an EU member state since 2007, while Ukraine is signatory to an EU-association agreement. Consequently, Romania is legally bound to EU Directives, including the Habitats Directive (HD) and Birds Directive (BD), respecting at the same time the national conservation legislation, while

Ukraine is currently in the process of approximation to the EU acquis to meet the conditionality requirements of the accession to the EU (Szarek-Mason 2010). The accession of a country to the EU does not only mean the approximation of the national legislation to the EU acquis, but also development and adoption of institutions and structures by which legally binding legislation can be effectively implemented (Börzel 2009; Carmin and VanDeveer 2004). This process is referred to as 'Europeanization'. Europeanization is known to have encouraged shifting of the old hierarchical governance system in Romania, where state actors would make decisions (Buzogány 2015; Kluvankova-Oravska et al. 2009; Wesselink et al. 2011), towards the new norms which empower different stakeholders to participate in environmental decision making and conservation planning (Dimitrova and Buzogány 2014; Stringer and Paavola 2013). Challenges remain however, due to lack of previous experiences with inclusive governance systems in Romania (Stringer and Paavola 2013). Furthermore, Europeanization resulted in new opportunities to finance biodiversity conservation and to build the European network of protected areas such as the Natura 2000 sites (Buzogány 2015). For comparison, in Ukraine a network of protected areas is built known as the Emerald Network (EN), which is part of implementation of the Bern Convention, as well as the EU conditionality requirements. Natura 2000 and EN are practically the same, providing opportunities for conservation of habitats and species of Resolutions 4 and 6 of the Bern Convention (EN), and all areas that are protected under the HD and BD (Natura 2000). The main difference is that EN is developed for non-European countries and those who are not full members of the European Union (EU) as well as for countries of Eastern European partnership. If such country becomes a member of EU, its EN automatically becomes a Natura 2000 network. In Ukraine, the national legislation on Emerald Network is currently under development; this process started in 2009 (Ministry of Ecology and Natural Resources of Ukraine 2018). Romania, however had to transpose the provisions of the BD and HD into its national conservation legislation before the accession to the EU (Ministry of Environment and Climate Change of Romania 2014). The legal bases for PC biodiversity conservation in Ukraine and Romania may therefore be different and needs to be understood whether they provide sufficient base for conservation.

National and international conservation agendas are controlled by the combined and interrelated interests of conservation policy, science and public opinion (De Klemm and Shine 1993). As a result, the choice of biotic communities or individual species as conservation priorities is often based on anthropomorphic factors, i.e., preference for protection of more 'charismatic' taxa (e.g., PC sturgeon species and a PC seal); and anthropocentric factors, i.e., choice of species with high economic value (e.g., Pontic shad species) (Male and Bean 2005). Based on a study on national red lists from 53 European and Mediterranean countries, Azam et al. (2016) showed that the choice of taxonomic groups for inclusion in the assessments is also greatly influenced by expert availability, data availability and funding opportunities. Despite the high diversity of invertebrate species and their importance to ecosystems and mankind, the universal trend is to focus on conservation of vertebrate species rather than invertebrate species. Invertebrate species are also often ignored in scientific projects, legal documents and conservation plans (De Klemm and Shine 1993; Glowka et al. 1998; Martín-López et al. 2009). Seven impediments have been identified globally to the effective conservation of invertebrate species (Cardoso et al. 2011) which also apply to PC biodiversity. These are 1) public dilemma – invertebrate species are usually unknown to general public, 2) political dilemma – policy-makers and stakeholders are often unaware of the conservation needs of invertebrate species (see e.g. Gogaladze et al. 2020a; Gogaladze et al. 2020b), 3) scientific dilemma – knowledge on invertebrate species is lacking and research is not adequately funded, 4) Linnean shortfall – many of the invertebrate species have not been described (Hortal et al. 2015), 5) Wallacean shortfall – distribution of known invertebrate species is largely unknown (Hortal et al. 2015), 6) Prestonian shortfall – invertebrate species abundance and population trends are not known (Hortal et al. 2015), 7) Hutchinsonian shortfall – invertebrate life history traits, functional roles and sensitivity to changes in the environment are largely unknown (Hortal et al. 2015).

Pontocaspian biodiversity conservation is obstructed by a plethora of challenges. Knowledge on PC invertebrate species identities and numbers, abundance and population trends, life history traits and functional roles, as well as sensitivity to environmental changes are lacking on all - public, political and scientific levels (Wesselingh et al. 2019). The current status of PC biodiversity trends in the BSB is poorly known due to taxonomic uncertainty, the lack of standardized observation data and the transient boundaries of PC habitats (Anistratenko et al. 2020; Sands et al. 2020; Son 2011a, b, c, d, e, f; Son and Cioboiu 2011; Wesselingh et al. 2019). This is further hampered by language barriers (Russia, Ukraine, Romania, Moldova and Bulgaria share PC habitats and species in the BSB and reporting has mostly been done in their respective languages and in unpublished reports), and the complex economic and political situation. Current conservation schemes and approaches, engagement and incentives of relevant stakeholder organizations to act together, legal and political frameworks and the conservation governance systems to address PC biodiversity conservation and management are also poorly known. Furthermore, due to the transnational nature of PC biodiversity distribution, cross-border cooperation and joint efforts are critically important to achieve effective conservation. However, a cross-border cooperation framework is lacking with regard to PC invertebrate diversity. When it comes to PC vertebrate species, such as PC sturgeons or herring species, the public, political and scientific knowledge is more comprehensive and conservation efforts clearer, but they face their own challenges such as poaching and weak law enforcement (Bloesch et al. 2006; ECODIT LLC 2017; ICPDR 2015, 2020).

This PhD project is part of the EU Horizon 2020 Innovative Training Network - Pontocaspian Biodiversity Rise and Demise (PRIDE) program (https://pontocaspian.eu/). PRIDE comprised a large scientific network involving 15 early-stage researchers and 25 institutions. The program aimed to understand the past, present and future of PC biodiversity dynamics in the Black Sea - Caspian Sea region and to investigate PC biodiversity awareness and pathways to effective conservation. It had an interdisciplinary approach involving earth and life sciences as well as social sciences.

The overall aim of this thesis is to contribute to the establishment of effective PC biodiversity conservation regime in the BSB by answering scientific questions to set the research and policy agenda required for improving PC biodiversity data collection, promoting PC biodiversity awareness and establishing a meaningful conservation regime. Specifically, the thesis aims to answer the following research questions:

1) What are the current status and trends in PC invertebrate species and populations in the BSB?
2) What are the direct anthropogenic drivers of PC biodiversity change (either positive or negative)?
3) Are there areas in the BSB that can support viable PC populations today, that could be considered as priority areas in conservation planning?
4) Does the current legal and political framework provide adequate protection to the PC biodiversity in the Danube Delta - a prime PC biodiversity hotspot shared between Romania and Ukraine?
5) Who are the practitioners and stakeholders of PC biodiversity conservation in Romania and Ukraine?
6) How are the stakeholder networks arranged in Romania and Ukraine?
7) Are stakeholder institutional alignments optimal for PC biodiversity conservation in these neighboring countries?
8) What social variables, external to the stakeholder network properties help or hamper PC biodiversity conservation in Romania and Ukraine?

Addressing these questions will shed light to the current state of PC biodiversity in the Black Sea Basin, current conservation capacity of institutional designs and governance architectures and shortfalls in effective PC biodiversity conservation actions.

1.1 Thesis outline

This thesis consists in total of 6 chapters (Fig. 1.1) with the first chapter providing the general introduction and outline of the thesis and the last chapter concluding my findings which are presented in 4 papers (chapters 2-5). Chapter 2 studies PC species and population trends and identifies the direct anthropogenic drivers of the PC invertebrate biodiversity change throughout the entire north and north-eastern Black Sea Basin, based on literature review and practitioner reflections. Chapters three, four and five address indirect anthropogenic drivers of PC biodiversity change. In chapter three we explore the political domain of conservation science, assessing the current legal basis and its effectiveness for PC biodiversity conservation. Chapters four and five address the social dimensions of biodiversity conservation and effective governance systems. Specifically, they deal with institutional alignment, which encompasses all formal interactions

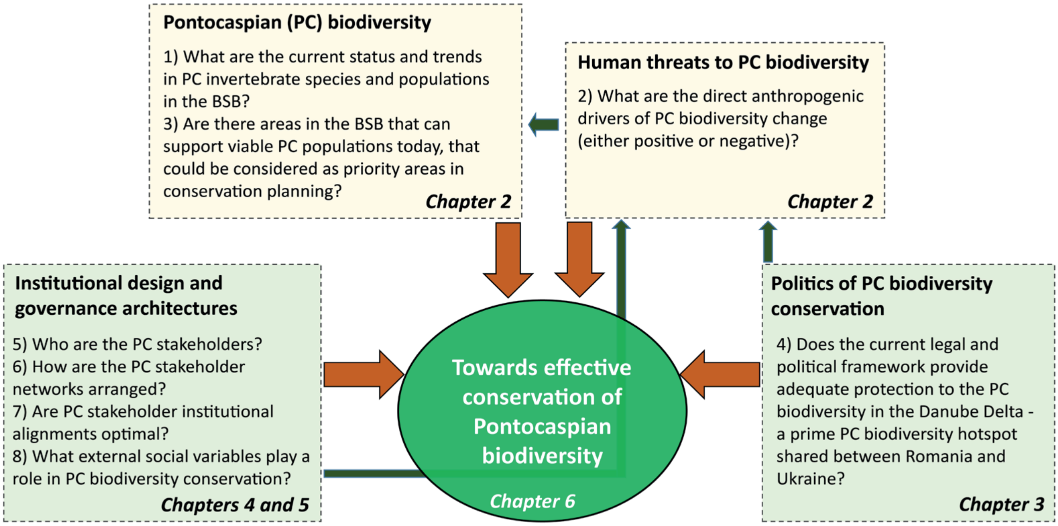

Figure 1.1 Structure of the thesis.

among the stakeholder organizations, including the exchange of scientific information, collaboration and authority/power relations, and their outcomes for conservation governance.

Chapter 2. Decline of unique Pontocaspian biodiversity in the Black Sea Basin: a review.

Lack of an overview of the status and trends of PC species, populations and communities hampers the assessment of risks and limits the design of effective conservation strategies. This chapter assesses the loss of PC habitats and species in the Black Sea - Azov Sea Basin in the past century, using PC molluscs as a model group, and identifies direct anthropogenic drivers of PC biodiversity change. We found that PC biota is severely affected by human activities in the BSB, which resulted in local extinctions, declining numbers and disappearing PC mollusc communities in all study regions. Four regions, namely, the Danube Delta – Razim Lake system (RO, UA), Dniester Liman (UA, MD), Dnieper-South Bug Estuary (UA) and Taganrog Bay-Don Delta (UA, RU) still contain ecological conditions to support PC communities and host threatened endemic PC mollusc species. We identified five direct anthropogenic drivers of change causing the decline in PC biodiversity throughout the BSB. These are 1) damming of rivers, 2) habitat modifications affecting salinity gradients, 3) pollution and eutrophication, 4) invasive alien species and 5) climate change.

Chapter 3. Legal framework for Pontocaspian biodiversity conservation in the Danube Delta (Romania and Ukraine).

Biodiversity conservation benefits from a clear and transparent legal and political framework. This framework is complex, operating on different levels of governance from multi-governmental United Nations (UN) Conventions to national and sub-national laws and practices. Consequently, a single species or a single population is often governed by different rules and regulations, especially if its distribution crosses national borders. Pontocaspian biodiversity has a patchy distribution that spans across the coastal areas of the north and north-western Black Sea Basin as well as the entire Caspian Sea Basin, that exposes them to diverse governments and governance systems. In this chapter we use the Danube Delta, shared between Romania and Ukraine, as a case system to assess the effectiveness of current legal framework to support the PC biodiversity conservation. We examined what was delivered in terms of policies on PC biodiversity conservation on global, EU, and individual country levels in Romania and Ukraine, and how effective the outcomes were. Additionally, we explored whether conservation of 'flagship' and 'umbrella' species such as sturgeons supported the associated lesser-known PC invertebrate species. We show that both PC habitats and invertebrate species are poorly represented in international and national legal documents. Protected areas cover large parts of PC habitats; however, management plans are either not in place or fail to address the PC biodiversity, providing incidental, therefore sub-optimal conservation. Additionally, the current PC biodiversity related legal landscape lacks coherence (mutual reinforcement) on both horizontal (between Romania and Ukraine) and vertical (between Romania and EU as well as Ukraine and EU) levels. Finally, there is little overlap in the distribution of sturgeon species and the invertebrate PC biota and a mismatch between the regulatory scope of sturgeon-related laws and conservation needs of PC invertebrate species. Therefore, a surrogate approach using the umbrella sturgeon species does not work for PC invertebrate species. We end with suggestions and recommendations for improved legal and political framework towards effective PC biodiversity conservation.

Chapter 4. Using social network analysis to assess the Pontocaspian biodiversity conservation capacity in Ukraine.

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. In this chapter we investigated the interorganizational network of stakeholders in Ukraine, and studied the implications of network properties for the conservation of Pontocaspian biodiversity. We identified a structurally optimal - well-connected and centralized network in Ukraine, with high numbers of reciprocated links and inclusive, participatory governance system. However, the strong network did not translate into effective conservation of Pontocaspian biodiversity because of the subordinate role of this biota in the interorganizational interactions, likely due to lack of knowledge on these taxa. Social variables, such as funding scarcity and legal constraints were found to further limit the effectiveness of conservation actions. We conclude that with the current stakeholder landscape in Ukraine, it can be expected that improved knowledge on PC species and better understanding/awareness, combined with increased research funding and more consistent conservation policy could quickly translate into increased and improved conservation actions.

Chapter 5. Social network analysis and the implications for Pontocaspian biodiversity conservation in Romania and Ukraine: A comparative study.

Different network structures of stakeholder organizations suit different conservation contexts and phases, and the suitability of structures as well as the network properties change over time. Romania and Ukraine have a common responsibility to address the conservation of Pontocaspian biodiversity. The two countries, however have different socio-political and legal conservation frameworks, which may result in differences in the social network structure of stakeholder institutions with different outcomes for PC biodiversity conservation. This chapter compares the institutional alignments in Romania and Ukraine and examines the outcomes of identified network properties for PC biodiversity conservation. We found that in Romania there is a room for improvement in the network structure through e.g., more involvement of governmental and nongovernmental organizations and increased involvement of central stakeholders to initiate conservation actions. When in contact, stakeholder organizations rarely discussed PC biodiversity conservation. Furthermore, social variables, such as lack of funding, hierarchical and a non-inclusive system of conservation governance, political constraints and continuous institutional reforms in the public sector hampered collaboration resulting in suboptimal conservation actions. Consequently, similar to Ukrainian network, the Romanian institutional alignment translates into sub-optimal conservation actions. However, the roads to optimal conservation are different in Romania and Ukraine.