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ORIGINAL ARTICLE

Global environmental governance for conserving migratory shorebirds in the Asia-Pacific

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Abstract

Understanding the sets of co-existing institutional arrangements and the role of different actors for transboundary conservation is not only paramount for migratory species survival but also for studying the transformation of international politics. We analyze the global environmental governance architecture for conserving migratory shorebirds in the Asia-Pacific. We ask, (i) how has the architecture emerged in relation to levels of governance, type of actors, formality, and topology?; and (ii) how does the topology and agency of actors vary across the architecture when accounting for different threats to these species (i.e., habitat loss and hunting)? We use a mixed method approach, based on qualitative data and quantitative network analysis, to characterize and examine the architecture, thereby extending the precision of singular approaches. We find that 28 institutional arrangements, involving 57 state and non-state actors, have emerged since the 1970s. The resulting architecture conforms to concepts and symptoms of institutional complexity, alternately exhibiting characteristics of a regime complex, fragmented governance, and polycentrism. Our results indicate increased interactions of actors across sectors of society and levels of governance, but do not support notions of state retreat and diffusion of power away from the nation-state. Instead, we show that actors beyond the nation-state have emerged as a complement to a nation state-centered architecture. Moreover, when we consider the subset of institutional arrangements for habitat conservation and hunting management separately, hunting management emerges as the exclusive domain of the nation-state. It remains unclear whether this difference is driven by differences in property rights or other sets of drivers.

Highlights
- A global environmental governance architecture has emerged for conserving migratory shorebirds in the Asia-Pacific.
- Actors interact across sectors of society and levels of governance.
- Despite reconfiguration of agency, the nation state remains central to the architecture.
- Architecture presents different characteristics for addressing different threats to shorebirds.
- Non-state actors participate in rule-making for habitat conservation, but not for hunting management.

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Introduction

Emerging trends of environmental governance in transboundary settings and conserving migratory species are two topics closely interwoven warranting further research. Legally binding international agreements have been traditionally considered the cornerstone of governance for addressing transboundary environmental issues. However, new forms of transboundary governance have emerged since the late twentieth century as apparent from three main trends: (a) increased participation of non-state actors, (b) rise of novel institutional arrangements, and (c) increased interactions across levels of governance and sectors of society (Pattberg and Widerberg 2015). Political scientists conceptualize this transformational phenomenon as global environmental governance (Biermann and Pattberg 2008) and are increasingly focusing on what this change means for the environment from the regional (i.e., subsets of countries) to the global scale (i.e., the whole world). These processes have often been theorized based on empirical evidence skewed towards particular issue areas, such as climate change, fisheries, and forestry, with other issue areas, such as biodiversity loss, receiving less attention (Dauvergne and Clapp 2016; Parry 2004). Further, the analysis of global environmental governance has been mostly qualitative and opportunities to add quantitative precision so far largely unexplored (O'Neill et al. 2013). It is within this context that we chose to study the governance of conserving animals that migrate across multiple countries. We do so to help advance theory about emerging trends of environmental governance, as well as conservation practice.

Some migratory species, including migratory shorebirds, are transboundary and global commons used and affected by humans in a variety of dimensions. Many of these animals provide a seasonal, yet predictable and superabundant, resource that humans exploit both directly (Eason et al. 2015) and indirectly (Bagstad and Wiederholt 2013). Migratory species are also appreciated intangibly by human societies (Close et al. 2002). Yet, despite their importance, many of these species have declined, some even to extinction, often compounded by the large spatial scales of their movements (e.g., Harris et al. 2009; Kirby et al. 2008). Key threats to migratory species include physical barriers to movement, habitat loss, overharvesting, and incidental mortality (Wilcove and Wikelski 2008). These threats may operate unevenly across their migratory ranges in association with an array of socio-economic and political contexts as they cross various countries (Kark et al. 2015; Piersma et al. 2016). The decline of migratory species does not only represent biodiversity loss from a compositional perspective (i.e., species extinction) but also from a functional standpoint (i.e., disruption of ecological processes; Noss 1990; Wilcove and Wikelski 2008).

Reversing the declines of migratory species requires mechanisms of coordination and cooperation between actors covering the entire spatial scale of their life cycle, so threats can be understood and addressed accordingly. Conservation actions need to be coordinated horizontally to account for the full spatial scale of populations across different jurisdictions (e.g., nation-states, high seas), as aggregate effects of single actions (e.g., harvest; Epstein et al. 2009) and disruption to the network structure of migratory movements (e.g., migratory bottlenecks; Morrison and Bolger 2014) can lead to population declines (Studds et al. 2017). In this context, multilevel governance is critical to their conservation, as centers of decision-making need to be vertically coordinated across jurisdictions that are hierarchically nested (e.g., from subnational to national and supranational, Runge et al. 2017; Piattoni 2009). This coordination allows for translation of rules at various governance levels into actions on the ground (Selin 2010), as well as to scale up local initiatives through regulatory frameworks at higher governance levels (Peters 2001). Cooperation, through financial assistance and capacity building, is also essential because of uneven capacity of actors to undertake monitoring and conservation actions. Conserving these species requires institutional arrangements, understood as explicitly agreed upon rules and principles to achieve collective action goals, at high levels facilitating coordination and cooperation across multiple jurisdictions, and also at lower levels, connecting governance processes from local scales to the full spatial scale at which species migrate (Berkes 2007; Giordano 2003).

Despite the recognized importance of overarching institutional arrangements to foster migratory species conservation, the large areas involved have often hindered their development. Depending upon the species' migratory cycle, their governance can include a wide range of actors across multiple countries (Ankersen et al. 2015; Gallo-Cajiao and Fuller 2015a) and levels of governance potentially resulting in tensions given by different discourses, interests, and values (Campbell 2007). The possibility of developing single overarching institutional arrangements matching the whole migratory range of particular species is constrained by geopolitics, cultural differences, political interests, and economic disparities (Boardman 2006). Additionally, variation in problem definition can influence the development of institutional arrangements; for example, understanding of migratory ranges has

been recently unveiled for some species (Shillinger et al. 2008), while for others, these remain insufficiently understood (Rowat and Brooks 2012). Consequently, conserving migratory species that cross national borders is often framed by a set of institutional arrangements, conceptualized as a global environmental governance architecture, which varies according to different provisions, membership, spatial scope, and formality (Boardman 2006; Matz 2005).

Here, we analyze the global environmental governance architecture for conserving migratory shorebirds in the Asia-Pacific, with a focus on institutional complexity and the reconfiguration of actor agency in rule-making accounting for problem structure (i.e., the nature of threats). We ask, (i) how has the global environmental governance architecture emerged in relation to levels of governance, type of actors, formality, and topology?; and (ii) how does the topology and participation of actors vary across the architecture when accounting for problem structure (i.e., habitat loss and hunting)? Migratory shorebirds in the Asia-Pacific provide a suitable model system because many of these species complete their life cycle across multiple countries (Bamford et al. 2008), some of their populations have been declining (Studds et al. 2017), and multiple institutional arrangements across countries relevant to their conservation have emerged (Boardman 2006). Additionally, while various institutional arrangements relevant to conserving migratory shorebirds in this region have previously been compiled (CMS 2014; Mauerhofer and Nyacuru 2014; MacKinnon et al. 2012; Scott 1998; Anonymous 1996) or researched in isolation (Takahashi 2012; Clarke 1999), no study has characterized and analyzed them in toto from a global environmental governance perspective at a regional scale. Hence, we approach global environmental governance as a transformational phenomenon of international politics, and global environmental governance architecture as the collective of institutional arrangements across countries including state and non-state actors. A thorough identification and understanding of this framework is fundamental for advancing migratory shorebird conservation in the Asia-Pacific, as these institutional arrangements set, in principle, the mechanisms of coordination and cooperation needed to, at least, avert population declines.

This research is theoretically framed within both the ecology of animal migration, as well as the study of global environmental governance (supplementary material 1). We use a mixed method approach based on qualitative data and quantitative network analysis focusing on membership to, and provisions of, institutional arrangements. Our analysis of reconfiguration of actor agency follows a proposed conceptual model that incorporates the two dimensions in which the locus of authority operates (i.e., level of governance and sector of society; Fig. S.1). This approach enables us to understand the dispersion of authority away from the nation-state over time. We identified and analyzed three architectures using quantitative network analysis, as follows: (1) a whole architecture that includes all institutional arrangements, (2) a habitat architecture that includes all institutional arrangements for designating conservation areas, and (3) a hunting architecture that includes all institutional arrangements for hunting management. Global environmental governance has emerged in the whole and the habitat designation architectures, but not in the hunting management architecture, suggesting that the reconfiguration of agency away from the nation-state is not a pervasive phenomenon of environmental governance in transboundary settings. Additionally, we observed that the emergence of other actors did not happen at the expense of nation-state participation. From a conservation perspective, we discovered that the global environmental governance architecture matches the full scale of shorebird migration in the region, but coordination amongst institutional arrangements remains likely a major challenge.

Key concepts for studying global environmental governance

Institutional complexity

The conceptualization of co-existing institutional arrangements in relation to specific issue areas spanning beyond single countries remains debated. Empirical studies have now established how issue areas are seldom addressed through single institutional arrangements, but rather by a suite of them (e.g., Keohane and Victor 2011). Analysis of institutional diversity in this context has focused on both patterns and symptoms of complexity and has included “regime clustering” (Oberthür 2002), “treaty congestion” (Lukitshc-Hicks 1999), “fragmentation” (Biermann et al. 2009a), “polycentricity” (Ostrom 2010), and “regime complex” (Keohane and Victor 2011). Whereas some of these studies have included state as well as non-state actor participation (Abbott 2012), others have been primarily limited to nation-states and formal international agreements (Keohane and Victor 2011). Some of these concepts have additionally been biased normatively, which has dismissed the ontology of co-existing institutions. For instance, while some of these concepts imply conflicting outcomes stemming from institutional multiplicity (e.g., treaty congestion; Lukitshc-Hicks 1999), others connote more flexible and effective governance (e.g., polycentricity; Morrison 2017). Furthermore, even though the concept of fragmentation has been proposed to be value free by some authors (e.g., Biermann et al. 2009a), it surely denotes the division of a whole, which has possibly never existed.

Within a global environmental governance context, architecture is defined as the sum of institutional arrangements that facilitate all actors, state and non-state, address transboundary issues. We approach global environmental governance

architecture as the *set* of institutional arrangements, *involving at least two actors across national borders*, relevant to a particular issue area. We base this working definition on the need to make it value-free, as well as in delimiting clearly the dimension in which institutional arrangements are embedded. Originally, the definition of environmental governance architecture (Biermann et al. 2009a) includes the "overarching system." We have replaced "system" with "set" to avoid the bias of perceiving a system as defined by interacting parts forming a functioning whole. Conversely, we view a set of institutional arrangements as a group of elements with some resemblance that do not necessarily interact or at least not with a particular outcome. This distinction is important, because the study of the global governance architecture in any given issue area needs to account for all relevant transboundary institutional arrangements across countries, regardless of their interactions. We have also replaced "overarching" with "involving at least two actors across national borders." We do so, because overarching, as a term, is not explicit enough to operationalize empirically what constitutes an institutional arrangement that is part of any given global environmental governance architecture. Therefore, we have introduced a more explicit dimension through which global environmental governance architecture can be analyzed, which is consistent with the transboundary notion of global environmental governance (Weiss and Wilkinson 2014).

Agency of actors

Global environmental governance postulates a reconfiguration of agency that remains insufficiently understood due to a lack of precision; therefore, we propose here a conceptual model that captures such an empirical reality redressing previous gaps. In this context, agency can be conceptualized as the capacity to influence and guide behavior of actors to achieve a particular outcome (Dellas et al. 2011). Agency, however, needs to be considered within the limits of how actors relate to one another, as well as to existing social structures. While this relationship can constrain possibilities for action, these actors can in turn influence other actors and the social structures constraining their own course of action (O'Neill et al. 2004). We approach the locus of authority of actors involved in institutional arrangements through a bidimensional model as a function of governance level and sector of society. This conceptual model overcomes shortcomings of previous models, which either fail to capture governance level (Abbott 2012), or do not allow the representation of multiple loci of authority across sectors of society (Andonova and Mitchell 2010). If the agency of actors engaged in institutional arrangements in transboundary settings is considered as their authority for rule-making, then the locus of their authority can be considered as a function of the level at which they exert authority and the sector of society they represent (Fig. S.1). Having a conceptual model that represents these two dimensions is fundamental, so that the process of reconfiguration of actor agency can be researched empirically and support theory-building. This process also makes it possible to carry out robust empirical studies that allow the accumulation of comparable data from different cases.

Migratory shorebirds in the Asia-Pacific

Many shorebird species complete their life cycle across the Asia-Pacific region (Bamford et al. 2008). Shorebirds are a group of birds that includes all families with non-web-footed species within the order Charadriiformes (Van de Kam et al. 2004; Hayman et al. 1986). In the Asia-Pacific, they primarily breed in the Arctic and boreal regions across northeast Asia and Alaska, migrating through East Asia, where they stop to rest and refuel at coastal habitats known as *stopping sites*. The Yellow Sea, between northeast China and the Korean peninsula, constitutes a bottleneck for a suite of species where a great proportion of their populations funnel *en masse* during migration (Bamford et al. 2008; Fig. S.2), which potentially renders some of those sites bearing a disproportionate importance for the maintenance of whole populations (Rogers et al. 2010). Non-breeding areas encompass mainly coastal and inland wetlands across Southeast Asia, Australia, and New Zealand. This entire region has become known as the East Asian-Australasian Flyway spanning 22 range states through which 57 species migrate (Bamford et al. 2008; Fig. S.3, Table S.1), which could be regarded as a complex social-ecological system (Berkes et al. 2003). This flyway in the Asia-Pacific is one of the four recognized global waterbird migratory flyways, the others being Americas Flyway, Africa-West Eurasia Flyway, and Central-Asian Flyway (CMS 2014).

A suite of anthropogenic threats to migratory shorebirds, which are unequally understood, define the problem structure in this specific social-ecological system. For instance, habitat loss monitoring at large spatial scales has been possible through remote sensing methods (Murray et al. 2012). Recent analysis of intertidal wetlands of the Yellow Sea has revealed the loss of two thirds of their area in the last 50 years (Murray et al. 2014). Hunting is a much more difficult threat to appraise at large spatial and long temporal scales (Gallo-Cajiao and Fuller 2015b). Nevertheless, this threat is likely to have been one of the most important drivers of the recent population decline for at least one species (Zöckler et al. 2010). Furthermore, a recent review suggests that hunting has been pervasive taxonomically, spatially, and temporally across the flyway, but that the empirical evidence is too scattered to conduct any robust analysis on population-level effects (Gallo-Cajiao and Fuller 2015b). These threats arise from a suite of underlying social, economic, and political

drivers (e.g., Choi 2014; MacKinnon et al. 2012). Additional threats to these birds include fishery by-catch, food resource depletion, water extraction, pollution, disturbance, and climate change (Wauchope et al. 2016; Harding et al. 2007). Even though the relative importance of each of such threats remains unclear, habitat loss and hunting are likely some of the most important imminent threats to these birds (Amano et al. 2010; Gallo-Cajiao and Fuller 2015b; Studds et al. 2017). As a result of these stressors, migratory shorebirds have been declining in the East Asian-Australasian Flyway, and consequently five species have been listed as threatened (VU, 1; EN, 3; CR, 1) and ten as near threatened by the IUCN (BirdLife International 2018).

Methods

Data collection

We characterized the global environmental governance architecture for conserving migratory shorebirds in the Asia-Pacific using desktop and field data collection methods (Yin 2011). The former included document analysis and database searches, whereas the latter involved interviews, participant observation at key policy fora, and analysis of key documents. Our aim was to identify all relevant and active institutional arrangements for conserving migratory shorebirds within the East Asian-Australasian Flyway. This strategy enabled us not only to carry out an exhaustive survey of institutional arrangements and how they operate but also to triangulate for data validation (for full details of data collection, see supplementary material 2.1). The membership of all institutional arrangements included in this study is presented as of December 2016 (supplementary material 5).

Data analysis

The global environmental governance architecture for conserving migratory shorebirds in the East Asian-Australasian Flyway was analyzed using a quantitative network approach (Robins 2015) with a focus on problem structure. We generated three governance architectures based on problem structure, as follows (supplementary material 3, 4, 5): (1) whole architecture (includes all institutional arrangements identified), (2) habitat designation (includes the subset of institutional arrangements relevant for designating areas for habitat conservation), and (3) hunting management (includes the subset of institutional arrangements relevant for managing hunting). Subsequently, we built an attribute table for the whole architecture and conducted temporal analysis of membership emergence (supplementary material 3, 4, 6) considering the bidimensional model of actor agency as a function of governance level and sector of society. As a final step, statistical analysis for modularity (Girvan–Newman algorithm) and nestedness (NODF) were conducted to test theories of institutional complexity based on topology (for full details of data analysis, see supplementary material 2.2).

Emerging patterns of institutional complexity and agency of actors for conserving migratory shorebirds in the Asia-Pacific

The whole global environmental governance architecture: configuration, membership, formality, scope, and temporal trends

We discovered that a global environmental governance architecture that includes consideration for conserving migratory shorebirds is already discernible in the East Asian-Australasian Flyway involving different actors and levels of governance. The topology of the architecture comprises three subsidiary networks and a main multilevel network at the macro-level given by membership of multilateral institutional arrangements to the East Asian-Australasian Flyway Partnership (Fig. 1). We identified 28 relevant and active institutional arrangements (i.e., 25 in the largest network and one in each of the smaller networks; Fig. 1, supplementary material 4). Amongst these, we identified eight configuration classes given by the locus of authority of the actors involved in relation to level of governance and sector of society (Fig. 2). With the exception of class I, all other classes (i.e., II to VIII) represent dispersion of authority away from the nation-state. Two of the classes involve both a single level and the same type of actor (i.e., class I and II), whereas the remaining six represent a combination of different types of actors or levels of governance (i.e., class III to VIII). The most prominent class involves only state actors at the national level (class $I = 66\%$), followed by only state actors at the subnational level (class II = 10%). The remaining institutional arrangements could be considered multilevel and/or multiactor and each of them accounts for a small proportion (class III–VIII = 4%) of all institutional arrangements.

The governance architecture covers the whole East Asian-Australasian Flyway through varied membership and spatial scopes. Jurisdictionally, all of the 22 countries that are part of this flyway have signed at least one of the institutional arrangements within the architecture, from the northernmost breeding grounds in Russia and the USA, to the southernmost non-breeding grounds in Australia and New Zealand (Fig. 3). This coverage has overlaps with institutional arrangements that include actors operating at different governance levels, from subnational (e.g., Brisbane City Council) to supranational (e.g., Wetlands International), with a total of 57. These institutional arrangements have primarily bilateral (74%) and secondarily multilateral (26%) memberships. When only class

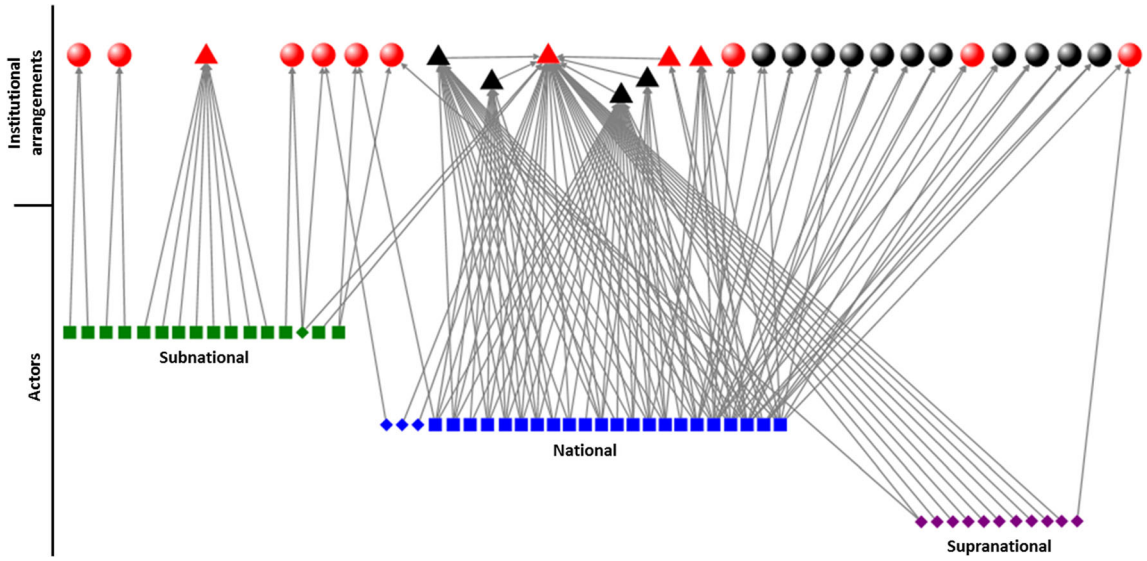

Fig. 1 Whole global environmental governance architecture for conserving migratory shorebirds in the East Asian-Australasian Flyway indicating the three levels at which actors operate [Institutional arrangements: legally binding (black), non-legally binding (red), multilateral membership (triangles), bilateral membership (circles); actors: subnational (green), national (blue), supranational (purple), state (squares), non-state (diamonds)]

I institutional arrangements are considered, bilateral memberships (68%) outnumber multilateral memberships (32%). The geographic scope of most institutional arrangements (82%) is restricted to the East Asian-Australasian Flyway, two (7%) are not global but are not restricted to the East Asian-Australasian Flyway either, three (11%) have a flyway-wide coverage, and three (11%) are global. The membership of those global institutional arrangements within the East Asian-Australasian Flyway is lowest for the Convention on Migratory Species (28%) and highest for the Ramsar Convention (81%) and the Convention on Biological Diversity (95%). Amongst all institutional arrangements, the East Asian-Australasian Flyway Partnership has the highest membership including state (n = 18) and non-state actors (n = 18) at different levels of governance. This institutional arrangement is a type II initiative registered at the 2002 World Summit on Sustainable Development. Type II initiatives are voluntary multiactor agreements involving state and non-state actors, whose emergence can be understood as attempts to redress governance deficits left by traditional state-centric international agreements (Bäckstrand 2006).

The range of institutional arrangement configurations represents different levels of formality and actor participation, to which accessions have also shown different temporal patterns (Fig. 4, Table S.6). This architecture has been emerging since the early 1970s, with the first agreement having been completed (entered into force) in 1972 (i.e., USA-Russia Agreement on Cooperation in the Field of the Environment and Natural Resources). Accessions have increased steadily ever since, with two periods of more rapid growth, the first half of the

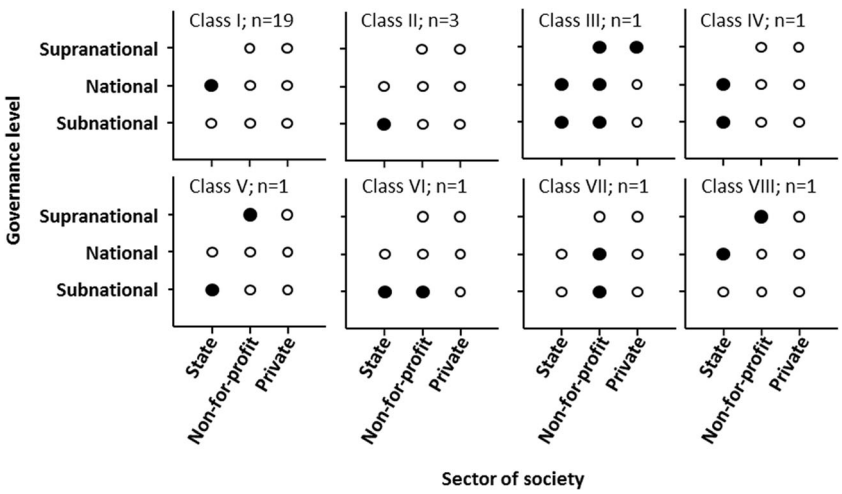

Fig. 2 Institutional arrangement configuration classes (I–VIII) given by the interaction of locus of authority (circles) of participating actors (solid circles) as a function of two attributes of actors (i.e., level of governance and sector of society) involved in each of them

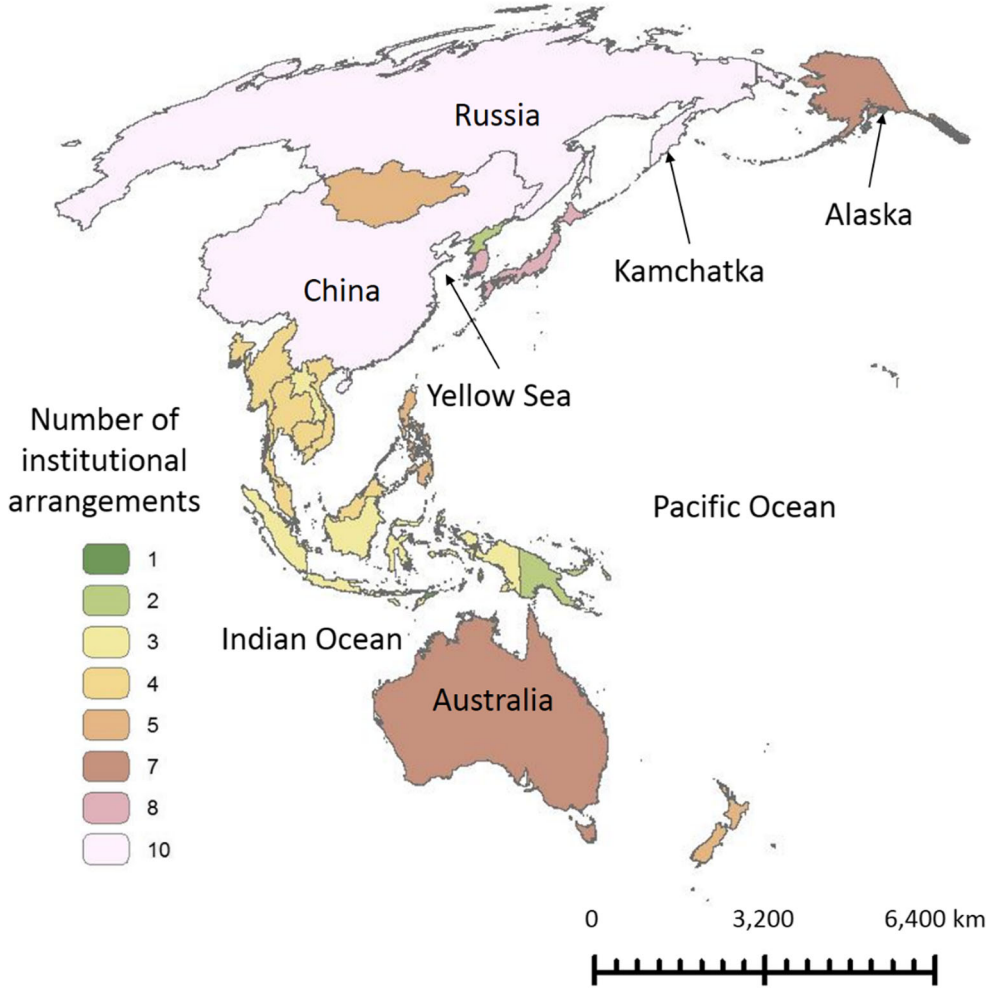

Fig. 3 Country membership of legally binding and non-legally binding institutional arrangements within the global environmental governance architecture for conserving migratory shorebirds in the East Asian-Australasian Flyway (the USA is represented only by Alaska; only select key geographic referents are labeled for interpretation purposes)

1990s and from the mid-2000s onwards because of increased development of institutional arrangements within classes III to VIII. The latter has occurred concomitantly with the emergence of non-state actors and accessions to institutional arrangements involving multiple levels of governance. Three institutional arrangements within class II have emerged since the 1990s, which involve city-to-city arrangements across Japan and Australia. No accessions to this class of institutional arrangement have occurred since 2007. In all, 54% of the institutional arrangements within the architecture are legally binding, which by definition correspond to class I. Within this period (1972–2016), legally binding accessions by countries peaked in the 1990s, while non-legally binding accessions peaked in the 2000s. We found that neither the accession to non-legally binding institutional arrangements by countries ($r = -0.013$), nor the emergence of class II to VIII institutional arrangements ($r = 0.27528$), was correlated with a decrease, or stagnation, in accessions to legally binding institutional arrangements by countries over time. However, accession to non-legally binding institutional arrangements since 2006 (mean accessions per year = 3.7), when they started in earnest, has been at least twice as high as accessions to legally binding institutional arrangements (mean accessions per year = 1.6). The accession rate to legally binding institutional arrangements did not change between the 1972–2005 and 2006–2016 periods.

The institutional arrangements examined in this study include a wide array of provisions and variation of how specific they are in relation to conserving migratory shorebirds. Various provisions are included by the institutional arrangements, such as knowledge sharing, collaborative research, and control of invasive species. Nonetheless, our focus is exclusively on habitat designation, which is included by 68% of institutional arrangements, and hunting management, which is considered by 57% of institutional arrangements. In relation to how specifically their provisions apply to migratory shorebirds, over half (54%) of the institutional arrangements have taxonomic appendices or reference to specific taxonomic groups that include migratory shorebirds, either at the species or family level (supplementary material 4). These institutional arrangements include all the bilateral migratory bird agreements ($n = 10$), the Ramsar Convention, the Convention on

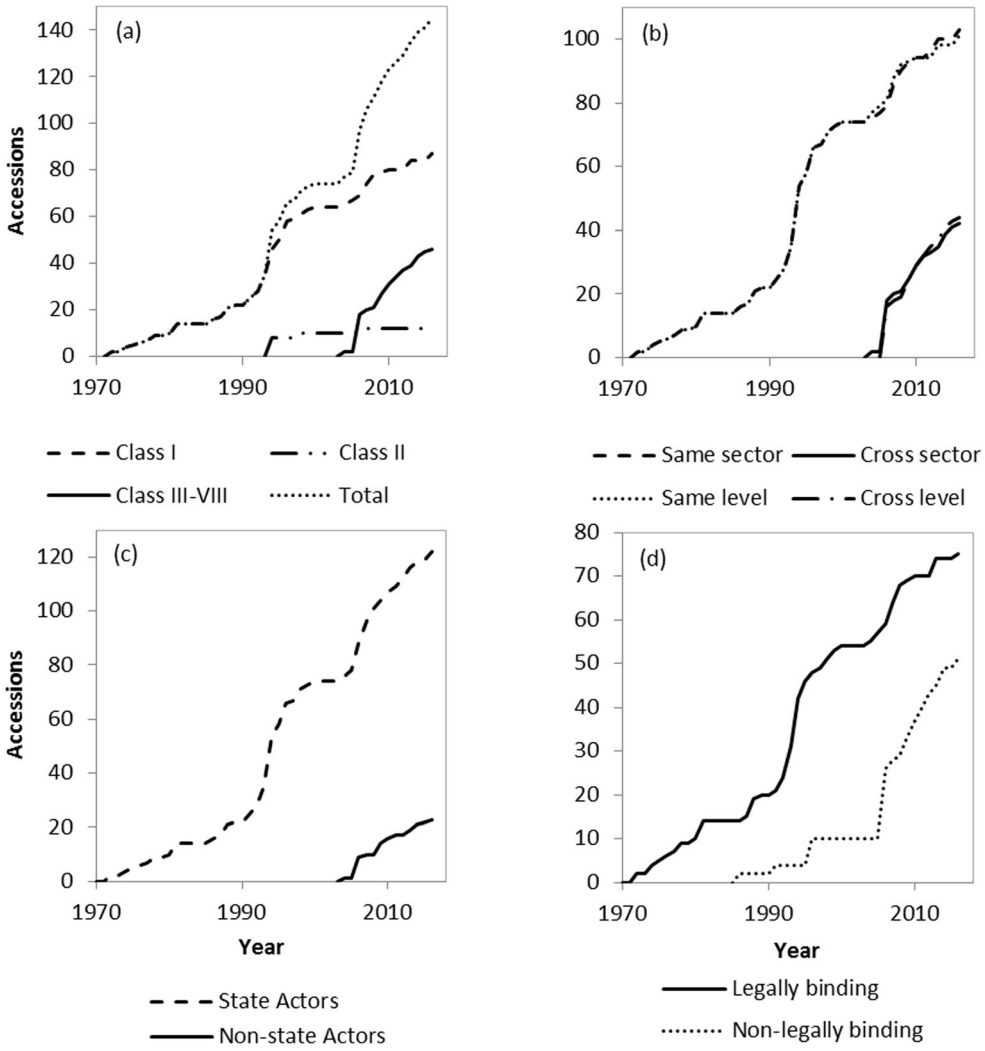

Fig. 4 **a** Accession to institutional arrangements according to institutional arrangement configuration class. **b** Accession to institutional arrangements according to the level and sector of actors involved. **c** Accession to institutional arrangements according to type of actors. **d** Accessions by country according to whether institutional arrangements are legally binding or non-legally binding

Migratory Species, the East Asian-Australasian Flyway Partnership, the New Zealand-China arrangement for migratory shorebird conservation, and the Memorandum of Understanding between Yalu Jiang and the Pukorokoro Miranda Naturalists' Trust (supplementary material 4). Most of the institutional arrangements (i.e., 79%) within the global environmental governance architecture have specific provisions for conserving wetlands, migratory species, migratory birds, or migratory shorebirds. The remaining institutional arrangements have a wider focus on biodiversity conservation. Nevertheless, they were found relevant because they either contain specific programmatic activities related to migratory waterbirds, such as the Framework for North-East Asian Subregional Programme of Environmental Cooperation, or provide a framework for catalyzing the mandate of other institutional arrangements. This is the case of the Convention on Biological Diversity and the ASEAN Centre for Biodiversity, which are members to the East Asian-Australasian Flyway Partnership.

Variation of topology and agency across the three architectures: whole, habitat designation, and hunting management

The whole architecture involves an array of actors presenting modularity and membership nestedness. State actors are more represented at the national level (59%) than the subnational level (41%). Conversely, most non-state actors are represented at the supranational level, which primarily includes non-governmental organization (NGO; 42%) and inter-governmental organizations (IGO; 37%). The participation of national NGOs is lower (16%) as well as the participation of the private sector across all levels of governance (2%). State actors present higher membership than non-state actors do (122 vs. 23; Fig. S.4, Table S.7, Table S.8). The state actors with the highest membership include six countries (i.e., Australia, China, Japan, Republic of Korea, Russia, and USA), which are the only ones with currently active bilateral migratory bird agreements (Fig. S.5; supplementary material 5). Conversely, the non-state actors with highest membership

($n > 1$) are NGOs, one subnational (i.e., Pukorokoro Miranda Naturalists' Trust) and one supranational (i.e., BirdLife International). When the Girvan–Newman algorithm is applied to the whole architecture, nine modules are revealed of which six are connected ($Q = 0.405$). Amongst them, there are three main modules, one with multilateral agreements and the other two primarily with bilateral agreements. The remaining three modules that are connected, as well as the modules that are not connected, could be considered as ancillary to the main three modules. According to this clustering, subnational actors are mostly peripheral, whereas all national and most supranational actors are part of the three main modules (Fig. S.6). The whole architecture presents a highly nested topology (NODF = 20.63, $P < 0.001$), with the Convention on Migratory Species, the ASEAN Centre for Biodiversity, the Framework for North-East Asian Subregional Programme of Environmental Cooperation, Conservation of Arctic Flora and Fauna, and all bilateral agreements, being embedded into the larger multilateral institutional arrangements (Ramsar Convention, Convention on Biological Diversity, and East Asian-Australasian Flyway Partnership; Fig. S.7).

When the whole architecture is analyzed considering habitat designation and hunting management separately, different patterns emerge in which the number of institutional arrangements and actors decreases and topology changes. The architecture for habitat designation contains mostly national state actors (53%) and supranational non-state actors (37%), with state actors having higher membership than non-state actors (103 vs. 18; Fig. S.4, Table S.7, Table S.8). Most state actors are represented at the national level (i.e., countries), including the same six countries with highest membership in the whole architecture (Fig. S.5). Additionally, the multilevel network structure is maintained by the East Asian-Australasian Flyway Partnership. The Girvan–Newman algorithm reveals three connected modules within this architecture, with two main modules resembling the same pattern presented by the whole architecture ($Q = 0.249$; Fig. S.8). The habitat designation network presents a highly nested topology following the same pattern as the whole architecture (NODF = 40.87, $P < 0.001$; Fig. S.7). By contrast, when only hunting management is considered, the architecture becomes simplified with the involvement of national state actors exclusively (100%; Fig. S.4, Table S.7, Table S.8), and again the same six countries as the ones with highest membership (Fig. S.5). The non-relevance of the East Asian-Australasian Flyway Partnership to hunting makes the network lose its multilevel topology. The hunting architecture clusters into two connected modules when the Girvan–Newman algorithm is applied, in which they segregate primarily according to membership to multilateral and bilateral institutional arrangements ($Q = 0.362$; Fig. S.8). The hunting management subgraph presents weak nestedness (NODF = 17.17, $P = 0.06$; Fig. S.7), with bilateral agreements, the Convention on Migratory Species, and the ASEAN Centre for Biodiversity embedded into the membership of the Convention on Biological Diversity.

Interpreting institutional complexity and agency of actors

To our knowledge, this is one of the first studies to identify and analyze the global environmental governance architecture of migratory species conservation in a particular social-ecological system. This governance architecture is part of a broader framework of institutional arrangements, which in turn is part of the global biodiversity conservation agenda. We discovered that global environmental governance, as a transformational phenomenon, has emerged in this architecture, though with variations when accounting for problem structure. Our results support propositions of reconfiguration of agency of actors for rule-making within governance in transboundary settings (Pattberg and Widerberg 2015), as follows: (1) emergence of non-state actor participation, (2) development of novel institutional arrangements, and (3) increased interactions across levels of governance and sectors of society. These features pose challenges and opportunities for conserving migratory shorebirds, as problems of scale mismatches can emerge, but also mechanisms for institutional learning and resilience (Ostrom 2010). Our study thus extends understanding of global environmental governance beyond issue areas more intensively studied, such as climate change, fisheries, and forestry (Dauvergne and Clapp 2016; Parry 2004), to now include the vitally important problem of migratory species conservation.

The whole global environmental governance architecture

We discovered that the topology of the global environmental governance architecture for conserving migratory shorebirds conforms to different conceptualizations of institutional complexity. The topology of the whole governance architecture presents various degrees of clustering and nestedness when considering the membership of all its institutional arrangements. When taken as value-free, the governance architecture could be considered as fragmented, since it is a patchwork of institutional arrangements that differ in their membership, spatial scopes, and objectives (Biermann et al. 2009a). This topology also fits characteristics of a regime complex, as the architecture could be considered as a loosely coupled system of nested (semi-hierarchical) institutional arrangements (Keohane and Victor 2011). This hierarchy does not entail authority, but rather layers of membership across institutional arrangements. Likewise, the architecture exhibits characteristics of polycentrism, in which formally independent centers of rule-making at different levels are active in a particular issue

area (Morrison 2017; Ostrom 2010). In addition to each individual institutional arrangement, the clusters identified in this study could also be interpreted as "centers" of rule-making, comprising three main cores (modules). Some of these concepts, such as regime complex and polycentricity, recognize the existence of a continuum along a gradient from high integration to high division. Hence, quantitative measurement of clustering and nestedness could be used to compare more rigorously coupling of institutional arrangements, as well as how hierarchical they are, along gradients of polycentricity (Galaz et al. 2012) and regime complexes (Keohane and Victor 2011).

Patterns of agency of actors

The participation of actors beyond the nation-state for conserving migratory shorebirds in the Asia-Pacific differs from other issue areas, whereas nation-state participation mirrors general geopolitical patterns. For instance, cities have remained at a relatively low level of participation in the East Asian-Australasian Flyway, whereas in climate change governance, cities have become a prominent feature (Bulkeley et al. 2012). Cities have also become active actors for rule-making of migratory bird conservation in North America, though this is confined to the USA, where 27 cities (e.g., New York, Philadelphia, New Orleans) have entered partnership agreements (i.e., Urban Bird Treaty) with the US Fish and Wildlife Service (Adams 2014). In the Asia-Pacific, at least one city (i.e., Incheon, Republic of Korea) is playing a major role within the global environmental governance architecture by funding the secretariat of the East Asian-Australasian Flyway Partnership (interview#19; participant observation). In contrast with other issue areas, market-based mechanisms are absent, such as third party certification schemes, which are common in fisheries (Ward and Phillips 2010) and forestry (Biermann and Pattberg 2012). The participation of the private sector has also been limited in transnational rule-making, unlike climate change governance (Green 2013). The only corporation within the global environmental governance architecture, Rio Tinto, has remained largely an inactive partner in the East Asian-Australasian Flyway Partnership (interview#14, interview#16, interview#17). Conversely, the six countries with highest membership could be regarded as regime entrepreneurs (Abbott 2014), as they have played a prominent role in rule-making through political leadership and provision of funding (Boardman 2006; interview#03, interview#17, interview#19). Furthermore, these countries are great powers within the region (Reilly 2013; Ross 1999), which may indicate not only their capacity to engage in addressing environmental issues, but also their political aspirations (interview#17, interview#21, interview#24, interview#29, interview#30, interview#31).

In all, nation-states have been and remain as central actors within the global environmental governance architecture. This pattern is signaled by the steady accession to already existing institutional arrangements, as well as the development of new institutional arrangements. For instance, membership of the Ramsar Convention has continued to increase, and the Democratic People's Republic of Korea, a long-time non-party country, was considering accession at the time we collected data for our study (Gallo-Cajiao et al. 2017). More recently, this country has officially become a party to this convention, coming into force on 16 May 2018. Considering this is outside the timeframe of our study, we still consider such a country as a non-party for analytical purposes. This coincides with the increased accession to multilateral environmental agreements by this country since the 1980s, which could potentially be influenced by environmental degradation and access to international aid associated with such institutional arrangements (Kim and Ali 2016). Likewise, membership of the Convention on Migratory Species is likely to increase in Southeast Asia in the short term (i.e., Cambodia, Malaysia, and Vietnam), as well as in Northeast Asia (i.e., China and Republic of Korea) in the long term (interview#28, interview#30). Furthermore, China and Russia developed a bilateral migratory bird agreement, which is legally binding, as recently as 2013. Overall, our results do not support the proposition of state retreat as a concomitant process of emerging global environmental governance (Abbott et al. 2016); rather, we found actors beyond the nation-state complementing the state-centered core of the architecture. These findings align with a state-centric relational approach to governance via associative mechanisms (Bell and Hindmoor 2009) that provide, in this case, technical capacity (e.g., bird surveys, training of site managers) primarily through supranational non-state actors (Boardman 2006; participant observation). Furthermore, non-state actors, such as the Hanns Seidel Foundation, also play a key role within the whole global environmental governance architecture allowing programmatic activities in countries that are politically isolated due to international relations issues, such as the Democratic People's Republic of Korea (interview#03; participant observation).

Temporal patterns of emergence

The temporal trends of emergence of the global environmental governance architecture present some regional idiosyncrasies. Globally, the number of international environmental agreements, understood as class I institutional arrangements, started emerging in the late 1800s. However, it was not until after World War II that their rate of development increased considerably (Meyer et al. 1997). In the case of the Asia-Pacific, the development of the global environmental governance architecture did not commence until the 1970s, likely coinciding with the 1972 UN Stockholm conference (Boardman 2006).

Furthermore, the steep rate of accessions during the 1990s was the result of the Rio Conference in 1992, which not only resulted in the Convention on Biological Diversity but also recommended the development of additional arrangements. Accordingly, the North-East Asian Subregional Programme for Environmental Cooperation was eventually established in 1996 (interview#03). This pattern is in contrast with the development of institutional arrangements for conserving migratory birds in North America and Europe, which have been emerging since the early 1900s (Boardman 2006; Ferrero-García 2013). This lag could be, for example, caused by: (i) differences in the historical development of politics in each region, (ii) delayed understanding of bird migration in the Asia-Pacific, and (iii) dissimilarities in societal values towards migratory birds (Boardman 2006; Kuijken 2006).

Additionally, the emergence of institutional arrangements including actors beyond the nation-state mostly started in the mid-2000s, whereas in other issue areas, such as forestry, started much earlier (Biermann and Pattberg 2012). That said, non-state actors became actively engaged in institution building in the East Asian-Australasian Flyway since the 1990s (Gallo-Cajiao and Fuller 2015a). Perhaps, issue areas that have a higher profile may be subject to, not just early but also, more intensive experimentation and policy learning that could then diffuse into other issue areas influencing choices for institutional design (Bulkeley et al. 2014). This trend of emergence coincides with the development of the East Asian-Australasian Flyway Partnership, which was the result of gridlock in developing a legally binding multilateral agreement (Gallo-Cajiao and Fuller 2015a; Boardman 2006; Anonymous 1996) and the emergence of the type II initiatives at the 2002 World Summit on Sustainable Development (Bäckstrand et al. 2012). Hence, this institutional arrangement may have fostered the legitimacy, discourse, and forum needed for the rise of actors in rule-making beyond the nation-state. For instance, twinning of flyway network sites through additional institutional arrangements has been promoted at the meetings of partners of the East Asian-Australasian Flyway Partnership, which is attended by state and non-state actors (participant observation). This process may support empirically the mutually constitutive, and iterative, agent-structure relationship, whereby agency of actors is enabled by institutional frameworks generated through the participation of new actors (O'Neill et al. 2004).

Factors accounting for institutional complexity

The emergence of global environmental governance processes, as well as of additional nation state-centered institutional arrangements, may be related to the slow progress achieved to date for protecting key stopping sites in the Yellow Sea. Interestingly, all five institutional arrangements within class IV to VIII include at least one actor whose jurisdiction includes this particular region. Habitat loss in the Yellow Sea has not only been identified by researchers as a likely key driver of population declines (Amano et al. 2010; Piersma et al. 2016; Studds et al. 2017), but has also been constructed through advocacy campaigns by non-state actors as the single most important threat to migratory shorebirds in this flyway (Lewis and Russell-French 2011; participant observation). This discourse advanced by non-state actors may have created a change in cognitive structures conducive of further emergence of agency of actors (O'Neill et al. 2004). Hence, it is plausible that the slow progress made through class I institutional arrangements may have spurred alternative pathways for rule-making beyond the nation-state, as has been documented in climate change governance as a response to perceived governance deficits and gridlocks in intergovernmental negotiations (Bulkeley et al. 2014; Biermann and Pattberg 2012; Morrison et al. 2017). For instance, the reclamation of Saemangeum in 2006, a then very important stopping site for migratory shorebirds in the Republic of Korea (Moores et al. 2008), could not be halted through any of the existing class I institutional arrangements, such as the Ramsar Convention (Cho 2007). The adjacent intertidal zone to Saemangeum, the Geum estuary, is now considered the most important remaining stopping site in the Republic of Korea (Moores et al. 2016), and the corresponding local government has entered two institutional arrangements to support its conservation. However, despite the emergence of alternative pathways for rule-making, class I institutional arrangements have still been triggered by Yellow Sea issues. For instance, New Zealand entered a bilateral agreement with China in 2016, though not legally binding. This institutional arrangement reflects the perceived importance of the Yellow Sea for shorebird conservation in New Zealand by its national conservation agency (participant observation).

Issues of international relations and sovereignty may have influenced membership of institutional arrangements in this flyway, with implications for conservation. For instance, Taiwan, having 12 internationally important sites for migratory shorebirds (Bamford et al. 2008), remains as a territory with no participation in any of the institutional arrangements considered within the flyway likely due to the One-China principle (Su 2014; Wei 2000). Furthermore, one of the striking features of the global environmental governance architecture in the East Asian-Australasian Flyway is the prominence of bilateralism, unlike the other global waterbird flyways (i.e., Central Asia, Africa-West Eurasia, and the Americas; CMS 2014; Boardman 2006). Despite this feature, some state and non-state actors recognize a legally binding multilateral waterbird agreement as a more desirable institutional design (Anonymous 1996). However, achieving that goal has been hampered by low membership to the Convention on Migratory Species, which provides the legal framework and has been recognized by some actors as a possible roadmap to

follow (Asia-Pacific Migratory Waterbird Conservation Committee 2001; interview#17) as occurred for the African-Eurasia Migratory Waterbird Agreement (Lewis 2016). Such a low participation has partially stemmed, at least in some key countries (i.e., China, Japan, and Republic of Korea), from national interests in other exploited migratory species (e.g., sharks and whales; Takahashi 2012; interview#09, interview#17, interview#21, interview#23, interview#28, interview#30, interview#31). The lack of regional integration through formal multilateral institutional arrangements is generally recognized as a noticeable feature of the overall governance architecture of this region (interview#03, interview#30), even beyond environmental issues (Söderbaum 2012).

Bilateralism for migratory bird conservation in this region may be related to power-based factors shaped by international relations. While "unilateralist" notions of international relations posit multilateralism as undermining national autonomy and bilateralism bypassing multilateralism (Rozman 2012; Blum 2008; interview#29), bilateralism can also be a strategy used by countries to pursue regional integration when multilateralism is politically unfeasible (Boardman 2006; interview#21). Furthermore, some bilateral institutional arrangements have only been possible with the easing of international conflicts. For instance, the Russia-Republic of Korea Bilateral Migratory Bird Agreement was concluded with the end of the cold war (interview#31), and the two relevant bilateral institutional arrangements between the USA and Russia were developed in the context of *détente* during the cold war (Josephson et al. 2013). Nevertheless, bilateral approaches have not always yielded results, as evidenced by unsuccessful attempts to complete additional bilateral migratory bird agreements, which in some cases may have been hampered by asymmetries in capacity (Papua New Guinea-Australia; Boardman 2006; interview#17), and in others by tensions arising from territorial disputes (Japan-Republic of Korea; interview#31; participant observation).

Emerging variation in topology and agency across the whole, habitat designation, and hunting management architectures

The topology of the global environmental governance architecture presents different characteristics when accounting for problem structure. The global environmental governance architecture for habitat designation is more integrated (i.e., clusters [modules] are more tightly coupled) than the whole governance architecture and the governance architecture for hunting management. Likewise, the whole governance architecture and the governance architecture for habitat designation are more nested than the governance architecture for hunting management. These patterns of clustering and nestedness can be understood along a continuum within conceptualizations of institutional complexity, such as fragmentation (Biermann et al. 2009a), regime complex (Keohane and Victor 2011), and polycentricity (Ostrom 2010); however, how these topological differences may influence performance remains an empirical question. Our approach enables linking empirical evidence with theoretical propositions, complementing the largely qualitative research of institutional complexity within global environmental governance (Pattberg and Widerberg 2015).

Drawing from other social-ecological systems, we hypothesize about how the difference in emergence of global environmental governance phenomena, when accounting for problem structure, may be explained by property rights. While global environmental governance processes have emerged in the context of habitat designation, hunting management has remained completely centered on the nation-state. This pattern is similar within the global environmental governance architecture for conserving migratory waterbirds in North America. In this instance, habitat conservation is addressed through a combination of state-based instruments, such as wildlife refuges, and multiactor partnerships, such as migratory bird habitat joint ventures, including state and non-state actors. Conversely, hunting is exclusively managed through state-based instruments, such as the flyway councils, without participation of non-state actors (Anderson and Padding 2016). Land tenure usually includes a wider range of actors than wildlife ownership, which has been chiefly limited to the state (Naughton-Treves 1999). Rule-making for harvesting migratory species as transboundary and global commons has also been the exclusive domain of the nation-state in other social-ecological systems, such as the historical case of fur seals in the Northern Pacific (Dorsey 1998) and the contemporary management of high sea fisheries through Regional Fisheries Management Organizations.

The variation of the governance architectures across specific threats also has likely direct conservation implications. Geographically, the whole governance architecture encompasses the entire East Asian-Australasian Flyway, though with spatial variation that may influence how threats are addressed. Policy density, understood as the quantity of overlapping institutional arrangements (Knight et al. 2012), is highest across most of the breeding grounds and migratory stopping sites but lower across the non-breeding grounds with the exception of Australia. On the other side of the spectrum, Southeast Asia presents the lowest policy density. This region provides non-breeding grounds for some species that do not reach Australia (e.g., Dunlin *Calidris alpina*), some of which are globally threatened (spoon-billed sandpiper *Calidris pygmaea* and spotted greenshank *Tringa guttifer*; BirdLife International 2018; Bamford et al. 2008). This low policy density in Southeast Asia, arising mainly from the absence of bilateral migratory bird agreements, occurs in a region where hunting is still likely to take place (Gallo-Cajiao and Fuller 2015b). Yet, bilateral migratory bird agreements are the only

institutional arrangements in this flyway with specific provisions to manage hunting. Thus, the spatial variation in policy density can have important repercussions for conservation, as different institutional arrangements have different legal status, membership, provisions, and decision-making procedures.

Conclusions

Our study demonstrates that global environmental governance, as a transformational phenomenon, has emerged in migratory bird conservation, and that the process shows significant variation even within the same issue area. We discovered a global environmental governance architecture that conforms with conceptualizations of institutional complexity that have also been applied to other issue areas, such as climate change. We also confirmed the emergence of non-state actors, novel institutional arrangements, and increased interactions across governance levels and sectors of society. Importantly, we discovered potential feedback loops through agent–structure relationships, whereby actors beyond the nation-state shape social contexts that enable their further participation. Despite this emergence of new actors, our data indicate that the nation-state has been and remains central to the global environmental governance architecture. Hence, we see global environmental governance, in the context of our study, as a process through which non-state actor participation likely strengthens the governance architecture, rather than necessarily signaling the weakening of the nation-state (Dorsch and Flachsland 2017). This finding supports the proposition that governing the commons requires actors operating at multiple levels, being nested within state structures (Morrison 2017; Mansbridge 2014). However, the reconfiguration of agency, as a signal of global environmental governance processes, is not pervasive and has presented different patterns in relation to actors when accounting for problem structure. It is unclear why the agency for rule-making disperses away from the nation-state for addressing some specific issues, such as habitat loss, but not for others, such as hunting. This remains as a major follow-up research question from our study (supplementary material 7). Further work grounded on robust empirical analyses could potentially enable theory-building to explain these patterns more broadly across social-ecological systems. Advancing this research agenda is paramount not only as a contribution to the governance literature more generally but also to the conservation of migratory species.

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