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Researchers as Scale-Crossing Brokers in Knowledge Co-Production and More: A Prerequisite to Tackle Mismatches in Ecosystem Restoration Governance

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Abstract

Misalignments or mismatches between governance and ecosystems are a key sustainability challenge that requires a collaboration and coordination network to design integrated solutions for tackling wicked problems of ecosystem degradation. Yet before any integrated solution can be designed, there is a dearth of knowledge on and comprehensive understanding about the complex social-ecological system that the restoration governing mechanism is embedded within and depends on. Recognizing the abovementioned epistemological challenge, this paper argues that one of the prerequisites to tackle mismatches in restoring ecosystem is the intervention of researchers as scale-crossing brokers to co-produce knowledge with multiple stakeholders and link the disconnected stakeholders to prepare a future coalition of ecosystem restorative activities. The endeavor of researchers as brokers in this case is to link not only social and ecological knowledge but also knowledge currently held in individual

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environment governing entities in order to create the database for a system-thinking approach and pave ways for future collective action.

By using urban river restoration governance as an exemplary field, this research showcases with empirical studies of the problem of both urban and rural sustainability, namely, the Wannian River and the Donggang River in Taiwan, respectively, how the role of researchers can actively play as scale-crossing brokers to link disconnected knowledge and stakeholders at the level of five scales: 1) human-nature scale, 2) temporal scale, 3) spatial scale, 4) institutional scale and 5) methodological scale. Moving beyond the empirical case demonstration, this study makes an additional attempt to match the roles of researchers with eight principles underpinning ecological restoration to explore specific tasks researchers can potentially play as intermediate agents in the future.

Keywords: scale-crossing broker, knowledge co-production, mismatch, social-ecological system, grey water

I. Introduction

This research emerges from two interrelated theoretical and practical backgrounds: 1) social-ecological mismatches literature (Beever et al., 2019; Breckheimer et al., 2020) or the specific mismatches between governance and ecosystems and 2) the recently proclaimed United Nations Decade on Ecosystem Restoration (hereinafter referred to as the UN Decade). Whereas the former refers to the challenges to create or adjust social or governing institutions to align or fit with complex ecosystem processes and structures across various scales (Bergsten, Galafassi & Bodin, 2014; Bodin, Crona, Thyresson, Golz & Tengö, 2014), such as spatial, temporal or functional-conceptual mismatches (Winkler, Dade & Rieb, 2021), the latter signifies how international organizations are determined to invoke new global strategies (United Nations, 2021) to mobilize resources for restoring key ecosystems (Maron et al., 2016). In particular, mismatches can contribute to a decrease in social-ecological resilience and the solutions to scale mismatches often require institutional changes at more than one hierarchical level (Cumming, Cumming & Redman, 2006), social learning (Charles, Loucks, Berkes & Armitage, 2020) and adaptive governance (Chaffin, Gosnell & Cosens, 2014). On the other hand, the UN Decade also emphasizes the

importance of engaging multiple stakeholders in a spirit of "partnership, inclusiveness and joint coordination action" (Chaffin et.al., 2014: ii) to tackle six barriers to catalyze large-scale environmental restoration: public awareness, political will, legislative and policy environments, technical capacity, finance, and scientific research. These barriers are also the underlying causes of the social–ecological mismatches empirically identified by researchers (Chien & Saito, 2021), with roots in a dearth of knowledge and a comprehensive understanding of the complex social-ecological system that natural resource governance is embedded within and depends on.

Against the above-mentioned background, the current study argues that there is a role that researchers can play *ex ante* to pave ways for knowledge co-production, to improve our collective understanding of the complex social-ecological system before proposing and implementing cutting-edge solutions with stakeholders. Therefore, it can be considered as a prerequisite to design cross-sector policy integration and integrated solutions (Baulenas, Kruse & Sotirov, 2021) for overcoming barriers to promote the restoration, conservation, and sustainable use of natural resources. This role is designated by this paper as the "scale-crossing broker," first formally defined by Ernstson, Barthel, Andersson & Borgström (2010) to describe "a social network position that links otherwise disconnected social actor groups … [and] interacts with the ecosystem process at different ecological scales at different physical sites." In practice, this brokerage occurs when social relations or social capital is mediated between heterogeneous groups (Burt, 2005).

Therefore, the research question asked by the current study is: in what aspect can researchers, as scale-crossing brokers, intervene to induce integrated solutions for tackling difficult problems in natural resource management? By using two aquatic ecosystem restoration case studies in Taiwan, 1) we empirically showcase five distinct scales: human-nature, temporal, spatial, institutional, and methodological, to which researchers can link disconnected knowledge and stakeholders to catalyze the emergence of integrated solutions; in addition, 2) we make an effort to match the empirical contributions of knowledge brokers with the eight international principles underpinning worldwide environmental restoration activities (Gann et al., 2019), to discuss additional potential roles that researchers might play. To be precise in our definitions of terminology, the "knowledge" referred to in this study includes anything that is useful (Clark, Van Kerkhoff, Lebel & Gallopin, 2016) for future decision-makers to craft ecosystem restoration policies, such as a tool, a concept, a framework or a solution to a problem, etc. (Latulippe & Klenk, 2020). The term "Stakeholder" used in this study refers to any individual or representative group that is crucial to the achievement of restoration objectives (Cordell et al., 2017),

including researchers from higher education or research institutes who are distinctively characterized in this study as simultaneously "scale-crossing brokers". Lastly, the term "non-traditional stakeholder" mentioned in this study indicates stakeholders for whom formal or organized entities do not exist (Majowicz, Parmley, Carson & Pintar, 2018), such as citizens or local farmers whose voices were not included or consulted regularly through farmers' organizations.

II. Social-Ecological Mismatch and Practical Solutions

The most common mismatch between governance and environmental reality can be found in the management of transboundary watersheds: the scale of a watershed is often in misalignment with the jurisdictions of the entity or entities that govern it (Grigg, 2015). Scholars use the label of "spatial-scale mismatch" to describe this specific sustainability challenge and suggest that collaboration and coordination networks, and/or multilevel governance, can assist in overcoming problems of scale mismatch. In particular, "collaboration quality" (Sayles & Baggio, 2017a) is identified as pivotal to the success of social-environmental restoration planning. In a similar vein, Guerrero et al. (Guerrero Bodin, Mcallister & Wilson, 2015) use empirical cases in Australia and statistical models of multilevel networks to inform us that a benefit of collaborative governance is that it fosters self-organization and flexibility. Moreover, Bergsten et al. (Bergsten et al., 2014) point out the shortage of approaches to systematically and quantitatively examine the level of mismatch to address habitat fragmentation, especially in urban and peri-urban landscapes, that limits critical species dispersal. To fix the mismatch problem, they propose engaging a variety of stakeholders to coordinate environmental restoration activities—specifically, in the ecologically interconnected wetlands of Stockholm—to address the problem at the most appropriate scale.

The takeaway from Bergsten et al. echoes the "geopolitical fit" problem identified by Treml et al. (Treml, Fidelman, Kininmonth, Ekstrom & Bodin, 2015) in their attempts to quantify ecological-institutional alignment across an environmentally and politically complex, large-scale marine social-ecological system. Failure to understand the interconnection and interdependence between these ecological and political systems in environmental governance results in so-called "governance silos" (Sayles & Baggio, 2017a) in which various organizations addressing the same ecological site work in isolation without sharing information and strategies, which is not only inefficient but also ineffective. Although an obvious and practical solution to avoiding such governance silos

is to promote network integration, scholars recognize the lack of knowledge about the structures and functions of these collaboration networks and stress the need for future research (Sayles & Baggio, 2017b). Building upon these theoretical discussions, this study argues that it is in this epistemological gap that researchers can play a role as scale-crossing brokers, before perhaps playing other roles to promote networked collaboration with policy makers and multiple stakeholders to co-design integrated solutions.

The responsibility and capability of researchers to fix social-ecological mismatches is argued by the present study as twofold: 1) to epistemologically link the disconnected knowledge currently held by individual agencies (Bundred, 2006) and 2) to ontologically link disconnected stakeholders (Korfmacher, 2019) to promote a transition from those stakeholders working in isolation to begin working in collaboration. This is exceptionally important and can be considered a prerequisite for the upcoming UN Decade on Ecosystem Restoration, the success or failure of which might depend heavily on the ability of the program to strengthen cross-sector collaboration. For example, the World Health Organization joined the UN Decade in the attempt to promote interdisciplinary and transdisciplinary cooperation and engagement at the human, animal, plant, and ecosystem interface, known as One Health (World Health Organization, 2021). Without the interdisciplinary and transdisciplinary research and action initiated by researchers of diverse expertise to support a more integrated and avant-garde mixed-policy solution, government silos remain the name of the game for bureaucracies and organizations to work at their most "efficient" terms in isolation. In other words, organizations tend to avoid inter-agency collaboration while preferring independent and vertical management, rather than horizontal communication, even with the aid of information and communication technology (ICT) in e-governments that champion the concept of joined-up or whole-of-government (de Bri & Bannister, 2010).

By conducting empirical research to improve our understanding of the structures and functions of social-ecological systems that can best "fit" an ecosystem targeted for restoration, researchers should act as scale-crossing brokers (Ernstson et al., 2010; Gould & Fernandez, 1989; Hopkins, Weddle, Gluckman & Gautsch, 2019) to integrate the distributed capacity "trapped" in the conventional division of work philosophy and organizational ethics (Gulick, 1937) and to connect otherwise unconnected parties (Stovel, Golub & Meyersson Milgrom, 2011). As for the scale on which a researcher or a group of researchers can act as brokers, further empirical case studies are required to support the theory of the scale-crossing broker role. The next section of this study endeavors to investigate two aquatic ecosystem restoration cases in Taiwan to explore the above-

mentioned role of researcher in linking disconnected knowledge and entities

III. Theorizing the Role of Scale-Crossing Brokers in Aquatic Ecosystem Restoration Cases

Aquatic ecosystem restoration is a typically complex environmental problem since water is by nature dynamic, with variety in flow and quality, and the subgroups who have access to a given body or system of water are highly distinct from one another. This duality of dynamics corresponds to the ecological and sociological complexity that almost always characterizes the governance of a river or lake (Stave, Goshu & Aynalem, 2017). The current study investigates two empirical cases of aquatic ecosystem restoration in Taiwan—one of an urban river and the other of a rural river—to allow empirical data to inform us about the kinds of roles researchers can play as intermediaries, linking the knowledge and actions of disconnected agencies to pave ways for future integrated solutions to restore degraded freshwater ecosystems. These two cases also can facilitate an initial comparison of the role of researcher as scale-crossing broker in tackling urban sustainability problems and rural sustainability problems, which will be discussed in more detail in the next section.

A. An Urban Sustainability Problem: Wannian River Restoration Activities

Our first case study of aquatic ecosystem restoration is selected at an urban setting: Pingtung City in southern Taiwan. Settled in the 1960s with a population of approximately 100,000 people, which slowly grew to over 200,000 people in the 1990s, the city's population was 197,647 at the end of 2020 (Pingtung County Government, 2020). This doubling of the urban population put pressure on the main urban river ecosystem of Pingtung City, the Wannian River. The name of the river means "tens of thousands of years," signifying the historical abundance of this water resource and its attractiveness for human settlement. However, in the modernized society of the 21st century, this mother river of Pingtung City is recorded with an average pollution status of "medium" (with an average record of 4.46 in the river pollution index, RPI) (Chien & Saito, 2021: 8) and occasionally reaches even the "severely polluted" RPI status of over 6.

This severely degraded aquatic ecosystem's performance continues despite the

millions of New Taiwan dollars, taxpayers' money, that have been invested in various ecosystem-restorative, human-made infrastructure interventions and activities, especially those undertaken since 2006 with Mayor Tsao and continuing through the present day under Mayor Pan. It also shows how urban river restoration is a pernicious environmental problem that cannot be easily tamed, not to mention solved. This makes the Wannian River an ideal site for researchers to intervene as scale-crossing brokers, since there are still abundant gaps to be filled and knowledge tends to be fragmented or held by the individual urban governing institutions that claim to have authority, such as the Water Engineering Bureau, the Environment Protection Bureau, and local non-governmental organizations (NGOs).

Sub-section 3.1.1 starts with an in-depth description reporting the academic endeavor of researchers, from 2019 to 2021, to link disconnected knowledge for local stakeholders across five different scales—the human-nature, temporal, spatial, institutional, and methodological scales (see Table 1) which were categorized based on our empirical case data in reference to the literature review in Section 2 on various scales of social-ecological mismatch. Sub-section 3.1.2 documents actions taken by the researchers to link the disconnected stakeholders in the Wannian River restoration case, again across these five different scales.

Table 1. Scale-crossing summary for Wannian River restoration activities

	Linking disconnected knowledge	Linking disconnected stakeholders
Human-nature scale	X Impact of blue, green, and gray infrastructures on urban ecosystem services	X Creating a common social–ecological concern to link various stakeholders
Temporal scale	X 1989–2019, across five mayoral mandates	X 2019–2020–2021 stakeholder engagement
Spatial scale	X Upstream vs. downstream in Pingtung City downtown	X* Upstream vs. downstream in Pingtung City downtown
Institutional scale	X Local government, local community	X Local government, local NGOs, local university, concerned citizens**
Methodological scale (natural science vs. social science approach)	X Mixing quantitative, qualitative, system thinking mapping, scenario simulation	X LINE online meeting/future app development discussion

* The Wannian River is 5.5 km in length, flowing through a city center of approximately 0.2 million people. Researchers have investigated both upstream and downstream river management.

** The highlighted area refers to stakeholders that are unique to this urban sustainability case when compared to the rural sustainability case.

Source: compiled by the authors

(A) Linking disconnected knowledge

The role of researchers as scale-crossing brokers can be demonstrated by the academic activities conducted by the authors of this paper between 2019 and 2021. With respect to the human-nature scale, we made an attempt to explore the impact of gray, blue, and green infrastructures on the urban ecosystem service of the Wannian River. We chose this approach to raise our collective awareness of how anthropogenic activities, through the man-made infrastructure construction, can positively or negatively influence an urban river's ecosystem service provisioning. With respect to the temporal scale, because we designed a longitudinal, policy-retrospective study, our data collection stretches from 1989 to year 2019, across five different mayoral mandates. By investing time and resources in combining an array of longitudinal data, our research can yield comparative findings that may not have been observed by incumbent practitioners, such as senior government officials or even environmental activists. With respect to the spatial scale, we endeavored to collect empirical data on the biophysical status of the Wannian River, both in the mid-stream section of the Wannian River flowing through the Pingtung City center (see Figure 1, left map) and in the upper stream area, in particular focusing there on three constructed wetlands planned by the Pingtung County government to purify the freshwater input: Golden Wetland (A in Figure 1), Chun-liao Wetland (B), and Hai-fong Wetland (C).

Figure 1. Spatial Scale of the Wannian River

Source: Drawn by authors using Google Maps (July 7, 2021).
Left: Wannian River through Pingtung City. Right: Three wetlands constructed to purify Wannian River in its upstream area. A = Golden Wetland, B = Chun-liao Wetland, C =Hai-Fong Wetland.

With respect to the institutional scale, researchers in this project conducted in-depth interviews with stakeholder representatives from different sectors, such as senior officials in the Environmental Protection Bureau, the Water Engineering Bureau, the Agricultural Industry Bureau, and the Information and International Affairs Department of the Pingtung County government, as well as interviewees from Ming-he Elementary School, the Wannian River Conservation Association, the Water Patrol Group, an environmental consulting company, et al. With respect to crossing the methodological scale, an array of research outputs was generated from our system thinking approach to investigating the social-ecological system of the Wannian River governance by mixing various methods—complementing quantitative data, such as the RPI, with qualitative data collected from in-depth interviews; system thinking mapping coupled with an infrastructure system (CIS) framework; and scenario simulation with urban communing as an intervention to urban river governance.

(B) Linking the disconnected stakeholders

With respect to crossing the human-nature scale, our research team established the "2019–2020 Kaohsiung Sustainable City Forum" website (Figure 2) and its corresponding Facebook page to address a common social-ecological concern by linking various stakeholders that previously might have lacked the motive or opportunity to meet and possibly collaborate. Through this steering of an online community that could expand participation to include non-traditional stakeholders, knowledge about the importance of the human-nature relationship was disseminated and advocated for, with best-practice cases being shared and physical forums being hosted. For instance, on October 15, 2020, we hosted a Floating Solar Panel forum in Pingtung City with more than 60 participants to showcase how renewable energy production can develop in harmony with the conservation of biodiversity and lake management. The invited speaker was Chief Executive Dong from a local factory that manufactures floating solar panels. Since the above-mentioned effort to steer the online and offline community was initiated in 2019 and continues into the present in 2021, we consider it to be a scale-crossing brokerage action that crosses the temporal scale as well.

Figure 2. Website of the Kaohsiung sustainable city forum.

Source: https://sites.google.com/view/kao-sustainable-city/home (accessed on July 7, 2021).

As for crossing the spatial scale, similar to the effort made to link disconnected knowledge as shown in Figure 1, we strived to organize various events to strengthen the human-nature relationship in both the mid-stream and the upper stream of the Wannian River. For example, our 2020 World River Day event was hosted on September 27, 2020 in Millennium Park, featuring river-water testing and citizen science activities in the mid-stream section of the Wannian River. A total of more than 200 participants from various sectors gathered, including representatives from local governments, educational facilities, civil society, universities, and even concerned citizens who voluntarily registered for the event free of charge through the website. The heterogeneous nature of the participant background can serve as an example of researchers playing active roles to cross the institutional scale. Lastly, the researchers' effort to cross the methodological scale can be represented by the mix of various online (LINE app, Google Meet, the website, the Facebook page) and offline tools (key-stakeholder working meeting, small vs. large size of the stakeholder forum) to catalyze changes in the way this urban river is governed in this community.

B. A Rural Sustainability Problem: Donggang River Restoration Activities

The second aquatic ecosystem restoration case study is in a rural-development setting,

two townships in Pingtung County: Zhutian, with a population of 16,615 as of 2020 (Wandan Household Registration Office, 2020), and Neipu, with a population of 53,330 as of 2020 (Neipu Household Registration Office, 2020). The main cause of environmental problems in these two rural townships is not the growth or decline in population but the concentration of livestock farms settled along sub-streams of the Donggang River. There are more than 148 swine farms in Zhutian (Pan, 2018 August 9), and Neipu is the livestock production base of more than 100,000 pigs.[1] In other words, livestock farming contributes massively to the economic development of these rural regions at the cost of degrading the freshwater ecosystem. After decades of failed attempts to restore the Donggang River, innovative action to reverse this vicious cycle of the dilemma between the economy and the environment began with the legal opportunity of recycling and reusing livestock-waste regulation, promulgated in 2017 and implemented by the Environmental Protection Administration under the Executive Yuan. In the same year, the Donggang Creek Conservation Association in Taiwan (ACTKR) became the pioneer in Taiwan in initiating non-governmental action to monitor and strengthen the implementation of this new regulation in Pingtung County. To further invest university resources into the above-mentioned innovative action and analyze the effectiveness of innovation through action research, our research team launched a closer collaboration with ACTKR under the University Social Responsibility (USR) project and funding scheme in February 2021 to engage professors and undergraduate students of 2021 spring, summer and fall semesters to create synergy in both raising awareness of the new restoration opportunity and calling for collective action to restore the Donggang aquatic ecosystem.

Table 2 summarizes the different scale-crossing roles that our researchers played in the Donggang River restoration activities. Sub-sections 3.2.1 and 3.2.2 elaborate the details of the scholarly endeavors both to epistemologically bridge the fragmented knowledge regarding the livestock wastewater problem through knowledge dissemination at the 2021 World Rivers Day with USR project funding and to physically bring together non-traditional stakeholders to redefine the cause of and solutions to this complex environmental problem, using the university as a coordinating hub for hosting additional online and offline meetings.

[1] Neipu Township website (accessed on Feb. 28. 2022) https://www.neipu.gov.tw/cp.aspx?n=44cf145f398d8ad8&s=7C6802625A5731C7

Table 2. Scale-crossing summary for the Donggang River restoration activities

	Linking disconnected knowledge	Linking disconnected stakeholders
Human-nature scale	X 2021 World Rivers Day (Figure 3) to explain impact of human activities on river (nature) and how uncertainty challenges impede river restoration (nature) to local stakeholders	X Livestock reuse promotion action by USR to emphasize human-nature relation in villages along the Longjing River (Figure 5)
Temporal scale	X Parliamentary: 2000–2021/city council: 1962–2018/local community: 2021	X 2021 Spring semester + Summer + Fall academic semesters
Spatial scale	X Compare all cities/counties in Taiwan	X* Neipu and Zhutian townships
Institutional scale	X Parliament/City Council/local community	X Local government, local NGOs, local university, local community, private companies**
Methodological scale (natural science vs. social science approach)	X Uncertainty typology analysis	X Google Meet online meeting/app concept design/website construction

* The Donggang River is 44 km in length, flowing through eight townships in the countryside area. In this study, researchers only selected two townships to conduct participatory research, Neipu and Zhutian townships.

** The highlighted area refers to stakeholders that are unique for this rural sustainability case when compared to the urban sustainability case.

Source: compiled by authors

(A) Linking disconnected knowledge

The first effort by our research team was to conceptually redefine or reorient the problem of livestock-waste water pollution. While most of the previous livestock wastewater research in Taiwan has been conducted by environmental scientists or engineers, such research from a natural scientists' perspective inevitably examines issues of pollutant sources by identifying 22 emerging compounds (Liu et al., 2018) or scientifically proving the benefit of the reuse of liquor and digestate from anaerobic digestion (AD) as fertilizers for agricultural lands (Tsai, 2018). Yet the current study argues that solving the issue of livestock wastewater is more than a hard-infrastructure problem. While an array of technological remediation solutions is available, whether these technologies can be successfully applied by users and how problems and solutions are perceived by stakeholders differently, i.e. how to reduce "uncertainty" in a wicked problem (Goel, 2019; Price & Toonen, 2017), also needs to be taken into account—a soft infrastructure account. In other words, we argue that to effectively solve the livestock

wastewater problem, we need to tackle uncertainty challenges at the intersection of science, economics, politics and human behavior as Incropera's approach in combating climate change (2016).

To fill this literature gap, the present study launched a discourse analysis (crossing the methodological scale) to rhetorically examine the "uncertainty" embedded in the complex debates around livestock wastewater, which are recorded at the level of Parliament and City Council in Taiwan. We also conducted a survey during our university engagement with local farmers within the farming communities of Zhutian and Neipu townships to explore causes of livestock-liquor reuse adoption or non-adoption by farmers. Then on October 7, 2021 our research team hosted a 2021 World Rivers Day celebration (Figure 3) with both an outdoor river-walk and indoor workshop. We aim to help local stakeholders better visualize the impact of human activities on nature and to share the initial findings from the livestock wastewater uncertainty challenge analysis to improve our collective understanding of the knowledge gap before co-developing strategies with local stakeholders to bridge the identified knowledge gap. In this event, we did not limit participation within the Pingtung area but also invited livestock wastewater stakeholders from Yunlin and Changhua counties where the aquatic ecosystems are similarly degraded.

Figure 3. 2021 World Rivers Day with an outdoor river-walk and an indoor workshop to improve the human-nature linkage

Source: photos taken by the authors in the capacity of the USR project on October 7, 2021

The above scholarly endeavor not only linked the knowledge of an aquatic ecosystem with its associated anthropogenic value and activities (crossing the human-nature scale) but also enabled temporal-, spatial-, and institutional- scale comparisons by non-discriminatorily collecting, analyzing and disseminating data from 206 parliamentary-debate records from 2000 to 2021, 90 City Council debate records from 1962 to 2018, and 30 local community surveys retrieved in 2021. Methodologically, the collected data were

reviewed and analyzed using the "nine lives of uncertainty" typology promoted by Dewulf and Biesbroek (Dewulf & Biesbroek, 2018) and presented in Table 3: epistemic substantive uncertainty (E-Sub), epistemic strategic uncertainty (E-Stra), epistemic institutional uncertainty (E-Ins), ontological substantive uncertainty (O-Sub), ontological strategic uncertainty (O-Stra), ontological institutional uncertainty (O-Ins), ambiguous substantive uncertainty (A-Sub), ambiguous strategic uncertainty (A-Stra), and ambiguous institutional uncertainty (A-Ins). By systematically analyzing and identifying these nine categories of uncertainty, we hope to provide a more comprehensive picture of livestock wastewater problems at stake to local stakeholders and pave ways to co-develop problem-solving strategies with stakeholders beyond problem identification.

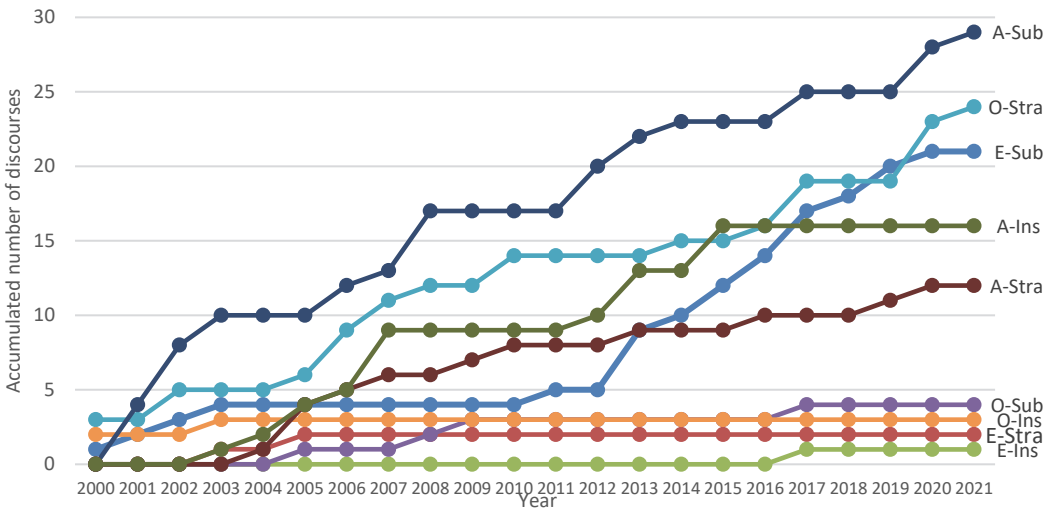
Table 3. 3 × 3 uncertainty typology

		Nature of uncertainty		
		Epistemic	Ontological	Ambiguity
Object of uncertainty	Substantive	Lack of knowledge on issue	Irreducible unpredictability on issue	Multiple frames on issue
	Strategic	Lack of knowledge on interaction of actors	Irreducible unpredictability on interaction of actors	Multiple frames on interaction of actors
	Institutional	Lack of knowledge on rules of the game	Irreducible unpredictability on rules of the game	Multiple frames on rules of the game

Source: Drawn by the authors, referencing Table 1 in (Dewulf & Biesbroek, 2018).

A sample of our empirical findings (Chien, 2021) is demonstrated in Figure 4, in which a comparison of 2000–2010 vs. 2011–2021 parliamentary-debate data reveals the distinct uncertainty types each period focused on. For instance, in the early years of discussing livestock wastewater, we did not yet have consensus in Taiwan as to which "frame" to use (A-Sub for 2000-2010 = 17) to understand the causes of and solutions to tackling the agricultural-effluent pollution from animal farms that goes into many freshwater ecosystems. One decade later, the same debate in Parliament shifted its focus to the lack of knowledge, marked by E-Sub (for 2011-2021= 17). Among the Pingtung local stakeholders, our survey results indicate that almost half of the expressed uncertainty type lies in the ontological-substantive type. For instance, concerns expressed by local farmers include unpredictability on quantity of biogas residue and slurry, bug issue, bad odor, impact on soil composition, et al. Another 20% of uncertainty lies on the epistemic-

substantive type, mostly referring to the lack of knowledge of livestock wastewater treatment process and proper management. For a comprehensive analysis of the livestock wastewater uncertainty challenge, please refer to the conference presentation of Chien (2021) and its related publication.



	E-Sub	E-Stra	E-Ins	O-Sub	O-Stra	O-Ins	A-Sub	A-Stra	A-Ins
2000-2010	4	2	0	3	14	3	17	8	9
2011-2021	17	0	1	1	10	0	12	4	7
Total	21	2	1	4	24	3	29	12	16

Figure 4. Comparing annual quantitative parliamentary-debate data

Source: compiled and drawn by the authors

(B) Linking disconnected stakeholders

As for connecting agencies that are not traditional stakeholders in managing the livestock wastewater problem, similar to our effort at the Wannian River, we started by identifying a common social-ecological concern: freshwater pollution from anthropogenic activities. Furthermore, we used the theme of "promoting the reuse of AD-based liquor and digestate for irrigation and fertilizer" to attract the attention of local governments, local communities, environmental consultants and technology-solution companies, local farmers, et al. We adopted the water-energy-food nexus framework (Smajgl, Ward & Pluschke, 2016) as one of the integrated solutions to use a circular economy as a means to restore an ecosystem while working in tandem to push for technological innovation and economic development. By doing so, we created a win-win scenario for most of the engaged stakeholders and encouraged them to collaborate for a common cause by

emphasizing the importance of recognizing human-nature linkage through our USR action plan designed around the Long-Jing River (Figure 5), which is a tributary of the Donggang River

Figure 5. Linking Neighboring Villages (Human) with the Long-Jing River (Nature) in the USR Project

Source: drawn by the authors

Three phases of action, corresponding to the spring, summer, and fall semesters of the 2021 university calendar, engaged three different groups of students in the university's social responsibility projects with local stakeholders along the Long-Jing River. Therefore, we demonstrate that researchers can play a more active role in linking stakeholders across human-nature, temporal, spatial, and institutional scales. Methodologically speaking, we have also mixed a variety of instruments—surveys, face-to-face meetings, Google Meet online meetings, conceptual app design and website construction (Figure 6), etc.—to create opportunities for multiple stakeholders to learn, engage, debate, and eventually to drive for behavioral change.

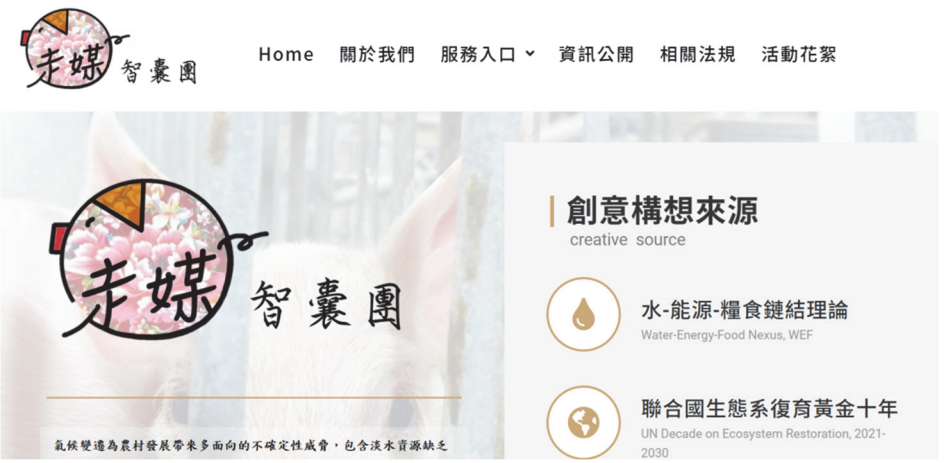


Figure 6. Stakeholder engagement app and website construction by a local university in Pingtung*.

* The logo of this stakeholder engagement initiative was designed by students from the Department of Animal Science. Students under the supervision of faculty members also conceptually designed an app, Zoumei (literally, "matchmaker" in the local Hakka language), to provide matching and scale-crossing services for local farmers, biogas producers, pig farms, local governments, etc. This conceptual app design was also presented at a climate change competition hosted by the Ministry of Education, Republic of China, Taiwan in Spring 2021.

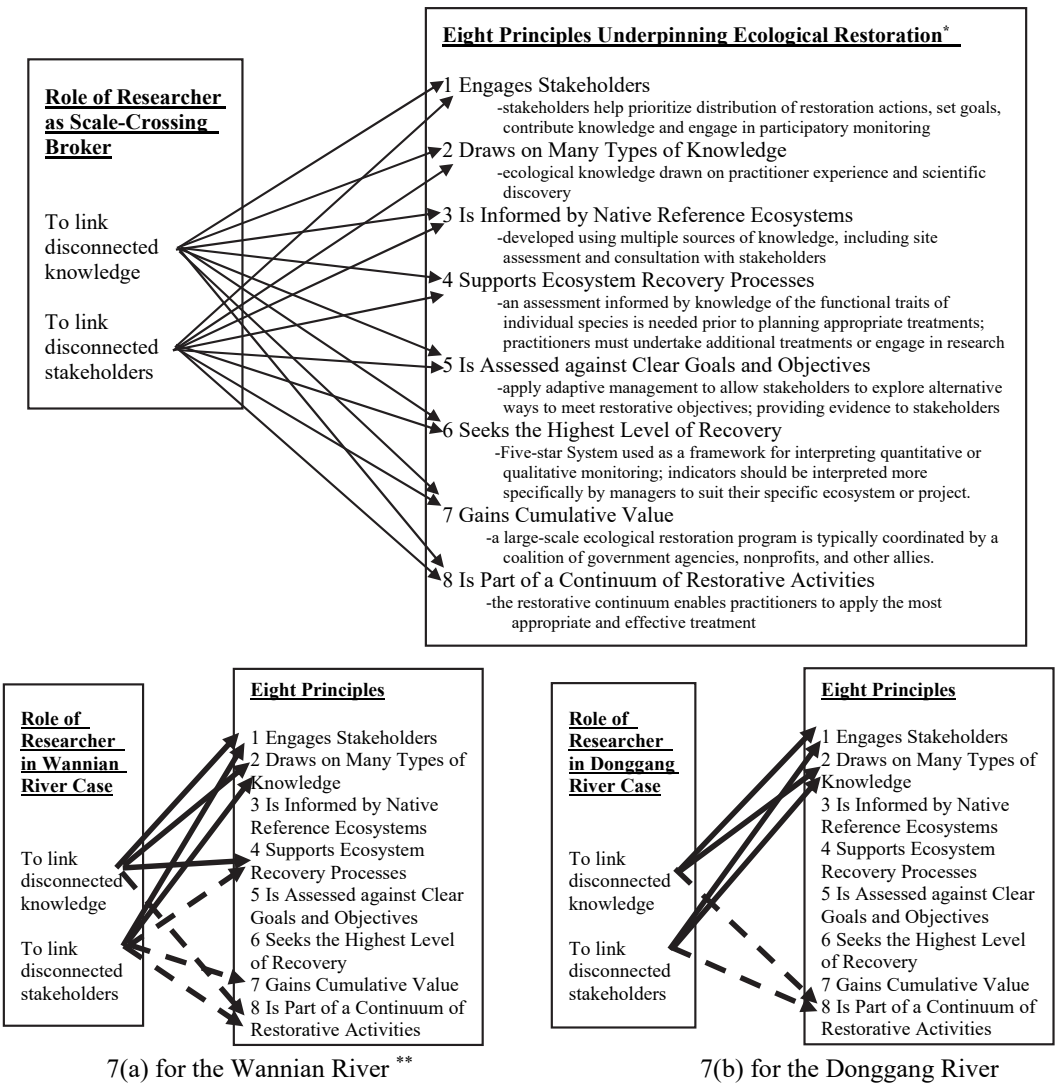
Source: https://zoumei.npust.edu.tw/ (accessed on May 17, 2022)

IV. Using Ecological Restoration Principles to Identify Unexplored Potentials of Researchers

In addition to using two empirical case studies of ecological restoration to showcase the role researchers can play as scale-crossing brokers, this study further adopted a standardized ecological restoration principle to systematically identify unexplored potentials of researchers in the two case studies in order to recommend a future action research agenda or policy direction. To be specific, we used a matching exercise based on eight principles underpinning ecological restoration, published by the Society for Ecological Restoration and its international partners in the second edition of the "International Principles and Standards for the Practice of Ecological Restoration" (Gann et al., 2019). Those principles are 1) to engage stakeholders, 2) to draw on many types of knowledge, 3) to be informed by native reference ecosystems, 4) to support ecosystem-recovery processes, 5) to be assessed against clear goals and objectives, 6) to seek the

highest level of recovery, 7) to gain cumulative value, and 8) to be part of a continuum of restoration activities.

As the matching exercise (Figure 7) depicts, the present study argues that all eight principles could have the potential to require researchers' active roles in linking both disconnected knowledge and disconnected stakeholders. To be more specific, each principle also expands and specifies more roles researchers can potentially play. For instance, Principle 1 points out that, ideally, engagement should occur at the conceptual phase, or well ahead of project initiation. This is where researchers, often as invited consultants to government restoration committees, can play a more active role in reminding local or central governments to include non-expert voices and opinions as early as possible, which is not the standard procedure in many of Taiwan's restoration projects that are similar to the Wannian River and Donggang River restoration activities.



7(a) for the Wannian River **

7(b) for the Donggang River

Figure 7. Matching with principles underpinning restoration activities.

* For more details about these eight principles, see reference (Gann et al., 2019).

** Thick arrow = already in action, dash arrow = in developing future action, no arrow = no action planned

Source: drawn by the authors

Principle 2 specifies the need for restoration programs to draw on many types of knowledge, based on both practitioner experience and scientific discovery. Again, it implies that researchers are not only needed in a traditional sense to provide scientific findings. Researchers can also contribute by acting as scale-crossing brokers, as

exemplified by this study, to systematically engage local stakeholders and intentionally ensure the inclusion of practitioner experience to co-develop restoration policy making recommendations. Principle 3 discusses the importance of setting restorative goals based on native reference ecosystems and again stresses the need to use multiple sources of knowledge, including site assessments and consultations with stakeholders. While most site assessments are conducted by scientific teams who can evaluate in an integrative and empirical manner the social and ecological benefit of restoration activities, if researchers can be more mindful of including in their assessments the first-hand observations of stakeholders, outcome assessments can receive wider support and get us closer to the in-situ ecosystem reality. In tandem with Principle 3, Principle 4 emphasizes how assessments informed by knowledge of the functional traits of individual species are needed prior to planning appropriate treatments. It also underlines that practitioners must undertake additional treatments, or engage in research that echoes the role of researchers as scale-crossing brokers to link not only disconnected knowledge but also disconnected stakeholders.

Principle 5 calls for the application of adaptive management to ensure the formulation and reformulation of clear goals and objectives while allowing stakeholders to explore alternative ways to meet restoration objectives. It also implies researchers' responsibility to provide empirical evidence to stakeholders during the adaptive management process. Similarly, as Principle 6 seeks the highest level of recovery, a five-star system is used as a framework for interpreting quantitative or qualitative monitoring, which inevitably requires researchers' scientific input and data comparison. Yet this principle once more stresses that these indicators need to be interpreted by managers to suit the specific ecosystem or project. As a result, linking the disconnected knowledge between scientists and managers is one step that cannot be omitted and is an area in which scientists can assume an active role in voluntarily engaging managers to co-produce knowledge.

Principle 7 refers to the need for coordination by a coalition of government agencies, nonprofits, and other allies to generate cumulative value by initiating a large-scale ecological restoration program. Since this kind of cross-sector or cross-scale coalition does not occur without intentional design and at least one, if not a few, intermediaries, if researchers can assume an active role in bridging the communication gap, a large-scale ecological restoration program can potentially be fast-tracked. Lastly, Principle 8 describes how the restoration continuum can enable practitioners to apply the most appropriate and effective treatments. Again, researchers not only can first assess the status of any activities in the restoration continuum—1) reduced social impacts, 2) remediation, 3) rehabilitation,

4) ecological restoration—but also can deliberately propose policy recommendations and devise constructive strategies to move the activities forward to the next level of the continuum.

When applying the matching of the eight principles with our two empirical cases, we can see from the Wannian urban river case in Figure 7(a) that the role of researcher is more active in linking disconnected knowledge and stakeholders in Principles 1 and 2 only, leaving the other principles either in planning (Principles 4,7,8) for future action or no initiative yet (Principles 3,5,6). The mapping reveals that there are several areas that we, as researchers, can strive to create additional integrated knowledge that is lacking at the present time by coordinating scholars of various disciplines to assess and help to determine the native reference ecosystem (Principle 3) with the engagement of stakeholder's viewpoint. Local researchers can also serve as a hub to invite both non-traditional stakeholders, such as citizens and encourage traditional stakeholders to collaborate with each other to form a coalition of different governmental agencies, nonprofits, educational institutions and even local churches for planning larger-scale and long-term restorative initiatives (Principle 7).

Similarly, the Donggang case presents even more opportunities that researchers can explore since the recycle and reuse of livestock wastewater is a new governmental initiative that is still at its experimental stage. With limited government resources, especially for the relatively small size of local governments administering rural areas, local universities could assume greater social responsibility to aid their local government and local community by proactively and voluntarily investing university resources, both human and financial, to catalyze rural river restorative activities. Based on the principle-matching exercise depicted in Figure 7, as of 2021, we were still at an early stage of identifying and mobilizing stakeholders to provide either scientific inputs or local perspectives (Principles 1,2) in preparation for devising the most appropriate strategy to implement restorative activities in the restorative continuum (Principle 8). In other words, the roles of researchers in future action research or policy recommendations on the Donggang River restoration can focus on inviting researchers' endeavors and rallying resources for the presently unexplored Principles 3,4,5,6 and 7 to co-develop Native Reference Ecosystems, key bioindicators, an adaptive management plan, quantitative or qualitative monitoring based on the Five-star System and the structure of a large-scale ecological restoration program coordinated by a coalition of government agencies, nonprofits and other allies, etc.

V. Concluding Discussion

Although the existing literature has increasingly pointed out problems of mismatches between governance and biophysical realities and has urged for the adoption of coordination networks or multilevel governance, there remains a dearth of knowledge about the structures and functions of these networks, whether that knowledge is based on theoretical discussion or informed by empirical cases. To fill in these particular research gaps, the principal theoretical argument of this study is that one of the pivotal prerequisites to tackle mismatches in ecosystem restoration governance is to more effectively leverage researchers' roles as scale-crossing brokers to 1) link disconnected knowledge that suffers from the problem of government silos and 2) to link disconnected stakeholders, especially to include and engage non-traditional stakeholders who have no formal or organized representation such as citizens or marginalized farmers to promote social learning. We also call for future studies to investigate both theoretically and empirically how and in which aspects researchers can be useful to catalyze the co-development of the structure and function of the coordination networks or multilevel governance needed to fix the mismatches problem between environmental governance and its biophysical realities.

To strengthen our argument, our paper first empirically investigates two river restoration cases in southern Taiwan to showcase the capacity of researchers as brokers in action to enable scale crossing in five distinct scales – human-nature, temporal, spatial, institutional and methodological. Whereas Table 1 summarizes the results of researchers' intervention for the Wannian River through various scholarly activities such as linking data from upstream and downstream in Pingtung City (across the spatial scale, see Figure 1) or promoting scenario simulation through LINE online meetings with local stakeholders (across the methodological scale); Table 2 demonstrates the capacity of researchers to link disconnected knowledge and stakeholders to achieve Donggang River restoration objectives. For instance, the latter was done by the design, implementation and evaluation of the slurry reuse promotion action of the USR project (across human-nature/temporal/spatial/institutional/methodological scales, see Figures 5,6) led by university professors and undergraduate students. The former was achieved through the hosting of 2021 World River Day (Figure 3) where the impact of human activities on the river and how nine types of uncertainty challenges (Table 3, Figure 4) impede river restoration (across human-nature/temporal/spatial/methodological scales) were explained and shared with the invited stakeholders not only from Pingtung but also from other

counties in Taiwan, namely Yunlin and Changhua counties (across the spatial scale) where livestock wastewater is also the main source of river pollution.

Secondly, in comparing our urban (Wannian River, Table 1) vs. rural (Donggang River, Table 2) river restoration data, the findings inform us that there is an empirical variation in the type of institutional scale researchers can be particularly useful to cross or link. For instance, there are more "concerned citizens" (see the institutional scale in Table 1), or non-traditional stakeholders who were not acquainted with each other or affiliated with a formal organization, showed their interest, in particular with the aid of ICT tools, to engage in restoration activities in the urban river setting compared to the rural river setting. We suspect that this finding might be related to the educational background, income status, or age composition of the urban population, and more empirical studies should be conducted to examine this initial case study observation. As for the rural setting, more "local community members," led by village heads and followed by a group of farmers who know each other well enough, as well as "private companies" (see the institutional scale in Table 2), showed their interest in engaging in restoration activities by creating new business models in the field of circular economy in agriculture. We suspect that this finding might be related to the relatively smaller size of the community, which facilitates the call for community action by stakeholders with formal or organized entities, and to the comparative lack of government resources invested in rural communities, which promotes a sense of *communitas* with a stronger need for the injection of non-governmental resources. Therefore, in their future studies, we remind researchers to pay attention to the situational context (such as rural vs urban context) the ecological restoration is embedded with in order to determine the type of stakeholders that the researchers can effectively link with.

Thirdly, by adopting a standardized ecological restoration principle (section 4) to conduct a matching exercise with the researchers' intervention in the two river restoration case studies, Figures 7(a) and 7(b) reveal different areas that were unexplored by our research team in the existing action research capacity. These areas of unexplored principles can serve as reference points for future action research planning or policy recommendation to improve the process and outcome of restorative activities. For instance, researchers in the Wannian River restoration projects have played active roles to achieve Principles 1,2 and 4 to engage stakeholders, utilize non-scientific knowledge or identify key bioindicators, and have plans to achieve Principles 7 and 8 to coordinate between agencies and to assist practitioners in applying the most appropriate and effective treatment. Yet areas that lack current researchers' input and are in need of future scholarly attention and resource input lie within the scope of Principles 5 and 6 to co-develop a measurable

indicator to assess restoration progress and to lay out the mandate for ecological restoration to the highest attainable level of recovery. For the Donggang River restoration projects to undergo the same principle matching exercise, there are several missing areas that require additional researchers' future engagement, i.e., in Principles 3,4,5,6,7. This immense gap between the roles of researchers and these five restorative principles indicates to us a myriad of innovative potentials for researchers. Their role as an intermediate agent is to co-produce knowledge and to engage multiple stakeholders to further scale up co-production equitably to improve our collective understanding of the complex social-ecological system before proposing and implementing innovative solutions with stakeholders. Again, such endeavors in knowledge co-production and more can be played out constructively by researchers and should be regarded as a prerequisite to design cross-sector policy integration and integrated solutions for overcoming barriers to promote restoration and other sustainable use or management of natural resources.

Lastly, as for the future research agenda, more studies focusing on researchers' roles as scale-crossing brokers in knowledge co-production, among others, can be conducted in reference to the emerging literature on quadruple or quintuple helix innovation emphasizing the relationship between university, industry, government and the media-based public in eco-innovations (Baccarne, Logghe, Schuurman & Marez, 2016; Carayannis, Grigoroudis, Campbell, Meissner & Stamati, 2018; Morawska-Jancelewicz, 2021). Such endeavors to recognize new roles and potentials of researchers can equally resonate with the literature on the Third Mission (TM) of universities or beyond to emphasize their capacity as making "contributions to society" (Compagnucci & Spigarelli, 2020; Gulbrandsen & Slipersaeter, 2007) and the function of co-creation for sustainability (Trencher, Yarime, McCormick, Doll & Kraines 2014).

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研究人員在知識合產暨更多面向中跨尺度領域的中介角色：探索解決生態系復育治理中不匹配問題的先決條件

簡赫琳*

《摘要》

治理和生態系統之間的錯位偏差或不匹配是一項關鍵的永續挑戰，需要協作和協調網絡來設計全面性的解決方案，以解決生態系統退化的嚴重問題。然而，在設計任何全面性的解決方案之前，我們對於修正治理機制與其息息相關的複雜社會生態系統缺乏全面性的理解和知識。本研究認知到上述認識論的挑戰，且認為解決復育生態系統中不匹配問題的先決條件之一可由研究人員作為跨尺度領域中介者來提出干預介入，與多個利害關係人共同生產知識，並與脫節的利害關係人串連，以便為未來籌備生態系統復育聯盟做準備。在這種情況下，研究人員作為中介者的努力不僅連結社會和生態知識，也連結個體環境治理實體中當前持有的知識，為系統思維方法創建資料庫，並為未來的集體行動鋪路。

本研究以河川復育治理為示範領域，通過實證研究分別對台灣萬年溪和東港溪的城鄉永續問題進行實證研究，展示研究人員如何在行動中發揮跨尺度領域中介者的作用，以鏈接在五個尺度領域的不連貫知識和利害關

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係人：（1）人與自然尺度領域，（2）時間尺度領域，（3）空間尺度領域，（4）制度尺度領域和（5）方法尺度領域。除了實證案例演示之外，本研究還嘗試將研究人員的角色與支持生態復育的八項原則相匹配，以探索未來研究人員可作為中間代理人發揮的更多具體任務。

[關鍵字]：跨尺度領域中介者、知識合產、不匹配問題、社會生態系統、灰水