Supporting Information

Methods

Bending the Curve – question solicitation

We define "bending the curve" actions in freshwater biodiversity conservation as those activities that aim to guide restoration, educate the public and decision-makers, and target investments in tools, research and policy that will lead to the recovery of freshwater biodiversity, not just the slowing of the current downward trajectory or the stabilization of the current crisis state. We requested questions from the freshwater community, based on this definition, that would aid in addressing knowledge gaps in freshwater biodiversity research.

The call for questions portal was available from September to November 2019. Participants accessed the call for questions through an online platform (i.e., surveyplanet.com). The call for questions was shared as broadly as possible by the authors and their network contacts with no limits on outreach (i.e., snowball approach or chain-referral sampling). It was therefore not possible to quantify the full extent of the call-for-questions' reach which is typical of the Sutherland et al. (2011) approach for these exercises. It is not known how many individuals or nations received a request to participate (or were aware of the survey) and chose not to respond. Those who did respond were asked to provide questions that would help address the knowledge gaps and barriers associated with "bending the curve" of freshwater biodiversity loss, as well as to provide information on their sector, role, and geographic location. To obtain as many questions as possible and to allow participants to contribute fully, there were no limits to the number of times an individual could participate.

Individuals could answer all or some of the questions provided and were not limited in the number of responses they could submit. All responses were made anonymously. For questions 1-4, participants were able to provide free-form answers, for questions 2-3, participants could select an unlimited number of categories (Table S1). Additionally, we requested basic information about participants that would help us determine the reach of our call for questions, including participant sector (industry, government, not-for-profit, academic and other), their primary role (research, practitioner, decision maker, student/post-doc, other) and the country where their work was based.

Question Inclusion/Exclusion

Narratives from participants were separated into unique questions and edited for clarity by the review team (MH, HSM, DL, and SJC). General statements, lists of terms, or calls for specific actions (i.e., "stop the logging") were not included, as it was not possible to create specific questions without making large assumptions as to meaning. Additionally, questions that considered identification of threats or natural history were removed from consideration as they are not expected to lead to "bend the curve" actions under our definition. We also eliminated questions that were regionally or taxonomically specific.

After the initial screening by the review team, a short list of questions were evaluated by the remaining authors who were asked to: 1) lump or split specific questions, 2) suggest re-wording for clarity and 3) assess the likelihood of a question leading to research that would advance curve-bending actions. Additionally, all authors had the opportunity to advocate for questions that had been initially removed or to suggest their own. Remaining questions were grouped by content and a starting list of 28 "essential questions" was created by the review team and edited by all authors for clarity and conciseness. This resulted in the final list of 25 essential

questions. The final list of questions was selected through an iterative process, edited by all authors, and then condensed to six major themes (Figure 3) using the methods described in Sutherland et al. (2011).

Finally, a small sample of participant questions within the essential question groups were then selected and edited to reflect questions with research potential. Each essential question has three sub-questions. All authors edited the final list of essential and sub-questions. Essential questions were also loosely aligned with the priority actions of the Freshwater Biodiversity Emergency Recovery Plan (Tickner et al. 2020), in order to identify synergies between our list of research questions and the actions suggested there.

Results

Participants represented all sectors: *Industry* (n=2; 1.2%), *Government* (any level; n=30; 18.5%), *Not-for-profit* (n=48; 29.6%) and *Academic* (n=61; 37.7%), and an additional 21 participants (13%) who self-identified as *Other* (see Figure 1 of main text). Several participants (n=11) selected more than one sector, so the total number of sectors (162) is more than the total participants.

The most common primary role was *Researcher* (n=74; 43.3%), followed by *Practitioner* (n=35; 20.5%), *Decision maker* (n=20; 11.7%), *Other* (n=25; 14.6%) and *Student/post-doc* (n=17; 9.9%); the only primary role that we expected which was not represented by our participants was *Funder* (see Figure 2 of main text). As with sector, participants often selected more than one primary role. A total of 21 participants selected 2 or more primary roles, therefore, the total number of selected primary roles (172) is greater than the total number of participants. While the authors are located in nine countries (Figure S1) participants worked, or

were located in, 45 countries world-wide. The top three participating countries were Canada (n=25 participants), the United States (n=23) and Australia (n=18). The majority of countries (27) had only one participant (Figure S2).

A total of 424 unique questions were received from 144 participants (Table S2). A total of 207 questions were removed due to a lack of applicability to the research goal of bending the curve for freshwater biodiversity. Of these, 69 (16%) considered threat identification, whereas 49 (12%) considered current status. The remainder were either too specific to taxa or location, considered natural history, or were calls for action, not questions. Not all questions that met the requirements for "bending the curve" for freshwater biodiversity were included in the final list of 25 questions and sub-questions, but all influenced the creation of these larger groups.

Of the 25 essential questions suggested by the freshwater community, 16 aligned well with the priority actions of the Freshwater Biodiversity Emergency Recovery Plan (Tickner et al. 2020), while the remainder provide new avenues of research for future priorities (Table S3). These questions are broad enablers of bending the curve for freshwater biodiversity (e.g., communication and awareness raising) and would likely be required to establish the conditions needed for change to occur. Consequently, while they do not explicitly align with the actions identified in the Emergency Action Plan, the research results these questions would generate would likely assist in the application of these actions in the future.
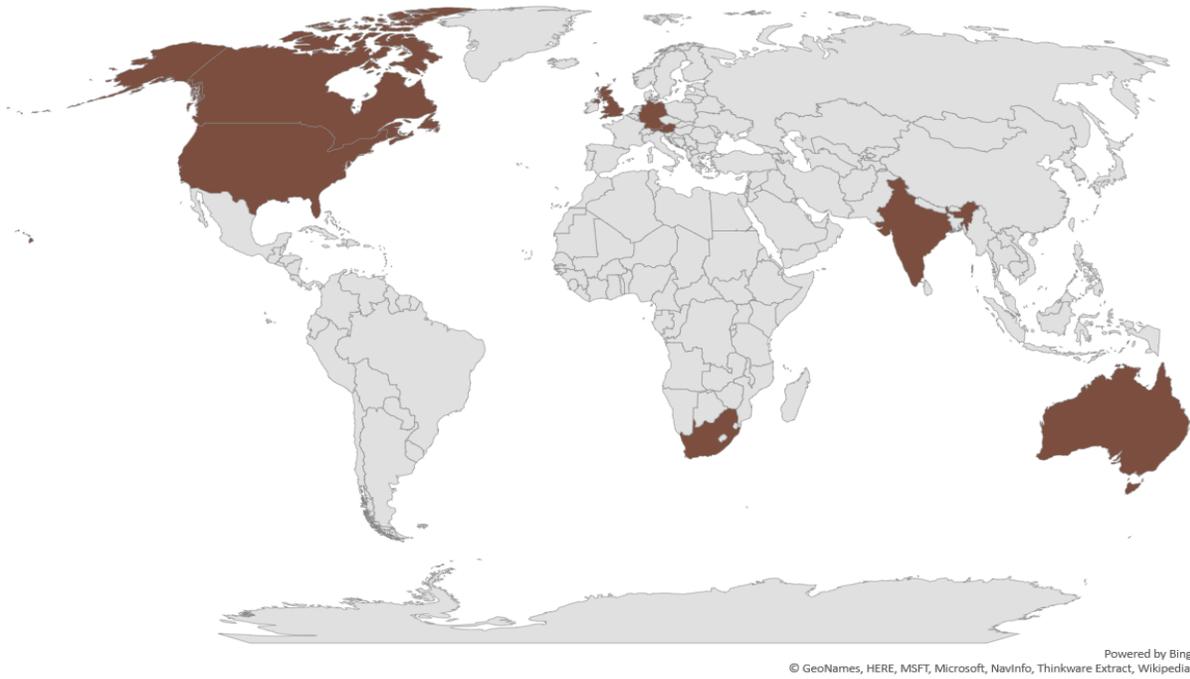
Figure S1. Authors represent nine countries (brown) globally.
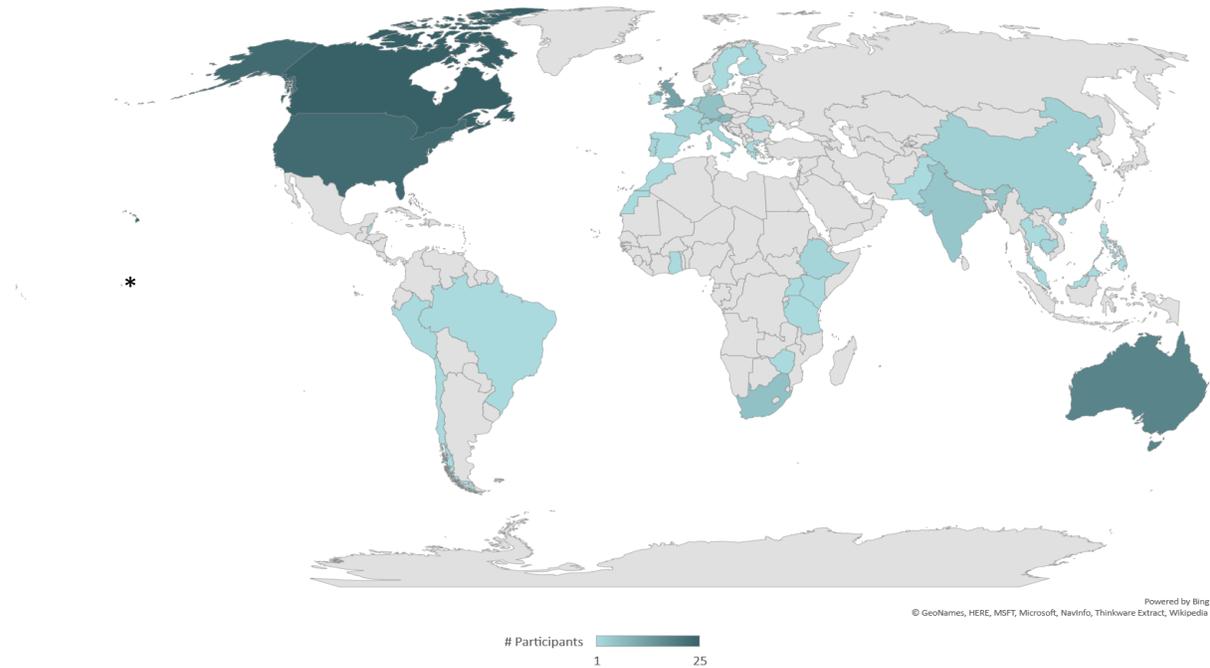
Participants
1   25

Figure S2. Participant countries. The gradient in colour indicates the number of participants per country, with Canada, the United States and Australia having the most participants. Kiribati is indicated by *.

Table S1. Questions and information requested of participants on the online platform
https://s.surveyplanet.com/fH1seZJ. Questions could be answered by selecting categories or by
including free form narratives.

Number	Questions/Information requested	Format of Answers
1	What are some questions that, if addressed, will improve our ability to understand the state of freshwater biodiversity and will help bend the curve of the current declining trajectory?	Free form Unlimited
2	Please indicate your sector or primary affiliation.	Category ▪ Government ▪ Non-profit ▪ Academic ▪ Industry ▪ Other (free form) Unlimited
3	What is your primary role?	Category ▪ Decision making ▪ Practitioner ▪ Funder ▪ Researcher ▪ Student/post-doc ▪ Other (free form) Unlimited
4	What country do you live in or are currently based?	Free form Unlimited

Table S2. Full question list from 144 participants. A total of 424 individual questions were submitted (submissions from participants were split where necessary if more than one question was included). Questions indicated with (*) were edited for clarity. Questions indicated with (†) were not applicable to "bending the curve" (i.e., threats, current status, overly specific, lists of terms etc.) and were excluded from further consideration.

Number	Participant	Questions
1	1	Under what circumstances can nature-based solutions contribute to bending the freshwater biodiversity curve?
2*†	1	Where might nature-based solutions have unintended consequences for freshwater biodiversity?
3†	1	What are the food security implications of losing freshwater species?
4*†	1	Can the food security benefits of securing freshwater species be quantified?
5†	2	Public support of conservation activities
6†	3	Valuation, common people, legislators, policies (local and national), ecosystems connectivity, coordination, integration, mainstreaming, monitoring, citizen science, housewife, climate change, biodiversity, peoples' way of life and water, freshwater and women, freshwater and youth, freshwater and men, freshwater and gender, ecology
7*†	4	What methods can be used to improve management of cyanobacterial blooms, caused by warming climate, in oligotrophic lakes?
8*†	4	What are the effects of different management practices on freshwater biodiversity?
9*†	5	Which should be the priority for freshwater biodiversity: addressing climate change, or mitigation of immediate threats (flow regulations, pollution, habitat destruction, etc.)?
10†	6	How important are terrestrial resource subsidies (allochthony) in freshwater food webs?
11†	6	What is the role of freshwater microbiota in allochthony levels?
12†	6	How do anthropogenic disturbances change affect allochthony?
13†	6	How do climate change affect allochthony?
14†	7	What are implications of climate change on freshwater biodiversity regionally?
15*†	8	What leverage can be used to ensure that critically endangered species receive the attention they deserve and do not simply dwindle to extinction?

Number	Participant	Questions
16*	8	Is there any viable alternative to assertions regarding 'right to exist' and 'intrinsic value' that can be deployed to help ensure survival of these species?
17*	8	How can we do a better job of protecting the Mekong capture fisheries (and the reliance of people on the largest freshwater capture fishery on Earth) for the likely (and widely predicted) devastation that will be wrought by multiple mainstream dams?
18*	8	Can we avoid the economic benefits to be gained by proponents of dam development (mainly urbanites) further impoverishing those people living along the Mekong who depend on artisanal fisheries?
19*	9	What actions can be implemented to better integrate world-views from traditional and indigenous knowledge, faith-based and multi-cultural understandings, in order to broaden the models, orthodoxies, and languages that drive the science-policy interface.
20†	9	Evaluating the impact of ecological and socially engaged arts practices on resilient regimes for management of freshwater biodiversity.
21	10	How do we create better links between academic understanding of ecosystem function and policy makers who are used to pressure based indices derived from a limited taxonomic group?
22	10	How can true catchment approaches be delivered on a large scale?
23†	11	What are the threats to aquatic biodiversity, especially fish, amphibians, etc.?
24*†	11	What causes the rate of degradation of aquatic habitats?
25*†	11	What are the root causes of aquatic habitat degradation?
26	12	Can we disaggregate freshwater biodiversity into genera and look at these trends in order to target management response?
27	12	Is it possible to work at basin and sub-basin scales to make sense of threats in functionally relevant/linked aquatic ecosystems?
28	12	What sort of in country/in-basin monitoring is reasonable to expect as a country commitment (i.e. not reliant on external funding)?
29†	13	How is land use changing?
30*†	13	How have aquatic ecosystems been fragmented?
31*	14	Why can't we find interested institutions and funding to undertake important research on new areas such as nano- and pico-plankton, or bacterial loops?

Number	Participant	Questions
32*†	14	Why are important limnological parameters, such as biomass in lakes, overlooked?
33*	15	What is the impact of groundwater depletion in freshwater ecosystems, habitats, and associated biodiversity that depend on groundwater-surface water interactions (base flow in rivers and lakes, springs, etc.)?
34	16	How can we build social license for conservation action that rationalizes economic development and integrates climate change adaptation?
35	16	How can we build an understanding of the linkages between groundwater and surface water resources at a resolution that informs local management?
36†	17	Can climate change influence natural host-parasite relationships and potentially drive freshwater species to local or global extinction?
37†	17	Can invasive species influence natural host-parasite relationships and potentially drive freshwater species to local or global extinction?
38*	18	What is working with regard to pollution reduction?
39	18	What are the most cost-effective measures for improving freshwater biodiversity?
40*	19	How will using less chemicals in agriculture and preventing the release of medicinals improve water quality?
41*	19	How can the production of real green energy while eliminating barriers and restoring longitudinal continuity be achieved?
42*	19	How can the expansion of urbanized areas be planned to avoid destruction or degradation of wetlands?
43*	19	How can transversal continuity in ripisylve forests and reed plots be maintained more effectively?
44*	19	Can the use of water for irrigation, drinking water, and cooling systems be better regulated to create new barriers to use and enable periodic times for natural hydrologic, ecologic and sedimentary dynamics?
45*	19	Can regulating leisure activities (water walks, canyoning etc.) be used to prevent the destruction of habitats and disturbance of fauna?
46*	19	How can the exchange of organisms (fish, bacteria, virus, ...) between different hydrographic basins be controlled?

Number	Participant	Questions
47*	19	How can the expansion of invasive species be controlled?
48*†	20	What are the long-term effects of road salting during winter periods on the ecology and evolution of freshwater species?
49*†	20	What are the effects that different introductions of exotic fish for aquaculture have had on endemic ictiofauna across habitats?
50*†	21	What is the reproductive timing and strategy for many understudied tropical river fish species?
51*	21	How can freshwater scientists work with cattle ranching communities in Latin America to implement best practices on their ranches?
52	21	How can freshwater scientists have their concerns brought to the table in larger tropical forest conservation initiatives?
53*	22	What are the priority areas for conservation in the tropics?
54	23	How have past conservation efforts led to resilient riverine ecosystems and what lessons stand to be gained from these efforts for expanding the application of freshwater conservation policies?
55	23	How can resilience assessments inform decision-making for freshwater biodiversity conservation?
56	23	How can we best prioritize dam sites for removal and subsequent river restoration?
57	23	What framings can be used to convince stakeholders to engage in biodiversity habitat conservation and restoration?
58*	24	What methods can be used to better and more effectively communicate the need for alternate freshwater fishing methods and/or equipment?
59†	25	What are the links between freshwater biodiversity and development?
60*†	25	Why does freshwater biodiversity matter in a growing world?
61*†	25	What are the solutions to bending the curve rather than focusing on the fact that everything is dying and in decline?
62†	26	What is the extinction risk (Red List status) of freshwater species?
63†	26	Where are the hotspots of freshwater species richness?
64†	26	Where are the hotspots of threatened freshwater species richness?
65†	26	Where are Key Biodiversity Areas (KBAs) for freshwater biodiversity?
66†	26	What are the primary drivers of decline in freshwater species?

Number	Participant	Questions
67†	26	Are particular life history traits (e.g. migratory behaviour) associated with greater extinction risk and why?
68	26	What conservation success stories are there for freshwater species?
69*	26	How can conservation success stories be translated to species at high risk of extinction?
70	26	How can general interest (e.g. in the wider public) in freshwater biodiversity be increased?
71	26	Are there any flagship freshwater species that could be used to generate interest?
72*†	27	What is the status of headwater biodiversity?
73	27	What are the most effective ways to tackle the freshwater biodiversity decline considering whole catchments?
74	27	Where in the river continuum should we especially place our efforts?
75	27	How can we assess the economical consequences of freshwater biodiversity loss?
76*	28	How much natural area should be maintained in riparian buffer zones?
77	28	How do we identify the best sites for freshwater protected areas?
78	28	What taxa/species are most appropriate for captive breeding programs?
79*	28	At what threshold of population abundance does it make sense to explore ex situ initiatives such as captive breeding programs?
80*	28	To what extent are on-the-ground local practitioners aware of the global state of freshwater biodiversity?
81*	28	To what extent do on-the-ground local practitioners feel equipped to address freshwater biodiversity issues?
82†	29	My interest is freshwater crustaceans, of Australia. Many species only occur in the upper high-altitude catchments, requiring cool conditions and flowing water to survive. We need water temperature data loggers and water flow meters now in all our upper catchment streams to start building a data base on just what is happening in theses streams. This is a long-term project that needs to start now
83*	30	What are the effects on the ecosystem of illegal groundwater prospecting?
84*	30	What are the alternatives to drainage channels and pesticide pollution in agricultural systems?

Number	Participant	Questions
85*†	30	What are the main impacts of freshwater loss on the human population?
86*†	30	What are the main actions of the public that enhance the loss of freshwater quality?
87*†	30	What are the main services of fresh water to ecosystems?
88*†	30	What does it mean for ecosystems to experience the loss of fresh water?
89*†	30	What are the first biological, chemical, and physical indicators of freshwater quality decline?
90*†	30	How many species are threatened by the loss of fresh water?
91*	30	Can threatened species be used as flagship species for freshwater conservation?
92*	30	Can these threatened species be used as umbrella species for freshwater conservation?
93*†	30	What is the effect on the ecosystem/community of the loss of biodiversity linked to the loss of fresh water?
94*	30	What are the measures that can be brought to local/general administrations in order to preserve fresh water?
95*	30	What are the measures that administrations can set in motion to protect freshwater biodiversity?
96	31	Why is conservation information not structured for management of resources?
97*†	32	Where are freshwater species found, what is their current status and what are their ecological requirements?
98*	32	Where are the sites of greatest importance for the global persistence of freshwater species?
99*†	32	What are the impacts of alien invasive species in freshwater ecosystems?
100*	32	How can we design and operate dams with reduced impact on freshwater species?
101*	32	What approach is needed to ensure the scientific definition of Environmental Flow is correctly translated into national legislation on water management without continuing to lose focus on "E" the environmental water requirements?
102*	32	How can we better understand and communicate the specific roles that freshwater species play in sustaining the provision of ecosystem services valued by people (water quality, etc.)?

Number	Participant	Questions
103†	32	What are the thresholds or "tipping points" at which we begin to lose freshwater species and ecosystem functions within a given system?
104	32	How can freshwater ecosystems be successfully protected within protected areas networks and do we require a new approach to better include connectivity between terrestrial, freshwater and marine systems?
105*	32	How can we shift the current mindset on management of freshwater ecosystems to move from management of water as a physical resource for people, to management of freshwater ecosystems as a provider of freshwater , other services of value to people, and as a highly diverse component of the world's biodiversity?
106*	32	What are the reasons behind the clear lack of focus on freshwater ecosystems in international and national policy on the environment and sustainable development and how can we make freshwater biodiversity conservation relevant to governments, companies and other stakeholders?
107†	33	stop the logging of the riparian-it warms up the fishes environment--- http://www.ramp-alberta.org/resources/forestry/potential+effects.aspx reintroduce the beaver back into areas that they have been over harvested out of---https://www.npr.org/2018/06/24/620402681/the-bountiful-benefits-of-bringing-back-the-beavers the reintroduction of the wolf into Yellowstone brought the river back -- https://www.youtube.com/watch?v=BYqD9WK-Voc Give Water the same right of a person-https://www.facebook.com/Waterwarrior1/
108*†	34	How can we bend the increasing drought in bogs and fens to ensure water capacity and how can we stimulate biodiversity in urban or countryside local settings?
109†	35	How do environmental stressors interact to impact freshwater biodiversity?
110†	35	What role does connectivity between fresh waters play in mediating biodiversity change?
111†	35	How have species composition and functional diversity changed alongside widely reported changes in species richness?
112†	35	Does loss of certain species induce cascading ecosystem change/secondary extinctions?

Number	Participant	Questions
113†	35	What time lags exist in the responses of biodiversity to environmental stress, and remediation?
114†	35	How has the biodiversity of under-represented groups (e.g. microbiota) been changing?
115*†	36	How important is the role of chemical contamination via air in freshwater biodiversity?
116	37	How do we learn to see freshwater less as a resource and more as a living environment?
117*	38	How can restoration of hydromorphology be improved?
118*†	39	How do we measure lignum health/recruitment and can we do genetic testing on lignum to determine if it clones, is it seed based, and is it genetically diverse?
119*†	39	How can we better understand the vegetation cover and communities of western New South Wales via mapping and ground truthing surveys?
120†	39	What are the effects of weirs, particularly raising and lowering on fish, veg, geomorphology?
121*	39	How can hypoxic blackwater events in streams be ameliorated to lessen their impacts?
122*†	39	Where do the golden perch spawn in the Darling system?
123*	40	How can we incentivize or convenience landowners to implement best management practices to reduce non-point source pollution?
124	40	How can we prioritize key sites that, if restored, would provide the greatest improvements for water quality?
125†	40	What are the habitat thresholds in a watershed to maintain water quality and natural flow regimes?
126*	40	How can we remove dams that currently are barriers to sea lamprey in the Great Lakes?
127*†	41	Why are governments in various countries not abiding by freshwater protection guidelines?
128*	42	Is there a template for a specific legal framework to protect freshwater biodiversity?
129*†	42	What type of support can be provided, in terms of expertise and logistics, for the development of legal instruments designed to protect freshwater ecosystems?
130*	43	Why are we unable to solve the extinction we face in freshwater species populations?

Number	Participant	Questions
131*	43	What is holding us back from doing what needs to be done to preserve freshwater biodiversity, and is already agreed on internationally, and how can we change this reality?
132*†	44	What are the upper thresholds of dissolved nutrient concentrations that determine the distribution of aquatic plants in the wild?
133†	44	How are densities of aquatic diatoms determined by nutrient concentrations in natural and semi-natural conditions?
134*†	45	What is the role of native invasive organisms in biodiversity loss?
135*†	46	How do freshwater organisms deal with the interaction between climatic change (temperate, water flows and extreme event), novel entities produced by man (nanoparticles and pharmaceuticals), and land-use-land-cover-change, including urbanisation?
136*†	47	What is the adaptive capacity (near-term acclimation to long term evolution) of tropical freshwater fishes to the novel, persistent, environmental conditions expected from climate change?
137*†	48	How has freshwater diversity been impacted by interactions with humans and how has this negatively impacted the environment, tourism and the economy?
138*	49	What mechanisms are responsible for the effect of high flow acceleration on fish richness in stormwater infrastructure (e.g. direct physical effects such as displacement, indirect effects on habitat quality such as nest disruption, a combination of both)?
139*†	50	How have the cumulative disturbances to headwater drainage features impacted biodiversity?
140*	50	How can we develop a better understanding of the interconnectedness of terrestrial and aquatic ecosystems as they pertain to headwater water drainage features?
141	51	How can we do a better job of translating scientific findings into policies and legislation that will actually make a difference?
142	51	How can we balance a healthy economy with increases to biodiversity and other environmental benefits?
143	51	How can we engage more citizens from all walks of life in efforts to increase biodiversity?
144†	52	How can we better understand or identify how cumulative effects negatively impact populations, productivity, and/or biodiversity?

Number	Participant	Questions
145*	53	How can we better integrate freshwater biodiversity into cross-sectoral policies, such as energy and agriculture, to avoid contradictory regulatory objectives and inconsistent financial initiatives?
146*	54	How can we integrate the evaluation of water bodies with decision-making processes?
147†	54	How can we ensure that all relevant data for such assessment is made available?
148	55	What rehabilitation and rejuvenation actions provide the most potent effects in urbanized areas?
149	55	How can retention ponds, and similar, be managed to provide sanctuaries for threatened species?
150*†	55	What drives small and large-scale synchrony in spawning success?
151*	56	How can we harmonize the food needs of the world's population with the needs of biodiversity conservation?
152*	57	How can we increase the monitoring of regional fish species in inland lakes?
153*†	57	What are the historic effects of phosphorus control on wetlands, and are more advanced research studies needed?
154†	57	How much emphasis is needed on energy relationships and the lower end of food chains?
155*†	57	How can we better evaluate and apply Tiered Aquatic Life Management efforts?
156*	57	How can the creation of sanctuaries for endangered and threatened species be improved?
157*	57	How can we better promote the creation of more restoration projects?
158	58	Are freshwater sanctuaries a realistic option for managing endangered aquatic species?
159*	58	How should such freshwater sanctuaries be protected, both legally as well as physically?
160*	58	How and where should Freshwater Reserves be established?
161*	59	What are the alternatives to hardening on lake shorelines?
162*	60	What are the storm water management temperature targets for all newly developed and re-developed urban areas that need to be adhered to?

Number	Participant	Questions
163	60	What volume of storm (e.g. 1st 25mm of runoff) should be captured from newly re-developed or redeveloped urban lands using low impact development techniques (e.g. infiltration trenches, bio-retention units etc.) in order to attempt to retain or rehabilitate pre-development or pre-deforestation hydrologic regimes?
164†	61	How does society view and value freshwater ecosystems and their biodiversity?
165†	61	How do we put freshwater's hidden biodiversity on the map?
166	61	How do we foster greater understanding of, and caring for, our freshwater ecosystems?
167†	61	How do we track large scale change in freshwater biodiversity condition?
168	61	How do we communicate freshwater conservation needs to decision-makers?
169	61	How do we inspire the next generation to be excellent freshwater ambassadors and custodians?
170	62	What freshwater populations have increased in abundance and health and what are the contributing factors that have led to this increase?
171*	63	How can we get salt out of storm water?
172*†	64	How can we better recognize a watershed approach or the protection of upstream catchments whether it be for research, protection or restoration?
173†	64	Where can we study a reference catchment of greater sizes or restore ones for study?
174†	65	Where do fish go in the winter?
175*†	65	How do fish cope with pulses of chlorides during the winter?
176*	65	How do we implement Low Impact Development in already developed areas?
177*	65	How do we convince landowners and decision makers to begin to implement mitigation of the many dams and barriers across the province?
178*†	65	How can monitoring programs be implemented or utilized to collect data?
179	65	How can we better communicate our findings to the general public?

Number	Participant	Questions
180*†	65	How do we make the links between human health and economic value of freshwater biodiversity more public?
181†	66	Transboundary rivers in the Global South remain understudied. For example, Zambezi River, despite offering ecosystem services to 150 million people in its watershed, there are no studies on the environmental chemistry and ecotoxicology of anthropogenic chemicals in the River Basin.
182*†	66	What are the impacts of shifting land use patterns in urban and rural landscapes in developing countries?
183*†	66	Can paleoecotoxicology provide essential information on the impact of historical use of anthropogenic chemicals on biodiversity?
184*	66	Are failing economies a curse or a blessing to biodiversity?
185*†	67	How do we understand the impacts of invasive species on a river by river, catchment by catchment basis?
186*	67	How can good science be used to influence policy and management changes before an invasive species is introduced?
187†	68	Natural Resources Wales is the largest Welsh Government Sponsored Body - employing 1,900 staff across Wales with a budget of £180 million. We were formed in April 2013. https://naturalresources.wales/about-us/what-we-do/our-roles-and-responsibilities/?lang=enNatural Resources Wales has developed a list of opportunities for collaborative research projects relating to the water environment in Wales. The priorities outline an early indication of the research themes and projects which present opportunities for collaborative working with partners and academic institutions. The evidence needs can be roughly categorised as: Water quality Monitoring Water resources Land management Ecosystems https://naturalresources.wales/evidence-and-data/research-and-reports/water-environment-collaborative-research-priorities/?lang=en
188*†	69	To what extent do lake species utilize the shoreline?
189	70	How can governments be persuaded that the value of freshwater ecosystems exceeds that of river development, e.g. for hydropower?
190*	70	How can dam removals be achieved in socially acceptable ways?
191	70	How can agricultural nutrient use be made for efficient, and runoff reduced?
192	70	How can water allocation systems be redefined to ensure sufficient water for freshwater ecosystems?

193	70	What management tools are effective to tackle internal nutrient loading in lakes?
194*	71	How can we better link hydrology (including flow intermittence) to biodiversity and ecology?
195*	71	How do we bridge the aquatic-terrestrial divide?
196*†	71	Can we bridge the taxonomic-functional-phenotypical divides?
197*†	71	How does artificial intermittence and human-induced perennialization affect freshwater biodiversity across small and large spatial and temporal scales?
198*†	71	How does climate change and adaptation affect freshwater biodiversity?
199*	71	Can and how do we improve science communication and exchange?
200*	71	How do we overcome or account for the knowledge gaps in freshwater biodiversity in understudied or underrepresented regions of the globe? and how can we find ways to overcome, or at least better account, for the knowledge gap in underrepresented regions to better understand the state of freshwater biodiversity and to help bend the curve of the current declining trajectory?
201*†	71	How do we reconcile uniqueness with generalisability and pervasiveness? and how can we reconcile this disparity by way of research to ensure the appreciation and wise management of non-perennial streams and their biota?
202	71	How do we ensure adequate dispersal to improve or maintain local and regional biodiversity of freshwater metacommunities, while protecting against biotic homogenisation (e.g. through dispersal of invasive species)?
203*	72	How can we develop ecological field assessment tools of freshwater and saline lakes?
204*†	73	What are the effects of regulation and fragmentation of our rivers on biodiversity?
205*†	73	What are the effects of contaminants in freshwater systems
206	73	How can urban freshwater ecology be supported?
207	74	Can we modulate effects of climate change via habitat restoration?
208*	74	Why don't we see positive effects of stream restoration (time, connectivity, lack of species pools, land use) and how does this vary by region?
209	74	Can riparian buffers and instream buffers modulate impacts of land use change?

Number	Participant	Questions
210	74	Does restoration of fluvial geomorphic dynamics lead to increased biodiversity?
211	74	How can we encourage site-based restoration (respecting geomorphic context) rather than homogenizing streams to same form?
212*	74	How do we encourage restoration/management of other species and biodiversity in general than just "dotted fish"?
213*†	74	What is the importance of stream-lake connectivity & dysconnectivity in local and catchment scale biodiversity?
214*†	75	What are the key (GIS-based country-specific) freshwater biodiversity hotspots?
215*†	75	What are the pertaining and upcoming threats to freshwater biodiversity?
216*	75	Do legislations or regulations exist to monitor the freshwater eco-health?
217*†	75	What are the implementation status of laws, acts, regulations.?
218*†	75	Is a nation-wide freshwater ecosystem policy in place?
219	75	Is there a mechanism to restore biodiversity in freshwater body?
220*†	75	What are the key contributing factors to reduce negative impacts on freshwater body?
221*	75	Do populations upstream or surrounding a freshwater body know their responsibilities regarding water quality?
222*†	75	What are the key anthropogenic activity around or upstream freshwater bodies that seem to have the greatest impact on biodiversity?
223	75	What are the site-specific mitigation measures required to maintain the health of the freshwater body?
224	76	How is freshwater biodiversity connected to services for humans?
225†	76	Why is freshwater biodiversity important?
226*†	76	How is freshwater biodiversity linked to climate change (risks)?
227	77	How can we influence the decision-makers (i.e. politicians), in order to improve their ability to understand the state of freshwater biodiversity?
228	78	How are Indigenous women and Two Spirit people being included (and excluded) in understanding biodiversity?
229	78	What government (federal, provincial, municipal, international) policies are preventing the bending of the curve upwards?

Number	Participant	Questions
230*	79	What are the complex interactions of multiple human uses across spatial and temporal scales?
231†	80	What can we do to make natural history a greater part of our cultures?
232*	81	What can be done to advance the science of environmental flows needs to better determine and understand how much water is needed and ensure the health and functioning of streams and rivers?
233*	81	How can we prioritize the development and investment of instream flow science to better guide management of biodiversity in running waters?
234*	82	Can we develop new technological solutions to meet the water needs for a growing human population?
235	82	Are there better ways (e.g. through biotechnology or improving risk assessment) of managing introductions of biocontrol agents for invasive species?
236*	82	How can we better understand the geopolitics of water allocation, particularly to reduce conflict?
237	83	How to get additional political support to link freshwater biodiversity to other complementary efforts such as climate change mitigation and adaptation, protection of natural heritage systems, and green infrastructure opportunities?
238*	84	What could we do to limit the amount of nutrients coming into lakes, rivers, ponds etc.?
239†	84	What can we do as a society to reduce our impact on these lakes?
240†	85	Is the biogeography of freshwater fauna changing, and if so, what is causing the decline or expansion?
241†	85	What is the impact of climate change on aquatic fauna?
242†	85	What is the impact of introduced taxa on native aquatic fauna?
243†	85	What is the impact of co-invading parasites and diseases of introduced fishes on native fishes?
244†	85	What is the impact of aquaculture escapees on native fishes and crustaceans?
245†	85	What is the impact of secondary salinization on aquatic fauna?
246	85	Should wild rivers be left alone from development?
247*	86	What are the minimum flow requirements for maintaining biodiversity in river systems?

Number	Participant	Questions
248	86	How do we identify priority areas that are critical for conserving biodiversity in freshwater systems?
249†	86	Do altered flow regimes favour invasive species over native species?
250*†	87	Can we digitize the animal and plant world and would this be valuable to maintaining biodiversity?
251*	87	Should we keep some parts of certain habitats and biodiversity untouched and can we apply strict conservation efforts in some places?
252*†	87	How will genetic science help freshwater biodiversity to tolerate and successfully pass this "bottleneck" period in the history?
253*†	87	Who is responsible in deciding what should be conserved and should this process of decision-making continue?
254*†	88	Do we expect to simply lose many of our freshwater species in response to climate change?
255*	88	What are the species most at risk from climate change?
256*†	88	Are migratory species (all types - anadromousandadromous, catadromous and potadromous) more or less at risk than other species?
257*†	88	Are we simply expecting that we might lose many of our narrow range endemics because of climate change?
258*	88	What are the mitigation measures that we can employ to species at risk from climate change?
259*	88	Are the conventional measures we currently focus on (securing fish passage, water quality etc.) enough and what more can we do?
260*†	88	Are there risky unknown synergisms to be aware of?
261†	88	I'm not sure it needs new research or just collating; ecological environmental health parameters for tropical rivers (I've just helped to create a river health scorecard and really struggled to set the thresholds for well known parameters like DO in tropical rivers at the elevations and alkalinity levels we had).
262*	88	How can we better adapt tools from temperate regions for use in tropical rivers?
263*†	88	What are the population trends of freshwater species in tropical regions?
264	89	Which pollutants can be managed and reduced at the watershed level?

Number	Participant	Questions
265†	89	How does the biodiversity of fish and invertebrate communities stabilize food webs, productivity, and overall freshwater health?
266	89	Does repatriation of local biota actually work?
267†	89	How long does it take for a full community to recover of invasive species eradication?
268	89	Are there other management approaches that can be used in conjunction with eradication to improve the recovery of native biota?
269*†	90	At what density must we consider meso predator numbers and the need to begin to bring them under a sustainable level?
270*†	91	Where are the threatened (critically endangered, endangered, vulnerable) freshwater species distributed, across the globe?
271†	92	As has been the case for many years, principal questions revolve around: Distribution of biodiversity (richness, diversity, and threatened taxa by river and watershed).
272*†	93	What are the biodiversity distribution impacts of alterations on aquatic habitats?
273*	93	Is there potential to restore, conserve, and protection habitats and watersheds that have been altered?
274†	94	What is the health status of biologic communities in rivers?
275*†	94	What is the relationship between human activities and the quality of local rivers and/or lakes?
276†	94	What is the global distribution of freshwater invasive animals and how does this overlap with endangered freshwater species distributions?
277	94	How can we best educate and inspire the general public to support freshwater biodiversity conservation action and policy?
278*†	95	How many large dams are currently being planned for major rivers of the world, and how do their locations affect KBAs and the distribution of critically endangered species?
279†	95	What is the global distribution of Freshwater Protected Areas, and how do these FPAs influence populations and richness of freshwater species?
280*	95	How can we put a better value on freshwater ecosystems in terms of their value as a functioning natural system rather than just a provision of resources?

Number	Participant	Questions
281	95	How do freshwater ecosystems fit into current practices for protected area management, where are the spatial gaps that need to be filled and where are the gaps in effective management?
282*	95	How will climate change impact existing freshwater ecosystem distribution, environmental flows, and how do we proactively manage that?
283*†	96	How can we best protect current freshwater biodiversity?
284*	96	At what locations and scales are ecosystem restoration projects most effective?
285*†	97	What are the trends and the current status of aquatic species outside of North America and Europe?
286†	97	How can we quantify threats to aquatic biodiversity?
287*†	98	What effect do pathogens from salmon farms have on wild fish?
288*†	99	How can we standardize the quantity and quality of information between countries?
289†	100	How does fine scale ecology (e.g., genetic diversity, small-scale habitat features) influence population and species persistence?
290†	100	How does the public want freshwater ecosystems managed?
291*†	100	How do invasive species contribute to function diversity loss?
292	101	Is it possible to develop biological indicators that are applicable to more than just single catchments?
293	101	Is it possible to integrate proactive risk management as it relates to invasion ecology, instead of reactive invasive species management?
294	101	How can we improve freshwater biodiversity sampling across broad swathes of historically neglected habitat?
295	101	Can we establish a global network for ex-situ conservation that takes stock of all IUCN threatened species, so that when a locality or wild population is lost, the species doesn't fall off the brink?
296*	101	How will the increasing global population affect the future state of aquatic systems, and what adaptive strategies can be implemented proactively to mitigate those impacts?
297†	102	Not really questions but needs 1. Get more curators to digitize (geo references and photograph specimen under their care. Particularly type specimens.
298*	102	How can NGOs be incentivised to increase funding for freshwater invertebrates?

Number	Participant	Questions
299†	102	Fund field research to document floral and faunal changes based upon collections data.
300*†	103	Which are the representative biodiversity elements that can (1) inform on status and (2) track state of freshwater biodiversity if they are monitored at large or fine resolution spatial scales?
301	103	What is the umbrella potential for freshwater biodiversity of very large freshwater fauna?
302†	104	How does land use influence freshwater biodiversity?
303†	105	Is bending the curve an attainable goal?
304*	105	Have freshwater systems already moved to a novel state in which bending the curve is not possible in terms of returning the level of biodiversity to what it was?
305*	105	What do novel systems look like in terms of biodiversity composition and structure?
306	105	Is there an optimal novel system that should be targeted?
307*†	106	What are the environmental limits of freshwater biodiversity and ecosystems (e.g. warming, drought)?
308†	106	What is the adaptive capacity of freshwater biodiversity and ecosystems to environmental and climate change?
309	106	How does freshwater biodiversity underpin critical ecological functions and human values?
310†	107	What are the status and trends for freshwater fish biodiversity in the hyper-diverse assemblages of the world (e.g. African Great Lakes, the Amazon, and Asian peat swamps)?
311*†	107	What is the relationship between water quality and freshwater biodiversity maintenance?
312*†	107	To what degree do freshwater species benefit when water quality is improved?
313*†	107	What effect does dam induced habitat fragmentation have on freshwater biodiversity?
314*†	107	How will freshwater communities be altered by anticipated changes in surface freshwater due to climate change, hydro engineering, water use, and other anthropogenic activities?
315	108	How could a shift away from the traditional fisheries management paradigm that is predicated on a minimum size at capture and towards the "Balanced Harvest" paradigm for the management of tropical inland fisheries influence fish population and ecosystem function sustainability in high exploited aquatic systems?

Number	Participant	Questions
316	108	Is the goal of long-term (>50 years) biodiversity conservation better served by continual efforts to maintain basic levels of ecological function in all aquatic systems or might conservation be better served by foregoing conservation in numerous locations in companionship with legal assurances for the persistence of one highly protected ecological system?
317†	109	What are the effects of contaminants on disease susceptibility and disease ecology?
318†	109	How rapid is the transfer of diseases between "pristine" and "disturbed" habitats?
319†	109	How can we use stable isotopes to determine biomagnification of contaminants in an ecosystem?
320†	109	How does population plasticity play a role in contamination and disease resistance?
321*	110	How do we communicate the importance of freshwater biodiversity to the general public in order to provide a satisfying perspective on biodiversity conservation?
322†	111	Which mechanisms facilitate the spread of certain bacterial species warming freshwater lakes with ongoing climate change?
323†	111	Do animals choose freshwater lakes for breeding (amphibians) and then it turns out the lakes do not provide conditions for a full metamorphosis anymore due to warming/climate change (ecological trap)
324*†	111	How does climate change impact aquatic metamorphosis?
325*†	112	What are the combined effects of freshwater biodiversity stressors?
326	112	What are the possible future scenarios for freshwater biodiversity stressors, and what potential intervention strategies do we have for these different scenarios?
327*†	113	What are the ecosystem and human health consequences of the loss of large, long-lived vertebrates from freshwater systems?
328*†	113	What impacts do the losses of long-lived vertebrates have on the rest of the ecosystem?
329*†	113	How can we prevent the decline of long-lived vertebrates and restore their previous ecosystem functions?
330*	114	How can we increase our effectiveness in communicating the perils facing freshwater biodiversity to stakeholders and the general public?

Number	Participant	Questions
331*	114	How can we incorporate freshwater biodiversity loss as part of sustainability education?
332*†	115	What is the most important limiting factor to freshwater biodiversity conservation?
333*†	116	How will research focused on habitat rather than taxa benefit freshwater conservation efforts?
334†	116	Habitat associated ecological changes in specialist species.
335*†	116	Will funding for molecular assessment along with field ecological studies benefit freshwater conservation efforts?
336†	116	Preliminary assessment for need of management interventions?
337*†	117	How will increasing our understanding of the behavioral ecology of local freshwater flora and fauna benefit freshwater conservation efforts?
338*†	119	How do we prioritise the reintroduction of beavers into their former ranges?
339	120	What are effective incentives for policymakers and the general public that could convince them of the need for conservation and restoration of freshwater ecosystems?
340*	120	What can be done to effectively communicate to the general public the potential impacts of translocating alien species into novel environments?
341	120	How can we convince industrial and commercial entities of the dangers of dumping physical and chemical waste into freshwater systems while providing a cost-effective solution to the creation and safe disposal of waste?
342*	120	How can we balance the needs of sustenance fishermen and commercial fishing industries with sustainable harvesting and conservation practices?
343	120	In the context of river systems, how can we effectively balance the needs for damming (from water abstraction to hydropower) with conservation of biodiversity and migratory pathways for fish and other aquatic life?
344	121	How important is biodiversity to the ecosystem service of fisheries yield?
345†	121	What is the link between biodiversity and ecosystem resilience to human induced stressors?
346*	121	Under what conditions can freshwater biodiversity be restored after deleterious events (e.g. following invasions).

Number	Participant	Questions
347*	121	How important is the maintenance of genetic diversity in restoration efforts?
348*	121	How do we value the intrinsic economic value of freshwater biodiversity?
349*	121	How do "novel" ecosystems function in this current era (i.e. the Anthropocene)?
350*	122	Is stocking fish an effective conservation tool, or should it be banned completely
351*	123	How can we limit the domestic and commercial use of water in an effort to conserve it?
352*	124	Do alternative water sources exist, which require less water than water sources currently used?
353*†	125	What is the global distribution of freshwater fish?
354†	125	What are the key environmental factors shaping the contemporary distribution of freshwater species?
355*	125	How do we increase the awareness of the freshwater biodiversity crisis?
356*	125	How can we contribute towards recognizing the importance of freshwaters as its "own realm"?
357	125	Given the knowledge of species distributions, how should we reassess the current spatial protection plans?
358*†	126	How will taxonomic research contribute to the conservation and management of freshwater species?
359*†	126	How will more taxon specific research benefit freshwater conservation efforts?
360*	126	How will improved systematic data publishing benefit freshwater conservation efforts?
361*	126	How can we secure more political commitment to support data portals, knowledge bases, and information platforms that collate and provide freshwater data?
362*†	127	How do freshwater systems function?
363*†	127	What is the goal in heavily modified freshwater systems?
364*†	128	How do meta-population processes affect the maintenance of freshwater biodiversity?
365†	128	What drives natural variability in freshwater communities?
366*	128	How can we best communicate the significance of freshwater biodiversity to the general public?

Number	Participant	Questions
367*	128	Where should conservation priority be put both geographically and temporally?
368†	129	First of all, start a global long-term monitoring system to document what still exist. Establish a network of selected sites, use indicators for different ecosystems where ecological information is available and establish new indicator groups. Document historic available occurrence information from all resources including specialists, dilettantes and museums. Analyse which traits declined along the timeline and identify stressors responsible. Mitigate the stressors.
369*†	130	How are freshwater fish distributed across European water bodies?
370†	131	Please forgive the possibly obvious - perhaps the biggest question could be "how do we identify what factors we're missing?"
371*†	131	What suite of interacting factors affect freshwater biodiversity most profoundly?
372*†	131	How do environmental chemicals affect freshwater ecosystems?
373	132	How can enforcement of environmental laws be improved?
374*	132	How can biodiversity threats be integrated in business ventures or human activities (e.g. a carbon tax)?
375*†	133	How does climate change influence water resources and aquatic biota?
376†	133	How should the impacts of climate change on water resources best be shared by water users and ecosystems?
377	133	Can wetland ecosystems co-exist with development and how do they function in developed landscapes?
378*	133	How much protection is actually provided by natural resource (i.e. threatened species) legislation on a global scale?
379*	134	How have human activities altered the water cycle and what effect has this had on aquatic biodiversity?
380*†	135	Under what circumstances should gene flow be enhanced between populations of freshwater organisms?
381*†	135	What are the fitness benefits and risks of enhanced gene flow between populations suffering genetic problems from small size and isolation?
382	136	Can we reverse declines of small populations by admixing individuals from multiple populations?
383*	136	What is the minimum effective population size required in order to trigger population restoration efforts?

Number	Participant	Questions
384*	136	How can we incentivize the general public and businesses to invest in biodiversity restoration?
385†	137	What process should be implemented to understand under what circumstances gene flow should be enhanced between population units of freshwater organisms?
386	137	What are the fitness benefits of enhanced gene flow between populations suffering genetic problems from small size and isolation, and are there any risks?
387*	138	What motivates unauthorised fish translocations and how can we reduce its prevalence?
388*†	138	How will climate change affect the introduction of invasive species?
389*	138	How can we facilitate the upstream and downstream passage of fauna through large dams?
390*	138	How can the knowledge, values and needs of indigenous peoples be incorporated into global freshwater biodiversity conservation?
391	138	How can citizen science be mobilized and used to conserve and monitor freshwater biodiversity?
392*	138	How can non-charismatic species be included in freshwater biodiversity conservation programs?
393	138	What are the key elements (fields, frequency of measurement, methods) required for an effective global freshwater biodiversity monitoring program?
394*	138	What are the best strategies to implement global freshwater biodiversity monitoring programs?
395*	138	What is the role of professional societies in freshwater biodiversity conservation?
396*	138	What novel survey and detection methods can be used to track global freshwater biodiversity trends (e.g. metabarcoding, drones)?
397*	139	Are umbrella species effective freshwater biodiversity conservation tools?
398*†	139	What are the ecological impacts on freshwater food webs when large predators are removed?
399*†	139	How are freshwater ecosystems affected by endocrine disrupting chemicals and how can we best monitor and manage this threat?
400*†	140	What is the conservation status of the world's freshwater biodiversity and ecosystems?
401*†	140	What are the primary threats impacting freshwater biodiversity at local, basin and regional scales?

Number	Participant	Questions
402*†	140	To what extent is there quantifiable evidence that land-use change is a threat to freshwater biodiversity, relative to other threats like invasive species, water use change, loss of habitat connectivity, and climate change?
403*	140	What are the most effective restoration intervention techniques for freshwater ecosystems?
404*	140	Why should anyone care about freshwater biodiversity and how do we develop framings and an evidence base that gain greater traction with these key actors such that we can address the underlying drivers of freshwater biodiversity loss?
405*	140	How can we conserve and restore freshwater biodiversity in ways that will also lead to different socioeconomic and cultural benefits?
406*	140	How do we map, communicate synergies and inevitable trade-offs, and provide relevant information to decision-makers who can then support equitable and sustained outcomes across environmental, social and economic concerns?
407	140	How do we learn from, and scale up successful conservation and restoration efforts?
408†	141	Better understanding of the status and threats to freshwater organisms in tropical regions, particularly in countries where taxonomy is incomplete
409*	141	To what extent can local-scale management interventions (e.g. farm-scale) reduce threats to freshwater biodiversity relative to corridor or catchment-scale management interventions, and what are the cost/benefit implications of making changes at these different scales?
410*†	141	How can wetland ecosystem service be better quantified and how can their benefits be more effectively communicated to decision makers and stakeholders?
411*	141	How can the development of better low-cost water quality monitoring technologies (including water chemistry and/or biological monitoring protocols) be used to engage citizens and local land managers in water quality monitoring and management?
412*	141	What are the costs and benefits of the usage of eDNA for aquatic biodiversity monitoring in tropical regions, and what are the limitations of this approach, particularly in terms of taxonomic resolution and probability of detection for different types of freshwater organisms?

Number	Participant	Questions
413	141	What management strategies can be used to transfer funding for freshwater conservation to local communities and/or land management authorities and under what circumstances are these management strategies most likely to provide long-term, effective protections?
414*	141	Under what circumstances will nature-based flood management be cost effective in tropical countries with high precipitation?
415*†	142	What is the quality and quantity of water flowing through riverine systems?
416	142	How can we incorporate biodiversity in the built or altered environment?
417†	142	How does biodiversity contribute to human well being?
418†	142	How does environmental diversity support ecosystem function and services?
419	143	What are the confounding and synergistic effects of climate change (e.g. wildfires, hurricanes, winter storms) on freshwater biodiversity?
420*†	143	How does habitat loss and organismal life history affect the ability of freshwater organisms to shift ranges due to climate change?
421†	143	How will climate change affect the synchrony of freshwater species populations, and how does this different in lotic and lentic habitats?
422*	143	How can climatic resilience be incorporated into freshwater ecological restoration projects?
423†	143	How do climate-induced changes to flow permanence affect freshwater ecosystem processes?
424†	144	Iimpacts of nicotine-based pesticides, Losing the headwaters, tributaries of waters. Upper basin waters provide a wide variety of supporting nutrients, habitat etc.

Table S3. Alignment of "bending the curve" research questions and the Emergency Recovery Plan priority actions (Tickner *et al.* 2020). For each theme and priority action, questions that would meet the requirements of bending the curve and grow knowledge of priority actions are listed (i.e., 'Question 21: Environmental Flows' is in the theme Reforming Policy and Investments, and aligns with the priority action 'accelerate implementation of environmental flows').

	Bending the Curve Themes					
	1. Learning from Success and Failures	2. Improving Current Practices	3. Balancing Resource Needs	4. Rethinking Built Environments	5. Reforming Policy and Investment	6. Enabling Transformative Change
Priority Actions						
1. Accelerate implementation of environmental flows			13; 14		21	
2. Improve water quality	7	11	14	17		
3. Protect and restore critical habitats	1; 2; 3; 4	5; 6; 11		16; 17; 18		
4. Manage exploitation of species and riverine aggregates			13; 15	17		
5. Prevent and control non-native species invasions	1	10				
6. Safeguard and restore freshwater connectivity	2	11	14	17		
Questions not in priority actions		8; 9; 12			19; 20; 22	23; 24; 25