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Virtual Growing Pains: Initial Lessons Learned from Organizing Virtual Workshops, Summits, Conferences, and Networking Events during a Global Pandemic

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Abstract

For many, 2020 was a year of abrupt professional and personal change. For the aquatic sciences community, many were adapting to virtual formats for conducting and sharing science, while simultaneously learning to live in a socially distanced world. Understandably, the aquatic sciences community postponed or canceled most in-person scientific meetings. Still, many scientific communities either transitioned annual meetings to a virtual format or inaugurated new virtual meetings. Fortunately, increased use of video conferencing platforms, networking and communication applications, and a general comfort with conducting science virtually helped bring the in-person meeting experience to scientists worldwide. Yet, the transition to conducting science virtually revealed new barriers to participation whereas others were lowered. The combined lessons learned from organizing a meeting constitute a necessary knowledge base that will prove useful, as virtual conferences are likely to continue in some form. To concentrate and synthesize these experiences, we showcase how six scientific societies and communities planned, organized, and conducted virtual meetings in 2020. With this consolidated information in hand, we look forward to a future, where scientific meetings embrace a virtual component, so to as help make science more inclusive and global.

Introduction

For many, attending a scientific conference is among one of the highlights of the year, as scientists come together to communicate recent findings, network with potential collaborators and future employers, and reconnect with old friends and colleagues vis-a-vis the informal "hallway chats." Aside from the effort to put together a presentation, poster, or panel talking points, participants invest additional energy to travel long distances, secure funding for travel, lodging, meals, and registration fees, and be proficient in the conference's working language. As a result, participation can favor more privileged scientists (e.g., well-funded, connected, established) while excluding talented but less privileged scientists who may not have available funds or flexible schedules to overcome barriers such as financial resources, travel time, disabilities (De Picker 2020), dependent care responsibilities (Calisi and A Working Group of Mothers in

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Science 2018), or visa acquisition (Matthews et al. 2020).

The COVID-19 pandemic, however, necessitated postponing or altogether canceling the vast majority of in-person scientific gatherings in 2020, ranging from small workshops to large, iconic conferences. Recognizing the need to rapidly alter personal and professional lives during 2020, the scientific community could have said that a conference "gap year" was warranted. Yet, such a hiatus from scientific meetings would also have come at a cost, especially for early career researchers (ECRs) who rely on scientific meetings to share their work, find career opportunities, and establish a peer cohort that provides emotional, mental, and personal support in addition to professional support. Given the benefit of meetings, the aquatic sciences community, and STEM (Science, Technology, Engineering, and Mathematics) community more broadly, spurred an increase in the number and diversity of virtual meetings and workshops. This same entrepreneurial spirit that gave rise to virtual meetings likewise has resulted in various solutions for recreating the in-person meeting via a virtual format. In particular, recorded and live-streamed oral presentations, virtual poster sessions, workshops using screen-sharing, and interactive networking events over video conferencing have empowered longstanding and inaugural conferences alike.

Additionally, the online format removed potential barriers and likely increased participation by peers unable to participate in previous years. Still, some barriers remained, and new barriers arose, such as access to a reliable computer and internet connection, time zone management for conferences with a globally distributed audience, the unexpected energy demand of sustaining online attentiveness (the newly coined term "Zoom fatigue"), and finding time for dependent care as many schools, nurseries, eldercare services, and similar facilities enacted restrictions or limited services as a result of the COVID-19 pandemic.

Given the quick pace that various aquatic societies incorporated virtual meetings, this year of transition, adaptation, and creativity also created opportunities to assess successes and challenges associated with the growing pains of virtual life. Here, we have collected the experiences of organizers from six major scientific gatherings in the aquatic sciences that went fully digital in 2020: the Global Lake Ecological Observatory Network (GLEON; Hanson et al. 2016, Weathers et al. 2013), the North American Lake Management Society (NALMS), the Physical Processes in Natural Waters (PPNW), the Ecological Forecasting Initiative (EFI; Peters and Thomas 2020), the Knowledge-Guided Machine Learning (KGML) Workshop, and the Virtual Summit: Incorporating Data Science and Open Science in Aquatic Research (DSOS; Meyer and Zwart 2020). By learning from the diverse organizational (Table 1), logistical (Table 2), and programmatic (Table 3) solutions to shifting from in-person to virtual settings, and the potential implications for the future of scientific networking, we can further create effective, inclusive, and productive experiences for all attendees. Even when we eventually revert back to our traditional mode of running conferences, hosting and running online conferences, summits, and workshops will continue to have certain

TABLE 1. General meeting information

	GLEON	NALMS	PPNW	EFI	KGML	DSOS
Dates	19–22 Oct 2020	16–20 Nov 2020	15–19 Jun 2020	12–13 May 2020	18–20 Aug 2020	23–24 Jul 2020
Number of registrants	180	725	90–110	205	>1000	436
Number of participants	180	725	Not recorded	110–150	Not recorded	125–160
Registration fee?	Yes	Yes	No	No	No	No
First virtual meeting for this society?	No, but first virtual meeting to replicate all aspects of the in-person All Hands' Meeting	Yes	Yes	First virtual meeting of this size	Yes	Yes
Funding for conference	Partial funding support for the GLEON All Hands' Meeting was provided through NSF grant EF-1702991 and an Anonymous GLEON Donor (via Cary Institute).	Registration and sponsorships*	None	The Research Coordination Network and workshop are supported by the National Science Foundation DEB-1926388.	NSF's Harnessing the Data Revolution (HDR) Big Idea Program, award 1934668 (CSU), 1934548 (Penn State), 1934600 (UVA), 1934633 (UW), 1934721 (UMN)	None

*https://www.nalms.org/nalms2020/nalms-2020-our-sponsors/.

TABLE 2. Logistical considerations for each meeting

	GLEON	NALMS	PPNW	EFI	KGML	DSOS
Software used	Cisco Webex, Zoom, Voice Thread, Slack	Whova, Zoom	Zoom, Slack	Zoom, Poll Everywhere, QUBES Hub	Zoom, Slido	Zoom, Google Forms, Slack
Conference time zones	Afternoons for European time zones/mornings for North American time zones	Focus on North American time zones	Central European Time	Focus on North American time zones	Central Standard Time	Afternoons for European time zones/mornings for North American time zones
Recordings available after conference	Yes	Yes, via Whova for up to 6 months after the conference	No but proceedings are available[*]	Yes[†]	Yes[‡]	Yes[§,‖]
Presentations were live or prerecorded	Most were prerecorded	Most were prerecorded	Live	Prerecorded	Live	Prerecorded
Was there a poster session?	Yes, via VoiceThread	Yes, via Whova app with "slam"-style presentations via Zoom	Yes	No	No	No
Language accessibility	Presentations had closed-captioning. Attendees were reminded daily to be cognizant of language barriers.	None	None	Presentations had closed-captioning	None	Presentations had closed-captioning

[*]www.ufz.de/ppnw2020.
[†]https://ecoforecast.org/efi-rcn-2020-workshop-videos/.
[‡]https://www.youtube.com/channel/UCMYTOjm4uAI3xKWGY7_7xKA.
[§]https://www.youtube.com/playlist?list=PL52fZTCEW54ckkg9mWUxMQq7gMZinr0HB.
[‖]https://www.youtube.com/playlist?list=PL52fZTCEW54fnuaL7tYLaXqfES2KTv12C.

advantages over in-person meetings, which may empower the continuation of virtual meetings or the adoption of hybrid in-person-virtual formats. Looking to the future, we—as organizers and conveners of virtual meetings—provide this synthesis to serve as a primer for others looking either to adopt virtual practices into their societies or to invent a new gathering of their own.

Global Lake Ecological Observatory Network (GLEON)

The GLEON 21.5 Virtual Meeting, GLEON's first entirely online, All Hands' meeting, was held 19–22 October 2020. Prior to the conference, working group facilitation training as well as four premeeting workshops on technical topics and scientific writing were offered to all participants. Aside from time dedicated to working group or ad hoc breakout group discussions, two plenary talks were held each day, with each talk being prerecorded for live-viewing at the scheduled time, followed by a live discussion with the presenter. A plenary on Justice, Equity, Diversity, and Inclusion in STEM disciplines occurred on the first day and was followed by a panel discussion. Each meeting day consisted of a 4-h time block with planned short breaks. At the end of two separate days, there were planned social events (an online Scavenger Hunt and the first annual LimnoOlympics).

GLEON 21.5, as a virtual meeting, provided the opportunity for people from all over the world to participate. While the virtual conference allowed for an increase in attendance from South America, the schedule was focused on North and South American as well as European time zones and likely ended up limiting participation from Asia and Oceania. Network-wide communications were enhanced through the use of the communication platform Slack. Slack allowed for searchable documentation of discussions, and is currently facilitating continued working group activity since the meeting ended. The virtual poster session, facilitated by the software VoiceThread, worked well by allowing people to spend more time examining posters, facilitating asynchronous interactions, creating an environment with balanced interactions, removing time constraints that frustrated participants in past in-person meetings, and allowing feedback to be stored and collected easily. To allow participants more time to examine posters and offer feedback, posters were available via VoiceThread for several weeks following the conference. Including plenary talks, which are uncommon for

TABLE 3. Networking and training events for each meeting

	GLEON	NALMS	PPNW	EFI	KGML	DSOS
Workshops organized	1. Simple guidelines for scientific writing and communication 2. Version control software (Git) for application in academic research 3. Process-based lake modeling in R using the General Lake Model 4. Ensemble lake modeling with LakeEnsemblR 5. Facilitation and Participation in Productive Working Groups.	1. Collection, Identification, Ecology, and Control of Freshwater Algae 2. Introduction to R for Aquatic Research (Beginners) 3. Smart Salting to Protect Lakes, Streams, and Groundwater 4. Stormwater Management for Lake Managers 5. Working with Sensors and Analyzing Sensor Data 6. Ecology of Cyanobacteria; Introduction to R for Aquatic Research (Advanced) 7. Telling Your Lake Story with Story Maps 8. Volunteer Lake Monitoring: A Train-the-Trainers Workshop	None	None	None, but the whole conference was organized as a kind of workshop	None
Social networking events organized	1. Networking activity for all participants organized by the GLEON Student Association (GSA) 2. Social/ Networking activity: Scavenger Hunt	1. Poster Socials 2. Awards Social with online Lake Trivia Night	Two post session social hours	None	None	Social and professional breakout groups with themes in: • Big Data • General Additive Models in the Aquatic Sciences • Tools and Software Development

(Continues)

TABLE 3. Continued

	GLEON	NALMS	PPNW	EFI	KGML	DSOS
	3. First International Limnology Olympics					• Applications of Open Science for Management
Social media used	Twitter, Facebook	Twitter, Facebook, LinkedIn, and Instagram were integrated into the Whova app	None	None	None	Twitter
ECR specific programming?	Yes, workshops and poster sessions were targeted for ECR training and networking	Yes, poster sessions and a ECR-targeted panel "Building Careers in Lake Management and Freshwater Science"	No	Yes, the EFI student association organized a student-only workshop	No	No

GLEON, having timed presentations worked much better in an online format, by allowing lake researchers from all continents to highlight and discuss their work and facilitating asynchronous viewing.

Interactive working group meetings worked well online, and collaborative document sharing allowed everyone to access and share their ideas. To some degree, this format replicated aspects of sitting around a flipchart and writing notes, but it did not fully replicate interpersonal interactions. At previous meetings, turning to the person next to you and having a short discussion about an idea or suggestion before bringing it to the full group helped to formulate the idea, lowered language barriers, and reduced time needed for further explanation. Similarly, the workshops worked well online and allowed for increased participation, but may be better when held in-person for the ability to informally interact with other participants and ask the instructor questions.

Informal and ad hoc discussions over meals, taking a walk with colleagues, and other activities important for effective team-building were not translatable into a virtual meeting. Networking and social activities, which are an important part of GLEON All Hands' Meetings, did not come close to replicating how we network in person. Yet several moderately successful social hours, such as a virtual treasure hunt, took place outside of the daily schedule. These networking and social events were likely less successful in an online setting in part due to "Zoom fatigue." In contrast to how typical in-person GLEON meetings are in out-of-the-way locations specifically to avoid distractions, having people's undivided attention and commitment for four days around a central topic is much more difficult in a virtual setting. As a result, not all participants were able to attend all four days of synchronous programming, thereby disrupting the continuity of subsequent meetings during the week.

In GLEON, there is the hope to return to in-person meetings soon, while retaining the best of the online activities to strengthen inclusive participation. GLEON is increasingly aware of barriers for meeting attendance, despite a long running sponsorship program. Hence, some form of a hybrid style meeting may offer the best way forward. Learning from past experience in running virtual meetings, a single platform which supports all means of communication would be easiest. Additionally, a dedicated technical officer to aid in the meeting setup is important, as the current set-up protocols put a tremendous burden on volunteers. The next virtual GLEON All Hands' meeting will follow a more feasible planning timeline. For example, advertising for the meeting will start earlier to give members ample time to submit registration and posters. Time scheduling will move away from a set time each day of the meeting to be more inclusive to certain regions of the world.

North American Lake Management Society (NALMS)

The NALMS has held an International Symposium every fall since its founding 40 yr ago. The annual symposium is where members and other lake management professionals come together for a collection of oral and poster technical presentations, hands-on workshops, field trips, and discussions on managing lakes and reservoirs. Attendees also have access to an exhibition hall where vendors display the latest lake-management tools and technologies. The symposium offers opportunities for networking, and lifelong professional associations are often forged at NALMS symposia. After careful consideration and in consultation with partners this year, NALMS decided to transition from an in-person to a completely virtual symposium during the same week as what had long been planned, 16–20 November 2020 in Minneapolis, Minnesota, U.S.A. This decision was especially difficult during the NALMS 40th anniversary year. In addition to the pandemic, the original location for the 2020 symposium was a city at the center

of the racial justice issues, making it an even more heart-wrenching year for NALMS members and partners. NALMS worked quickly to restructure the symposium planning committees and was lucky to have some members from the original Minnesota planning committees join with members of the Executive Committee, Conference Committee, and staff to form a virtual host and program committee. NALMS also had the benefit of two experienced conference coordinators (J. Schloss and S. Peel) to guide the transition to an online event, including the careful vetting of a virtual conference hosting platform. This virtual symposium program included many of the same activities as an in-person event, such as plenary and poster sessions, technical demonstrations with live Q&A, an early career panel, and even the Clean Lakes Classic Run/Walk.

NALMS used the Whova event app (for both web and mobile) to host the meeting with a Zoom integration on the backend. Whova received favorable reviews by attendees and is where presentations were stored, live streams were run, sponsors were featured, and all networking took place. Much like an in-person NALMS conference, attendees could set their own agenda, participate in Q&A sessions, and network with their peers via the community electronic bulletin board and interactive sessions during the week-long program. The planning team organized several networking and informal social events, but decided not to include a virtual exhibition hall and other traditions from the in-person meeting format, mainly to keep the program as simple as possible and focus on aspects of the meeting most likely to succeed in the online format. A successful lake trivia night was organized for the first time during the virtual symposium and will likely become a new tradition, even when returning to in-person meetings.

The main benefit of the online format was to create an inclusive meeting that removed financial and travel barriers and allowed for the convenience of listening to more talks with the online catalog available for 6 months. Attendance increased 50% over previous successful conferences with a significant portion (40%) of first-time symposium attendees. Another advantage was the increased dialogue across the entire organization with the community e-forum, session Q&A, and chat features. Ideas were shared more broadly throughout the community, leading to new NALMS initiatives (e.g., Urban Lakes). Initial feedback suggests that the poster sessions were better using the online format with options for viewing posters asynchronously via the Whova app. Poster slam sessions were also organized with 1-min videos prepared by presenters, played live, and then session attendees could join presenters in a Zoom breakout room for interactive discussions or leave questions or chat messages for presenters anytime during the week.

Many workshops adapted well but not all workshop formats could readily transform into a virtual platform. Those that could adapt well to a virtual format could accommodate more people and topics. The Career Panel, a new session at this meeting, was the highlight of the symposium for many participants. With the online format, we were able to open up the panel to nonmembers and those who were not registered for the meeting, creating an opportunity for early career professionals to network and learn more about NALMS.

Networking and interpersonal interactions were minimal during the week, especially with using Zoom webinars for most sessions, Q&A, and chat via text versus live voice or video interactions. This was especially unfortunate, because many NALMS members have established career-spanning, collegial relationships and friendships when attending the annual symposium. Field trips were not planned during the virtual symposium.

For future virtual NALMS events, more live opportunities for networking and interaction with presenters and other attendees would be ideal. In addition to the General Sessions for asynchronous viewing, presenters could be invited to participate in live, moderated Q&A discussions by topic. Furthermore, additional guidance for attendees and presenters is needed, particularly on using the various features in the online format and more effectively adapting presentations and sessions to a virtual meeting. A virtual exhibit hall will be organized at the National Monitoring Conference, the next NALMS-organized virtual conference in April 2021. Overall, organizers of virtual conferences need to pay more attention to scheduling networking events to accommodate participants from different time zones.

Physical Processes in Natural Waters (PPNW)

The PPNW conference was planned as an in-person meeting in Vancouver, Canada 15–19 June 2020, but then was changed to a 4-d virtual meeting filled with presentations. Each day was 3 h long so that participants were not overstressed and able to avoid conference fatigue. Originally enrolled presenters were first asked if they would like to present in a virtual conference and then assigned a dedicated time slot for presenting. Remaining time slots were then offered to attendees, who previously did not have a presentation time allotted. ECRs especially took advantage of this opportunity. The word spread and the organizing committee received more new applications for presentations than could be accommodated in the former reduced schedule. The online format promoted a better representation of ECRs, who contributed most of the presentations. In total, the virtual conference included one plenary talk, 15 thirty-minute talks, and 13 three-minute flash presentations.

The virtual format facilitated the inclusion of a well-known plenary speaker who likewise might not have been available for participation in-person. In addition, this plenary speech was accomplished at no cost for transportation, accommodation, and daily allowances as was normally associated with PPNW in-person meetings. In general, sound and video quality was good. Audio-visual quality was noted as even being better at the virtual conference than in some in-person conference rooms. In only one presentation (from remote China) out of 29 in total, the connection broke. On three of the four days, participant Zoom login worked well. On the other day, the organizers had to set up a new Zoom session due to technical glitches.

Each presenter shared their screen, and no software issues were encountered. Presenters used animations sparingly. The virtual meeting was relatively easy to organize in comparison to a physical meeting, as it required only setting up a local website, a participant enrollment system, and the distribution of Zoom invitation links. In general, the absence of in-person activities and participation fees made things straightforward for attendees and organizers alike:

travel and visa costs were eliminated, food restrictions were not an issue, and no last-minute hotel accommodation problems were encountered.

One of the main challenges was to ensure the general information reached all participants. During the 2 weeks prior to the meeting, the organizing committee received more than 450 emails, which needed to be answered individually. However, email was the only tool used to reach out to each participant. Although a Slack workspace was created after the meeting, participants have not used the platform much (about 20% of participants joined the Slack workspace). To ease session facilitation, we asked presenters and chairs to join the meeting 15 min before the start of their respective session. Sessions were not recorded because of legal concerns. In general, the sessions proceeded smoothly. In only a few cases during discussion, moderators had to intervene when some participants were talking over each other because of difficulties in discerning when someone had finished speaking, especially when attendees were on a slow internet connection. Additionally, some questions might have been overlooked and attendees might not have been comfortable asking a question in front of a big virtual audience. The organizing committee created virtual social hours, but attendees found them difficult for informal conversation, as they could not recreate the side-conversations that naturally occur in group settings. Consequently, the virtual format seemed to minimize interpersonal interactions. Aside from the format, some participants did not join due to inconvenient meeting times in their respective local time zones (as sessions were ending 19:00 to 20:00 CET) despite the efforts to shift part of the conference program to times that suit participants from Asia and Oceania (particularly day 2 was 10:00 to 12:00 CET).

Looking forward, the active use of any communication platform, like Slack, to provide some sort of acquaintanceship between presenters and the audience seems worthwhile. Also, consent from attendees to record the sessions and a designated server to host the videos seem ideal to help bridge differences in time zones. Nonetheless, some presenters had concerns about distribution of their content beyond the conference.

Ecological Forecasting Initiative (EFI)

The virtual conference "Ecological Forecasting Initiative 2020: Coordinating the NEON-enabled forecasting challenge" was hosted on 12–13 May 2020 to replace a 3-d in-person workshop scheduled at the same time. The objectives of the conference were to (1) introduce the NSF-funded EFI Research Coordination Network (RCN) for individuals interested in ecological forecasting, (2) highlight the "supply side" of National Ecological Observation Network (NEON) data products available for use in ecological forecasting, (3) discuss the needs of governmental and nongovernmental organizations for ecological forecasts, and (4) provide the vision of the NEON Ecological Forecast Challenge designed to bring the community together to collaboratively create forecasts using NEON data products, including ecological forecasts for aquatic systems.

The virtual conference included a combination of prerecorded plenary talks and panels, live breakout sessions, and live open discussion or reports from the breakout session, as well as plenty of time for breaks. Zoom was used as the conference platform, and Poll Everywhere was used to brainstorm ideas as word clouds and posts for participants to submit and vote on questions for panelists and speakers.

Moving to an online format allowed EFI to broaden its community by increasing participation and diversity. The in-person meeting was space-limited to 65 participants. The virtual format opened registration to anyone. In total, 205 people had registered to access the workshop materials, with 150 individuals and 110 individuals consistently joining on days 1 and 2, respectively. Instead of the original limit of 15 in-person graduate students, the conference welcomed over 50 graduate and undergraduate students. The EFI virtual conference had more global participants than were originally registered for the in-person meeting with almost 10% of attendees joining from outside the U.S.

From a postconference survey, 84% of participants said they intended to stay engaged with the EFI-RCN and 81% felt more engaged in the ecological forecasting community. The Zoom breakout room feature was key to allowing conference participants to get to know each other in small groups (< 10 participants per room). Out of the 10.5 h of EFI-RCN meeting time, 3.7 h were spent in breakouts with an additional 1.3 h spent in open discussion or reports from the breakout groups.

In the virtual setting, ideas for educational, cyberinfrastructure, and methodological training and needs were broadly brainstormed using the survey platform Poll Everywhere. However, defined written products were more challenging to generate. One of the original goals of the planned in-person meeting was to develop targeted working groups to collaboratively write a document that defines the protocols of the NEON Ecological Forecasting Challenge (here, the Challenge is similar to a model-intercomparison project with the goal to improve the predictive capacity of forecasts for population, community, and ecosystem dynamics using NEON data while building a collaborative ecological forecasting community). Although this objective was not fulfilled during the virtual conference, organized postmeeting virtual working groups of conference participants finalized the Challenge rules (https://ecoforecast.org/efi-rcn-forecast-challenges/). As a result, the organizers learned that the virtual format required all participants to scale back the expectations for the meeting and to focus more on getting community input from diverse perspectives than completing particular products.

As mentioned above, the breakout rooms worked well for building community and engagement. However, in future meetings EFI plans to change how breakout rooms are implemented. In terms of logistics, random assignment to breakout rooms was very easy. In contrast, the host-assigned breakout sessions were more beneficial for putting people with similar interests together, but more time consuming to manually assign individuals in the Zoom controls. Zoom developed some new features after the EFI workshop, including the ability to preassign rooms (but this only works for participants that have an email associated with a Zoom account) and for participants to choose their own breakout rooms. In particular, allowing participants to choose their own breakout rooms would be useful to promote additional mingling among conference attendees. A fuller description of additional lessons learned while preparing for the EFI-RCN virtual meeting, the general meeting setup,

suggestions for using Zoom and breakout rooms, and communicating throughout the workshop can be found in Peters and Thomas (2020).

Knowledge-Guided Machine Learning (KGML) Workshop

A virtual workshop on Knowledge Guided Machine Learning (KGML) was held in August 2020. The workshop was part of a 2-yr conceptualization project funded by the NSF's Harnessing the Data Revolution (HDR) program, involving researchers from the University of Minnesota, University of Wisconsin-Madison, Pennsylvania State University, Colorado State University, US Geological Survey, and the University of Virginia. The goal of the project is to develop a framework that uses the unique capability of data science models to automatically learn patterns and models from data, without ignoring accumulated scientific knowledge. Specifically, the project is building the foundations of KGML by exploring ways to bring together scientific knowledge and machine learning models using pilot applications from four domains: aquatic sciences, climate and weather, hydrology, and translational biology.

Initially planned as an in-person, ~ 50-person workshop in Minneapolis, Minnesota, U.S.A., the inaugural workshop took place 18–20 August 2020, virtually over Zoom. The workshop included invited live talks and panel discussions by leading experts, and was structured into six, half-day, 3-h sessions. As sessions focused on each of the four application themes, attendees could pick-and-choose which sessions were of interest. In total, 1038 registrants from over 30 countries participated, with individual session attendance in the low-hundreds. For presenters who provided consent, their slides have been published on the workshop website, and video recordings have been published on the KGML YouTube channel (https://www.youtube.com/channel/UCMYTOjm4uAI3xKWGY7_7xKA). The online tool Slido was used to engage the virtual audience to ask and promote popular questions.

Prepandemic, the organizing committee never considered running the workshop virtually. Of all the decisions to be made, hosting the workshop in-person in Minnesota was a given. In hindsight, going online was beneficial to the group and to the wider community. The virtual platform enabled a much wider range of attendees than possible in-person. In striving to make science more equitable, online workshops such as these are emerging as a valuable asset to the community by making science more equitable. They provide free access to cutting-edge science, and because many talks are posted online, viewing hours are flexible. Thinking back on the original list of invitees, an in-person workshop would have been a mix of well-known scientists and their students—a KGML inner-circle that would have talked among themselves about engaging the broader community. The pandemic forced the team outside its comfort zone and with great success.

The equitability and convenience of this virtual workshop outweighed the disadvantages of not hosting it in-person. However, some disadvantages were apparent. For one, there were no social activities built into the workshop, so it was not possible to get to know people or engage in conversations that spur new ideas. Panel sessions were aimed at soliciting feedback from attendees, but often questions were limited. Also, because the talks were delivered live, invited speakers were limited to those who could reasonably accommodate the time zone.

Virtual Summit: Incorporating Data Science and Open Science in Aquatic Research (DSOS)

On 23–24 July 2020, a grassroots group of scientists convened the first "Virtual Summit: Incorporating Data Science and Open Science in Aquatic Research" (Meyer and Zwart 2020). The summit was intended to bring together researchers of all career stages, and curious individuals in general, into one space to discuss four major themes in the aquatic sciences: (1) Big Data, (2) Data-Intensive Modeling, (3) Tools and Software Development, and (4) Applications of Open Science for Management. In total, the summit featured eighteen 10-min prerecorded presentations, which were divided into four sessions that paralleled the summit's four major themes. During each session, the summit's coconveners played prerecorded presentations sequentially over a shared Zoom screen. Prior to each session, the summit's coconveners sent participants Google Forms, through which attendees could submit questions either to a specific presenter or all presenters within a session. While talks were streamed, presenters could view the Google Forms response document, which would automatically populate questions as they were submitted. Following all talks for a particular session, the coconveners moderated a live Question and Answer discussion, where each presenter was allotted 4 min to either respond to questions or expand on their talk. After the second and final day of the summit, attendees participated in breakout groups that mirrored the summit's four major themes and were designed to replicate an "unconference" or "working group" format. To facilitate conversation and ensure equitable opportunity in voicing thoughts, the coconveners preemptively assigned breakout group facilitators. During breakout groups, facilitators noted attendees frequently asking for resources and training opportunities in data science and open science techniques. To begin addressing this need, the coconveners created a Slack workspace, which is intended to serve as a place of mentoring and training as well as a hub for crowdsourcing errors, analytical questions, and best practices in open science.

After the virtual summit, several attendees and presenters offered feedback about what worked well and what could be improved. In general, attendees expressed highly positive feedback. Most notably, attendees appreciated that talks were recorded, played sequentially, and questions were pooled in a panel-style format at the end of each session, all of which enabled the summit to run efficiently and punctually. Having talks in advance of the summit also allowed organizers to close-caption talks, which many attendees commented as being helpful for non-native English speakers. Attendees and presenters alike commented that submitting questions via the Google Form with an ensuing moderated panel enabled (1) equitable opportunities to ask questions, especially in instances when an attendee may not feel comfortable voicing the question in front of a group, and (2) time for presenters to consider responses while the talks were streamed. Even though attendees liked the overall structure and organization of the virtual summit, several attendees remarked that they would have

appreciated a slight introduction or pause between presentations so as to orient thoughts towards the next speaker or finish note-taking. Similarly, attendees enjoyed the breakout groups, commenting that they appreciated the chance for casual conversation with other attendees and speakers; however, attendees also remarked that priming facilitators with topics for leading group discussion or specific ideas would help provide goals and structure for conversation in the breakout groups.

While feedback on the summit's organization and networking opportunities were generally positive, diversity needed to be improved. Original solicitations for speakers were conducted before the COVID-19 pandemic and were relatively balanced with respect to sex and gender; however, this diversity was not achieved in the final speaker lineup, which was completed during the COVID-19 pandemic. Meyer and Zwart (2020) describe how the COVID-19 pandemic had the potential to present additional or enhance existing barriers to conference participation and leadership, especially for individuals who have childcare or eldercare responsibilities (Malisch et al. 2020) as well as those from intersecting minoritized groups (Louisias and Marrast 2020; Staniscuaski et al. 2020). Looking forward to future virtual summits, increasing representation across sex, gender, racial, ethnic, and other minoritized groups is a main priority.

Looking back on the virtual summit, the overwhelming positive feedback from attendees and presenters alike suggests that this newly formed conference has identified a need for data science and open science programming in the larger aquatic sciences community. By actively working to include less represented groups, future summits can be a space and time of mentoring and skill development in addition to sharing science, where numerical, machine learning, and statistical modelers of various experience-levels can converge. By creating this community, the virtual summit can benefit by receiving feedback from a large, diverse member base, thereby benefiting the aquatic sciences community more broadly.

Looking forward

In a year that demanded creativity from the scientific community, many established and inaugural communities crafted their own solutions to connecting virtually. The All Hands' meetings, conferences, summits, and workshops described here used complementary software and information sharing formats, which likely provided fewer chances for technical glitches throughout each gathering. As a result, many of these meetings were produced with limited funding, further enabling both new societies to arise and established societies to adjust. Above all though, each society was able to recreate the conference experience using available tools, although the delivery may have been different from previous in-person meetings. Watching a previously recorded talk over YouTube, even when followed by live Q&A, could not replace connecting with a speaker in person, but did provide greater access for a larger number of participants. Communication software, such as Slack, could not really replace the casual "hallway chats," but did provide more complete documentation of conversations and a forum that could continue following the meeting. Despite the challenges of 2020, the aquatic sciences community has demonstrated ingenuity and commitment to translating the traditional in-person meeting into a productive and engaging experience.

Even with these successes, our review of each society's attempts to facilitate virtual communication highlighted areas for improvement. In particular, programming targeted toward ECRs was less prevalent. While this is understandable given the rapid realignment towards an online format, future virtual meetings should consider building in specific programs for ECRs, since networking and collaboration at scientific meetings can be especially crucial for career development. Aside from programmatic needs, the community learned that mental and physical fatigue are inherent to both in-person and virtual formats. Much like an in-person, session-packed meeting, virtual meetings occurring for long hours, across multiple time zones can drain energy. Although a virtual format may more easily afford attendees the chance to "log-off" from the meeting, building in diverse events, such as social hours, breakout or working group sessions, and mixed presentation formats are crucial to prevent attendees from logging off too often or feeling drained by a meeting.

Moving forward, the combined experiences from each society suggest that virtual conferences and meetings in some form are here to stay. While we have documented successes and areas for improvement, virtual meetings on their own are likely inadequate replacements for in-person settings. Hybrid models tailored to a specific society's resources and needs could incorporate components of both the in-person and virtual experiences. One variant could be offering both the in-person and virtual components simultaneously, allowing attendees, who are not able or willing to travel, to partake in in-person sessions and panels through video-conferencing software. Here, an alternative hybrid form could consist of regional in-person meetings, to minimize travel, while still being connected to other regional meeting hubs via a shared online program. Another hybrid model could be re-envisioning the in-person conference altogether, where traditional presentation and poster sessions are conducted virtually, and a companion, asynchronous in-person conference parallels the themes of the virtual meeting but with a focus on working groups, networking, and research products. Regardless of the format, the successes from each of the examples given here provide evidence that these models are indeed possible, and the time may be ripe to explore alternative avenues for sharing science.

Overall, the collective creativity, patience, and dexterity of the aquatic science community have led to meaningful, productive virtual meetings. Yet, the broader scientific community is still learning from one another, as well as experimenting in how to adapt approaches and techniques to best serve the function at hand, be it scientific exchange, networking, or mentoring. Through social media, network publications, and personal experiences, we—the community—can see in real-time how we evolve and adapt to new ways of educating and communicating that can be more equitable. Even so, virtual meetings will never fully take the place of face-to-face interactions. Amidst a workweek of constant video streaming, tired eyes can limit enthusiasm for even the best-run activities, and nothing can replace the excitement of being in a room full of colleagues with shared interests. However, moving forward, when we start planning workshops, perhaps our default choice will be to consider virtual components. We have the collective knowledge to do it well, and the benefits are well worth it.

BOX 1. 10 Lessons learned and points to consider when planning a virtual meeting

1. Virtual meetings can increase global participation.
2. Virtual meetings can require less overall funding to convene.
3. Recorded presentations help bridge time zones and busy daily schedules.
4. Closed-captioning content benefits many, especially non-native English speakers.
5. Have a plan to ensure equitable opportunities for participants during Q&A sessions.
6. Communication platforms help facilitate informal conversations.
7. Plan multiple breaks, organize social hangouts, and limit daily programming to minimize fatigue.
8. ECR-specific programming should be prioritized.
9. New and existing barriers to diversity and inclusion should be considered and addressed.
10. Everyone is still learning how to adjust virtually. Positive and constructive feedback can greatly help improve future meetings.

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MFM and RL conceptualized the bulletin, wrote the introduction and synthesis, and harmonized each conference's paragraphs. HAD contributed to the synthesis paragraphs. TNM, RJC, GF, BWI, PI, FPL, ARB, DP, LND, JDS, LB, PCH, and KCW wrote the sections about GLEON. LB, AA, CD, EJF, PF, SP, DL, JAS, APS, PT, and TT wrote the sections about NALMS. MS and BB wrote the paragraphs about PPNW. JAP and RQT wrote the sections about EFI. HAD, PCH, and RL wrote the paragraphs about KGML. MFM wrote the paragraphs about DSOS.

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