Volume 30 Issue 1 February 2021

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About the cover image: Close up of a branching coral spawn pinkish egg-and-sperm bundles taken in 2018 in the Red Sea. These bundles will be carried away by the currents, mixing in the water, until they encounter a match – a sperm fertilizes an egg and new life is created. This phenomenon of coral spawning usually happens once a year in a certain month of the year, on a specific night of the month, and at a certain hour of the night for a very short time window of only few minutes. Title: Colorful snowstorm – Coral spawning. Photographer: Tom Shlesinger.
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
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 on 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/nalms-2020/nalms-2020-our-sponsors/.
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 2. Logistical considerations for each meeting |
|-----------------------------------------------|
| **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 |

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*www.ufz.de/ppnw2020.
†https://ecoforecast.org/efi-rcn-2020-workshop-videos/.
‡https://www.youtube.com/channel/UCMYTOjm4uAI3xKWGY7_7sKA.
§https://www.youtube.com/playlist?list=PL52fZTCEW54ckkg9mWUsMQ7gMZint0HB.
||https://www.youtube.com/playlist?list=PL52fZTCEW54fnuaL7tYLaXqfES2KTv12C.
| Workshops organized | GLEON | NALMS | PPNW | EFI | KGML | DSOS |
|---------------------|-------|-------|------|-----|------|------|
| 1. Simple guidelines for scientific writing and communication | 1. Collection, Identification, Ecology, and Control of Freshwater Algae | None | None | None, but the whole conference was organized as a kind of workshop | None |
| 2. Version control software (Git) for application in academic research | 2. Introduction to R for Aquatic Research (Beginners) | None | None | None |
| 3. Process-based lake modeling in R using the General Lake Model | 3. Smart Salting to Protect Lakes, Streams, and Groundwater | None | None | None |
| 4. Ensemble lake modeling with LakeEnsemblR | 4. Stormwater Management for Lake Managers | None | None | None |
| 5. Facilitation and Participation in Productive Working Groups. | 5. Working with Sensors and Analyzing Sensor Data | None | None | None |
| | 6. Ecology of Cyanobacteria; Introduction to R for Aquatic Research (Advanced) | None | None | None |
| | 7. Telling Your Lake Story with Story Maps | None | None | None |
| | 8. Volunteer Lake Monitoring: A Train-the-Trainers Workshop | None | None | None |

| Social networking events organized | GLEON | NALMS | PPNW | EFI | KGML | DSOS |
|------------------------------------|-------|-------|------|-----|------|------|
| 1. Networking activity for all participants organized by the GLEON Student Association (GSA) | 1. Poster Socials | None | None | None, but the whole conference was organized as a kind of workshop | None |
| 2. Social/Networking activity: Scavenger Hunt | 2. Awards Social with online Lake Trivia Night | None | None | None |
| | | None | None | None |

(Continues)
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 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. The 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 U.S., which 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.

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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 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.

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 session, 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.

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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/UCMYT0jm4uAI3xKWGY7_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 equity 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-capture 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; Staniscuasi 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, since network- 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 videoconferencing 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.
Acknowledgments

We are very thankful for conference planning contributions and diverse creative as well as technical support of Jacob A. Zwart, Mary E. Lofton, and Vipin Kumar. Partial funding support for the GLEON All Hands’ Meeting was provided through NSF grant EF-1702991 and an Anonymous GLEON Donor (via Cary Institute). The KGML coordination (HDR) Big Idea Program, award 1934668 (CU), 1934548 (Penn State), 1934600 (UVa), 1934633 (UW), 1934721 (UMN). EFI’s Research Coordination Network and workshop are supported by the National Science Foundation DEB-1926388.

Author contributions

MFM and RL conceptualized the bulletin, wrote the introduction and synthesis, and harmonized each conference’s paragraphs. HAD contributed to the synthesis paragraphs. TNM, RJF, GF, BWT, PI, FPL, ARB, DP, LND, JDS, LB, PCH, and KCW wrote the sections about GLEON. LB, AA, CD, EFJ, PF, SP, DL, JAS, APS, PT, and TT wrote the sections about NALMS. MS and BB wrote the paragraphs about PPPNW. 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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February 2021
Coral Reefs could be gone in 30 years. (National Geographic 2017)

The Great Barrier Reef has lost half its corals. (The New York Times 2020)

Earth’s coral reefs could be gone by 2100. (NBC News 2020)

From Australia’s Great Barrier Reef to the Caribbean islands, the message is clear: coral reefs are struggling. Many that have dedicated their lives to these ecosystems are seeing them vanish in front of their eyes. Coral reef scientists wake up to this reality every day and have been waking up to this reality for a long time! The increasing amount of negative news reports can be discouraging and exhausting. These messages of hopelessness can be especially demotivating to young and early career scientists. There is, of course, a valid need to highlight the urgency of our situation in order to inspire action. However, in parallel, there is also a need to focus on opportunities and actions that can change our current course—both to motivate the next generation of scientists and society.

Despite the negative headlines, there are plenty of reasons to be optimistic and to have hope that there may be a positive outcome for coral reefs. In recent years, increasing public and political awareness has led to a number of new movements in reef conservation internationally. Indeed, awareness of the importance of our reefs and our oceans at large has given rise to the next United Nations Decade subject: The UN Decade of Ocean Science. Most importantly, though, is that these efforts range far beyond just scientists and scientific byproducts. The global community, from concerned locals to passionate citizens far from reefs, plays an increasingly significant role in the fight to save coral reefs. Scientific research provides the backbone for well-informed actions and decision-making processes at local and international scales. But scientific efforts must go hand in hand with community engagement and advocacy. As such, hope for the future of coral reefs lies at the intersection of science and society.

In order to succeed in bringing science into societal decision-making, scientists, and academic institutions must undergo a transformation—structural and functional. Signs that this transformation has already begun are everywhere: from the growing engagement of scientists in community outreach events to the increasing presence of scientists on twitter. Academia may be old fashioned in regards to many aspects, but, as with every generation, the young are bringing fresh perspectives. Early career scientists now channeling hope for coral reefs within their research as well as in their interaction with society.

It is from this vision of hope in coral reef science beyond research that this article series was born. A group of six young marine scientists, connected through their mutual experiences in ASLO’s Limnology and Oceanography Research EXchange (LOREX) program, joined together to discover what gives them hope for the future of coral reefs. Of course, fundamentally, we are confident that our research findings are increasingly leading to a more in-depth understanding of coral reef ecosystems and ultimately contributing to more informed decision making. But through our work we discovered that our hope for ensuring the future of coral reefs ultimately did not stem from data itself—its roots are in communication and collaboration.

In the following articles, we describe why we have hope for coral reefs and how we envision science and academia transforming so hope continues to grow across all sectors of society (Fig. 1). We introduce the importance of science, marine protected areas, and marine spatial planning in ensuring short and long-term improvements of ecosystem’s health. Next we focus on the importance of communication and collaboration, within academic institutions and communities, and the value placed on these initiatives. Finally, we discuss the future of academia itself, how we need to adapt to changes in expectations of professional scientists and the importance of providing equal opportunities and increase diversity. There is much left to do, but the vision of these six marine scientists is one of opportunities and optimism. Because as long as we have reefs to save, there is hope.
Coral reef ecosystems face a number of local threats, including increasing human populations, coastal development, fisheries, and pollution, which cause severe destruction on reefs, while global anthropogenic climate change is altering the environment of coral habitats. Due to these stressors, there is a crucial need to reevaluate and implement effective management practices to protect coral reefs immediately and in the long term. Broadscale management techniques currently exist, including a wide variety of conservation, technological, ecological, and monitoring techniques, to name but a few. However, due to the complexity of coral reef ecology and local and regional differences, understanding and identifying effective management practices to address corals’ present and future fate is challenging.

Given these difficulties, maintaining the future health of coral reefs can often seem like a daunting task for early-career researchers. However, increasing understanding of coral reef ecosystems through scientific and economic research, as well as a surge in technological innovations, has led to improved management ambitions, techniques, and implementations which have resulted in successful recovery and rejuvenation of previously threatened reefs (Duarte et al. 2020). These successful endeavors provide hope, not only for early-career scientists, but also for those who have been fighting for the protection of reefs for decades, that it is not too late to take action. With the development of more tools and improved knowledge, there are also increasing ambitions to protect reefs from local as well as global anthropogenic stressors. There are several actions which we can take to improve current management strategies (Fig. 1). As early-career researchers, we provide our perspectives on promising immediate and long-term coral reef protection strategies which are currently being developed and applied that show hopeful steps to ensuring the future of reef ecosystems.

ImmediatE AcTion for reef protection

Currently, there are a few research-based management strategies which we believe can be effective. In the short term, one hopeful management strategy which is currently used widely is the designation of marine protected areas (MPAs), which manage specific conservation objectives. Incorporation of new research findings has greatly improved these management practices and led to much success. MPAs have become widespread in various social and economic situations with 26.9 million km² of the ocean protected by them (http://mpatlas.org/) and with coverage increasing by 8% per year (Worm 2017). We have seen that this management tool has successfully improved the recovery of fish populations by managing overfishing, controlling local stressors, and recovering habitats (Duarte et al. 2020). We believe that hope for the immediate protection of coral reefs comes primarily from international efforts led by the International Union for Conservation of Nature (IUCN) to protect 30% of the ocean by 2030 through the implementation of a network of MPAs. MPAs have shown much promise thus far, but there is room for improvement. Expanding current MPAs by 5% has been estimated to improve fish stocks by as much as 20% (Cabral et al. 2020). We believe that the implementation of long-term managing programs can reduce local stressors. For that effectiveness to be realized, an assessment of the conservation needs of the specific MPAs are required due to the wide diversity of coral reef ecosystems and local vs. global stressors acting upon them. After a needs-based evaluation, continued monitoring should help inform specific follow-up management practices, such as the use of bioindicators and biomonitoring approaches. We believe if we take immediate action to improve MPA practices with the changing environment, we can continue to alleviate stressors in corals in the future.

Although MPAs have led to many success stories of marine habitat protection, we see several other areas for improvements. The benefits
of MPAs on marine populations are often insufficient due to the young age of MPAs, lack of resources, and lack of enforcement (Duarte et al. 2020). Notably, to see positive outcomes and gain benefits from MPAs, they must be well established. However, most MPAs are less than 10 yr old, and there is often a time delay between an intervention and its effects. Hence, besides ensuring effective resource management, we must have patience to see these efforts bear fruit. MPAs require many resources to be an effective management tool, and current MPAs often do not have sufficient resources to uphold management for long periods. Of the current registered MPAs, 65% report an insufficient budget, and 91% have reported limited staffing (Gill et al. 2017). In addition, MPAs may not always be the most effective techniques for all types of regions, so region-specific policies for MPAs need to be drafted to ensure success. Local communities often are not involved in the development of MPA policies within their regions. Acceptance of these rules and regulations is easier when the local community’s goals are considered and met. We need to incentivize stewardship practices in local communities and authorities to ensure the enforcement of the managed areas. Finally, MPAs are most effective when combined with other management tools. Through improved maintenance and support, MPAs could build resilience to climate change and provide a more sustainable solution in the future (Roberts et al. 2017).

Another current management tool which complements MPAs is the use of marine spatial planning (MSP), which results in the targeted designation of MPAs. MSP has solved many management issues by considering the complexities in the marine environment, which make management challenging. The overall aim of MSP is to provide a strategic plan for management. Many countries have successfully implemented MSP. For instance, one of the greatest success stories is the Great Barrier Reef Marine Park (GBRMP; Douveere 2008). Australia has implemented spatial planning and zoning which protects coral reefs while also allowing space for human activity to continue (Day 2002). Their plans have continuously changed since their first enactment in 1983 to match the changing marine policies and the changing environment. This is a great example of protection, but the well-funded nature of the GBRMP highlights the intricacies which exist. Many reef ecosystems are near coastal communities which do not have access to these vast resources which has led to less successful implementation in these areas. The challenges with MSP are largely attributed to improper assessment, monitoring, and implementation strategies. In order to ensure a high level of success with MSP as a technique, clear oversight and continual monitoring are necessary. The GBRMP sets a great example to future projects and gives us hope that these management strategies can be successfully applied with adequate resources. Future management plans should take inspiration from older protected areas and learn from what has worked, while also adapting to what did not. Re-assessment of MSP should occur every few years to reflect developments in socioeconomic and environmental parameters to keep up with and implement the benefits of evolving information in the field.

LONG-TERM STRATEGIES FOR REEF PROTECTION

Current strategies for managing anthropogenic effects on coastal and reef environments are only part of the solution. While MPAs and MSP are effective, they do not stop climate change associated alterations such as ocean acidification, temperature increase, and hypoxia. Heat stress and associated mass bleaching events are of primary concern. In the last 10 yr, research has seen exceptional steps forward in understanding the molecular underpinnings of temperature tolerance of the corals including not only the coral host, but also associated symbiotic algae and the microbiome, known as the coral holobiont (Cziesielski et al. 2019). The understanding of basic holobiont function lends itself to another style of management, which production of specific stress markers (i.e., metabolites or transcripts) will be expressed in all coral species/populations and can be used as indicators for stress levels of different types of stressors.

Deciphering the genetic traits which determine tolerance, as well as the underlying mechanisms of metabolic and chemical communication between symbiotic partners, is fundamental in our efforts to help coral reefs survive climate change. Hope that corals are indeed capable of adapting to warmer oceans has often come from reefs which exist in the warmer waters of the Red Sea, where corals have often been hailed as particularly heat resilient (Osman et al. 2018; Kleinhau et al. 2020). Scientists have recently succeeded in new assisted evolution approaches which enabled lab grown temperature tolerant symbionts to be taken up by coral larvae and overall increase coral’s heat tolerance (Buerger et al. 2020). If these efforts continue to show success in a variety of coral and symbiont species, hope exists for the reseeding of dead reefs with more tolerant coral offspring helping to replenish many of the damaged populations.

While these developments are of significance, it is important to remember that we are far from conserving reef diversity as a whole. Due to phenotypic variations from one coral colony to another, it is imperative to remember that not all colonies will experience stress the same way (see review Cziesielski et al. 2019). The role which phenotypic variation plays in genetic adaptation and responses are so far only broadly understood. Furthermore, relationships between corals and their symbionts are inherently complex and selective. Thus, a heat tolerant algae may not necessarily be accepted into host tissue or, if it is, may not necessarily confer thermal tolerance. The complexity of the coral holobiont and the intricacy of genetic markers and responses require significantly more work. Here, it will require not only researchers working on various parts of the holobiont to come together, but also for marine scientists to look for expertise regarding mechanisms and methods from other fields. If we wish to conserve coral reef diversity as a whole, immediate action toward effective MSP and MPA planning will have to occur in parallel to continued long-term investments into understanding fundamentals of molecular mechanisms and developing tools for assisted evolution.

HOPE FOR THE FUTURE

Although there are numerous threats which coral reef ecosystems face, we continue to identify areas of hope for the survival of corals in the short and long term. These approaches will have to be adapted not only by location (i.e., local ecosystems, capabilities, and climate change impacts), but also over time. As technology and our understanding of corals continues to develop, management methods need to stay informed and up-to-date to be the most effective. Ultimately, this will require management practices, and those enforcing them, to stay flexible and dynamic in order to adjust as conditions and knowledge change. Importantly, the future implementation of successful management practices requires communication, collaboration, and mentorship (Nowakowski et al. 2021). In order to develop management plans which can adapt with time, gaps between science, industry, governments, and local communities need to be closed, and the communication channels developed. The growing international recognition that reef protection is desperately needed as well as
an increase in scientific, political, and social interest in coral reefs, indicates to us as early-career scientists that there is reason to continue our work. Much learning and adapting is still left to be done in terms of management techniques, but evidence indicates that we can ensure a future for coral reefs if we act now. This awareness fuels hope and motivation in us early-career scientists to continue striving for new horizons.

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COMMUNICATING HOPE FOR CORAL REEFS

There is hope for coral reefs and communicating excitement around coral reef research and discoveries is a key opportunity to grow it. Amidst the trawling scars and gear tangents on the Northwestern Hawaiian Ridge and Emperor Seamounts, researchers have identified signs of coral recovery since protection measures were expanded 30–40 years ago (Baco et al. 2019). It is expected that coral ecosystems will take centuries or more to recover from anthropogenic influence, and the discovery that improvements can be seen in decades is reason to celebrate. The current narrative tone for coral reefs revolves around difficulties to restore their ecosystems and conserve the species. This often means combating the communications conundrum that comes with the constant imagery of dead and dying reefs that are used so often to depict the climate crisis. To convey the urgency and scope of the challenges without causing people to lose hope we need to shift the narrative. By engaging broader audiences in case studies like the Emperor Seamounts that show what management actions can achieve, the gleam of hope it inspires can provide an impactful promise (Duarte 2020). Things can get better. Yes, it is impossible to deny the increased urgency and concern our community feels around coral ecosystems, but we also need to prioritize space for the increased excitement around new discoveries and successful management practices. Therefore, our goal is to harness that excitement we hold and to share it with those entering the field, as well as a broader audience, so we can foster productive conversations as we continue to strengthen and improve our actions to save coral reefs.

To communicate this excitement, we need to find ways for our audiences to connect to and identify the strong link between coral reefs and humans. Therefore, putting corals into a context that your audience is both engaged in and can relate to will help fuel the conversation. This can be done by changing the delivery of our narrative and in turn, our dialogue around corals. Presenting coral reefs as a standalone, struggling system that is already bound to be doomed makes saving them seem like a hopeless task. This set up can quickly lead to the end of a conversation: “No, I don’t see what I can do about this. Coral reefs are dying anyways.” By making the change from No to Yes, you completely reframe the argument and open the conversation to many more possible outcomes: “Yes, corals are dying, but evidence shows there is hope for their survival, therefore we must take care of them and make proactive decisions” (Palermo 2014). A second method to reshape the way we present science narratives is to incorporate elements of humanity and vulnerability. This approach emphasizes what we have in common—emotions—and helps make the content more relatable. This could look like sharing personal narratives of those who experience how the loss of coral reefs in their communities redefined their socioeconomic framework (McKinnon et al. 2016). By sharing emotions with our audiences, we connect through vulnerability and trust. By communicating optimism, we move another step in the direction of mobilizing people to act.

In addition to changing our tone, we can present the scientific method as a narrative process; delivering it in the context of a story gives our message both more power and structure (Olson 2015). Learning how to apply storytelling skills to communicate excitement takes practice that can be accelerated through training. Therefore, seeking out workshops that target these skills, such as Improve 2020 (www.palermoimprovetraining.com) and The Story Collider 2020 (www.storycollider.org/workshops), can be an invaluable undertaking.
Investing in these soft social skills calls for applying the value we place in broader public engagement efforts as well. This can include written or video logging (blog or vlog), as well as social media platforms. These platforms are well suited for sharing stories and developing personal connections; by distributing science in this format, we are fostering a broader audience connection than was historically possible. Social media posts can simultaneously reach communities from island nations to the most inland schools while enabling conversations between every location and promoting discussion far past the traditional show and tell methods. Additionally, these platforms are well suited for short anecdotes, which is important because the more specific the stories are that we provide, the more effective our communication will be. By carving out individual narratives from the often overwhelming, broader context, we can then present approachable problems with relatable, easier to act on solutions. Taking steps to expand each scientist’s ability to reach the public makes a long-term investment in the future for corals by expanding the breadth and application of our research and through building stronger communities and conversations around coral reefs.

We aim to ensure that our excitement resonates with as wide of an audience as possible; achieving this could look like reevaluating who we are communicating with while developing our research plans and goals. Corals are complex species that support the base of ecosystems all across the globe, and they require an extensive set of skills to understand and manage. Shifting from field specific collaborations to interdisciplinary teams and engagement with other communities will be key. This process should include learning how to share what makes us excited with groups outside of academia, such as both coastal and inland communities, policy makers, lawyers, shareholders and more. The level of excitement and investment we share reflects the level of investment other people can return. Afterall, if we cannot portray our own personal commitment, how can we expect someone else to take on saving coral reefs as their own passion too? By communicating where our personal excitement begins with our careers in coral reefs comes from, we implore a powerful tool to call for motivation and action that can be directed at preserving and restoring our coral reef ecosystems.

We would like to acknowledge Brian Palermo for his input and passion for enabling science communicators.

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Rethinking Collaboration for Coral Reef Science

Connor Love ©, Maha J. Cziesielski ©, Hunter Hughes, Catherine Nowakowski ©, Angelique Rosa Marin ©, and Keiko W. Wilkins ©

The narrative that scientific advancement requires effort from one dedicated individual, the “mad” scientist cutoff from the help of others, is being replaced by new generations of scientists. This new wave of scientists is adept in communication, cooperation, and allocation of unique skills to solve a unified problem. This type of collaboration is reflected as an increase in the average number of authors per paper within all disciplines (Mallapati 2018), establishment of national and international research centers, and a rise of Big Science, in which the scale and comprehensiveness of research projects have increased (Price 1963; Westfall et al. 1993). Indeed, scientific collaboration is widespread and growing.

Coral reef science presents a unique case for collaboration between highly varied disciplines due to the overwhelming network of biota and the complex interactions with humans and climate, from local to global scales. Current and future collaborations are further placed under the pressure of a “timer,” since it is expected that the majority of coral reefs will experience annual severe bleaching by the mid-2050s (van Hooidonk et al. 2016). To adapt to this, collaboration encompassing coral reefs cannot just include working across different laboratories to publish scientific papers, but must incorporate a holistic approach beyond academia that heeds the complex and highly interconnected nature of reefs. Studying the reef system requires precise cooperative planning and allocation of international resources to achieve unified and agreed upon goals. We identified two forms of collaboration that have shown to be promising avenues to improve understanding and conservation of reefs: collaboration within scientific research and collaboration of scientists with local coral reef communities.

Big Science Presents Opportunities for Coral Reefs

The ticking clock on coral reef ecosystems as we know them requires extra diligence in coordinating research efforts around primary understanding and how to directly implement our findings. Each scientific action must be well planned and pointed towards a common goal, similar to those described by the recent Convention on Biological Diversity (UNEP 2019). In this plan, the unique approach of each scientific laboratory should be viewed as a unique puzzle piece that describes one (or several) of the key parameters of a reef system. The wide array of approaches to understand reefs can be seen as a reflection of the multitude of interactions that affects the coral holobiont itself (Cziesielski et al. 2019). Approaches can be
broadly categorized by discipline, such as sociopolitical science, economics, geology, ecology, chemistry, and climate. Variation within these broader disciplines can then be defined at the research group level by the unique approach to the reef system, i.e., the shape and area of coverage of the puzzle piece. How can we most effectively put these puzzle pieces together to build a full action plan to maximize benefit to the reefs and use resources most effectively?

We propose that to start this process as a community, we must establish committees to lay out the most immediate and important scientific goals that enable reef preservation worldwide. Committees of broad disciplines (ecology, chemistry, etc.) would have several community-nominated (with consideration of diversity and inclusion initiatives to avoid selection bias) and elected principal investigators whose research interests represent the discipline well. Committee meetings would take the form of an informal working group that could fit well into preexisting meetings, such as a Gordon or NCEAS (National Center for Ecological Analysis and Synthesis) conference. Before meeting, these committees would be responsible for sending out online surveys and communicating with scientists within their discipline to assess discipline level goals. These goals would then be formulated and communicated with the committees of other disciplines to establish overarching scientific goals and beneficial collaborations for our understanding and conservation of coral reefs. A 4-yr recurring report written by committee members with clearly defined goals for the scientific community would then serve as a framework for researchers moving forward. Formulation of these committees and dissemination of collaborative goals could be generated as a component of a preexisting organization, such as the International Coral Reef Initiative, with an emphasis on scientific goals for required understanding of reef systems. As we have all seen from the COVID-19 pandemic, a large degree of scientific work can be completed online and this could be done just the same. While the exact form of collaboration between research groups may vary, it seems clear that increased communication and community defined goals for knowledge are necessary if we are to support global coral reef preservation moving forward.

**MEANINGFUL ENGAGEMENT AND INCLUSION OF LOCAL COMMUNITIES**

Perhaps the most often acknowledged but least applied form of collaboration in reef science is with local communities that live on or near coral reefs. Many of these communities have a deep empirical and historical knowledge of the function of their reefs over time whereas scientific research is typically restricted to short visits (<1 yr) with brief to no temporal coverage. For modern understanding, local communities reside on reefs year-round and are in a unique position to greatly strengthen understanding of reef systems by conducting year-round observations and studies, particularly for understudied and remote reefs. Consultation of local people for traditional ecological knowledge provides high temporal coverage understanding of the reef and has been used for management strategies (Thornton and Scheer 2012), but a gap still remains between current scientific studies and local communities, creating a scientific inequity. If we are to have the most complete understanding of coral reefs and provide scientific equity to all groups involved with reefs, there needs to be meaningful teamwork with local peoples in research projects.

Local community inclusion must extend beyond a relay of information on what foreign scientists are doing on their reefs and needs to include elements such as reciprocal training (Baines 1992), community-based monitoring (Obura et al. 2002), co-management (Fernandez-Gimenez et al. 2006), and long-term partnership (Moller et al. 2009). Offering work-for-pay opportunities and including local communities from the very beginning of projects would establish inclusion and scientific equity and would garner participation for year-round research of coral reefs. Employing local collaboration practices in rural reefs, where there is no well-established research station would also aid in filling the large gaps in our knowledge of understudied reefs (Fisher et al. 2011). Local community inclusion sets up a tone of shared responsibility to protect indispensable natural resources. One such example comes from a partnership between scientists and communities in Palau in which sedimentation stress to coral reefs was alleviated by designing taro fields to better trap sediment and moving them higher up in the watershed to protect the reefs (Richmond 2014). The benefits are immediate and long-lasting once ties are established. Local community inclusion sparks discussions of reef health and changes on an international scale and beyond the scientific community. With such a small amount of time left to preserve reef health, we must gather and incentivize the efforts of everyone that is willing to help.

Collaboration to improve our understanding and protection of coral reefs worldwide is not only an exercise in large scale teamwork to achieve a goal, but an exercise of inclusion of diverse views and establishing trust across borders and backgrounds. Large-scale scientific collaboration, once established, will produce greater products than the sum of the efforts involved. Meaningful partnership between diverse scientific interests and local communities living with the reefs will facilitate a unified approach to protect reefs globally and lead to increased coastal resilience and climate mitigation strategies of at-risk regions. The underlying effort and success of developing a well-informed society lies in everyone’s commitment to communicating and cooperating across sectors and disciplines, with some levels of sacrifice for a common unified goal being paramount. As a scientific community we must exercise our social skills as much as possible, and work with people far outside our disciplines if we are to assure a future of coral reefs worldwide.

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If we look to the future of coral reef science and see an inclusive and diverse field where researchers from a variety of disciplines are widely engaged with the community at large, it will herald the success of the issues discussed thus far in this series of essays (Cziesielski et al. 2021; Love et al. 2021; Nowakowski et al. 2021; Wilkins et al. 2021). Interpersonal communication and collaboration are necessary to garner excitement for the future of coral reefs. It is also necessary to implement these within an open and inclusive atmosphere, to welcome and ensure diversity in future generations of scientists who will bring with them important and unique perspectives. This is not only a moral obligation; recent research demonstrates that diversity in research teams leads to more impactful publications (Freeman and Huang 2014, 2015). The dire future of the planet’s coral reefs is an urgent problem that will require the best working scientific collaborations to resolve. To address this urgent problem, we have identified three aspects of coral reef science that should be focused on for future generations: connecting people to coral reefs, inclusion and diversity, and holistic training programs that prepare future generations for an evolving science.

Connecting the general public and stakeholders to coral reefs means implementing communicative and collaborative tools that were discussed in previous sections, such as personalizing narratives (Nowakowski et al. 2021) and local outreach (Love et al. 2021). Beyond incentivizing interpersonal outreach, coral scientists now and in the future should be more proactive about sharing their discoveries and results through the variety of platforms that exist on the internet. Laced within that communication piece (geared toward a non-scientific audience) needs to be a message of hope, with tangible goals that can be achieved through actionable plans. That same plan of action should be refined through collaborations with local stakeholders who help to manage the reef where scientific studies are being conducted. With ample attention drawn toward interpersonal communication and collaboration, scientists can use their emotional attachment to coral reefs as a conduit to incite both excitement and action in the general public.

However, perhaps the most relevant and timely way to connect more people to coral reefs is to broaden the diversity of individuals who represent coral reef science. Toward this end, coral scientists have a particular part to play as role models. Institutions need to be mindful of this when hiring new faculty and researchers, because senior professionals that students (both current and prospective) can personally identify with are crucial for recruitment and retention (González 2006). Despite the fact that this is well-understood at the institutional level, a recent study documenting faculty recruitment of under-represented minorities (URMs) at four major institutions reported that only 4–9% of tenure-track faculty between 2011 and 2015 were from URM populations (Gumpertz et al. 2017). Worse perhaps is that the coral sciences are no exception, where URM groups are typically those most impacted by the social and economic repercussions of degrading coral reefs. Inclusion of a broader set of experiences leads to asking more important questions and therefore discovering more sustainable solutions. By missing this representation, we are missing essential opportunities that the planet’s coral reefs cannot afford.

While current representation is far from ideal, steps are being taken toward addressing the lack of diversity, inclusion, and equity in STEM fields. STEM-support programs typically help URM students from various universities by arranging campus visitations, assisting with summer research opportunities, and promoting informal mentoring relationships. While many programs like this exist for general STEM fields, there are none that we are aware of specifically targeting coral research. Given the important links between coral reefs, the URM populations that typically inhabit them, and diverse research groups, this should be a priority moving forward for the future of coral science.

Expectations for professional scientists are changing. Dwindling funding opportunities coupled with increasingly available technologies are putting greater demands on the skill sets that scientists must have in order to succeed as working professionals. Graduate programs must therefore adapt to these growing demands and properly equip their graduate students with a more holistic set of tools to ensure their success beyond graduation. Coral scientists are finding
that their collaboration teams need to include more than just other researchers in the physical sciences. Economists, policy-makers, and various stakeholders are taking an interest in research being conducted on coral reefs, yet scientists are often not trained to operate in such eclectic working groups. Training for this evolving scientific environment should come in the form of collaboration through internships and opportunities within nongovernmental organizations, industry, and even on the scientific advisory staff of political candidates. Important personnel from these organizations should be regularly invited to give talks to graduate students at their local seminars, creating avenues for job opportunities outside of academia.

Much of the training of graduate students is laid at the feet of their respective mentors, who are expected to teach the budding scientists everything they need to know about life as a successful researcher. Even some of the best mentors will admit that taking on a graduate student is a “labor of love.” This monumental task of training a graduate student must be shouldered with the high demands placed on career scientists in this modern “publish or perish” professional climate. This is an unrealistic expectation that creates inefficiencies in a scientific discipline that demands efficiency to thrive in the current political and environmental climate. While workshops are offered to both graduate students and faculty members alike to improve skills in grant proposal writing, laboratory management, and classroom teaching, further attention needs to be paid toward proper training in mentoring. Many corporate structures in the business world have already instituted management classes to maximize efficiency at a variety of management levels. Coral science working groups, academic institutions, and funding bodies must recognize the merits of investing into the professional development of their science staff and graduates moving into the future.

The next generation of coral reef scientists stands on the precipice of the unknown. Coral reefs are in an unprecedented state of decline, and if the current generation of coral scientists wishes to pass the proverbial torch of knowledge that will illuminate such an uncertain state, then they must prepare future generations for inevitable change. Encouraging coral scientists to embrace their place as role models will help garner excitement and action from the general public. Improving the state of diversity, inclusion, and equity in coral reef science will heighten both the quality and reach of coral research. Finally, providing the next generation of coral scientists with a holistic set of tools will prepare them for the rapidly changing field of professional science. If coral scientists in the coming century prove to be as adaptable as coral reefs to the coming challenges, then hope for their future is indeed well warranted.

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AN OFTEN OVERLOOKED ELEMENT OF DIVERSITY
Disability

Caroline Solomon

Dear ASLO community,

Since I last spoke to you as the recipient of the Ramon Margalef Award for Excellence in Education in 2017, COVID-19 and the Black Lives Matter (BLM) movement have vastly reshaped my thinking regarding equity, diversity, and inclusion (EDI) and tested my resilience as a deaf aquatic scientist.

The BLM movement has spotlighted many issues with systematic racism and the underlying principles that unify marginalized communities especially in regards to stereotyping and exclusion from the system. People with disabilities are often one marginalized group that is overlooked.

If you consider the historical framework, the Civil Rights Act was passed in 1964, and 30 years later in 1990 the American with Disabilities Act (ADA) was passed. Some may say that the disability movement is 30 years behind the civil rights movement, but many do not realize how much the disability movement relies on many elements of the civil rights movement.

Gallaudet students marched to the U.S. Capitol in 1988 with a sign “We still have a dream” and this march was one of the impetus that led to the passage of the ADA (Fig. 1).

In the past, I tried to put positive spins on my talks, including the one I did in 2017 and earlier in 2006 about breaking communication barriers, to encourage peers to not see us as a burden but an equal partner in doing science. While this is all still true, I have become bolder about sharing what I see is the inequality in the system.

The anti-racism framework that scholars such as Ibram X. Kendi advocate for involve uncomfortable conversations and recognizing the work that the majority needs to do for the minority. During my career as a deaf scientist, I have dealt with the fear and discomfort to approach the topic of disability, not recognizing the work and pain we deal with every day as people with disabilities, and the burden on us to educate.

The fear to have uncomfortable conversations is real. At the countless ASLO/AGU meetings I have attended, I have lost track of the times that I stand alone with the interpreters and no one approaches me to talk about science (sometimes it is to talk about how cool signing oceanography terms might be); the burden is always on me to approach you. I am thankful for my friends from graduate school who know me well and treat me as an equal, but those who have not had the experience of working with me approach me much less.

The invisible work truly stays unseen and not recognized. My preparation for talks is twice that of my peers as I spend a significant amount of time preparing transcripts and practicing talks with the interpreters to ensure that my materials are conveyed correctly. The searching, planning, and arranging for qualified interpreters and captioners takes time that could be used toward research.

Microaggressions, intended or not intended, happen every day. People dim lights during presentations, forgetting that I no longer can see the interpreters. The interpreters and I have been asked to move several times so that we are not in the way of others, not recognizing that we have fought hard to obtain access. While interpreters and captioning are extremely helpful in understanding the content that is being delivered, subtle nuances are lost so sometimes our comments seem a bit out of context and get stares or puzzlement. Often there is a delay in interpretation so we often cannot jump into a free-flowing conversation and seem disruptive when we try to contribute to the conversation. Recently, a nonprofit organization refused to use auto captions for a webinar because of the worry that the captions would not be accurate and be offensive to the larger population and offered to caption it afterward and to have a person summarize the panel. The option was only offered to me when they should have found a way to provide universal access for all and denied me the opportunity to ask questions like everyone else in real time.

I cannot help increase the number of deaf and hard-of-hearing scientists alone; the more people that become deaf-aware mentors will vastly increase opportunities for prospective deaf and hard-of-hearing scientists (Braun et al. 2017, 2018; Lynn et al. 2020). When I entered the field of oceanography, I was not aware of any other deaf or hard-of-hearing scientists until a few years later. My doctoral advisor, Dr. Patricia Gilbert, and undergraduate advisor, the late Dr. James McCarthy, believed in me and encouraged my love for oceanography and to continue research and teaching. While they never had a deaf student before, it did not let it stop them from being wonderful deaf-aware mentors. Many of you in ASLO can do the same.

There have been some silver linings in the last few months. Virtual meetings have provided more accessibility by having captioning and/or interpreters visible near people and presentations, reducing visual dispersion. I can see conversations in real time in chat boxes. Everyone is limited by the delivery platforms from impromptu conversations that occur in the hallway at conferences which actually equalizes opportunities. Prerecorded lectures can be provided with captions if the speaker uses the autocaptioning and editing features provided by YouTube and other software. Speech-to-text

FIG. 1. Gallaudet students marching to the U.S. Capitol in 1988 with the “We still have a dream” banner used during the civil right protests. Photo courtesy of Gallaudet University Library Deaf Collections and Archives.
recognition software (e.g., GoogleTranscribe and Otter.ai) has exploded in use, improving the algorithms leading to more efficiency and accuracy. Instead of worrying about whether the local and unfamiliar interpreters will be able to handle scientific jargon, a group of interpreters well versed in the discipline can be hired from anywhere in the country, vastly improving the quality of interpreting I get at the conference. In the post-COVID-19 world, I hope that there will be a mixture of both virtual and in-person conferences.

ASLO has been a leader for providing access for years; I have never been denied a request for interpreters when I want to attend a meeting. My work with deaf and hard-of-hearing students in marine science has been recognized and supported through various ASLO programs. I have been very fortunate as a member of ASLO as the major complaint among my deaf and hard-of-hearing colleagues is accessibility at conferences around the country. I currently sit on an advisory board for a Bridges to the Doctorate program for deaf and hard-of-hearing scientists. The advisory board members recognize that the largest obstacle is accessibility and lack of networking opportunities at regional, national, and international conferences. ASLO as a professional society must make their leadership more visible and share their experiences with other professional societies.

ASLO, both as a professional society and among individual members, have made strides but yet much is left to be done to ensure an equitable, inclusive, and diverse community of limnologists and oceanographers.

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I had just started my Ph.D. when I got the offer for a position as an Ecology Instructor at a nearby university. They wanted me to teach an Ecology course! This wasn’t really part of my plan. I was supposed to focus on my research for several more years so that one day in the distant future I could teach my very own course. But here was my chance right now, and I accepted immediately without hesitation or any real rational thought.

Two months later, I was one week away from the first day of my teaching gig. Although I had spent days neglecting my Ph.D. and carving out the lesson plans for my course, I now found myself consumed with thoughts of how to look and act like a Professor. What is a Professor supposed to look and act like anyway? Whatever the answer, it seemed very different from who I was: a first-generation Bengali woman who just started her graduate studies, standing at an undaunting 5’2”. My mind in a frenzy, I spent the next few days buying overpriced professional clothes, aimed at making me look older and more professorial. I was now out $500.

On my first day of class, I tried to maintain a scripted, professional appearance. I spoke in a lower pitched voice, remained sedate, and presented my slides exactly as I had rehearsed. To my surprise, the students seemed to accept me as their teacher with no real suspicion. Unfortunately, none of that really seemed to matter by the end of the class. Coming into my lecture on primary productivity, I was worried about being met with lack of enthusiasm or interest in my course. I was worried about being met with lack of enthusiasm or interest in my course. When I had missed classes or generally knew from my own turbulent undergraduate experience that sometimes life can get in the way. When I had missed classes or generally underperformed in school, it was not due to a lack of enthusiasm or interest in my field. Rather I was overwhelmed with life’s other stressors. In these times, negative reinforcement only exacerbated my stress, amplified my guilt and further reduced my productivity. From these experiences, I learned that teachers should only ever be creating a positive incentive to learn. In the end, my student received a B as his final grade, and to his credit, did make it to a handful of my classes.

My goal of fitting the mold of a “Professor” shifted to the back of my mind, and I was now set on getting my students excited about our next lecture topic on secondary productivity. Walking into the next class, I lectured as myself: higher-pitched, excitable, and floating through slides unrehearsed. Although learning about secondary productivity is objectively no more exciting than primary productivity, I could tell that something magical was happening. The faces staring back at me were slightly less bored.

In the coming days, I stopped trying to blend into the monolith of Professors I saw around me, and instead started integrating my own philosophy and personality into my teaching style. This was a much more natural process that drew on my past experience and sense of identity. Mainly, I wanted to cultivate an atmosphere where students weren’t limited by the student–teacher power dynamics that I had disliked so much growing up. In one interaction, a student asked me after class. “Why is there always more biodiversity near the equator?” To be honest, I didn’t entirely know and hypothesized that it was because it received more solar energy leading to more primary production and species richness. I followed this by stating, “I’m just theorizing. Feel free to research it and tell me I’m wrong.” The next class, she let me know that there were several competing hypotheses, just one of which was the one I mentioned. I realized then that welcoming students to challenge me encouraged them to think more critically about the topics that interested them, which often went beyond the scope of our course material.

Here is another example of how my past influenced my teaching style. There was one student who showed a great amount of enthusiasm in the first two weeks of class, stating that it was his favorite class of the semester. However, he mostly stopped showing up soon after. I decided not to create any negative reinforcement for him, or any other student who missed my classes. Instead, I made lecture notes available online and welcomed them when they did show up. I knew from my own turbulent undergraduate experience that sometimes life can get in the way. When I had missed classes or generally underperformed in school, it was not due to a lack of enthusiasm or interest in my field. Rather I was overwhelmed with life’s other stressors. In these times, negative reinforcement only exacerbated my stress, amplified my guilt and further reduced my productivity. From these experiences, I learned that teachers should only ever be creating a positive incentive to learn. In the end, my student received a B as his final grade, and to his credit, did make it to a handful of my classes.

As a woman of color, I was distinctly aware of the need to create inclusive teaching environments for my students. I felt an additional sense of pride in being an Instructor since it allowed many of my female and people of color students to see themselves reflected in a leadership position. Although this was never explicitly stated, I knew there was an added relevance to my interactions with these students. To ensure that all of my students saw themselves reflected in the science that was being taught, I also invited other diverse scientists as guest lecturers, and introduced different scientific perspectives through my lectures. There was an awesome Asian-Canadian herpetologist who taught us about turtles. I spent another lecture delving into Indigenous-led conservation initiatives. These strategies paid off, with students noting that the classroom environment was “non-hostile,” “safe,” and “conducive for learning.”

My classroom evolved into a fun environment where lectures were interactive, students stopped me to ask questions mid-lecture, sometimes challenged my teachings, and even recommended future lecture topics. For example, they wanted to learn more about arctic ecosystems! Improved student–teacher connectedness meant that I loved going into my own class and being part of this creative energy of teaching and learning about ecology, ecosystems, and society. Oh, and the students seemed to be enjoying themselves as well.

When I finished teaching my course, and reflected on my experience and student evaluations, I realized one main thing: although the majority of current Professors have a similar look and teaching style—the kind that I don’t fit nicely into—this is not necessarily the ideal. Instead, embracing our own unique identities may be well received by our students and make for an effective learning environment. Indeed, having diversity in faculty members will expose students to a variety of intellectual thought, teaching style and personal experience which together offer a breath of ideas that constitute a dynamic intellectual community.

For me, embracing my own identity meant presenting spontaneous and interactive lectures, fostering a learning environment where students were encouraged to critically think and challenge ideas, being compassionate in student interactions, and employing inclusive teaching strategies. Students showed appreciation for this teaching approach in their course evaluation, noting my “very dynamic way of teaching” and “enthusiasm, something that is severely lacking in many of the professors [here].” While this teaching style is friendlier and perhaps viewed as “soft,” it did not lead to less rigorous learning outcomes. As one student noted, “She doesn’t act like she’s above all of her students, in that she encourages you to challenge ideas and ask questions. She is a bit of a tough marker though.” Hey, I’ll take it!

**Suchinta Arif, Department of Biology, Dalhousie University, Halifax, Nova Scotia, Canada; suchinta.arif@gmail.com**
CREATING MORE INCLUSIVE WATERS IN THE AQUATIC SCIENCES

Keiko W. Wilkins and Angelique Rosa Marín

In 2018, 1.4% of the U.S. population earned a Ph.D. (US Census Bureau). When we look at the number of Ph.D.s across all fields held by Black, Indigenous, and People of Color (BIPOC), we see that the percentages are very low. In 2018, 35,404 total doctorate degrees were awarded in the United States to U.S. citizens and permanent residents (NSF, see https://nces.nsf.gov/pubs/nsf20301/data-tables). Of those, only 0.3% were awarded to American Indian or Alaska Native students, 6.9% were awarded to Black or African American students, 7.3% awarded to Hispanic or Latino students, and 9.3% awarded to Asian students (NSF). When looking at STEM degrees, specifically, we see that similar trends are seen with BIPOC students representing far fewer Ph.D.s than White students (Fig. 1). It cannot be argued that much progress needs to be made to ensure that BIPOC students reach completion of their degrees. One way to encourage this process is to create more inclusive and welcoming fields.

As BIPOC early career researchers, we have taken it upon ourselves to try to make progress towards these efforts by helping graduate students interested in being involved in international research collaborations feel supported. Through our leadership involvement within ASLO’s Limnology and Oceanography Research Exchange (LOREX) program, we have identified a necessity to provide resources, support, guidance, and share our experiences with other BIPOC participants and allies in the program. As BIPOC, we often face anxiety about how we will be treated based on our racial identity when traveling to new places. We often ask ourselves questions about how smoothly the interaction will go or if we will be welcomed (Fig. 2). These thoughts may seem surprising, but they are the reality BIPOC individuals face when considering traveling. This anxiety alone prevents many people from participating in the same ways that their White counterparts actively engage.

To minimize the shock and prepare future LOREX cohorts and other students in their international research experience with a written guide, we helped create the ASLO Handbook for International Collaboration Advice (https://www.aslo.org/resources/international-collaboration-advice/). We hope that this living handbook will continue to be updated, especially the cultural considerations chapter, where we discuss how to create a mutual understanding between cultures. Additionally, the Handbook has a chapter where LOREX Fellows share their experiences abroad. In the chapter, you can also find the perspectives of BIPOC LOREX Fellows sharing their time abroad. Lastly, LOREX students and others are working on establishing an anti-racist handbook for the aquatic sciences.

For far too long, BIPOC individuals and their contributions have been silenced. In response to the increased international awareness of racial injustice and oppression in the US, many people have stepped up to try to help amplify their Black and People of Color colleagues in the aquatic sciences. Although well intentioned, statements of support without action will not result in change. We hope that compiling a list of resources and specific actions in an anti-racist handbook will allow people to move past the “thoughts and prayers” statements to direct actions to make a more just, equitable, diverse, and inclusive field.

It is often acknowledged that there is a lack of diversity and racial acceptance in the aquatic sciences. Through an increase in diversity, it has been shown that everyone benefits. Furthermore, many organizations have made strides toward addressing the lack of diversity within their organizations this year. We are far from achieving our goals of removing barriers for BIPOC scientists. Although the issue at hand may seem discouraging at times, there is much hope that we can, and we will continue to make positive changes. We challenge our fellow aquatic scientists to ask themselves, their labs, their academic departments and their professional societies what they are actively doing to be anti-racist and ensure a more diverse and equitable future.

Keiko W. Wilkins, Kewalo Marine Laboratory, University of Hawai‘i at Manoa, Honolulu, HI, USA

Angelique Rosa Marín, School of the Environment, Florida Agricultural and Mechanical University, Tallahassee, FL, USA

FIG. 1. Percentage of U.S. citizens and permanent residents who received Ph.D.s in STEM in 2018. Data taken from NSF Survey of Earned Doctorates (https://ncses.nsf.gov/pubs/nsf20301/data-tables).

FIG. 2. There are many questions that we as BIPOC ask ourselves when planning to travel abroad. We have to consider and be prepared for anything to happen.

All fields  Engineering  Physical and earth sciences  Life Sciences  Mathematics and computer sciences

1.0 0.8 0.6 0.4 0.2 0.0 0.0 0.2 0.4 0.6 0.8 1.0

American Indian or Alaska Native  Black or African American  Hispanic or Latino  Asian  White

0 10 20 30 40 50 60 70 80

Percentage (%)
MESSAGE FROM THE PRESIDENT

What Has COVID-19 Taught Us about Science?

Roxane Maranger 📜

I am writing this message on 14 December 2020. What a difficult year it has been. As of today, over 1.6 million people have died of COVID-19 as a function of the spread of SARS-CoV-2 in this global pandemic. On behalf of ASLO, I wish to extend my sincerest condolences to all members of the aquatic community who have lost family members or to those who have been seriously adversely affected by this terrible infectious disease. It is a very dark time. We have all been affected to some degree, but to quote Greta Thunberg on climate change: “We are all in the same storm. But we are not all in the same boat.” This speaks to the inequities of how different demographics have been affected and challenged during this time. Many people have lost their jobs; it has been a struggle for many business sectors; divorce rates are high; front line workers in the health and essential service sectors are exhausted and continue to take risks. In academia, people of color and women with young children and older parents have been most adversely affected in terms of the ability to keep up with professional demands, and graduate students are suffering with high rates of depression (Gabster et al. 2020; Malish et al. 2020; Zahneis and June 2020). This is not an exhaustive list of the many challenges faced. New cases are spiking all over the world, and we are headed in lockdown for the Christmas holidays. We can all conclude that 2020 has been a difficult year.

There is however hope on the horizon for 2021 and that hope is thanks to a global effort in scientific discovery and rapid communication. This includes the processes designed and the people involved to set up accelerated discovery in order to work together to find ways to combat COVID-19 for the benefit of the commons. So the purpose of this Bulletin article is to reflect on some of the more positive outcomes from this major global crisis. These thoughts come off the heels of a rather inspiring workshop I had the privilege to attend as part of the Council of Society Scientific Presidents (CSSP) a week or so ago, as well as the exchanges I have been able to have with my microbiologist life partner who works in drug development research. As such, these are more personal reflections on what mechanisms helped enable our accelerated understanding of COVID-19 leading to solution pathways, with the additional thought of what can ASLO as a community of aquatic scientists learn and possibly enable to address the multiple pressing issues facing our precious water resources.

From a drug discovery perspective, there was an unprecedented effort to mobilize and open the science needed to develop several vaccines in record time. SARS-CoV-2 was first sequenced in January 2020, and the first vaccine against COVID-19 developed by Pfizer-BioNTech was approved last week. As I write this message, the first vaccines are being administered to health professionals here in Canada as well as in other countries with appropriate storage facilities. Britain was the first to begin the process of administering the vaccine a week earlier. There are two more vaccines that should be approved shortly that will facilitate broader distribution as they do not have the same refrigeration constraints (Moderna’s is stored at −20°C whereas Oxford-AstraZeneca’s can be refrigerated) and can be manufactured at lower cost, but supposedly perform with the same high degree of efficacy. The process of approval was fast tracked, but remains rigorous in that approval must achieve certain targets. There are mechanisms in place to ensure scientific rigor and a robust regulatory review during the rolling submission process as additional information on safety, efficacy, and quality accrues. Three vaccines approved within a year of disease discovery surpassed the most optimistic targets.

How did this happen? Science and business are largely competitive endeavors. However, to solve wicked problems, rapidly, we all know that this requires collaboration. Now for competition to bring out the best in all of us, some level of collaboration and shared knowledge is required. Enter the term coopetition: a strategic alliance that fosters cooperation among competitors (Bengtsson and Kock 2000). The stakes were too high and the collective purpose was clear: we are in a global health crisis. To resolve it requires the rapid development and administration of vaccines to billions of people. As such, a strategic approach that involved a public-private partnership called ACTIV (Accelerating COVID-19 Therapeutic Interventions and Vaccines) spearheaded by the U.S. National Institutes of Health (NIH) to bring all the strengths together from the different sectors to help in this time of urgency was formed (Corey et al. 2020). This involved major investments to several different pharmaceutical companies to facilitate the development of, or the clinical trial of, or the buying of approved vaccines while getting the community to work together by sharing essential information was key. It also involved getting them to work on multiple solution pathways for broader global administration. To accelerate vaccine discovery, this involved information sharing and harmonizing protocols, which included a common data and safety monitoring board, common primary and secondary targets, and common parameters to use as correlates of immunity. This enabled the “COVID-19 pivot” and a concerted effort in discovery where researchers from around the world were able to adapt their fundamental research to help in the search for an effective vaccine.

The COVID-19 pivot also resulted in a huge amount of discovery about the epidemiology of the disease, how quickly the virus has spread, the main transmission pathways, and its origins and ecology. In fact there was such an onslaught of scientific information; this has pushed the frontiers of Artificial Intelligence to sift through a large amount of information permitting for more rapid synthesis (Brainard 2020). Used diligently and ethically, this will become such an asset to all future discovery as machines will be able to process more information much faster than humans. Increasing access to supercomputing also became a necessary asset on the road to accelerated discovery. During the pandemic, Dario Gil, Scientific Director of IBM, codeveloped and codesigned the COVID-19 High Performance Computing Consortium to help facilitate research to combat the pandemic. The consortium of 43 member institutions is a unique private-public effort spearheaded by the White House Office of Science and Technology Policy, the U.S. Department of Energy, and IBM to bring together federal government, industry, and academic leaders who are volunteering free computer time and resources on their world-class machines. As of today, this initiative has supported 95 different projects that must adhere to open science principles at 6.8 million CPU cores, again accelerating discovery on multiple frontiers.

My “coup de coeur” initiatives (“coup de coeur” is tough to translate—closest to my heart perhaps), however, are more grassroots
but again embedded in the practice of working open. Both scientific initiatives were recognized and awarded by the CSSP for their vision in further accelerating discovery through the development of platforms and models for disseminating valuable information in meaningful ways in the face of this pandemic. One was the interactive dashboard that tracked COVID-19 cases around the world initiated by Lauren Gardner, codirector of the Center for Systems Science and Engineering at Johns Hopkins University. Out of that open data and information initiative, the data were used in over 2000 other publications! Open access enabled the creative use of that data from users around the world, more so than the original creators could have ever imagined. The data visualizations were powerful and understandable to the non-scientist; I tracked it daily for months and smiled when my musician brother from Germany shared it with my family. A second was the team from the University of Washington’s Institute for Health Metrics and Evaluation (IHME) that established and continued to develop models to forecast COVID-19 outcomes for public health. This initiative developed as a response to requests from the UW’s School of Medicine et al working to determine when COVID-19 would overwhelm the ability of their hospital systems to care for patients. The forecasts developed by IHME show demand for hospital services, daily and cumulative deaths due to COVID-19, rates of infection and testing, and the impact of social distancing, organized by country and state, with additional forecasts projected from countries around the globe. A handful of people started the initiative but this has now grown into a collective of over 500 people involved! Their models are in constant development and trying to integrate the best available knowledge, now including the use of vaccines to help better understand outcomes.

In his recent article in the Atlantic entitled “How Science Beat the Virus and what it lost in the process,” Ed Yong (2020), an award-winning science writer, presents a more balanced picture of the good and the bad. He states: “At its best, science is a self-correcting march toward greater knowledge for the betterment of humanity. At its worst, it is a self-interested pursuit of greater prestige at the cost of truth and rigor. The pandemic brought both aspects to the fore. Humanity will benefit from the products of the COVID-19 pivot. Science itself will too, if it learns from the experience.” Although there were scientific opportunists playing the game, a great amount of useful knowledge and share information openly to accelerate discovery; this must become common practice and we need more resources and incentives to do so. Third, money. There is no doubt that financial resources matter which is why these public and private partnerships were so fruitful. But it was the combination of large and small injections of money combined with open practices that tipped the balance. Great science can come from anywhere, anywhere. So both large and small initiatives should be supported and open practices favor this. Finally, effective scientific communication and political will. This was patchy of course and we need the vision to ramp up quickly and share valuable information, a much greater proportion of the population perished. We need to also consider the number of people whose lives were saved as a function of this.

The world is still on hold as the vaccination process slowly begins. We must remain patient and diligent despite the COVID-19 fatigue in all of us. That said, this is a defining moment for society and a defining moment for science. Perhaps it is our opportunity to rebuild public trust in science and work together in new ways to accelerate finding applicable solutions to the world’s most wicked environmental problems. I invite you as ASLO members to imagine ways scientific societies can help to enable processes for accelerated scientific discovery to address pressing issues and to please share them with me.

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MESSAGE FROM THE EXECUTIVE DIRECTOR

Interview with Eilea Knotts, ASLO Spring/Fall 2020 Science Communication Intern

Teresa Curto

In April 2015, ASLO launched a new science communication internship (http://aslo.org/news/2015-aslo-science-communication-internship/). This initiative was led by ASLO Director of Communications and Science, Adrienne Sponberg. The selected interns work with Adrienne on a variety of communication, social media, policy, education, and public outreach projects designed to provide direct experience in how science is communicated to a variety of audiences.

Eilea Knotts was selected as the Spring/Fall 2020 ASLO Science Communication Intern. Eilea worked with Adrienne last year and is continuing to assist with the LOREX grant as well. I sat down with Eilea to talk about her experience.

ED: WELCOME, EILEA. TELL US ABOUT YOUR BACKGROUND AND WHAT PROMPTED YOU TO APPLY FOR THE INTERNSHIP?

EK: I graduated from the University of South Carolina in December 2019. During my time in graduate school, I gained international collaboration experience through the Limnology and Oceanography Research Exchange (LOREX) program, educated both my scientific community and the public, and used what I learned to communicate that information both on social media and journal publications. My heavy involvement in societal and departmental communications inspired me to apply for the ASLO Science Communication Internship. I wanted to gain insights into the management of science organizations by assisting with the LOREX program as well as develop pathways that engage the scientific community to utilize communication tools.

ED: WHAT HAVE YOU LEARNED ABOUT ASLO DURING YOUR INTERNSHIP? IS THERE ANYTHING THAT SURPRISED YOU?

EK: Most of my experience with societal organizations came from my regional society, the Southeastern Estuarine Research Society (SEERS). I was a student representative for SEERS and got to learn some of the behind-the-scenes management. Working for ASLO showed me that, as a society increases in size to include national and international members, management of multiple programs, business operations, and advertising (both internally to members and externally to the public) it takes a huge amount of effort that needs to be divided amongst an entire team. I knew that running social media was an entire job in itself when I ran that form of communication for my department. I was surprised to find that ASLO’s Communications team was so small to handle the amount of work that came through the office.

ED: WHAT WERE SOME OF THE PROJECTS YOU HAVE BEEN WORKING ON DURING YOUR INTERNSHIP? HOW HAVE THOSE IMPACTED YOUR OWN PROFESSIONAL DEVELOPMENT?

EK: The main projects that my internship revolved around included the LOREX program, general ASLO social media coverage, helping to create the Career Corner Virtual Issue, running the 2nd ASLO photo contest, and developing the Dissertation Registry. I think the greatest project that I had the pleasure of working on was LOREX’s formal mentoring program. This mentoring initiative facilitates communication between the students and their hosts, enhances the participants’ ability to network, and increases opportunities for peer-to-peer mentoring between cohorts. This project was my first opportunity to develop my own proposal, vet a variety of software companies, and manage the software’s platform. I have learned that I love it!

ED: BEFORE YOUR INTERNSHIP, YOU WERE A PARTICIPANT IN THE LIMNOLOGY & OCEANOGRAPHY RESEARCH EXCHANGE (LOREX) PROGRAM. TELL US ABOUT THAT EXPERIENCE.

EK: I was a member of the first LOREX cohort in 2019. I had the opportunity to go to Dalhousie University in Halifax, Nova Scotia, Canada and work with Dr. Zoe Finkel. It was an incredible experience, and I became very close to several postdocs in the lab I worked in as well as my fellow Canada LOREX cohort that traveled with me. Although my six-week fellowship ended, I continued to remain active with the LOREX community. I attended the 2020 OSM Conference in San Diego where I was given the opportunity to pass on my knowledge to the 2nd LOREX cohort. My intention is to remain connected with this program and its members. The network I have developed here has been incredible!

ED: THE IN-PERSON COMPONENT OF YOUR INTERNSHIP WAS SADLY CUT SHORT DUE TO COVID. HOW DID THAT IMPACT YOUR EXPERIENCE?

EK: COVID definitely changed my experience but not in an undesirable way. My internship’s path was just altered. There were plans to network and attend professional development workshops in the DC area. I thought I would have more time to see the inner workings of ASLO and touch into the policy realm. While policy projects were not likely once the country shut down, I am thankful to have the opportunity to focus on the education and outreach side of the internship. In all honesty, education and outreach have been my passions and now I have obtained more skills and experience to address that realm of communication.

ED: EILEA, YOUR WORK WITH ASLO HAS BEEN VITAL TO THE ASLO COMMUNICATIONS AND SCIENCE OFFICE. WOULD YOU RECOMMEND THIS EXPERIENCE TO YOUR PEERS?

EK: Of course, I would recommend this experience! Working with Dr. Adrienne Sponberg has been the highlight of my internship. Her dedication and hard work to scientific communication has been awe-inspiring. I am grateful to have her as a mentor in my life. Her constant encouragement and guidance truly made my internship one of the greatest experiences of my career. This internship allowed me to grow both personally and professionally. Thank you for this amazing opportunity.

ED: THANK YOU, EILEA.
OUTSTANDING L&O ASSOCIATE EDITORS AND REVIEWERS

K. David Hambright, Editor-in-Chief

Reviewing for L&O during the past year took on a completely new meaning, as did almost every task we faced. In addition to the many challenges presented by the COVID-19 pandemic, we received a record number of manuscripts that required us to ask even more from our selfless editorial board and dedicated pool of reviewers. Although there are so many people to thank, I hope that by highlighting these few members of our editorial collective, all reviewers and members of our editorial board know that they are highly valued and respected by the ASLO membership, and the aquatic science community as a whole, because of their unyielding service in holding our authors to the highest of expectations that have made L&O the journal it is. The Associate Editors and reviewers listed below have provided, in total, more than 100 reviews and recommendations for the journal. As Editor-in-Chief, I thank these generous editors, reviewers, and everyone they represent who pitched in to help keep L&O running during what was a remarkably difficult year.

ASSOCIATE EDITORS

ILANA BERMAN FRANK
Director of the Leon H. Charney School of Marine Sciences, and Professor, Department of Marine Biology, University of Haifa-Israel.

“My research focuses on the effects of environmental changes on coastal benthic organisms from the micro-scale to the community scale. I work on a variety of ecosystems from tropical coral reefs to the Mediterranean Sea to the Arctic. I have had the honour to serve as AE for L&O for the past two years and I am enjoying this difficult task. I find it very rewarding to work with dedicated reviewers and to help our community to have access to high quality studies.”

HANS PETER GROSSART
Head, Aquatic Microbial Ecology Group (MIBI), Domain Speaker; Department of Experimental Limnology, Leibniz Institute for Freshwater Ecology and Inland Fisheries (IGB), Berlin, Germany.

“My research focuses on understanding the eco-evolutionary dynamics of marine plankton and the resulting impacts on marine biogeochemistry in a changing climate. Serving as an AE is an honor and a concrete way to contribute to the community. I’ve been so impressed and inspired by the time and

STEEVE COMEAU
Research Scientist, Sorbonne Université – CNRS, Laboratoire d’Océanographie de Villefranche sur Mer, Villefranche sur Mer, France.

“I am a microbial ecologist in both freshwater and marine ecosystems and my group is trying to understand ecological processes from the gene level to the community, ecosystem, and finally global scale. Linking molecular approaches including genome, metagenome and transcriptome analyses with classical microbiology and modern biochemical tools, we try to better understand the responses of aquatic microorganisms to a changing environment (including urbanization) and the related biogeochemical consequences, e.g. in terms of greenhouse gas emissions from aquatic systems to the atmosphere and their feedbacks to global climate. It is a great honor to be an AE and a board member for ASLO, which I consider one of the most important international societies in aquatic sciences. ASLO and its premier journal L&O has greatly influenced and shaped my scientific carrier. To serve as an AE for L&O is an exciting opportunity for me to give a bit back from what I have received from ASLO. It is a privilege to receive the newest and forefront submissions in aquatic science and be able to steer them in a way that achieves the high scientific standards of the journal. If possible, I always try to improve the quality of manuscripts by providing guidance to the authors and stimulate them to reach the highest possible scientific standards, which should keep L&O in the front position of aquatic sciences.”

TATIANA RYNEASON
Professor, Graduate School of Oceanography, University of Rhode Island, Bay Campus, Narragansett, RI.

“This year has greatly influenced and shaped my scientific career. To serve as an AE for L&O is an exciting opportunity for me to give a bit back from what I have received from ASLO. It is a privilege to receive the newest and forefront submissions in aquatic science and be able to steer them in a way that achieves the high scientific standards of the journal. If possible, I always try to improve the quality of manuscripts by providing guidance to the authors and stimulate them to reach the highest possible scientific standards, which should keep L&O in the front position of aquatic sciences.”
energy reviewers consistently dedicate to reviewing L&O manuscripts.”

REVIEWERS

KAY DAVIS
PhD Scholar, National Marine Science Centre, Southern Cross University, Coffs Harbour NSW, Australia.

“I am a marine researcher focusing on the interactions between water chemistry and biology to determine ecosystem-scale health. My main interest lies in climate-driven influences on coral reef ecosystem metabolism. These types of studies can provide information about how reefs are affected by environmental disturbances and, therefore, how we can protect them. I review papers for L&O to share my expertise and ensure the value of scientific rigor while giving back to the scientific community.”

SILVIA NEWELL
Associate Professor of Aquatic Biogeochemistry at Wright State University in Dayton, OH.

“My lab mostly works on nitrogen cycling interactions with harmful algal blooms around the world. I review for L&O because I am committed to helping new science make it into the literature, particularly student research.”

ROBERT SCHWEFEL
Postdoc, Department of Chemical Analytics and Biogeochemistry, Leibniz Institute for Freshwater Ecology and Inland Fisheries (IGB), Berlin, Germany.

“I am a physical limnologist especially interested in the impact of physical processes on the biology and biogeochemistry of waterbodies. Currently, I work at IGB Berlin on a project about the impact of climate change on physical properties on lakes. Why do I review in L&O? Reviews are a great opportunity to engage with the research of others. Since L&O published many outstanding studies in my field, I enjoy supporting the authors and editors during the review process.”

REZA VALIPOUR
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“My expertise is in physical processes in lakes and coastal waters, and their impacts on nutrient dynamics to support ecosystem management strategies. I proudly review for L&O to contribute to the collection of outstanding L&O papers, which I always find most relevant for my ongoing research.”

K. David Hambright, Editor-in-Chief, Limnology and Oceanography, Plankton Ecology and Limnology Lab, Geographical Ecology Group, Program in Ecology and Evolutionary Biology, Department of Biology, University of Oklahoma, Norman, OK, USA; dhambright@ou.edu
MESSAGE FROM THE BUSINESS OFFICE

Helen Schneider Lemay

It's been a very different and challenging year for everyone and I hope that you and your family are safe and well. As we face these challenges, it’s also been a year to reconnect with family and friends virtually. These virtual encounters allow more interactions with people whom we might not get to see in person. ASLO will have our first virtual meeting this June. It will be our “ASLO only” Aquatic Sciences Meeting (ASM), normally held in the winter. We moved it to June, hoping that we could meet in person in Palma de Mallorca, Spain, but the risks are still too great. We will, however, return to Palma in the very near future. Otherwise, the 2021 ASM will remain with great plenary speakers and presentations. The deadline for abstract submission is 12 March. The meeting will also have some fun activities and opportunities to network and interact with other attendees.

We all continue to be challenged with working with our students and organizations, as well as making sure we are a diverse and inclusive society. I recently attended a workshop that showcased The Next Generation of Leaders in Science (Furiosi, W., Scalf, B., Santra, L., Patel, K., & Thompson, G. (2020 December 5-8). Looking to the next generation of leaders in science [Workshop presentation]. CSSP 2020 Winter Leadership Workshop, Washington, DC, United States. https://www.sciencepresidents.org/2020-winter-leadership-workshop). Three high school students from Oviedo High School, Florida and one sophomore from the University of South Florida presented their science fair projects. Not only were the projects outstanding in the topics and science they presented, but their ability to communicate and be challenged with questions was outstanding. Our high schools need encouragement and resources to prepare future scientists.

Please continue to support ASLO and be sure to renew your membership.

Helen Schneider Lemay, ASLO Business Manager, ASLO Business Office; business@aslo.org
L. R. POMEROY (1925–2020)
E Conchis Omnia

Amie Michelle Wood

Nor did I know before… a sea breathes in and out upon a shore.

From “Until I Saw the Sea” by Lilian Moore

When Lilian Moore wrote these words, she was no doubt thinking of the tides. However, if she had ever met Larry Pomeroy, worked alongside him on a cruise, or sat with him on a boardwalk listening to the pop and snap of a salt marsh at low tide, she would know that the breath of the sea is the respiration of small things, lost to the naked eye, but capable of capturing the imagination and guiding a scientific life of extraordinary focus, impact, and generosity.

When Lawrence Pomeroy died on 26 March 2020, aquatic sciences lost one of its most respected intellectuals (Fig. 1). Pomeroy was a former President of ASLO. He received the A. G. Huntsman Award for Excellence in Marine Science from the Royal Society of Canada and Bedford Institute of Oceanography, the G. Evelyn Hutchinson medal for research from ASLO, and the Odum Lifetime Achievement Award from the Estuarine Research Foundation. Widely known for his foundational role in establishing the Microbial Loop as a central concept in oceanography, his legacy is much broader and reflects decades of research on mineral cycling, coastal ocean processes, and holistic system-level thinking applied to a wide range of ecosystems from the tropics to the poles.

Larry was born on 02 June 1925, in Sayre, Pennsylvania. He spent his early years in Watkins Glen, New York, where his father was an engineer and his family kept a seasonal general store. Larry helped dish out ice cream and developed appreciation for both geology and biology, but had an apparently lifelong aversion to “tourist traps” (unless they sold ice cream). The family spent some vacations in Pass-A-Grille, Florida, and moved there permanently when Larry was 10. A budding naturalist, he kept seahorses as pets, collected shells, and used his rowboat to explore Tampa Bay. He camped in a Florida wild enough that he once heard a panther scream right outside his tent, and spent many hours exploring central Florida’s springs and caves with friends whose “quiet, European” motorcycles could cover many miles on the little gasoline available during wartime. Before leaving Pass-A-Grille for college, Pomeroy worked on a commercial fishing boat, the Wye Goodie. Always of slight build, Pomeroy still managed to haul in two 30-pound groupers at a time, and he was delighted to see the Wye Goodie still afloat on the Georgia coast in the 1990s.

Pomeroy earned his B.S. (1947) and M.S. (1948) in Zoology at the University of Michigan, and his Ph.D. in Zoology at Rutgers (1951) where he worked with Hal Haskin. Haskin had earned his Harvard Ph.D. with Alfred C. Redfield at Woods Hole Oceanographic Institute (WHOI) and joined the faculty at Rutgers shortly before Pomeroy arrived. In Haskin’s young lab, Pomeroy used P-32 to understand the mechanisms by which oysters take up phosphorus from seawater, a necessary step in shell deposition. Cited as recently as 2020, this work (Pomeroy and Haskin 1954) was a harbinger of distinction for both men. Haskin became an iconic figure in shellfish biology and Pomeroy’s career reflected the biogeochemical interests of his “grandfather professor”; he followed the phosphorus.

Mineral cycling and particularly phosphorus cycling occupied much of Pomeroy’s early career. After a few years as an “oyster doctor” in New Jersey postgraduation, Pomeroy took his wife Janet to Florida to show her the Everglades. While stopping in the Okefenokee Swamp, he received a call: “Would he be interested in interviewing for a job at the new University of Georgia Marine Institute on Sapelo Island?” “Well, yes, he would,” he recounts in his personal memoirs. Soon afterword, he and Janet moved to Sapelo where Larry became one of the founding resident researchers at the lab. Soon the facility was home to a congenial, if isolated, interdisciplinary group that included Robert Ragotzkie, Theodore Starr, Pomeroy, John Teal, Dick Dugdale, and their families. They were supported intellectually by visits from Gene Odum and scientists, including Haskin and Redfield. Late in his career, Redfield became interested in salt marshes and he and Pomeroy spent some days traipsing through the Sapelo salt marshes making geomorphological measurements. Tobacco-magnate R. J. Reynolds, who funded the lab and often hosted the scientists at his island home, enlivened the social scene. Pomeroy needed to do work that he could sustain at low cost without research assistants. Thus, he used Ragotzkie’s oxygen setup to study photosynthesis and respiration by benthic algae and microbes in the water column, an approach to community metabolism he never abandoned.

In 1960, Larry, Janet, and their two children moved to the University of Georgia (UGA) main campus where Larry joined Odum as a faculty member in the Zoology department. By this time, Pomeroy had published papers on algal productivity in salt marshes, the role of hydrography in dinoflagellate blooms, and a paper in *Science* on the residence time of phosphorus in natural waters (very short—both the paper and the residence time) (Pomeroy 1960). The *Science* paper attracted the attention of Bob Johannes, who had been doing phosphorus work for his Ph.D. at the University of Hawaii and he moved to Sapelo to continue Pomeroy’s salt marsh research. They soon showed that P-32 or Zn-65 added to the water column reached higher trophic levels through microbes in the surface sediments, not the *Spartina* cordgrass which never showed any radioactivity (Fig. 2), thus paving the way for a view of detritivores as the dominant movers of energy and material in the ecosystem (Pomeroy et al. 1969).

Pomeroy visited Eniwetok atoll for the first time in 1960, accompanying Odum student E. J. Kuenzler. In 1967, he sent his first two Ph. D. students, James Marsh and Berton Roffman, to Eniwetak to do their dissertation research while he spent a year as a Program Officer at the National Science Foundation (NSF). Throughout this time, he thought about the experiments he could do with radiotracers to test hypotheses about nutrient conservation on reefs. He thought it ironic that on this site, famous for nuclear bomb testing, radioactivity for research was not allowed. However, in 1971, Johannes and Pomeroy returned for 2 months with a team of 23 researchers. They were to conduct what *Symbios* Expedition chronicler Chris D’Elia describes as “the most comprehensive study of a coral reef undertaken until that time” (D’Elia and Harris 2008). In this instance, Pomeroy fnagled his P-32 and, working with Bill Weibe and Michael Pilsen, demonstrated, for the first time, that the reef communities were not phosphorus-limited, “having evolved recycling loops to satisfy their (nutrient) requirements” (Pomeroy et al. 1974). Radioactivity remained on the minds of the scientists in other ways.
the first time, coconuts were safe to eat. Fish and coconuts proved popular additions to staples of bread, peanut butter, and beer.

Pomeroy was an adventurous person; he continued spelunking through graduate school (his first date with his future wife was a caving trip), and was thought missing on a small boat at least once in the cold waters of the Jersey shore. Enewetak almost proved his undoing. One morning, on a sampling trip to the middle of the lagoon with his postdoc Jim Alberts, the motor died and the radio failed. Drifting downwind, Pomeroy used an anchor line, too short to reach the bottom, to try to catch a coral pinnacle and prepared to use their tarp as a sail if they were actually transported out of the lagoon. In the end, after their extreme tardiness was noticed by Johannes, they were rescued, severely sunburned but otherwise OK. Larry lived to explore quite a few more places.

By 1970, Pomeroy had framed many of the ideas that led to his famous paper in BioScience “The Ocean’s Food Web, A Changing Paradigm” (Pomeroy 1974). Notably, he and Johannes had published two important Deep-Sea Research papers that documented a high percent of total respiration by the “nanoplankton” fraction in the Peru upwelling, identified detritus as an important substrate and habitat for bacteria, and identified flagellates as the dominant metabolic component of the plankton in the Gulf Stream and Sargasso Sea (Pomeroy and Johannes 1966, 1968). In 1970, Pomeroy published a remarkable paper in Annual Review of Ecology and Systematics (Pomeroy 1970). This is where he first uses the term “paradigm” in print, challenging not just the paradigm of a linear food web, but also the paradigm in which bacteria are relegated to mere “regenerators, to close the cycles of nutrients” and by which mineral cycles are “conceived from standing stocks of dissolved phosphorus and nitrogen.” Here, work from all the sites he had studied came together in support of his then-novel hypothesis that turnover rates, not biomass, standing stock, or Liebig limitation were the key to understanding productivity. Pomeroy wrote quite a few synthetic reviews, but this one stands out because he so comprehensively considers a very wide range of Earth’s ecosystems, from salt marshes to reefs, rumens, and rain forests. Terrestrial and aquatic ecosystems are not so different, he suggests, particularly since so much energy passes through the detrital compartments in both.

In his 1974 BioScience paper, Pomeroy applied these ideas exclusively to the ocean’s food web, and directly considered implications for fisheries and management (Pomeroy 1974). Most of the paper’s longstanding impact comes from its memorable presentation of the food web as a network involving many compartments, and its emphasis on the importance of detritus, bacteria, and heterotrophic protists to energy flow. However, he also emphasizes that most primary production in the sea is probably done by phytoplankton too small to catch in nets. In the days before the discovery of Synechococcus and Prochlorococcus, this was a bold position and an aspect of the paper that is often ignored. He also identified “unseen strands” in the food web, and might have been the first to include mucous net makers as a stand-alone compartment in a marine food web diagram. While the term “microbial loop” had not yet been coined, Pomeroy effectively synthesized a new way of thinking about the ocean that encompassed the microbial loop and that has largely been proven correct.

Pomeroy liked to go to sea and valued ship time as gold (Fig. 3). Both taxpayer dollars and scientific opportunity were not to be wasted. Between 1965 and 1998, Pomeroy went to sea more than 50 times, not counting many short cruises on the R/V Blue Fin (Georgia), R/V Kit Jones (Georgia), and FRS Shamook (Resolute, Canada). He had more sea days on Duke's
R/V Eastward than any scientist but one. He was a compassionate observer of scientists and the ship’s crew at sea, and something of a connoisseur of the myriad personalities he met among mariners.

Only one cruise seems to have gotten the best of him and even that cruise led, indirectly, to a Science paper. In 1969, at the end of his term at NSF, he was offered the chance to be Chief Scientist on an Eltanin cruise in the Antarctic. After gathering a group of investigators, including graduate student Jim Thomas, the ship left Melbourne after solving major problems with gear. At sea, they suffered multiple disruptions that included an emergency run from the Polar Front to Tasmania to get a crew member to a hospital before his appendix ruptured. Most of all, Pomeroy was frustrated by the extremely low rates of bacterial respiration he and Thomas measured; why just the bacteria when every other component of the ecosystem seemed to be humming? The work proved difficult for them to publish, so much so that he ultimately gave the data away. However, years later, the Eltanin experiments finally began to make sense after he and Don Deibel showed that, in cold temperate waters, respiration by heterotrophic bacteria is inhibited in early spring, while phytoplankton production is not, a result they published in Science (Pomeroy and Deibel 1986) with considerable impact (cf. “Pomeroy hypothesis” in Kirchman et al. 2009).

Pomeroy devoted much of the late 1980s and 1990s to research on the implications of this finding, working with Weibe on temperature/substrate trade-offs in bacteria and conducting multiple projects in the Arctic with Canadian and American collaborators. He spent several spring seasons in Newfoundland, a month at the Canadian Ice Island Camp at 80°N in both 1988 and 1989, and made two trips to Resolute in the NW Territories. In one classic Pomeroy maneuver, he quickly reworked a research plan to use H-3 instead of C-14 so that he could remain on a Polar Star cruise out of Dutch Harbor. The initial plan would have interfered with measurements of naturally occurring carbon isotopes, so he was in danger of being kicked off the ship. As he said of his response to this short period of agonizing uncertainty, “they (cruises) are the lifeblood of oceanography, but they are also very expensive... oceanographers will lie, cheat and steal to get on a cruise. All I did was my homework.”

Dozens of graduate students had their first opportunity to go to sea on a Pomeroy cruise and were inspired to work around-the-clock by his example (Fig. 4). In addition to more than 30 graduate students of his own (including more than 20 Ph.D. students), he welcomed other students whose research would either benefit from some ship-time, a little extra funding, or a scientific conversation. He fostered extraordinary independence in his students and did not hold regular lab meetings. Instead, he met individually with students or groups of people involved in specific projects. He did not suffer fools gladly but was an active listener who gave encouragement when it was needed. Notably, Pomeroy did not accept authorship on papers resulting from his students’ dissertation research unless he was closely involved with the actual work. A Web of Science search suggests that, if he had, Pomeroy’s impressive C.V. listing more than 100 papers (~70% first-authored) and three

FIG 3. Pomeroy cocking the 200-liter Gerard-Ewing water sampler on the R/V Eastward. 1969. Photo by: J. Thomas.
edited books would expand by 40–60 papers. The vast majority of students he advised followed scientific careers, and he remained in touch with most of them for decades.

Pomeroy also worked incredibly well with interdisciplinary groups of scientists where his clear, objective thinking and cordial demeanor facilitated creative collaboration with peers. The Symbiosis expedition, hatched by Pomeroy, Johannes, and Wiebe in a bar waiting for an Eastward cruise, included senior geologists and mycologists and other biologists from multiple institutions. Much of the observational salt marsh work was coordinated through his collaboration with Wiebe and Dick Wiegert, Wiebe being, as he put it, “a card-carrying microbiologist” and Wiegert an expert in modeling ecosystems (Pomeroy and Wiegert 1981). For the large team of UGA faculty and students studying the marsh, the models provided a way to test hypotheses about material and energy flow, identified missing links when the numbers did not add up, and led to better and more targeted field experiments.

Equally productive was Pomeroy’s long collaboration with physical and biological oceanographers on the ecology of the continental shelf and coastal ecosystem of the South Atlantic Bight, or that region of the U.S. Atlantic shelf from north Florida to Cape Hatteras. The unfolding understanding of physical processes on the shelf developed by Jack Blanton, Larry Atkinson, and their colleagues allowed Pomeroy to show the importance of fronts, Gulfstream intrusions and eddies, and rivers to the balance of autotrophy and heterotrophy in the water column. He also remained very interested in models for their own sake and as heuristics for hypothesis building and testing (e.g. Pace et al. 1984; Pomeroy 2004). Overall, this collaborative multi-investigator work spanned almost 50 years and the Southeastern Atlantic Bight, from the estuaries to the Gulfstream, was his testbed for hypotheses relating to material and energy flow in coastal waters.

As long as this tribute is, it still leaves out a lot. It does not speak to Larry’s matter-of-fact inclusion of women in his field programs, his outstanding classes in Oceanography and Marine Ecology, or his important role in founding Georgia’s Institute of Ecology and Odum School of Ecology. It does not speak to his great interest in the history and philosophy of science (e.g., Pomeroy et al. 1988, with noted environmental ethicist Eugene Hargrove), and it definitely does not do justice to his wry
sense of humor and his integrity. Most important, it does not do justice to his warm relations with his family (daughter Cheryl, son Russell, and three grandchildren) or to Janet Pomeroy herself, who passed away in 2009 (Fig. 5). Where Larry was an introvert, Janet was an extrovert. Neither had time for gossip or small talk so, according to Cheryl Pomeroy, one of Janet’s main opportunities to have parties was to host gatherings of Pomeroy’s students and colleagues where he would be free to talk science. I am not sure how this worked out for her but, for us, these gatherings and her kindness were truly important opportunities to talk to Pomeroy in a relaxed setting and gain extraordinary encouragement from her ever-positive attitude. She read and critiqued all of Larry’s papers and she knew our stories. It is easy to hear her laughter even now. In fact, she even charmed Reynolds so much that he named the ferry to Sapelo Janet.

Larry Pomeroy probably would have liked to have a boat named after himself as well, but his eponymous honor is more scientific. Two microbes have been named after him: Vibrio pomeroyi (Thompson et al. 2003), and the important model organism Ruegeria pomeroyi, (Syn: Silicibacter pomeroyi) which is the first bacteria from a major heterotrophic lineage to have its complete genome sequenced (Moran et al. 2004). This workhorse organism is a very fitting memorial, likely to lead to new discoveries and possibly new paradigm shifts as future students use it to explore his ideas and follow his example of a scientific life well lived.

ACKNOWLEDGMENTS

Many people contributed to this tribute review and I would particularly like to thank Cheryl Pomeroy, Evelyn Sherr, Jim Marsh, Jim Thomas, Francesc Peters, Lita Proctor, Wade Sheldon, Chris D’Elia, Gene Turner, and Jim Alberts, for their recollections and photographs. Barbara Roy, Lorraine Heisler, Francesc Peters, Evelyn Sherr, and Don Deibel read various drafts, and I would finally like to thank Cheryl Pomeroy and Chris Filstrup for the great honor of being invited to write it.

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DEVELOPING SCIENCE COMMUNICATION SKILLS IN EARLY CAREER SCIENTISTS

Hayley Schiebel, Rebecca Stone, Echo A. Rivera, and Jessamyn Fairfield

For two consecutive years, a workshop entitled Developing the Science of Science Communication has been offered at the Aquatic Sciences Meeting (2019) and Ocean Sciences Meeting (2020). The goal of these workshops was to provide training for early career scientists specifically related to verbal and visual communication skills that are sorely lacking in early career science curricula. Both qualitative and quantitative data was collected from 91 participants across the two workshops through pre- and postsurvey data. Participants overwhelmingly agreed that they (1) would recommend the workshop to others and (2) found the workshop content would be useful in their careers. Workshop participants had the opportunity to offer more feedback in response to several open-ended questions related to the visual and verbal components of the workshop, each of which provided interesting feedback in terms of which session(s) were the most useful for different types of audiences and how to proceed in future workshops. The workshop hosts created a report with background information, survey data results, and recommendations moving forward. The full report can be found at: http://bit.ly/ECRworkshop.

BACKGROUND

Scientists, academics, and researchers must have strong communication skills to explain their work in effective ways. Graduate schools, however, rarely include this type of training in their programs, which creates a significant skill gap for early career professionals. As a result, many professionals in the academic and scientific field struggle to communicate effectively to their peers, outside disciplines, and the public. Without adequate training in communication, scientists tend to (unintentionally) reinforce ineffective communication strategies. Despite the momentum of a growing communication field and pressing need for the delivery of accurate and engaging scientific information to any audience, such training is not always available for early career scientists: undergraduate students, graduate students, and those within 2 yr of graduation from a graduate degree program (Coil et al. 2010; Brownell et al. 2013; Mercer-Mapstone and Kuchel 2015; Cirino et al. 2017). Mercer-Mapstone and Kuchel (2017) conducted a meta-analysis of 99 articles from the fields of science, science communication, and education and found that only 19 of these articles contained information relevant to communication with nonscientists (and, by proxy, other scientific disciplines as well).

There are many types of communication and, for this report, we will focus on the two most common types used by scientists and academics: verbal and visual (e.g., slide presentation) communication skills. The goal of this pilot was to test whether we could train early career scientists on the knowledge and skills to improve their communication skills through an intensive workshop focused on verbal and visual communication. To meet this objective, a full day workshop funded by the National Science Foundation was held at the 2019 annual meeting held by the Association for the Sciences of Limnology and Oceanography (ASLO) and the 2020 Ocean Sciences Meeting (OSM) cosponsored by the ASLO, the American Geophysical Union (AGU), and The Oceanography Society (TOS).

WORKSHOP DETAILS

We piloted a 1-d workshop package of both verbal and visual communication skills. The goal was to create a 1-d workshop that could be implemented at any research conference, so scientists already attending a conference could benefit from a communication skills workshop. We piloted this workshop twice: (1) the ASLO conference in San Juan, Puerto Rico in February 2019, and (2) the OSM conference in San Diego, California in February 2020. Workshop attendees participated voluntarily in a full day workshop comprised of verbal and visual communication skills sessions. The workshop was advertised with preregistration and was free for attendees, with 50 available slots. The only requirement was that participants attend the entire day.

The all-day workshop included two verbal face-to-face communication sessions, facilitated by Dr. Jessamyn Fairfield. These sessions were based in performing arts methods that use improvisation to help researchers develop clear and engaging stories about their work with good vocal technique and physical awareness. This training has been validated in the Bright Club Ireland model of science communication over 4 yr of evaluation and testing (Roche et al. 2020). The training involved improvised monologues and research pitches, without prepared text, with special emphasis given to three act story structure, accessibility of language, and body language. Improvisation exercises, which have been effective at teaching science communication in a university context (Rossing and Hoffmann-Longtin 2016; Ponzi et al. 2018), were also employed. The provision of several opportunities to practice to a live audience, as well as interactive feedback, helped address anxiety about public speaking in the group by repeated exposure in a safe and supportive environment. The use of humor was also discussed, as humor can be an important tool to frame science in new ways and improve the perceived accessibility of technical topics (Pinto et al. 2015; Riesch 2015). Thus, the verbal communication sessions provided a highly interactive, hands-on opportunity for participants to develop their skills in storytelling and communication of their research.

Three visual communication sessions were delivered via webinar by Dr. Echo Rivera. Workshop participants learned how to design and deliver presentations that help their audience pay attention, understand the material, remember the material, and use the information at a later time. More specifically, Dr. Rivera taught participants how to (1) keep their audience engaged and interested; (2) remove clutter and distractions from their slides; (3) use less text and more visuals; (4) use design to enhance audience learning; and (5) design compelling and easy-to-understand data visualizations. The content of this webinar was developed by Dr. Rivera, who has a mixed method research/evaluation background in the social sciences, and combines lessons from psychology, pedagogy, graphic design, and information design. The content for these sessions was developed over years of testing with multiple audiences (scientists, academics, evaluators, and service providers). This training is software neutral and teaches principles that can be applied regardless of which slide application participants use. As such, the session format did not require participants to have a laptop with them to learn the material.

All study protocol and supplemental materials were approved by the Suffolk University Institutional Review Board (IRB) prior to implementation at the workshops. Evaluation folders
In 2019, all 50 registration slots were filled, but there were several no-shows from this list on the day of the event. Several people were walk-ins and we ultimately had 41 participants attend the first pilot. All 41 participants completed the evaluation surveys. In 2020, all 50 registration slots were once again filled. This time, however, Dr. Hayley Schiebel sent several reminder emails to the registrants before the event. For the second pilot, all 50 registrants attended the workshop and 40 participants completed the evaluation surveys. The full report with all results/data can be found at: http://bit.ly/ECRworkshop.

Participants were asked to report on their level of comfort speaking to a variety of audiences before and after the workshop. In addition, participants were asked three questions about whether they can describe their research presentations before and after the workshop. In addition, participants were asked to rate their confidence in several presentation domains on a scale of 1 (Not at all confident) to 4 (Very confident). As expected, participants reported a decrease in confidence for most items.

Generally, participants felt that the workshop was helpful and would recommend this workshop to colleagues (Table 1).

Workshop participants had the opportunity to offer more feedback in response to several open-ended questions related to the visual and verbal components of the workshop, each of which provided interesting and different feedback. For the open-ended questions specifically related to the visual communication portions of the workshop, it was clear that the participants (1) had not had a lot of training in visual science communication skills and/or had been trained improperly and (2) learned a great deal about how to move forward with visuals in their science mostly for peers and the scientific community. Comprehensively, responses related to the verbal communication portions of the workshop seemed to find that it would be most helpful for relaying science to a non-science audience. Participants also found the 2019 verbal storytelling session helpful and mentioned that they will use this approach in future presentations to fully break down their research to either a non-science audience and/or a scientific community other than their own. Participants could use this skill specifically at a research conference in a poster hall when they need to get a passerby’s attention (who may or may not have research interests similar to that of the presenter) in a small amount of time. This same activity would also be useful in trying to explain one’s research to a family member with no science background.

| Table 1. Pre- and post-workshop survey results |
|------------------------------------------------|
|                | 2019 |        | 2020 |        |
|                | % disagree | % agree | % disagree | % agree |
| I would recommend a workshop like this to my colleagues, mentees, and/or students. | 7.3  | 92.7  | 7.2  | 92.8  |
| I would recommend that other scientific conferences offer workshops like this. | 4.9  | 95.1  | 0  | 100  |
| This workshop material will be useful for advancing my career or professional goals. | 10  | 90  | 0  | 100  |
| This workshop provided me with new information and skills to improve my science communication. | 12.2  | 87.8  | 0  | 100  |
RECOMMENDATIONS FOR FUTURE WORKSHOPS
Based on the evaluation results, as well as the research team’s reflections, we have compiled a list of recommendations and next steps for this workshop as well as for science communication training more broadly.

Content
Not surprisingly, participants provided a conflicting set of feedback: they both wanted more information and found the workshops engaging, while also mentioning that there was too much information and it was an exhausting day. For example, one participant suggested cutting one session but noted they could not decide which one since all were so helpful. Several requests were made for adding more information to the workshop. As another example, many participants wanted more information, clarification, and/or discipline-specific examples for how the base training on data visualization could be expanded to advanced analyses. Participants also mentioned an interest in training on other types of communication skills beyond the scope of the pilot. For example, many participants requested more practice with designing a poster for a scientific workshop.

For future workshops, there will be one session on verbal communication skills, one session on presentations, and one session on poster design to address these complexities and see if the outcome from participants is more favorable. To address the issue of information overload for participants, the workshop hosts aim to create a packet with online information and more resources for participants to use after the workshop concludes to still disseminate this information as needed.

Technology
In 2019 and 2020, Zoom Meetings was used to deliver the visual webinars. In both 2019 and 2020, it was difficult to engage with participants, because as many of them did not have a laptop they could use for the chat feature. While a few attendees did use their laptop or phone to answer the questions and engage during the webinars, engagement was very low. For 2020, Dr. Rivera attempted to use Poll Everywhere to improve audience engagement, but this was still limited to official polls. In regular webinars, where every attendee joins with their own device (usually at their desk or at home), participants can use the chat or Q&A feature to engage at any time.

The research team was concerned about audio quality, video quality, and internet connection stability for both pilot sessions. In 2019, there were no technical issues and the webinar sessions went smoothly. In 2020, however, there were some audio issues with Zoom Meetings (likely due to how Zoom processes and compresses audio). It is unclear whether this would have been an issue with other software. Although this caused a small delay at the start of the workshop, the issues resolved over time. As with any training that involves additional elements of technology, there is additional risk involved in doing webinar trainings at a conference setting.

After the pilot, the research team recommends that training be either fully in-person or a traditional webinar where every participant has a device that makes it easy to engage at any time. The middle ground approach implemented in the pilot significantly stifles engagement between presenter and audience.

Another challenge was that although many participants expressed a desire for more information, some participants provided responses that there was perhaps too much information covered or was too fast paced. For example, some participants mentioned a need for greater inclusion and accessibility for participants for whom English is a second (or third, etc.) language, some of whom found the workshop hard to follow due to pace. This may be a common challenge across all presentations as two participants requested more information about improving this aspect of their own presentations. In the 2020 workshop, this issue was addressed by adding captions to the visual presentation skills sessions. The captions were deemed accurate and nondistracting to most participants, though most did not find them helpful because they did not need this particular accommodation. Therefore, the questions about accuracy and distraction level are probably the most helpful evaluation questions to ask, with the other questions remaining off the survey.

CONCLUSION
For two consecutive years, a workshop entitled Developing the Science of Science Communication has been offered as the Aquatic Sciences Meeting (2019) and Ocean Sciences Meeting (2020). The goal of these workshops was to provide training for early career scientists specifically related to verbal and visual communication skills that are often lacking in early career science curricula. Both qualitative and quantitative data was collected from 91 participants across the two workshops through pre- and post-survey data. Participants overwhelmingly agreed that they (1) would recommend the workshop to others and (2) found the workshop content would be useful in their careers. Workshop participants had the opportunity to offer more feedback in response to several open-ended questions related to the visual and verbal components of the workshop, each of which provided interesting feedback in terms of which session(s) would help participants reach different types of audiences. Due to a lack of time, information overload, and technology issues, we recommend in-person workshops where possible with paired curricula materials online in the future. It is an impossible feat to include all verbal and visual skills needed for early career scientists to communicate their research effectively in 1 day. Both presenters had more material to share than could comfortably be included in a day-long workshop, which points to an unmet need to have more comprehensive communication training embedded within graduate programs. The workshop hosts created a report with background information, survey data results, and recommendations moving forward. The full report can be found at: http://bit.ly/ECRworkshop.

ACKNOWLEDGMENT
This work was funded by National Science Foundation project numbers 1911531 and 1950394.

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