COBRA Master Class: Deep-Sea expedition leadership training to accelerate early career advancement

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest

Author contribution statement

All co-authors participated in the co-design, co-development, participation, and execution of the COBRA Master Class. RDR and KLCB co-led the drafting of this manuscript. BNO, JAH, RDR, CGW, ATF, and JM secured the funding for this project. BNO, JAH, and RDR led the conceptual design of the Master Class, with curriculum development input from KLCB, CGW, ATF, and RS. All co-authors contributed to the drafting and editing of the manuscript.

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Abstract

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Leading deep-sea research expeditions requires broad training and experience, and the opportunities for Early Career Researchers (ECRs) to obtain focused mentorship are scarce. To address this need, the Crustal Ocean Biosphere Research Accelerator (COBRA) launched a 14-week virtual Master Class to empower students with the skills and tools to successfully design, propose, and execute deep-sea oceanographic field research. The Master Class offered training and created an open-access syllabus with resources, including reading material, lectures, and online resources freely-available online (cobra.pubpub.org). All COBRA Fellows were ECRs, and engaged in topics related to choosing deep-sea research assets, learning about funding and how to tailor proposals, and working through an essential checklist of pre-expedition planning and operations. The Master Class covered leading an expedition at sea, at-sea operations, and ship-board etiquette, and telepresence. It also included post-expedition training on data management and report preparation. Fellows also discussed education and outreach, international ocean law and policy, and team science. Fellows further learned about how to develop concepts respectfully with regard to geographic and cultural considerations of their intended study sites. An assessment of initial outcomes from the first iteration of the COBRA Master Class reinforces the need for such training and shows great promise with one-quarter of the Fellows having submitted a research proposal to national funding agencies within six months post-class. As deep-sea research continues to accelerate in scope and speed, providing equitable access to expedition training is a top priority to enable the next generation of deep-sea science leadership.

Contribution to the field

This "Community Case Study" article describes a novel model for training future deep-ocean expedition leaders, launched by the Crustal Ocean Biosphere Research Accelerator (COBRA). In the field of deep-sea science, there is a practical need to train early career deep-ocean leaders to maximize productivity and minimize costs that can occur when “learning while leading.” Deep-sea shiptime is expensive, ranging from $10,000-100,000+ USD per day, and subpar leadership can waste tens of thousands to millions of dollars in lost productivity. To reduce that inefficiency, lead scientist training efforts have been developed for US-based deep submergence assets. This training effort is a valuable and critical tool to help burgeoning PIs with developing the at-sea experience and post-award period, however, a comprehensive approach to the lead scientist experience, ranging from proposal preparation to final expedition report, is lacking. As part of the COBRA Initiative, 12 inaugural Fellows co-developed a COBRA "Master Class" to empower students with the skills and tools to successfully design, propose, and execute deep-sea oceanographic field research. The Master Class offered customized and distributed training approaches and created an open-access syllabus with resources, including reading material, lectures, and on-line resources freely-available on the Master Class website: (cobra.pubpub.org). These materials are made publicly available to help accelerate deep-sea leadership. The main contribution of this manuscript is the articulation of this novel Master Class concept, which is an intermediate education tool that bridges the time investment gap between workshop and formal graduate training. This manuscript will increase the discoverability of Master Class course materials, as well as lay a blueprint for future courses of this style by describing the methodological and pedagogical detail involved.

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Abstract

Leading deep-sea research expeditions requires a breadth of training and experience, and the opportunities for Early Career Researchers (ECRs) to obtain focused mentorship on expedition leadership are scarce. To address the need for leadership training in deep-sea expeditionary science, the Crustal Ocean Biosphere Research Accelerator (COBRA) launched a 14-week virtual Master Class with both synchronous and asynchronous components to empower students with the skills and tools to successfully design, propose, and execute deep-sea oceanographic field research. The Master Class offered customized and distributed training approaches and created an open-access syllabus with resources, including reading material, lectures, and on-line resources freely-available on the Master Class website (cobra.pubpub.org). All students were Early Career Researchers (ECRs, defined here as advanced graduate students, postdoctoral scientists, early career faculty, or individuals with substantial industry, government, or NGO experience) and designated throughout as COBRA Fellows. Fellows engaged in topics related to choosing the appropriate deep-sea research asset for their Capstone "dream cruise" project, learning about funding sources and how to tailor proposals to meet those source requirements, and working through an essential checklist of pre-expedition planning and operations. The Master Class covered leading an expedition at sea, at-sea operations, and ship-board etiquette, and the strengths and challenges of telepresence. It also included post-expedition training on data management strategies and report preparation and outputs. Throughout the Master Class, Fellows also discussed education and outreach, international ocean law and policy, and the importance and challenges of team science. Fellows further learned about how to develop concepts respectfully with regard to geographic and cultural considerations of their intended study sites. An assessment of initial outcomes from the first iteration of the COBRA Master Class reinforces the need for such training and shows great promise with one-quarter of the Fellows having submitted a research proposal to national funding agencies within six months of the end of the class. As deep-sea research continues to accelerate in scope and speed, providing equitable access to expedition training is a top priority to enable the next generation of deep-sea science leadership.

1 Introduction and Context

The deep ocean (greater than 200 m) is the largest ecosystem on planet Earth, yet, only ¼ of the deep ocean has been mapped with state-of-the-art multibeam technology (Mayer et al 2018; Seabed 2030 Project), and considerably less of the seafloor has been observed by humans. To accelerate the pace of discovery, a multitude of efforts have emerged to bring affordable technology (Phillips et al. 2019, Dominguez-Carrió et al 2021, Giddens et al. 2021, Bell, Chow, et al. 2022; Novy, Kawasumi et al., 2022), accessible data (Pesant et al. 2015; Katija et al., 2022), standardized protocols (Pearlman et al. 2019), and more inclusive training (Amon, Rotjan, et al. 2022, Harden-Davies et al. 2022, Smith et al. 2022) to the global ocean community. These efforts are laudable and necessary and work in complement with each other to demystify the deep ocean and address goals of the UN Ocean Decade (Howell et al. 2020). Understanding the deep ocean is critical as the human population (Kramer 2019) continues to exploit deep-sea fisheries (Watling et al. 2020), interrupt deep-sea planetary processes in terms of carbon sequestration (Teng and Zhang 2018) and O_2 production (Gao et al. 2019), and now is on the verge of deep-sea mining and other invasive extraction activities (Amon et al. 2022a, b). Yet, the community of deep-sea scientists is small, with relatively few deep submergence assets (Bell et al. 2022; Global Ocean Science Report 2020). Though there are Early Career Researchers (ECRs) and other community stakeholders trying and willing to engage in deep-sea research, there is little formal opportunity to access training and preparation to lead such expeditions.

Coordinating and leading a deep-sea expedition requires a wide range of skills and experience, and each individual expedition often takes months-to-years of preparation, and additional months-to-years of post-expedition work and analysis. Therefore, it is difficult for new leaders to enter the field of expedition leadership, and ECRs have limited access to targeted mentorship on leading expeditions. Even for current expedition leaders, few have received formal training, and many have trained "on the job", making unnecessary (and expensive) mistakes that could have been otherwise avoided. Expedition lead scientists often learn from being a participant on other research expeditions; however, this experience is often insufficient to gain comprehensive insight into expedition leadership, and for many ECRs, simply getting a berth and the financial support to participate on a cruise can present challenges. As such, the learning curve towards becoming a lead scientist is steep, and may indeed be too steep to enable inclusive entry for newcomers to the field without formal training in expedition leadership. Ocean sciences are among the least diverse STEM fields (Orcutt and Cetinič 2014, Bernard and Cooperdock 2018, Johri et al 2021, Giakoumi et al. 2021, Legg et al. 2023), and though many countries have deep-sea ecosystems (Amon et al. 2022, Bell et al. 2022), few have opportunities to access them for scientific study (Osborne et al. 2022). Recent surveys show a strong interest in gaining deep-sea research capacity, (Bell et al. 2022), but there are few, if any, training opportunities available. In countries with deep ocean environments, the lack of human capacity and training opportunities were identified as top barriers to pursuing deep-sea research (Amon, Rotjan, et al. 2022). Thus, while the desire to accelerate deep-ocean exploration exists globally, there remains a critical gap in opportunity and access.

To date, many programs have tried to address this gap. The US National Science Foundation (NSF) has supported numerous Chief Scientist training programs aboard UNOLS research vessels, including those with deep-sea assets like the HOV *Alvin* (Marlow et al. 2017). Such opportunities are of course invaluable, but currently, they are only open to individuals residing in the US, regardless of citizenship, and training material products have been limited. Alternatively, multi-year training programs exist in the form of graduate degrees that include field-based experiences, but PhD programs are long, and few (if any) offer formal training in expedition leadership. Workshops can help with a specific skill, but are often too short to fundamentally alter preparation. To truly accelerate deep-sea research across the globe, the field needs formal expedition leadership training opportunities that are inclusive and equitable, open to all citizens, and that also accomplish the goal of genuine and authentic preparation for career longevity in deep-sea science (Amon et al. 2022).

The Crustal Ocean Biosphere Research Accelerator (COBRA) is an NSF-funded international network-of-networks with a mission to accelerate research on the structure, function, resilience, and ecosystem services of the crustal ocean biosphere, which includes deep-sea seamounts, hydrothermal vents, and below the seafloor (Huber and Orcutt 2021). One of the express goals of COBRA is to train future generations in inclusive ocean exploration, policy, research, and data accessibility. To that end, in 2022, COBRA launched its inaugural COBRA Fellowship and accompanying Master Class, which trained 12 early career Fellows in deep-sea expedition leadership (and will do so annually for five years). The goal was to equip Fellows with the skills and tools to successfully design, propose, and execute deep-sea oceanographic field research, with a collaborative, just, equitable, diverse, and inclusive approach. This 13-week virtual class included weekly synchronous, online sessions for two hours, followed by asynchronous interaction throughout the week. The "master class" concept was designed to be a class taught by masters in the field, for the upcoming generation of masters in the field. To do this, Fellows engaged in a variety of topics that included an overview of planning, at-sea, and post-expedition operations to launch their capabilities of leading future expeditions. Fellows also applied these lessons to a "Dream Cruise" project, where they assembled their ideas with resources and methodologies for a proposal of their own. To reflect the time commitment made by the participants to participate in this professional development training, a modest stipend was offered to the Master Class fellows, as is common for other NSF-funded participant support programs.

2 Key Programmatic Elements

2.1 Cohort Selection Process

Participation in virtual Master Class was offered to ECRs from around the world, and previous experience with deep-sea research or policy was not required. Early career was defined as senior graduate students, postdoctoral scientists, junior faculty less than 10 years from their terminal degree, and other junior professionals, such as an early career employee of a government, NGO, or industry. Chosen ECRs were provided a stipend for participating in the Master Class. The selection criteria included a) a background in oceanography, marine science, ocean engineering, marine policy, or related field; b) a strong interest in deep-sea exploration and research, at sea and/or from shore; c) an advanced graduate (Ph.D.) student, Postdoctoral scientist/researcher, untenured faculty, or an early career employee of a government, NGO, or industry with sufficient experience to benefit from and contribute to future expeditions; d) a compelling reason to take part in the COBRA Master Class; e) a compelling reason to contribute to COBRA's goal to create a more diverse pool of talent engaged in leading deep-sea research that addresses societal needs. To that end, applicants were asked for a CV and to answer two questions (500 words or fewer): 1) Tell us about your career goals and how becoming a COBRA Fellow will help you achieve those goals, and 2) Tell us about your journey and how you would like to contribute to COBRA's goal to create a larger, more diverse global pool of talent engaged in leading deep-sea research that addresses societal needs. Each application was then read and reviewed by two COBRA CO-PIs and/or partners, and a decision was made as to the eligibility of the applicant, given the selection criteria.

Applicants were also asked to voluntarily provide some personal identity information to help the evaluation committee to understand the demographics of the applicant pool and assess how different dimensions of diversity are maintained through the selection process, and if efforts to recruit diverse audiences are effective. COBRA aims to increase representation of diverse genders, races and ethnicities, and nations in deep-sea research, with a metric of offering programs that have more demographic diversity than the demographics of recent ocean science graduates in the U.S. (CITATION). If provided, demographic data was summarized and reported to the evaluation committee in aggregate, without personally identifying applicants.

To avoid conflicts of interest, demographic data was only made available to the COBRA Director and Managing Director, who were not part of the evaluation committee. All eligible, qualified applicants (determined by the evaluation committee) were then entered into a lottery pool that was subjected to a random lottery process, re-sampling from the qualified population as needed to achieve a diverse demographic based on gender identity, race and/or ethnicity, country of citizenship, and country of residence. In this way, the COBRA team actively attempted to remove bias and authentically provide each eligible and qualified applicant with a non-ranked selection opportunity. For the 2022 Master Class, 107 applications were received, 52 were deemed to be eligible based on their qualifications, as determined by the above-mentioned selection criteria, and a randomly-selected cohort of 12 of these eligible applicants was developed to maintain the demographic diversity of the eligibility pool.

2.2 Activities / Assignments and the Dream Cruise Project

In addition to weekly synchronous classes, Fellows were assigned pre- and/or post-class reading, activities, and other tasks to support learning and to build toward a Capstone Project known as the "Dream Cruise Project" (https://cobra.pubpub.org/pub/2023-fellow-project-template). The purpose of the Dream Cruise Project was to assign guiding questions over the entire course such that the Fellows would end the class with a draft expedition prospectus for a "Dream Cruise" idea that they could then use as a scaffold for proposals or other expedition planning purposes. They were asked to write a project overview about an expedition that they would like to undertake, including the project title, objectives, team, and timeline (Supplementary Table 1). Fellows then added three objectives to challenge them to think about them in further detail regarding specific hypotheses, samples and analysis required to answer their questions, expected importance, and expertise required to accomplish their objectives. Fellows worked in teams to identify data repositories where they could find information about their areas of interest that may already exist. In addition to the science, Fellows also drafted education, public outreach, and/or communication approaches for their expedition. Fellows completed a table based on the US Department of State's Application for Consent to Conduct Marine Scientific Research table for their area of interest, or another area if theirs was not in another country's jurisdiction. Finally, Fellows were asked to prepare a 3-slide / 3-minute overview about their Dream Cruise Project or prepare a presentation on any aspect of the class, which would be delivered to the COBRA instructors and Fellows during the final week.

2.3 Class / Schedule / Modules / Topics

The Master Class met synchronously and virtually weekly, with asynchronous materials provided in advance and with follow-up. To promote asynchronous communications, a Slack channel was devoted to the course. The combination of virtual synchronous and asynchronous delivery was a major factor in successfully engaging a geographically dispersed cohort. In addition, to deliver the Master Class materials, we made use of the open-source publishing platform PubPub to create a course website (https://cobra.pubpub.org/). Class materials from 13 weeks of instruction were made available to Fellows approximately one week prior to the relevant class. Fellows' Dream Cruise Project work remains private for their intellectual use and development.

2.3.0 Week 0: Kickoff

The first week of the COBRA Master Class was an asynchronous introduction to COBRA, the Fellows, instructors, and class materials. During this week, Fellows were asked to watch a short introductory video about the COBRA project, record and post an introduction of themselves in the 2022 COBRA Master Class Slack Channel, and watch the introduction videos of other Fellows and instructors to get to know the team. They were also asked to complete two surveys: the first was a pre-class survey to help the instruction team assess their knowledge and feelings about leading deep-sea expeditions, and the second was to help the instruction team identify the Master Class weekly topics that the Fellows were most excited to learn about, and those that they thought would challenge them the most.

2.3.1 Week 1: Deep-sea Assets

Week 1 was the first synchronous class for all Fellows and instructors. The goals were to: (1) give an overview of deep-sea exploration and research tools, including costs, availability, procurement, etc., (2) introduce the Global Deep-sea Capacity Assessment (Bell et al., 2022), (3) explore how to access deep-sea assets from different countries and institutions, and (4) discuss the importance of relationship building in finding seagoing opportunities. During this class, COBRA instructors gave an overview of deep-sea research assets, such as ships and deep submergence vehicles. The class covered capacity gaps around the world, and in particular, what kinds of technological capacity exists (or not) in different regions. During class, Fellows worked in teams to investigate the capabilities and availability of assets, and discussed their findings with the class. The class ended with a discussion on relationship-building within the oceanographic community to facilitate access to seagoing assets.

2.3.2 Week 2: Funding & Proposals

The goals of Week 2 focused on Funding & Proposals were to: (1) provide an overview of proposal structure and important components to consider in writing, (2) explore how to leverage different programs and funding models for getting to sea and doing your work, (3) introduce Fellows to the Schmidt Ocean Institute proposal and funding model, and (4) develop and discuss Fellows' own proposal ideas. COBRA instructors gave an overview of scientific proposal writing, including structure, operational constraints to consider, how to partner or leverage institutions or resources, different funding models, and more. Class discussion highlighted the Schmidt Ocean Institute (SOI) and provided information about SOI's proposal and funding model, which is multinational. Fellows were asked to come to Week 2 prepared with a proposal idea for their "Dream Cruise" that they would use throughout the Master Class to develop a deep-sea proposal. During class, Fellows presented their ideas to small groups in breakout sessions to discuss progress, receive feedback, and think more broadly about their ideas and potential ways to express those ideas to demonstrate need and importance to resolve proposed questions.

2.3.3 Week 3: Respectful Concept Development

Week 3 focused on Respectful Concept Development, with goals to: (1) understand how to build relationships with diverse stakeholders that might be interested in research, and how to engage in equitable co-creation of knowledge before developing proposals; (2) discuss best practices for recruiting and promoting diverse and inclusive teams; (3) acknowledge the history of discrimination in deep-sea science; and (4) begin to unlearn parachute science approaches, with case studies in Trinidad & Tobago and Kiribati. Two guest lecturers from the NOAA Office of Ocean Exploration and Research joined Week 3 to introduce common barriers to entry, persistence, advancement, and success for marginalized and minoritized scholars in STEM, and share findings from a study on supporting marginalized team members at sea (Kelly and Yarincik 2021; Amon et al. 2022). Additional resources were also provided to Fellows (and are available on our PubPub site) to provide information on Anti-Harassment, Safety in the Field, Training & Support Services, Reporting & Response. COBRA instructors then discussed two case studies from Trinidad and Tobago and Kiribati under the My Deep-Sea, My Backyard project, which was established in 2018-2019 to develop long-term deep-sea capacity in these Small Island Developing States (SIDS) (Amon, Rotjan, et al., 2022). Presentations led to discussion between Fellows, instructors, and guest lecturers on how to change processes from applications through project execution to ensure equitable access to and support for opportunities in deep-sea exploration and research.

2.3.4 Week 4: Pre-expedition Planning

Week 4 addressed Pre-expedition Planning and focused on determining: (1) how to assess and prioritize the science needs of the expedition team and to communicate these needs with vessel operators, (2) what a Shiptime/Marine Equipment Request form might include, (3) what to consider when working in various ports regarding permitting and logistics, (4) what types of content are helpful to have in a Cruise Prospectus, and (5) the primary role of the Lead Scientist, which is to set the expectations for preparedness, safety, civility and respect on the expedition. Being a Lead Scientist is a big responsibility, but it is made easier by planning ahead and partitioning tasks into smaller and more manageable goals. COBRA instructors led discussion and activities to help Fellows think through the steps needed to prepare for an expedition as the Lead Scientist, divide responsibilities among the research team, and engage expedition participants for a successful and enjoyable experience at sea. Example documents and guides for pre-expedition preparation were provided, including shiptime requests, expedition prospectuses, and permit applications. The Marine Facilities Portal website (mfp.us) was highlighted as a tool for expedition planning, given many agencies and institutions in Europe (Netherlands, Germany, Spain, Finland, Sweden, Belgium), the UK, and the US are now using this for expedition planning.

2.3.5 Week 5: At-sea Operations

During Week 5, which focused on At-Sea Operations, Fellows built on the foundation of Week 4, examining more closely the activities that a lead scientist leads or delegates while at sea. Fellows were introduced to (1) planning and documentation of the expedition (plan-of-the-day, dive plans, reports, contingencies, etc.), (2) how to prepare a general operational plan that considers the time required to complete operational objectives (e.g., bathymetric mapping, transit, ROV/submersible operations, etc.), (3) approaches for assigning shifts, and (4) how to set the tone for maintaining good team relations and a healthy work environment. COBRA instructors reviewed the plan-of-the-day, dive plans and associated documents, daily logs and situation reports, dive reports, sample logs, video and photo archives, and expedition reports. They discussed how to prepare a team for the various tasks that need to happen pre-, during-, and post-dive or operation, and how to help a team succeed while maintaining physical, mental and emotional health. They also reviewed operations for mobilization and demobilization. Fellows and instructors had an open discussion at the end of the class about leading at-sea operations, particularly focused on looking after teammates at sea to ensure good health and a respectful working environment.

2.3.6 Week 6: Telepresence

For Week 6, which was focused on Telepresence, the goals were to understand: (1) what telepresence is and (2) the strengths, opportunities, weaknesses and challenges of telepresence with regards to science and outreach. A COBRA instructor and guest lecturer discussed telepresence technology and its power, goals, strengths, and weaknesses. Fellows also participated in a live telepresence interaction with scientists aboard EV *Nautilus,* which supports the ROV *Hercules*. This opportunity enabled Fellows to participate in real-time data streams and use the scientist ashore portal to get a glimpse of the shipboard experience (Wagner et al. 2023).

2.3.7 Week 7: Unwritten Rules

Week 7 focused on some of the “unwritten rules” of deep-sea science, which are different from other areas of ocean science that may require less collaboration by design. Goals of this week were to: (1) get an operational view of the shipboard “rules of the road,” (2) discuss the protocol, convention, and guidance for naming new seafloor features, sites, and species, and (3) discuss sometimes contentious subjects such as authorship, fundraising responsibilities, and collaboration expectations. COBRA instructors and guest lecturers discussed Chain of Command and how to interact with the ship’s operation teams as a leader or member of the science party; about life on a ship, including how to be respectful of a ship’s crew, safety, and other issues that are unique to living and working at sea; on guidance for naming discoveries, and collaboration etiquette with regard to data sharing, publication authorship, and funding.

2.3.8 Week 8: Introduction to Deep Data

In Week 8, we focused on Introduction to Deep Data, and the goals were to: (1) familiarize Fellows with existing data repositories, (2) enhance data discoverability by learning to find desired publicly-available data types and datasets for regions of interest, and (3) determine feasibility of at-home data use and what requires pro-software. This class focused on discoverability and use of existing data. COBRA instructors reviewed data repositories, types of data repositories, and how to extract and display data. The class focused on GeoMapApp as a case study of one innovative open-access data repository linked to a data manipulation and display application. In preparation for this class, Fellows researched one or more locations to identify and access data including bathymetric data, but also searched for data types and datasets most relevant to their ‘Dream Cruise’ projects. The class discussed selected examples of physical repositories that contain seafloor and sub-seafloor samples, such as the Smithsonian and IODP Core Repository, and discussed how researchers can discover available sample types and place requests to obtain desired samples. Fellows also discussed how to cross-reference data, and data limitations (including missing data, and QA/QC issues). During the class Fellows produced a bathymetric map.

2.3.9 Week 9: Data Management Plan to Cruise Report

Week 9 focused on Data Management Plans to Cruise Reports and built upon lectures and work introduced in Week 8. Goals for this week were to: (1) learn about data management plan (DMP) goals, components, and formats for metadata, digital data, sample data, and engineering plans; (2) understand various data storage challenges and strategies; (3) create a data management plan for the Fellows’ Dream Cruise; (4) learn about goals for expedition reports, components, and formats; and (5) create an expedition report outline for Fellows’ proposed Dream Cruise. COBRA instructors explored the details of DMPs and expedition reports. They reviewed the necessary components of DMPs, as well as a range of styles and resources to help create them. In the first half of this class, Fellows worked in breakout groups to begin drafting their own DMPs. In the second half of the class, discussion focused on different types of expedition reports and the requirements for each. Fellows were then provided the opportunity to revise their DMPs.

2.3.10 Week 10: Education & Outreach

Week 10 focused on connecting education and public outreach (EPO) with oceanographic expeditions, as this is becoming increasingly common, and is thus an additional layer of planning, execution and assessment for a lead scientist to manage. The goals for Week 10 were for Fellows to: (1) understand the types of common EPO connected with deep-sea oceanographic expeditions, what is required to implement them, and common pitfalls; (2) understand where to get communication training to create effective products; and (3) understand what kinds of assessment tools, processes, and metrics are useful and often required by funders. COBRA instructors reviewed some of the common ways that EPO is incorporated into field work, what is required to implement them (technology and personnel), and some of the common pitfalls of such activities. Two guest lecturers spoke during the first half of the class, about their paths in science communication to help Fellows think creatively about the potential gamut of at-sea and post-expedition EPO opportunities. Finally, COBRA instructors discussed assessment tools, processes, and metrics that are used to gauge the efficacy of EPO activities, and how to describe these for inclusion into proposal planning.

2.3.11 Week 11: International Ocean Law

Week 11 focused on ocean law and policy, which are critical when conducting oceanographic work within other countries’ maritime jurisdiction and, increasingly, in areas beyond national jurisdiction. Goals were for Fellows to: (1) understand maritime jurisdictions and what can and cannot be done within different jurisdictions, (2) understand the process for applying for Marine Scientific Research authorization in another country’s exclusive economic zone (EEZ), (3) learn about effective international collaborative research strategies and how they can lead to policy-relevant outcomes, and (4) become familiar with the ongoing negotiations for a new high-seas treaty and understand the pros and cons of such a treaty. In preparation for this class, Fellows were asked to complete an application for consent to conduct Marine Scientific Research in another country’s EEZ. Guest lecturers from the US Department of State joined the class to review maritime jurisdictions to understand roles and responsibilities within the different areas, as well as discuss the process by which scientists obtain authorization to conduct work in other countries’ waters. Other guest lecturers discussed effective international collaborative research strategies and how they can lead to policy-relevant outcomes and ongoing negotiations for a forthcoming high-seas treaty and its implications for high-seas research.

2.3.12 Week 12: Team Science

Week 12 focused on Inclusive Team Science with goals for Fellows to (1) understand benefits and challenges of participating in diverse and inclusive science teams, and (2) learn practical strategies for participating in and leading diverse science teams. During this class, guest presenters described the social science research on high-performing teams and provided practical steps Fellows can take to lead and participate in effective collaborations. Fellows then participated in an exercise on team building and inclusive communication to understand how effective teams work together. COBRA instructors discussed factors that predict collective intelligence and the beneficial impacts of diverse teams. Finally, the class discussed how to attract and retain diverse teams, reduce status differences, ensure equitable opportunities, tackle goal differences and knowledge utilization, integrate team members to avoid tokenization, recognition and rewards, build and maintain team trust, resolve conflicts, and start and fund collaborations.

2.3.13 Week 13: On the Horizon

The final week of the COBRA Master Class was an opportunity for Fellows to present their work, receive feedback, discuss preparing the open access manual, and share ideas for future engagement as a cohort within the COBRA community. The majority of this class was dedicated to Fellows sharing their class experience. Fellows had three minutes to present a topic of their choice. Many of them discussed the development of their Dream Cruise projects, focusing on their progress from initial concept to expedition prospectus. One Fellow focused on the challenges that they encountered and how they took a different approach to the assignment, preparing them for a future expedition proposal. Prior to the class, Fellows were asked to complete a post-class survey to assess their attitudes on key metrics for the course (described below). The class ended with a presentation of the change in attitudes before and after participating in the Master Class, followed by a discussion on what Fellows thought went well during the class and what could and should change for the future. The final topic of discussion was how Fellows would like COBRA to support sustained engagement following the Master Class, including preparation of an open-access manual based on their learnings that can be used by the following year's cohort.

3 Assessment

3.1 Pre- and Post-Class Surveys

Optional surveys were given to Fellows at the beginning and end of the Master Class to assess readiness and preparation on class topics. All Fellows completed the pre- survey, with one Fellow not completing the post-survey. The following questions were asked in each survey to assess changes in attitudes after participating in the Master Class using a Likert scale (Figure 1):

1. I know where to find information about deep-sea research vessels and assets.
2. I know where to look for funding for deep-sea expeditions.
3. I understand what "co-creation of knowledge" means in the context of working with local and/or Indigenous communities.
4. I know what information should be included in a Cruise Prospectus.
5. I know how to create a Plan-Of-The-Day.
6. I understand how telepresence can be used for scientific purposes and for outreach.
7. I feel confident in my ability to help resolve conflicts with diverse teams.
8. I know how to prepare a Data Management Plan.
9. I know how to archive and report on all data types generated during a deep-sea expedition.
10. I understand the difference between international and national jurisdictions.
11. I understand how to apply for international and national permits.
12. I am ready to submit a proposal to use a deep-sea research ship or asset.
13. I am ready to lead a deep-sea expedition.

In addition, the post-survey asked an additional Likert scale and free-form response questions to assess overall satisfaction with the Master Class:

1. I feel like I was respected by the instructors during my participation in the COBRA Master Class.
2. I feel like I was respected by the other participants in the COBRA Master Class.
3. I think the level of instruction was appropriate.
4. Receiving a stipend was a key factor in my ability to participate in the Master Class.
5. I would recommend the Master Class to a friend.
6. Free-form response: What was the most valuable topic for you?
7. Free-form response: What was the least valuable topic for you?
8. Free-form response: What topic do you wish we had spent more time on?
9. Free-form response: Suggestions for how the Master Class could be improved?

Overall, the assessment indicated that attitudes improved (i.e., more agree/strongly agree compared to disagree/strongly disagree) for all categories (Figure 1). The biggest shifts in opinion were in readiness to propose and lead a deep-sea research expedition, indicating that the Master Class was successful in boosting the confidence of participants to be deep-sea expedition leaders. Some notable anecdotal feedback from fellows included:

> *Fellow A:*
> "More than a topic it was everything as a whole because it made me start thinking as a Chief Scientist! Something just clicked for me, perhaps with the knowledge that I was acquiring every week, my confidence increased."

> *Fellow B:*
> "The course was really helpful to boost my confidence. The learning curve is steep, but here I go...MUCHAS GRACIAS."

When asked to identify the class topic that Fellows deemed most valuable, every topic had at least one person saying it was the most valuable, suggesting that the class successfully offered a wide range of topics to bolster the self-identified priorities across the diversity of the participating Fellows. When asked to identify class topics that were least valuable, there were very few requests to de-emphasize something, and feedback was constructive and minor. Overall, participants requested more time on each topic, suggesting that the two-hour synchronous online sessions were not too lengthy or onerous. Though there was a Slack channel for asynchronous discussion, more infrastructure for asynchronous learning would be helpful to deepen understanding of topics without expanding synchronous session-time.

In addition to the pre- and post-class surveys, Fellows were also asked to select the five topics that they were "most excited to learn about" and the five topics that they thought would "challenge them the most." The most-selected topics that respondents were excited about were Funding & Proposals (100%) and Cruise Preparation (73%). The most-selected topics that respondents thought would challenge them the most were Data Management Plan to Cruise Report (82%), Funding & Proposals (73%), and International Ocean Law (64%).

3.2 Public access to course resources

In addition to supporting the Fellows and the class, the COBRA PubPub site (https://cobra.pubpub.org/) was also intended to be a public resource for deep-sea expedition leadership and planning. All class plans, readings, videos, etc., are publicly available. In the 63 weeks between the creation of the PubPub site (Feb 17, 2022) and the writing of this section (May 3, 2023), 943 users from 59 countries and territories have accessed 20,966 page views on the site (FIG 3).

4 Discussion

Expedition leadership in the modern era transcends technical skill alone: good leaders create strong and diverse teams, inclusive, safe and creative spaces, efficient and productive workflows, and enable cross-team competency and growth in addition to the scientific goals and deliverables of a deep-sea expedition (Amon et al. 2022c, Johannesen et al. 2022, Shellock et al 2022). There is an increased emphasis on team science in the deep-sea, and the skill sets required are essential for future leaders (Bennett et al 2013, 2014, Hall et al. 2018). Some of these hard and soft skills can be taught by example, but life on-ship is busy, and a trainee rarely gets the full access to every part of the expedition leadership and decision-making process. Thus, there is a need to more thoughtfully and deliberately advance and accelerate the training of early career deep-ocean leaders to help diversify the leadership pool and advance the stated outcomes of ocean exploration, conservation and science in a team setting.

At the same time, there is a practical need to train early career deep-ocean leaders to maximize productivity and minimize costs that can occur when "learning while leading." Deep-sea shiptime is expensive, ranging from $10,000-100,000+ USD per day, and subpar leadership can waste substantial funds in lost productivity. To reduce that inefficiency, lead scientist training efforts have been developed for US-based deep submergence assets. This training effort is a valuable and critical tool to help burgeoning PIs with developing the at-sea experience and post-award period, however, a comprehensive approach to the lead scientist experience, ranging from proposal preparation to final expedition report, is lacking.

For all of the above-mentioned reasons, many potential deep-sea PIs do not achieve lead scientist status as quickly as they are capable of, thus delaying their discoveries for science as well as their own career advancement. In an effort to accelerate scientific understanding of deep-sea ecosystems and their resilience to inform decision making, prevent serious harm, and provide benefit to society, deep-ocean research remains critical and can only be enabled by nurturing and fostering the next generation of deep-ocean scientists and expedition leaders. The COBRA Master Class was the first attempt at an intermediate scale training program. Based on participant feedback and demonstrated outcomes of getting involved in expedition leadership since participating - the inaugural year was a success. Moreover, the COBRA Master Class has created an intermediate time investment model for future training for this (and other) topics of similar complexity.

Specific successes for this inaugural expedition from the Fellow perspective were evident from the pre- and post- class surveys. The biggest shifts in opinion were in readiness to propose and lead a deep-sea research expedition, indicating that the Master Class was successful in boosting the confidence of participants to be deep sea expedition leaders. Fellows also report cohort cohesion and have maintained communication through the COBRA Slack Channel and other COBRA activities. The biggest indicator of success will be demonstrated by the number of Fellows who lead deep-sea expeditions, and to-date, several fellows have submitted proposals to do so (one quarter of the Fellows have submitted their "Dream Cruise" within 6 months of completing the Master Class).

Despite the success of the COBRA Master Class, there were some noted challenges, namely time and balance. Because this class was designed to accommodate working professionals within the context of a normal work week, synchronous time was limited to two hours per week and asynchronous assignments were typically optional. As such, the depth of coverage for each topic was never wholly complete - Fellows commented that each week could have easily been a month of conversation and activity. However, to achieve balance and avoid burnout and fatigue, the content balance provided was sufficient to achieve the COBRA goal of introducing each topic in detail, and providing the follow-on resources, contacts, or tools to enable Fellows to subsequently self-propel. In addition, the balance of time spent on each topic was designed to benefit Fellows regardless of prior preparation. Each topic was covered in sufficient introductory detail for a novice, but also covered in enough advanced detail for a working expert and to glean insights and advance their toolset and skillset. Future iterations of this Master Class will keep the existing balance, but as the class grows, the additional on-line (Pubpub) and written resources will continue to grow as well, thereby providing additional depth of coverage for future COBRA Fellows and the community in general.

One key component of the Master Class model is class size. We found that twelve Fellows was sufficient to generate lively and substantive conversation, but could also ensure space and time for every voice to be heard. In addition, the relatively small cohort size was essential to facilitate contemplative and productive small working groups and partnered activities. The drawback to a small cohort is the number of

Fellows trained, but with repeated classes (five total over five years), sixty fellows will be trained over the lifetime of this current program. In addition, online resources can benefit the community at large, and it is hoped and expected that COBRA Fellows will use these materials to help train ECRs under their leadership. Because of the relatively small size of the deep-sea PI community, the contribution of sixty new, capable expedition leaders dramatically increases the existing PI pool. It should be noted that there are many current attempts to broaden and diversify the deep-sea community, and it is hoped that corresponding assets and resources will be amplified to accommodate our growing community.

5 Conclusions

As deep-sea research continues to accelerate in scope and speed, providing equitable access to expedition training is a top priority to enable the next generation of deep-sea science leadership. The COBRA Master Class has generated a successful model for training 12 ECR Fellows at a time, with additional open-access training materials that are freely available to all. While there is no substitute for at-sea training, the Master Class model represents a more modest time investment with a comprehensive approach to expedition leadership, including pre- and post-expedition expectations and responsibilities of a Lead Scientist. This online, 14-week training model involving synchronous and asynchronous activities is an important bridge between targeted workshops and at-sea apprenticeship that will accelerate deep-sea leadership, and therefore deep-sea research and stewardship across the globe.

6 Article types

Community Case Study: https://www.frontiersin.org/journals/marine-science/articles?type=131&publication-date=01%2F01%2F2007-09%2F05%2F2023

7 Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

8 Author Contributions

All co-authors participated in the co-design, co-development, participation, and execution of the COBRA Master Class. RDR and KLCB co-led the drafting of this manuscript. BNO, JAH, RDR, CGW, ATF secured the funding for this project. BNO, JAH, and RDR led the conceptual design of the Master Class, with curriculum development input from KLCB, CGW, ATF, and RS. All co-authors contributed to the drafting and editing of the manuscript.

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federal requirements for human subject research according to the NIH Office of Extramural Research, especially as the subjects are co-authors on this manuscript.

11 Figures

Figure 1. Comparison of COBRA Master Class participant attitudes pre- (top panel, N = 12 respondents) and post-class (bottom panel; N = 10 respondents) for 13 assessment questions based on a Likert scale of 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree. Colors correspond to the Likert scale rating; while the X-axis denotes the number of respondents who listed each ranking. Survey questions are found in section 4.1 of the manuscript.

Figure 2. Post-class assessment of opinions about whether the COBRA Master Class met expectations. Using a Likert scale of 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree. Colors correspond to the Likert scale rating; while the X-axis denotes the number of respondents (N = 10) who listed each ranking. Of note, all participants strongly agreed that they were respected in class (Q1), there was strong agreement that level of instruction was appropriate (Q2), and all participants agreed that they would recommend the class to a friend (Q5). While receiving a stipend to participate was not important for some, it was important for others (Q4).

Figure 3. Locations of 943 users from 59 countries and territories (as of 3 May 2023). Color bar denotes number of users per country.

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13 Supplementary Material

Supplemental Table 1. Dream Project Activities associated with each week

Week	**Topic**	**Assignment**	**Dream Project Activity**
Week 0	Kickoff & Introductions	Introductory activities to COBRA and each other Complete a pre-course assessment survey	
Week 1	Deep-sea Assets	In pairs, research capabilities of and access to vessels and DSVs at two research organizations worldwide	

Week 2	Funding & Proposals		Overview: project title, big picture problem, three specific objectives, assets needed, team required, and timeline
Week 3	Respectful Concept Development	Watch video on planning an extreme overland adventure expedition	Objective 1: hypothesis, location, samples and analysis needed, expected significance, expertise required
Week 4	Pre-expedition Planning		Work on Objective 2
Week 5	At-sea Operations	Complete a check-in form to assess how the ECR Master Class is going Watch videos on preparing ROVs and HOVs for deep-sea research	Continue working on overview and Objectives 1 & 2
Week 6	Telepresence	Register to be a Nautilus Scientist Ashore and watch scientist ashore video	
Week 7	Unwritten Rules	Read about naming bathymetric features (REF?)	Work on Objective 3
Week 8	Intro to Deep Data	Download and install GeoMapApp	
Week 9	DMP to Cruise Report	Register for DMPTool Readings on DMPs	Finish preparing list of data that was begun in Week 8, inlcuding finding multibeam bathymetry data and one other type of data from a public repository for area of interest
Week 10	Education & Outreach		Draft one paragraph on your education, public outreach, and/or communication approach Add a map to your Dream Project prospectus
Week 11	International Ocean Law		Complete the Application for Consent to Conduct Marine Scientific Research table for your area of interest, or another area if yours is not in another country's jurisdiction
Week 12	Team Science	Complete a post-course assessment survey	
Week 13	On the Horizon	Come prepared to share feedback about how you think the Master Class went, and your readiness to lead a deep-sea research expedition.	Prepare 3-slide / 3 minute overview about your Dream Project or prepare a presentation on any aspect of the class that you want

Figure 1.JPEG

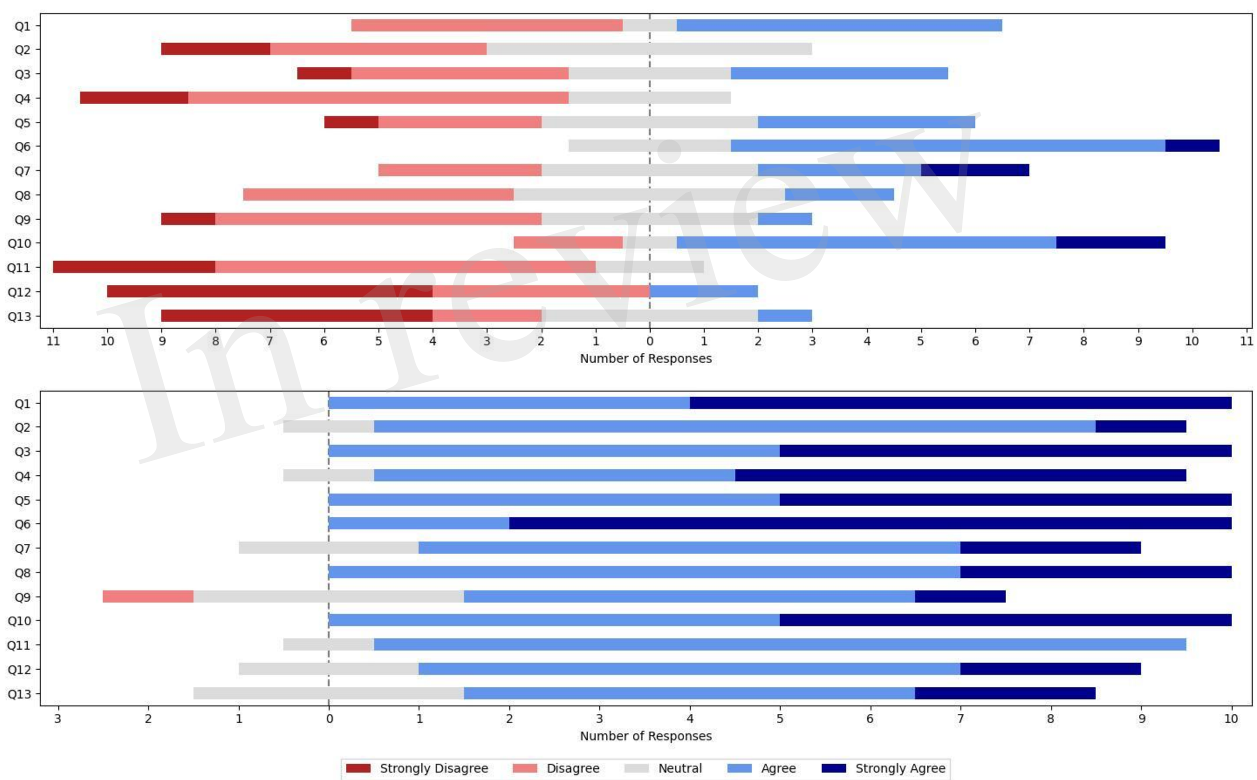

Figure 2.JPEG

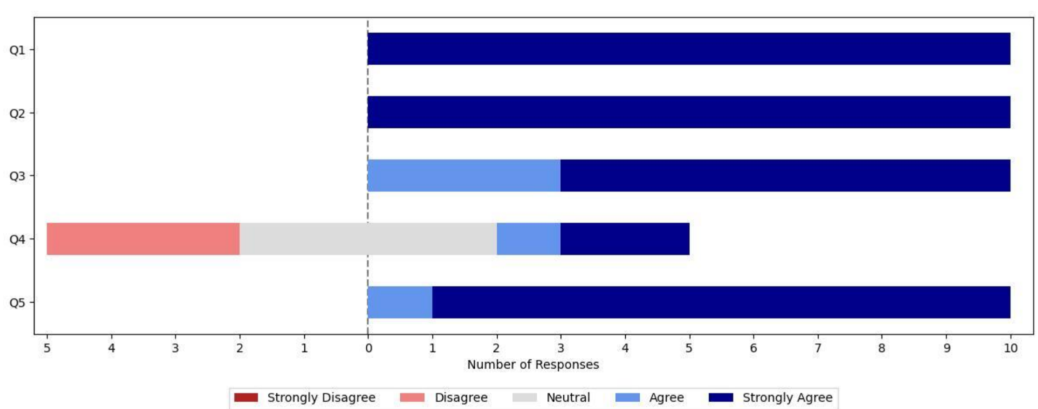

Figure 3.JPEG